Geology

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THE GEOLOGY OF
RUSSIA IN EUROPE
AND
THE URAL MOUNTAINS.

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BY

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AND

COUNT ALEXANDER VON KEYSERLING,

GENTLEMAN OF THE CHAMBER OF H. I. M. THE EMPEROR OF ALL THE RUSSIAS, ETC.

"Ce temps qui nous manque ne manque point à la nature...... Cet instant, la vie humaine étendue même autant qu'elle peut l'être par l'histoire, n'est qu'un point dans la durée, un seul fait dans l'histoire des faits de Dieu."—*Buffon, Théorie de la Terre.*

IN TWO VOLUMES.

VOL. I.

GEOLOGY.

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TO

His Imperial Majesty

NICHOLAS THE FIRST,

Emperor of all the Russias.

Sire,

The most substantial aid of Your Imperial Majesty & my August Sovereign, and Your cordial sanction by my coadjutors, have augmented my just pride in the privilege so graciously accorded to me, of dedicating to Your Imperial Majesty this Work, descriptive of the Geological Structure of a large portion of Your Majesty's Empire.

This privilege enables me to evince the warmest gratitude of my fellow travellers and myself for the kindness with which Your Imperial Majesty has been pleased to sanction and advance researches carried on under Your own auspices, and also to record our lasting acknowledgments of the unbounded hospitality of Your generous and loyal people.

With sentiments of profound admiration for Your Imperial Majesty's great qualities as a Sovereign, with unfeigned respect for Your domestic virtues, and with sincere thanks for the honours you have deigned to confer on us, I subscribe myself,

Sire,

Your Imperial Majesty's

Most devoted and most grateful Servant,

Roderick Impey Murchison

Belgrave Square London May 1, 1845

PREFACE.

ALTHOUGH the physical geography, mineralogy and natural history of the distant and mountainous parts of Russia have been well illustrated, from the days of Pallas and Hermann to those of Humboldt and Rose, the true geological structure of the country, particularly of her great flat regions, has never yet been adequately developed. We need not now enumerate all those persons who have recently offered contributions towards this object; but we must specially notice the early efforts of our precursor Strangways, who, so far back as the year 1822, after minutely describing the environs of St. Petersburgh, prepared a short general memoir on Russia in Europe; and essaying the first sketch of a geological map of that great portion of the empire, endeavoured to place its various rock masses in relation to their equivalents in England. This enterprising effort did not, indeed, result in determining the true succession of the strata; for no geologist had paved the way by any classification of the most ancient fossiliferous deposits, of which the North of Russia is almost exclusively composed, according to their superposition and imbedded organic remains. Viewed, however, as the first attempt to unfold the nature of the subsoil of large, undulating regions, necessarily most obscure from being covered over with much detritus, the map of Strangways is entitled to the most respectful consideration from those who were destined to follow him.

After this effort, some years elapsed before the geological school of St. Petersburgh began to participate in the forward movement which the study of organic remains had produced in other parts of Europe. The first signs of advance are to be seen in the works of M. Eichwald and M. Pander on the fossils of the Baltic governments and the environs of St. Petersburgh. But notwithstanding these publications, the utmost doubt and confusion prevailed respecting the geological relations and succession of the different rock masses. No one had attempted to carry out the general project of Strangways; nor even had any one then observed, that the strata in the neighbourhood of the metropolis of Russia were the oldest in which remains of organic life could be traced, and were overlaid by other groups charged with distinct fossil contents. Nor was any sort of connection traced between the various strata. The red-coloured deposits of Novogorod, Lithuania and Courland, for example, were still considered to belong to the New Red Sandstone, chiefly because they contained rocks of gypsum and springs of salt; whilst their most striking fossil reliquiæ were said to be bones of Saurians and Chelonian reptiles. If such had been the case, coal-beds might be looked for beneath such red deposits, and the correct determination of their age became, therefore, of great importance to Russia.

The publication of the 'Silurian System' first dispelled this confusion. In that work Mr. Murchison succeeded in proving, that the Russian organic remains described by Pander must be the equivalents of those which occurred in certain lower fossiliferous strata of the British Isles; and, by studying its pages, Russian geologists at once saw, that the red strata immediately surmounting their Silurian strata were characterized, as in the British Isles, by certain fishes (among the most striking of which is the *Holoptychius nobilissimus*),—the very forms, in fact, that until then they had supposed to be the remains of reptiles and tortoises. The inference, indeed, was so evident, that M. von Buch, who had not visited the country, but to whom its fossils had been sent, speedily communicated to Mr. Murchison his conviction, that Russia, when properly worked out, would be found to contain the same succession of palæozoic deposits as had been described in the Silurian region of England and Wales. From that moment Mr. Murchison resolved to visit Russia, and fairly to test, whether the British palæozoic classification would be found equally true over a vast area, in which, since few or no igneous rocks were known, the history of succession might, he hoped, be read off in a very perfect and unbroken manner. Having in the meantime unravelled the structure of the Rhenish provinces, in company with his friends Professor Sedgwick and M. de Verneuil, he invited the latter (whose acquaintance with the specific distinctions of the ancient mollusca is so well known) to join him in a geological survey of Russia.

To invade Russia, however, as unassisted geologists, with mere hammers and compasses, would have proved but a fruitless mission, had not the countenance of the Imperial Government been obtained. This was secured through the very friendly intervention of Baron de Brunnow, His Imperial Majesty's representative at the Court of London, who, exhibiting a generous feeling for the advancement of science, strongly recommended the undertaking to the protection of his Sovereign.

Arriving in the Neva in the early summer of 1840, Mr. Murchison and M. de Verneuil were previously assured of profiting by the aid of their friend Baron A. von Meyendorf, who having been appointed to conduct an inquiry into the state of manufactures and trade of the internal governments, had begged them to unite with him, and had further obtained the cooperation of two able naturalists, the Count A. von Keyserling and Professor Blasius; thus hoping that his tour might afford many interesting results besides those immediately connected with its object. With these associates, the first researches were commenced in the environs of St. Petersburgh, and on the banks of the rivers Volkof and Siass; and they were followed by others on the banks of the Lake Onega and the environs of Petrozavodsk. Notwithstanding, however, the zeal and assistance of Baron A. von Meyendorf, it was not possible that geologists, having one continuous and special object, could long continue to act in concert with an expedition mainly devoted to statistical inquiry[1],—a difficulty which had, indeed, been foreseen by the Imperial Minister of Finance, the Count de Cancrine, under whose auspices the arrangement had been made, and whose executive officer as chief of the staff of the Imperial School of Mines, General Tcheffkine, had selected Lieutenant Koksharof, an intelligent young mineralogist, to attend the English and French geologists. At Vitegra, then, Mr. Murchison and M. de Verneuil took leave of the expedition of the Baron A. von Meyendorf, and thence travelled to Archangel, the edges of the White Sea, Pinega, &c., whence they ascended the banks of the great river Dwina to Ustiug-Veliki, in the heart of the government of Vologda[2]. Meeting with their other friends at that town, the parties again separated. Mr. Murchison, after making a very wide circuit through Vologda, by Tcherepovetz, and round to Yaroslavl and Kostroma, once more joined Baron von Meyendorf at the latter place. They descended the Volga together to Jurievetz, where they parted, and only casually met again in Moscow; the English and French geologists having in the meantime visited Nijny Novogorod, Murom, Jelatma, Kacimof, Riaizan and Kolomna.

Returning northwards by Moscow, Mr. Murchison and M. de Verneuil were enabled to correct some previous errors respecting the geological equivalents of the chief rocks around that metropolis, and to show, that instead of belonging to the Oolitic series, as had been surmised, they were of Carboniferous age, and were surmounted by Jurassic shales. Finally, an examination of some deep recesses in the Valdai Hills, the southern edges of Lake Ilmen, and the banks of small rivers between

[1] See Baron A. von Meyendorf's instructive statistical map of Russia, which resulted from this survey. German edition, M. Schropp and Co., Berlin.

[2] Professor Blasius having been taken ill at Ustiug, Count Keyserling kindly resolved upon remaining with his friend. Their operations were thereby much interfered with, and their exploration of the country south and west of Moscow was retarded till long after the snow fell. Count Keyserling developed some results of his observations in memoirs read before the Moscow Natural History Society, and Professor Blasius has since published a sketch of his travels, Brunswick, under the title of "Reise im Europæischen Russland, 1844."

Novogorod and St. Petersburgh, confirmed on another parallel the conclusions they had arrived at by their north-eastern traverses, of a general ascending succession of deposits from the Silurian on the north, to the Carboniferous basin of Moscow; and convinced them that those two systems were clearly separated from each other by a full development of Old Red Sandstone, as abundantly charged with ichthyolites as in Scotland, and containing also many of the same species of shells as in Devonshire and the Rhenish Provinces.

Through these researches, as well as those of Colonel Helmersen and his associates in the Valdai Hills and around Pskoff and Dörpat, the chief physical relations of these palæozoic rocks of the northern and central provinces were placed beyond all doubt.

On his return to England, Mr. Murchison exhibited to the British Association for the Advancement of Science a first geological sketch map of the regions examined, and read a memoir thereon to the Geological Society of London in the name of M. de Verneuil and himself, explaining the conclusions at which they had then arrived.

Shortly afterwards Professor Eichwald published his work on the Silurian organic remains of Esthonia[1]; and in the course of the ensuing winter, Colonel Helmersen, grouping together all the information obtained from the earliest to the most recent researches, produced a small general geological map of Russia, very superior to any one which had preceded it. But although a good *aperçu* of the true succession of the older palæozoic rocks in Russia had thus been obtained,—though the volumes of the Imperial School of Mines had laid before the public many materials concerning the mineral structure of distant and important tracts,—though, in short, Rose was then preparing to publish his elaborate description of the crystalline rocks and minerals of the Ural Chain, and Dubois de Montpéreux had already given a clear geological *ensemble* to the Caucasus and Crimæa, and had described the tertiary strata of

[1] Esthlands Silurische Schichten System. M. Eichwald obligingly furnished the authors with many Silurian fossils.

Volhynia and Podolia, extensive observations were yet wanted before any well-grounded attempt could be made to propound such a general view of Russian geological classification as that which is now put forth. Viewing the subject in this light, the Count de Cancrine laid before His Imperial Majesty a project for a well-combined additional geological survey of Russia, which being approved of by the Emperor, a communication was made to Mr. Murchison by that Minister, the object of which was to secure the services of M. de Verneuil and himself. Under these high auspices, the researches of these geologists were resumed early in the spring of 1841, when, travelling overland to St. Petersburgh, they united with their friend Count Keyserling, and made fresh observations in the Governments of Wilna, Courland, Livonia and Esthonia.

On their arrival at St. Petersburgh[1], His Imperial Majesty received the foreign travellers in so marked and cordial a manner, and with such expressions of confidence in their renewed efforts, that they felt doubly anxious to acquit themselves with credit of the task they had undertaken.

Count Keyserling had now been formally named one of the same geological expedition, and Lieutenant Koksharof was again appointed to accompany it Thus organized, the general plan was devised by which the Ural Mountains and the southern provinces of Russia, particularly the coal-field of the Donetz, were to be examined,—a plan in which General Tcheffkine took the most lively interest, and in preparing which he manifested the greatest intelligence, friendliness and zeal.

Previously accustomed to act together, and imbued with the same geological animus, the little force first made some explorations to the south of Moscow (Tula, Kaluga, Serpukhoff, Kolomna, &c.), and then

[1] Mr. Murchison must gratefully acknowledge, that on this occasion, his position at St. Petersburgh was rendered most agreeable through the friendly support of the Marquis of Clanricarde, then the British Ambassador, and that during former and subsequent visits he experienced the kindest attention from the Hon. John Bloomfield, Her Britannic Majesty's Envoy.

dividing into two companies proceeded to Kazan by different routes, the one by Arzamas and Simbirsk, the other by Nijny Novogorod. Separating in this way for short periods, and meeting at given points to combine new observations, it is not too much to assert, that the power of acquiring knowledge was nearly doubled, and that the results of the labour of nearly two summers were thus concentrated in one. The vast cupriferous regions to the east of Kazan and around Perm being first explored, the Ural Mountains were crossed and re-crossed on seven different parallels, between 60° and 54° north latitude; the one party examining the European, the other the Asiatic flanks of the chain,—the latter occasionally advancing into the flat regions of Siberia.

Returning westwards from the environs of Orenburg[1], Mr. Murchison and M. de Verneuil retraversed, in its greatest width, the southern and central part of the vast cupriferous country, the strata occupying which they again studied in detail, and thus became enabled to classify and connect them with the inferior systems. In the meantime Count Keyserling journeyed over the steppes of the Kirghis between Orenburg and Astrakhan, visiting by the way the isolated Mount Bogdo; whilst the northern division were travelling over the banks of the Volga from Samara to Sarepta, there tracing the relations of the carboniferous, Jurassic, cretaceous and tertiary deposits. The steppes of the Kalmucks, the mouth of the Don, and the edges of the Sea of Azof being skirted, with a view of examining the peculiar tertiary limestone of the southern steppes, a month was devoted to the exploration of the carboniferous region of the Donetz, from whence the expedition returned to Moscow, again moving on two lines of observation, the one by Kharkof, Kursk and Orel, the other by the valley of the Don and Voroneje.

It was then that, having finally worked out and compared the chief results of the labours of his friends and himself, Mr. Murchison proposed the establishment of the name Permian, as applied to the youngest

[1] The deep obligations of the authors to General Perovski, then Governor-General of Orenburg, and to the other authorities in the Ural Mountains, are expressed in the body of the work.

of the palæozoic systems, and explained the classification implied thereby, in a letter addressed to the venerable Dr. Fischer de Waldheim. Subsequently at St. Petersburgh he presented, in the name of his friends and himself, a report upon the whole survey to His Excellency the Count de Cancrine. This report, with an improved map and a general section across Russia from south to north (those which in an improved state now appear in Pl. VI.), was shortly after laid before the Emperor, when His Imperial Majesty not only received the travellers with his accustomed kindness, honouring them with his warmest thanks and special marks of his favour[1], but further assured them that he considered their labours to be of great importance to his country.

And here the authors must observe, that their efforts could have had no such result, if the wishes of the Emperor had not been admirably put into execution under the directions of his enlightened minister the Count de Cancrine, and by the excellent arrangements made by General Tcheffkine in his department of the Imperial Corps of Mines. Nor can they omit to notice their obligations to Colonel Helmersen for his good advice concerning the Ural Mountains, with which he had rendered himself so familiar. To these and numerous other kind friends, both in the Russian metropolis and in the provinces, particularly to many officers of the Imperial Corps of Mines, as well as to various authors who have assisted them in different auxiliary departments of science, they will, in the course of this work, have other opportunities of expressing their obligations.

Having thus arrived at more definite conclusions, the authors explained their matured general views to the Geological Society of London in the subsequent winter, and soon afterwards commenced the preparation of the present work, which in the summer of 1842 was brought into a systematic plan, during a visit which Count Keyserling and M. de Ver-

[1] This survey having been carried out under the special orders and protection of the Emperor, the foreign geologists who were fully accredited to the governors and chief officers of the provinces, were substantially and virtually "pro hâc vice" *in the Russian service*; and for such gratuitous service they were honoured by marks of His Imperial Majesty's satisfaction.

neuil paid to England. As it advanced, however, Mr. Murchison perceived, that though well-grounded in the great features of classification, further researches in the field were called for, before the design could be satisfactorily executed. Aware that his colleague Count Keyserling had resolved to explore during the following year (1843) the almost untrodden regions of north-eastern Russia, watered by the great river Petchora, he naturally sought to defer the publication until that survey should be completed; since many original geographical and geological features must in that way be obtained—features now, for the first time, correctly delineated upon their map, and which exhibit the previously unknown Timan Range stretching to the icy sea through a region inhabited only by Samoyedes, and a great portion of it beyond the limits of arboreal vegetation. Whilst, therefore, Count Keyserling was thus occupied in such north-eastern wilds, Mr. Murchison revisited several parts of Germany, exploring many tracts which he had not previously seen, more correctly to determine the true relations of their palæozoic deposits to those of the British Isles on the one hand, and to those of Russia on the other; his principal object being to define with greater accuracy the equivalents of the Permian system, and at the same time to become acquainted with the structure of Poland and those edges of the Carpathians which border upon the Russian empire.

Another year passed over, and the work was already considerably advanced, both as respected this first or English volume, and the second or French volume, in which the chief organic remains are described by M. E. de Verneuil[1]. But still it was felt, that without a survey of the Scandinavian rocks which form the north-western girdle of Russia, the book would necessarily be incomplete; and accordingly the summer of 1844 was devoted to that purpose. This last journey has, indeed, been even more productive of valuable knowledge than was anticipated; for

[1] In 1843, M. de Verneuil, accompanied by Vicomte d'Archiac, examined the palæozoic rocks of Normandy, Brittany, &c., with a view to general conclusions and results; and in 1844 a severe attack of illness alone prevented his joining Mr. Murchison in the examination of Norway and Sweden.

it has not merely shown a close agreement of the older palæozoic or protozoic strata of Norway and Sweden with the contemporaneous group in England and Wales, but by its actual superposition to still older crystalline rocks void of all traces of organic life, has given the authors a clear base line wherewith to connect and from whence to trace their whole ascending series of Russian sedimentary deposits.

This excursion to Norway and Sweden (where through the friendly aid of Baron Berzelius and Professors Keilhau and Löven Mr. Murchison obtained access to every collection) has not only been advantageous to palæozoic classification, but has also been highly serviceable in developing some prominent features of the great Scandinavian drift that covers such large portions of the surface of Russia and Germany, and the consideration of which naturally occupies many of the subsequent pages[1].

Revisiting afterwards St. Petersburgh, Mr. Murchison personally communicated with Count Keyserling on the subject of the Petchora and Timan country, and at the same time examined some newly-discovered natural relations of the strata not distant from the capital[2]. He also derived some important additional knowledge from M. Pander, M. Wörth, Colonel Helmersen, M. Khanikoff and other friends.

In presenting to the public geological maps of Russia in Europe and the Ural Mountains, and in attempting to classify upon what they conceive to be a sound general basis, the various deposits of so vast a territory, the authors bespeak the indulgence of their brother geologists,

[1] The complete examination of these most interesting countries was incompatible with the publication of a work on Russia; but having been graciously honoured with an invitation from the King of Sweden and Norway to revisit them, Mr. Murchison has the full intention of doing so, with the prospect of being once more accompanied by M. de Verneuil.

[2] On this occasion Mr. Murchison was the bearer of a medal struck in England, in honour of the recent visit of the Emperor Nicholas to the Queen of England. This medal is executed by Mr. Leonard Wyon of the Royal Mint, and is represented in the medallion which accompanies the dedication to His Imperial Majesty. The inscription on the reverse will, it is hoped, be equally gratifying to all loyal persons in both countries. During this, as in former visits, Mr. Murchison had strong reasons to be grateful to the Count A. von Orloff for the kindest support, and he has recently been informed by His Excellency that the Emperor had cordially accepted the medal.

towards the inaccuracies of detail which must inevitably accompany such a first outline of regions which they traversed rapidly and only partially examined. But although when engaged in the pursuit of a favourite science their chief end was to test the truth of certain broad generalizations, suggested by the examination of other countries, they have reason to hope, that their labours may somewhat aid in administering to the wants of their kind friends in Russia. A government which controls the power and rouses the latent energies of so great a country, is ever desirous to know, what are the tracts within its rule, in which from their structure no useful minerals are to be found, as well as, on the other hand, to be acquainted with those districts wherein such substances may be searched for with reasonable hopes of success. Russia, in truth, stands pre-eminently in need of correct internal exploration, and to no country can the revelations of the geologist be of higher importance. Covered, as she has been, with magnificent forests, which have hitherto supplied her inhabitants alike with shelter and with fuel, the time is fast approaching (and in some large tracts has already arrived) when these resources will no longer meet the exigencies of an increasing population, daily advancing in their acquaintance with the comforts, arts and manufactures of civilized life. Under these circumstances a prudent government naturally asks, where are we to seek for the best building-stones and limestones for constructing new edifices and public works? Does not the level surface of our land naturally suggest to us the advantage of railroads to connect our chief cities, and is it not an important inquiry how these great national objects can be best effected? Where, in a word, can we look for coal to further our enterprises, and where can we never find it?

These, indeed, are but a few of the most obviously important economical queries to which the geologist is enabled to reply; and the extent to which such questions have been answered will be seen in the body of the first volume. To their ensuing pages, therefore, the authors must now refer; though in the meantime they may assure the reader, that the labours they have encountered have been infinitely overpaid, by the pleasing reflections with which they can never cease to dwell upon the hearty hospitality and generous support of all classes of Russians.

Recurring to that distinctive trait of national Moscovite character—a will which admits of no obstacle—they are bound to record, that their own impatient "forward" was ever cheerfully responded to by the *mōjna* of the natives[1]. With this talismanic word the Russian has, indeed, raised monuments on the Moskva and the Neva, that rival the grandest efforts of ancient and modern times.

Amidst such a people, no real difficulty could be experienced. If a bridge were broken, it seemed rebuilt by magic. Though a river-bed was dry, the travellers beheld it converted, as if miraculously, into a navigable stream[2]. Was the water too shallow, then did the athletic peasants cheerfully lift the boats over rocks, enlivening their progress with a merry carol. Wet or dry, hot or cold, no murmur escaped these resolute men, and *mōjna* was their only cry.

To the illustrious Monarch, then, of the wide realms whose structure they attempt to describe, and to all His loyal subjects with whom they held communication, the authors beg once more to express their sincere attachment and lasting gratitude.

[1] This word *mōjna*, the literal translation of which is, "It is possible," may be rendered into English by the colloquial sailors' phrase, "Ay, ay, sir."

[2] See the account of the descent of the Serebrianka river, p. 382.

London, April, 1845.

CONTENTS.

VOL. I.

PART I.

CHAPTER I.

INTRODUCTION.

Page

PALÆOZOIC ROCKS.

CHAPTER II.

SILURIAN ROCKS OF SCANDINAVIA.

CHAPTER III.

SILURIAN ROCKS OF RUSSIA.

CHAPTER VII.

CARBONIFEROUS ROCKS ON THE WESTERN FLANK OF THE URAL MOUNTAINS.

CHAPTER VIII.

PERMIAN SYSTEM.

CHAPTER IX.

PERMIAN ROCKS OF THE NORTH ON THE RIVERS DWINA AND PINEGA.—OVERLYING RED DEPOSITS OF THE CENTRAL AND SOUTHERN REGIONS.

PART II.

THE URAL MOUNTAINS AND TIMAN RANGE, SUPERFICIAL DEPOSITS OF RUSSIA, AND CONCLUSION.

CHAPTER XIV.

THE URAL MOUNTAINS.

CHAPTER XV.

NORTH URAL OF THE MINERS.

CHAPTER XVI.

NORTH URAL OF THE MINERS—(*continued*).

CHAPTER XVII.

THE ARCTIC URAL AND THE TIMAN RANGE.

(MAP, PL. VI., AND COLOURED SECTIONS, PL. V.)

CHAPTER XVIII.

SOUTH URAL.

(MAP, PL. VII., AND COLOURED SECTIONS, PL. III. AND IV.[2])

CHAPTER XIX.

ANCIENT SURFACE OF THE URAL MOUNTAINS AND THE ADJACENT COUNTRIES.—GOLD AND MAMMOTH ALLUVIA.

[1] Subsequently placed as Lower Devonian (see Appendix F., p. 645, and Tabular View, Pl. VI.).

[2] Erroneously referred to in text, p. 420, as Pl. V.

CHAPTER XXII.

BLACK EARTH.—TERRESTRIAL CHANGES IN RUSSIA.—CONCLUSION.

APPENDIX.

RUSSIA IN EUROPE

AND

THE URAL MOUNTAINS.

CHAPTER I.

INTRODUCTION.

Origin and Progress of the Palæozoic Classification of the British Isles explained.—Its recent extension to various parts of Western Europe, America, &c.—Its application to Russia, Scandinavia and the Ural Mountains, the chief object of the authors in this work.—General outline of the contents of the work.

ONE of the great objects which geologists have of late years been striving to attain, is a knowledge of the order of the older sedimentary strata and of the organic remains they respectively contain.

Among the questions involved in this inquiry, several at once present themselves. Are these older rocks, for instance, made up of various formations as distinguishable from each other by their imbedded fossils, as certain younger deposits which had previously been studied? Is a regular succession to be traced downwards from formations, the position and contents of which were well-known, to other undescribed beds of far higher antiquity? Can we, by such a process, lay open the earliest vestiges of animal life, and amid palæozoic forms, trace backwards primæval history to a protozoic type? And if so, can we separate such protozoic strata from those which went before them, and were deposited ere life had been breathed into the waters? If such questions could be satisfactorily answered, then, indeed, would geology not merely have developed a wondrous succession of the ancient works of Nature, but young as she is among the sciences, would have been the first to afford undeniable proofs of a beginning. Such, at all events, are among the problems which we have been endeavouring to solve during the last fourteen years, by examining the earlier productions of the earth, and by researches in the field carried on through various parts of Europe and along the borders of Asia.

Geologists have generally admitted, that those labours in the British Isles, which terminated with the establishment of the Silurian system, made the first unequivocal step in this inquiry, by affording clear evidences of a natural descending order, from the Carboniferous formations, that had previously been well illustrated[1], down to a group of deposits essentially differing from all above them in the various forms of animal life which they contained. To these peculiar lower deposits, whose members were then first classified and their fossil remains described, one of the authors of this work applied a term derived from a region formerly occupied by the British *Silurian* people, and affording clear evidences of a certain order and succession in primæval life. In addition to the establishment of a normal distinction between the Carboniferous and Silurian strata, it was then also shown, that certain accumulations of great thickness, separating these two groups, and long known under the name of the Old Red Sandstone, were characterized, as in Scotland, by ichthyolites, which in the Silurian region were perfectly distinct in form from any remains of that class in the carboniferous beds above or in the Silurian strata below. At the period when these chief results were published, the Old Red Sandstone had afforded no remains whatever of mollusca; yet judging from the enormous thickness of this system of rocks, as well as from the diversity of character of the fossils found in the overlying and underlying formations, we suggested, that should future researches bring to light molluscous remains in the Old Red Sandstone, they would, like the ichthyolites, be found to be peculiar to the intermediary rocks in which they were entombed[2]. This surmise has been

[1] See the work of Professor Phillips, 'Geology of Yorkshire,' vol. ii., which contains the earliest good monograph of the organic contents of the Carboniferous system of England.

[2] See Silurian System, p. 585. Although that work bears the date of 1839, we may observe that it was really completed in 1838. The term *Silurian* and the classification implied thereby were indeed pro-

realized by a train of inquiries which proved, that the group of fossils which occur in the calcareous slaty rocks of Devonshire were of the same age as the Old Red Sandstone. A new survey of Devonshire established, in short, the fact, that though they had previously been considered to belong to the older grauwacke rocks, large masses of schistose deposits overlying certain limestones and slates of that country and of a small part of the adjacent county of Cornwall, were nothing more than equivalents of the carboniferous series; and subsequent inquiries showed that the subjacent strata, into which the carboniferous formations appeared to pass conformably downwards, occupied the place of the Old Red Sandstone[1].

It being thus shown that these lower rocks, though black and slaty, contained shells, which, when the formation was developed in its sandy and red characters, had never been found in it, the term "Devonian System" was proposed as a synonym, if not as a substitute, for that of "Old Red Sandstone," the lithological import of which had led to much confusion, and had prevented the comparison of various grey, black and slaty deposits of Europe with the Old Red Sandstone of the British Isles. As, however, it might have been possible, that the distinctions pointed out in the British Isles were local, the authors, who had suggested this change of nomenclature, next undertook an extensive survey of the Rhenish Provinces, including the Hartz district and Franconia on the one side, and Belgium and the Boulonnais on the other, in the latter part of which they were accompanied by M. de Verneuil.

This inquiry may be said to have verified and established in that part of the continent of Europe, a portion of the palæozoic classifications first worked out in England. It proved that rocks immediately beneath those having a true carboniferous type, assumed the same characters and contained many of the same shells as the rocks

pounded by Mr. Murchison (after four years of previous labour) in July 1835, and the system was *then* divided into Upper and Lower Silurian rocks, each containing subordinate formations. (See Lond. and Edinb. Phil. Mag., vol. vii. p. 46, with a section explaining the relations.) The term *Devonian* was first applied in 1839, or immediately after the publication of the Silurian System.

[1] See the memoirs of Professor Sedgwick and Mr. Murchison, Trans. Brit. Assoc. for the Advancement of Science, 1836, Sect. Trans. p. 95; Trans. Geol. Soc., 2nd series, vol. v. p. 633; and Lond. and Edinb. Phil. Mag., April 1839, pp. 241, 354, where the term *Devonian* was first proposed. From an examination of certain organic remains collected in South Devon by Mr. Austen, Mr. Lonsdale had previously suggested that these forms were of characters intermediate between those of the Carboniferous and Silurian systems, and consequently of the age of the Old Red Sandstone. (See Trans. Geol. Soc., 2nd series, vol. v. pp. 690, 696, and 721. See also the work of Sir H. T. De la Beche, 'Geological Report of Devon and Cornwall,' and the Palæozoic Fossils of Devon and Cornwall, by Professor Phillips.)

in Devonshire, the whole reposing upon ancient grauwacke masses, which, however poor in calcareous matter and fossils, apparently represented a portion of the Silurian system of the British Isles. The proofs of this German succession are to be found in the 6th volume of the Transactions of the Geological Society of London[1]; the chief geological inductions of the English authors, Professor Sedgwick and Mr. Murchison, are there sustained by an elaborate analysis of the Devonian organic remains by M. de Verneuil and Vicomte d'Archiac.

But although the classification of these ancient formations was thus in great part established, the questions of what is the *protozoic* type, and whether a distinct and peculiar assemblage of fossils could be discovered in rocks of higher antiquity than the Lower Silurian, had not yet been completely grappled with,—questions, indeed, not even approached by the investigations in any part of Germany. In short, it still remained to inquire whether the older Cambrian slates were so characterized, and whether they were entitled to be considered a separate zoological system? And here it is right to acquaint geologists who may have misapprehended its meaning, that the term Cambrian was applied by Professor Sedgwick to the great slaty and partially fossiliferous group of North Wales, the chief relations of which he defined as early as 1833, distinguishing it from an upper group in Denbighshire. Unfortunately ill health and other circumstances prevented his examining and describing the fossils he had collected, and thus the types of the lower rocks of North Wales were unknown when the Silurian divisions were proposed and established. At that time, indeed, Professor Sedgwick believed, and in this opinion Mr. Murchison coincided, that when developed, these Cambrian organic remains, at least all the lower part of them, would prove to be distinct from the Lower Silurian types, which as a whole seemed to repose upon the slaty and crystalline rocks of North Wales. When this division was first suggested, it was, however, shown, that many of the most common fossils of the Lower Silurian type descended into the so-called Cambrian rocks. Speaking of the *Orthidæ*, *Leptænæ* and other shells which had even then been found in the latter, Mr. Murchison said, "As these shells abound in the Lower Silurian rocks, it would seem that as yet no defined line of *zoological* division can be drawn between the Lower Silurian and Upper Cambrian groups, and that *as our knowledge extends* we may probably fix the lower limit of the Silurian system beneath the line of demarcation which has for the present been assumed." And further, the same opinion is more strongly

[1] pp. 221 *et seq.*

enforced in these words: "To what extent the same species of shells which characterize the Lower Silurian rocks descend into the Cambrian system has not yet been satisfactorily determined, nor can it be until the oldest fossiliferous rocks of Cumberland, Wales and Devonshire, are brought into close comparison, and their specific contents accurately determined." (Sil. Syst., p. 308.)

Judging from their infraposition, their great thickness and distinct lithological characters, it was, indeed, presumed, chiefly from the analogies of the overlying deposits, that the lowest stage of these slaty rocks might be found to contain a class of organic remains peculiar to themselves. Subsequent appeals to nature have, however, decided otherwise. In the slaty tracts of Cumberland and Westmoreland Professor Sedgwick has satisfied himself, that the earliest organic remains which can be traced, are no others than those published from the Caradoc sandstone or uppermost part of the Lower Silurian; the great subjacent series being filled up with igneous, crystalline slaty rocks. Again, having recently revisited North Wales, the structure of which he long ago described, and where the series is infinitely more developed, he has come to the conclusion, that the oldest tracts of that country do not contain any group of fossils differing from those of the Lower Silurian type[1]. In the mean time, through the valuable labours of Sir Henry

[1] Professor Sedgwick was unquestionably the first geologist, after Mr. Jonathan Otley, who attempted to classify and map on an extended scale the rocks of Cumberland and Westmoreland. Since that time the detailed structure of that country has been worked out by himself and other authors, including Professor Phillips, Mr. James Marshall and Mr. D. Sharpe; for an acquaintance with whose memoirs the reader must consult the Transactions and Proceedings of the Geological Society of London and the Philosophical Magazine (see also the General Sketch of the Geology of the Lake District in a series of letters to Mr. Wordsworth by Professor Sedgwick, 1842). In North Wales, Mr. Bowman performed some good service, by developing the exact equivalents of certain Upper Silurian rocks in a tract where they have assumed a very slaty character, and Mr. D. Sharpe instituted certain tabular comparisons between the Silurian groups of North Wales, Shropshire and the north of England. This is not, however, the place to offer an exact historical sketch of these labours, still less to enter upon any discussion of the relative merits of memoirs, all of which more or less go to show, that despite of variations in mineral character, there are both Lower and Upper Silurian groups in all these tracts.

On the present occasion we would simply state, that as Professor Sedgwick led the way in deciphering the physical structure of North Wales, so after a full re-examination of both countries he has shown, that with a great expansion of equivalents of the Ludlow and Wenlock rocks in the lake districts, there are there no organic remains of higher antiquity than the very upper part of the Lower Silurian rocks; and that however differing in mineral characters and containing a few species hitherto undescribed, all the great inferior slaty masses of that region and of North Wales are the equivalents of those to which the term Lower Silurian had been applied (see Map and Tables, Quarterly Journal of the Geological Society of London, vol. i., and memoir read before that Society, March 1845).

De la Beche, Professor Phillips and the Ordnance Geological surveyors, large tracts of South Wales, which also had been grouped as Cambrian by Professor Sedgwick and Mr. Murchison, have not only been proved to contain the same typical fossils as the Caradoc sandstones and Llandeilo flags, but also to be for the most part mere replications and expansions of those Lower Silurian strata, assuming, however, to a great extent distinct lithological characters, due to numerous eruptions of igneous matter[1]. In North Wales, we have indeed convinced ourselves by personal examination of the flanks of Snowdon, that the most abundant organic forms of the oldest fossiliferous slates are certain species of *Orthidæ* and *Leptænæ*, which also abound in the typical Lower Silurian strata; and we therefore believe, that whilst the Snowdonian slates may be considered the lowest fossil stage in Britain, they are so zoologically united, that they cannot be geologically separated from the inferior strata of the Silurian region. From all these data then it followed, that the Cambrian system became identified with the published zoological type of the Lower Silurian rocks. We may now further state our belief, that in the British Isles, as in every other part of the world in which they have been observed, the Lower and Upper Silurian groups are so bound together by fossils common to the upper part of the one and the lower part of the other, that they really constitute one natural system; though in most instances they may be usefully distinguished on geological maps by different tints of the same colour.

Such having been the progress made in the British Isles, from the period when this classification began to be worked out, down to the day at which we write, let us now cast a view over the contemporaneous advances of palæozoic knowledge in other parts of the world. And, first, we may speak of Germany and Belgium. Though represented by thick masses of slaty grauwacke, particularly in the axis of the Ardennes, the Silurian type, such as we have described it, is very feebly represented by fossils, either throughout the Rhenish provinces[2], or in the more

[1] See Mr. Murchison's Address to the Geological Society of London, 1842 (Proc. Geol. Soc., vol. iv. p. 75), in which these observations of Sir H. De la Beche and his followers are noted. The complete and detailed elaboration of all the Upper and Lower Silurian rocks of North Wales, will, indeed, be one of the important results of that government survey, which will, doubtless, be rendered doubly valuable by the zoological illustrations of Professor Phillips and Professor E. Forbes, and by the clear and methodical field work of Mr. Ramsay and other geological surveyors.

[2] In his very instructive work, "Das Rheinische Uebergangs Gebirge, 1844," Dr. F. Roemer has indeed endeavoured to show, that all the fossiliferous grauwacke of the Rhenish provinces, as well as its overlying limestone, ought, from its fossils, to be classed as Devonian.

eastern tract of the Hartz. Again, in Franconia and the country around Hof, upon the southern flank of the Fichtelgebirge, true carboniferous and Devonian rocks exist, like those of the Rhenish and Belgian tracts; but the lower grauwacke series is, it must be admitted, a very imperfect representative of the Silurian system, though a tract of slaty rocks around Schleitz in which Graptolites abound, is really, we think, of that age. Throughout large mountainous tracts in central Germany, as in the Riesen Gebirge, and particularly in the eastern termination of that chain between Breslau and Glatz, where there are distinct carboniferous and Devonian limestones (the former overlaid by a productive coal-field), no Silurian strata can be detected. Thus also is it in the southern portion of the kingdom of Poland (for we have recently examined all these tracts), where the mass of the palæozoic rocks around Kielce, and formerly described by Pusch, are unquestionably Devonian, and are succeeded on the west by carboniferous limestone and a great productive coal-field. Thus, indeed, in Northern Moravia, the oldest limestone wherein organic remains have been found, must also be considered Devonian.

In one tract, however, of Germany,—in that, namely, around Prague,—which has been long celebrated for the number and beauty of its Trilobites, and where favouring sedimentary conditions prevail, the Silurian strata are richly developed. In a journey through Bohemia in 1843, we were much gratified to find, that by assiduous labours, M. Barande had made a copious collection of fossils in the environs of that city, and had identified many of them with published Silurian types. The collections of this geologist, from the limestones and shales of the district around Prague, present an assemblage which leaves no doubt of the age of the deposit. Thus amongst the corals and Graptolites, are found the *Catenipora escharoides* and *Graptolites Ludensis*; among the Brachiopods, *Leptæna euglypha*, *L. depressa*, *Terebratula Wilsoni*, *Terebratula reticularis*, with *Cardiola interrupta*, &c. In a profusion of chambered shells (and forty-five forms of Orthoceratites have already been collected), the *Orthoceras Ludense*, *O. gregarium*, *O. excentricum*, have been recognized, with Lituites, Cyrtoceras, Phragmoceras, and Gomphoceras, some of the species of which, if not absolutely identical, approach very closely to the published Upper Silurian forms; whilst amidst a multitude of Trilobites, the *Asaphus caudatus* and *Calymene macrophthalma* are unquestionable types of that age.

The strong analogy between the Silurian rocks of Bohemia and England is still further sustained by evidences of a Lower Silurian group composed of quartzose sandstones, in which Trinuclei have been found, one of which is undistinguishable from *T. Caractaci*. The assiduous exertions of M. Barande have thus demonstrated by fossil evidences, what we longed to have the power to assert,—the presence of an unequivocal Silurian system in the very heart of Germany[1].

In France the oldest palæozoic rocks are also Silurian, but owing to the metamorphosed nature of many of the tracts in which they occur, it has not yet been practicable to work out accurate boundary-lines between the different subdivisions in ascending order; particularly on the flanks of the Pyrenees. We are, however, sanctioned by the distinguished authors of the great geological map of France[2] in believing, that, on the whole, a succession like that in the British Isles prevails. From our own knowledge we should be disposed to state, that in Brittany[3] and the adjacent tracts of Normandy, strata of Devonian age (Nehou, Izé, La Bacconière, &c.), containing many fossils in their calcareous members, repose upon great masses of slaty schists and quartz rock, which at Angers, La Hunaudière, Bain and Vitré in Brittany, and Siouville and May in Normandy, are charged with Silurian Trilobites and Graptolites. Among the characteristic and abundant Trilobites are the *Calymene Tristani*, *Ogygia Guettardi*, and a large Illænus approaching to *I. crassicauda*, though considerably larger, and named by M. Burmeister, *I. giganteus*[4].

In the Boulonnais the palæozoic series has already assumed the Belgian and Rhenish type[5], exhibiting a clear descending order from a Carboniferous to a Devonian formation, each loaded with typical fossils, and underlaid by ill-developed Upper Silurian shale with Graptolites.

In comparing the Silurian deposits of different parts of France with those of Spain, it is interesting to observe, that the Silurian type of Brittany is extended southwards into the north-western territories of Spain, particularly the Asturias.

[1] Whilst we write, we find that M. Emmerich has just published an important memoir on Trilobites, through the aid of which class of fossils only he recognises the different stages in palæozoic series; and his opinion agrees with the conclusion at which we arrived on the spot, that the rocks of Prague are Silurian (see Leonhard's Journal, 1845).

[2] M. Dufrenoy and M. Elie de Beaumont. M. Durocher has recently attempted to divide the palæozoic rocks of the Pyrenees, but without reference to fossils. Ann. des Mines, tome viii.

[3] Whilst Mr. Murchison was visiting the interior of Germany and Poland (anno 1843), M. de Verneuil, accompanied by M. d'Archiac, was examining the palæozoic rocks of Brittany.

[4] See M. Burmeister's excellent new work on Trilobites, which has already obtained high commendation from distinguished naturalists.

[5] See Mr. Murchison's description of the Devonian rocks in the Boulonnais. Bull. Soc. Géol. Fr., vol. viii.

From the recent researches of M. Paillette it would appear, that beneath certain strata laden with characteristic Devonian mollusca (*Terebratula concentrica*, and other forms allied to that species, with *Leptæna Dutertrii*, &c.), are slaty schists which that author identifies with the Silurian schists of Brittany, and containing the *Calymene Tristani*, so distinctive of the Breton slates[1].

Whilst such has been the progress in the extension of the palæozoic classification to different parts of Western Europe, its truth has been conspicuously sustained by researches in the New World. No sooner were the Silurian rocks distinguished by their fossils and position from all overlying deposits, than several geologists of the United States showed, not only that large masses of the Alleghany or Appalachian chain were composed of them, but also that enormous coal-fields on its western and northern flanks were deposited on a series of strata very analogous to the Silurian rocks of Great Britain. Already geologists of several of the states have so far published their outlines, that the symmetry of succession common to their country and Europe can no longer be doubted. Copious as are the subdivisions, to which they have applied numerous local names, we can at once recognize in their published fossils, not only the existence of Lower and Upper Silurian groups, but also a true Devonian system, the whole forming the base of the vast carboniferous deposits of the west[2]. And if any doubt could have been

[1] That some of the Spanish schists are of true Silurian age, is established by their having been found to contain (in the Sierra Morena) the *Calymene Tristani*, so characteristic in Brittany. According to M. Paillette, certain strata, charged with many Devonian mollusks, repose in gentle undulations on beds loaded with coal and plants of the carboniferous age (Arnao). If this observation should prove correct, it will still more develope phænomena respecting the extent to which land plants descend into the palæozoic rocks,—phænomena to which Professor Sedgwick and Mr. Murchison alluded in their memoir on the Rhenish Provinces (Geol. Trans., vol. vi. p. 262.).

[2] The brothers Professor W. B. and H. D. Rogers, have already published some of their general views, which will be followed by detailed maps and sections, and illustrations of the structure of the Appalachian chain in Virginia and Pennsylvania. Mr. Conrad has made us well acquainted with many of the Silurian species of Mollusca, and has, by means of the trilobites alone, divided the system into three groups. Dr. Dale Owen communicated a memoir on the geology of the region of Indiana, with its great coal-fields and subjacent palæozoic rocks, to the British Association and Geological Society of London. Dr. Emmons, besides his Report of the northern part of New York, has just published a work, entitled the 'Taconic System,' descriptive of the oldest slaty fossiliferous rocks in Massachussets and the surrounding states, which is possibly the equivalent of those fucoidal strata which in the countries we are about to describe form the base of the Silurian system ?. Dr. Troost of Nashville has described the fossiliferous Silurian divisions of Tennessee. To Mr. Vanuxem we are indebted for a volume on one of the four districts into which the extensive state of New York was divided. Mr. J. Hall has recently put forth his detailed researches made during the New York survey, in a clear and copiously illustrated

entertained, it has been at once dispelled by the collections brought to England by Mr. Lyell, and submitted by him to our examination, whilst he was preparing for the public eye a work and map, in which the parallelism of the American with the British succession will be clearly pointed out. Notwithstanding the number and variety of new forms peculiar to that continent, we there find a sufficient number of species, either identical with, or closely allied to those of Europe, to enable us to recognise the development of the same series of phænomena. There, for example, as is the case in Russia, the most ancient mollusca are Brachiopods, void of an articulated hinge, and provided with a horny shell. The lower sandstone of the tracts near Lake Champlain, so copiously charged with fragments of Lingulæ, that they mark the lamination of the rock, and almost give to it a micaceous aspect, are therefore strikingly analogous to what has been described as the Ungulite grit of St. Petersburgh[1]. Above the sandstones occur the Trenton and blue limestones, fully developed in North America, and charged with Trilobites characteristic of strata of the same age in Northern Europe. Among these Trilobites we have but to name *Illænus crassicauda* and *Asaphus expansus*, with *Trinucleus* and *Isotelus*, to show at once how these forms represent the most numerous and characteristic species of the Lower Silurian strata of Northern Europe. Such also is the position of that most decisive coral the *Chætetes* (Favosites) *Petropolitanus* and of the shell *Spirifer lynx*, the varieties of which, abundantly diffused through the states of Ohio, Tennessee, Kentucky and Indiana, occupy exactly the same geological position as in Russia and Scandinavia. Lastly, besides certain Graptolites, this lower stage terminates, in ascending order, with a calcareous band

volume, the mere inspection of which led us at once to infer, that in the vast series which he simply designates the "*New York System*," the Devonian, Upper Silurian and Lower Silurian rocks are clearly to be distinguished. It is somewhat remarkable that the *Ludlow*ville rock of this author seems to be the exact equivalent of the Ludlow rocks of England! So numerous is the list of American authors who have written on the older rocks of their respective states, that we cannot now mention, still less do them justice; though we must not omit to notice Professor Hitchcock, who so fully described the geology of Massachussets, and Dr. Green, whose monograph on the Trilobites, published some years ago, clearly indicated the existence of Silurian rocks in that country. Nor can we conclude this note without stating, that in addition to a previous general application of English classification to the chief sedimentary deposits of the United States, Mr. Featherstonhaugh placed in a general way the lower strata of the Alleghany chain on the parallel of the Silurian system as early as the year 1836.

[1] See Proc. Geol. Soc. of London, abstract of Memoirs read in April 1842, at which time the authors of this work had not drawn the true distinctions between the Lower and Upper Silurian rocks of Russia. Pander's Beiträge, and Chapter III. of this work.

loaded with *Pentamerus oblongus*, the very fossil by which we have distinguished the same zone in the British Isles[1], Norway and Sweden!

The great abundance of corals constitutes in the United States, as in the old continent, the striking feature of the Upper Silurian rocks, and, as with us, the *Catenipora escharoides*, *Favosites Gothlandica* and *F. alveolaris* there form massive reefs. These coralline rocks may, without hesitation, be grouped with the Wenlock limestone; for it is in this stage also that the *Calymene macrophthalma*, *C. Blumenbachii*, *Bumastus Barriensis*, *Asaphus caudatus*, *Homalonotus delphinocephalus* also occur, with several mollusca, which remind us of the European fauna of this formation[2].

The Silurian system, thus clearly divisible into two groups, is overlaid in the United States by shales, sandstones and flagstones[3], which must be referred to the Devonian system, for they contain, in effect, the very fossils which we have published as characteristic of that age from the Boulonnais in France and the Rhenish provinces, among which are the *Spirifer Verneuilli* and *Orthis crenistria* or *umbraculum*. The beds are crowned by a red sandstone with peculiar fishes, which every one must at once admit to be characteristic of the Old Red Sandstone of the British Isles. If, however, from this fact some persons might suppose, that a division were practicable between the Old Red Sandstone and the Devonian shelly limestone, we beg to refer, not only to our memoir upon the Rhenish provinces before cited, but also to the third and fourth chapters of this work, wherein proofs will be adduced of the absolute intermixture of these ichthyolites and shells in the very same strata. Lastly, the Carboniferous system is distinguished in North America as elsewhere by its Producti, whilst the coal-beds contain plants for the most part identical in species with those of Europe, and by shells, such as the *Bellerophon Urii* and *Euomphalus carbonarius* (Sow.), which are undistinguishable from species of the Scottish coal-fields[4].

[1] This is the Horderly and Woolhope limestone of the Silurian rocks (see Sil. Syst. p. 217, 414, 419). We shall show in the sequel the exact position of this limestone in Norway and Sweden, where it contains the same species of Pentamerus, which in Russia is represented by our *P. borealis*.

[2] We may here further mention some of the true Upper Silurian molluscous species that we have recognised in the collection of Mr. Lyell. *Cytherina alta* (very near to *C. Baltica*), *Terebratula Wilsoni*, *Atrypa sphærica*, *Pentamerus* (*Atrypa*) *galeatus*, *Leptæna depressa*, *L. euglypha*, *Orthis canalis*. From the work of Mr. J. Hall we may further cite the Wenlock species *Spirifer cardiospermiformis* and *Hypanthocrinites decorus* (see Silurian System, p. 630, 672).

[3] The Tully, Genessee, Portage and Chemung groups of Mr. J. Hall.

[4] M. de Verneuil recognised these good British types in a collection brought by Mr. Lyell from certain beds of shale at Frostburg in Maryland which rest directly on a bed of coal.

Judging from the numerous Orthoceratites and Trilobites long since supplied to us from the British colonies of North America, we were, indeed, well aware, that the strata to which we affixed the term Silurian must there have a very wide extension; and this general point was sustained by the publication of numerous Silurian fossils from that region by M. de Castelnau[1]. But even whilst we write, new data crowd upon us from the researches of Mr. Logan and Captain Bayfield, which more clearly indicate the exact nature of the palæozoic succession in those regions, and show us how analogous it is to that of Europe. The Lower Silurian rocks are well-developed at the Falls of Niagara and in various parts of the Canadas and Nova Scotia, where they rest, it appears, on gneissic and granitic rocks, just like similar beds in Scandinavia, which are described in the next chapter. The northern side of the Gulf of St. Lawrence is composed of more ancient crystalline rocks, whilst the Lower Silurian occupy the isles of Mingan and Anticosti. In the collections made in these islands by Captain Bayfield, we were delighted to recognise our Russian friends *Illænus crassicauda*, *Orthoceratites duplex*, *Spirifer lynx* and *Leptæna Humboldti*, and still more to find that this group was there (as in England and Scandinavia) overlaid by limestones containing the *Pentamerus oblongus*. Again, the north coast of Newfoundland offers a like succession, for near Norman Cape the *Orthoceratites duplex* and *Euomphalus qualteriatus*, both characteristic Lower Silurian types in Russia, are associated with other Orthoceratites and chambered shells, some of which are allied to Nautili and Lituites, as in the Bay of Christiania. The same enterprizing naval surveyor (Captain Bayfield), has further observed the junction of the lowest Silurian deposits with the subjacent crystalline rocks along a frontier of not less than 2000 miles, or from the Straits of Belleisle on the north-east, to the end of Lake Superior on the south-west[2]; whilst from this grand base-line, an ascending succession has been traced eastwards and southwards, through Upper Silurian and Devonian, to the Carboniferous deposits of New Brunswick and the United States.

Extending our views from North to South America, we have to thank M. Alcide d'Orbigny for a splendid geological work, in which he has endeavoured to sketch out, through many degrees of latitude, the great subdivisions of the Silurian, Devonian and Carboniferous series; whilst Mr. C. Darwin had long ago satisfied us of the existence of Lower Silurian rocks in the Falkland Isles. We can now therefore affirm, that throughout the western hemisphere, from the far north to isles

[1] Système Silurien de l'Amérique Septentrionale.

[2] See Memoir read before the Geological Society of London, March 1845.

almost within the antarctic circle, the palæozoic deposits succeed each other in the same order as in the British Isles.

By our own researches it is shown, that the same palæozoic order extends from the typical countries of Western Europe already explored, through Scandinavia into Russia, and thence into Asia. In justice, however, to the adventurous explorers of the north-eastern and southern parts of Siberia, we must state that we owe what acquaintance we possess of those lands not only to the published account of Baron Humboldt and Mr. G. Rose, but also to the travels of M. Adolph Erman, M. de Tchihatcheff and Professor Middendorff[1].

In Hindostan, so eminently British, we regret to say, that although the secondary rocks of that district have been to some extent described, and the tertiary deposits on the south flank of the Himalaya, with their extraordinary fossil contents, have, in the hands of British officers, thrown a flood of new light on the characters of the fauna of that recent period, no well-defined and precise labours have yet been devoted to the older rocks of the vast peninsula of India; a fact the more extraordinary, when it is recollected, that without such researches those to whom the government of that country is entrusted can never really distinguish its old and true coal strata from those of comparatively worthless character.

In Africa, particularly in its southern extremity, we are acquainted with Silurian rocks containing characteristic Trilobites and other organic remains, though in respect to their details and succession we can do no more than refer to what we formerly said of them (see Silurian System, p. 217.).

Through the labours and collections of M. Strzelecki and other travellers, we learn that in Australia there are deposits loaded with fossils analogous to those of our carboniferous group, one of which approaches to the *Productus antiquatus*, another is a *Conularia* very near to *C. quadrisulcata*, and these deposits repose on strata in which corals of Devonian age have been discovered.

Lastly, we come to the consideration of the extensive investigations which we

[1] M. A Erman has published a geological map of Siberia and several Silurian fossils from the banks of the Lena in 57° north latitude. (Archiv für Russland, vol. iii. pp. 161 and 542.) M. Pierre de Tchihatcheff has explored the higher tracts of the Altai mountains bordering on China, from the Irtysh river to the Yenisei, where he observed a copious development of Devonian and carboniferous rocks. (Voyage Scientifique dans l'Altai Orientale, &c.) Professor Middendorff, after thoroughly exploring the Taimyr region of the far north, has retraversed Siberia to the extreme south-east or to the Shantar Isles in the Sea of Okhutsk! and has shown that vast tracts, extending over the Stanovoi mountains and along the Amur frontier of China, consist of carboniferous and other palæozoic deposits, with granites, greenstones and metamorphic rocks. (See Bull. de l'Acad. de St. Pétersbourg, Dec. 1844.)

have ourselves made in Scandinavia, European Russia and the Ural Mountains. This appeal, we have no hesitation in saying, has unequivocally sustained the conviction, that whilst the Lower Silurian is there the lowest fossiliferous type, it is also the base of a series composed of overlying formations, very distinctly referable to the Upper Silurian, Devonian and Carboniferous groups. We may, indeed, assert, that as the proofs of these natural divisions there extend over a very large portion of the earth, and in a completely unaltered state, so are they still more clear than those offered by any one region hitherto examined. In the north of England, for example, the palæozoic succession is broken; for the Old Red Sandstone is a mere conglomerate without fossils, and although the Upper Silurian rocks are copiously developed in a slaty and subcrystalline form (the beds containing many fossils), the place of the Lower Silurian, with the exception of the uppermost strata, is occupied by great masses of chloritic schist, alternating with countless, contemporaneous ribs of porphyry, as well as with trappæan conglomerates and slaty beds derived mechanically from materials of igneous origin[1]. In Scotland, where the old red formation is copiously spread out in sandstone, shale and conglomerates, and contains many ichthyolites, it is void of mollusks, and the schistose rocks which succeed to it have been as yet but obscurely characterized as Silurian by their organic remains, though certain bands with trilobites, corals and other fossils have been observed in the Galloway hills, which, overlying the older grauwacke, must, we think, belong to the Upper Silurian group[2]. Even in the typical Silurian region, where the stratigraphical order and succession are so unequivocal, the Old Red Sandstone contains, as before said, no shells; and in Devonshire, where shells abound in the same system, no fishes have been seen and a few broken portions only of Silurian rocks have recently been recognised in Cornwall[3]. Again, in most of these tracts, as well as in the Rhenish provinces, the

[1] See Professor Sedgwick's memoir read before the Geol. Soc. of London, March 1845.

[2] See Professor Sedgwick's memoir, Proc. Geol. Soc. vol. iii. p. 553. Some years ago Graptolites were, indeed, discovered in the schists of Wigtonshire by Mr. John Carrick Moore (Proc. Geol. Soc. vol. iii. p. 277), and even whilst we write, we have seen Orthoceratites from the black schists of St. Mary's on the southern shores of Kircudbright, recently found there by the Earl of Selkirk, which are unquestionable Upper Silurian forms.

[3] By the discoveries of Mr. C. W. Peach, shells and fishes apparently belonging to the uppermost beds of the Silurian system have been recognised between Looe and Fowey in Cornwall. Mr. Peach indeed believes, that several fossils of other and lower formations of the Silurian system also occur in Cornwall; but the very imperfect condition of these bodies and the absence of stratigraphical order have hitherto prevented very decisive identifications. (See 31st Report of the Royal Geol. Soc. of Cornwall.)

palæozoic strata are for the most part in such a highly disturbed and fractured condition (sometimes, indeed, inverted), that their true symmetry is not easily ascertained. Such difficulties are, in truth, much increased throughout Western Europe by the prevalence of rocks of igneous origin, through whose eruption many dismemberments and alterations of the strata have been produced.

Russia, on the contrary, being a vast region, by far the greater portion of which has been singularly exempted from all such igneous agency, is found to present an unaltered succession of older rocks, whose nature we shall presently define, by considering them in an ascending series; and in doing so we hope, not only to exhibit the distinct development of the earliest sedimentary strata over a very wide space, but also to point out that certain desiderata not supplied by other countries are there clearly furnished. This we shall endeavour to do, first, by developing an unequivocal base-line of palæozoic existence in the Lower Silurian strata, as indicated both by the gradual decrement and disappearance of vestiges of animal life in the inferior member of the series, which, void of all traces of the lowest vertebrata and containing fucoids only in the inferior beds, rest upon pre-existing crystalline rocks without fossils; secondly, by pointing out over large territories, the co-existence in the same strata of the fossil fishes of the Old Red Sandstone of Scotland with the shells and other fossils of the shelly and calcareous rocks of South Devon and the Eifel[1]—thus demonstrating that they constitute one inseparable natural group; and thirdly, after describing a peculiar form of the carboniferous system and giving a detailed account of the coal-bearing tracts in the empire, by establishing under the name of "Permian" a copious series of deposits which form the true termination of the long palæozoic periods.

This last-mentioned system has not hitherto obtained the attention to which it is entitled. In France it is known only as a deposit of red sandstone with a few plants; in Belgium it is a mere conglomerate (the "*Penéen*" or sterile group of M. d'Omalius d'Halloy). In England and Germany, where its members are much more expanded in the form of red sandstone and conglomerate, magnesian limestone, copper slate, &c., the strata have never received a collective name, nor have they till recently been united as a natural group[2], distinguishable from the inferior

[1] We have just ascertained from M. Vogt, the friend of Agassiz, that certain remains of fishes brought by us from Gerolstein in the Eifel, belong to the Old Red genera *Osteolepis* and *Coccosteus*.

[2] Professor Phillips was the first to maintain, that the fossils of the magnesian limestone of England ought to be classed with those of the palæozoic rocks, and our Permian researches confirm his view.

formations by peculiar species, though connected with them by the general aspect of their fauna, and entirely different in all their organic contents from the overlying or triassic system.

Finding that this supracarboniferous group was not only spread over a region of enormous dimensions in Russia, extending from the Volga to the Ural Mountains on the east, and from the Sea of Archangel to the southern steppes of Orenburg, but that among certain fossils characteristic of the Zechstein in other parts of Europe, it also contained many new species of shells and a fauna somewhat differing from that of the carboniferous age, we have ventured to apply to it a collective name derived from the ancient kingdom of Permia, which was situated in the centre of the vast territories overspread by these deposits.

In strata of the secondary period, Russia is much less rich than in those of palæozoic date. She contains, for example, no masses which can be distinctly referred to the New Red Sandstone or Trias; for wherever we have attempted to define such beds, we have found them to be intimately associated with those of true Permian age[1]. This view has been strengthened by the entire absence of the muschelkalk in Russia proper; one small and dubious representative of it only having been observed in the isolated hill called Mount Bogdo (steppe of Astrakhan).

The Jurassic deposits cover detached districts of Russia, from the Icy Sea on the north to the Caucasus in the south. In Russia proper they exist chiefly in the form of shales and sands, which are exclusively referable to the middle or Oxfordian member only of the oolitic or Jurassic series of other parts of Europe; the lias and lower oolites, as well as the Kimmeridge and Portland or upper oolite, being everywhere wanting.

Unlike the Jurassic, the Cretaceous system is exclusively confined to the southern half of Russia, where it often presents the peculiar characters and organic contents of the white chalk of other parts of the world, and in some tracts the equivalents, though never fully developed, of the greensand strata.

[1] These introductory pages being among the last printed in our book, we take this opportunity of alluding to a work by Dr. Kutorga that has just appeared (2. Beitrag zur Palæontologie Russlands), which from the form of certain plants therein figured, as well as from a shell which that author considers to be a *Posidonomya*, might lead geologists to believe in the existence of Trias at Kargala near Bielebei in the government of Orenburg. We cannot, however, admit the inference of Dr. Kutorga (and of his fossils we may speak in the Appendix or second volume), more particularly as he states, on the authority of Major Waugenheim, who surveyed the tract, that the fossil beds of Kargala lie *low* in the series which we have demonstrated to be of Permian age.

The Jurassic and cretaceous rocks of Russia, possessing to a great extent, wherever we have examined them, the same mineral and zoological aspect as in the British Isles, northern France and Germany, thus present the strongest contrast to the sub-crystalline limestones of the same age in the south of France, Spain, the southern flank of the Alps, Italy, Greece, Asia Minor, and the Caucasus, which exhibit what has been termed the Mediterranean type[1]. The tertiary deposits, exclusive of a few patches of very recent age, are most expanded in southern Russia, where beds will be described which truly represent the Eocene and Miocene divisions, the former having, in parts, the very same structure and contents as the London clay, and the latter being, in fact, the extension of the great basins of Vienna and Hungary. Nearly if not entirely deficient in marine deposits of the Pliocene or newer Tertiary period, the southern extremities of Russia, from the confines of the Black Sea and the Sea of Azof to the Caspian and Aral seas, as well as wide tracts of Asia, the Crimæa and Caucasus, are composed of deposits, which distinctly overlying the oceanic tertiaries of Miocene age, are completely distinct from any great geological group hitherto described. Uniformly and copiously charged with a limited number of species of shells, more or less similar to those of the Caspian of the present day[2], these widely-spread accumulations of the steppes will be shown to have been formed exclusively in the same brackish waters that must once have occupied an area as large, if not larger, than the present Mediterranean Sea.

Directing the especial attention of geologists to this grand feature in the former arrangement of the surface of the globe which has hitherto almost escaped their attention, and then describing certain raised bottoms of the Northern Seas, the first part of this work will conclude with an account of the last scene of a long series of subaqueous deposits, traced chronologically from the period of the earliest-formed organic types, to that in which the shells of the sea were to a great extent the same as those now prevailing.

Having shown that throughout all this long succession of deposits, the whole sedimentary superficies of central Russia (forming nearly one-half of the continent

[1] By M. von Buch.

[2] See observations on a recent memoir of Colonel Helmersen on the character of certain shells found in the Ust-Urt by M. Basinier (Appendix). The discoveries of M. Basinier have somewhat modified our views (pp. 309–324) concerning the whole area which we supposed to be occupied by the brackish Aralo-Caspian Sea. See Appendix on this point, and also for some important facts concerning the tertiary deposits on the south coast of the Black Sea, and the plateaux west of Ararat, as derived from our friend Mr. W. Hamilton, M.P., Sec. Geol. Soc. (see Map, Pl. VI.).

of Europe) has been disturbed by broad undulatory movements only, but has not been subjected to great disruptions, nor affected by any intrusions whatever of igneous matter; and further, that all the deposits from the oldest to the youngest are very little altered and in many instances unsolidified, we then transport our readers to the Ural Mountains and Siberia. There, on the contrary, we indicate how formations of the same age as those which in European Russia are slightly coherent and horizontal, have been thrown up in mural masses, broken into fragments, impregnated with minerals and often inverted in their order. All these phænomena occur along a grand meridian fissure in the earth's surface, through which copious masses of igneous matter have been evolved at intervals from very remote antiquity, whilst the chain has undergone elevation and even impregnation with gold ores at a period not very distant from our own. Although we naturally refer to such disturbances as the cause of the great change that the sedimentary masses are there found to have undergone, yet in describing these mutations, a clear distinction is drawn between the ancient crystalline or azoic rocks of Scandinavia on which the Silurian strata rest, and those Uralian metamorphosed rocks which often to a great extent assume the same primary characters and aspect.

In the concluding chapters of this volume we take a general survey of the superficial deposits of the vast region of the Ural Mountains and Siberia, wherein have been found the abundant remains of large mammalia, and which are so celebrated for the gold ore they contain; and reasoning from geological evidences we have endeavoured to delineate certain ancient geographical features, at a time when a large portion of those vast regions constituted a continent, inhabited by these extinct mammals, whose destruction will be shown to have been coeval with the last elevations of the Ural chain. On the other hand, we adduce our reasons for believing, that whilst Siberia and the Ural were above the waters, Russia in Europe must have been beneath them; a conclusion which seems necessary in order to render explicable upon rational grounds the phænomena of the great Scandinavian drift, by which all the low countries of the north have been covered by far-transported materials. Lastly, after an account of that singular overlying deposit the black earth of Russia and an attempt to explain its origin, followed by an account of the present causes as tending to produce a change of the surface, whether by the agency of ice, water, alluvial deposits, or the elevation of land, the first volume is concluded by a short résumé, showing to what extent our conclusions are borne out by an appeal to such extensive observations.

The second volume, or Part III., being exclusively devoted to the description of Organic Remains, necessarily constitutes the great mass of evidence which practical geologists and palæontologists will require.

This brief exposition of the objects we have laboured to attain, will, we trust, suffice to enable our readers to judge of the success with which our leading views have been developed. A few years ago only, when unable to indicate the first created animals, or the exact relative places occupied by some of the earliest formations, we were compelled to trace the sequence downwards by commencing with deposits previously analysed, proceeding thence to those of anterior date[1]; but now having learnt to decipher the very first letters in the long records of animal life, we assume a more distinct position as historians, and exhibit in their natural order, the successive organic features which appear in the stony legend of the earth, from their earliest dawn to the present condition of the planet.

In a word, after a patient study of the types of palæozoic life, we can now fearlessly assert, that the geological history or sequence of the earliest races of fossil animals is firmly established. Its truth is sustained by the display of forms, which mark the period when the first vestiges of life can be discovered, as well as the following successive creations; and thus whilst, with the exception of one sacred record, we can truly say, that the origin of the greatest empires of man is buried in fable and superstition, the hard and indelible register, as preserved for our inspection in the great book of ancient Nature, is at length interpreted and read off with clearness and precision.

Passing, however, from these grand, general considerations, to which we may be pardoned for alluding, since they bear so directly on the sublimity and truthfulness of geological science, we now proceed to the special objects of our own undertaking.

[1] See the 'Silurian System,' and the plan pursued in that work (*passim*).

CHAPTER II.

SILURIAN ROCKS OF SCANDINAVIA.

The Lower Silurian Rocks of Scandinavia shown to form the true base of all deposits containing Organic Remains.—Their relations in the Territory of Christiania to pre-existing Gneissose and Granitic or Azoic Rocks.—Norwegian Sections showing the ascending order from Lower through Upper Silurian to Old Red Sandstone inclusive.—Intrusive Rocks associated with the Palæozoic Formations distinguished from those which have affected the Azoic Rocks.—The chief Palæozoic Phænomena of Sweden explained, and the Lower Silurian Rocks of various localities shown to rest upon Granitic Gneiss, which has furnished the materials of their lowest stratum (Sections of Kinnekulle, Lugnos, Omberg, Grenna, Berg, &c.).—Upper Silurian Group of England perfectly represented in the Isle of Gothland.—Comparison of the Fossils and close analogy of Lower and Upper Silurian Divisions of Scandinavia with those of the British Isles.

A GLANCE at our Map and a few words of explanation from ourselves, will at once lead the reader to understand, that the geologist who would effectively write a history of the whole series of sedimentary deposits that encumber the surface of Russia, must naturally begin with a sketch of the adjacent Scandinavian regions, which, chiefly occupied by highly crystalline rocks, are in many places covered with patches of ancient strata containing organic remains. This indeed was specially called for, by the previous works of Hisinger, Wahlenberg, Von Buch and Dalman, whose representations of organic forms had long ago led us to conclude, that deposits of true Silurian age existed in Sweden and Norway[1]. Finding that the low level of the country, and the mass of detritus with which it is covered, prevented our detecting junctions between the lowest known sedimentary deposits

[1] See Silurian System *passim*.

and any crystalline rocks of anterior age in Russia, it became indeed essential, that previous to writing our first pages of the history of succession in this part of the globe, we should see and describe what might be exhibited amid the hard and rocky lands of Scandinavia, of the absolute contact of the lowest sedimentary strata with the crystalline rocks of that region.

On this point we have recently convinced ourselves, by clear and indisputable sections, that the lowest beds charged with anything like animals or vegetables, are the exact equivalents of the Lower Silurian strata of the British Isles, and that these have been distinctly formed out of, and rest upon, slaty and other rocks which had undergone crystallization before their particles were ground up and cemented together to compose the earliest beds in which organic life is traceable. To the crystalline masses which preceded that palæozoic succession to which our researches were mostly directed, we apply the term "Azoic," not meaning thereby dogmatically to affirm, that nothing organic could have been in existence during those earliest deposits of sedimentary matter, but simply as expressing the fact, that in as far as human researches have reached, no vestiges of living things have been found in them, so also from their nature they seem to have been formed under such accompanying conditions of intense heat and fusion, that it is hopeless to expect to find in them traces of organization[1].

Since it is not our object, on this occasion, to enter further into the details of the structure of Scandinavia than is essential to sustain the accuracy of this our fundamental view, we will now merely offer a general sketch of the phænomena on which our inferences are founded.

One of the Scandinavian features which first strikes the ordinary observer with surprise, is the enormous amount of crystalline rock that occupies the surface of the country. In the term Azoic rocks, we include all the crystalline masses belonging to the ancient group of gneiss, together with ancient granitic and plutonic rocks by which they have been invaded. Those who wish to become acquainted with the varied composition of these rocks, must consult the works of various authors from those of Von Buch, who first described them in Norway, to those of Keilhau, who in the same country has recently bestowed so much labour

[1] Hypercritically, it may be said that this word might also be applied to other deposits of subsequent age, in which the organic remains are also obliterated, and thus be merged with the *Hypogene* of Lyell. But in our sense the word *azoic* is synonymous with *pro-zoic*, or before recognizable traces of life. Professor Phillips has applied the word *Hypozoic* to the same rocks which we term *Azoic*.

upon them. Occupying the great bulk of Sweden, they are there, even whilst we write, undergoing an elaborate survey by several able mineralogists, who following the contortions of each separate mass, are now laying down their outlines on what may be termed a lithological map of that highly crystalline country[1].

It forms no part of our object to describe the varied mineral features of the gneissose rocks of Norway, which extend westward to the Ocean and eastward into Sweden. We may, however, say that, on the whole, they very much resemble the ancient gneiss of Scotland and other countries, and present, in many tracts, an almost infinite succession of felspathic, quartzose, micaceous and hornblendic laminæ, often highly contorted, but in which very determined *strikes* are perceptible over large tracts. They are indeed specially distinguished by the great abundance of granitic veins which they contain; the phænomena which the Scottish philosophers Hutton, Playfair and their followers took such trouble to indicate in the isle of Arran and other localities, being here laid bare in thousands of examples. So numerous are the granites, chiefly rose-coloured, which with countless divergent veins penetrate the gneiss in every direction, that geologists have usually given to the mass the name of granitic gneiss. These azoic rocks are also intruded on by numerous bosses and dykes of greenstone, and in some districts contain metalliferous veins, including those of the celebrated silver mines of Kongsberg and the cobalt mines of Modun. All that we are now concerned to state is, that the gneissose masses constitute in themselves the loftiest mountains of the whole region, and that in numberless sections, whether exposed on the sea shores, on the sides of the fiords or in the interior, they are seen to constitute a

[1] MM. Forsellis, Erdman, Franzen and Troilius have already finished, but not yet published, a geological map of various provinces, including Dalecarlia, which through the obliging directions of Baron Berzelius, was exhibited and explained to us by M. Erdman. Our readers may have some conception of the detailed labours of its authors, when we state, that granites, gneissose rocks, mica schists, hornblende rocks, syenites, greenstones, jaspers, porphyries, &c., as well as many varieties of each of these classes, are distinguished on the map by different colours and marks. Not having examined in detail the tracts thus illustrated, we are not able to say to what extent the authors of this map have distinguished the masses of azoic age from certain metamorphic strata which, if like those of the Christiania territory, are of palæozoic age. Their "flötz" limestones and sandstones are evidently palæozoic, and for the most part Silurian. The chief promontories are, however, occupied by great bands of gneiss, the strike of which varies prodigiously, and, subjected to enormous flexures, range in one district east and west, in another north and south with many intermediate directions. It is this great and dominant mass of crystalline granitic gneiss, that, according to our views, is anterior to everything to which the term palæozoic can be applied.

group of enormous thickness, which, containing very little calcareous matter, is in general composition, strike and position, entirely distinct from the Silurian strata by which it is overlaid.

In Norway these ancient crystalline rocks rise into mountains and form the flanks of troughs of palæozoic strata, which have in their turn been invaded by granites, syenites, porphyries, greenstone and trappæan rocks of another epoch. Let us take the territory of Christiania as an example. Rising in altitude from south to north, the gneiss there occupies the rocky and barren country on either side of the long fiord of Christiania[1]. The mass upon the west extending from Christiansand to the lofty mountains of Bergen, flanks the palæozoic rocks in a devious line, extending from the marine bay of Lango Sund, by the east of Kongsberg, and thence north-north-east by the river Drammen and the western sides of the lakes of Tyri fiord and Rands fiord. The eastern gneissose boundary advancing from Gottenburg and Sweden to Friederickstadt, constitutes nearly all the eastern rocky shore of the salt water fiord of Christiania, and occupying the mountain called Egeberg to the east of that town, extends to the north-north-east by the eastern side of the great lake Miozen.

The palæozoic deposits lie in a long trough between these crystalline masses; such general features being correctly laid down in the geological map of the territory of Christiania by Professor Keilhau[2]. Minute details are here uncalled for, and we have now simply to state, that by making two transverse sections across this palæozoic trough on different parallels, we found that although extremely broken up and diversified by various plutonic rocks, and very much dislocated, its lower members consisted of quartzose sandstone and hard slaty schists; the

[1] Mr. Murchison seizes with pleasure this opportunity of expressing his obligations to his friend the Rev. W. Bilton, F.G.S., who repeatedly urged him to visit Norway, and in whose attractive *piscatorial* volumes will be found some good suggestions and many interesting geological souvenirs. ('Two Summers in Norway,' vol. ii. p. 150.)

[2] A sketch of the palæozoic succession from the lowest Silurian to the Old Red Sandstone inclusive, as exhibited in the southern parts of Norway, was read by Mr. Murchison before the General Meeting of Scandinavian philosophers, held at Christiania, July 1844, and has, we believe, been published by them in their volume with an explanatory woodcut (essentially the same as that which we give at p. 13). After traversing Sweden in the same summer and arriving at St. Petersburgh, Mr. Murchison there read before the Imperial Mineralogical Society of that Metropolis, a brief outline of his general views respecting the relations of the Silurian rocks of Sweden and Gothland to those of Russia with which he was previously acquainted. These ideas are now essentially embodied in the text, and more detailed descriptions have been given by Mr. Murchison to the Geological Society of London.

former visible in some tracts only, as at Vigersund on the Drammen, the latter being the well-known fucoid alum shale of the country and forming the prevalent base in the Christiania fiord. These lowest strata are surmounted by black limestones and shale charged with fossils, which leave no doubt that the inferior group represents the Lower Silurian rocks of the British Isles.

Amid a profusion of Trilobites, some of which are of new species and have been named, but not figured by Dr. Boeck[1], we find in the inferior member of the series (the lowest beds of which contain fucoids), the genera Battus or Agnostus (with Paradoxides or Olenus); and in other beds *Trinucleus Caractaci*, *Asaphus Buchii* and *A. tyrannus*, with various Orthoceratites and other chambered shells, and some Orthidæ, including the *O. alternata* and *O. virgata*; all forms highly characteristic of the Lower Silurian rocks in the British Isles. With the latter are associated and in still greater abundance, the *Illænus crassicauda*[2], *Asaphus expansus* and *Chætetes (Favosites) Petropolitanus*, *Orthoceratites duplex*, and certain remarkable circular bodies related to Crinoidea, the *Sphæronites aurantium*, all of which specially distinguish the Lower Silurian rocks of Sweden and Russia As a whole, these

[1] Of the forty-eight species of Trilobites (exclusive of a Battus) enumerated by Dr. Boeck, many of them, it must be stated, are named from mere fragments, which circumstance, skilful naturalist as he is, render the number of true and distinct species doubtful. Without distinguishing the genera (and we agree with him that many of the generic distinctions hitherto proposed are obscure and evanescent), he ranges, however, certain forms around common types. Judging from his own description and the fossils we examined in the museum of Christiania, we should say, that his species, *Trilobites ellipticus* and *T. elegans*, are what we should call varieties of *Calymene macrophthalma* and *C. variolaris*, which with *Asaphus caudatus*, *T. semilunaris* (Esmk.), *Calymene Blumenbachii* and its varieties are characteristic of the Upper Silurian strata which are seen in the Isles of Malmoe and Malmoe-kalv, Long Oen, Holmestrand, &c. All the other Trilobites cited by Boeck, of which the *Illænus crassicauda* is by far the most abundant, belong to the Lower Silurian group, wherein also occur the *Asaphus expansus*, four species of *Trinuclei*, and the forms which range round *Asaphus Buchii* and *A. tyrannus*, similar, indeed, to varieties with which we are perfectly familiar in Wales; together with several published Swedish species of Dalman, Wahlenberg, &c. (see Gæa Norvegica, 1 Lief. p. 138.)

[2] It appears that the *Illænus perovalis* of the Silurian system (drawn from an imperfect specimen) is identical with the *I. crassicauda*. This species has been found in the Lower Silurian rocks of Wales, since Mr. Murchison's work was written, by Mr. Sharpe, Prof. Sedgwick, and the officers of the Ordnance Geological Survey. The coral *Chætetes (Favosites) Petropolitanus*, so very characteristic of the Lower Silurian of Russia, has also been detected by Prof. Sedgwick in the older strata of North Wales. This and other facts, showing the identity between the Silurian system of Great Britain and Scandinavia, have been made known for the first time by comparing the fossils we brought back from Norway, Sweden and Russia, with those collected by Professor Sedgwick and described by MM. Sowerby and Salter (see Table, Journal of the Geol. Soc. vol. i. facing p. 20). The other results of the comparison of other species brought by us from Scandinavia, with the Upper Silurian British types, will be spoken of in the sequel.

Lower Silurian rocks of Norway have very little of the arenaceous character which the same group assumes in certain tracts of Britain, but are most analogous to the schists and calcareous flags of Llandeilo, where those masses have not assumed a slaty structure. This lower division is overlaid by shales and massive coralline limestones containing many of the typical species of the Wenlock limestone in the British Isles, and these again by calcareous flagstones and schists which from their fossils and position may be taken to represent the Ludlow rocks.

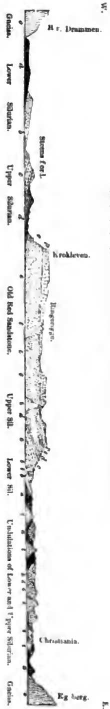
Though packed into a narrow band of no great vertical dimensions, the Silurian strata of Norway are thus clearly divisible into an upper and lower group. These groups are further separated from each other by a limestone loaded with *Pentamerus oblongus*, which fossil, occupying exactly the same place in the Woolhope or Horderley limestone of the British Isles, and lying between the two, may thus, according to the natural features and prevailing fossils of each country, be classed either as the base of the Upper Silurian rocks or as the uppermost bed of the Lower. The Upper Silurian group is distinguished by the *Catenipora escharoides*, *C. labyrinthica*, and many other typical species of corals, as well as by a multitude of shells, among which are many which occur in rocks of the same age, both in the British Isles and in the Isle of Gothland.

In truth, no English geologist acquainted with the organic contents of the Wenlock limestone can view the little isles of Malmoe Oen and Malmoe Kalv in the bay of Christiania (which we examined in company with M. Leopold Von Buch[1]), and see in them the *Calymene Blumenbachii*, *C. macrophthalma*, *C. variolaris*, and other Trilobites associated with the *Leptæna depressa*, *L. euglypha*, *Terebratula reticularis*, and many corals most familiar to him, without at once recognising in the upper strata the distinct representative of that British formation[2].

[1] This eminent geologist was, like ourselves, at the Christiania meeting of Scandinavian savants of 1844.

[2] We do not here note all the corals and shells which are common to the Upper Silurian of Norway and Britain, because the Gothland list, afterwards given, may be taken as the best sample of the identity of the formations in Britain and Scandinavia. We cannot, however, avoid noting, that besides the usual Upper Silurian brachiopods, we procured from M. Keilhau a specimen of the *Nucula cingulata* (His.), which proves to be identical with a shell which we had long ago obtained from Dudley, but which Mr. James Sowerby, unable perfectly to satisfy his mind concerning its relations, had refrained from describing in our former work on the Silurian System. It is further worthy of remark, that this shell, so rare at Dudley, has recently been discovered pretty plentifully by Mr. Sharpe, Professor Sedgwick and Professor Phillips in the Upper Silurian rocks of Westmoreland, near Kendal, and is there associated with *Leptæna depressa*, *Cypricardia*, &c. We thus see the value of not omitting considerations of minute palæontological detail, since a shell extremely rare in one region may thus become a type of the same epoch in another.

These Lower and Upper Silurian rocks constitute one inseparable and closely connected system. Their highest member, composed of calcareous flagstones containing the *Leptæna lata*, a peculiar Spirifer and a shell closely allied to *Terebratula Wilsoni*, is clearly overlaid in the mountainous tracts called Ringerigge, to the west of Christiania, by red quartzose sandstone and shale, that forms a deposit of great thickness (perhaps 1000 feet) lithologically undistinguishable from the Old Red Sandstone of the British Isles, its summit being composed of a conglomerate as in the Herefordshire, Salop, &c. In the course of a rapid survey, we thus obtained evidence of a succession from Lower through Upper Silurian to the Old Red Sandstone inclusive. In a word, the latter formation, with great tabular masses of porphyry, is thus separated from the ancient gneiss on either side, and occupies a lofty tract in the centre of the trough, having the Christiania fiord on one side, and the Steens fiord and Drammen on the other, both of which depressions are filled with the Silurian rocks in question (see woodcut and note 1).



1. SECTION ACROSS THE TERRITORY OF CHRISTIANIA[1].

In the Steens fiord, whither we first went in the company of Professor Keilhau and afterwards with Professor Forchhammer, we were, indeed, truly delighted to perceive the great symmetry with which the Upper Silurian flagstones and tilestones[2], per-

[1] Explanation of the woodcut:—

Old Red Sandstone—*e*. Red sandstone and conglomerate.

Upper Silurian { *d*. Calcareous flagstones, &c.
c. Coralline limestone and shale.

Lower Silurian { *b*. Pentamerus limestone.
a. Schists, flags, and lower sandstone.

o. Azoic or gneissose rocks, with old granite, greenstone, &c.

{ *p*. Rhombic porphyry in the Old Red Sandstone.
t. Eruptive and trappæan rocks of various characters.

[2] Mr. Murchison takes this opportunity of acquainting geologists who may not have attended to the successive development of his ideas on classification, that certain red tilestones at the base of the Old Red Sandstone of England, which from mineral aspect were formerly classed with that formation, he has for some years considered as forming, together with the bone-bed, the uppermost stage of the Silurian rocks. (Anniversary Discourse, Proc. Geol. Soc. vol. iii.) He had, indeed, from the first described these beds as being charged with Upper Ludlow fossils (see Silurian System, pp. 192, 602).

fectly identical in aspect with those of Shropshire and Herefordshire, rise out from beneath the great mass of Old Red Sandstone of Ringerigge and Krokleven. In carrying the same section across to the gneiss range on the west bank of the river Drammen, the upper and calcareous coralline formation is separated from the black Lower Silurian flags, by the same limestone with *Pentamerus oblongus*, which forms the intermediate bed between the Upper and Lower Silurian in many tracts of the British Isles. These very clear general relations are illustrated in the accompanying woodcut.

But whilst we thus speak of the undoubted parallel, which, from practice in detecting the equivalents of rocks of this age, we have been able to establish between the different members of the Silurian rocks of Norway and those of the British Isles, we must admit, that in many parts, particularly on the sides of the bays of Christiania and Drammen, they are so perforated by eruptive rocks of posterior age, that, except in such very typical localities as those of Steens fiord and Krokleven, which appear to the left of the accompanying woodcut, it is difficult to distinguish a clear order of superposition; so much are the strata thrown into undulations. These intrusive rocks (*t*), whose characters and the effects they produced upon the strata they have invaded were long ago described by M. von Buch, consist of granites, syenites, porphyries (including the hyperite of that author), greenstones, amygdaloids, &c.[1]

Perfectly distinct from the older granitic rocks associated with the gneiss, these eruptive masses are now demonstrated by our observations to be of younger age than the Old Red Sandstone, and they, therefore, play the same part in geological history as great masses of the trappean rocks of English authors. Whether they can be divided into two groups of different age protruded at different periods to the surface is more than our limited time enabled us positively to determine; but it may be remarked, that, with the apparent exception of the large crystalled porphyry of Ringerigge (*p* of woodcut and rhomb-porphyr of Von Buch), we nowhere saw any of those contemporaneous porphyries, greenstones, and other stratified igneous masses which are so abundantly interlaminated with the Silurian rocks (particularly the lower) throughout large districts in the British Isles, where in expanding such deposits they often necessarily obliterate the organic remains, and

[1] The reader may form his idea of these intrusions from the representation on a small scale towards the right-hand side of the woodcut, though it is not pretended that the section (woodcut, p. 13) exhibits a twentieth portion of the intrusions and flexures.

give to the sedimentary masses a peculiar and subcrystalline character. Of such eruptive rocks contemporaneous with the Silurian and older palæozoic strata, we shall, however, hereafter treat in describing the Ural Mountains. Here we simply note their absence, as accounting, in some measure, for the small vertical dimensions of the Silurian formations of Norway which have evidently been accumulated in a sea that has been exempted from those contemporary igneous evolutions, which in many other tracts, have naturally tended to swell the thickness of the ancient formations.

The mineral changes however produced by the eruptive rocks upon the Silurian beds of Norway are, indeed, as beautiful and striking as in any region that we ever examined. Thus in the tracts north-west of the Steens fiord and in the Solvsberg, where igneous rocks protrude, it may be said, that the black shales (Lower Silurian) are changed into hard subcrystalline schists (the Harte Schiefer of Keilhau, or Kiesel Schiefer of the Germans); but however altered, the original character of the stratum is discernible, and fossils are found in it at intervals. On the left bank of the Drammen, opposite Vigersund, a lower fucoid sandstone in contact with greenstone becomes a quartz rock. At the town of Drammen, eruptive rocks of granite and greenstone, apparently passing into each other, exhibit in the adjacent escarpments fragments of highly altered micaceous red sandstone (Old Red) and Lydian stone, surmounted by and included among amygdaloids. At Djelebeck or Jelebeck, to the north of Drammen, granite forming the hill called Paradis-backen, throws off the Pentamerus limestone, which though metamorphosed into a saccharoid marble and charged with garnets in the neighbourhood of the granite, becomes less and less altered as it recedes from that rock, and then contains its usual fossils[1].

Following the same bands of younger granitic and porphyritic rocks to the south, they are seen to spread out and occupy nearly the whole of the southern portion of the palæozoic basin, crowning considerable heights, and extending into the promontories on either side of Laurvig and Fredricksvärn. There they form

[1] We examined this altered rock with our friend Professor Forchhammer, who thus writes of it:—"This impure limestone contains, besides carbonate of lime, some carbonate of magnesia, alumina, oxide of iron and silica. The compact carbonate of lime has assumed a granular form and has become white marble; the magnesia has lost its carbonic acid, and has combined with lime and silica to form the mineral tremolite; and the oxide of iron has combined with alumina, lime and silica, to form greenish and beautifully crystallized garnets."—Trans. Brit. Assoc. for 1844, p. 165.

nearly the whole of a crystalline country like Cornwall[1], in which the eruptive rocks constituting the chief masses have left mere remnants only of the palæozoic rocks at a few places on the flanks. The knolls around Fredricksvärn are, in truth, quite analogous to many Cornish granitic hills which have been shown similarly to penetrate strata chiefly of the age of the Old Red Sandstone, &c[2].

But to return to the metamorphosed Silurian strata: we lastly observed, in company with Professor Forchhammer, that at the foot of the Egeberg near Christiania, where the Lower Silurian alum-slate is pierced by greenstone, it is converted into a micaceous, quartzose, crystalline rock, to a considerable extent resembling the old gneiss of the adjacent mountain. Here, however, as in another example at the fortress of Christiania, and in every other case where true palæozoic strata have been transmuted by igneous agency, the observer can follow the beds from the points of contact where they are crystalline, until receding from the disturbance, the strata, as they unfold, first appear as mere indurated, black and contorted schists, and then passing in a short space into the dark and calcareous Silurian shale of the bay, are overlapped by its fossiliferous limestones[3].

Developing elsewhere more precisely the nature of these phænomena of meta-

[1] The granitic rock of Fredricksvärn with its zircons is a beautiful crystalline rock loaded with minerals, including magnetic iron ore and labrador felspar, with the new species *Polymenite*, *Illæolite*, &c. When treating of the Ural Mountains, we shall have occasion to express a wish that distinctive terms should be given to eruptive rocks of age posterior to the palæozoic strata, in order to distinguish them from the older granites associated with gneiss. Foreign geologists naturally enough object to the use of the word trappean as sometimes applied to the newer group, which in truth includes granites; and as syenite, in its strict mineralogical sense, as well as greenstone, occurs in the older plutonic division also, it is clear that some term should be adopted to mark the age of the eruption of each class, since there are granites and syenites of different ages. We might venture to suggest for this purpose such names as *Proto-plutonic*, *Palæo-plutonic*, &c., which, if approved, might be extended to *Mezo-plutonic*, &c., as more precisely defining the age of eruption than the terms hitherto used. In our general Map, Pl. VI., all these younger granites younger than the azoic rocks are necessarily grouped under one colour and letter. In the Map, however, of the Ural Mountains, the granites are distinguished from the greenstones and serpentines by separate marks.

[2] Since the publication of various memoirs by Professor Sedgwick and Mr. Murchison, Sir H. T. De la Beche and Professor Phillips (including the work on palæozoic fossils of the last-mentioned author) certain fossil remains, supposed to be Silurian, have been discovered in Cornwall by Mr. Peach and other persons. (See Ann. Report Roy. Geol. Soc. of Cornwall, 1844, p. 7.)

[3] A memoir by Mr. Murchison, containing more detailed views on the structure of Norway and Sweden, has been communicated to the Geological Society of London, in which it was shown how the able memoir by Professor Forchhammer on the chemical changes from fucoid schists into gneiss-like rocks bears upon our views. (See Report to the British Association for the Advancement of Science, 1844, p. 155.)

morphism, we now allude to them merely to show, that although quite alive to their value (and our account of the Ural chain will, we trust, sufficiently prove this), we still see a clear distinction between such palæozoic changes and a previous metamorphism of the azoic rocks.

But if the examination of Norway alone sufficed to lead us to entertain this opinion, we were still more fortified in it by the survey of Sweden, to the consideration of which we now proceed.

Silurian Rocks of Sweden and their relations to the older Crystalline Rocks.—In the following short outline of some prominent features of the geology of Sweden, we will first describe the relations of the Lower Silurian group to the subjacent crystalline rocks, as they appeared to us in a traverse from Gottenburg to Stockholm[1], and will afterwards advert to the fossiliferous distinctions of the Upper Silurian group of Gothland.

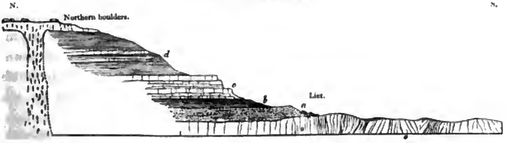
In the hills of Hollaberg and Hunneberg, to the east of the Falls of Trollhætten, which are covered by a thick mass of trap rock (basaltic greenstone), one subordinate member only of the Silurian series is visible, namely, the alum-slate; but no one who knows from numerous other sections, that this band is very near the Silurian base, can glance his eye over the lower adjacent lands, all composed of gneiss and granitic rocks, or look up from the latter as they appear on the banks of the river, near the Falls of Trollhætten, without being convinced, that the horizontal band of black schistose Silurian rock lies above the crystalline granitic rocks of the low country, though the absolute junction of the two is hidden by a talus of detritus.

Advancing to the next Silurian oasis at Kinnekulle and the hills of Billingen, the same general relations, of a low surrounding country of gneiss and granite, to high tabular plateaux of horizontal Silurian strata, usually capped by trap, present themselves to the traveller. In ascending the hills of Kinnekulle, from the flat gneissose country of Lidkoping, he is no sooner above the low level of those crystalline rocks, than he meets with a terrace composed of quartzose sandstone, already mentioned as frequently forming the lowest Silurian stratum in Scandinavia. This rock, here arranged in beds from a few inches to a foot and a half thick, is light-

[1] In this journey Mr. Murchison was accompanied by that excellent naturalist, Professor Lóven of Stockholm, through whose acquaintance with the country, and references to the works and map of Hisinger, it was easy to select the points for examination by which the question of true protozoic succession could be best determined.

grey, whitish and fine-grained, in parts freckled with ferruginous stains, and assumes, at intervals, a quartzose character, with divisions of chloritic shale. Its lowest beds, or those which, as we shall presently show, rest upon the adjacent gneiss of the valleys, are not here visible, owing to a talus of detritus, but in those which are visible, we found branching, fucoid-like bodies. This sandstone is, in fact, seen to constitute the prevalent base of all the Silurian strata, and in the hill of Kinnekulle is surmounted, first, by the black alum schist and limestone; next by red Orthoceratite limestone; and, lastly, by Graptolite schists with some calcareous courses and Orthoceratites. Though irregularly denuded over a very considerable area, the Orthoceratite limestone (*c*) of the following woodcut occupies a prominent step on the sides of the plateau, and standing out high above the surrounding gneiss, is in its turn covered by black schists (*d*), through which a point of basaltic trap (*t*) has pierced, occupying only a small upper portion of the central part of the tract. In descending from this summit (whereon a few northern erratics occur), we were much struck with the perfect symmetry of the Lower Silurian beds. To the north, or on the side of the Wenern lake, the crystalline and gneissose rocks being in a depression, the fucoid sandstone ranges down to the water-edge, surmounted by the alum-slates, but as you pass over the hill of Kinnekulle to the hamlet of Liet, upon its south-eastern face, the gneiss is again seen to present exactly the same inferior relations to the lower sandstone as on the western side. At this spot, as here represented, the section is much more clear and explicit. The Orthoceratite limestone (*c*) is strikingly developed by extensive quarries, which form the first great steppe-like

HILL OF KINNEKULLE. 1*.



terrace between the basalt-capped schists (*d*) above and the low country of gneiss beneath. Descending from these limestones (in which we found fine specimens of *Asaphus tyrannus*, *A. expansus* and *Illænus crassicauda*, besides numerous Orthoceratites), and passing over the beds of alum-slate and black limestone (*b*), with their Trinuclei, Paradoxides or Olenus, Agnosti, &c., the fucoid sandstone (*a*) is there seen in horizontal masses, perfectly conformable to all the overlying strata, and distinctly superposed to the gneiss below (*o*). For, though the absolute junction of the sandstone and gneiss is not seen, the two rocks are within a hundred paces of each other, and without the slightest indication of any other substance between them. Now the gneiss is here not merely in a lower position than the contiguous sandstone, but, besides its crystalline structure, is at once seen to belong to rocks of an entirely different class, and to be quite independent of the overlying Silurian formation. In short, the one must have assumed its direction and structure before the other was accumulated. Denuded in large rounded protuberant bosses, the gneiss, as laid bare in numerous places, consists of fine alternating layers of felspathic and quartzose, black, white and pink colours, which having a strike that varies from magnetic north and south to north-west and south-east, are either vertical, or dip at angles of 70° and 80° to the east or west.

In offering the above woodcut to explain these relations, we apprehend that we have already said enough to convince our readers, that the gneiss, including many varieties to which it is not now our intention to allude, must be considered the fundamental rock of Sweden, which existed and was even highly inclined, contorted and crystallized before the very lowest Silurian beds began to be formed.

But if, after examining the section of Kinnekulle, we could have entertained any doubt on this point, it would have been dispelled by what we saw in other localities, where the lowest of the Silurian or protozoic strata are not only absolutely superimposed on the granitic gneiss, but are proved to have been derived from it, and composed of its very materials. We saw the first example of this phænomenon at Lugnos, near the northern end of the Billingen Hills, where the Lower Silurian beds (as at Kinnekulle), being deprived of their cover of basalt, which has protected them from denudation over a considerable area to the south, are worn down, so as only to exhibit their lowest portion, the alum-slate (*b*) being partially visible above the slopes of the rising ground, and the fucoid sandstone (*a*) lying beneath it, as expressed in this section.

LUGNOS. iii.

S. Erratic blocks. N.

Millstone grit or *arkose* covering the granitic gneiss.

Low, undulating granitic rocks, with decomposing spheroidal surfaces.

Here, at least, there can be no ambiguity; for the whole of the adjacent low tract is composed of rolling hillocks of granite or granitic gneiss, which assume exactly that appearance of bell-shaped masses, so happily illustrated by M. von Buch[1], and which we have endeavoured to represent in the preceding woodcut.

In one spot, we traced the granitic gneiss to within a few yards of certain quarries a little above it which have been largely worked for millstones. The upper beds, consisting of sandstones like those to which we have previously alluded, alternate with greenish-grey shale; but in passing downwards they become a hard, dark-grey, ferruginous and siliceous grit, beneath which is the band worked for millstones. The latter (*a'* of the preceding woodcut) is, in truth, nothing but a pink-coloured, recomposed granite or granitic gneiss, in which the felspar and quartz are aggregated into a mass completely resembling the *Arkose* of Brongniart. Though here evidently constituting the true base of the Silurian system, this rock, resting on the granitic gneiss of Sweden, could scarcely be distinguished in mineral characters from an Arkose of tertiary age in Central France, which we saw many years ago; so essentially do sedimentary rocks of different age resemble each other when constructed out of similar crystalline materials[2]. (See Lyell and Murchison, Ann. des Sciences Naturelles, Oct. 1829.)

Again, in exploring the eastern shore of the great Wettern Lake, to the south of Wadstena, among the phænomena of great interest to which we shall elsewhere advert, we found that along the steep shores of the Omberg, one of the few hills in Southern Sweden where the granitic gneiss occupies a tract of any considerable

[1] We know of no more instructive or truly original description of the structure and form of granitoid rocks than that which is embraced in Baron Leopold von Buch's recent memoir in the Transactions of the Berlin Academy of Sciences, 1842. We have also great pleasure in saying, that we think it is probable that the striation of granitic rocks may in *some* instances be referred (as M. von Buch suggests) to the friction by the movement of overlying masses over underlying domes of granite as resulting from structural conditions. (See pp. 540 *et seq.*)

[2] Professor Löven called our attention to a passage in the Swedish works of Hisinger, wherein that geologist describes these millstone quarries, though in his time they were probably not worked down to so low a level as at present. We may further state, that this author's maps and sections of the strata of Billingen, as well as of Kinnekulle (all Lower Silurian), are very faithful. On visiting Lugnos, we found that the millstones were split off by horizontal fractures from vertical cylindrical columns, cut out of the hard *arkose*; and it is worthy of remark, that in its separation, this regenerated rock flakes off with a surface more or less raised in the centre, as if imitating the subjacent crystalline mass, from which it has been derived. See the opposite woodcut, in which the granitic rock is seen to exfoliate *in situ*, leaving detached sphæroidal fragments of its surface, and thus forming the commencement of the *felsen-meer* of M. von Buch

height, the relations of the Lower Silurian strata are, if possible, still more strongly indicative of their having been derived from the adjacent pre-existing crystalline rocks. Details of these features would be here misplaced, and we shall therefore offer a few words only upon them.

The Orthoceratite limestone is largely quarried at the village of Borghamm, near the northern end of the Omberg; but by coasting that mountain in a boat along its western face, the granitic rock of which it is composed, is seen to occupy the whole surface for some distance, in cliffs rising to 400 or 500 feet above the lake. In about a mile, however, broken masses of the Lower Silurian rocks (*b* and *c*) occur in nearly vertical positions, plastered as it were against the great wall of crystalline rock (*o*), as represented in this sectional drawing. Still further on, or

THE OMBERG. 2*.

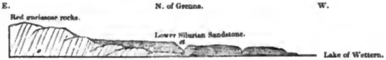
Mulakrederna (a great fall of rock.)

southwards, the chief mass of granitic gneiss retires somewhat inland, laying open combs upon its inclined surface, and in these are very considerable masses of Lower Silurian strata with an occasional Orthoceratite, but with little calcareous matter and few fossils. These strata occupy a considerable thickness, both in a slightly inclined, almost horizontal terrace, and also in vertical and highly inclined positions, as represented in the above woodcut. The inclined strata (*b* and *c*) are chiefly composed of soft argillaceous shale entirely unaltered, even when they are in absolute contact with the granitic rocks, and in them, and also in certain alternating courses of calcareous grit, are many included small pebbles and fragments of the crystalline rock. Pacing across the edges of one group only of these beds near their southern extremity, where the mass of the granitic rocks retires inland, and which, as above exhibited (towards the right-hand of section), are inclined at about 35° to the north for upwards of 800 paces, their lower part (*b*) consisting of black shale (alum-slate) wholly unaltered, we came to the lower fucoid sandstone (*a*). Here again there could be no misgivings; for this sandstone having been considerably eroded and worn away by the stormy action of the waters of the lake, the lower granitic gneiss beneath it (*o*) has been exposed as a nucleus, around which the white, sandy and regenerated sandstone (*a*, *a*) has been wrapped, and is still in a wholly unaltered state.

These facts completely demonstrate what we are contending for, that the granitic gneiss and associated rocks of Sweden formed the solid materials of that country before the earliest vestiges of palæozoic deposits were called into existence. Nay, they further prove, that as the Lower Silurian strata in question which are actually adherent to the granitic rocks, though highly dislocated, occur in the state of soft shale and unaltered impure limestone and sandstone, the crystalline ridge of the Omberg must have been upheaved as a hard and solidified mass (like the granite and gneiss of the Ord of Caithness through the oolites of Brora[1]), long after the period when it had undergone the fusion and metamorphism which gave to these ancient slaty rocks their crystalline aspect.

Other phænomena, proving that the lowest Silurian sandstone of these tracts has been formed out of the ancient crystalline rocks, are indeed to be found in many other parts of Sweden, and we particularly noted them still further to the south, on the high eastern banks and slopes of the Wettern Lake near Grenna, where, as well as in the large isle of Visings, the strata are composed of a sandstone that, from its red colour, had been mapped as *Keuper* by Hisinger, but which is simply a continuation of the base of the lowest Silurian stratum, its red colour being derived from adjacent red felspathic and quartzose rocks (*o*) out of which it has been formed and on which it rests, as here represented.

3.



Whether this sandstone, which over large tracts in Vestrogothia and Ostrogothia is truly the lowest member of the Silurian system, be universally so in Sweden, can only be determined by more extended researches; but from what we observed on the gneissose and granitic hills to the south of the lake of Roxen and near the inn of Berg, we should say not. Considerable masses of Orthoceratite limestone with associated shales there occupy the depressions and slopes, in cutting through which, the numerous fossils known to collectors under the name of the locality of Hysbifiol were obtained. The black alum shales full of fossils, rising out from beneath their calcareous cover with its Trinuclei and Agnosti, are exposed in

[1] See Geol. Trans., vol. ii. 2nd series, p. 306. Professor Phillips has since shown, that the chief mass of the Malvern Hills is of age anterior to the Caradoc sandstone; but that section affords no unequivocal Lower Silurian or Protozoic base like the Swedish cases.

shallow quarries and fold over upon the subjacent granitic gneiss, which occasionally surrounds them on all sides, and without the appearance of any intermediate sandstone. Such relations, indeed, we have already alluded to at the Egeberg near Christiania; and it is so obvious that in no country can mineral characters be considered indicative of the relative age of beds, that we simply here make the remark, because we shall presently have to show, that in Russia the lowest member of the Silurian system is not a sandstone but a shale, the latter being there overlaid by sandstone.

In certain quarries of argillaceous limestone at Freberga, to the north of Motala, we met with beds absolutely loaded with the circular bodies spoken of at Christiania, *Sphæronites aurantium* (His.), *Echinosphærites* (Wahl.), of the same species as those to which we shall afterwards have to allude near St. Petersburgh. They are there clustered together like bundles of enormous grapes, and are associated with one of the small *Orthidæ* so common in the Russian deposits of the same age. Here again the beds, though entirely unaltered, are tilted at the high angle of 70° to the north, in the proximity of a hill of ancient granitic or syenitic rock, which had doubtless been heaved up *en masse* like the Omberg, whilst in all the lower flat beyond the slope of the limestone hillocks, and extending for many miles along the north-western shores of the Wettern See, the lower or fucoid sandstone lies in grand horizontal sheets, and is extensively quarried as a building stone.

Upper Silurian Rocks.—Having thus satisfied ourselves concerning the true base of the Silurian rocks, and further of their close relations to strata of the Russian governments of St. Petersburgh and Reval, with which we were previously well acquainted; and being further convinced that with very rare exceptions there are no traces of Upper Silurian rocks in the central or southern part of the continent of Sweden, it was not essential to our views of classification that we should visit Gothland, where such upper strata are so well known to abound.

In fact, through the kind and liberal arrangements of Baron Berzelius and the assistance of our companion Professor Löven, to whose zeal, intelligence and good arrangements we were singularly indebted, the rich collections of Hisinger and Dalman were laid before us and a selection made from them, for the purpose of comparison with those of Great Britain, Russia and other countries. A glance at the fossils which were brought to England and examined by other palæontologists as well as ourselves, is sufficient to convince any one acquainted with the Silurian rocks of the British Isles, that whilst the long island of Öland is essentially composed of the same Lower Silurian group which we had followed over the main land, (its Orthoceratite marble limestones having been largely exported to all parts of the Baltic), the island of Gothland is exclusively of Upper Silurian age. The chief rock of this island is a limestone very similar to that of the upper deposit of Christiania, and is loaded with corals, many of which, including *Catenipora escharoides*, *C. labyrinthica*, *Favosites Gothlandica*, are well-known species in the Wenlock and Dudley limestone of England. With these are associated

Leptæna depressa, *L. euglypha*, *Atrypa tumida*, *Pentamerus* (*Atrypa*) *galeatus*, *P. conchidium*, *Delthyris cyrtæna* (*Spirifer radiatus*), *Terebratula Wilsoni* Sow. (*T. lacunosa* of the Swedish authors), *T. marginalis* Dalm. (*T. imbricata* Sil. Syst.), *T. reticularis* Linn. (Silur. variety of *T. prisca*), *T. nucula*, *T. plicatella* Dal., *Euomphalus sulcatus* His., *Posidonia alata*, *Avicula retroflexa* His., *Tellina prisca*, *Orthoceratites communis* Wahl. (*O. Ludense* Sil. Syst.), *O. imbricatus* Wahl., *O. annulatus* His. (*O. ibex* Sil. Syst.), *O. annulatus* Sow. (*O. undulatus* His.), *Phragmoceras*, *Lituites*, *Calymene Blumenbachii*, *C. variolaris* Brong., *Asaphus caudatus*[1],

and a number of other Trilobites, among which is a rare example of the genus *Brontes* (Goldfuss).

The coincidence of numerous fossils published as Upper Silurian types in England is so truly remarkable, that doubtless the rocks in the two countries are of exactly the same epoch. The actual examination of these fossils has also enabled us to see, that certain British species which, judging from the published figures of Hisinger, were supposed to be distinct, are, in fact, identical with forms previously named by that author, whose terms will necessarily in all such cases be adopted.

Whilst the whole Gothlandian group is thus unquestionably proved to be Upper Silurian, a large part being undoubtedly on the exact parallel of the Wenlock limestone, we might (judging from certain fossils, such as the *Avicula retroflexa* and a species of *Brontes*[2], both found with certain Orthoceratites in a sandy rock at Mount Homberg in the southern part of the island) be led to think, that the true equivalent of the Ludlow rocks is also there present. This is, indeed, rendered highly probable from what is found to be the case in the Russian island of Oesel (see p. 35*). But we desist from any further attempt at close subdivisional comparison until we have personally examined the localities[3].

[1] Among the Gothland Crinoidea we observed the remarkable *Hypanthocrinites decorus* as well as the *Actinocrinites moniliformis* of Dudley.

[2] Though not published in the Silurian System, the genus *Brontes* has been found by Dr. Lloyd in the Ludlow rocks, and even in their lower division. The genus is, therefore, common to the Upper Silurian and Lower Devonian strata.

[3] In his detailed map Hisinger correctly lays down the Island of Öland as consisting in ascending order of sandstone, alum slate and Orthoceratite limestone, whilst Gothland is all composed of his younger limestone.

In the Swedish Upper Silurian group there are, indeed, a few species unknown to English geologists. But even these, though wanting in England, are found in rocks of the same age in other countries. Such, for example, is that peculiar shell the *Cytherina Baltica*, or a variety of it, which has been detected in Normandy and Brittany, and also, as we shall hereafter show, in the Timan range of north-eastern Russia. Such also is the *Posidonia alata*, which is, if we mistake not, a fossil of the Clinton division of the Silurian rocks of North America. We cannot make the last allusion without observing, that several of the species enumerated, viz. *Leptæna depressa, L. euglypha, Atrypa tumida, Pentamerus galeatus, Orthis elegantula, Delthyris cyrtæna, D. sulcata, Avicula retroflexa* and *Hypanthocrinites decorus*, as well as *Calymene Blumenbachi* and other Trilobites with some corals, are identical, not only with English but also with North American species of the Upper Silurian rocks,—a striking illustration of the wide diffusion of similar conditions in the early stages of the formation of the surface, of which we shall hereafter adduce many other examples.

To whatever extent, therefore, future researches may prove, that English subdivisions are practicable in it, the Gothlandian group is at any rate a most copious and unequivocal display of true Upper Silurian types, which in Sweden are quite as distinct from those of the Lower Silurian rocks before described, as in the best-studied districts of the British Isles.

In taking leave of Scandinavia for the present, we must, in the mean time, specially advert to the close relations which exist between its Lower and Upper Silurian groups and those of Great Britain and distant parts of the world. Of 133 Silurian fossils which we brought back or noted on the spot during our recent survey, at least eighty-four are British, and from twenty-five to twenty-seven are North American species. In this comparison the identity of the Upper Silurian groups of the Baltic and Great Britain is, indeed, most surprising; for among seventy-four Scandinavian species upwards of sixty are common to the strata of this age in both countries, and of these fifteen to sixteen species are also found in the Upper Silurian rocks of America.

Such, then, is a brief comparison of the Silurian rocks of Scandinavia with those of Great Britain, where their order was first established. In publishing our earliest general results concerning these deposits we pointedly reminded our brother geologists, that although in applying the Silurian classification to extensive tracts, the minor and local subdivisions of the typical English region would probably not be maintainable, a natural separation into Lower and Upper groups might generally be looked for in other countries, where strata of this age prevailed[1]. In Scandinavia, indeed, the identity of two such groups with the British types is not only most striking, but even many of the subordinate details in both countries are to a remarkable degree analogous.

Having now sufficiently defined the dawn of palæozoic succession, and our readers being, we hope, convinced, that the Lower Silurian rocks constitute the earliest-formed sediments in which animal life has been discovered in tracts where the series, void of all animal remains in its lowest stratum, rests on crystalline rocks, they will now proceed to the consideration of the successive deposits of Russia with a clear idea of the earliest stages in the long series of deposits that we are about to describe.

[1] See Lond. and Edinb. Phil. Mag., 1835, p. 46, and Silurian System *passim*. Since the last-mentioned work was published, a certain number of fossils not noticed in it have been discovered. Thus, in the Upper Silurian, Mr. J. W. Fletcher and Mr. J. Gray, of Dudley, have collected many new forms of Crinoidea, including the remarkable bodies named Pseudocrinites by Mr. C. Pearce, and which seem to be allied to the genus Pentremite.

CHAPTER III.

SILURIAN ROCKS OF RUSSIA.

Introductory View of the prevalent physical Features of Russia in Europe.—Crystalline Rocks to the North of the Silurian Zone.—Line of Elevation accompanied by eruptive Rocks and Fissures transverse to the Crystalline frontier of the North.—Consequent Obscuration of the Junction between the Azoic and Protozoic Rocks.—Silurian strata in the government of St. Petersburgh represent the Lower Group only.—Transverse sections of the same to the South of St. Petersburgh and on the rivers Ishora, Tosna, Volkof and Siass, showing that the Lower Silurian Rocks are there at once surmounted by strata of Devonian age.—Silurian Dislocations and Flexures accounted for.—The Lower Silurian beds of Esthonia and Kovno pass upwards into Limestones with Pentameri, intermediate between the Lower and Upper Groups.—Upper Silurian Rocks developed in the Isles of Dago and Oesel.—Review of the characteristic Silurian Organic Remains, proving a division into Lower and Upper Zones in Russia, as in Norway and Sweden. (See Map, Table and Section, Plate VI.)

AS a prelude to the description of the geological structure of Russia, we must be permitted to say a few words upon the physical features and drainage of that great central portion of the empire, the exploration of which has been our main object.

Bounded on the north by a vast country occupied by crystalline rocks, and surrounded on other sides by the mountains of the Ural, the Caucasus and the Carpathians, Russia in Europe may be viewed as a spacious, low, undulating region, which opens out into the great depression of the Caspian Sea on the south-east, and to the flat countries of Northern Germany on the west.

Considering its magnitude, this mass of land is very remarkable in being devoid of a single elevation approaching to the character of a mountain; whilst with this absence of altitude, no portion of Europe contains so great a number of fine rivers. The principal watershed which divides Russia into two hydrographical basins, and throws off some rivers into the Baltic and White Seas, and others into the Black Sea, the Sea of Azof and the Caspian, is not even defined by any chain of continuous and decided hills. Ranging from the frontiers of Poland on the south-west through the Valdai Hills, and thence to the north-east, the central part only of this watershed is entitled to be called a ridge. As erroneous views have prevailed respecting them, we may here briefly state, that these hills consist simply of plateaux which originate between the south end of the Lake Peipus and the river Düna, from whence, rising to an average height of 800 or 900 feet, with a few summits attaining to about 1000 feet, they continue to the north-east, and constitute the Valdai Hills. When studied as a whole, however, these hills extend in reality also from Livonia to the south-east, and range by the sources of the Velika and the Düna to Orel, Kursk, and Voroneje, where they form a domelike elevation in the centre of Russia, to the geological influence of which we shall hereafter advert. It may in the meantime be remarked, that the south-eastern branch of these high grounds, near Kursk and Orel, deflects the river Oka to the north until it merges in the Volga, and also determines the northward course of the Don, until that stream finds a depression by which it escapes southwards to the Sea of Azof.

It must also be stated, that the Valdai Hills do not form, as some geographers had supposed, a continuous elevation which unites with the mountains of the North Ural. On the contrary, they rapidly decrease in altitude towards the north-east, and are lost in marshy lacustrine tracts, just of sufficient height to determine the flow of the river Vitegra into the Baltic, of the Onega into the White Sea, and of the tributaries of the Volga to the south. These upland lacustrine grounds on the north-east, wherein the north- and south-flowing streams are united by the splendid canal of Marinsk, are, in fact, analogous to the marshes of Pinsk on the south-west, where the south-flowing Dnieper has, in like manner, been connected with the north-flowing rivers Niemen and Bug.

And here it is worthy of remark, that a line prolonged between the very distant canals of Vitegra and Pinsk passes also through the grounds traversed by the intermediate canals of Tichvin and Lepel, the former uniting the Volga with Lake Ladoga, the latter joining the south-flowing Berezina with the north-flowing Düna,

—such line being at the same time coincident with the main elevation of the Valdai Hills. As geographers we may observe, that this line is parallel to the axis of the great Scandinavian chain, whilst as geologists we can show in the sequel, that along the minor as well as along the major elevation, the older palæozoic rocks only have been upheaved and affected. It was, in truth, an acquaintance with the peculiar nature of this long and low Russian watershed which enabled that illustrious sovereign Peter the Great to unite these north and south water basins by canals, and thus to secure to his country such important commercial advantages and so much internal power[1].

Since the Valdai Hills lie at no great distance from the Baltic Sea, it is evident that the streams which flow from them to the north and fall into that sea must have much shorter courses than those which flow to the south. Thus the Düna, the Msta and Volkof have comparatively rapid descents; whilst the Volga, which rises on the southern slopes of these heights, runs its tortuous course for about two thousand five hundred miles before it debouches into the Caspian.

It might, therefore, be supposed that this south-flowing stream, having to glide over an immense space of ground of little elevation, must necessarily afford much

[1] Of the few heights which we have ventured to mark upon our Map, those which have been determined by the barometrical observations of Colonel Helmersen, Count Keyserling and others, are, of course, to be viewed as approximations only. In one district (Livonia) we have, indeed, been provided with the means of inserting some correct altitudes, as determined by trigonometrical survey conducted under the direction of our distinguished friend the Imperial Astronomer Struve; but even in this instance we can, on the scale of our map, do no justice to his most important triangulation, which having been carried along the Baltic provinces, is now in the act of being extended to Southern Russia along the Polish frontier. Other triangulations having been already carried over Finland, with the certainty of their being extended, through the cooperation of the Swedish Government, to Cape North, the Imperial Government will, through the survey of M. Struve, have obtained the renown of measuring an arc of the meridian of the earth of much greater extent than any which has been executed either by the French or English Governments. For the Livonian triangulation, see "Resultate der Astronomisch-trigonometrischen Vermessung Livlands, von W. Struve, Mem. de l'Acad. des Imp. Sciences, St. Petersburgh, 1844." (See also Address to the Royal Geographical Society of London, 1845.) The southern portion of the Russian survey above alluded to, is conducted by General Tenner, who has recently communicated to M. Struve and the Imperial Academy, 168 elevations in the Western governments. In a letter to Mr. Murchison, M. Struve makes the important remark, that throughout more than 12 degrees of latitude, the greatest elevations are everywhere nearly the same, or about 1000 English feet above the Baltic; and that one point only, near Kremenetz, has a height of 1328 feet, the maximum level, probably, of the western governments between the Gulf of Finland and the Black Sea. This last observation is of geological and geographical importance, in marking the western extremity of the granitic steppe of Volhynia and Podolia, and the high grounds from whence the rivers Dnieper, Bogh, Dniester and Bug take their rise (see Map, Pl. VI.).

less geological instruction than the more rapid, north-flowing rivers. But this is not the case; for whilst the streams which flow northwards, from the Valdai and its dependencies, expose the older palæozoic strata in comparatively short distances, the Volga, when followed in its long track, affords lessons not less instructive in respect to the newer formations. In fact, the promontories which invariably constitute throughout so vast an extent the *right* bank of this mighty stream, by no means diminish in altitude with the descent of its waters; for whether examined at Nijny Novogorod, in the cliffs opposite Kazan, in those between Simbirsk and Samara, or from thence to Saràtof, the right bank of the Volga maintains an average height of 200 to 300 feet, sometimes rising to 400 and 500 feet above the stream. The geologist, therefore, often reads an instructive lesson in these cliffs, and traces how the younger palæozoic and secondary strata are related to each other, and how they are depressed beneath the more recent accumulations of the southern steppes.

The north-eastern angle of Russia, which lies between the Glacial Sea, the river Dwina and the Ural Mountains, is distinguished by a line of elevations called the Timan ridge, the direction of which is at right angles to that of the Valdai, and the chief mass of palæozoic rocks. Far removed from civilization and most imperfectly known to geographers till recently explored by one of our own party, this narrow low range, never rising to more than 1000 feet above the sea, is very remarkable for its persistence from south-east to north-west, through a space of about 500 miles. Almost branching off, as it were, from the Ural Mountains in north latitude 62°, it separates, in fact, the great basin of the Petchora from the affluents of the Dwina and Volga, and forms the north-eastern stony girdle of European Russia[1].

The central and southern divisions of the eastern region are diversified by low watersheds only, none of which have the persistent character of a chain. Thus in the vast government of Vologda, the sources of the rivers Suchona, Jug and Inga, which feed the great Dwina in its northern course to Archangel and the White Sea, are separated by a tract of small elevation only from the Unja, the Viatka, and the Kama, which flow southwards into the Volga. Lastly, the other numerous tributaries of the Dwina and the Volga, which spring in the Ural Mountains, and

[1] The basin of the Petchora and the Timan ridge were surveyed by our associate, Count A. von Keyserling, accompanied by Lieut. Krusenstern in 1843 (see pp. 230, 332, 412 *et seq.*). A separate work and map of this region are in preparation by its explorers, in publishing which Count Keyserling describes many additional species of fossils. This work will form a sequel to the present publication.

intersect the wide and flat regions of the governments of Vologda, Perm, and Orenburg, are there also respectively turned to the north or to the south by elevations like the Obschey Sirt, which are very slight in reference to the enormous spread of land by which they are surrounded.

If it be asked, what is the direct connexion between these streams and a geological inquiry, the answer is obvious;—at least to every one acquainted with Russia. In other countries the upper lands often expose stony masses which emerge from beneath the soil as separate or continuous rocks, and afford the knowledge the geologist requires; but here the round-backed plateau and loftiest elevation are so loaded with detritus of sand, clay, and far-transported blocks, that inspection of the concealed strata can seldom be obtained, except in the deep ravines which are daily forming on the sides of the valleys, or on the banks of rivers, where the subsoil is laid bare by denudations. The water-courses are, therefore, as truly the keys of the internal structure and mineral wealth of Russia, as they are the sinews of her commercial intercourse.

Before, however, we describe the various sedimentary deposits watered by these streams, we must first give a brief sketch of their crystalline northern frontier.

Crystalline Rocks of the North.—The fundamental rocks of Finland and Lapland, consist, as in Scandinavia, of gneissose and granitic with plutonic rocks, many of which have been described by native writers, and some of the prominent varieties of which, in the region north of St. Petersburgh, were long ago made known to English geologists by Mr. Strangways[1]. By reference to the Map, Pl. VI., it will be seen that such rocks, ranging from Norway and Sweden, spread out to the north-east over the vast territory which comprehends Finland, Russian Lapland, and large portions of the governments of Olonetz and Archangel. Having touched at intervals only upon the edges of this crystalline region, it is not in our power to describe it. We may, however, be permitted to say a few words upon certain small islands in the Bay of Onega, an arm of the White Sea, since no account of them has yet been published, whilst their description may serve to give the reader some idea of one of the classes of rock, so largely developed in these northern latitudes.

Of the islands we examined, Ki-Ostrof is the principal, and lies a few miles north of the town of Onega. This narrow strip of rock, surmounted by a picturesque monastery, and affording barely sufficient soil to sustain a few fir-trees, does

[1] Geological Transactions, vol. v. 1st series, and vol. i. 2nd series.

not rise more than from sixty to eighty feet above the sea, and is about three miles in circumference. It is entirely composed of granitic gneiss, which is regularly bedded. The strata are vertical, and have a strike north-north-west, to south-south-east (*magnetic*), with many joints, the most dominant of which are also vertical and cut the strata obliquely, passing from north-east to south-west. The surface of the rock being generally laid bare, the different, vertical beds are well-exposed. Among several varieties, some contain much black mica and quartz, others hornblende, quartz and felspar, with a little mica; and in a third, still more quartzose, are certain micaceous beds charged with garnets, occasionally of considerable size. Quartz veins are apparent here and there, but in our short examination we did not observe any signs of true granitic or other intrusive rock. This isle is chiefly interesting as being the most southerly point (at the mouth of the river Onega) to which the crystalline rocks of Lapland advance in that parallel of latitude[1]. Other islands of similar composition are dotted about the bay, to the north of Ki-Ostrof, and one of these, celebrated as the site of a great monastery, the resort of many pilgrims, is called Solivetsk.

But, though not seen by us in these north-eastern isles or promontories, various rocks of intrusive character have been already mentioned as associated with the azoic or crystalline rocks of Scandinavia, from whence they continue through Finland into Lapland and the northern tracts of Russia (see Map). The same sort of collocation exists in Finland and Lapland, where the late M. Böhtlingk has recently observed, in numerous instances, that the greenstones have been injected into the surrounding crystalline masses[2].

Intrusive Rocks and Metamorphosed Palæozoic Strata.—Passing from the consideration of the older crystalline rocks, and those which we had no opportunity of distinguishing from them, we would now briefly advert to masses that are certainly of posterior age. In the region under our review, we purposely examined the central and northern parts of the Lake Onega and its western bank, where trappean rocks occupy a large portion of the surface. Referring our readers who

[1] M. Böhtlingk, in a recent journey round the northern shores of the White Sea, has shown the extension of hard sandstone and other rocks on the northern shores of the White Sea (as we have laid it down in the Map), but the great mass and nucleus of the country, as in Scandinavia, is made up of gneiss and granite, with greenstone.—*Acad. Petro. Bull. Scient.*, vol. vii.

[2] See Bulletin Scientifique de l'Académie Impér., vol. vii. p. 194.

seek for detail to a memoir by M. Engelmann[1], we shall not further describe their lithological character than to say, that these eruptive rocks chiefly consist of greenstones, graduating through coarse and fine-grained varieties into syenite and porphyry, with hornblende slate, &c.

The little isle of Solimen, north of Petrozavodsk, is so far an exception, that it is composed of a very remarkable trap-breccia or greenstone conglomerate, the "Solimenski-kamen" of the Russians. This rock, which extends over a considerable space, is composed of angular fragments of apparently altered slate or Lydian stone, imbedded in a trappean matrix, with very minute felspathic veins.

These eruptive masses, advancing from the crystalline region of Russian Lapland, trend in long bands from N.N.W. to S.S.E., which are parallel to the numberless lakes of this northern country (see Map), the latter occupying depressions between promontories of greenstone. One of these promontories, for example, runs parallel to the western banks of the Lake Onega, where it rises through hard quartzose sandstones, into prominent wooded hills, 400 or 500 feet above the water. The most southern tongue of these trappean rocks is composed of hornblende and compact felspar, and from a greenstone passes into syenite and syenitic greenstone, which form a picturesque headland on the left bank of the Svir, where that clear stream issues from the Lake Onega[2].

Although, strictly speaking, we ought not to speak of altered rocks before we have described the strata in their normal or unaltered condition, we shall render our view of the general relations of the masses more clear, by at once saying a few words upon this point. Whenever the quantity of overlying detritus permits their northern edges to be examined, the unaltered sedimentary rocks we are about to describe, are separated from the great granitic or azoic region of the north by a zone of considerable width, in which the shales have been converted into coarse slates or Lydian stone, the limestones more or less into marble, and the sandstones

[1] Annuaire du Journal des Mines de Russie, année 1838, p. 50, "Sur la composition géologique de l'arrondissement minier d'Olonetz:" in which the author gives an elaborate description of the Solimenski-rock.

[2] Colonel Armstrong, the Director of the Imperial Iron Foundry at Petrozavodsk has prepared a mineralogical map of this neighbourhood. We were indebted to that officer, not only for a most hospitable reception, but also for much information, in regard to the range of the crystalline rocks and the alluvial phænomena, including the deposits in lakes which supply the foundries with iron ore. (See account of the superficial phænomena of this tract, pp. 514, 567.)

into indurated, siliceous masses, passing here and there almost into granular quartz rock. Such phænomena are well displayed in the tracts near to and to the north of Petrozavodsk and the Lake Onega, where the hills rise to heights of 500 and 600 feet above the sea, and where the long ridges of greenstone, just alluded to, prevail. The crystalline limestones, which we saw, betrayed few recognizable forms of organic remains; but the flat-bedded, quartzose grits are occasionally of a reddish colour, exhibit rippled surfaces, fucoid-like markings, imbedded fragments of older rocks, and many other indications of their original condition. They have also varied and sometimes opposite dips; but this condition, as well as their structure, changes instantly upon quitting the region where intrusive rocks are visible. In travelling from north to south you pass suddenly from slates to shale and mud, and from inclined, hard quartzose rocks, to horizontal soft sandstones and marls with organic remains. In this respect, indeed, the phænomena of the northern region are similar to those of many other parts of the earth's surface where intrusive rocks have risen through sedimentary deposits; but over what exact area this metamorphism of the original strata has been carried, we are not now prepared to show. We have now simply to state, that all along this Lappish frontier, in the governments of Olonetz and Archangel, nature has placed a bar to a correct examination of the sedimentary strata, in descending order, beneath those of Devonian age. The thorough examination, however, of this great band of Silurian rocks, more or less metamorphic, which lies between the purely crystalline or azoic rocks of the north and the wholly unaltered Devonian and carboniferous deposits on the south, well merit the special attention of the geologist, mineralogist, and chemical philosopher; for the scale on which these operations of change have been conducted is gigantic. Our present acquaintance with the phænomena is, however, sufficient to convince us, that here, as in other countries, the consolidation, rupture, and alteration, of large portions of the earth's crust, have been effected by the agency and eruption of igneous and gaseous matter. In our subsequent account of the Ural Mountains we shall develope our views on this subject; and in the meantime terminate this sketch of the northern frontier with a few reflections on the line of separation between the more ancient crystalline rocks and the sedimentary strata of the central regions of Russia.

Transverse Dislocations along the Northern Palæozoic Frontier.—By casting his eye over our Map the reader will perceive, that the masses of metamorphosed palæozoic rocks on the Lake Onega, to which we have been adverting, form part of a long and broken girdle, which extends from south-west to north-east, upon the frontier of Finland and Russian Lapland, and is more or less parallel to the chief axis of Scandinavia. Passing to the north of Archangel, the north-eastern extremity of this great line of disturbance is represented by the channel of the White Sea, its south-western end being equally marked by the Gulf of Finland. Throughout a large portion of the intermediate tract, similar eruptive and metamorphic phænomena are visible, and the chief physical features are everywhere nearly the same. The line of separation between the crystalline and sedimentary rocks being, on the whole, from south-west to north-east (though curvilinear and adapting itself to the contour of the northern continent), that line is, in fact, broken through, at numerous intervals, either by the eruptive rocks above mentioned, or by numberless depressions occupied by lakes and bays, whose major axis is also, on the whole, from north-west to south-east. Both the linear eruptive ridges and the adjacent and parallel depressions are, therefore, transverse to the great line of strike or elevation. At the very threshold, then, of a history of the subsoil of Russia, it is essential to bear these great features in view, because they explain to us how, by eruptions, metamorphism and dislocation, all the original junctions between the ancient crystalline and palæozoic rocks, of which we have such clear evidences in Scandinavia, have been obliterated in Russia. These phænomena are further, we think, of deep interest in confirming, on a great scale, the accuracy of a view in geological dynamics which has recently been worked out in the British Isles by Mr. Hopkins[1], who has shown that in the production of any great line of elevatory disturbance, whether affecting straight, curvilinear or ellipsoidal masses, the strata must have frequently been rent by fissures at right angles, or nearly so, to the chief line of strain or elevation. Now, the Finnish and Lappish frontier of Russia, marking a great geological boundary, presents us with such transverse chasms on a grand scale; for they constitute the marine bays of Archangel, Kundulaska and Onega, and the great freshwater lakes of Onega and Ladoga, with innumerable smaller sheets of water, as well as parallel ridges of eruptive matter, all of which are transverse to the direction of the strata. The plutonic force has thus found its way to the surface through fissures or rents which have given free vent to ebullient matter formerly beneath the crust.

[1] See British Association Reports for 1836, Tr. Sec. p. 78, and Proceedings of the Geological Society of London, vol. iii. p. 363. A memoir, fully illustrative of the views of Mr. Hopkins, is about to appear in the 1st part of the seventh volume of the Transactions of the Geological Society of London.

In sailing along the Gulf of Finland and passing close under the Isle of Hochland, we could not avoid there recognising the development of the very same phænomenon as that which we had witnessed on the Lake Onega. Rising abruptly to upwards of 500 feet above the sea, that isle, consisting essentially of porphyritic and greenstone rocks, presents a fine rugged outline, the major axis of which ranging equally from north-north-east to south-south-west, is parallel to the isles and promontories of Petrozavodsk, like which it has carried up upon its surface, masses of limestone which have been altered into marble, and sandstones which have been changed into quartz rocks[1].

The Gulf of Finland, wherein there are three other eruptive islets[2], is, therefore, not merely the line of physical separation between the crystalline rocks of the north and the unaltered sedimentary deposits of which we are about to treat, but is also distinguished by the same *transverse* emissions of plutonic matter as the great north-eastern boundary. Whether, then, from violent dismemberments and changes along the natural frontier of the Azoic and Silurian rocks, which have often produced great intervening depressions, or, as in other tracts, from the enormous accumulation of granitic and crystalline detritus that encumber the surface, enough has already been said to explain, why no satisfactory junctions like those of Scandinavia can ever be looked for, upon the long frontier line we have been considering.

In the sequel and through many chapters we shall have to treat of very different phænomena, and to show, that over the largest region in Europe, which has been geologically described by any one set of observers, nearly all the sedimentary masses are unaltered and undisturbed. And here we must request our readers again to cast their eyes over the Map and glance southwards from the line of disturbance, alteration and fracture to which their attention has been called, and observe, that,

[1] The structure of Hochland is described by Professor Hoffman. (See Beiträge zur Kenntniss des Russischen Reiches. 4 Bändchen, p. 101.

[2] M. Baer, who has visited them, thus speaks of these isles in the Gulf of Finland in a letter to Mr. Murchison:—"In the middle of the gulf there are two parallel lines of islets, the one somewhat to the north of the other. These latter, embracing the isles of Nerva, Sommer, Hochland and Rodscher, constitute a series of porphyritic eruptions. Hochland is essentially composed of porphyry and greenstone. Sommer and Rodscher contain porphyry only; and though I was unable to land on Nerva, I was sufficiently near to it to induce me to believe that it also is porphyritic. All these porphyritic isles have worn and striated surfaces, here and there covered with a quantity of erratic blocks, among which the variety of Finnish granite called 'Rappakivi' prevails. The southern range of isles nearer to the mainland and parallel to it are mere sandy dunes covered with blocks."

with some exceptions not far removed from this northern frontier line, all the great transverse dislocations cease in the succeeding sedimentary formations; for in tracing the Devonian and Carboniferous rocks from the slopes of the Valdai Hills to the mouth of the great Dwina, no great upheavals have occurred; and with this absence of elevation no transverse fissures are visible, and the whole region is void of a trace of eruptive rocks. To feebler exertions of the same influence whereof we have been speaking, we shall, however, presently advert in describing the Silurian strata near St. Petersburgh (see p. 31).

Silurian Rocks of St. Petersburgh and the Baltic Russian provinces (see Map, Pl. VI., with tabular view on the right, and Section across Russia beneath).—The oldest rocks in Russia containing organic remains form one great series, whose different members have a certain affinity in their zoological contents, yet exhibit marked distinctions, and are clearly separable from each other by superposition, imbedded fossils, and lithological characters. In the north-western regions of Russia they are composed of three zones, synchronous with those rock-systems of the British Isles and Western Europe to which the terms Silurian, Devonian, and Carboniferous, have been applied. A fourth system of this series, largely spread out over the eastern countries of Russia in Europe, is that which we have termed Permian. Our actual knowledge of these rocks in other parts of the world has been sketched in the first chapter; and in the sequel we shall describe their succession in order of time, as well as their passage from inferior to superior formations, each characterized by typical fossils. The complete description, however, of these remains, particularly in reference to many species not published by other authors, will form the chief part of the appendix to this volume, and the third part or second volume of our work. In the meantime, the remainder of this chapter is devoted to the consideration of the oldest or Silurian group of these deposits, as developed in the Baltic provinces of Russia.

The geologist who has formed his ideas of the older palæozoic rocks from the splendid examples they offer to his inspection in the British Isles, where they attain a vertical thickness of several thousand feet, may well be disappointed when he first surveys their equivalents in Russia. Instead of the mountain masses, frequently in a subcrystalline condition, and often highly dislocated, to which he has been accustomed, he sees before him very low undulating hills only, whilst ravines of little depth occasionally expose horizontal beds of soft clay, incoherent sandstone, and slightly consolidated limestone and shale; the whole differing little in external aspect (in some instances not at all) from the tertiary and cretaceous rocks which are spread out around the estuaries of many parts of Europe.

Little elevated above the Baltic sea, the Neva, and other tributary rivers of the northern watershed before alluded to, the calcareous or harder portion of these Silurian rocks constitutes, in fact, a low terrace, the strata of which, whether absolutely horizontal, occasionally undulating and even partially dislocated, or almost imperceptibly inclined to the south and south-east, are surmounted towards the interior by other masses, which represent the Old Red Sandstone or Devonian system of English geologists.

Whatever may be the thickness of these deposits, they thus cover a large area, and offer numerous points for examination and comparison, wherever they can be detected beneath the superficial detritus. And although this detritus is a great impediment to clear observation, a large portion of it has a direct connexion with the true subsoil. Abstracting the erratic northern blocks, sand or gravel, often accumulated in patches, and which will be described in the concluding chapters, a practised geologist can form a tolerably correct estimate of the nature of the sub-strata, by the colour and aspect of the broken materials upon the surface. In other words, much of the drift is merely local, and the subjacent rocks have been so worked up, as to give a dominant colour to the outline of each geological tract. Thus the Silurian zone of the Baltic provinces is at once distinguished by its dull light grey colour, from the red (Devonian) zone of Livonia and Novogorod, which lies to the south of it.

As developed in the government of St. Petersburgh the Silurian or grey zone consists, in an ascending order, of the following subformations:—1. Blue Shale or Clay. 2. Ungulite Grit and Bituminous Schist. 3. "Pleta," or Orthoceratite Limestone.

This, in truth, is the exact order long ago pointed out by an English geologist. So early as the year 1819, and long therefore before anything like the true general succession of the lower or transition formations had been ascertained, the physical features of the environs of St. Petersburgh and the ascending order of the strata were correctly and even minutely laid down upon maps and described by Mr. Strangways[1]. That author showed, that the lowest stratum was a blue clay, which occupying all the flat country around the metropolis, was seen in cer-

[1] Trans. Geol. Soc., 1st Series, vol. v. pp. 382, 392 *et seq.* (See remarks on the successive and subsequent contributions of other authors in the Preface.)

tain ravines (particularly in all those occupied by the brooks which descend from the plateau on the south) to be overlaid by sands and schists, to which he gave the name of the "intermediate bed," because it lay between the clay of the valleys and the limestone of the upper tracts or "pleta" of the Russians. In the lowest of these bands no fossils were then known, and since then they have only afforded a few fucoidal impressions. In the intermediate bed, however, Strangways recognised shells which he termed "chamites," and these were subsequently described, first under the name of Obolus by Eichwald, and afterwards as Ungulites by Pander. The third formation in ascending order, or that of the "pleta" limestone, is that in which the great mass of the fossils of the government of St. Petersburgh have been found, many of which have since been made known through the works of Pander and Eichwald, and on these we shall hereafter dilate. Those who wish to make a detailed study of the environs of St. Petersburgh cannot, therefore, do better than take the maps and sections of Mr. Strangways in hand, and apply to his faithful and beautiful sketches of the ravines and valleys, the palæontological knowledge since obtained, which enables us to show, that this group of strata fairly represents the *Lower* Silurian rocks of Scandinavia and the British Isles.

This group occupies a zone varying from forty to sixty miles in width in the government of St. Petersburgh. To the west it is clearly exposed in the cliffs of the Gulf of Finland and Reval, and in the south of Esthonia and the government of Kovno is surmounted by sandy beds and limestone with Pentameri; whilst the isles of Oesel and Dago consist of still younger limestone laden with corals, and represent the Upper Silurian rocks. (See tabular view to the right-hand of the Map, Pl. VI.) To the east-north-east the continental or lower group traverses the rivers Slavenka, Ishora, Tosna, Volkof, and Siass, and is lost under the northern drift beyond the fifty-first degree of east longitude. It is afterwards deflected to the east-north-east, and is next found in the altered form before alluded to, in association with the intrusive rocks north of Petrozavodsk, and is, as far as we know, no further traceable in the low tracts forming the coasts of the White Sea. We shall first describe the Lower Silurian strata where we examined them in the ravines and hills south of St. Petersburgh, and on the banks of the rivers Tosna, Volkof, and Siass, afterwards following them along the cliffs of Esthonia and into Lithuania, the Isles of Oesel and Dago.

Excepting some dislocations in the hills south of St. Petersburgh, to be hereafter spoken of, these Lower Silurian strata are generally inclined to the south-south-east at an angle of about 2° or 3° only; an inclination indeed for the most part so slight, as scarcely to be measurable by a clinometer. With such a feeble dip the true direction could only be detected by observing those points on the rivers Tosna, Volkof, and Siass, at which the Silurian group passed successively under the overlying Devonian rocks, and they were thus found to range, as before said, from west-south-west to east-north-east, or parallel to the Gulf of Finland and the shores of Esthonia.

1. *Blue Clay.*—The oldest beds of this zone which are visible, consist, as before said, of clay which occupies the low country on each side of the delta of the Neva. This clay or shale is often of a pale greenish or bluish grey colour, in which respect it is not unlike some of the soft shales or mudstones of the Silurian series, though it varies in being partially sandy, occasionally slightly micaceous and streaked. Certain yellow argillaceous veins which are peculiar to it on the sides of the Cocrovca ravine near St. Petersburgh are described by Mr. Strangways, and it is unnecessary that we should here enlarge on points of this nature, since, in common with that author, we have not been able to observe in this stratum any organic remains, except a few fucoids, which M. Pander has kindly submitted to us[1]. Though a small thickness only of this clay is visible in any natural section, it has been pierced in search of water to several hundred feet in depth, both in the vicinity of the metropolis and at Reval, without offering any notable difference in the beds traversed, except a few occasional sandy courses. This fact and the absence of all traces of animal remains are of high geological importance; and as a few fucoids only have been detected in this deposit, that underlies a zone which unquestionably contains fossils belonging to the very oldest known Silurian or protozoic type, we may fairly believe that this band, like the Swedish fucoid sandstone, is the true base of the palæozoic series, as indicated by a gradual dwindling out of animal life in the lowest sedimentary deposit of a region, where no eruptions have taken place, and where the strata are wholly unaltered.

If, owing to the absence of elevatory movements, the bottom of the shale is unknown, the relations of its upper part to the overlying strata are satisfactorily seen on the sides of several rivers and water-courses, as also in many of the ravines

[1] This clay is not only exceedingly useful in the manufacture of bricks, coarse pottery, &c., but from the very fine levigation of its particles, is also an excellent material for casts in sculpture, and is largely used for that purpose in St. Petersburgh. When moist it has the greenish tint of many of the Silurian *mudstones*.

which intersect the line of hilly grounds extending from Czarskoe-celo to Duderhof, where it is seen to crop out from beneath low promontories of superjacent sandstone and limestone. The general order of the strata from Petersburgh on the north to the hills of Czarskoe-celo on the south is sufficiently expressed in this woodcut.

5*.

a. Blue shale. b. Ungulite grit and bituminous schist. c. Orthoceratite limestone.

The backwardness of the vegetation on the argillaceous tract near St. Petersburgh may with great reason be attributed to the influence of a subsoil, so retentive of moisture, wherever its surface is not ameliorated by a cover of northern drift, the sandy portions of which afford, on the contrary, a good drainage and a healthy residence. Though differing widely in age, the oldest Silurian clay of St. Petersburgh (the equivalent of the lowest Silurian slates of other countries) and the tertiary clay of London produce precisely similar effects. The English florist, farmer, and valetudinarian, have long since learnt to avoid the heavy and cold clay, even where it rises into hills around the English metropolis, and to prefer the absorbent gravel and sand with which fortunately in so many parts the clay is overspread, and under which its noxious qualities are buried. A similar distinction is quite as apparent between the district of the undulating sandy hills to the north of the Neva, and at Pavlosk and Peterhof, and the lower argillaceous tracts around St. Petersburgh.

2. *Ungulite Grit.*—This sandstone, first described as "intermediate sandstone" by Strangways, and since named Ungulite Grit by Pander from the peculiar fossil bivalve which it contains, is seen to overlie and pass down into the shale, in the ravines and banks of the brooks on the south of St. Petersburgh. Its lowest layers frequently consist of whitish sandstone, composed of grains of sand cemented by siliceous matter, and in rarer instances assuming the structure of a hard calcareo-siliceous grit. In the "chatoyant" lustre of their newly-fractured surfaces, certain portions of the rock, seen in the bed of the Pulkovka brook near Petersburgh, very closely resemble the slightly calcareous grits of the tertiary and secondary formations, such as the "grès de Fontainebleau," the concretions of the Hastings sandstone of England, or the calcareous grits of Brora, and, like these rocks, such parts of the Russian sandstone effervesce slowly with acids.

The upper strata are yellow and ferruginous, and are surmounted by a bituminous schist, which sometimes, indeed, is first seen to alternate with the upper beds of the sandstone, and then distinctly to separate it from the overlying limestone.

The rock derives its name from being in parts copiously filled with minute fragments of the *Obolus* or *Ungulite*[1], which, from their dark and shining aspects, give to it a very remarkable aspect. This peculiar rock, which on the Pulkovka and Popofka brooks (the first to the west, the second to the south of Czarskoe-celo) is not more than from twelve to twenty feet thick, expands gradually in its course both to the east and to the west, until it becomes, in some places, a considerable mass. Upon the Ishora[2] and Tosna rivers it is seen to rest upon the lower shale, and to be capped by the schist and limestone. Its lower or whiter beds are there laminated with thin courses of shale or impure fuller's earth, whilst the uppermost bed (which there alone contains Ungulites) is highly ferruginous, with a few large pebbles of quartz. On the Volkof and Siass rivers, the Ungulite grit is also seen reposing upon the blue shale; on the former, about two miles below Starai Ladoga, on the latter between Pulnitza and Rebrova. On the banks of these rivers the sandstone assumes the importance of a distinct formation, and occupies cliffs upwards of 100 feet high, the lower portion white, the upper yellow and ferruginous.

On the Siass it is composed of thick bands of an incoherent sandstone which weathers to a white colour on the external surface of the cliff, but is of a pinkish hue when fractured, and slightly freckled with ferruginous stains. The beds are occasionally separated by thin courses of shale or clay, and the whole rests distinctly upon the blue clay. Occasionally these ferruginous beds become a botryoidal or mammillated iron sandstone.

Near Starai Ladoga on the Volkof, the rock is for the most part a friable, incoherent sandstone, though it is probable that if deeply cut into, it might afford a tolerable building-material. In its range to the west it is often, indeed, more

[1] This fossil shell was first described by Eichwald under the name of *Obolus*, which we retain in our description of the organic remains. We use, however, the name of Ungulite grit (so applied by Pander) because it has obtained geological currency. The multitude of the small shining fragments of this horny shell might, at first sight, be mistaken for plates of mica, and we have already adverted to shells of similar characters in the oldest Silurian shelly rock in North America.

[2] In one spot on the Ishora, as remarked by Strangways, the white sand is so fine that it is extracted for hour-glasses and writing purposes.

calcareous, frequently concretionary, of a harder consistency, and apparently of a very durable composition. This is well seen in the escarpments on the banks of the river Narva, on which the ancient Moscovite castle stands, where a ferruginous and calcareous cement has so bound together the minute and broken Ungulites with coarse grains of sand, that the faces of the rock are quite impervious to the action of the weather. For a long time we supposed that the Ungulites were exclusively found in the lower sandstone or grit, but at Vassilkova on the river Lava (between the Volkof and the Siass), M. Pander has found them intermixed with the Orthidæ, Orthoceratites, Trilobites and Sphæronites of the overlying pleta limestone; the calcareous mass in which these remains occur being superposed to a considerable thickness of Ungulite sandstone.

With the exception of two very rare species of Orbicula[1] which we detected on the banks of the Tosna and the brook near Crasnoe-celo, the Ungulites seem to be the sole tenants of this sandstone. These fossils, to which we naturally paid great devotion, as being the most venerable animal remains of northern Europe, are not confined to one part of the rock, but are scattered throughout it, usually in vast quantities, often in very small fragments, but at intervals are better preserved. On the Volkof and Siass the same courses of clay or shale are observed as at the Tosna, and the sand-rock is often of a delicate pink colour, but with the exception of some irregular courses of sub-concretionary purple grits, the whole mass falls readily to pieces under the hammer. The Ungulites vary in their dimensions from the size of a pea to that of a sixpence[2], and occur in great profusion. We refer to our description of these singular protozoic fossils in the second volume, merely observing by the way, that they have not yet been found in any portion of Western Europe, and that they have been rightly formed into a genus by the Russian authors Eichwald and Pander.

[1] One of these we named after our eminent friend M. von Buch. (See vol. ii. and bottom of the Table of fossils attached to the Map, Pl. VI.)

[2] In some rare instances they reach to the size of three-fourths of an inch in diameter, particularly at Baltisch Port, in the cliffs of Esthonia. As in all sub-formations which constitute parts of a group, the Ungulite grit or sandstone passes in some situations into and alternates with the overlying calcareous strata. This observation was made by our friend M. Pander at Baltisch Port in Esthonia, from whence we have obtained rock specimens in which the sandy laminæ with Ungulites are interlaced with impure limestone containing green grains and fossils of the overlying "pleta." At Briggetten Kloster and Baltisch Port, the Ungulite grit has been found by Pander to be occasionally a pebbly rock, in parts of which are pebbles of white quartz, but the greater number of the included fragments consist merely of rounded schist.

Bituminous Schist.—This schist, sometimes of darkish green, but usually of black colour, which occurs pretty generally between the Ungulite grit and the limestone (and was classed with the former by Strangways), is mineralogically not unlike many beds known in the carboniferous rocks of England. It may be compared with the "bat" of the Staffordshire coal-field, and might even be assimilated to certain hard beds of the Kimmeridge clay, so little do lithological characters alone enable us to decide upon the age of rocks. It is specially distinguished by containing rounded, or oblate sphæroidal nodules, or calcareous concretions, the surfaces of which are marked by projecting crystals of calcareous spar and pyrites radiating from a common centre. Being highly carbonaceous at the falls of the Sablenka, a tributary of the Tosna, it is there partially extracted from beneath the limestone, for the manufacture of coarse pencils. Though this black schist is very persistent, and is seen in all the sections of the hills which range from Duderhof to Czarskoe-celo, as well as on the banks of the Volkof and Siass rivers, it is of inconsiderable thickness, and seldom contains organic remains. In Esthonia, however, where it is in parts highly bituminous, a few graptolites and organic remains have been discovered in it.

3. "*Pleta,*" *or Orthoceratite Limestone.*—Occasionally, as on the Pulkovka brook, beyond the observatory, and again on the Popofka, a feeder of the Slavenka, some of the bottom layers of the limestone are of a dullish red colour, and have the glistening fracture of a sandy dolomite, but in general the lowest strata are characterized by containing a profusion of grains of dark green mineral like chlorite in a light grey-coloured base. According to the examination of M. Abich of Dörpat, it would appear that such green grains are the detritus of the ancient augitic rocks of the Finnish frontier; and our friend M. Wörth has even detected small portions of malachite and "blei glanz" in these lower beds. In lithological aspect, however, these lower beds usually so resemble the "craie chloritée" of the French, and some varieties of our upper greensand, that when mineral characters were the chief guides of geologists, they were even supposed to belong to the cretaceous system! They are usually separated by way-boards of reddish and greenish-grey shale. These are again surmounted by a considerable thickness of dingy grey, earthy, flat-bedded and slightly consolidated limestone. The lower as well as the central or argillaceous beds of the limestone, may be well seen in the ravines of the St. Petersburgh hills, extending from Czarskoe-celo to the hills of Duderhof,

viz. on the banks of the Pulkovka and Popofka brooks, and on the banks of the Tosna.

It is in these districts that the greater number of the Lower Silurian fossils of Russia have been obtained, many of which are figured in the works of Pander and Eichwald[1]. In the beds exposed on the sides of the Pulkovka brook, we collected the following fossils: *Lingula longissima* (Pand.), *Orthis obtusa* (Pand.), *O. calligramma* (Dalm.), *O. inflexa* (Pand.), *O. adscendens* (Pand.), *O. hemipronites* (V. Buch), *Leptæna imbrex* (Pand.), *Orthoceratites vaginatus* (Schloth.), *O. duplex* (Wahl.), *Illænus crassicauda* (Dalm.), and *Asaphus expansus* (Dalm.). All the valuable specimens (some of them unique) which enrich the cabinets of St. Petersburgh, also come from this and other ravines in which the strata are exposed. Besides the two usual above-mentioned Trilobites, these strata are found to contain other species already known in Sweden or in England, such as *Calymene polytoma* (Dalm.), *C. Fischeri*, *C. sclerops* (Dalm.), *C. Downingiæ* (Murch.), *Ampyx nasutus* (Dalm.), *Metopias aries* (Eichw.), *Tr. sphæricus* (Boeck), and very rarely the *Asaphus Buchii* and *A. Heros* (Dalm.), or *tyrannus*[2].

Among the brachiopods from these spots we may cite as particularly worthy of note the *Spirifer lynx* (*biforatus*, Schloth.), a species around which as a type many varieties may be ranged, the Spirifers of the group of *S. æquirostris* (*Terebratula equirostris*, Schloth.), the *Siphonotreta unguiculata*, *Orthis parva* and *Crania antiquissima*

[1] See Pander, Beit. Geogn. Russland, 1830, St. Petersburgh; and Eichwald's works, Geogn. Zool. per Ingriam marisque Balt. Prov., &c., 1825; Zoologia Specialis, 1829; Urwelt des Russlands, H. 1 and 2; and Silurische System in Esthland, 1840. Both M. Eichwald and M. Pander have compared the palæozoic rocks of Esthonia and St. Petersburgh with those of Sweden, and have shown that the fossils of the two countries are essentially the same.

[2] The *Asaphus tyrannus* (*heros*, Dalm.), or a form which M. Eichwald thought might be united with it, is mentioned by that author as occurring at Odinsholm (Silurian System in Esthland, p. 80). Since then it has been found by His Imperial Highness the Duke of Leuchtenberg at Grafskaya Slavenka as well as the *Asaphus Buchii*, an important addition to our knowledge. The quarries of Grafskaya Slavenka and Fedorofski, south of Czarskoe-celo, particularly the former, have afforded to the zealous researches of the Prince a great variety of other fossils, including three new species of Trilobites, which he has named *Asaphus centron*, *A. longicauda*, *A. hyorrhinus*, and *Nileus nanus*. Besides some species of Trilobites, Orthoceratites and Testacea, previously named by M. Eichwald and M. Pander, the Duke has further discovered and named the new species *Pileopsis borealis*, *Terebratula digitalis*, with two new species of Crinoidea, one of which is termed the *Gonocrinites giganteus*, &c., &c. See "*Beschreibung einiger neuen Thierreste von Tzarskoje-celo, von Maximilian Herzog von Leuchtenberg*," with a copy of which memoir His Imperial Highness has honoured us.

(nob.). The ravines in the calcareous plateau are also rich in those peculiar bodies (*Cystideæ* of Von Buch) which characterize the Lower Silurian rocks of Scandinavia and Russia, of which the *Sphæronites* (*Echinosphærites*) *aurantium* and *S. pomum* are the most abundant. With these are occasionally associated *Echino-encrinites angulosus*, *E. striatus*, together with *Cryptocrinites cerasus* and *Hemicos-mites pyriformis* (the two latter being new species described by Von Buch). Of these the *Echinosphærites aurantium*, with some minute *Orthidæ* and the *Favosites Petropolitanus*[1] (Pand.), seem to be characteristic of the upper beds exposed in the hills of Duderhof.

On the Tosna, a little above the village of Nikolskaya, the cliffs present in one vertical section the whole series from the top of the blue clay at the base, through the Ungulite sandstone and bituminous schist to the chloritic beds, or bottom of the overlying limestone. In the latter we collected many specimens of the small *Orthis obtusa* and *O. parva* (Pand.), associated with the *Leptæna imbrex* (Sil. Syst.), and the *Asaphus expansus*.

So far, then, the different members of the same system are developed at those well-known localities; but before the period of our first visit, no natural section had been discovered which clearly exposed the relations between this Lower Silurian group and the next overlying formation. This we first effected by an examination of the banks of the river Volkof, as explained by the following woodcut.

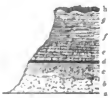
4.

a. Blue clay of the low country near the mouth of the river. *b*. Cliffs, 80 to 100 feet high, of Ungulite grit and sandstone, which to the south of Starai Ladoga are overlaid by bituminous schists (*c*), and the lower and upper limestone (*d*, *e* and *f*); the latter occupying the cliffs at Petropavlosk (the Upper Silurian group being absent), is at once surmounted by rocks (*g*), which form the base of the Devonian system.

We may here offer some details of the succession of these calcareous strata. After passing over the low country occupied by the blue clay and the cliffs composed of Ungulite sandstone, the banks of the Volkof show the superposition of the lowest beds of the limestone to the bituminous schist and Ungulite sandstone. Such an order occurs about three versts above Starai Ladoga, and on the right bank of the river opposite the hamlet of Isvosk.

[1] Mr. Lonsdale shows that this coral, so characteristic of the lower rocks of Russia and Scandinavia, and also, as we believe, now found in the Lower Silurian of North Wales, is a *Chætetes* (see Appendix A.).

4*.



g. Thin beds of impure limestone, alternating with dull red and green, concretionary marlstone, the whole covered by drift (h), containing granitic and other blocks.—*f*. Upper and thin-bedded limestone, without chlorite, and containing *Orthoceratites vaginatus*, *O. duplex*, *Illænus crassicauda*, and *Asaphus expansus*.—*e*. Chloritic limestone, in beds from six inches to one foot thick, of light grey colour, in part earthy, in part compact, and speckled throughout with numerous grains of dark green chlorite, some of which are crystalline. Among the fossils are *Orthis calligramma*, *O. obtusa*, *O. parva* (Pand.), and abundance of Trilobites, *Asaphus expansus* and *Illænus crassicauda*. A few Sphæronites are also present, and on the surface of the beds are some markings of fucoids?—*d*. Bituminous schist, with concretions of calcareous spar.—*c*. Ferruginous grit with Ungulites.—*a* and *b*. Yellow sands and sandstone, and whitish incoherent sandstone. The cliff is about sixty feet high.

Other beds of highly argillaceous limestone, superior to those represented in the above woodcut, and forming the central mass of the deposit, occupy the cliffs between Isvosk and Petropavlosk, and are largely excavated for the manufacture of hydraulic cement. In these quarries we found several fossils similar to those of the lower limestone at Isvosk, viz. *Asaphus expansus*, *Illænus crassicauda*, *Orthoceratites vaginatus* and *O. duplex*; and in addition to them, *Orth. bacillus*, *Euomphalus qualteriatus* (Schloth.), *Siphonotreta verrucosa* (*Lingula*, Pand.), *Leptæna imbrex* (Pand.), &c. Fucoid-like bodies also occur upon the surfaces of the strata[1].

At Petropavlosk, where the cliff rises to a greater altitude than in any other part of the river-banks, still higher strata appear, and these, sloping away at an almost imperceptible angle to the north of the village of Bor, pass under certain red and green strata which are the lowest beds of the Devonian system. Like the highest strata, which are exposed in the hills of Duderhof near Petersburgh, these upper limestone beds on the Volkof contain Sphæronites in vast abundance, particularly the *S. aurantium*, together with the *Chætetes Petropolitanus*, and a few small *Orthidæ*.

On the Siass we observed a succession of the lower formations precisely similar to that which is exposed on the Volkof and at Rebrova, where quarries of the chloritic limestone afforded, among other characteristic fossils, a gigantic specimen of the *Asaphus expansus*. In recently ascending the banks of this river above the point of our united explorations in 1840, we also obtained unequivocal proofs of the Lower Silurian strata being at once overlaid by true Devonian beds between the villages of Siaski, Rodok and Buyanetz[2]. The lower strata there consist of calcareous flags alternating with red and green marl, overlaid by a limestone with small concretions, and loaded with *Orthis calligramma* (Dalm.), *O. plana*, *O. inflexa*, *O. extensa* (Pand.), *Asaphus expansus*, *Orthoceratites vaginatus*, *Chætetes Petropoli-*

[1] Colonel Helmersen discovered traces of copper ore in these limestones of the Volkof.

[2] Observation of Count Keyserling.

tanus, &c. This perfectly characterized Lower Silurian band is at once conformably surmounted by other red and green marls with calcareous flags, followed by micaceous brownish-red sandstone and other marls and flags[1], and in this group are the following true Devonian types, viz. *Orthis striatula* (Schloth.), *Terebratula Livonica* (V. Buch.), *Spirifer muralis* (nob.), *Orthoceratites cochleatum* and *Serpula omphalotes*; with which species are mingled fragments of ichthyolites, such as Dendrodus and a remarkable species, of which we shall speak in the next chapter as having been been first found on the river Siass by Mr. Strangways, *Placosteus meandrina* (Ag). (See note, p. 47.)

The same flaglike structure of the upper calcareous beds, which is apparent on the banks of the Volkof and the Siass, is also seen on the Vloia, a small tributary of that river, and at about twenty-five versts north of the junction before alluded to, where these Silurian flags rise out by an undulation, from beneath a trough of Devonian strata, and occupy a low dome near the village of Possobea, as represented in this figure.

5.

These uppermost Silurian beds are yellowish and white, sandy, calcareous flagstones, in parts having a delicate green tint. They contain several fossils which clearly refer them to the Lower Silurian group; such as *Orthis adscendens*, and two other species of this genus; together with a Terebratula and a Trilobite closely approaching to the *Asaphus expansus*.

Dip, Undulations, and Dislocations of the Strata.—It was in the quarries of the hydraulic limestone, north of Petropavlosk, that we first ascertained the very slight inclination of the strata to be towards the south-south-east. Large surfaces of the rock being laid bare, we perceived that the rain-water, which had recently fallen, flowed slowly to the south-south-east, and lodged against the edges of the unquarried rock in that direction[2]. The clear continuous section of the Volkof obviates, however, the necessity of such a test, even where the clinometer may fail to register the inclination; for though some difficulty may exist, when one vertical face of rock only is examined, the geologist who views at a *coup-d'œil* the strata

[1] M. Pander, we may further observe, has recently observed a similar junction of Lower Silurian with Devonian on the banks of the river Loya, a feeder of the Lake Ladoga, thirty-six versts above Schlusselburg.

[2] A similar experiment gave a like result in the limestone quarries on the river Siass.

exposed for several miles on the banks of this straight-flowing stream, can recognise, without hesitation, their order and succession, as indicated in the little preceding woodcut. Looking southwards from the abrupt cliff at Petropavlosk, he sees the upper beds of the grey Silurian rocks declining gradually in the distance till they are overlapped by the red Devonian beds.

Whilst we speak of a very slight, general inclination to the south-south-east, we must explain, that we believe it to be often accompanied by broad undulations, sometimes leaving the strata in almost horizontal positions, and at other times producing domes and troughs like those on the Volkof and Vloia, to which we have just adverted. It will hereafter appear, that such undulations occur also in the Devonian rocks of Courland, and in other districts; and we would now show, that in certain tracts, the movement of the strata has proceeded to such an amount as to produce considerable dislocations.

Although, therefore, we have spoken of the horizontality of the Silurian rocks, we must, therefore, except from this remark some of the beds which are exposed in the ravines of the hilly grounds watered by the Pulkovka brook to the south of St. Petersburgh, *i.e.* between the Duderhof Hills and Czarskoe-celo. The sections of Mr. Strangways established by clear evidences, that the strata on the sides of this rivulet are fractured and thrown into rapid undulations[1], which M. Pander has since sought to prove might be explained by subsidence and derangement of the inferior clay. To us, however, it is manifest, that the dislocations on the Pulkovka cannot be referred to such a cause. The breaks and repetitions seen along the sides of the little valley, from above the village to a verst or two below it (as expressed in the following woodcut), can, we contend, be alone explained by elevatory movements[2].

SECTION ALONG THE PULKOVKA BROOK. 5*.

s. Drift, and northern erratic blocks.
d. Limestone.
c. Bituminous schist.
b. Ungulite sandstone.
*b**. Ungulite sandstone in hard concretions.
a. Blue clay.

[1] Geol. Trans., old series, vol. v. pl. 25 and 26.

[2] Colonel Helmersen has well remarked, that the blue clay rises to a much higher level to the south of St. Petersburgh than in Esthonia, and he accounts for this fact as well as for these dislocations by elevation.—*Ann. des Mines de Russie*, 1838, p. 102. M. Pander was formerly disposed to attribute the contortions and dislocations on the Pulkovka to subsidences caused by the conflagration of the bituminous and pyritous schists beneath the limestone; but we apprehend that with the present amount of evidence he would no longer adhere to that idea.

That such rapid undulations and breaks (though partial exceptions when such a large surface as Russia is considered) are due to disturbances of the strata by elevations from beneath, we have further satisfied ourselves by an examination of the banks of the Popovka rivulet to the south of Pavlosk. This stream, which falls into the Slavenka, occupies a longitudinal chasm, which as nearly as possible coincides with the general direction of the strata in the environs of St. Petersburgh, or from wèst-south-west to east-north-east. Near the plateau from which the water descends, the pleta limestone lies in great horizontal masses, and is thus observed to fold over in gentle undulations, which so increase in measure as they approach the village of Popovka as to form a complete arch, as represented in the following woodcut. By this curvature the Ungulite sandstone (*b*), with the bituminous schist (*c*) over it, is thrown up in an arch, over which the pleta limestone (*d*) folds rapidly over to the east, and is seen in highly inclined beds at the little bridge. After several minor flexures a decided transverse fault is exposed in a low hill, and winding along another denudation, the cliff on the right bank is a marked and decided elevation, called the Pastor Hill, from sixty to seventy feet above the water. Here the great mass of the "pleta" limestone, rising gradually to the west, is again regularly succeeded, first by the bituminous schist (*c*) and Ungulite sand (*b*), and finally, near the village of Poselevo or Peselova, by the lower shale (*a*), which there is of a greenish tint.

6.

No geologist can view these sections without admitting, that they exhibit clear evidences of dislocation. When, indeed, it is seen that the brooks of Pulcovka and Popovka both run in rents nearly parallel to the general strike of the formation, and that, though separated from each other by a space of twelve or fifteen versts, they so exhibit the same violent transverse flexures and even fractures, that those of Pulcovka, when prolonged, coincide with those of Popovka, no doubt can be entertained that they have resulted from the same operation. In truth, the axis of these arches and the direction of the faults are from north-north-west to south-south-east, or directly at right angles to the general bearing of the formations, and we therefore feel confident, that such dislocations athwart the prevailing line of elevation of the mass, must be viewed as parts of the same phænomenon to which we have alluded as occurring all along the Finnish and Lappish frontier, and of which the isle of Hochland in the Gulf of Finland is the prominent sign upon the west. In a word, we regard all the transversal valleys, by which numerous streams flow from the palæozoic plateau on the south to the Gulf of Finland, as having been determined at the time when that plateau was raised, and subjected to a tension by which it was transversely broken. The causes of this elevation are to be sought in the same expansive forces through which the plutonic and eruptive rocks have found an issue to the north; and which, though suppressed in the more southern tracts, have manifested their influence in the transverse domes and fissures we have just described. We further believe that these upheaving causes have been mainly instrumental in the formation of the larger river gorges, and even perhaps in determining the great transverse depression of the Lake Peipus (see Map). These phænomena afford, therefore, we repeat, a confirmation of the views of fracture as resulting from elevation, to which we have previously referred, p. 24 *et seq*.

Now here we must observe, that the strata thus affected in the government of St. Petersburgh are precisely of the same age as those which at Kinnekulle, the Billingen Hills, and other places in Sweden have been perforated and covered by basaltic trap, and which on the Lake Wettern we have shown to have undergone great flexures and breaks (p. 17). But whilst we speculate on some of the ancient movements which affected this region and parts of Sweden having taken place after the completion of the Lower Silurian group and before the accumulation of the Upper,—movements by which it was placed beyond the influence of the waters wherein the Upper Silurian strata were accumulated, and which seem to have increased in intensity from south-west to north-east, we must admit that the breaks and contortions which have just been described may have occurred at a much more recent period, or after the consolidation of the carboniferous rocks. This opinion is grounded on the facts, that along the northern frontier (p. 23*) the Devonian strata are equally metamorphosed as the Silurian; and that the carboniferous limestone of the Valdai Hills has also been affected by similar transverse breaks, as will appear in the 5th Chapter. In short, as far as we had the means of determining it, the amount of disrupture is frequently coincident with the height to which the strata have been elevated, and the greatest elevation certainly took place after the completion of the carboniferous limestone.

Junction of Lower Silurian with Devonian Strata South of St. Petersburgh.—The clear and unambiguous sections of the Volkof and the Siass have already demonstrated, that Lower Silurian limestone, similar to that of the hills of Czarskoe-celo, is at once surmounted by a red formation with ichthyolites of the Devonian age. This occurs at a very few miles only to the south of the section on the Popofka, and only thirty-five versts to the south of St. Petersburgh. In his work on the environs of St. Petersburgh, Strangways, who must have closely surveyed this district, has indicated in his map the occurrence of a "red earth of doubtful character" on the sides of the Ishora river, at the hamlet of Ontoleva.

The spot thus indicated appears, however, to have escaped the notice of geologists during many intervening years; for since the notice of it by Strangways, no one seems to have explored this locality until M. Eichwald recently visited and described its rocks. At that period (1843, subsequent to our two first visits to Russia), and after the existence of the true Old Red or Devonian along the southern frontier of the Silurian rocks had been established and even laid down by Colonel Helmersen in a small general map, there could be little difficulty in asserting, that this red earth of Strangways formed really part of the Devonian system. But M. Eichwald had then found no fossils in it. Such, however, were soon afterwards discovered by one of our own party (Count Keyserling), accompanied by M. Wörth, the account of which result has already been published in the last volume of the Mineralogical Society of St. Petersburgh. This sketch further contains an account of the extension of these beds high up the Ishora, thus connecting them with the great mass of the Devonian system which we had formerly recognised and shall hereafter describe. As this discovery was made long after our chapter on the Devonian strata and a large portion of this volume were printed, and as another member of our party has since visited the principal localities (August 1844), we deem it essential to give a short account of the order of the strata with a brief allusion to their contents, particularly as the latter have thrown new light upon the fauna of the Devonian system.

Inclining very slightly to the south or south-south-east, the pleta limestone of the plateau of Czarskoe-celo, here of greenish and reddish colours and loaded with *Orthoceratites*, and passing by Grafskaya Slavenka, is overlaid by other beds of somewhat similar structure, as exposed near the hamlet of Ontoleva. These upper strata are so perfectly conformable to the lower, that if unquestionable Devonian remains had not been found in them, they might have passed for some ambiguous and hitherto undescribed member of the Upper Silurian group. At Ontoleva, however, where they contain concretions of calcareous spar, these sandy and marlstone beds have afforded fishes' scales disseminated in a cream-coloured marlstone; and on following them up the stream to Marina and Poritz, the few feet of marlstone visible at Ontoleva expand into cliffs twenty to thirty feet high, in which bands of purple and grey colours are found to be absolutely loaded with fragments of ichthyolites. Thanks to the repeated visits and liberal expenditure of M. Wörth, who encouraged the peasants to break up this rock, a rich collection of these fossils, some of them in the highest state of preservation, has been obtained, a selection of which was transmitted to M. Agassiz[1].

In referring our readers to the descriptions of them by that great authority, whether in our second volume or in his own admirable work[2], we may here briefly state, that with a number of species, identical with forms of the Old Red Sandstone of the north of Scotland, several new and remarkable genera are also found here. Of the former we may cite *Diplopterus macrocephalus* (Ag.), *Glyptolepis leptopterus* (Ag.), *Holoptychius Flemingii* (Ag.), *Actinolepis tuberculatus* (Ag.) (a new genus and species common to Scotland and Russia), *Dendrodus strigatus* (Owen), *D sigmoides* (Owen), *Lamnodus biporcatus* (Ag.) (Dendrodus of Owen), *L. Panderi* or *hastatus* (Ag.) (Dendrodus of Owen), and *Glyptosteus* (*Bothriolepis*, Eichw.) *favosus* (Ag.). Other forms as yet unknown in the British Isles (though belonging to typical Devonian genera of that country) are species of the genera *Onchus* and *Byssacanthus*, Ag., which with the *Psammosteus arenatus* (Ag.) and some of the above-mentioned species range from Riga to Andoma, near Vitegra, in the deposits we shall describe in the next chapter as Devonian. Among the rarer forms are two species of Ctenodus, a genus never found hitherto in any other system but the Carboniferous, and these have been named by M. Agassiz, *Ctenodus Keyserlingii* and *C. Worthii*. Other species pertain to the new genera which that author terms *Homacanthus*, *Haplacanthus*, *Narcodes*, *Naulas*, *Cladodus*, &c.

These ichthyolites, like those mentioned in the next chapter, are not only of deep interest from proving the absolute identity of the Russian deposit with the Old

[1] The shells and other fossils of the Devonian system are mentioned in the next chapter, and the present introduction of this passage explanatory of the Devonian rocks of the Slavenka has solely been introduced because their discovery was made long after the third chapter was printed. Higher up the Slavenka and Ishora, the calcareous and marlstone beds mentioned in the text graduate into complete sands. Mr. Murchison, accompanied by Count Keyserling, M. Wörth and M. Volborth, examined the chief localities of these Devonian beds at Ontoleva, Poritz and Marina, in August 1844.

[2] Monographie des Poissons du Système Dévonien ou Old Red, liv. iii.

Red Sandstone of Scotland, but also from showing the existence of many placoid fishes of the highest organization in strata of such remote age. It is, indeed, the more necessary to dwell upon this last-mentioned feature, since the Upper Silurian rocks of the Scandinavian and Russian Isles, though teeming with other marine remains, have not afforded a trace of fishes, and that the ichthyolites here mentioned lie in the very lowest beds of the Devonian rocks of the northern continent[1] (see Observation and Postscript at the end of this chapter).

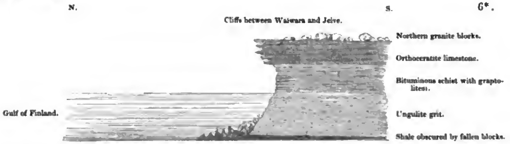
Lower Silurian Rocks of Esthonia.—The chief masses of "pleta" limestone which occur along the Baltic coast, where they equally repose upon the Ungulite grit and sandstone, and usually with the separation of bituminous schist, as in the country already described, offer few mineral distinctions from masses of the same age in the government of St. Petersburgh. Near Jeive, a post-station to the west of Narva, and between that place and Waiwara, the limestone occupying the summit of cliffs about 150 feet in height, has a thickness of from thirty to forty feet, and being in many parts completely denuded, exposes a floor of thick, calcareous flagstone, absolutely loaded with Orthoceratites, among which the *O. vaginatus* and *O. duplex* are by far the most abundant, one other species, which is rare, being the *O. bacillus* (Eichw.).

Like the Silurian rocks of England, these calcareous masses are affected by symmetrical, vertical or highly inclined joints, which, cutting through the horizontal strata, divide them into rude prisms. The chief directions of these joints trend obliquely to the Gulf of Finland, one set to the north-east and the other to the north-west, the line perpendicular to the re-entering angle being from north and by west, to south and by east, or, in other words, at right angles to the general strike of the formations. The result of this crystalline and prismatic division of the heavy calcareous roof of a cliff, the lower parts of which are composed of incoherent materials, is the rapid wearing away of its seaward face; which presents a succession of salient and re-entering angles, like those seen in quarries among jointed rocks. The spectator who places himself in the innermost extremity of one of these angles has on either side of him a beautiful vertical section of strata.

[1] The presence of very peculiar and small ichthyolites (one of which is the Old Red or Devonian genus Onchus) in the Upper Silurian rocks of England was first pointed out by Mr. Murchison (Sil. Syst., pp. 198, 605). As yet no fossil fishes have been observed in the Upper Silurian rocks of the continent of Europe or in America, and *in no country has a trace of them been heard of in the Lower Silurian.*

showing the whole succession, from the shale beneath to the limestone on which he stands.

6*.



To the east of this spot, where the calcareous plateau recedes towards the interior, the river Narva is precipitated to the south of the fine old castle of that name, over this same limestone, and the jointed structure of the rock has there been a most powerful auxiliary in causing the retrocession of that broad and picturesque cascade[2].

In its range westward to Reval and Baltisch Port, the same rock changes but slightly in its lithological or zoological characters; and even at the latter place the limestone is superposed to a grit with Ungulites.

To what extent it may be practicable to trace a direct passage from the pleta limestone upwards into superior strata by the examination of the country west of Baltisch Port and opposite to the isles of Oesel and Dago (which are, as we shall presently show, essentially composed of Upper Silurian rocks), we had no means of determining. By observing, however, the succession between the cliffs just described and the higher plateau of the country extending to the Lake Peipus and Dörpat, we convinced ourselves, that the whole lower group of which we have hitherto been speaking, is there overlaid by a limestone characterized by other

[1] From the descriptions of Colonel Helmersen, it appears that bands of inflammable bituminous schist are interpolated with beds of fossiliferous limestone on the estate of Tolks, on the river Jemmbach, 110 versts east of Reval. The *Asaphus expansus* with shells and corals, &c. are found even in the schist itself. —*Ann. des Mines de Russie*, an. 1838, p. 126. The carbonaceous character of these beds is probably derived from fucoids, as in the Swedish examples, where the bituminous schists are frequently employed as fuel for roasting the alum-slate.

[2] That the falls of the Narva are receding has already been well expressed by Colonel Helmersen, who states that it is only a fine development of what he illustrates in detail at the cascade of the river Fall in Esthonia. Alluding to the Falls of the Narva, and comparing them to those of Niagara, he says of the Russian stream, " Son Ontario est le Golfe de Finland, et son Erie le lac Peipus." Ann. de Jour. des Mines de Russie, an. 1838, p. 117.

fossils, as at Kleine Pungarn and Paggar[1]. In the limestone at these places we could no longer detect the characteristic Orthoceratites and Trilobites before spoken of; but with some species of the lower rocks, such as *Spirifer lynx* (Eichw.) and *Terebratula deformata* (Eichw.), we also found the *Leptæna depressa* (Sow.) and *L. deltoidea* (Conrad). These beds indicate a passage into, and form, indeed, part of a calcareous band, which ranges by Mustel north of Wissenstein in Esthonia, and reappears in the government of Kovno[2]. This band, like that which is in the same geological position in Norway, where it is immediately superposed to the chief mass of the Lower Silurian rocks, is here, as in that country, characterized by containing Pentameri, the Esthonian species being the *P. borealis* (Eichw[3].)—a shell which approaching very near to it, is, we consider, the equivalent of the *P. oblongus* of Scandinavia and the British Isles[4].

In one tract north-west of Wissenstein, it would appear (from a friendly communication of M. Pander) that the Pentamerus limestone is underlaid by a course of sandstone. In the tract of the government of Kovno, where we observed these beds, the upper calcareous strata alone appear through the great mass of overlying detritus. Judging from the red colour of the matrix of this detritus, and from certain cuttings on the sides of the new road between Tauroggen on the Russian frontier and the third post station, we were induced to suspect that the subsoil must belong to the Old Red or Devonian rocks. This view was confirmed by the relations of those deposits to the Lower Silurian rocks in the government of St. Petersburgh.

The emergence of grey Silurian rocks from beneath a surrounding region of red deposits (due probably to a flexure like that upon the Volkof, p. 30*) is even seen by the change in the colour of the soil in the neighbourhood of Bublia and Shavli. The limestone which gives rise to this superficial aspect is, however, worked at Neici and Grüs to the west of Shavli (see Map) in the extensive domains of the

[1] The residence of Count O. V. Stackelberg.

[2] This government has recently been separated from that of Vilna.

[3] We had absolutely named and spoken of this shell in print (Proc. Geol. Soc.) as *Pentamerus Letticus* three years ago, but whilst our publication was in progress Professor Eichwald described it as *P. borealis*.

[4] We owe our knowledge of this extension of the Silurian band in question to M. Pander, who, when we visited him at Riga (1841), identified the fossils we had found at Shavli with forms known to him in Esthonia. We also learned from this author, that at about forty to fifty versts north of the locality near Shavli, where we observed it, this Pentamerus limestone is exposed from west to east throughout a space of twenty versts in perfectly horizontal strata.

Zuboff family, and doubtless forms part of the calcareous zone observed by M. Dubois de Montpéreux at Pocroi[1]. This limestone is thin-bedded, of grey colour, in parts compact, in parts earthy, here and there graduating into a spotted red and green rock, with soft shale partings. The exceptional beds are yellowish, having slightly a magnesian aspect, and the surfaces are frequently marked with fucoid-like bodies. We detected about fifteen species of fossils in our hurried view of this deposit (including those from Meshkovitza, north of Shavli), and among these are *Pentamerus borealis* (Eichw.), *Terebratula Duboisi* (nob.), *Favosites Gothlandicus*, *Catenipora escharoides*, *Monticularia Sternbergii* (Lons.), *Stromatopora concentrica*, *Cyathophyllum ceratites* (Goldf.), and fragments of *Euomphali* and indeterminable *Encrini*.

On the whole, it would appear (though the western end of the tract has not been examined by us) that in no part of the mainland of the Baltic provinces is there any Silurian stratum of younger age than the equivalent of that peculiar limestone with Pentameri which has been hitherto classed as the uppermost bed of the Lower Silurian rocks. In Russia, however, as in Scandinavia, the fossils of this calcareous zone are, as indeed we should expect they must be, of an intermediary character, and already contain some true Upper Silurian forms. Such, indeed, ought to be the case; for this limestone is nothing more than the bed of passage between the two groups (see tabular view to the right of the Map).

Upper Silurian Deposits.—If nowhere apparent on the mainland, true Upper Silurian strata are clearly developed in the Isles of Oesel and Dago[2]. Even the corals[3] collected from thence by M. Eichwald and submitted by him to our inspection left no doubt in our minds on this subject when we first saw them. M. Pander has, indeed, completely confirmed the view by communicating to us the results of his examination of the Isle of Oesel. In the limestone which forms the fundamental rock, he cites the undermentioned fossils:—

Catenipora escharoides, C. labyrinthica, Favosites Gothlandica, F. basaltica, F. polymorpha, Syringopora reticulata, Aulopora serpens, A. conglomerata, Millepora repens, Porites pyriformis, Cyathophyllum turbinatum, &c., *Orthoceratites*

[1] See Karsten Archiv. 1830, and Leonhard Jahrbuch 1832. The latter contains a description of the fossils by M. v. Buch (p. 109).

[2] From what M. Eichwald says of the presence of the *Illænus crassicauda*, *Spirifer lynx* and *Orthis trigonula* in the Isle of Dago, it would seem that portions of both the lower and upper groups may there co-exist. (Urwelt des Russlands, H. 2.)

[3] These corals have been compared and identified with typical Silurian forms by our valued friend Mr. Lonsdale, who has so well described the Silurian and Devonian corals of England. (See Sil. Syst. p. 675, plates 16 *et seq.*, and Trans. Geol. Soc., plate 58, and descriptions and figures in the Appendix (A.) to this volume.) The best species of corals we possess are those supplied by M. Eichwald.

lineatus, *Tentaculites annulatus*, *Calymene Blumenbachii* var. *pulchella*, *Terebratula diadonta* (Dalm. and Sil. Syst.), *T. tumida*, *T. canalis* (Sil. Syst.), *Atrypa depressa* (Sil. Syst.), *A. reticularis* or *A. affinis* (Sil. Syst.), *A. didyma*, *Orthis orbicularis* (Sil. Syst.), *Delthyris sulcata* (His.), *Avicula reticulata* (His. and Sil. Syst.), *Mya rotundata*? (Sil. Syst.), *Cardium striatum* (Sil. Syst.), *Cyathocrinites pinnatus*.

This list, prepared by so good a palæontologist as M. Pander, at once establishes the true age of the chief limestone to be Upper Silurian, and shows that it is, as nearly as possible, the equivalent of the Wenlock limestone. But the evidence is rendered more decisive when he tells us, that the deposit containing these fossils is there surmounted by another calcareous band in which occur the very group of organic remains that characterize the Upper Ludlow rock of the British Isles, and certain tilestones which, though first classed as the base of the Old Red Sandstone, are, as we have said, now considered to constitute the highest stratum in the Silurian system[1]. In these beds the *Terebratula reticularis* (vel *prisca*), *T. lacunosa* (His.), and *T. didyma* (Sil. Syst.), are associated with a Spirifer (we believe the species to which we have adverted in the uppermost Silurian band of Norway and Sweden), and with these are the two very characteristic British species of the tilestone, *Turbo Williamsi* and *Turritella obsoleta*.

These evidences are, therefore, quite decisive in proving, that the chief deposits of the isles of Oesel and Dago are of the same age as those of the Isle of Gothland; and that, distinct from the palæozoic rocks of the mainlands of Sweden on the one hand, and of Russia on the other, they truly represent the Upper Silurian group of the British Isles.

As geologists we must further express our belief, that the phænomena of succession in these regions are thoroughly well explained by the signs of eruption and elevation which we have already described. The protrusion to the surface of igneous rocks in the fissure of the Gulf of Finland and all along the north-eastern frontier of the palæozoic deposits of Russia, as well as the continent of Sweden, is amply sufficient to satisfy our minds respecting the cause whereby the most ancient sea-bottoms in which animals lived, were raised into lands on either side of the Baltic, and put beyond the influence of those marine conditions under which the Isles of Gothland, Dago and Oesel were subsequently formed in an ancient geological trough.

The ascending succession of strata which we have described in passing from east to west in the Russian Baltic provinces strongly favours this view, and leads

[1] See *ante*, note 1, p. 13.

us to infer, that to the east (in the government of St. Petersburgh), where the elevation has been more powerful, it has also acted at a somewhat earlier period; for whilst in the eastern tracts watered by the Siass, the Volkof and Ishora, the pleta or lower limestone is at once surmounted by true Devonian strata, so as we proceed to the east the intermediate Pentamerus limestone is interpolated between the two systems; and, finally, in the Baltic Isles we have the full development of unequivocal Upper Silurian strata, all traces of which, physical or zoological, are excluded in the government of St. Petersburgh.

Silurian Organic Remains.—Recurring to the works of Eichwald and Pander, and availing ourselves of the light recently thrown upon some of these forms by Von Buch, it will be our effort to point out in the second volume the zoological resemblances and differences between the Silurian and other palæozoic fossils of Russia, and their analogues in Scandinavia and Western Europe. In the meantime we may, however, offer some general remarks upon the distribution of the Silurian fossils.

When the remains from St. Petersburgh, Esthonia, and the Russian Baltic Isles are laid before a geologist versed in palæozoic forms, he at once pronounces them to belong to the same system in the series, as that which has been named Silurian in other parts of the world, for he finds them to consist, as a whole, of the same profusion of Orthidæ, Leptænæ, Trilobites and Orthoceratites. Further, if his eye is sufficiently accustomed to the distinctions indicated by these fossils, he will at once see, that the system thus generally portrayed, is divisible into the two stages adverted to, and which are the equivalents of those which have been recognised in Western Europe and America. Of the Lower Silurian fossils of Russia a few only are, it is true, absolutely identical with forms of the same age in the British Isles; but the mass of them is essentially the same as that of the main land of Scandinavia; which region, being intermediate between England and Russia, is found to contain a considerable number of forms common to deposits occupying the same position in both the other countries.

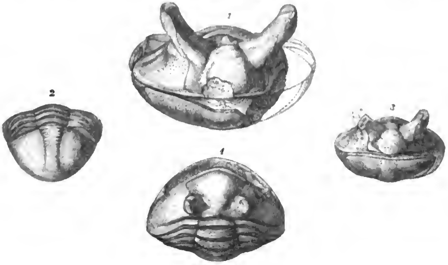
On the present occasion we shall simply adduce some of the leading evidences concerning these two groups; and first, as to the Lower Silurian.

The earliest formed palæozoic strata in Russia, as in Scandinavia, are characterized by fucoids only, and to this extent there is an agreement; but in examining the ascending series, some differences in lithological characters are found to characterize its subdivisions in the two countries, and these variations in the structure of the masses are accompanied (as might be expected) with corresponding peculiarities in the distribution of their organic remains. Whilst the lowest stratum in Sweden is, for the most part, a sandstone, and in Russia a shale (both void of any vestiges of animal life), we no sooner ascend into the overlying sandstone of the latter country, than we find that its fossils bear a general analogy to some of the Lower Silurian rocks of England and America. The Ungulite or Obolus which occupies this sandstone has, indeed, its parallel in the similarly constituted horny shell, *Lingula attenuata* (Sil. Syst.), which is in some places copiously disseminated in the Lower Silurian rocks; and in America, where one of the very lowest fossil rocks is a sandstone, the analogy, as we have before mentioned, is still more striking. Although the Orthidæ with simple plaits, common in some of the very lowest Lower Silurian beds of Snowdon and North Wales, are not found in this Russian sandstone, we have but to ascend from it into the next fossiliferous member, the "pleta" limestone, and we detect such forms as the *Orthis calligramma*, *O. orthambonites* and *O. moneta*; all belonging to the division of that genus which is typical of rocks of this high antiquity. From the community of their fossils, no doubt whatever can exist, that the great lower limestones of Norway and Sweden, with their Trilobites and Orthoceratites, are precisely of the same age as the pleta limestone of the Russians. But here it is well to observe, that although, upon the whole, there is a close resemblance between the lower fossiliferous limestone of the two countries, there are marked distinctions of detail. Thus in Sweden, the bed beneath the great limestone in which the earliest vestiges of animal life have been seen, is a black bituminous and aluminiferous stratum with calcareous courses, in which peculiar Encrinites, Trinuclei and Paradoxides or Olenus are associated with masses of fucoids; whereas in Russia this band, or one upon the same horizon, being much less developed, and on the whole much less rich in calcareous matter, and rarely affording traces of fucoids, is to a great extent barren of organic life. As soon, however, as we mount to the great fossiliferous band, in which calcareous matter has been equally diffused in the two countries, the synchronous deposits of Scandinavia and Russia are found to be alike loaded with the same group of fossils, and to a great extent the very same species. Thus, among the Orthoceratites, the *O. vaginatus* and *O. duplex*, which are by far the most abundant, though unknown in the British Isles, have even there their equivalents in the rarer species with *lateral siphuncles*. In Scandinavia, however, where more typical British species of various Lower Silurian genera exist than in

Russia, the *Orthoceratites duplex* is as common as in the tracts of which we are now treating; whilst the Russian *Orthoceratites vaginatus* is represented in Sweden by the closely allied *O. trochlearis*. The *Lituites convolvans*, it may be further stated, is common to these two countries.

The lower limestone of Russia abounds in Trilobites, two of the prevailing species being, as in Norway and Sweden, the *Asaphus expansus* and *Illænus crassicauda*; the former being the most abundant in Russia, the latter in Scandinavia. Referring to the work of Pander, in which some of the species are published, we may further state, that the characteristic Russian crustaceans, including the *Calymene Fischeri* (Eichw.), *C. polytoma* (Dalm.), *Ampyx nasutus* and *Metopias aries* (Eichw.), are Scandinavian forms, two of which have been described by Dalman, and the last mentioned by Boeck. Of these, the *Asaphus expansus* being the most profusely distributed in Russia, though as yet very rare indeed, if known at all in the British Isles or France, we here annex a figure of the usual form of the species (4) of the following woodcut, adding in a note its description by Dalman[1]. This species

Asaphus cornutus, var. of A. expansus? 6**.



Asaphus expansus.

[1] The following is Dalman's description of *Asaphus expansus*: "Capite semilunari, angulis posticis rotundatis; sulco subbasali transverso profundoque; linea faciali (postice) oblique extrorsum decurrente, tandem intus flexa; pygidio semi-orbiculari, costis obsoletis. (Syn. *Entomostracites expansus*, Wahl., and *Asaphus cornigerus*, Brongn.)." According to Dalman, this species has many varieties, and his figure, pl. iii. fig. 3 (*c*), exhibits one with prominent eyes, but not approaching to the remarkable varieties (1) and (3) of our woodcut. *Ueber die Palæaden oder die so genannten Trilobiten von J. W. Dalman*, p. 45.

exhibits, however, such remarkable variations in the eyes, probably due to the greater or lesser age of the individual, that we take this opportunity of also figuring a second example (3), in which the eyes project from the head to about four-tenths of an inch; and thirdly, a case of extreme projection of this member in figure 1, which represents a very remarkable specimen of the *Asaphus cornutus*[1] (Pander).

We have already said that the *Asaphus Buchii* and *A. heros* (Dalm.) (or *tyrannus*, Sil. Syst.), so abundant in England, seem gradually to disappear in the eastward range of the deposit. They are consequently very rare in Russia.

Among other Trilobites of this age, Professor Eichwald speaks of the *Asaphus Vulcani*, a species found in the Lower Silurian rocks of England, and we ourselves recognised the *Calymene Downingiæ*, which is a Dudley fossil. The occurrence of the latter is by no means hostile to our views of classification, for we now know that the *Calymene Blumenbachii*, which in England is most abundant in the Ludlow and Wenlock formations, there descends in some places into the Caradoc sandstone. The occurrence of a few of the same species in the Lower and Upper Silurian deposits, is indeed just what may be looked for in a system, which, on the whole, is characterized by a general community in its organized beings. Thus there are certain shells as well as crustaceans which are common to the conterminous formations of the lower and upper groups in Russia, Scandinavia and England, and of these we may cite the *Leptæna depressa* and *Terebratula reticularis*; shells which having a very wide geographical distribution, are found to have also an extensive vertical range; or, in other words, to have continued longer in existence than their congeners, in accordance with a law to which we formerly directed the attention of geologists[2]. But here we must observe, that the Silurian rocks of Russia hold their place well in the general series of palæozoic life, and bear a strong resemblance to their equivalents of Western Europe[3], in containing a large proportion of Orthidæ

In addition to the work of Pander, in which many structural details of the Russian Trilobites are given, we have already referred our readers to the 'Silurischen Schichten' of M. Eichwald, and to a recent memoir by His Imperial Highness the Duke of Leuchtenberg.

[1] We owe these specimens, which so clearly exhibit the transitions in the length of the eye and the variations between *Asaphus expansus* and *A. cornutus*, to our friend Dr. Wörth, who detected them in the ravines of the Pulkovka brook. The caudal portion (2 of woodcut) is identical in all the varieties; and after examining a great number of individuals which exhibit various shades of transition, we confess that we think the *A. cornutus* (Pand.) is only a variety of *A. expansus* (Dalm.).

[2] See Trans. Geol. Soc. of London, vol. vi. p. 335.

[3] Among the shells common to the Lower Silurian rocks of Scandinavia and Russia, we must further mention *Euomphalus qualteriatus*, *Orthis calligramma*, *O. testudinaria*, *Leptæna sericea*, *Spirifer poram-*

and Leptænæ, both these genera being completely separated from the Producti, which are never found in rocks of this high antiquity. Of these fossils, twenty species are known in the Silurian rocks of the environs of St. Petersburgh, twelve of which belong to Orthis, whilst in the overlying or Devonian system, so full of other genera of shells, two species of Orthis and three of Leptæna have only been discovered (see next chapter, vol. ii., and Table of Organic Remains).

The Lower Silurian strata of Russia, still more than those of Scandinavia, are distinguished by those singular plate-covered bodies of circular forms, with central mouths and lateral oval apertures (whereof the *Sphæronites aurantium* is the prevailing type), which, though closely approaching to Crinoidea, well merit to be distinguished therefrom. The greater number of these belong to the genera Echinosphærites and Echino-encrinites of Wahlenberg, but M. von Buch, who has thrown so much light on these fossils, has formed other genera, such as the Hemicosmites and Cryptocrinites, which as yet have been alone found in Russia, and has even whilst we write grouped them under the name of *Cystideæ*, and has added to those which he had previously described, the new genus Sycocystites, equally with the others characteristic of the Lower Silurian of Russia, whilst his Caryocystites occurs in the Upper Silurian of Gothland only. In the meantime we may state, that whilst the Cystideæ abound in great clusters throughout the Lower Silurian beds both of Scandinavia and Russia, they have recently been discovered in strata of the same age in England. They were noticed long ago in Sweden by Linnæus and other authors, and were distinctly described in a very able manner by Gyllenhall. The genus Echino-encrinites is also found in Sweden, where it was for some time confounded with the Echinosphærites[1].

bonites, *Terebratula nucella* and *Lingula longissima*. We may add that the very characteristic *Spirifer lynx* of Russia has its representative in the *Atrypa dorsata* of Sweden. This *Spirifer lynx*, which is a common variety of the *S. biforatus* (Schloth.), has a very wide geographical range, and is one of the most abundant fossils in the Lower Silurian beds of North America; viz. the blue limestone of Kentucky, Tennessee, Ohio and Indiana.

[1] M. Hermann von Meyer and M. Volborth have also written on the organization of the genus *Echino-encrinites*, and the last of these authors has endeavoured to show that it had true arms around the mouth; an opinion from which M. von Buch entirely dissents. The Echino-encrinus of Von Meyer is the Sycocystites of Von Buch. (See M. von Buch's last memoir, "Ueber Cystideen." Trans. Acad. Berol. 1844.) The existence of Cystideæ in England, spoken of in the text, has been made known through the researches of the Ordnance geological surveyors under Sir Henry T. De la Beche. The fact of the presence of such bodies in the unquestionable Lower Silurian rocks of South Wales, was mentioned to us by Professor Phillips whilst these pages were undergoing their last revise. Fortunately the great authority on this subject, M. Leopold von Buch, being then on a visit to London, the specimens were submitted to him; and

Although not rich in variety of coralline species, the Lower Silurian rocks of Russia are occasionally loaded with numerous individuals of two or three species, of which the *Chætetes Petropolitanus* is by far the most abundant; a coral, which, it is important to remark, is also prolific in the lower beds of Norway, and has recently been detected in similar strata in North Wales[1]. Overlying the deposits in which the fossils already cited are accumulated is a calcareous band with Pentameri, which we consider the representative of that zone which in the British Isles, Scandinavia and North America, contains the *Pentamerus oblongus*, to which our *P. borealis* makes a close approach. And just as this band is intermediate between the lower and upper groups, so does it contain fossils which range into both (such as the *Leptæna depressa*), and in it we already find the *Catenipora escharoides* and one or two species of corals of the true Upper Silurian group.

The striking distinctions between the Upper Silurian deposits of the Baltic Isles and those lower formations which constitute the mainlands of Sweden on the one hand and of Russia on the other, have been already so clearly defined, that it is unnecessary now to say more, than that through a multitude of corals and many typical shells, the Wenlock and Ludlow rocks of England are there very adequately represented, the latter even exhibiting the very highest beds of the system.

We have therefore to repeat, that the Russian palæozoic strata described in this chapter are unquestionably of the same age as those which are termed Silurian in other parts of the world; and that here, as in Scandinavia and the British Isles, they are divided into two natural groups, and are overlaid by the Devonian or Old Red system of deposits which we are about to describe.

In concluding this chapter, we may further briefly state, that whilst our present observations refer to the Silurian formations of the Baltic provinces of Russia only, we believe, from the descriptions of other authors[2], that strata of the same

he has authorized us to state, that among these forms of Cystideæ, which are, however, mere internal casts, the *Sphæronites aurantium* is clearly recognisable. The remains seen by M. von Buch are from the quarry of Sholes Hook, near Haverfordwest, a locality which we formerly described as Lower Silurian. (See Silurian System, p. 397.) We are also informed by Captain James, R.E. of the Ordnance Geological Survey of Ireland, that he suspects he has found similar bodies in the Lower Silurian strata of the county of Waterford. The Lower Silurian rocks of Scandinavia, Russia and the British Isles are therefore closely bound together through these remarkable fossils.

[1] By Professor Sedgwick.

[2] We not only trust to the published descriptions of Eichwald and Pusch, but also to communications we have received from Major Blöde and M. Dubois de Montpéreux, and to our having seen unquestionable Silurian species, such as *Conularia Sowerbyi* and *Terebratula plicatella*, obtained from these tracts.

age occur in Podolia, near Kamenetz on the Dniester, and on the banks and tributaries of that river.

On the other hand we have already expressed an opinion, derived from personal examination, that the oldest palæozoic limestones of Kielce in Poland are of Devonian age[1].

The Silurian rocks which constitute the chief mass of the sedimentary deposits in the axis of the Ural Mountains will be described in the second part of this volume; and we shall now therefore simply state, that they are there so powerfully metamorphosed, dislocated and intermingled with masses of igneous origin, that unless we had been previously well acquainted with them in countries where they are undisturbed, we never could have unravelled their complicated relations. Even there, however, we have been able to decipher, though obscurely, the same order from a Lower to an Upper group, as in the regions which have been under consideration; the latter (which is charged with a Pentamerus very closely allied to the *P. Knightii*) being clearly succeeded on the flanks of the chain by a copious development of strata charged with Devonian fossils.

[1] After the first chapter was printed off, Mr. Murchison received from M. Ferdinand Oswald, of Oels, near Breslau, a communication which shows that true Silurian rocks exist in Silesia, as well as the Devonian and Carboniferous strata, which have been there previously recognised (see p. 3*). These Silurian strata occur at the villages of Sadewitz and Ober, and Neu Schmollen, south of Oels, where they occupy an area of about one and a half German square mile, and are loaded with many characteristic Silurian fossils. Among these are the corals *Favosites Gothlandica*, *Catenipora escharoides*, and *C. labyrinthica*, with *Orthis testudinaria*, *O. transversalis*, *O. Pecten*, several Orthoceratites, the Trilobites *Calymene Blumenbachii*, *C. macrophthalma*, and forms common in Western Europe, with others, such as the *Illænus crassicauda*, *Asaphus expansus* and *Sphæronites*, whi h are characteristic of the Lower Silurian rocks of Scandinavia and Russia. M. Oswald's notice will be communicated by Mr. Murchison to the British Association for the Advancement of Science, and it is here alone necessary to observe, that, quite alive to the necessity of distinguishing these fossil accumulations from the surrounding northern drift, the author asserts, that they clearly occur in stratified limestones and shale "*in situ*." (See Map, Pl. VI.)

Obs.—This chapter was printed and undergoing a last revise, when we received from Professor Eichwald a copy of his memoir "On the Fishes of the Devonian System in the neighbourhood of Pavlosk," published in a recent number (Band 17) of the Bulletin of the Imp. Soc. of Naturalists of Moscow, in which he attributes the discovery of these ichthyolites to a young mineralogist, M. Siemaschko. We have no wish whatever to enter here into a discussion respecting the collector who may have been the first to find these fossils; though in stating that, as far as we know, Count Keyserling and M. Wörth were the first to announce to a scientific Society the presence of ichthyolites on the Slavenka, we merely adhere to the truth. Quite independent, however, of all disputes about priority of names and discovery of certain forms, a very grave geological question is involved in the memoir of M. Eichwald, and we must, therefore, in justice to ourselves, say a few words on the true determination of these ichthyolites. Not pretending to be judges of the generic and specific value of all the fragments collected by M. Wörth and Count Keyserling, we brought a large quantity of them to England, and, aided by that sound ichthyologist Sir Philip de Grey Egerton, we transmitted a selection of them to Professor Agassiz. The chief results are here made known in the text, and the details are given in the second volume. In the meantime, M. Eichwald wrote the memoir alluded to, in which he makes certain comparisons that will, doubtless, astonish M. Agassiz as much as ourselves, and indeed we may say all geologists. He cites, for example, from these beds, so truly Devonian, the *Pleuracanthus tuberculatus*, a species never previously found beneath the carboniferous limestone. To a second he gives the name of *Saurichthys*, a genus hitherto known in the Muschelkalk; whilst a third and fourth he terms *Hybodus longicornus* (Ag.) and *Pristacanthus*; genera which Agassiz has recognised in the Lias and Jurassic strata only; whilst even a Pleuracanthus, by which Agassiz characterizes the tertiary molasse, is said by M. Eichwald to be here mixed up with true Devonian and Silurian genera! Again, in adverting to the existence of the Ctenodus, M. Eichwald commits the mistakes of saying, that this well-known carboniferous type had hitherto been found in the *chalk* only, and that the Onchus (an Old Red and also a carboniferous genus) had been hitherto detected in the Upper Silurian only. In short, if M. Eichwald is right, and the authors of this work and M. Agassiz are wrong, then is the deposit on the Slavenka a geological *omnibus*, wherein creatures of all epochs, from protozoic to tertiary, lived together in the very same bed. As such a phænomenon would, if admitted, subvert all those inductive processes by which geologists have been hitherto guided, M. Eichwald must excuse us if, relying on the identifications of M. Agassiz and our own views, we entirely deny its existence. We must also state, that the example of St. Cassian in the Alps, where, on the authority of Count Münster, palæozoic and secondary forms are said to be mixed together, has no real bearing, as M. Eichwald infers, on this Russian question. In the Alpine case (which has never been *geologically* described) there exist, if we are not misinformed, lofty and almost vertical mountain escarpments, at and near the summits of which one group of formations may very well exist, and another at their base; whilst the remains, to which the name of St. Cassian has been applied, are simply those which are collected by the peasants from the valley,—fossils which have fallen from various heights and are necessarily mixed together below. On the Slavenka, on the contrary, the supposed *mélange* occurs in one and the same stratum.

We need scarcely add, that beyond the lithological features described, there is not on the Slavenka, any more than on the Volkof or Siass, the smallest evidence of transition from the Lower Silurian to the Devonian fish-beds, as asserted by M. Eichwald; still less of any intermixture of the fossils of the two groups, except where the strata have been broken up, and their surface affected by the northern drift (see Chapters XX. and XXI.). If such a transition and passage were admitted, we might in Russia cite many other equally apparent examples of such,—as between the carboniferous limestone and Jura rocks of Moscow (p. 235), or the Permian rocks of the Vaga and their overlying pleistocene beds! (p. 331.) But such an idea requires no serious refutation, and geologists must rest contented with our distinct and unequivocal denial of M. Eichwald's supposed facts; whilst M. Agassiz assures them, that the fishes in this Russian deposit (which we affirm is true Devonian) *are either well-known types of the Old Red Sandstone only, or forms hitherto never found in any other overlying or underlying deposit.*

Postscript on Devonian Fossil Fishes.—The geological student will soon perceive, that the ensuing chapter on the Devonian rocks was written and printed without the knowledge of the ichthyolites of that age communicated to us by Professor Agassiz, whilst preparing the opening chapters of this work, which, for reasons before assigned, were the last sent to press. Whatever changes of names that author may have ultimately applied to the Devonian ichthyolites (for which we refer to our preceding observations and to his descriptions in the second volume, or in his 'Monographie des Poissons du Système Dévonien ou Vieux Gres Rouge'), our readers will find that our arguments and reasoning employed two and three years ago, have been prodigiously strengthened by the additional light thrown upon many new types of true Devonian age. Thus, besides the numerous species of fishes of the Old Red Sandstone already spoken of (p. 64), and the new genera and species found on the Slavenka, we learn from M. Agassiz, that we had really obtained from the red sandstone of the Andoma (p. 48), the *Pterichthys major* (Ag.), a species previously named from a specimen found on the banks of the Findhorn, near Elgin. This, it is important to remark, is the first representative of the family of the Cephalaspides found in Russia. In addition to the forms of teeth of Dendrodus alluded to (pp. 52 and 66) as occurring near Riga (and which have recently been sent from Cremoo in Livonia by our distinguished friend the Baron H. de Meyendorf), M. Agassiz announces the presence of *Dendrodus latus* (Owen), and *Lamnodus Panderi* or *hastatus* (Ag.) (*Dendrodus hastatus*, Owen), both of them published Scottish species, whilst Professor Owen, examining the structure of the teeth with the microscope, has named another Russian ichthyolite, *Dendrodus Murchisoni*, showing how it is distinguished from the Scottish species *D. biporcatus* (see Appendix B. and Plate B.). The fossil which M. Agassiz had named *Glyptosteus favosus* (see p. 46), is, it appears, accompanied by another species of the same genus that we had named *G. reticulatus*, which is the same as M. Eichwald's *Bothriolepis ornata*. These last-mentioned ichthyolites appear not only on the banks of the Priksha (erroneously spelt Priutchka in our next chapter), in the Valdai Hills, and at Tchudova, but also on the Siass and Andoma rivers, in the north-eastern range of the Devonian rocks. One of them occurs at Kipet, near Bielef (p. 58), in the great central Devonian dome (see section beneath the Map, Pl. VI.). Both these species of Glyptosteus, or Bothriolepis, so widely diffused in Russia, are common to the north of Scotland; the first-mentioned being found in Perthshire (Clashbennie) and Elginshire, the last in Nairn, Elgin and Murray shires. Not only is the smaller species of Chelonichthys, *C. minor* (Ag.), (*Asterolepis*, Eichw.[1]), found both in Scotland and at Riga; but we now learn that the Scottish locality of Elgin also contains fragments of the Russian monster *C. Asmusii*! Lastly, we may state, that in confirming our view of the identity of the Devonian rocks of the dome-shaped region around Orel, Voroneje and Bielef with those of the Baltic and North-eastern governments, M. Agassiz assures us that certain bones from all these tracts, and which he has not yet described, belong to the same species.

The results of the close and careful comparison of M. Agassiz are truly remarkable in sustaining our views of the great uniformity of the palæozoic deposits over very wide areas of Europe, and in showing the necessity of considering the Devonian or Old Red group a separate system. The reader will, indeed, see, that instead of eight or ten species of the Devonian fossil fishes of Scotland and Russia being identical, as we have printed it in the next chapter, that number is already more than doubled; or, in other words, of the known Russian ichthyolites peculiar to this age, two-thirds are *specifically* the same as those of the same epoch in Great Britain!

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[1] Though we have now learned that M. Eichwald used the word Asterolepis in reference to the gigantic ichthyolite of Dörpat, before M. Agassiz had named it, we adhere in this volume to the word Chelonichthys, simply because we have long used it in print, as derived from the great authority of Neufchatel. If, according to the understood custom of accepting the first name (which ought, however, to depend upon the object having been figured and described), the name of Asterolepis be finally adopted, we have in the meantime simply endeavoured to preserve in this chapter and in the Table attached to the Map, a coincidence with the text (Chap. IV.) which we printed two years ago.—*April*, 1845. (For all palæontological details, see Appendix and vol. ii.) The Russian Palæozoic corals are described by Mr. Lonsdale in the first part (or A.) of the Appendix to this volume; and a new species of Dendrodus is described by Professor Owen (B. of Appendix) from a microscopic examination of the teeth of that genus.

CHAPTER IV.

DEVONIAN, OR OLD RED SYSTEM.

Great extension of the System.—Described in ascending order, from the junction of its lower strata with the Silurian rocks of the Volkof, to the contact of its upper beds with the Carboniferous Limestone in the Valdai Hills.—Range to Vitegra, Andoma, and Archangel.—Range and contents in Courland, Livonia, &c.—Great South-eastern band extending to the Governments of Orel and Voroneje, and sections of it on the rivers Oka and Don.—Organic Remains of the System in Russia compared with those of Western Europe.

THE red rocks which lie to the south of the Silurian strata of the Baltic constitute one of the largest systems of Russia [1], and extend over an area of not less than 150,000 square miles :—a region much more spacious than the British Isles. Reposing upon the low plateaus which have just been described, and rising into hills, varying from five hundred to upwards of nine hundred feet above the sea, this zone is well defined both at its lower and upper limits; for it passes down into beds of Silurian flagstone and is surmounted by true carboniferous limestone. Thus, occupying the same geological horizon as the Old Red or Devonian system of Great Britain, these rocks form the substratum of Courland and of Livonia, from whence they range north-eastwards into the governments of Pskof, Novogorod, Olonetz and Archangel, and south-eastwards through Vitebsk, Smolensk, Kaluga and Tula, to Orel and Voroneje. We shall first describe these deposits in their north-eastern and afterwards in their south-eastern range.

Northern Devonian Zone.—With the exception of certain summits of carboniferous limestone, the Valdai Hills, and all the hilly region around Lake Ilmen, are composed of Devonian rocks. On the sides of the high road from St. Peters-

[1] See Map, Tabular View and Section annexed to it.

burgh to Moscow natural sections are very scarce, but the lower members of the system are observable in the water-courses of the little rivers Kerist and Polist. For some versts, indeed, to the north of the former, the surface of the soil begins to assume a reddish tint, and in the purple and grey limestones recently extracted for the use of the chaussée, we found remains both of shells and fossil fishes[1]. At Tchudova, 112 versts south of St. Petersburgh, both banks of the Kerist, particularly below the bridge, exhibit flag-like, compact limestones, which are from one to three inches thick; the upper or lower beds of whitish cream-colour, and the central of a reddish hue, have a more concretionary structure. The surfaces of these calcareous flagstones convey the idea of their having originated in a sediment which had been accumulated in a tranquil sea; for they are crossed with fucoids and other peculiar bodies, whilst Mollusca and Encrinites are arranged along the fine laminæ of deposit.

The shells are unquestionably of Devonian age; such as *Serpula omphalodes* (Goldf.), *Spirifer muralis* (nob.), *S. speciosus* (*S. micropterus* according to V. Buch), *S. Archiaci* (Murch.), *S. granosus* (nob.), *Terebratula ventilabrum* (Phill.), *Orthis striatula* (Schloth.), *O. micans* (V. Buch), *O. crenistria* (Phill.), *Bellerophon armatus* (nob.), together with cylindrical, branching, indeterminable bodies, fucoids ?, and remains of Encrinites and Pentacrinites.

These strata at and to the north of Tchudova may be classed as the lowest members of the Devonian system. At Kalapi-polist, a hamlet some versts to the south-south-east, other beds, which, from the general slight inclination of the strata, and the gentle rise of the country to the south, must be overlying, are detected in ancient quarries on the right bank of the Polist. They consist of finely laminated, red and cream-coloured, flaggy limestones, in parts compact, in parts more sandy, and showing a strong tendency to concretionary structure. The concretions are of a more or less compact, argillaceous limestone, having a sandier base of dark green, ochreous and reddish colours. In parts these concretions resemble some varieties of the Herefordshire cornstone, from which form they graduate on the one hand into micaceous, greenish sand and sandstone, and on the other into calcareous flagstone. Nests of calcareous spar are not unfrequent, and fucoid-

[1] Upon our last return from Moscow, late in the season, and when we were too much hurried to quit the chaussée, we examined numerous heaps of fresh-quarried, red, calcareous, shelly flagstone, recently discovered in the ravines *north* of Tchudova, in which were some large fishes' scales (*Glyptosteus reticulatus*, Agass.) with true Devonian shells.

bodies ornament the surface of the flagstone as at Tchudova. But besides one or two of the shells mentioned as occurring at that place, we here met with scales of fishes which characterize the Old Red system,—belonging to the genera *Diplopterus* and *Glyptosteus* (Ag.).

If the sectional line be prolonged in the direction of Moscow, these lowest strata of the Devonian system pass beneath the red masses of Novogorod, Lake Ilmen and the Valdai Hills. But before we follow this ascending order, let us describe clearly the lower strata in the best natural section which the north of Russia affords, and where, as before stated, they are seen in absolute contact with the uppermost Silurian rocks (see woodcuts, p. 28 and 30).

Continuing the section on the Volkof, we find the uppermost Silurian beds loaded, as explained, (p. 29) with Sphæronites, Favosites, and small Orthidæ. These graduate upwards into flag-like courses more siliceous, which in ascending the river are overlaid by other thin-bedded strata, gradually becoming more red and green with marly way-boards. Concretionary forms begin to prevail, with courses of deep red and light green mottled marlstone, and at length red and green impure limestones, in beds from three to six inches, abound, interlaminated with much red marl. The fossils from about one verst south of the village of Bor to the hamlet of Vindin-Ostrof are unequivocally *Devonian*.

Along the banks of the river at this place and at Prussino we collected the following fossils:—*Serpula omphalodes* (Goldf.), *Spirifer muralis* (nob.), *S. speciosus* (*S. micropterus*, V. Buch), *S. Archiaci* (Murch.), *S. plicistria* (D'Arch. et De Vern.), *Terebratula prisca* (Schloth.), *T. Meyendorfii* (named by us after our friend and companion Baron A. Von Meyendorf), *T. concentrica* (V. Buch), *T. ventilabrum* (Phill.), *Orthis striatula* (Schloth.), *Leptæna productoides* (Murch.), *Productus spinosus* (Sow.), according to M. V. Buch, *Avicula Wörthii* (nob.), *Modiola antiqua* (Goldf.), *Bellerophon globatus* (Murch.), *B. armatus* (nob.), *Natica*, &c. With these shells, among which are several species published as Devonian types from other parts of Europe, are also found fossil fishes, particularly scales of the *Glyptosteus* (Agassiz), a genus which also characterizes the Old Red Sandstone of Scotland.

The banks of this fine river diminish gradually from a height of sixty to seventy feet at Petropaulosk, to twelve and fourteen feet near Vindin-Ostrof, Cherensorok, and Prussino, but the red marls and associated sandy calcareous flags and cornstones are traceable a little higher up the stream, and are then lost under the superficial detritus which obscures the edges of the Volkof and of its great feeder the Tigoda[1].

It may here be observed, that the ichthyolites of the lower beds of the system, whether from these localities or those of Tchudova and Kalipi-polist before mentioned, differ specifically from the forms which we shall afterwards point out in the uppermost strata in the Valdai Hills (on the Priutchka, a tributary of the Msta). The *Glyptosteus* and *Diplopterus* are genera common to the north of Scotland and Russia, but the species in these lower beds, *G. reticulatus* and *D. rugulosus*, are, according to the recent determinations of Professor Agassiz, unknown in the British Isles. We shall presently, however, indicate the existence of several species of ichthyolites in the middle and upper beds of the system which are identical with Scottish types.

The central members of the Devonian system consist of red and green argillaceous marls or clays, limestones, both flag-like and concretionary, and courses of flag-like sandstone and grit, and for the most part little coherent. Gypsum is disseminated at intervals, and salt-springs issue from the deposit. The lower parts of the Valdai Hills are composed of these central members of the system: they consist of red and green marls, in which concretions of impure limestone and calcareous flags are only to be detected at intervals, as on the banks of the Msta, in certain cuttings of the Moscow chaussée, and occasionally in ravines at short distances from it. At and near the Imperial summer-palace of Korostino, the banks of the southern end of the Lake Ilmen, and the edges of a ravine at Porogi, present cliffs from forty to fifty feet high. The upper beds are greyish and purplish, compact, calcareous flags, which split into numberless small cubes, and weather externally to a yellowish colour. They are often spotted with blood-red circles, and their surfaces are much diversified by long, tubular, incurvated bodies. These calcareous strata having a maximum thickness of about thirty feet, rest on a deep red, rough limestone, charged with many prevalent Devonian shells. Among these are several of the forms noticed on the banks of the Volkof near Prussino, with another species, which, though not detected in that locality, is associated with the same group in the Devonian limestones of the Boulonnais in France and elsewhere; viz. the *Spirifer Verneuillii* (Murch.). Besides the common shells,

[1] The beds here described are those which lie in the trough before mentioned, and from beneath which the Silurian rocks of the Vloia rise to the surface (see woodcut, p. 30).

Terebratula prisca, *Leptæna productoides*, *Serpula omphalodes*, &c., &c., we also met with *Terebratula Helmersenii* (V. Buch), *Spirifer tenticulum* (nob.), and the *Orthoceratites subfusiformis* (Münster).

A little to the east of Korostino, and at Porogi, where the same strata undulate to some extent, dark purple, unctuous clays and marls are exposed at the base of the cliffs.

The great thickness to which inferior strata of the system expand to the south of Lake Ilmen, has been proved by the sinkings recently made in the hope of penetrating to the sources of the salt-springs at Starai Russa, and in which, it is said, no perceptible change of ground was met with through a depth of about 600 feet. As the deepest point from which these brine-springs rise has not been attained, we are left in doubt whether the real source of the salt is in the lowest beds of the Devonian rocks or even in the Silurian system.

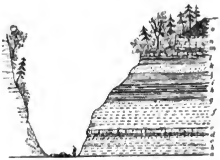
It will be shown in the sequel, that salt-springs and rock-salt are very prevalent in the red rocks overlying the Carboniferous system, and thus Russia affords distinct proofs within itself, that this mineral occurs in formations of very dissimilar age.

From the absence of rocky cliffs, the rounded nature of the elevations, and the detritus which obscures the surface, the whole of the intermediate strata cannot be seen in any one section of the Valdai Hills. Still, by examining the banks of the Msta and its tributaries (the only river of any magnitude which runs transverse to the Valdai), we find sections of the upper division of the system, which for clearness are not exceeded, if equalled, in any part of Europe. The best evidences of a succession from the red ground into the overlying carboniferous limestone, are seen in the sequestered valley of the Belaia (or White River), a tributary of the Msta, about twenty-five versts south of Borovitchi[1]. Immediately to the north of the picturesque village of Sherokovitchi, the rivulet Priutchka falls into the Belaia, and by following the former to its source you ascend a well-wooded and watered, narrow gorge, on the sides of which are natural sections, in great part vertical, of near 200 feet in height. The greatest number of strata exposed in any one spot, may be seen near the place where coal-works have been established, and galleries have been driven from the side of the hill into certain bituminous schists, half-way up the cliff, which occur in the lower member of the Carboniferous system,

[1] We were conducted to this spot by our young friend and companion Lieut. Koksharof, who had previously accompanied Colonel Helmersen in his examination of the tract.

and which are capped by the lowest beds of the mountain or carboniferous limestone, to be hereafter described. Whilst we refer to this woodcut for the general order and detail of the succession, we now confine our description to the strata beneath the carbonaceous beds.

7.



The lowest beds visible (*a*) are green marl, with some remains of small fish-bones. These are separated from overlying red and green marls (*c*) by an intermediate course of sandstone (*b*), which also contains fragments of minute fish-bones and ichthyodorulites.

The red and green mottled marls (*c*), having a thickness of about thirty feet, are surmounted by the most remarkable "bone-bed" (*d*) which ever fell under our examination. This bed has altogether a thickness of about four feet, the upper part being a mottled, marly "cornstone," in which few remains exist, whilst the lowest part—a yellow marl about two feet thick—is almost entirely composed of bones and scales of ichthyolites. Of these, three species are pronounced by M. Agassiz to be identical with forms known in the Old Red Sandstone of Scotland[1], viz. the *Holoptychius Nobilissimus* (Ag., Sil. Syst.), *Glyptosteus favosus* (Ag.), *Diplopterus macrocephalus* (Ag.). Above the bone-bed is a whitish marly limestone (*e*) ten feet thick; then follow about sixty feet of red and green marly clay (*f*), with occasional harder courses, the whole being surmounted by the sands and bituminous schists which form the bottom of the Carboniferous system.

The lowest of the carbonaceous strata is a thin band of yellowish marly incoherent sandstone (*g*), which here has not a greater expansion than six feet. In this bed, and in those above it, the carboniferous plants prevail, whilst the characteristic Old Red fishes are no longer to be detected in them. A line of physical demarcation is therefore neatly drawn between the Devonian and Carboniferous deposits.

Range of the System to the North-east.—Having thus presented a general ascending section of the Devonian or Old Red system in the region between Petersburgh

[1] The observations of Professor Agassiz on these identifications, and others to which we shall presently allude, will be given in a subsequent part of the work (see also end of this chapter).

and Moscow, we may now describe it in its extension, first to the east-north-east, and afterwards to the west-south-west, concluding our account by a sketch of its range to the south-east, or into the central governments of Orel and Voroneje (see Map).

From what has been said of the transformation of the Silurian rocks in their course to the north-east (p. 19), it will not be expected that much instructive evidence is to be obtained, from that region, of the lowest Devonian beds. In our journey to Archangel, however, we traced the middle and upper members of the system in many places[1], the latter being invariably capped, as in the Valdai Hills, by the carboniferous limestone[2]. At the river Mgra, about four versts south of a post-house on the high road to Vitegra, are light-coloured and reddish mottled, micaceous, incoherent grits and siliceous flagstones, in which we discovered scales of *Diplopterus?* and *Glyptosteus*, associated with portions of the jaw of a new genus to which Professor Agassiz has given the name of *Ctenoptychius*[2]. To the south and west of the Lake Onega the strata of this age are more or less incoherent sandstones, which in parts have the aspect of the New Red Sandstone of Western Europe, though they are in general more flaglike. These are the beds which we conceive to have been altered by the intrusion and eruption of the trappean rocks of Petrozavodsk and the northern regions; for at the south-western end of the Lake Onega, the sandstone is soft and incoherent, and when followed on the same level is found suddenly to become a hard siliceous rock, wherever it is in the proximity of the greenstone, which abounds to the north of the river Svir (pp. 18 and 19).

The eastern banks of Lake Onega a little to the south of the embouchure of the river Andoma present cliffs, about 150 feet high, composed of red and green marls, which pass into incoherent, variegated sandstone, resembling on the whole both the New and Old Red Sandstones of England[3]. Owing to their fragile nature,

[1] We are indebted to a collection made by Mr. Strangways, and now in the museum of Dr. Buckland at Oxford, for a fine specimen of a very peculiar ichthyolite found in the red sandstone between N. Ladoga and Tichvin, and to which Professor Agassiz has given the name of *Placosteus meandrinus*.

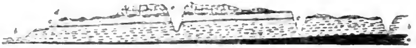
[2] This locality is on the left bank of the stream, about one mile above the saw-mills, where (in the heart of Northern Russia) we met with a most intelligent director of the works, who possessed a well-assorted small library and philosophical instruments, in a neatly arranged establishment, and who welcomed us with the hospitality so characteristic of all Russians.

[3] See 'Silurian System,' in which the lithological identity of the Old and New Red Sandstones in certain parts of England is much insisted on, pp. 27 and 55.

these hills are perpetually subsiding into under-cliffs, and the varied streaks produced by these subsidences, might induce any person who viewed them from the lake, to believe that the strata were inclined. This, however, is far from being the case, for they deviate only from horizontality in exhibiting slight undulations, or by rising very slightly to the north-north-west. Among the rolled fragments which cover the shore of the lake, near the mouth of the Andoma, are numerous masses of red rock loaded with remains of ichthyolites, chiefly Holoptychius (?), which, being of a much harder nature than the surrounding strata, have probably been derived from the cliffs which lie to the north, where the sandstone has undergone more consolidation and alteration.

In ascending the banks of the Andoma and those of its tributaries, the Nosreka, &c., the place of the rocks which constitute the lower or red region is distinctly seen. All the plateaus or high grounds are there occupied by the carboniferous limestone and its associated bands of bituminous schist and yellow sandstone. The annexed woodcut represents the general relations of this instructive and picturesque district, in which we made excursions through some of the finest and most accessible of the Russian forests. The beds marked *a* and *b* are the Devonian rocks, and they are overlaid by the carboniferous strata *c*, *d*, *e*, to be described in the next chapter.

S.



The lowest beds (*a*) are light brownish red, siliceous sandstones, occasionally flag-like, and sometimes of concretionary form, in which (on the banks of the Nosreka) we found disseminated bones and scales of ichthyolites. The strata *b* consist of a great thickness of red and green spotted argillaceous marls, with some sand, &c.

In no part of this extensive district of red sandstone around Vitegra, and which occupies the banks of the Lake Onega, and of which such deep denudations are exposed on the banks of its tributary streams, did we observe a single course of limestone, and with this absence of calcareous matter, we no longer found the mollusks of the same age, which abound in Livonia, St. Petersburgh, and Novogorod; fossil fishes alone being, as far as we could observe, the inhabitants of these sandy and argillaceous rocks. We shall presently draw attention to this phænomenon in our remarks upon the distribution of the organic remains of this system.

To the south and east of Vitegra the old red strata descend beneath the carboniferous limestone, the uppermost beds being seen at Vitegraski, and on both banks of a little rivulet. The same relations exist to the west of Divitinskaya, the head-quarters of the engineers of the great canal, which, passing over the low watershed of this region, is among the most wondrous of the works devised by Peter the Great. It connects the drainage of the vast government of Vologda with that of St. Petersburgh and the Baltic.

To the north-east of this spot the country becomes so low, and the high road to the Dwina runs so much upon the carboniferous limestone, that rapid travellers like ourselves, who made few deflections from the route, could not define the southern limits of the underlying red system. From personal inspection, chiefly judging from the red colour of the surface, we believe that strata of this age form the subsoil at the mouth of the river Onega, where that river empties itself into the White Sea. We also detected these beds (though with great difficulty, owing to the quantity of northern drift) in the form of shale and incoherent psammite, on the banks of the river Kianda, between Onega and Archangel—a district in which salt-sources are not unfrequent and still worked at one locality[1]. Again, we think that the fundamental rock beneath the city of Archangel belongs to the Devonian or Old Red System, for the colour of the country (where bogs do not prevail) is of a reddish tint, and all the river cliffs, which rise to some height between this city and Kholmogor, consist of scarcely any other matter than regenerated red materials. Lastly, by marking the most northern points on the rivers Onega and Dwina, to which the carboniferous limestone extends, we gain a tolerably accurate line of demarcation, from which the Old Red strata may be said to range up to the edges of the metamorphic rocks of the White Sea[2]. We further beg to say, that from information, derived unfortunately too late to profit by it, we are led to think, that the junction of the Old Red Sandstone and Carboniferous Limestone, is to be seen on the banks of the river Onega, about 160 versts above its mouth, where these rocks occupy a distinct escarpment.

[1] M. Launitz, an intelligent gentleman of Courland, who has been some time resident at Onega and Archangel, assured us that he had seen ravines between Archangel and Onega, the banks of which consisted of finely laminated *red and green marls*. In our expedition along the edges of the White Sea to Onega, we were accompanied by our kind friend Mr. Whitehead, the British Consul at Archangel.

[2] M. Böhtlingk showed us hard sandstones from the northern shores of the White Sea, which we consider to be identical with the rocks of the Lake Onega near Petrozavodsk.

Devonian Rocks in Courland, &c.—We have already stated our belief (p. 33) that Devonian rocks occur beneath the superficial red detritus near the Prussian frontier, and in the government of Vilna (see Map). In Courland, however, we are not left in any doubt. Argillaceous limestones, spotted red and green, are seen to alternate with variegated marls and other beds more sandy, which are exposed on the banks of the chief rivers of this province.

The fine escarpments and the cascade of the river Windau at Goldingen, the ancient capital of the province, present strata having exactly the same lithological characters as those we have described on the Volkof and elsewhere, and though they have not yet afforded organic remains in this locality, there can be no doubt of the age of these strata; for on following them to Asuppen, a distance not exceeding thirty miles (which is inconsiderable where strata are so horizontal), they offer the requisite evidences.

A small river at the country-seat of the Baron Hahn lays bare, beneath the alluvial soil, a group of marly, siliceous flagstones, each about half a foot thick, alternating with thinner flags. In their upper part these flagstones are of deep yellow, greenish, and spotted red colours; in which respect they are undistinguishable from the rocks of Goldingen, and like which they contain no fossils. The lower beds, however, are of a yellow colour, and are loaded with the *Spirifer Archiaci*, a characteristic Devonian species of the Boulonnais. Again, beneath these flagstones is a bed of red clay about three feet thick, which overlies a course of similar dimensions of a blueish or greenish marly grit, striped with laminæ of red marl. In these lowest marly laminæ we discovered a good number of remains of ichthyolites, among which are scales of Holoptychius ?. The beds at this locality have a slight inclination of about 3° to the north, and they doubtless participate in one of the numerous undulations to which the strata of this horizontal country have been subjected, as explained by the section of the Düna above Riga, the river which separates Courland from Livonia, and which we now proceed to describe.

Devonian Rocks in Livonia—Section of the Düna.—All the strata exposed along the banks of this river in ascending from Riga to Kirchholm and Kokenhusen, belong to the Devonian system, and they form numerous undulations, by which they are inclined both to the north-north-west and to the south-south-east. For example, at the ancient castle of Kirchholm, where the beds are bent into a double flexure, there is the following section:—

	Feet.
Compact grey limestone and shale without fossils	4
Concretionary limestone; grey in its upper part, red beneath, and containing a remarkable species of univalve of the genus *Rotella*, together with a *Natica*	8
Red compact limestone	3
Marly limestone and shale with red spots	12
	27

The bed above spoken of as characterized by univalve shells, affords us the means of knowing, that nearly the same strata are prolonged by undulations from north to south, across the whole of Livonia. Thus higher up the Düna, at the Castle of Selburg, and at the country-house of Stockmanshof, we meet with the four beds indicated at Kirchholm, including the limestone with the univalves; and the only addition is a greenish blue shale, the lowest bed visible, which is brought in by an increase of flexure. At the Castle of Selburg, the cliffs, upwards of seventy feet high, exhibit very clearly the same succession.

The picturesque rocks in the environs of the Castle of Kokenhusen particularly deserve notice, not merely on account of the thickness of the vertical section (speaking of course by comparison), but specially because the beds contain ichthyolites. The little river Perse, which there empties itself into the Düna, runs in a deep gorge, in which many beds of impure concretionary limestone are seen to alternate with courses of calcareous shale or marl. These alternating strata, occupying a thickness of about 100 feet, repose on a band of arenaceous limestone, distinguished by impressions of fucoid-like or polypiform bodies, and beneath it is a bed of concretionary limestone with marly limestone, in which are remains of *Ctenacanthus serrulatus* (Ag.), and *Osteolepis*, &c., both of which genera occur in the Old Red Sandstone of Scotland.

An example of undulation, almost amounting to a dislocation produced by anticlinal elevation, occurs on the right bank of the Düna, near the mouth of its tributary the Evst, where the inferior shale or clay throws off the calcareous flagstones and marls at an angle of 30° towards the north-east, and at 17° to the south-west.

Concerning the gypsum which occurs in this great deposit, we have nothing to add to the notices of Strangways[1] and M. Dubois de Montpereux[2]. It is nowhere exposed in the strata upon the Düna, except in the neighbourhood of Kirchholm, but at Dünhof in Courland it is largely quarried. Though no salt-springs have

[1] Geol. Trans., new series, vol. i. p. 11. [2] Karsten's Archiv.

yet been discovered, their rise from still lower strata at Starai Russa, to which we have already adverted (p. 45), may induce researches and sinkings, which, if successful, would be of great benefit to the Baltic provinces.

Throughout a wide space east of Riga and the Düna, the Devonian rocks appear chiefly, in the form of incoherent and lightish coloured sandstones, the disintegration of which may have contributed to form the dunes of blown sand which are here so prevalent. Between Riga and Dörpat, red sandstone, both yellowish white and dark red, crops out at intervals, associated, however, with stiff, reddish clays. On the whole, the northern zone of the Devonian age maintains throughout Courland and Livonia the same lithological characters as in the governments of Novogorod and St. Petersburgh, and containing much more calcareous matter than the same rocks in Olonetz and Archangel, is charged with the remains both of mollusca and of fishes. This association has been noticed on the Volkof, at Tchudova, Korostino and in Courland, and we would now merely observe, that at several localities east of Riga, where calcareous matter is interlaced with sand and clay (Roop, &c.), the *Terebratula Livonica* (V. Buch) and other typical shells are associated with remains of ichthyolites.

Our acquaintance with the fossil fishes which occur in the vicinity of Riga, we owe to M. Pander, whose fine collection, made chiefly on the banks of the little river Aa[1], was submitted to our inspection, and from which we were liberally furnished with a number of characteristic specimens. Of these we will now merely say, that several forms appeared to us, when on the spot, to be identical with species which occur in the Old Red Sandstone of Scotland, whilst others were unknown to us. The subsequent examinations of Professor Agassiz and Professor Owen, some of the results of which will be given at the end of this chapter, completely confirm our view, for among these Riga fishes, three species of *Dendrodus* + (Owen) are identified with known Scottish forms[2].

The low cliffs at Dörpat afford, however, the most remarkable specimens, we venture to think, of all fossil fishes ever yet discovered. They occur in about the middle beds of a section, where micaceous, red and green, finely laminated

[1] The rivers Salis, Raune, Ammat and Aa are mentioned by Strangways as flowing in rocky valleys of Lithuania, the last-mentioned of which, near Treyden, is remarkable for its caverns.—Geol. Trans. vol. i. p.12.

[2] In the sequel it will be seen, that Professor Agassiz divides the *Dendrodus* (Owen) into three genera, *Dendrodus*, *Lamnodus* and *Cricodus*. The specific forms, however, are the same in Russia and in Elginshire, Scotland.

sands, with ripple-mark surfaces, are in contact with red and green marls and marlstone. These remains are so gigantic (one bone measuring two feet nine inches in length), that they were formerly supposed to belong to Saurians; but before our arrival at Dörpat, Professor Asmus, of that University, to whose labours the discovery and restoration of the best specimens are due, had completely convinced himself that they were parts of fishes. We shall again refer to these extraordinary ichthyolites, the largest of which, after a study of casts made by Professor Asmus, M. Agassiz has named *Chelonichthys Asmusii*[1].

Central Region of Devonian Rocks, or Geological Axis of Russia in Europe.—Before our second journey and a visit to the central and southern provinces, we supposed with our precursors, that in proceeding from north to south, the observer would naturally pass over a regular succession from older to younger deposits, until the region of the granitic steppe was reached, where crystalline and carboniferous rocks occupy the surface. On our return from the Sea of Azof we undeceived ourselves, by discovering in the centre of Russia a broad zone of rocks, loaded with Devonian fossils[2] (see Map and the section beneath it). The structure of this dome-like mass is duly exposed in the gorges of the Oka above and below Orel, and in the denudations of the Don north and south of Voroneje. Occupying the higher ground, about 800 feet above the sea, between the Oka, which flows northwards into the Volga and the Donetz, and other tributaries of the Don which run to the south, we already know that this zone extends for nearly 200 English miles in the parallel of Voroneje and Orel; and from the observations of Professor Blasius, we have strong reason to believe[3], that, though much obscured

[1] Our Scottish friends of the Moray and Cromarty Friths will be rejoiced to learn, that their country has already produced fragments of this gigantic *Chelonichthys Asmusii*, which, until he saw the noble and perfect specimens from Russia, M. Agassiz had referred to *Coccosteus*. We believe that the Professor owes his Scottish specimens of the type to the researches of the lamented Lady Gordon Cumming. We trust that the next edition of the work of Mr. Hugh Miller, who is "the genius of the Old Red Sandstone," may contain some description of a more perfect *Chelonichthys* in Scotland, even though it should be a rival in interest to his own *Pterichthys*.

[2] According to our custom, the expedition in travelling from the south was divided into two parties, the one moving parallel to and at some distance from the other. Mr. Murchison and M. de Verneuil took the line of Kharkof, Kursk and Orel, and Count Keyserling that of the Don by Voroneje; and, on meeting at Moscow, their results exactly agreed as to the existence of this mass of Devonian deposits which separates Russia into two distinct geological basins.

[3] Although he did not then class them as Devonian, our friend Professor Blasius, on his return to Germany in 1840, identified certain rocks at Orsha with others at Bolkhof, north of Orel, which we now know to be unquestionably Devonian.

by detritus, it ranges from the environs of the latter place to near Orsha on the west and north, and thence is confluent with the western limits of the same deposits, to which we have already alluded as extending to the north-eastern frontier of Prussia.

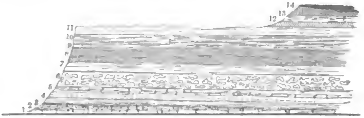
The general section from north to south across Russia, viz. from Petersburgh to the Sea of Azof (see below the Map), and which is carried through Moscow, Kaluga and Orel, gives a clear idea of the relations resulting from this great undulation, which separates Russia in Europe into two distinct geological basins. The northern basin, or that of Moscow, is included between these Devonian rocks in the centre, and those on the north which we have previously described; and the southern extends to the rise of the carboniferous rocks and granitic axis of the southern steppes. By reference to the same section it will also be seen, that the northern basin consists, to a great extent, of carboniferous limestone, with some patches of Jurassic rocks, and a few spots of overlying, quartzose, tertiary sandstone; whilst in the basin of the south (Kursk, Kharkof, &c.), the older rocks subside to a much greater depth, and the surface is occupied by a large development of Cretaceous and Tertiary deposits.

Having previously explained that the Devonian rocks of the Valdai Hills—those forming the northern limits of the basin of Moscow—pass upwards into the lowest beds of the Carboniferous system, we now proceed to point out the peculiarities of the central Devonian zone, and to show how, from its lower strata at Orel, it is composed of various beds, the highest of which dip under the rocks forming the southern limit of the carbonaceous basin of Moscow. In order of superposition, and characteristic fossils, this central zone bears a close affinity to that of the North; for it contains some of the same ichthyolites, with a profusion of Devonian shells, and is also surmounted by beds of limestone, charged with the *Productus giganteus*, which shell invariably occurs at the base of the carboniferous limestone. In lithological structure, however, it is scarcely possible that two deposits of precisely the same age and relations, separated from each other only by a basin having the width, from north to south, of about 300 miles, can present greater distinctions; and this will appear the more remarkable, when it is stated, that in both cases (as indeed nearly all over Russia in Europe) the strata are unaltered.

The central zone, of which we are now treating, is certainly as little entitled to the name of Old Red Sandstone as the black slaty rocks of Devonshire, for it contains very little sand, and is nowhere of a red colour. It is, on the contrary, made up of numerous alternations of flat-bedded, light yellowish limestone, sometimes pure, sometimes earthy, and often so impregnated with magnesia (being occasionally even dolomitic), that it is frequently undistinguishable from the magnesian limestone of England, or the zechstein of Thuringia. When, travelling northwards from the plateau of Kursk, composed of cretaceous and tertiary rocks, we suddenly came upon these yellow calcareous cliffs on the river Oka, we were naturally disposed to believe that they were of the age of the magnesian limestone near Sunderland in England, or the zechstein of Germany, so completely did they resemble those rocks; and with infinite surprise our first impression was corrected, by discovering that the fishes and shells which they contained were true Devonian types!

Sections along the banks of the Oka show the succession from the lower to the highest members, and the same light yellow colour still prevails. Some of the strata have a breccia-like aspect, caused by a rude concretionary action, which has formed hard, irregular nodules of impure limestone, the intervals being occupied by sandy or calcareous marl; and where the latter disintegrates, the face of the cliffs presents a rough, sinuous and grotesque aspect, resembling the rustic-work in the basement story of a Florentine palace. Courses of sandstone are rare, but they are seen near Orel, generally incoherent, and occasionally of greenish colour, but more frequently yellow or ferruginous. Sandy, yellowish limestones and fawn-coloured, sandy marls, form the chief dividing masses of the strong calcareous bands, which vary in thickness from mere tilestones to beds of two and three feet thick; whilst hard, thick paving flags, of mottled light indigo and yellow colours, with way-boards of black and white mottled marls in the lower division (Orel), constitute the chief, if not the only material difference of colour, in these buff-coloured cliffs. The magnesian limestones and their associated marls (very rarely green and blue) are exposed at intervals all down the river Oka, occupying cliffs from sixty to eighty feet in height, from which the strata crop out or are laid bare in adjacent ravines. Shelly calcareous flagstones are prevalent in different stages, and some beds assume a chocolate hue, but red rocks are nowhere visible.

Section of the Oka from Orel to Lichvin and Peremishl.—After this general survey, we shall best convey to our readers an adequate knowledge of the structure of these rocks by describing the transverse sections of the Oka and the Don. And, first, at Orel the following strata are seen in numerous large quarries on the right bank of the Oka to the south of the town :—



9.

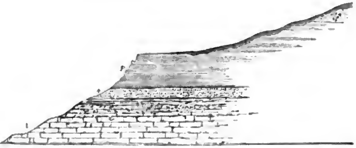
		Ft.	In.
11.	Sandy and shattery tilestones of white colours, with yellow, compact marlstone	3	0
10.	Green and grey marl	4	0
9.	Sandstone, for the most part incoherent, but occasionally hard, and of bright green, yellow and ferruginous colours. (One of the subordinate courses of this stratum is a coarse iron grit, with minute concretions of iron ore (pisolitic iron).)	12	0
8.	Impure yellowish, sandy limestone	15	0
7.	Thin-bedded, yellow and white limestone	9	0
6.	Small concretionary compact limestone, in a yellow, sandy, magnesian matrix. This rock, which is the chief building-stone of Orel, weathers to the rude, cavernous exterior before alluded to, and is laminated by bluish-grey and ferruginous, calcareous courses	12	0
5.	Fawn or light buff-coloured, sandy, finely-laminated, magnesian limestone in two or three beds only, the laminæ marked by ochreous stripes	6	0
4.	Light grey, concretionary limestone, in parts cavernous, with crystals of calcareous spar	6	0
3.	Yellow, thin, magnesian limestone	1	6
2.	Marly, light-coloured limestone	1	6
1.	Mottled indigo and yellow, hard limestone, used as paving-stone, with way-boards of black and whitish shale. The surface of this rock is sandy, and weathers to a ferruginous colour	4	0
		74	0

The lowest beds offer numerous fragments of small ichthyolites, which we consider to be the same forms as those described in the lower Devonian strata near Prussino and Tchudova (*Diplopterus* and *Glyptosteus*).

The beds exposed in other quarries east of the town (12, 13 and 14 of woodcut) represent a higher part of the formation, which extends over a considerable area, and is probably the same rock which occurs in the ravines west of Novazilskaya, the first post-station to the south of Orel. Here we found (under black earth and surface clay) beds of greyish, greenish and yellow marls or shales, with a subordinate course of yellow, sandy, magnesian limestone, in all about 15 or 16 feet thick. Beneath these, the strata which are extensively quarried for use, consist of thin beds of limestone, varying in colour from deep yellow to almost pure white, and containing numerous fossils, among which we recognised *Arca Oreliana* (nob.). This shell alone forms entire beds, together with the characteristic *Serpula omphalodes*, *Natica spirata*, a very small Orthoceratite and two species of Corals.

In proceeding from Orel to the north, we met with proofs at every natural denudation of the continuance of the same system of strata; and whilst the left bank of the Oka exhibited them in distant cliffs, we recognised them on the sides of the little stream the Optika, at Ivanofsk, nineteen versts from Orel, where the yellow, sandy beds, with sub-concretionary courses of a sort of lumachelli, contain bones of fishes. At the village of Ottrada, the cliffs on the right bank of the Oka expose excellent sections, particularly in a lateral ravine north of the village. Ascending from the river edge the strata are seen to consist of

10.



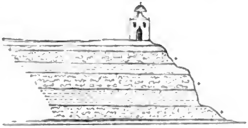
1. Thin-bedded shelly limestones of greyish colours, with surfaces marked by fucoid-like bodies, as at Trhudova and neighbourhood; like which also, these beds contain *Spirifer Archiaci*, *S. Anosoffi* (nob.), *Leptæna membranacea* (Phill.), *Terebratula ventilabrum* (Phill.), *Orthis striatulus* (Schloth.), *Arca Oreliana* (nob.), *Natica* like the species at Orel, with internal casts of *Cirrus*, *Serpula omphalodes*, Encrinites, and many small fragments of ichthyolites. Among the overlying beds (+) in the adjoining ravine we met with two or three alternations of the same thick-bedded, impure, small concretionary limestone, to which we have partially alluded at Orel, and which we shall again describe at Mtzensk.

Towards the summit of the section, where the yellow strata (for the whole have a prevalent yellow tinge) are lost under drifted sands, clay and detritus, one of the subordinate limestone beds (*p*) excited our attention, being made up of myriads of a minute shell, which seems to bear an analogy to the *Venus gemma* of the shores of North America. This fossil is associated with fine, pisolitic, ferruginous concretions, like those in the upper beds near Orel, and also with grains of siliceous sand, both white and black. Another course is composed of small serpuline bodies.

Among the calcareous and flag-like beds of this system, some weather white; and others, not exceeding a quarter of an inch thick, are chocolate-coloured, compact, siliceous limestones. These strata range to near Mtzensk, on the Zucha, a tributary of the Oka.

The left bank of the river, on which that town is built, offers a most striking section of the concretionary, dolomitic, grotto-like limestone, which we noticed at Orel and Ottrada, and which we here saw expanded into three distinct bands (+ +), as represented in this woodcut.

11.



In the cliffs at this place are scales of fishes, and at its base we found the *Arca Oreliana*, which is characteristic of the highest stratum at Orel and of the middle beds at Ottrada. This fact seemed to indicate very clearly, that the general inclination was to the north, and that in proceeding from south to north, we were ascending in the series of strata.

In travelling from Mtzensk to Bielef, the grotesque concretionary rocks, (often covered unconformably by ferruginous sandstone of a much younger age) sink gradually under other Devonian strata, in which argillaceous marl, occasionally almost a pipe-clay, rarely green and much more frequently yellowish, alternate with impure, light yellow, sandy limestone, passing into sandstone, with pisolitic beds similar to those of Ottrada. At the station of Budevich, the *Terebratula Livonica* (V. Buch), and *T. ventilabrum* (Phill.), are grouped with ichthyolites; and from Piscavadi, to near Bielef, an occasional Orthoceratite may be detected.

At Bielef the precipitous bank of the Oka under the town is interesting, in showing marly strata reposing upon the uppermost bed of the grotesque limestone, which at Mtzensk forms the top of the cliff. As this stratum is here on the level of the Oka, it is thus probable (however imperceptible the inclination of the strata may be) that the beds have actually dipped to the north more than 100 feet in the space of about forty-five miles; the cliff at Mtzensk having a height of about seventy feet, and allowance also being made for the descent of the Oka between the two places.

At the convent of Jabrim, four versts north of Bielef, yellowish, marly and earthy limestone prevails, and afterwards the yellow-coloured rocks gradually disappear and are succeeded by cream- and white-coloured marls. At Jabrim we collected *Orthoceratites vermicularis* (nob.), *Terebratula plebeia* (Sow.), with Cytherinæ and casts of Modiola and Nucula.

Between Bielef and Lichvin we first met with fossils which showed an approach to the Carboniferous system; for the *Orthoceratites vermicularis* is there associated with the *Cirrus acutus* (Sow.), which, though generally considered a carboniferous fossil, occurs also in unquestionable Devonian rocks at Wilmar on the Lahn (Nassau).

At Kipet we discovered thin calcareous flagstones charged with fishes. In the bed of the little brook, blueish, yellow and bright green spotted marls and clays are overlaid by brown, hard, flag-like limestones, from three to four inches thick, containing Holoptychii. These are covered by yellowish marl and marlstone, and a thin course of dark blue, calcareous flagstone, charged with *Serpula omphalodes*, *Terebratula plebeia*, Modiola, with Orthoceratites and Cytherinæ. The strata in this little ravine are inclined 15° to the north-north-east, but this inclination is evidently a local phænomenon[1].

The light and buff-coloured marly limestones to the south of Lichvin are the highest beds of the Devonian system which we could trace, owing to the great cover of sand and detritus. In these we collected a Terebratula analogous to *T. pleurodon* in its general form, *Cirrus acutus* (Sow.), *Bellerophon striatus* (D'Orb.), *Orthoceras vermiculare* (nob.), together with casts of Modiola, Nucula and Turritella, which are indeterminable. The re-occurrence at this spot of fossils, which in other places (as towards Mtzensk and at Voroneje) are associated with unquestionable Devonian types, left no doubt of the age of these beds. By their low position in the hill sides, independent of the gentle inclination to the north, they undoubtedly lie beneath the sands with coal and the carboniferous limestone, which succeed to the north of Lichvin, and which on the frontier of the Moscow basin, as well as in the Valdai Hills, form the base of the Carboniferous system. The long, coloured section under the Map, sufficiently illustrates the general succession in this part of the country.

Among the equivocal sections of the upper members of this system—for we had not time to place it exactly in the series—is one which we met with on the bank of the rivulet Ulabue, sixteen versts east of Krapivna (between Tula and Lichvin), in the undulating slopes near which, a little water-course laid bare this section.

Marls, blucish, yellow, &c.
White marlstone, like hardened chalk, in beds of one to two feet.
Calcareous flagstones, in parts sandy and siliceous, with Producti, Leptænæ, Terebratulæ and Spiriferæ.
Concretions of cream-coloured marly limestone.
Yellowish limestone of magnesian aspect.
Flagstones, with minute fossils (Cytherinæ?), small fishes' teeth and scales.
Clays and marls.
Concretions and thin calcareous courses.
Thick-bedded, grey, compact limestones of conchoidal fracture, with traces of silicified wood.

The uppermost beds are covered with ferruginous sand containing ironstone concretions, and the plateau is spread over by some detritus (drift) as well as by the black earth or "Tchornozem," of which and all the superficial deposits we shall treat in the concluding chapters.

Besides a curious fish's tooth, the occurrence in these beds of, apparently, the

[1] The flagstones quarried at the spot are used as tombstones in the churchyard of Kipet, and it was from observing forms of ichthyolites on these monuments, that we were led to discover them, *in situ*, in the bed of the adjacent rivulet, about half a verst to the west of the church.

same minute *Cytherinæ* which occur near Bielef and at Kipet, together with the characteristic shell, *Leptæna productoides* (Murch.), induce us to consider these beds as part also of the uppermost member of the Devonian system; and we the more adhere to this belief, since we are unacquainted with any series of strata resembling them in the numerous well-known sections of the carboniferous strata of Russia. Among the other fossils of this locality, we may cite *Leptæna arcuata* (nob.), a species approaching to *L. sarcinulata*, so common in the carboniferous rocks of this country; two species of Terebratula, the one resembling *T. concentrica*, the other *T. seminula* (Phill.); *Spirifer muralis?*, Spirifer near to *S. glaber*, with fragments of Modiola, Orthoceratites, and Syringopora? &c.

Devonian Rocks upon the Don.—The most southern point at which we observed any rocks of this age upon the river Don is near the village of Pietina. At the junction of the river Vorona with the Don, a few sandy, calcareous, fossiliferous flagstones, of a few feet thickness only, are overlaid by reddish, ferruginous sandstone, and finally by siliceous sands, which towards their lower part contain courses of blackish clay. These last-mentioned sands, like others to which we shall afterwards allude, and which equally overlie the Devonian rocks in the Oka, may possibly belong to the greensand of the Cretaceous system. Blocks of quartz rock with sands, form the cap of all these strata near Pietina.

The Devonian strata near Voroneje are, however, best seen on the left bank of the little stream Devitza, on the sides of a ravine where they are arranged in the following order:—

	Feet.
Calcareous, shelly flagstone, loaded with fossils	7
Red clay or marl	1
Yellowish sands	10
Whitish and red spotted clays and marl, forming the base	20

the whole covered by reddish-coloured drift and black earth.

The calcareous flags at this spot have furnished us with a greater number of characteristic fossils than the beds of any other locality in Russia. They not only abound in species published as Devonian types from the Boulonnais, the Eifel, and Devonshire, but also contain the remains of ichthyolites—and all this in a thickness of about seven feet! Among the most characteristic published[1] shells are *Spirifer Verneuilii*, *Productus caperatus*, *Leptæna Dutertrii*, *Terebratula aspera*; and among the new forms are *Spirifer Anosoffi* (nob.), *Leptæna Fischerii* (nob.), *L. asella* (nob.).

[1] Murchison on the Boulonnais, Bulletin de la Société Géol. de France, vol. xi. p. 255.

At Jendovistie, on the stream Veduga, another feeder of the Don, sandy, calcareous flagstones of greenish colours, are interlaced with spotted red marl and clay, containing Devonian fossils, and similarly covered by sands and ferruginous concretions. In ascending the Don we traced Devonian rocks in the hillocks of Sadonsk, and in them we no longer found the same fossils as those collected in the neighbourhood of Voroneje: others, however, became dominant, such as the *Spirifer Archiaci*, with its elevated area, and a plicated Terebratula resembling *T. ventilabrum*.

At Lebedian, on the Don, the sloping banks of the river give a section, where upwards of seventy feet of strata are exposed in the following order:—

	Feet.
Black earth and detritus	
Ferruginous grit (greensand?)	3
DEVONIAN ROCKS.	
Marly limestone	4
Impure, compact, finely laminated, light grey limestone, containing remains of the same species? of fishes as at Orel	10
Flagstones: in parts magnesian and cavernous, with *Leptæna caperata*	8
Finely laminated and striated siliceous limestone	12
Beds filled with the same minute fossil as at Ottrada (see p. 57)	4
Sandy beds, with breccia-like (concretionary?), marly limestone	4
Thick flags of compact, hard limestone, in part concretionary, with cavernous surfaces, and filled with *Spirifer Archiaci* and *Leptæna caperata*	12
White, marly fragmentary limestone, with broken concretions	15
Concretionary, siliceous limestone, consisting of large, spherical concretions, composed of concentric laminæ, forms the base of the cliffs	

Beds of the same lithological structure as those previously mentioned, viz. yellow, sandy, magnesian limestones and marls, extend to Donkof, a little to the north of which, we place the upper limit of the Devonian system, in this parallel.

The peculiar type of the system which has just been described, being so very calcareous and so equably bedded, is, as might be expected, more highly charged with the remains of fossils, than the red and green marls, impure limestone and red sand, which lie to the north of the Moscow basin (see Map and section below it). Organic remains are, it is true, much more abundant in some parts than others. Thus, as above stated, the strata which have afforded us the greatest number of species of shells are the flag-like limestones near Voroneje. These are probably among the inferior beds of the central region; and we form this opinion, not simply because Voroneje is situated at a lower level than Orel, a point of some little value in a country where the strata are so nearly horizontal, but chiefly from zoological evidences; for the prevalent forms are identical with those of the lowest Devonian rocks of other countries[1]. These beds may be strictly compared with the Devonian limestones of the Boulonnais, there being at least twelve species of characteristic shells common to the Russian and French localities, as will be detailed in the sequel. On the whole, we may say, that the sections of the Upper Don[2] have afforded about thirty species of true Devonian fossils, *i. e.* of characters intermediate between those of the Silurian and carboniferous types.

Our last survey of Russia has, indeed, impressed us forcibly with the value of possessing a correct knowledge of the fossils of this system. Unacquainted with them, and the place which they occupy in the series, the best field-geologist might have been misled in making out the true succession, in the little-disturbed and undulating region of Central Russia; for in proceeding from the Valdai Hills on the north he quits a Devonian zone, with a true "Old Red" type, dipping under the Carboniferous rocks of Moscow, and having passed through the latter, he finds himself suddenly in a yellow-coloured region, entirely dissimilar in structure to what he has seen in any of the northern governments. Hence he might naturally conclude—the order of superposition being difficult to trace, and the level of the country being considerably higher than that of Moscow —that he had reached a horizon superior to the carboniferous limestone, and which, from its aspect, might be the Zechstein or magnesian limestone: and yet this very zone is the true equivalent of the Old Red system, which, loaded with its characteristic fossils, rises out in a dome or broad-backed elevation to form the central watersheds of the empire.

General view of the Organic Remains of the Devonian Rocks of Russia.—Having shown that the widely spread deposits (No. 3 of the Map, and coloured dull red) are the true equivalents of the Devonian rocks of Western Europe, their foundation being based upon Silurian strata and their upper beds covered by carboniferous formations, we now offer a few general remarks upon their organic remains. The reader who is acquainted with the characteristic fossils of this age in Scotland, England, and parts of Germany and France, has learnt by the perusal of the preceding pages, that in its Russian development, the system contains an union of

[1] See Murchison on the Devonian strata of the Boulonnais, Bulletin de la Société Géol. de France, vol. xi. p. 229.

[2] See description of the Organic Remains in the Third Part.

palæontological evidences of its age, which are not so clearly exhibited in any other country. The Old Red Sandstone of the British Isles, for example, which is charged with peculiar ichthyolites, several of which have been already alluded to as also common to our Russian deposits, has never yet afforded a single species of the Mollusca so prevalent in the slaty limestones and schists of Devonshire, that have been placed upon the same parallel. On the other hand, Devonshire, the Boulonnais, and the greater part of the Rhenish provinces, where these Mollusca abound, contain none of the Scottish ichthyolites. In one part of Belgium and in the Eifel only, have one or two fossil fishes been found, associated with the other members of that fauna. The examination of Russia has, therefore, not only enabled us to trace these deposits over an enormous area, but also entirely dispelled any doubts which might have existed in respect to the identity of the Old Red Sandstone of Scotland with those slaty rocks of Devonshire and the Continent with which it had been compared [1]. It has, in short, offered numberless proofs, that the ichthyolites and mollusks, which in Western Europe are separately peculiar to smaller detached basins, were here cohabitants of many parts of the same great sea. If our researches in Russia had led to no other result, they would, we conceive, have well repaid our labours.

The fauna of the Devonian rocks of Russia is, indeed, most remarkable in presenting to us a number of forms of each great class of animals, which are positively identical with species hitherto known only in deposits of the same age in Western Europe. Thus, among the Mollusca, these rocks contain many species of shells which are undistinguishable from published Devonian species. The most characteristic of these have been already cited in the previous pages, or are mentioned in the tabular view attached to the Map, and the remainder will be enumerated, and the whole described in the concluding or Third Part of this work.

We may, however, enumerate two or three general results of our inquiry. The genus Serpula, for example, no trace of which has been discovered in the Silurian rocks, here makes its first appearance. The Orthoceratites with annular siphons, and of which the *O. cochleatum* is the type, are peculiar to this system. Among other important distinctions between this group and that which lies beneath it, are the appearance, for the first time in ascending order, of Spirifers with simple plaits, and the great profusion of Terebratulæ; the last-mentioned genus being very rare

[1] See Geol. Trans., vol. v. p. 633, vol. vi. p. 221. Sedgwick and Murchison.

in the Silurian rocks. On the other hand, Trilobites, which are so profusely distributed in the Silurian rocks of the Baltic governments, are of very unusual occurrence in the Devonian strata.

But the greatest distinction of all, between these Devonian beds and those on which they repose, is the profusion of ichthyolites, none of which are found in the lowest fossiliferous system of Russia[1].

In Polypifers, the Devonian rocks of the northern and central districts are not rich, as might be expected from the sandy, marly and flag-like nature of the strata; but on travelling to the confines of Asia, we find that beds of the same age in the Ural Mountains, having the subcrystalline, slaty and calcareous *facies* of the rocks of Devonshire, are like them loaded with corals. Nay more, these polypifers are associated with several species of mollusks identical with those of the British Isles, whilst the agreement between these very distant synchronous deposits is still further maintained by the negative feature common to both, of the absence of ichthyolites.

The connexion between the character of the fossils and the nature of the matrix in which they are imbedded, is, indeed, more pointedly brought before the observer who ranges over the boundless tracts of Russia, than in any other country which it has been our lot to examine. In Courland, Livonia, and the Baltic governments, as well as in the great central region to which the system extends, thin beds of finely laminated limestone alternate with and are subordinate to great masses of sand, marl and flagstone; and whilst in the thin limestones mollusks prevail, occasionally mixed up with the remains of fishes, the latter are often found exclusively in marly and sandy beds.

Now in tracing these rocks from the Baltic provinces on the south-west, towards Archangel on the north-east, the limestones (as stated p. 48) gradually thin out, and the system (as in the government of Olonetz) being represented by sand, clay, and sandstone, we there lose the Mollusca, and find that the rocks having the essential characters of the Old Red Sandstone of Scotland are, like that deposit, inhabited by fishes only! A remarkable phænomenon, in showing an accordance

[1] In Great Britain, where the Silurian system is so copiously developed, no ichthyolites have been discovered by the authors beneath its uppermost member—the Ludlow rocks; but very recently palates of a fish have been discovered by the Rev. P. B. Brodie, near Dursley Cross, May Hill, Gloucestershire, in strata which are referred to the Wenlock limestone. It is possible that ere long some trace of ichthyolites may be found in the upper part of the Silurian rocks of Russia.

between the lithological and zoological contents of rocks of the same age in the most distant countries.

Again, in passing from the Baltic governments into the central country of Orel and Voroneje, we perceive, that with the change in lithological features which has been described (viz. red sands, marls and calcareous flags prevailing in the former, and yellow magnesian limestones and marls in the latter), a corresponding change occurs in the relative proportion of mollusks and fishes. In the one, the ichthyolites predominate in number of genera and in the profusion of species ; and in the other, whole bands are loaded with characteristic mollusks, the remains of fishes being more rarely found among them.

These facts concerning the relative distribution of different classes of the submarine fauna of an ancient period, the earliest in this part of the world in which Vertebrata have yet been discovered, present strong analogies to the manner in which the adjacent parts of the present seas are inhabited. The great receptacles of fishes are often, if we mistake not, deep sandy bottoms, in which comparatively few shelly creatures exist, whilst the latter are prone to congregate in multitudes towards the shores, where calcareous springs and other favouring circumstances attract them.

Abandoning, for the present, these general zoological analogies, we might now proceed to cite the language of Professor Agassiz and Professor Owen, who have each contributed to this work, by developing the character of the ichthyolites of the Devonian system of Russia ; but we refer to their own words, as given in the Third Part of the volume. We must, however, anticipate their remarks so far as they bear upon our general conclusions. We have already alluded to such of those fossil fishes as were discovered by M. Pander and Professor Asmus ; and we know that these authors were about to publish works descriptive of the Russian ichthyolites of their respective neighbourhoods (Riga and Dörpat). Not doubting the ability with which they will describe such remains, we had too many obvious and pressing reasons to refer all our specimens to Professor Agassiz. Our great object is distinctly to place in parallel, the palæozoic types of Russia with those of the countries with which we are acquainted, through our own labours in the field, and the fossils of which have been described by good naturalists. Among the latter, it is well known that Professor Agassiz has, from the commencement of our palæozoic researches, taken the lead in describing ichthyolites. With his powerful mind, and by having at his disposal the remains of fossil fishes from many regions, he has been enabled to institute general comparisons, and to trace their resemblances and differences in various formations, over all those parts of Europe which geologists have explored. No naturalist, however accomplished, who is acquainted with one group of ichthyolites only, could afford us the knowledge of which we stood in need. To M. Agassiz, then, we referred all those remains of fishes with which our explorations in Russia had furnished us, being assured that it was in his power to clear away the great difficulties in which the study of the fragments of ichthyolites is involved. Whatever, therefore, may be the name, which the Russian naturalists above alluded to might be about to give to the fossil fishes of their own country, we trust that the nomenclature of Agassiz will be adopted by them, as forming part of a great scheme of ichthyolitic classification, which has been carried out in accordance with physical phænomena and the distribution of mineral masses as determined by geologists.

Professor Agassiz acquaints us, that of the specimens which we referred to him there are certainly *eight*, and probably *ten* species, which are common to the Old Red Sandstone of Scotland and the Russian strata. " So complete," says he, " is this identity, that the specimens of the two countries resemble each other to the extent of being confounded, often appearing to be the very casts of each other. It is rare (he adds) to find so perfect a resemblance occurring among specimens in the very same locality, and there cannot therefore exist the smallest doubt as to the geological horizon to which these fossils belong." The species which are thus identical are, the *Glyptosteus favosus*, Ag., *Chelonichthys Asmusii*, Ag. (the name given to the strange monster mentioned p. 53), *Diplopterus macrocephalus*, Ag., *Holoptychius Nobilissimus* (Ag. Sil. Syst.), *Dendrodus strigatus*, Owen, *Lamnodus biporcatus*, Ag. (*Dendrodus biporcatus*, Owen), *Cricodus incurvus*, Ag. (*Dendrodus incurvus*, Owen); whilst two other species, *Glyptosteus reticulatus*, Ag., and *Chelonichthys minor*, Ag., are presumed to be the same as fragments which M. Agassiz possesses from the north of Scotland.

With this striking coincidence, there are, however, great distinctions between the group of Russian ichthyolites of this deposit, when viewed as a whole, and that of the British Isles, for, as Agassiz well remarks, some of the forms most characteristic of the system in Scotland have no analogues even in Russia. Such are the Acanthodians, which division comprehends the genera *Acanthodes*, *Diplacanthus*, *Cheiracanthus* and *Cheirolepis*, and the genera *Pterichthys* and *Cephalaspis* of the group of *Coccosteini* of that author. Nor has the very common

Scottish genus, the *Coccosteus*, yet been found in Russia; for although, when upon the spot, we were disposed to consider certain mammillated scales and bones as belonging to that genus (see Proceedings of Geol. Society, vol. iii. p. 401), we now learn from the great ichthyologist, that it is not present, though its place is taken by the allied genera *Glyptosteus* and *Chelonichthys*. And here it is gratifying to reflect, that some of the more perfect specimens which we brought from Russia have enabled M. Agassiz to describe, for the first time, the less well-preserved fragments of bone which he formerly procured from Scotland, but which he had put aside as doubtful forms. All these Ganoid types, as well as the very peculiar Russian genus *Placosteus*, Ag., and other Placoid fishes of the genera *Ctenoptychius* and *Ctenacanthus*, will be described in their appropriate place, accompanied by some ingenious observations of the author, on the analogies which a comparison of the contents of the Russian and Scottish deposits has enabled him to draw, between the conditions of that ancient epoch, and the existing distribution of fishes in the different seas of Europe (see Part III.).

We cannot, however, quit this subject, without alluding to the great light which is thrown upon ancient nature, by the application of the microscope to fossil teeth and bones. To Professor Owen geologists are most indebted for the new employment of this valuable power. First testing its importance in distinguishing Mammalia and Saurians, he also applied it to certain teeth of fishes brought to him from Scotland, and discovering in them a dendridic disposition of the vascular canals, he named the genus *Dendrodus*. Now, on submitting to Professor Owen some teeth of similar outline and appearance from Riga in Russia, he detected by the same process, that they were absolutely identical with those from Scotland, which he had named *Dendrodus strigatus* as the type, with *D. hastatus*, *D. biporcatus* and *D. incurvus* as subordinate species. In the subsequent account of the organic remains, this point will be illustrated by Professor Owen himself.

But the value of this application of the microscope does not stop here, for whilst we write, Professor Agassiz acquaints us, that, availing himself of the weapons which Professor Owen had so skilfully wielded, he has commenced a series of researches, not only into the teeth, but also into the structure of all the hard, enamelled bones of the Russian fossil fishes, and by which he will be able to show the same distinction in the other bones of the different genera of this class, which Professor Owen has successfully established in relation to the bones of the higher orders of animals. He has, indeed, already forwarded to us a diagram which shows in three small sections, the distinctive osteological characters of the remarkable genera *Glyptosteus*, *Chelonichthys* and *Psammolepis*[1].

Returning from this digression, we cannot better conclude our present subject, than by reminding the reader, that the Devonian rocks of Russia are of very dissimilar lithological structure in different tracts of this vast empire. In one tract they are composed of red and green flags and marls, in another of red sandstone, and in a third of magnesian limestones and marls of light and yellow colours; whilst in the Second Part of this work, we shall have to speak of them, in the Ural Mountains, as black and calcareous slaty masses. Looking, therefore, to these facts, and having further ascertained that the ichthyolites of the Old Red Sandstone of Scotland, and the Devonian mollusks of England and the Continent, are here intimately associated, we have no hesitation in adhering to the word "Devonian," and in urging geologists to follow our example. That term, we repeat, was adopted to prevent the confusion arising from the employment of the name Old Red Sandstone, so inapplicable to great tracts of Europe where the system prevailed, but where its existence had been unnoticed, because it contained no traces of red sandstone. In the preceding pages we have offered strong reasons for the use of the new term in Russia, by pointing out that great portions of the deposits of this age, which are there neither red nor sandy, contain those forms of extinct life which have been published and adopted as Devonian types.

[1] This drawing of the internal structure of the above-named ichthyolites, and sketches of the external form of all the characteristic Russian species, will be given in the Third Part of this work.

CHAPTER V.

CARBONIFEROUS SYSTEM.

Carboniferous System of Northern and Central Russia the equivalent of the Mountain Limestone of Great Britain.—Divided into three Fossiliferous Zones.—Lower Zone with seams of Coal in Sand and Shale described in the Valdai Hills.—Extension of Limestone to Vitegra.—White Limestone of Archangel.—Great Central Basin of Carboniferous Limestone.—Lower Southern edge of, near Kaluga, Tula, &c.—White Limestone of Moscow.—Extension of this central mass along the river Oka to Kasimof and Jelatma.—Upper or Fusulina Limestone at Kovrof and near Samara on the Lower Volga.

WE have now to treat of a system equally vast in horizontal extension with that which has been just described, and infinitely more important in mineral contents. In the older palæozoic rocks of Russia we met with no signs of terrestrial fossil vegetables, still less with any traces of carbonaceous matter, but we no sooner ascended to the horizon of the strata under consideration, than coal beds occur, and we were surrounded by organic remains which characterize the great Carboniferous epoch.

Throughout the whole of the enormous area over which this system extends (see letter *c* upon the Map), the subsoil, whether in the northern or central governments, or in the southern steppes, consists of limestones, with beds of sandstone, shale and marl, which are the undoubted equivalents of the Mountain Limestone or lower portion of the Carboniferous group of English geologists. The upper member of this system, which is so copiously developed in Western Europe under the names of coal-measures and "terrain houiller", has not, as will hereafter appear, any decided representative in Russia, where the rocks of this epoch are analogous to the carboniferous deposits of Ireland, which, though very largely developed, contain no representative of the upper and productive coal-fields of Great Britain[1].

[1] See Griffith's Geological Map of Ireland.

In sketching the features of this great expanse of calcareous matter, we shall follow the same course as that adopted in the preceding chapter, by resuming the account, in the ascending order, from the strata of the preceding system, with which the beds under consideration are in contact. We first, therefore, describe the lower members on the Msta and the Priutchka, and then follow them in their extension to the north-east, south-west, and south-east. The description of the southern carboniferous tract, so important from its mineral contents, will occupy the next chapter.

In our last year's survey we were led to divide the chief calcareous mass of this system into three subformations, each typified by characteristic fossils. When, however, fully developed (as on the western flank of the Ural Mountains), the limestones are surmounted by a peculiar group charged with Goniatites, and made up of grits, flagstones and conglomerates (see Tabular view and Chapter VII.).

The attention of the reader is now called to the lower or great calcareous masses only; and these, constituting the whole Carboniferous system of northern, central and southern Russia, consist in ascending order of—

1. Lower limestone, with *Productus giganteus*; for the most part dark grey and bituminous, and which is associated with sands and a little coal.

2. Middle or white Moscow limestone, with *Spirifer Mosquensis* (*Choristites*, Fisch.). This portion is void of carbonaceous matter in the northern or central governments, but in the southern steppes contains coal of good quality.

3. Upper limestone, with *Fusulina cylindrica* (Fisch.), without coal in the north or upon the Volga, but in the south containing a little.

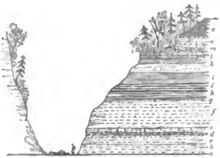
Lower Limestone, &c. in the Valdai Hills.—The lower limestone may here be detected at many places along the southern and eastern edge of the Devonian rocks, which it immediately surmounts. Its bottom beds consist of sand and shale, which, however slight may be their commercial value in any tract yet explored, are unquestionably of the same age, and occupy the same geological position as the productive British coal-field, which on the banks of the Tweed rises out from beneath the great mass of the mountain limestone of Northumberland[1].

In the natural sections of the Msta and its tributary the Priutchka in the eastern part of the Valdai Hills, the lowest carboniferous beds, or those immediately above

[1] See Transactions of the Nat. Hist. Soc. of Newcastle-on-Tyne, vol. i.; in which the memoirs of Mr. N. Wood, Mr. Winch, and particularly a paper by Mr. Witham, show the position of this coal-field. Having revisited the coast near Berwick since our return from Russia, we must say, that this coal-field, so very low in the series, is worthy of being described in greater detail.

the red and green Devonian marls, &c. before described (p. 46), are seen to consist of the following ascending order:—

7 *bis.*



g. Sands: generally incoherent, of light yellowish colour, occasionally passing into sandstone, with pyritized plants, chiefly *Stigmaria ficoides*, &c. On the Msta, these sands are not less than thirty feet thick, while on the Priutchka they do not exceed six feet.

h. Bituminous schists, with Coal. On the Msta the coal is so thin and poor as hardly to merit that name; on the Priutchka, however, the bituminous schists having a total thickness of about forty feet, are characterized, in their upper portion, by four beds (*i*) of impure, imperfectly consolidated, pyritous coal, which is partially extracted in horizontal galleries. The uppermost bed is ten inches, the lowest five thick. Some of the tertiary lignites of Germany and France are superior in qua-quality to this material, which has been even named by Colonel Helmersen "*Mor kohl*," but it may prove serviceable when the great rail-road to Moscow is completed.

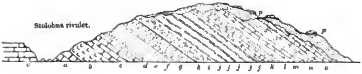
Red, white, and green argillaceous marls (*j*) surmounted by whitish sands with red bands (*k*), and mottled marls (*l*). The last-mentioned support the lowest beds of the carboniferous limestone. On the Priutchka these sands and marls occupy a thickness of about seventy feet.

m. Lower Limestone of both dark grey and purplish colours and compact structure, divided into several beds which vary in different localities from two to two and a half feet each in thickness. The way-boards between these strata are often dark-coloured schists, more or less bituminous, as well as the limestones. The characteristic fossils of this lower bed of limestone (*m*) are the large ***Productus giganteus*** (***hemisphericus***, Sow.) or ***P. variabilis*** of Russian authors, ***P. punctatus*** (Sow.), ***P. antiquatus*** (Sow.), and the large coral ***Chætetes radians*** (Fischer), with Encrinites. The shells are, it is well known, common to the mountain limestone of England, and the coral, ***Chætetes radians***, is found in the same rock, both near Bristol, where Mr. Lonsdale discovered it, and in Northumberland and Westmoreland, where we have recently collected it.

n. White Limestone.—It is doubtful whether this band of limestone can be considered to represent the same member of the series as the white limestone hereafter to be described, which is so abundant near Moscow and to the south of that city, for we did not detect its characteristic fossil, the *Spirifer Mosquensis* (Fisch.), in the Valdai Hills. This upper limestone of the Priutchka (twelve to fifteen feet thick) is milk-white, resembling the finest varieties of "calcaire grossier," and contains *Bellerophon clathratus* (D'Orb.), *Cirrus rotundatus* (Sow.), = *Euomphalus Dionysii* (Goldf.), *Pecten Noæ* (Eichw.), *Orthis arachnoides* (Phill.), *Productus striatus*[1] (*Mytilus*, Fisch.), *P. scabriculus* (Sow.), *Nautilus tuberculatus* (Phill.), *Orthoceras annulatum* (Sow.), *Cidarites Deucalionis* and *Pyrula monticola* (Eichw.), with corals, including *Lithostrotion floriforme*, *Fenestella*, &c.

Magnesian Limestone.—Without pretending to assert that the mineral succession which we observed in the sides of the brooks above the Priutchka, particularly on the rivulet Stolobna, is to be taken as the type of the strata in other places, we may state, that upon the left bank of that brook, the cliffs (fifty feet high) exhibit a series of very varied beds inclined at 35° to 40°, and including yellowish, sandy, dolomitic limestones, sometimes very earthy and impure, and some remarkable bands of flint, as represented in the annexed woodcut.

12.



ASCENDING SERIES.

a. Strong-bedded, dark purplish limestone, dislocated along the course of the rivulet Stolobna.—*b.* Sandy, reddish marls.—*c.* Soft white limestone.—*d.* Red and yellowish argillaceous sands.—*e.* Red clay, ochreous sandstone, &c.—*f.* Greyish white limestone.—*g.* Thin-bedded ditto.—*h.* Bituminous schist.—*i.* Yellowish, sandy, magnesian limestone.—*j.* Courses of flat-bedded flint, subordinate to sandy magnesian limestone.—*k.* Yellow magnesian limestone.—*l.* Flint layers repeated in two courses.—*m.* Greyish encrinite limestone.—*n*, *o*, &c., which are not fully drawn in the woodcut, represent in ascending order a course of flint, grey thin-bedded limestone, with greenish marlstone, white siliceous flinty band, dull greenish, earthy, impure limestone, and yellowish, sandy, magnesian limestone, passing upwards into other beds of impure sandy limestone. The whole is covered by local detritus and northern blocks (*p*).

Besides displaying both magnesian and white limestone so common in the Carboniferous system of Russia, this section is instructive in exposing certain bands of siliceous matter, which, from the durability of their fragments, when broken up, are permanent features in the detritus of Russia, just like the chalk flints of

[1] This shell, so characteristic of the carboniferous limestone in the most distant countries, is known under several synonyms. It was first named and figured by Fischer *Mytilus striatus*, and, believing with M. de Buch that it is a true Productus, we have retained the earliest specific name. It is the *Pinna inflata* (Phill.), *Productus limæformis* (V. Buch), and the *Leptæna anomala* (Sow.). Yet, with these different names, the shell is identically the same from Britain to Siberia.

Western Europe, which they much more resemble than any varieties of the chert of the mountain limestone.

In treating of the Silurian strata near St. Petersburgh, we have before remarked that it was on the sides of the hills only, and in ravines of the hilly district, that small local dislocations were observable, and so is it in the Valdai Hills, where, although the gorges for the most part show beds perfectly horizontal (as in the woodcut, p. 71.), they also exhibit local disruptions, as on the Stolobna rivulet.

The fossils which we collected at this place are the small Trilobite *Otarion Eichwaldi* (Fisch.), *Orthoceratites ornatus* (*Amplexus ornatus*, Eichw.), *Gervillia laminosa* (Phill.), *Bellerophon depressus* (Eichw.), *Avicula Valdaica* (nob.), *Solemya primæva* (Phill.), *Spirifer glaber* (Sow.), *Productus scabriculus* (Sow.), *P. latissimus* (Sow.) a small variety, *Terebratula hastata* (Phill. var.), *Orthis arachnoidea* (Phill.), with *Chætetes radians*, *Lithostrotion*, and other corals, several of which occur in England. It is worthy of remark, that in these magnesian beds, the fossils present their interior casts only, the surfaces of which are covered with small crystals of dolomite[1]. These sections of the tributaries of the Msta have been dwelt upon, because we nowhere else saw so good an ascending succession from the Devonian beds, through the overlying coal-bearing strata and the lower limestones.

Extension to Vitegra. White Limestone of Archangel.—Before we trace the carboniferous limestone over the great basin of Moscow, in which its central member is so much developed, we would first describe its range to the north-east. Exposed on the banks of the rivers Kolp and Suda, between Tichvin on the north-west and Tcherepovetz on the south-east, its northernmost limits range by Vitegra and the plateaus north of the Andoma. Rising to the surface throughout considerable flat tracts near Kargapol, it is continuous across the Onega, appears in force upon the Dwina to the south of Kholmogor, and passing that river, extends by the north of the Pinega to Mezene, the capital of the country of the Samoiedes[2]. The southern limits of this limestone may be indistinctly traced at

[1] The above observation applies very generally to all the crystalline limestones, largely charged with magnesia. The fossils which are obtained from the magnesian variety of the Mountain Limestone at Breedon Hill, Leicestershire, such as Productus, Orthis, and Spirifer, the latter having the spiral brachia beautifully preserved, occur only in the state of casts, having their surfaces coated with regular dolomitic crystals. The fossils of the Magnesian Limestone of Humbleton Hill, near Sunderland, are also found in the same state.

[2] Our knowledge of the extreme points to which this limestone extends on the north-east, beyond Mezene, as represented in the Map, has been very recently obtained by one of us (Count Keyserling) from the distinguished botanist and traveller M. Ruprecht.—Dec. 1842.

intervals beneath the drift to mark its general direction, in a line passing between the lake Bielo-Ozero and the town of Kirilof, a few miles only to the north of the latter, and thence to the banks of the Dwina near Süskaya.

On the Andoma near Vitegra the lower or hard grey beds cover the same yellow sandstone and carbonaceous shale, and contain the same fossils as in the Valdai Hills, viz. the *Productus striatus* and the *Chætetes radians* (Fischer). In the calcareous woodland plateau of that district, the white limestone of the formation assumes, indeed, a character which we have not seen elsewhere. It may be called a coral reef, to the formation of which the *Chætetes radians* has profusely contributed, and the limestone, in some places as white as chalk, has been aggregated in large concretionary masses, with cavities occasionally containing caverns of some extent [1].

Other beds of the limestone in the same district are of dingy yellowish colour. On the whole, the strata represented in this woodcut, though clearly forming the bottom of the limestone, are not so dark-coloured as in many other places.

8 *bis*.

The lowest carboniferous beds in this section are the sands and bituminous shale (c), which here become very inconsiderable and repose on the Devonian rocks (a and b). Then follows the peculiar coralline form of the limestone (d), irregular in its deposit and thinning out on the rise, to give place to a great mass of grey limestone (e).

From all that we could see of the limestone in its course to the north-east, we believe, indeed, that its bituminous and dark-coloured beds gradually thin out and disappear; and the coral reefs with Chætetes were never observed by us to the north-east of the canal Maria.

On the banks of the rivulet Vitegraski, seven versts south of Vitegra, the lower limestones, with *Chætetes radians*, *Harmodites parallelus* (Fisch.), and other fossils, are, however, much expanded, and form strong cliffs, in which purplish and greyish hard bands are associated with a dolomitic variety. Here the limestone overlies the usual inferior beds of black, bituminous [2] shale and incoherent yellow sand-

[1] The pure white colour of this limestone has induced some individuals to reduce great quantities of it to powder, and when kneaded into a paste, it is sold chiefly for the purpose of whitening the churches and other buildings, according to a custom very prevalent in Russia.

[2] The bituminous schist in parts of this tract might almost be used as a black pigment.

stone with coal-plants; the latter being well seen in the cliffs at the mouth of the valley.

13.

f. Grey carboniferous limestone (summit).
e. Dolomitic limestone.
d. Red and green mottled shale, with thin courses of limestone, in parts concretionary.
c. Sands, yellowish.
b. Bituminous shale, — the representative of the coal of the Valdai Hills.
a. Inferior sands, with *Stigmaria ficoides*.

The peculiarity of this section consists in a variety of magnesian limestone occurring at the very base of the calcareous group, and also in red and green mottled shale (*d*) being placed between the limestone and the inferior yellow sands (*c*). In the last respect, however, the lithological succession is pretty nearly the same as that seen on the Stolobna, in the Valdai Hills.

To the east of Vitegra, in the flat ground between that place and the Mgra, the white limestone prevails, and at one small quarry we collected many fossils in beds of a yellowish and white, sandy limestone, pisolitic in some parts, and having very much the aspect of the oolitic tertiary deposits of Lower Styria[1]. Here the *Nautilus tuberculatus* (Sow.) and *Spirifer Mosquensis* (Fischer) abounded, with other fossils, among which we may here note *Cardium elongatum* (Sow.), *Buccinum acutum* (Sow.), with the *Chætetes radians* and *Lithostrotion floriforme* (Martin), and fragments of *Terebratula*, *Natica*, *Turritella*, *Avicula*, &c.

Great masses of the limestone occur in cliffs on both banks of the river Vitegra, where it feeds the great canal Maria, at Dwytenskaya, the central station near the crest or watershed of this region before alluded to (p. 14). Again we found the *Chætetes radians* and many fossils, including *Leptæna Hardrensis* (Phill.), *Cidarites Deucalionis* (Eichw.), and a new species of Natica which we have named *N. Mariæ*.

As our observations between this spot and the Dwina were confined to the vicinity of the high road, the reader will not expect, particularly in a country of such monotonous outline, that we should be able to point out the exact order of each stratum. We must therefore content ourselves with stating, that a large region is composed of carboniferous limestone, different beds of which are exposed on the sides of the road which makes great flexures to the south-east or north-west.

In the flat tracts east and west of Cargopol, the white limestone forms the surface, and disintegrating in many places into a fine gravel, is dug out by the

[1] See Trans. Geol. Soc. Lond., vol. iii. p. 397 (Sedgwick and Murchison).

peasants to form the roads, which in consequence are there excellent. At Brañeva, the first station beyond Cargopol, the *Spirifer Mosquensis* occurs; and at Volosofskaya a section exposes hard limestone, subordinate to red and green marls. These are covered by white and yellowish sandy limestones, full of fossils, in which the *Avicula lunulata*=*Gervillia lunulata* (Phill.), and the *Natica Mariæ* (nob.), prevailed.

At this locality, where the road makes a bend to the east and south, or towards the overlying deposits, we first met with Fusulinæ, fossils which we shall hereafter show, are abundant in the upper calcareous strata only. The limestone, often the white variety, occupying a low ridge between Archangelskaya and Korishevo, is even seen to crop out and form ledges for some distance, a rare phænomenon in this district, and it reappears at intervals as far as Denislofskaya, beyond which it is obscured by the drift of clay, sand and boulders. Wherever the calcareous rock comes near the surface, the vegetation is rich in papilionaceous plants, and the larch (*Pinus Larix*) occurs amid the common northern firs, with which and the birch-tree this region is so much covered. At Archangelskaya we collected *Spirifer glaber* (Sow.), *S. Lamarckii* (Fisch.), *S. incrassatus* (*Terebratula*, Eichw.), *O. arachnoides* (Phill. var.), *Productus scabriculus* and *antiquatus*, *Cardium elongatum*, Sow. (*Pleurorhynchus*, Phill.), *Natica Mariæ* (nob.), with *Calamopora incrustans* (Phill.) and *Cidarites Deucalionis* (Eichw.). At Denislofskaya the prevalent fossils were *Productus antiquatus*, *Terebratula pugnus* (Sow.), and *Euomphalus pentangulatus* (Sow.). Beneath the hills, of 150 to 200 feet in altitude, the summits of which are occupied by drifted materials, the limestone again appears in a low ledge along the edges of the river Dwina. Between Süskaya and Rakolskaya, on the road to Archangel, the left bank of this magnificent river (which even here, at 100 miles above its mouth, is broader than the Thames at Greenwich,) exhibits cliffs of limestone, which in summer, when the stream is low, appear at heights of thirty and forty feet above the water, and are covered towards the interior of the country by mounds and terraces of detritus.

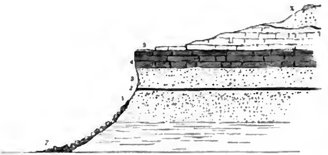
This white-coloured limestone of the Dwina is rich in organic remains, and contains many of the species already mentioned in other localities, particularly the *Spirifer Mosquensis*, *Leptæna Hardrensis*, and two species of Cidaris, one of which is the *Cidarites Deucalionis*. The other fossils are *Spirifer rotundatus* (Sow.), *S. rhomboideus* (Phill.), *Productus punctatus*, *P. antiquatus*, *Euomphalus calyx* (Phill.), *Orthis arachnoides* (Phill. var.), with a fish's tooth. Beds similar to those upon the Dwina, and containing some of the same shells, with the corals *Lithostrotion floriforme* and *Harmodites parallelus*, were observed by us to extend for a short distance up the river Pinega. The lower carboniferous strata are obscured on the banks of the Dwina, and we would recommend those who follow us, to descend the river Onega, which passes through a gorge, about seventy miles above the town of that name, and where a junction of the limestone and underlying Devonian rocks is said to be exposed. We adhere, however, to the belief before expressed, that the bituminous shale and sands and dark limestones thin out, and that the subformations of the system are not nearly so much developed in their north-eastern range, as in the central regions of Russia, to the consideration of which we now return.

Great Central Basin of Carboniferous Limestone.—By reference to the Map it will be seen, that from the Valdai Hills as a centre, the carboniferous limestone extends not only to the north-east, into the country we have been describing, but also by Moscow, and far to the south and south-east of that city. We know little from personal observation of the western side of this great mass, the boundaries of which are with difficulty defined, in consequence of the superficial detritus with which it is covered. On the east, however, we endeavoured to trace it in a tedious course by Tcherepovetz, Ustiujna, Mologa, Rybinsk and Yaroslavl, and having also made traverses across the governments of Vologda, Perm, &c., we are enabled to state, that no Carboniferous limestone appears in the wide area coloured red (No. 4) to the east of the Volga, until you reach the flanks of the Ural Mountains.

Confining our remarks in the first instance to the lower division, we may state that our researches along the southern edges of the Moscow basin afforded us precisely the same results as in the Valdai Hills upon the north. In the zone of country extending from the north of Lichvin, on the west by Peremishel to Tula, the lowermost carboniferous strata, which succeed to the Devonian rocks, consist of sand and shale, with thin coal-seams, which are immediately surmounted by a limestone with *Productus giganteus.*

The thickness of the sand and sandstone varies in different places, and the thin courses of coal which are subordinate to them, vary considerably in quality and thickness in different localities. Thus at Jelèniena, north of Lichvin, bands of poor coal appear in a ravine under the village, subordinate to bituminous schists, some of which, like many similar beds in England, sound like wood under the hammer. Incoherent sands surmount the black mass, and sandy layers with stems of *Stigmaria ficoides* appear at intervals, whilst the impure and slightly consolidated coal is for the most part very pyritous, containing both sulphuret of iron minutely disseminated, and small geodes of crystallized pyrites. To show the slight persistence of any one of these coal seams, we may state, that in the bold cliffs of the Oka at Vornova, opposite Peremishl, they are represented (as on the Andoma, in the government of Olonetz, see p. 74) by a band of bituminous, stiff, black clay. This woodcut conveys a clear idea of the order, the sands and shale being covered by the Productus limestone.

14.



Near Alexina the coaly matter in the same strata expands so as to form layers subordinate to sands and shale. The thickness and relations of the coal-seams vary exceedingly in at least, forty localities, where they have recently been explored by Colonel Olivieri. In all the chief points, however, he has invariably observed the same order of superposition as that which is conveyed in the above diagram, viz. sands, shale and coal, surmounted by the limestone with *Productus giganteus*. Most of these localities have been marked in detail by that officer on the map of Schubert, and we visited some of them with him.

Throughout this region, as in the Valdai Hills, the coal is very pyritous, impure, fragile and light, and seldom equals in quality the best lignites of the Tertiary age in the Alps (Styria, &c.). We would account for the bad condition of this carbonaceous matter, by the strata in which it lies not having assumed a lapidified condition, or having never undergone consolidation. The sands, in fact, are often as incoherent as the dunes of a sea-shore, the shale is mere blue clay, and the associated lignite is naturally light and impure, representing the first and second stages only in the chemical change which plants undergo in their transition into coal. Some seams, however, are superior in quality to others, from three to six feet thick, and presenting a natural outcrop in many ravines, the coal might be extracted at slight cost. It may therefore doubtless be profitably used in manufactories, and subsequently supply steam-engines, when the great railroad now commenced shall have been completed[1]. The chief, indeed the only fossil plant which we observed in this coaly deposit, is the *Stigmaria ficoides*. As we have seen it both in the sands and shale associated with the coal, its position in Russia did not seem to us to afford evidence in favour of a theory which has recently become prevalent in England, that this plant was a sort of gigantic marsh or lagoon creeper, and that all coal strata in which it was found were formerly jungles, marshes or masses of vegetation which subsided upon the spots of their growth. Again, the facts that the underlying Devonian beds are charged with fishes and marine shells, and that the Stigmaria sands resting on them are surmounted by another marine limestone, prevent our hastily applying this theory to the Russian coal deposits. We shall revert to this subject in our description of the coal-fields of the Donetz, where the evidences still more decisively prove a marine succession, and are therefore much opposed to such a theory.

Lower Limestone of Tula and Kaluga.—This limestone affords the same clear horizon-line in the lower division of the Carboniferous system of the governments of Tula and Kaluga, as it does in the Valdai Hills and other parts of the north of Russia; being very generally characterized by the presence of the *Productus giganteus* (*hemisphæricus*, Sowerby). In the cliffs opposite Peremishl (see woodcut in opposite page), and other places where we saw it, the limestone is a hard rock with conchoidal fracture, of grey, whitish and bluish colours, and is divided into beds from two to four feet thick. It is sometimes siliceous, and contains flattened concretions and obscure laminæ of flinty chert and even of pure flint. At Tarusa on the Oka we found in it *Productus giganteus*, *P. latissimus*, *P. punctatus*, *Euomphalus pentangulatus*, *Solemya primæva* (Phill.), *Catenipora* (*Harmodites parallelus*, Fisch.), with *Pinna*, casts of *Bellerophon*, *Turbo* and *Natica*, and stems of *Stigmaria ficoides*. Again on the river Ocetre, in the government of Tula, the *Productus giganteus* occurs and is there associated with the *P. striatus*. At Alexina, the limestone overlying the coal and sands, contains the *Productus giganteus* with *P. lobatus* (Sow.), *Orthis* (Spirifer) *resupinata* (Sow.), and *O. arachnoidea* (Phill. affin.).

In the neighbourhood of Kaluga this lower limestone expands and divides itself

[1] Two thousand poods, or about twenty-five tons of this coal were sent by Colonel Olivieri for trial to Moscow last summer, but some of the localities are too distant from water-carriage to render such supply economical.

into two or three courses, alternating with thin seams of shale and impure coal. This band is overlaid in the neighbourhood of Serpuchof, as in the Valdai Hills, by other courses of grey limestone, sometimes associated with shale, which near the former place is of red and greenish colours, and in these rocks we collected *Orthis resupinata*, *O. arachnoidea*, *Spirifer glaber* (Sow.), and *S.* (*Anomia*) *triangularis* (Mart.).

White Limestone of Moscow, with Spirifer Mosquensis.—This limestone is very characteristic of the Russian carboniferous group, in which it occupies a central place and has an enormous extension. It ranges, in fact, from the neighbourhood of Moscow, to the south of Kolmogor near Archangel, and well developed at many places around Moscow, it stretches out from near Serpuchof along the course of the Oka to the south-east into the government of Riaizan. In this woodcut we

15.

a. White and magnesian carboniferous limestone with *Spirifer Mosquensis*.
b, c. Lower shale with Ammonites, Belemnites, and sands and shale with Jurassic fossils.
d. Tertiary siliceous sandstone.
e. Detritus and drift, with northern blocks.

offer a general view of the relations of this white limestone to the overlying strata as seen on both banks of the river Moskva, near Miatchkova, to the south of Moscow. When examined in a single quarry and in tracts where the strata of all ages are so generally horizontal, the overlying Jurassic beds appear to be conformable to the carboniferous limestone; but on examining the country it is found, that the surface of the latter rock is uneven, rising and sinking beneath the superjacent strata, like the corroded chalk of Western Europe beneath the Tertiary deposits.

The prevalent characters of the rock, as it appears in the governments of Tver and Moscow, is a white, more or less coarse-grained, limestone, or "calcaire grossier[1]." At the quarries of Miatchkova, represented in part of the above

[1] All the limestone coloured light yellow on the map of the environs of Moscow, 'Oryctographie de Moscou', 1830–1837, by M. Fischer de Waldheim, is of the carboniferous age. Guided too much by lithological characters, M. Fischer referred some of these beds to the coral rag, and at the time of his publication considered them to be superior to the Lias, but recently our excellent friend has seen cause to change his mind and adopt our views. In the sequel we shall have numerous occasions to express our obligations to Dr. Fischer, and to show how much service he has rendered to science by his publications on organic remains.

woodcut, the lower strata are composed of the excellent white limestone of which Moscow is chiefly built, surmounted by beds of a compact, yellow magnesian limestone with flat and conchoidal fracture, and often a pure dolomite without the appearance of crystalline structure.

At Pudolsk on the river Pakra, the uppermost beds of the white limestone contain a little chert, and have in parts a coarse oolitic structure. These rest upon a thicker bedded rock, with courses of flint and some magnesian strata of a cavernous nature. It would thus appear, that the white limestone alternates with magnesian bands, for at Miatchkova they overlie, and here they underlie that rock. We have already described magnesian limestones of the Devonian age, and in addition to their great frequency in the carboniferous rocks we shall hereafter point out their prevalence in an overlying system.

Though very generally preserving its most characteristic fossils, the *Spirifer Mosquensis* (Fisch.), *P. punctatus*, *P. antiquatus*, and *P. lobatus* (Sow.), this rock changes its lithological associations in different places. We have already alluded to the occurrence of red and green marls with the limestone on the route to Archangel. The same relations are seen at one spot on the banks of the Moskva, near Moscow, as pointed out to us by an English gentleman, Mr. Frears, long resident in that city[1]. Again, at Radionofka, twelve versts north of Serpuchof, a section in a ravine exposed a thin band of the white limestone, with *Spirifer Mosquensis*, associated with flinty or cherty and yellowish bands, passing down into red and green marls with geodes of impure limestone, the whole based upon micaceous, incoherent, green sands.

In fact, the prevalence of red and green marls, shales, and sands throughout the lower palæozoic series, and in the overlying Permian deposits which we shall afterwards describe, is one of the striking lithological features of Russian geology. The sections on the Oka, to which we now direct attention, are specially illustrative of this feature.

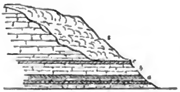
Moscow Limestone on the Oka.—This central member of the carboniferous limestone is, perhaps, more fully exposed and with a greater variety of lithological features, on the banks of the river Oka between Serpuchof and Kolomna, than in any other part of the wide region over which it is spread.

In descending this river from Serpuchof, some bands of white and grey, brown and

[1] In a subsequent chapter we shall speak of other researches of Mr. Frears, and of the instructive suites of Jurassic fossils which he collected around Moscow and kindly placed at our disposal.

yellow limestone, containing *Productus spinulosus* (Sow.), *P. antiquatus*, and *Lithostrotion floriforme*, are seen at Lutshki, where they repose on red argillaceous marls; and a few versts lower down the river at Tiesholovo, twenty-five feet of similar red marls surmount a white limestone, twenty feet thick, which descends to the water's edge. At Putshino, a few hundred yards beyond this spot, a section exposes the white limestone, charged with *Spirifer Mosquensis*, surmounted by red grit and resting upon white and rose-coloured marls, which alternate with other and thinner bands of limestone, containing the same characteristic shell. The cliff at this spot is not only interesting, in exhibiting the Moscow limestone subordinate to red and variegated sandstone and marl, but also in exposing a vast accumulation of calcareous tufa, not less than 110 feet thick, and charged with existing species of Helix and Limnæa. As this tufa is seen to rest upon some of the carboniferous strata, it has probably exuded from other and higher layers of the same formation, in the manner represented in this woodcut.

16.



d. Calcareous tufa with *Helices* and *Limneæ*.

c. Red sandstone.

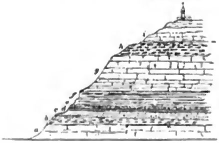
b. White limestone, with *Spirifer Mosquensis*.

a. Reddish and white marls alternating with the Spirifer limestone.

Outcrops of the limestone are also seen at the village of Tultshino; but the most remarkable section, visible in any portion of this tract, is that of Kashirov, where upwards of 250 feet of strata are seen in the following order in ascending from the level of the Oka.

Kashirov on the Oka.

17.



		Feet
	White marls, rising to the top of the cliff.	
i.	White limestone, passing upwards into marls	30
h.	Reddish and white spotted marls	30
g.	Marly, schistose limestone, white as chalk	60
f.	White limestone in thick slabs	30
e.	Porous, sandy, hard limestone, in beds of three feet	10
d.	Thin course of red marl	1
c.	Soft micaceous green sandstone	20
b.	Marly clay, spotted with red sand and thin courses of hard limestone	30
a.	White compact limestone, divided into strong beds of five or six feet thick	30

The upper beds are the most fossiliferous, but the same species of shells are found also in the lowest strata. Among these the most abundant are *Orthis eximia*

(*Productus*, Eichw.), *Spirifer Mosquensis*, *Productus antiquatus* (the variety without concentric striæ), *Melania rugifera* (Phill.), Euomphali, with fragments of small Trilobites, Reteporæ, &c.

At Romanovo and Lublino the limestone appears again in force, but at the latter place, in a thickness of 150 feet, the red and green marls have to a great extent disappeared; whilst a little further on they reappear, and below Rostshielaf a rock of brick-red sandstone is intercalated between calcareous marl and limestone, the whole reposing on beds with *Spirifer Mosquensis*. Other bands of white marl and limestone range onwards to Kolomna, one bed of which contains the corals *Strombodes pentagonus*, *Chætetes radians* and *Cyathophyllum*, and another the *Cidaris Rossicus* (V. Buch.). These strata rest upon a mass of Spirifer limestone. The white limestone which is here quarried for building, is equally associated, as in the neighbourhood of Moscow, with a yellow, magnesian variety like that of Miatchkova and other places near the metropolis; which is usually employed as a road-stone.

In making allowance for the undulation of the strata and also for the thinning out of some layers and the reciprocal substitution of limestone for marl and sandstone, and *vice versâ*, we believe that the Oka, in its course from Serpuchof to Kolomna, exposes, on the whole, a descending section, and therefore that the limestone of the latter place is the lowest stratum of this section. For although no perceptible inclination can be detected in the strata, at the greater number of the spots cited, there is a rise to the north, from the angle where the river flows northwards towards Kolomna. We also draw our conclusion from the manner in which the limestone near Serpuchof is surmounted by much red earth, and still more from the succession of fossils; for in the upper portion of the great cliff at Kashirov, the *Orthis eximia* is abundant and characteristic, and we shall afterwards show that this shell is never found in the lowest limestone, but is, on the contrary, associated with Fusulinæ, in the limestone which we consider superior to that which we are now describing.

With this central member of the carboniferous limestone we group all the strata which extend southwards and eastwards to Riaizan and Kasimof. In these regions, however, it is at rare intervals, and, as usual, on the sides of the water-courses only, that the rock can be seen. Near the post-house of Gorodnia, south of Kolomna, and on the banks of the Oceta river, we detected white limestone in masses upwards of 100 feet thick, associated with courses ofblack, grey and yellow flints.

One of the most remarkable outcrops of the limestone from beneath the sands or clays which so generally obscure the rocks of the government of Riaizan, is at the ancient Tartar town of Kasimof. The rock must here be of great dimensions, for it rises from the level of the Oka, to plateaus at least 300 feet above it. Some beds are so yellow and magnesian (they lie chiefly towards the middle of the section), that they cannot be distinguished from specimens of zechstein, like which they often disintegrate into a fine powdery sand, and the lower beds, which are hard and white, project upon the road which descends from the town to the ferry over the river.

Here we found some characteristic fossils, together with spines of the same species of Echini, as on the Dwina, near Archangel [1].

The rocks of white limestone (in this region void of alternating red marls and sandstones) extend from Kasimof towards Jelatma, where they are surmounted both by Jurassic strata and ferruginous sands. At the iron-works on the little river Unja, a tributary of the Oka, the lowest beds visible, as seen on the right bank of the stream, in the high road, and not far distant from the forge, consist of thin-bedded, concretionary, hard, flag-like beds, in parts cavernous, and fissured by many vertical joints. On the opposite bank, the beds, being slightly inclined to the east-south-east, may be followed across a low promontory, subtended by the river, in which they appear as represented in this woodcut.

18.

a. Limestone, concealed.

b. Yellowish and magnesian limestone, with thinly laminated bands of flint and ochreous argillaceous way-boards. The rock is very cavernous, and the cavities are often lined with corals, chiefly a large Cyathophyllum; and among the other fossils are *Orthis eximia*, *Productus comoides*, *P. undatus* (De Fr.), *P. antiquatus*, *Spirifer Mosquensis*, *Leptæna Hardrensis*, with Encrini. These beds are corroded on the surface, and their superficial depressions filled with iron sand are succeeded at a little distance in the cliff by a white, hard, flag-like, sandy limestone (*c*). The iron sands (x), which cover indiscriminately the denuded beds of limestone and the drift (*y*), will be described in subsequent chapters.

As the carboniferous limestone is succeeded in a very short space by Jurassic strata, which are clearly exposed on the banks of the Oka, near the adjacent town of Yelatma, and as all the region to the south is occupied by cretaceous or

[1] Kasimof is a very picturesque town, and the Oka is there a magnificent stream. Any traveller would be well repaid by visiting a spot so celebrated in Russian history, and in which a very ancient tower and mosque of the Tartars are still to be seen among the gay churches of their conquerors.

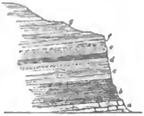
tertiary rocks (see Map) and vast tracts of sand, it is evident that the regular ascending section has here been interrupted throughout this region as in the neighbourhood of Moscow (see woodcut, p. 80).

Fusulina Limestone.—Upper Division of Carboniferous Limestone.—Our most recent researches have convinced us, that the limestone charged with Fusulina, which during our first journey we had seen in the government of Archangel only, but which we then could not separate from the other masses, is, in truth, a superior member of the great deposit of carboniferous limestone. In a flat region like Russia, where the same beds range over such very wide spaces, the order of superposition of the different members of a system can seldom be seen in any one section. In the southern carboniferous tracts, where the strata are highly inclined, better proofs of this order are naturally obtained, in sections which will presently be described. In the mean time we may remark, that from the great extension of the strata on the eastern limits of the large area of carboniferous limestone, of which Moscow is the centre, it is impracticable there to trace so clear a sequence. In one district only were we enabled to see what may be considered a passage into beds of nearly this age, in the white limestone which is worked along a low ridge extending from Kosrof to Velicovo on the right bank of the Nerecta, a tributary of the Kliasma. The sand and clay (drift) having been removed, and the beds laid bare by the workmen, the best or white courses of the rock are extracted (above Velicovo) from beneath coarse roof-stones, and though almost horizontal, these strata incline slightly to the east-north-east, so as to pass under the red deposits of the great basin of Nijni Novogorod. In these bands, in which chert is no longer so abundant as in the central limestone, we did not perceive any Producti, the fossils being ***Euomphalus pentangulatus, Spirifer Mosquensis***, with an occasional Fusulina.

As this limestone of Velicovo differs, somewhat, from all the bands we have hitherto described, lies upon the exterior of the great carboniferous masses, and is followed on the east by newer deposits, we had no hesitation in considering it to be the superior member of the carboniferous limestone. We have already adverted to Fusulina limestone in the north (p. 76), and in pursuing our journey from Moscow to the east upon two lines of research, we met with this rock at one other locality only, viz. at the village of Schwetzi, north-west of Murom. Beyond this boundary, all the vast region extending to the foot of the Ural Mountains is composed of the overlying deposits which we have called Permian. To the south, however, after dipping beneath the surface throughout large tracts, occupied sometimes by secondary and at other times by tertiary rocks, which we shall presently describe, this younger member of the carboniferous limestone reappears in great force on the right bank of the Volga, and occupies the splendid cliffs, 200 to 300 feet high, between Simbirsk and Samara, which give rise to that remarkable flexure in the course of this monarch of European streams, which is seen on every map of Russia.

At the mouth of the Ussa, and on the Volga, the beds are exposed in a fine vertical section in the following ascending order, and consist of—

19.



a. Thick beds of grey sandy limestone with *Orthis resupinata?*; and a small species associated with Fusulinæ. The vertical face of this lower stratum is affected to a height of thirty feet by the action of the periodical vernal rise of the waters, the least solid portions being corroded, and other parts protruding in undulating depressions, and the whole polished and smoothed off, the highest water-mark line being very permanent[1].

b, c, d. White limestone of soft texture, and charged with myriads of the *Fusulina cylindrica*, alternating with other beds of grey and yellowish colours, more or less compact, of scaly conchoidal fracture, in which *Euomphalus pentangulatus* and *Orthis resupinata* are occasionally detected, and round concretions of very pure flint are not unfrequent. Corals and Encrinites also occur, and among the former are species of Turbinolia, Cyathophyllum, Retepora, and Fenestella, which will be described in the Third Part of the work. In those parts of the cliff which have stood firm, the surface is covered by an ochreous coloured lichen, but whenever the opening of the fine symmetrical joints has given rise to the fall of large masses of the rock, the white and grey colours are well exposed.

e. Thinly laminated, almost papyraceous strata, with courses of a lithographic stone, much resembling that of Solenhofen, surmounted by bands of pure Fusulina limestone, from fifteen inches to four and five feet thick (Upper quarries).

f and *g.* Thin, rubbly limestones, with occasional Fusulinæ and courses of chert, rise to the summit in a slope, and complete these sections of Fusulina rock, which is at least 200 feet thick. As other and higher hillocks rise to the back of this

[1] This phænomenon is common throughout all those parts of Russia where rocky cliffs are at hand to show the limits of the rise of water during the great floods of the spring.

cliff, which, owing to tempestuous weather we were prevented from examining, it is probable that the ascending series may be better traced by those who succeed us, and who may detect a passage into newer deposits.

Pallas, with his usual perspicuity, notices this singular limestone of the Volga and speaks of the Fusulinæ as small Madreporites resembling grains of wheat, but he gives no sections of the strata, nor could he in his day have spoken of their geological relations, for our science was then unknown. There now seems no reason to doubt, that the Fusulina is a foraminifer, closely allied to the Alveolina (D'Orbigny), and as countless millions must have succeeded each other when these finely laminated strata were accumulated, we would now merely remark, that their method of conservation is a strong proof of the very tranquil condition of the sea in which they were deposited.

The limestone we have been describing is capped in some parts of this remarkable promontory, particularly near Usolie[1], by a tufaceous agglomerate, made up in great part of the limestone itself, which is probably a part of the great Permian system, to be described as occupying large tracts east of the Volga, in the governments of Kasan, Perm and Orenburg. In following, however, the river to Sysran, the Fusulina limestone is covered by dark-coloured Jurassic shale containing Ammonites. The sequence of the strata on the western side of this tract is, in fact, interrupted, and those members of the geological series which exist in some other parts of Russia, between the carboniferous limestone and the Jurassic system, are here absent, as at Moscow (see p. 80).

In concluding our account of the carboniferous limestone of Northern and Central Russia, we may repeat, that we consider the Fusulina limestone to constitute its uppermost member, being invariably found near the southern and eastern frontier of the formation, where it is succeeded by rocks of the age of the Zechstein (see Map). Thus in the northern tracts, extending from the south of Vitegra to the Dwina, Fusulinæ have been noticed at Perkina and Filosofskaya, in the interior at Velikovo, and upon the Ussa, as just described. Fischer has noticed these fossils in the government of Vladimir, we observed them in limestone to the north of Murom, and in the sequel we shall advert to them, both on the western

[1] Usolie is the property of M. Davidoff, who has constructed a tower and pleasure-house on the summit of this tufaceous rock, commanding extensive and splendid views of the windings of the Volga; flanked on one side by the lofty cliffs of limestone, on which the tower of Peter the Great is placed, and on the other by the low and wide expanse which extends into the governments of Kazan and Orenburg.

flanks of the Ural and in the northern part of the great carboniferous district of the south of Russia. At both the last-mentioned localities they unquestionably occur in the highest members of the carboniferous limestone.

We shall now direct attention to the great carboniferous tracts of Southern and New Russia, between the Dnieper and the Don, where the strata are highly inclined, and in a very different lithological condition from the rocks described in this chapter.

CHAPTER VI.

CARBONIFEROUS REGION BETWEEN THE DNIEPER AND THE DON[1].

Introduction.—Extent and general Relations of the Tract.—Crystalline Rocks of the Southern Steppes.—Carboniferous Rocks described in an ascending order on the river Kalmiuss.—The same Section prolonged to the Upper Carboniferous strata North of Gorodofka.—Sections on the river Miuss and Krinka.—The Bituminous Coals of the Western and Northern Districts shown to be of the same age as the Anthracite on the South-west.—Anthracite of Popofskoe, and its value.—Sections on the Donetz.—Bituminous Coal-fields of the Northern Tracts.—Coals worked by the Peasantry on the tributaries of the Toretz.—Imperial Coal-works of Uspensk, and their relations to the Chalk.—Great Imperial Works of Lissitchia-Balka.—The Coal subordinate to the Central Member of the Carboniferous Limestone.—Shown to be a purely Marine Formation.—Theory of the Origin of this Coal.—General relations and relative value of the different Coal tracts of the Southern Steppes.—Probable extension of valuable Coal-seams under the Cretaceous and surrounding Rocks.—Future Prospects, and Conclusion (see Map and Pl. I. of coloured sections).

PASSING over, for the present, the undulating surface of secondary and tertiary rocks which occupy the central governments, we continue the subject of the carboniferous deposits, by calling attention to those tracts lying between the Dnieper and the Don, and watered by the Donetz, which constitute by far the richest coal district in the Russian empire. The portion of this country which contains rocks of the carboniferous æra, lies between $47\frac{1}{2}°$ and $49\frac{1}{2}°$ north latitude, and 36° and $41\frac{1}{2}°$ east longitude. The major ellipse of the chief mass extending from near the river Voltchia[2] on the west-north-west, to the Kargalinsk, an eastern tributary of the Donetz on the east-south-east, has a length of about 230 English miles, and its greatest width from Karakuba on the south to the tracts around Bachmuth

[1] Generally known as the coal-field of the Donetz.

[2] Pronounced *Voltshia*.

on the north, is upwards of 100 miles. Throughout this wide area all the rocks, with very slight exceptions, are of the carboniferous age, and they thus cover a surface of not less than 11,000 square miles. Occupying hills which have to some extent the character of low mountains, these rocks form a portion of the Upper Steppe, peopled by the Don Cossacks and New Russians.

This tract, which in reference to the southern steppes may be called elevated, is bounded on the east by the river Donetz, a partially navigable stream, along the banks of which, or of its tributaries, the strata are frequently exposed. Other rivers, which have their sources in the higher part of this territory, also offer good natural transverse sections; such are the Krinka, the Miuss, and the Kalmiuss, which flow southerly into the Sea of Azof; the Toretz, the Bachmutha and smaller streams which run northwards, and eventually fall into the Donetz. We examined the banks of all these rivers, and also those of the Voltchia, which, deflected by the granitic axis, flows northward and westward into the Dnieper, there to ascertain the western limits of the field. We also made various traverses across the central and eastern portions, and visiting most of the localities where coal is partially worked, and collecting many fossils, we hope to be enabled to give a definite idea of the general geological relations of the tract, and to point out an ascending order from the base of the Carboniferous system into the next overlying deposits.

Though overlapped on their northern boundary by Permian, Jurassic, Cretaceous and tertiary deposits, which will be described in subsequent chapters, these carboniferous rocks crop out again to the north, at points near Petrofskaya, and the real extent of country in that northern direction, in which they may form the chief substratum, is probably very considerable.

To the south the carboniferous rocks are separated from the Sea of Azof by low hills, for the most part composed of tertiary deposits, and partially also by a narrow band of chalk (see Map). To the south-west they rest upon the eastern extremity of that vast mass of crystalline rocks, usually known under the name of the granitic steppe, which, extending from Volhynia and Podolia on the west-north-west, passes the Dnieper near Ekaterinoslaf, and disappears beneath the formations we are about to describe on the banks of the Kalmiuss.

Axis of the South Granitic and Crystalline Rocks.—Before we proceed to describe the strata in an ascending order, we must say a few words upon the crystalline rocks which rise up from beneath this tract, and forming its axis, separate the Carboniferous districts from the Tertiary basin of the Sea of Azof and the Crimea.

In the sequel we shall necessarily advert to the general relations of this crystalline chain, the direction of which is so exactly parallel to that of the Caucasus and the Crimea. In the present chapter, however, we shall confine ourselves to showing, that eruptions and elevations along the same line have powerfully affected the contiguous strata of the Kalmiuss and the Donetz.

Stratified crystalline rocks are instructively displayed upon the banks of the rivers Voltchia and Kalmiuss. The former of these streams runs to the west of all the carboniferous strata. Along its banks to the south of Paulograd, and between that town and Alexandrofsk, the rocks consist of varieties of felspathic and quartzose gneiss, passing into grey compact quartz, which alternates with very thin laminæ of greenish talc, rarely micaceous. Some of these beds, a few versts east of the river, are so much charged with iron as to oxidize, or decompose into courses of hydrate of iron. Other layers consist of yellowish, coarse-grained mica schist, with irregular grains of garnet, alternating with thin beds, two to three inches thick, of a highly granitoid gneiss, in which the flesh-coloured felspar is beautifully laminated with red-coloured quartz, mica, and traces of steatite.

These variegated, crystalline rocks are very striking to those who have been long wandering amid the unconsolidated deposits of Central Russia. They occupy low hillocks only, and their prevalent direction is north-north-west and south-south-east. Their strike along the banks of the Voltchia is nearly parallel to the course of that stream, or about 15° west of north, whilst their ordinary dip is at a high angle to the east, and they are often vertical. This strike is, it will be observed, transverse to the main direction of the chain of the Donetz. For some distance to the east of the Voltchia these crystalline rocks are obscured by blown sand, and on this frontier it is difficult to mark their boundary, though by borings directed some years ago by Colonel Olivieri, it would appear, that thin patches of poor coal set on, at intervals, a very little to the east of the river.

The granitoid rocks of the Kalmiuss consist, chiefly, of flesh-coloured and pink felspar, often laminated with grains and crystals of dark-coloured quartz. These materials are sometimes so arranged as to approach to the character of graphic granite; other parts resemble the coarser varieties of Cornish granite.

But besides the granitic rocks of the Dnieper, the Voltchia and the Kalmiuss, other crystalline masses of very different characters advance to the Kalmiuss, and there pierce the gneiss and granite in dykes, at many places to the south of Karakuba and between that place and Sartana, just as the porphyries and elvans traverse the granites and schists of Cornwall and Devon. Some of these are coarse syenitic greenstones, occasionally very hornblendic, others are red, claystone porphyries. Red porphyry usurps, indeed, the whole surface in some localities, particularly around the picturesque Greek colonies of Laaspe and Karan. It increases in importance and in variety of structure as you approach Karakuba from the south, near to which place there are many varieties of vein stones, jaspers, and altered strata.

We have prefaced the account of the carboniferous deposits of the regions between the Dnieper and the Don with this brief sketch of the crystalline and intrusive rocks, which form the western and southern limits of the coal region, in order to give some idea of the masses, evidently crystallized at a very ancient period, on which the older sedimentary and carboniferous strata repose, and also of the agents by which the latter have been thrown into those inclined positions, breaks and undulations, which we are about to describe. The sections along the banks of the Kalmiuss clearly demonstrate, not only that the fundamental masses of this region are slaty granitic rocks, but also that they have been penetrated by intrusive matter, whilst the jaspers and altered strata prove that igneous eruptions have been continued along this line posterior to the carboniferous era. This last-mentioned phænomenon is of theoretical importance, and, when coupled with the fact, that the numerous powerful flexures of the carboniferous strata, to which attention will speedily be called, are parallel to the great axis of crystalline and eruptive rocks, we can have no difficulty in believing, that such high inclination and contortion owe their origin to the elevatory agency of this axis.

Ascending Section of the Kalmiuss. Red Sandstone, Shale and Conglomerate. Great or Lower Carboniferous Limestone[1].—From an inspection of many fossils brought to France from this region by M. Le Play, and shown to us by him in the spring of 1840, as well as from others examined in the Ecole des Mines at St. Petersburgh, we had formed an opinion before we visited the south (which opinion Professor Eichwald also entertained), that the mountain or carboniferous limestone was greatly developed in this district, and that the coal was associated with that rock. So far, then, we entered this country with some previous knowledge of one of its main features, but from no one could we derive a settled idea of the base of

[1] Among Russian writers, Colonel Olivieri, General Kovalefski, and Captain Ivanitski have given sketches of different parts of these carboniferous tracts in the 'Journal des Mines de Russie.'—Vol. iii. p. 1; vol. iv. p. 3; and vol. vi. pp. 140, 156, 192.

these deposits, from which we might develope a true ascending order. Whether we referred to the Russian authors who had described the country, or to M. Le Play, who was preparing an account of it, we were met on all sides with the statement, that, owing to the convolutions of the strata and the want of fixed mineral characters, no regular order could be established. To geologists, therefore, who like ourselves were thrown into a new field, in which the succession of the beds was perfectly unknown to us, nothing could be more satisfactory than to find, in one of the first sections which we made, a key to the whole order of this country, and by which we established that the most ancient strata occupy the southern zone of this carboniferous region.

Of Silurian or true Devonian rocks we could perceive no traces. Immediately, however, to the north of the crystalline rocks at Karakuba and on the right bank of the Kalmiuss, we discovered a red sandstone and shale with some conglomerate, which is so loaded with fragments of porphyry, that it seems in parts almost to pass into that rock, upon which it may be said to rest [1].

The lower grounds and slopes are there occupied by these red strata, which are laid open in ravines, and are distinctly overlaid by the carboniferous limestone at heights of 200 to 300 feet above the valley.

As this undulating and diversified tract differs essentially from the countries of Northern and Central Russia, in exhibiting within comparatively short distances both numerous flexures and the most decided changes in the succession of strata, we have illustrated it with the opposite plate of coloured sections (see Pl. I. fig. 1, and also the general section below the Map).

In some of its lower beds this sandstone is argillaceous, of grey and green, as well as red colours, and towards its upper limits becomes more and more a conglomerate; the pebbles, varying from a small size to that of pears, consist chiefly of the felspathic and quartzose rocks before described, lumps of pink, felspar porphyry particularly abounding. The ascending section, as far as our short examination enabled us to detect it, consists of greyish coarse grits and alternations of purplish red and green sandy shale, partly micaceous, with strong bands of greyish quartzose grit, in parts a pebble rock, with false bedding. Silicified or sandy casts of plants (apparently Stigmariæ) occur in the uppermost of these strata. Red and

[1] Through the kindness of General Tcheffkine, who had in fact provided us with every document at the disposal of the Corps of Mines which could throw light upon our inquiries, we were furnished with a map of this tract by Colonel Olivieri, on which this porphyry was laid down.

white felspathic quartzose conglomerate succeeds, covered by yellowish sandstone and shale with reddish and green shale. The whole of this red series is surmounted by carboniferous limestone of considerable thickness and forming fine cliffs, in which are several species of Producti. Among the fossils Colonel Olivieri assured us that he had found the large species (*P. giganteus*) so common to the lower band. In our very rapid examination, however, we detected only the *Productus antiquatus*, *Spirifer glaber*, and some corals. The whole of these strata dip to north-north-east at angles varying from 12° to 15°.

The composition of the red beds, and their infraposition to what we considered to be the lowest mass of the carboniferous limestone, at first disposed us to consider them as the uppermost member of the Old Red Sandstone; for by their position and aspect they seemed to be the exact equivalents of the Old Red Conglomerate of the South Welsh coal-field, which occupies so well-defined a place throughout the Silurian region of England. This comparison may, after all, prove to be correct, and the Upper *Red* Conglomerate of South Wales, notwithstanding its colour, may eventually be classed with the carboniferous limestone, since it is by no means an easy task, even in England, to separate the Devonian from the Carboniferous system, particularly when fossils are absent and mineral character is our only guide. Judging, however, from the analogies of Northern Russia and the Moscow basin, where carboniferous plants and seams of coal unquestionably underlie every trace of limestone, and repose upon beds with true Devonian fishes, we are now disposed to group these red strata of Karakuba with the base of the Carboniferous system, the more so as the Stigmaria which we found in them seemed to be a species common to both. A visit which we made to the Berwickshire coal-field, subsequent to our return to Great Britain, has further induced us to adopt this opinion; for we there found a great thickness of red sandstone and shale with coal, the upper beds of which only are interlaced with courses of carboniferous limestone, and the lowest of which lie far beneath all traces of that limestone, the whole constituting one great, red-coloured coal-field of considerable value (containing seven workable seams), which clearly overlies the Old Red Sandstone properly so called. We shall revert to this subject in our general conclusions. In the mean time, whether coal-seams may or may not exist in the red rocks of Karakuba, it is evident, that as they underlie the lowest mass of carboniferous limestone, they offer a distinct base-line for the section which we now continue to describe in ascending order.

The chief and lower limestone of these southern steppes might, from its light grey colour, thickness and position be strictly compared with the great "Scar limestone" of English geologists. After several undulations in hills to the north of Karakuba, it plunges under flagstones and grits with plants. At Bechef the latter are surmounted by shale and sandstone with plants and thin seams of coal, which are again overlapped by other strata, often undulating, but still on the whole inclining to the north. Among these are hard flagstones, of white, grey and light pinkish colours, the surfaces of which are occasionally discoloured by carbonaceous matter. These beds are followed by hard, greyish grits, and these again by thinnish courses of encrinite limestone. This series of beds is very analogous in lithological succession to the group which in Yorkshire, Cumberland, Westmoreland, and other northern counties of England, overlies the great Scar limestone (limestone and shale of Sedgwick, Yoredale rocks of Phillips). The analogy is further borne out by the occasional outcrop of a thin seam of coal, no bed of which has yet been worked to profit. Sinkings, however, have been made both by Russian engineers and by M. Le Play, under the directions of M. Demidoff, the results of which are not yet known to us.

In proceeding to the north, the impure limestone and grits which overlie the lower limestone, undulate, inclining on the whole to the north-north-east, and at Gorbatchofskaya, the strata dip steadily in that direction (see section, Pl. I. fig. 1.). They consist in ascending order of yellow micaceous sandstone, with carbonaceous surfaces, much resembling the moorstone of the Yorkshire dales, and with it are associated flagstones, very similar to those which abound upon the banks of the Ure near Hawes, on the Tees above Barnard Castle, and at Brignal upon the Greta. As in those parts of England, the surfaces of the flags are also often covered with large serpuline bodies. These beds are followed by black shivery shale, greyish shale, and quartzose sandstone, above which appear masses of dark-coloured, bituminous encrinite limestone, the surfaces of which are distinguished by peculiar corallines, resembling branching sea-weeds, identical in form with an undescribed species, which we have seen in the limestones of this age near Howick in Northumberland and at Ingleborough in Yorkshire. This bed is succeeded, or rather it inosculates with a stronger grey limestone, the harder beds of which form distinct scars in the sides of the hills on the right bank of the Kalmiuss, that river being here reduced to the size of a brook. Though there are many undulations, the prevalent dip is to the north-north-east; thus proving, both geometrically as well as by the differences in the beds, that the ascent of the Kalmiuss from Karakuba exhibits on the whole an ascending section, or a passage from older to younger strata.

In the limestone, near a spot called Mantrika, we detected the *Spirifer glaber*, *Leptæna Hardrensis* (Phill.), *Asaphus globiceps* (Phill.), a small Terebratula, as well as some corallines. Coal is again visible, subordinate to a bed of schist, east of Gorbatshofskaya, at a spot called Gruskaya, on the south bank of the little river Yeskino, where it crops out in small brittle fragments of good quality, and is overlaid by psammitic sandstone. At sixty versts to the east of this spot, as we were informed, coal has been regularly worked in thicker masses.

In approaching the higher limits of the Kalmiuss, as we did in dry autumnal weather, a geologist might almost be led into an error, and suppose that the limestone series, of which he had seen so much, was at an end, and that he had at length reached the true equivalents of the coal-fields of Western Europe; for the surface of the whole region is then densely covered with the finest black dust. At the period of our visit, this substance rose up everywhere from beneath the withered grass of the steppes, and looked exactly like the coal-dust near productive collieries. This appearance was, however, entirely due to the desiccation of the superficial deposit called Tchornozem, or black earth[1], which covers this portion of the tract, as well as many other countries in Central and Southern Russia; for wherever a depression and water-course afforded a natural opening, the strata were seen to consist of coaly sandstones, flagstones, coarse grits, and yellowish impure magnesian limestones (Pl. I. fig. 1.), containing fossils of the carboniferous limestone.

At Alexandrofsk, on the left bank of the stream, the only spot in this district where coal is worked by the government, the mineral is found to lie on sandstones and flagstones with "coal-plants," and is distinctly overlaid by a limestone charged with species of *Productus*, *Spirifer*, and the large *Lithodendron*, which is abundant in the mountain limestone of England and Ireland, the whole dipping 40° north-north-east. The coal at Alexandrofsk is about seven feet thick, and is composed of a number of fine laminæ of brittle, bituminous coal[2], somewhat light, easily destructible, and rendered of less value by frequent thin films of pyritous matter.

[1] This black earth will be described in the concluding chapters.

[2] This coal has been partially transported to the Black Sea for the use of the steamers of the Imperial fleet.

Lumps of pyrites are indeed seen, at intervals, in the coal itself. In some parts, however, it seemed to be of very good quality.

These workings are made by shallow shafts, the mouths of the highest of which are not 100 feet above the Kalmiuss, and the lowest not above seventy, with a shaft eighty-four feet deep, and hence the mines are occasionally stopped by the influx of water: for here, as in other parts of the carbonaceous region, steam-engines are unknown, and with the exceptions of the Imperial mines at Lissitchia-Balka and Uspensk (of which we shall treat hereafter), pits are never sunk, except in those situations where a natural drainage and open adits will keep them dry.

Continuation of this Section through still higher strata on the North.—The high grounds to the north of Alexandrofsk, from whence the Kalmiuss flows to the south, and where the feeders of the Voltchia and the Dnieper are deflected to the west and south, constitute one of those broad domes of elevation, several of which occur in the eastern and northern portions of these coal tracts. If the section is prolonged directly to the north-north-east, or to the east of Bachmuth, other lines of elevation are met with, and beds of coal and limestone are repeated at localities (Jeleznoe, &c.), to which we shall hereafter refer; but as we did not follow up these masses to their junction with superior strata, we prefer to complete, in the first instance, what we consider to be one continuous ascending section, by carrying our present line almost due north. Passing over, for the present, certain central members of the series with *Spirifer Mosquensis*, because in this line of section (near to Celidofka) they are either sterile in coal or little exposed, and returning to their consideration in another transverse section upon the Toretz, where they are highly inclined and well known, it is sufficient for our present purpose to state, that reposing upon the lower series of the Kalmiuss, these middle carboniferous rocks occupy a broad undulation, and dipping slightly to the north-north-east, are carried under reddish and white grits with red shale, which, occupying poor moorlands, slope down to the large village of Goradofka (see Pl. I. fig. 2.). The grits are there quarried for door-posts and troughs, and afford an excellent, porous freestone, of almost pure white colour, occasionally with a greenish tinge, in parts a conglomerate, in which the grains of quartz are cemented in a felspathic base. In this tract, where no trees are in existence, and where, as nearly all over Russia, the great mass of the inhabitants live in wooden houses, this stone might be very largely employed for building purposes. This rock, dipping 12° to the north-east and north-north-east, is covered by red, green, and greyish clays and shales, above which a thin seam of poor coal is seen outcropping; then follow other beds of dark grey shale, capped by a band of limestone, in which are observed Encrinites, Corals, Productus, Euomphalus, and other characteristic fossils. Beds of shale, of blue and yellow colours, with some concretions of argillaceous ironstone, overlie the limestone, and are succeeded by a second thin seam of coal (six to nine inches), which is composed of hard and fine layers alternating with sooty laminæ. The coal and shale are capped by a band of strong-bedded limestone, twelve to fifteen feet thick, in which is a small Trilobite resembling *Asaphus globiceps* (Phillips). We here also found several Fusulinæ, fossils which, as before said, we never observed in any part of Russia in the lower members of the carboniferous limestone.

The advantage of having made a section from Karakuba to Goradofka is thus evident, for we thereby learn that the Fusulinæ occur in beds superior to the middle limestone with *Spirifer Mosquensis*, and hence the position we had assigned to the rock containing these fossils upon the Kliasma and the Volga is established.

Pursuing this section still further, in ascending order, viz. to the north-west of Bachmuth (Pl. I. fig. 3.), this upper limestone is conformably overlaid by a considerable thickness of shale of different colours, with nodules of impure argillaceous iron-ore and some brownish micaceous ironstone, sandstones, and flagstones with concretions, all of which range in very slightly inclined beds (observable only in ravines and water-courses) up to the post-station of Marchinsk, on the road from Bachmuth to Ekaterinoslaf. To the north these uppermost beds of the carboniferous series are overlapped by the chalk.

We have described this section from Karakuba on the south, to Goradofka and Marchinsk on the north, because it affords a good explanation of the order of the carboniferous deposits, and also proves that certain red rocks, which from their lithological characters have been referred to other deposits, unquestionably form an integral part of the Carboniferous system. We shall have occasion to recur to this point in establishing the age of the red rocks near the sources of the Bachmutha river (Gossuderaya-buyerak, &c.), which have been described as the Rothe-todte-liegende; and eventually it will be made manifest, that another red formation, consisting of limestone, marl, gypsum and conglomerate, which occupies the vale of Bachmuth and overlies all the carboniferous strata, is not, as has been supposed, the Keuper or *marnes irisées*[1], but is the equivalent of the Zechstein, and represents the great Russian deposits which we have grouped under the name of the "Permian System." (See Chaps. VIII. and IX.)

Country watered by the rivers Krinka and Miuss.—Before we continue the description of the north-eastern and most productive coal tracts, we may offer a general sketch of the southern districts watered by the Krinka and the Miuss, and also say a few words upon the anthracitic region.

In passing from the river Kalmiuss on the west, to the valley of the Krinka on the east, the great calcareous masses which form the base of the whole carboniferous tract disappear, both by thinning out and probably also by great flexures, which carry them beneath a highly inclined and contorted group of sandstone and schist. On the little river Cinka Kalinova the carboniferous rocks are overlaid by the chalk, and near this junction is an elevated hilly steppe made up chiefly of reddish and grey micaceous sandstone, occasionally schistose, and charged with many impressions of Calamites and other plants. The beds are much contorted, but their chief direction is west and by north, east and by south. Their inclination, which is usually very great, sometimes vertical, is for the most part to the north-east; but as there are many folds, the southerly dip is occasionally apparent. In our journey along the banks of the river Krinka, we met with many natural sections of sandstone and shale, the latter being mostly in the valleys, and the former occupying terraces, as above the village of Artemefka, where three of these terraces, stretching from east to west, are composed of hard gritty sandstone with plants and quartz veins, and separated by bands of shale.

In one spot north of Artemefka the usual strike of the strata is reversed to the north and by west, the dip being to the west. The same phænomenon is repeated at Kuteinikof, the inhabitants of which village informed us that traces of coal had been found a little to the south-east; but the only natural outcrop of the mineral (and it was of worthless quality) which we observed was at Sniefka, where the valley of the Krinka is very deep, and the rocks consist of coarse-grained grit and shale. In approaching the valley of the river Miuss and in the neighbourhood of the village of Orlova, a thin band of dark-coloured limestone occurs, having a thickness of four feet only, and no fossils: strike west 20° north of west, and dipping to the north-east; and the same limestone is again met with in the plateau near the village of Grabovaya.

In the valley of the Miuss, at Grabovaya, flagstones alternate with shale, the direction of which is west-north-west by east-south-east, and the dip north-north-east at 50°; and on descending the river to Novo-pavlofka the same beds reappear under similar conditions, and with the exception of a thin band of limestone on the height near that place, flagstones and shales, having very variable directions, occupy all this valley even to the village of Demetriefka. Limestone reoccurs, however, at twelve versts south of the village of Ivanofka, and also at about an equal distance to the north of that place, the black compact limestone, apparently not differing from that before alluded to, contains small Spirifers and Encrinites. This portion of the tract is conterminous with the coal-bearing district of Krasnoi-kut which we shall presently describe.

Making every allowance for contortion and repetition of the same strata, we still believe that the group of rocks on the Krinka and the Miuss is of considerable thickness, and that it represents those lower members of the series upon the Kalmiuss which we have described, and in which much more calcareous matter is developed. In fact, we have only to follow any one of the zones, upon the strike of the strata, from the tracts in which limestone abounds, and we find the calcareous matter

[1] See Ivanitzki's 'Journal des Mines de Russie,' vol. vi. p. 192.

thinning out towards the east; and with this alteration a great decrease in the amount of carbonaceous matter is also observed, the bituminous coal disappearing, and its place being eventually taken by pure anthracite.

Relation of the Anthracite to the Bituminous Coal.—From what we have just said, the reader will perceive, that this region is divided into anthracitic and bituminous coal-fields. Owing to the prevalent strike of the beds from west-north-west to east-south-east, it is obvious, that notwithstanding considerable flexures and variations in lithological structure, the same groups of strata we have been describing are continuous eastwards to the Donetz. Thus the anthracitic rocks without limestone to the north of Novo Tcherkask, and the schists with some thin courses of limestone on the Donetz, are the equivalents of the shale, sandstone, and bituminous coal with limestone, to which we have already alluded.

This phænomenon is analogous to that which exists in the South Welsh coal-field, where at one extremity of the tract anthracitic coal prevails almost exclusively, in beds of precisely the same age as those which bear bituminous coal at a little distance to the east. In the Russian example, indeed, we see the mineral character of the coal-beds change gradually as we follow them from west to east. In the districts intermediate between the western or bituminous tracts, and those containing pure anthracite, the combustible is frequently in that intermediate condition to which mineralogists would have a difficulty in applying one decisive name, as it is made up of both bituminous and anthracitic materials. The line of demarcation between the anthracitic and ordinary bituminous coals of commerce being arbitrary, all combustible matter which partakes of the two characters must remain without a common descriptive term. We leave it to M. Le Play, Capt. Ivanitzki, and others who have analysed these coals from many localities, to state the shades of chemical distinction by which each variety is found to be more or less useful to the metallurgist and engineer; our object is simply to record the geological relations of the masses. We content ourselves, therefore, with stating, that in proceeding from the north and by west to the south and by east, or through the hilly steppes to the north of Novo Tcherkask, the limestones thin out to insignificant bands, the sandstones and shales become hard; and with these changes, the coal-seams, becoming gradually less bituminous, assume in their western extremities all the characters of pure anthracite. However unwilling to blend too much theory with our positive geology, we cannot refrain from adverting to the remarkable coincidence between the line of anthracitic coal and the crystalline axis of the southern steppes, and from suggesting, that in their subterranean prolongation, the igneous rocks there rising near to the surface, may have converted the superjacent ordinary coal into anthracite, and have indurated the associated grits, sandstones and schists.

Krasnoi-Kut.—Of the coal of intermediate quality, to which we have alluded, we would cite the beds which outcrop and are worked in horizontal galleries on the slopes of the hills near Krasnoi-Kut, the residence of General Papkoff, and south of the post-station of Ivanofka. Here we examined two beds of coal (Pl. I. fig. 4.), the one included between two thick bands of shale and overlaid by dark limestone with *Chætetes radians*, Encrinites, and the undescribed branching coral of the English mountain limestone before alluded to (p. 93), the other resting upon sandy schist with plants, surmounted by yellowish, thick-bedded sandstone and then by encrinital limestone, undulating at slight inclinations of about 10°. These coals, occurring in beds three feet and three and a half feet thick, are readily extracted in the mines of General Papkoff, and have been employed in working a steam-engine used in manufactories which he has established[1]. They are excellent seams for their dimensions, many parts of the coal being undistinguishable from iridescent British varieties. Coal of similar quality has been observed outcropping in several places in the same neighbourhood. In following these bands to the east, they are found to lose their bituminous properties as they approach the Donetz, and to become more anthracitic.

Anthracite of Popofskoe.—The most important works of anthracite in this region are those on the rivulet Grujefka, near the hamlet of Popofskoe, thirty versts north of Novo Tcherkask, to which place and to the neighbouring rivers Don and Donetz the coal is conveyed in the light carts of the country. It is, in fact, already the fuel used to some extent in the towns of Novo Tcherkask, Rostoff and other places on the Sea of Azof, where his Excellency Count M. Woronzow, Governor-general of these provinces, has encouraged the natives to abandon the use of wood, which is extremely dear, and to construct fire-places for the use of this superior substitute.

Two seams (as shown in Pl. I. fig. 5.) are exposed on the left bank of a small stream, above whose banks they are seen to crop out on the sides of low hills. A brownish, micaceous gritty sandstone, having the characters of many ordinary coal strata, and dipping to the north at about 15°, forms the principal substratum, and

[1] 'Journal des Mines de Russie,' vol. vi. p. 140 *et seq.*

rises on its escarpment side into rocky eminences. The lower coal, in all from two and a half to three feet thick, is made up of very thin courses, most of which consisting of hard and pure anthracite, are subordinate to unctuous shale. It is chiefly worked by galleries, in which the poor Cossack miners have followed it to short distances from its natural outcrop on the sides of the brooks. A roof of schist, of about fifty feet in thickness, separates the lower from the higher coal, which is less thick, but of equally good quality, and when we visited the locality, was reached by shallow shafts from the surface of the hill[1]. From the gentle inclination of the beds and the height of the ground, drainage may indeed be effected to a great extent without recourse to steam-engines; but the use of the latter and the sinking of shafts might, doubtless, open out the mineral to greater advantage.

Sections on and near the Donetz.—Approaching this coal country as we did from the eastern steppes of the Kalmucks, we were at once made acquainted with the powerful convulsions to which it had been subjected, by examining the natural sections which are exposed on the right bank of the Donetz above the station of Donetzkaya. Seams of coal and anthracite are seen at intervals in highly dislocated positions at several places, viz. at Nijni and Verkni, Kundriutcheskaya, and on the river Kundriutshia which falls into the Donetzkaya. The relations of the black schists, impure limestones, flagstones, grits and coal along a portion of these streams, are explained in Pl. I. fig. 6.

Whilst the violent dislocations and high inclination of the strata render it unlikely that coal can be worked to much profit in this neighbourhood, its inhabitants have an agreeable compensation in their fine climate and fertile soil; the vine, pomegranate and water-melon being as abundant and fine-flavoured in this corner of the Russian coal-field as in Italy.

To the east of the embouchure of the Donetz, and indeed to some extent up that stream, the carboniferous strata are obscured by much blown sand. We conceive, however, that the formation ranges on the south-west up to the river Kargalinsk, because we there observed brown, grey and ferruginous sandstones

[1] The details of the working of these mines, as well as of the quality of the anthracite, are given by Captain Ivanitzki in the sixth volume of the 'Journal of the Imperial Mines.' Upon visiting the Zavod of Lugan, we became aware of the superiority of this anthracite over all the other coals of this territory, whether in forging iron or in the production of steam; facts which were ascertained through trials instituted by order of General Tcheffkine. The reader will find these points clearly explained by Captain Ivanitzki.—*Journal des Mines*, vol. v.

with schists, which, though covered with much detritus and clay, seemed to belong to the carbonaceous tract.

In briefly describing the country watered by the Krinka, we have said that amid numerous steep anticlinal flexures the northerly dip prevailed on the whole considerably over that to the south. This phænomenon, general throughout the anthracitic region, and to which we have adverted in the sections (Pl. I. figs. 1 & 2), convinced us, that the whole of this anthracitic mass was carried under the more productive coal tracts of the north-east, to which we shall presently direct attention. In ascending the Donetz to the villages of Gundrofskaya and Kamenskaya, we met with other anticlinal ridges and synclinal troughs parallel to the general direction of the region, and with dips both to the south and north; but here the alternating grits are charged with Stigmaria, and the coal-seams are subordinate to mural masses and stony beds of limestone, the whole offering a great resemblance to the productive coal tract around Uspensk, which we shall soon describe. Thus in a ravine eight versts from Gundrofskaya, where the strike is west and by north, east and by south, and the dip 34° southerly, we met with a thin bed of coal subordinate to sandstone, with Stigmaria and some clunch-like beds, the lower strata exhibiting three courses of limestone, with sandstone, grit, shale, ironstone concretions, and a second layer of coal: an anticlinal line succeeds, and similar strata are repeated.

Near the village of Isvorin, in the valley of the Kameuka, the structure of the country is no longer the same as that of Gundrofskaya; and instead of mural calcareous masses, the crests of the ridges are composed of sandstones, black shale, schists, and hard grits, the latter forming terraces like those upon the banks of the Krinka; thus showing, that owing to great undulations, the same groups are repeated upon different parallels.

Without detailing minute sections, which would only embarrass the general reader, we may assert, that on the whole, the survey of the south-eastern portion of this coal tract proves, that the strata gather in ascending order from south to north, the country being composed on the whole in ascending order of—

1st. Sandstones and schists, with plants, forming high steppes and plateaus, with some limestone and anthracite. The grits become harder and more powerful to the north, and then constitute remarkable terraces, and give a more varied outline to the country.

2nd. Limestone, sandstone, shale, and bituminous coal. It is this member which is so much developed in the north-eastern corner of the coal region, and in which coal is so largely worked at Lissitchia-Balka.

Coal-fields in the Northern Tracts.—The section of the Kalmiuss having taught us the order of the strata, and a survey of the banks of the Krinka, Miuss and Donetz having induced us to surmise, that no very productive coal-seams are yet known in the southern or older zone (with the exception of certain beds of anthracite), we now proceed to describe, first, some other localities which we visited to the south and south-east of Bachmuth, next the more productive mines of Uspensk, east of the foundry of Lugan, and lastly those of Lissitchia-Balka on the Donetz, in all of which places coal is worked.

On the right bank of the larger of the two small rivers called the Toretz, coal is extracted by the natives for their own use at several localities. To the east of this stream the country rises in dome-shaped hills, attaining to several hundred feet of elevation, which are in great part composed of red, white, grey, and olive-coloured sandstones and grits. Some of these grits, indeed, seem to rise up from beneath the coal-seams to form the plateaus of Gosudarev-Buyerak, &c., and others are seen to fold over to the north, and pass upwards into thin bands of carboniferous limestone, loaded with Producti and Encrinites, or rather the limestones are included in a great development of sandstone. There is, however, a large expanse of pure white and red sandstone between Zemliaka and Scotovaitova, which, like the strata to the south of Goradofka, we have little doubt belongs to the same portion of the Carboniferous system (Upper Limestone series). At Scotovaitova, where the village is built of white grit, the ascending section from the valley of the Krivoi-Toretz up the sides of the hills offered,—1st. Hard greyish and yellow mottled sandstones. 2nd. White grits. 3rd. Flagstones. 4th. Deep red, micaceous, earthy sandstone, passing into shale. On the whole, this sandstone group reminded us more of certain white and red grits which underlie some of our English coal-fields, as in the Forest of Wyre, Salop, and along the North Welsh border at Oswestry, than any other rocks with which we could compare them. Wherever they contained no coal plants, and were in juxtaposition to the new red sandstone, such strata, even in England, were formerly classed with that formation, at a time when mere colour and mineral characters prevailed over other considerations. In a sketch by Captain Ivanitzki of this portion of the country, these deposits are considered to be the equivalents of the Rothe-todte-liegende, but we are not of this opinion, because we know, that in the regular ascending order as previously described (p. 95.), red sandstones pass under and alternate with beds of carboniferous limestone, and that the highest beds of the system, consisting of black shale and ferruginous sandstone of very dissimilar composition, are not surmounted by any such strata. The whole of the seams of coal which occur at intervals throughout this district are invariably interlaced with calcareous courses, which are charged with the fossils of the mountain limestone; and as such fossils are seen at intervals throughout the whole series, we consider (subject always to corrections resulting from more detailed survey) that all these grits and sandstones, whatever may be their colour, are subordinate to the carboniferous limestone. Such, at all events, are the whetstones, flagstones and grits which repose upon and alternate with thin courses of limestone between Gosudarev-Buyerak and the great road from Novo Tcherkask to Bachmuth, and which constitute a plateau, with anthracite and coal-seams in the valley on either side of it. Nor do we see how any of the red rocks in question can be separated from the same group (see Pl. I. fig. 7.).

Coal-mines of Jeleznoe or Nikitofka [1].—On the east bank of the Toretz lies the village of Jeleznoe, deriving its name from a little stream, the Jeleznaia, and distinguished, like some other places in those tracts, by numerous remains of the idols of the Aborigines, carved out of the stronger and coarser grits previously described. Ascending by the Jeleznaia, we were conducted to the chief coal-works of the villagers, situated at a height of perhaps 300 or 400 feet above the adjacent valley, and about seven versts from the village, on the western slope of the round-backed plateau or steppe which intervenes between Jeleznoe and Gosudarev-Buyerak.

The strata being here considerably inclined (from 40° to 80°), a succession of coal-seams and shale is exposed, alternating with hard bands of grit, sandstone and limestone, as represented in the section (Pl. I. fig. 8.).

In descending from the plateau to the west and south, the lowest strata, which occupy indeed the largest surface of these upper steppes or moorlands, are seen to consist of hard, grey, gritty sandstones, weathering to a rusty colour, and very much resembling the moor-stones of the west of Durham, the Yorkshire Dales and

[1] A correct and minute description of these coal-mines will be found in the memoir of Capt. Ivanitzki. We merely describe what we saw at one spot and at a period when the works were abandoned.

West Northumberland. The lowest beds are about two feet three inches thick, the second and third seams about three feet each; these are separated by clunch, clay and shale, and a little sandstone. The fourth seam is about two feet four inches thick, and is surmounted by a coarse, pebbly grit. This is followed by an impure grey limestone, containing Encrini and Producti, alternating with grit and sandstone, which is succeeded by another band of limestone, in which we found a few Fusulinæ, and a great thickness of shale, the latter being capped by a ledge of coarse, pebbly sandstone, forming the roof of the sixth or uppermost coal observable in this section.

By pacing across the strata from the lowest, which are exposed on the high ground, to the uppermost ledge which rises from the bank of the Jeleznaia, our rough estimate gave a thickness of about 1200 yards, in which space the hard rocks form little ridges, slightly protruding through the slopes of long grass, the shales having been worn into depressions. The strike of the beds is from west-north-west to east-south-east, and the dip to the south-south-west, the angle increasing gradually from 40° near the rivulet, to 55° and 80° as you ascend the hill to the last bed worked, is marked by piles of coal recently extracted. The uppermost coal is the best and most solid, but as it lies in the lowest position, the peasants have not been able to follow it in their rude works, on account of the influx of water.

The best and hardest beds, or those upon the dip, having soon plunged beyond the reach of the natives, who employ neither engines nor adits to dry their shallow mines, (in this country, indeed, they can with difficulty obtain sufficient wood even to support the roofs,) the two lowest seams only have been latterly worked in this locality. The same beds are explored by the peasantry in other localities (which we did not visit), whenever a favourable outcrop tempts them to employ their spare hours in thus procuring fuel[1]. Though most of the coal lying at the mounds was of the broken and small character which in the English northern coal-fields would be consumed for steam, or sold for waste, we had little doubt, judging from a few of the fragments, that, by deep works and an improved system of mining, better coal might be obtained, although it is improbable that such thick masses of the mineral will ever be discovered in this tract, as have been pro-

[1] At the period of our visit (September), the harvest and autumnal sowing having been long finished, the peasants were employing their spare teams of oxen in transporting coal from the adjacent pits.

cured in the very productive north-eastern angle of the field, with an account of which we shall terminate our observations.

Imperial Coal-works of Uspensk.—Having, we conceive, sufficiently explained our general views concerning the districts in which coal has been a little worked, it does not accord with our object to enter into details, or to cite many localities where the outcrop of the mineral is known, all of which we leave to Russian engineers. We, therefore, proceed to describe the north-eastern angle of this coal tract, to which the attention of the Imperial Government has been most directed, because it has afforded the greatest quantity and best quality of fuel. This coal is not only used in the adjacent foundries of Lugan, but is transported by the river Donetz (navigable in the spring and early summer season) to the mouth of the Don and Sea of Azof.

In the same manner as upon the Lower Donetz and the Krinka, where we first noticed the existence of anticlinal and synclinal lines, the whole of the northern districts may be said to be split up upon numerous lines of dislocation, trending for the most part from west-north-west to east-south-east, and often producing great folds and repetitions in the strata.

Thus, in passing from south to north over dome-shaped masses of grit, to which we have before adverted as lying to the north of Ivanofka, and in which hard grey grits and sandstones are sometimes prevalent, the observer who descends into the valley of the little river Alkovaia is struck with the violent breaks and highly inclined positions of the strata.

It was the natural outcrop of beds of good coal on the northern sides of this valley which originally induced the Russians to establish works here, the first shafts having been sunk about forty years ago by the Scottish miner Gascoigne, whose name has acquired a permanent place in Russian history, as having explored some of their earliest sites of iron-ore and coal, and established many of their great iron-foundries. Employing a small company of his countrymen, Gascoigne first opened the coal-pits of Uspensk, of which we are now speaking, and next those of Lissitchia-Balka, to be described in the sequel; and though no English workman now remains, it is worthy of remark that the insular names of *main*, *splent*, *cherry*, &c., by which the different seams were first distinguished, from their resemblance to certain English coals, are still preserved, and now form part of the vocabulary of the Russian miners.

At Uspensk, which is situated to the east of the foundries of Lugan, eleven seams of coal are known, but of these only three are now worked, viz. from fourteen inches to three feet thick each, the remainder being thin, impure and profitless. These beds are subordinate to grits, schists and limestones, and among the fossils of the latter we perceived both the *Spirifer Mosquensis* and the *Chætetes radians*, thus proving beyond a doubt that the coal is included in the central member of the carboniferous limestone, and superior to the rocks of the Lower Donetz and Krinka, and to the great limestone of Karakuba. The prevailing strike is east and by south, west and by north, and the dip is usually to the north and by east, at very high angles, viz. 50° to 60°. Some of the seams of coal thin out, when followed downwards to a depth of thirty fathoms, in the same way as has been observed in the coal-field of Coalbrook Dale, where such wedging-out is termed a "Simon fault" [1]. In general the roofs of the coal are grits and sandstones, and their floors are composed of shale; but in one instance the roof is a bed of Spirifer and Encrinite limestone, and in another a clunch or clay. Many plants occur, chiefly in the schist and clunch, and among them are numerous Ferns as well as Stigmariæ. The coal of Uspensk being extracted on the sides of the hills high above the line of drainage of the country, no steam-engines have been yet employed; but when we were there, the difficulties having increased with the greater depth, a small twelve-horse power machine had been prepared to obviate them. This coal is somewhat of that mixed nature to which we have before alluded, being very far from a pure bituminous coal; and although it gives little or no flame or smoke compared with that of Lissitchia-Balka (the great mine of the region), it is very useful in forging iron, and contains so much of bitumen as to set well and coagulate when heated.

The natural sections presented by the hills on the north of the Alkovaia, between Uspensk and Lugan, are singularly instructive in presenting a succession of highly inclined strata of the Carboniferous system, one of the depressions between the ridges being filled with a small basin of chalk which is unconformable, as expressed in Pl. I. fig. 10; and finally, the carboniferous sandstones subsiding in their progress to the north, are covered by the vast and thick development of chalk in which the Lugan iron-foundries are placed.

[1] See the memoir of Mr. Prestwich on the coal-field of Coalbrook Dale (Geol. Trans. vol. v. p. 413.), one of the most valuable pictures of the underground relations of a highly complicated coal-field which has ever been communicated to the public. A brief account of this field is also given in the "Silurian System" of Mr. Murchison, p. 99.

Imperial Coal-works of Lissitchia-Balka.—A long and narrow promontory, subtended by the Donetz, and extending to Privolnoe on the north-north-west, is composed of carbonaceous masses, the chief strike of which is in that direction, and therefore oblique to the prevalent bearing of the other masses which have been described (see Map). At Verknie, to the north of the great iron-foundries or Zavod of Lugan, the carboniferous strata emerge from beneath the cretaceous deposits, the relations of which will be hereafter described. Upcasts, similar indeed to those displayed near Uspensk, are exhibited in ascending the Donetz, and they constitute the nucleus of the hills on the right or west bank of that river. The existence of coals has been proved at three or four localities, but the site where the best seams were formerly discovered by Mr. Gascoigne, and where he commenced the chief Imperial works, is at a spot called Lissitchia-Balka, or "Fox Dingle," near the end of the promontory alluded to. Deep ravines which open out into the valley of the Donetz had here laid bare those natural outcrops of coal, which led to the present extended works. This spot, about thirty versts north-east of Bachmuth, is now the centre of a flourishing establishment, producing a considerable quantity of coal, the greater part of which is used in the manufacture of iron at the forges of Lugan.

The works at this place have shown that the strata fold round, to some extent, in the form of a dome of elevation, dipping to the east, south and west, but the present levels are driven upon the easterly dip or towards the river Donetz, to which they incline at about 18°. A ravine, however, which opens out to the north, exposes the beds in very highly inclined positions with a disturbed strike, in parts vertical, and the dip even quite reversed. Ascending from the river banks by this ravine, we saw in succession highly inclined beds of limestone, clunch, sandstone and coal, each of which were well known to the superintendent who accompanied us, as being identical with some of those which are explored in the works beneath and on the regular dip.

Including small and profitless layers, not less than thirteen seams of coal are passed through in the shafts at Lissitchia-Balka, seven of which are extracted for use; the greater part of the coal is of fair quality, and some exceedingly good. The larger portion may be called bituminous coal, as it cements together in the fire, gives much flame and smoke, and serves for reverberating furnaces. Argillaceous schist and slate clay (clunch and clod) abound in great thicknesses, and although some of the beds contain small nodules of argillaceous iron-ore, with a septarian structure, it does not appear that these concretions are numerous enough to induce the Russian miners to use them. All the best iron manufactured in the Imperial Zavods is brought from the Ural chain and its flanks [1]. In order to dry the upper portion of these mines, a noble adit, nearly seven feet high, resembling in its dimensions one of the ancient mining conduits of the Romans, is now nearly completed, and we ascended it from its outlet at the mouth of one of the chief ravines, examining the bands of sandstone and shale along the sides. Anxious to explore still lower strata than those which will be drained by this adit, General Tcheffkine has resolved to sink yet deeper shafts, and then to dry the lower mines by a steam-engine, which was almost finished when we left the place.

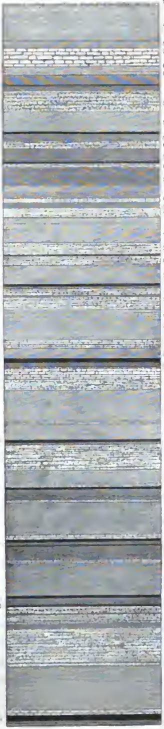
The fossil contents of the limestone which alternate with these coal-seams, prove most clearly that the whole occur upon the same geological horizon as those which are the most productive of coal throughout the other parts of this region, viz. the middle carboniferous or Moscow limestone ; for the engineers had collected a suite of the fossils characterizing each stratum, to illustrate a carefully drawn vertical section prepared by them, of which the opposite woodcut is a reduced copy .

We thus had the means of naming each species on the spot, and in presence of the persons who had actually seen it in its place in the coal-shafts, and this scrutiny convinced us, that the whole of the great mass here passed through is the representative of the central or Moscow limestone. The *Spirifer Mosquensis*, for example, so characteristic of that zone, and which we have never found associated with the *Productus giganteus* of the lowest limestone, here ranges from one of the upper beds of limestone to the very lowest calcareous bed of the annexed list. The *Productus antiquatus*, so characteristic of the mountain limestone of Britain, and indeed of Western Europe generally, is found in the uppermost fossil beds, where it is associated with an Orthis and the small Trilobite *Otarion Eichwaldi* (Fisch.), and again the same characteristic fossil occurs in argillaceous beds above the main coal, where it is accompanied by a small Productus, Orthis, Bellerophon, Turritella,

[1] The profusion of fine magnetic iron-ore in the Ural Mountains, and the immense quantities of the less valuable hydrate of iron which is spread out at intervals near the surface in the low countries of Russia, render it almost useless for the miner yet to think of working clay-iron ores, even though they occur, like those of Lissitchia-Balka, in association with coal and limestone.

[2] The opposite detailed section of the strata furnished to us by the Russian miners, was prepared by order of the Imperial Administration of Mines, whose intentions were completely carried out through the agency of Colonel Bethman, the director of the Zavod of Lugan, and mining chief of this country, with the aid of our friend Major Teploff, and the director of the coal-mines Captain Smirnoff.

20.


Soil.
Argillaceous beds.
Shale.
Limestone, in parts ferruginous, with shale, and *Spirifer Mosquensis, Orthis lata, Productus antiquatus,* (Corals and small Trilobites.
Clod.
Grit.
Clunch-clay, with a thin seam of coal...
Sandstone and grit.
Schist.
Coal: uppermost bed worked
Shale.
Grit.
Schist.
Coal.
Grit.
Shale and schist.
Trace of coal.
Grit.
Schist.
Sandstone and grit
Argillaceous beds, with bands of grit.
Sandstone and grit.
Schist, with thin course of coal...
Grit.
Shale.
Coal.
Sandstone, grit and shale, &c.
Grit and shale.
Shale.
Limestone and grit.
Shale, with *Productus antiquatus, Orthis planissima,* [*Bellerophon, Nautilus,* &c
Main coal......
Shale.
Limestone.
Grit.
Limestone and shale, with *Spirifer Mosquensis, Pecten, Retepora,* &c.
Splent-coal, with argillaceous schist.
Grit.
Schist.
Limestone, with *Pecten, Retepora,* &c
Coal (in work).
Shale.
Grit.
Schist.
Limestone.
Cherry-coal (not worked).
Shale.
Limestone.
Schist.
Coal (pyritous and fetid).
Shale.
Thin course of coal, with clay and schist
Grit and schist
Thin limestone.
Schists.
Flagstones and compact sandstones.
Argillaceous schist.
Limestone, with *Spirif. Mosquensis, Euomphalus,* &c.
Lowest coal, divided by shale.
Schists and shale.
Sandstone and grit, with many plants: base of section.

Pecten and Nautilus. In the limestone and slate-clay above the splent coal, the *Spirifer Mosquensis* is again seen, associated with a Pecten, a Retepora and other flexible Polypifers; and lastly, in the limestone overlying the lowest coal, this shell is again found, together with the *Euomphalus Baeri*, n. s. (Eichw.).

Of the plants we have not the means of speaking with the same precision, not having brought away good specimens; but we are certain that many of the forms of Equiseti, Calamites, Sigillaria and Ferns which we saw are identical with species common to the coal formations of Western Europe.

The section of Lissitchia-Balka proves to us, that in a vertical depth of near 900 English feet, the united thickness of the coal-seams is upwards of thirty feet; of the limestones, near fifty; of the grits and sandstones, above 200; whilst the argillaceous beds, which vary in quality from the clunch to the clod of the miners (or slate-clay, schist, shale of the mineralogist), amount to near 600 feet.

These lithological statistics are of theoretical as well as of practical value, for they enable us to speculate on the conditions under which the coal was accumulated, whilst they teach us how, with varying lithological and organic contents, the same beds, in different parts of the globe, assume such very different aspects. Seeing the argillaceous schists, shale, sandstone and grit, which here alternate with the coal, and the frequency and dimensions of the coal-seams, any practical collier from the best-worked tracts, even of the British Isles, who had not studied fossil remains, might be convinced that these shafts were sunk in the coal-measures, the "Terrain Houiller" of the French; and still more closely would he cling to this belief, when he saw that the forms of the plants were identical with those to which he had been accustomed in his own coal-fields, imbedded in similar clod, clunch, sandstone and grit. Yet would he have erred in classification, to the extent of one great and important member of the geological scale, for the bands of limestone and calcareous shale which alternate with this great argillo-carbonaceous mass, inform us without any doubt, that all these accumulations (unlike those of our upper coal-fields, in which marine exuviæ are either absent or exceedingly rare,) were deposited under the sea. From the top to the bottom of the section, we find unequivocal remains of marine animals, many being, indeed, identical with those which abound in the great limestone that forms the support of the coal-fields of the British Isles. In the western dales and moors of Yorkshire, Durham and Northumberland, there also exist, it is true, certain beds of coal in the lower or marine members of the Carboniferous system, but they are not by any means so rich in coal, coal-shale and plants, as this Russian deposit, which is the more remarkable *per se*, when compared with the strata of the same age previously described in the basin of Moscow, where there is not a trace of carbonaceous matter or black shale in deposits containing the same species of Spirifer and Productus. Instead of the grey and dark bituminous limestones of this southern tract, the whole calcareous mass around Moscow, and extending to near Archangel, is, as we have before shown, a pure white limestone, with some inosculating bands of magnesian character, and also of red and green marls and sands. In the Valdai Hills and in the governments of Tula and Kaluga, coal, on the contrary, is found only in strata beneath the lowest zone of carboniferous limestone, as in Berwickshire in the British Isles; whilst in the south of Russia we are as yet unacquainted with any notable seam of coal so low in the system, unless it be the anthracites of Popofskoe and the Lower Donetz.

The tabular view, therefore, which we have prepared and annexed to the Map, and which exhibits on one side of the coloured scale a central mass of pure limestone (Moscow), graduating on the other side into a series of shale and grit, with thin courses of limestone (Donetz), conveys a true picture of the great difference in composition between *the same* carboniferous masses in the northern and southern regions of Russia.

In regard to the theory of the origin of coal, which has of late attracted so much the attention of English geologists, the sections of Lissitchia-Balka and of the southern regions of Russia assure us, that the hypothesis of the formation of coal-beds by masses of vegetation, and the ground on which they grew having subsided *in situ* (the truth of the application of which to *some* coal-basins we do not dispute), cannot be applied to the cases in question, any more than to the pure marine coal-beds of the northern districts of Northumberland, and the north-western parts of Yorkshire, &c. It is true, indeed, that several of the seams of coal at Lissitchia-Balka have a sub-stratum of argillaceous schist, and that perchance these sub-strata might be identified lithologically with the bottom or fire-clay of the observers who support that view. But what does this prove? Supposing even that it was a creeping plant that grew upon the spot, is the *Stigmaria ficoides* alone there? By no means, for we meet with a confused assemblage of many terrestrial plants both above and below the coal-seams; whilst from the uppermost to the lowest bed, throughout a thickness of about 800 feet, the shells are exclusively of *marine* origin. What then does the finely levigated shale or clunch, which is the support of the coal-seams, indicate, but that in those periods when the bottom of the sea was spread over with the detritus of matted and broken plants, washed into it by inundations or freshes of former rivers, that the heavier earthy matters which accompanied such accumulations (in the same way as in the floating islands or snags of the great American rivers), sank to the bottom, whilst the lighter plants floated, and formed the upper stratum?

The plants thus left upon the muddy slime which had either been drifted with them or derived from the destruction of the lands on which they grew, were subsequently covered by other sediment, sometimes in the form of siliceous sand, at other times of argillaceous matter impregnated by calcareous springs, thus accounting to us for the varied nature of the roofs of the coal-seams, which consist of grit, sandstone, or limestone, according to the condition of the water which succeeded the deposit of each layer of vegetable and earthy matter. We may, however, express our belief, that here as elsewhere some of the coal which is found in strata alternating with marine deposits, may have resulted from the washing away and the entombing at short distances from their original site, of the low jungle edges of tropical islands; in other words, by the sinking into the adjacent sea of floating masses of matted earth and plants.

Strata overlying the Carboniferous Rocks.—Before we quit the consideration of this productive coal tract, we would invite our successors who may have more time at their disposal than we had (for the summer was past when we quitted Lissitchia-Balka), to examine well the succession of strata between that place and Bachmuth. Even in our rapid movements, however, we saw enough to convince us that the carboniferous strata of the promontory of Lissitchia-Balka fold over, and dipping to the west and south, disappear beneath other peculiar limestones, whilst these again (Pl. I. fig. 3.) descend into the vale of Bachmuth, and pass conformably under red marl, limestone, sandstone and gypsum.

In leaving the coal country of Lissitchia-Balka and in passing to Bachmuth, we found the series overlying the Carboniferous promontory near the village of Bielagorskaya to consist, in ascending order, of—1. Yellowish sandy magnesian flag-like limestone, with flattened siliceous concretions and casts of Aviculæ. 2. Yellowish and brown sandstone, with concretions. 3. Massive gypsum. 4. Limestone of much lighter colour than any of the adjacent carboniferous region, in parts cavernous and tufaceous, in parts sandy and magnesian, with some green grains.

This thin-bedded rock, though absolutely subordinate to white and other marls with gypsum, contains small Producti very analogous to fossils of the Zechstein; one, indeed, having since been identified by Mr. J. Sowerby with the *P. horridus* of the English magnesian limestone, whilst another shell is undistinguishable from the *Leptæna sarcinulata* of the Carboniferous rocks. 5. White and grey marlstone in layers with gypsum. 6. Red and brown marl and gritty sandstone, interlaced with gypseous flags and pure white gypsum. 7. Coarse pebbly calcareous deposit (see Pl. I. fig. 3.): these beds are exposed in a succession of low hills within the distance of three versts, and they all plunge westwards and form the eastern side of the vale of Bachmuth.

We have no doubt that this red and yellow group represents as a whole the Permian system hereafter to be described, and we trust that future geologists will be enabled to give other and more detailed sections, showing the exact manner in which the carboniferous strata pass upwards into that deposit, which occupies the valley of Bachmuth and its slopes[1].

Outliers of the Carboniferous Rocks at and around Petrofskaya, &c. &c.—Besides the great southern coal tract, carboniferous strata associated with limestones similar to those we have described, are visible about two versts to the west of the military colony of Petrofskaya on the right bank of the Upper Donetz.

The intervening country between Bachmuth and this spot is occupied by overlying red sandstone (Permian?), Jurassic rocks, chalk, &c. The coal strata which we examined at this spot are exposed in a ravine at a slight elevation above the Donetz and its tributaries, and are overlaid by incoherent materials of reddish sand

[1] In reference to this section, we must state that we urged our friend Major Teploff, who accompanied us, to endeavour to work out this point upon returning to his station. In the mean time it may be observed, that in a memoir illustrated by a small map and several sections, published in the Russian edition of the 'Journal des Mines,' 1838, Capt. Ivanitzki has described the environs of Bachmuth. We feel confident that many of the red rocks near Bachmuth, with gypsum, conglomerate, &c., which he referred to the Keuper and Red Sandstone, constitute an integral part of the Permian system. Indeed our section above proves that they are intimately connected with the limestones with Producti we have just described. The sections of Capt. Ivanitzki exhibit alternations of limestone with green and red clays, gypsum, &c., on the banks of the Kolima, a tributary of the Bachmutka. Other beds of his "marnes irisées" consist of large concretions of gypsum, subordinate to red and green argillaceous marl; and again, other strata, which are horizontal as well as curved and highly inclined, and which occur on the Donetz, Soukaia-plotiva and Bachmutka rivers, are red, greyish, and ferruginous grits and conglomerates, sands, argillaceous marls and clays, calciferous grits (macigno). The whole, in short, is a lithological epitome of the great Permian system hereafter to be described.

and clay. The following succession of beds is developed in ascending order, dipping to the north-west at angles of which 45° may be taken as the average:

1. Highly bituminous, black, subcrystalline limestone, in which no fossils were observed (this rock has an altered aspect).
2. Ferruginous shale with some ironstone, &c.
3. Thick-bedded, mottled, subconcretionary compact limestone, in parts of light grey, in others of dark bluish grey colours, of scaly conchoidal fracture, passing here and there into a ferruginous "lumachelli."

In this limestone Lieut. Vasilief, of the Mining Corps, who was stationed here and obligingly explained the section to us, had collected many fossils, some of which are identical with species which abound in the southern tracts.

4. Sandstone and shale, with impure iron ores.
5. Coal, subordinate to beds of bluish shale or argillaceous schist, formerly worked by a shallow shaft eight toises deep, but now abandoned on account of the influx of water. This coal is about two feet thick and approaches in quality to Cannel coal.
6. Great developement of ferruginous sandstone, occasionally pebbly, with traces of carbonaceous matter.
7. Upper coal-beds, consisting of three seams of small thickness, alternating with shale and worked by shafts, six and ten toises deep, but now almost abandoned.
8. Ferruginous sandstone and shale.

These coal-seams of Petrofskaya having been worked in the most simple manner only, and at little or no expense, it is difficult to say to what account they may eventually be turned, for the small seams alluded to, have been extracted for the use of the military village only, and the whole force employed, with the exception of the engineer, consisted of a few soldiers, placed under his orders at intervals by way of punishment.

As coal has been discovered at Gussadofka four versts north, and at Dimitrofka fifteen versts to the south of Petrofskaya, it would appear (whatever may be the nature of the overlying deposits) that coal-bearing strata constitute the fundamental rocks of this region.

With the improved culture, however, introduced by the military colonies, and the rapid rise into commercial and manufacturing importance of the city of Kharkof, nearly 100 versts to the north of these coal-beds, it is highly probable that the tract around Petrofskaya may eventually be brought into notice. It would, indeed, be highly desirable that the Imperial Government should direct researches to be made between the known outcrops of coal and the city of Kharkof, as the carbonaceous masses *may* extend northwards and be found at moderate depths beneath the cretaceous rocks of that government. It is right, however, to bear in mind, that the coal strata of Petrofskaya are in a highly dislocated condition, with a strike from north-north-east to south-south-west (almost at right angles to the prevailing direction of the great adjacent coal tracts), and with a dip to the north-west; which inclination, if continued, would occasion them to be soon buried at unattainable depths beneath the younger rocks on the north. But should this prove to be the case, and that the coal near Petrofskaya is merely at the surface through local upcasts, still the area over which it has been already seen, and its good quality, may induce the Imperial Government to prosecute the works immediately around Petrofskaya in a scientific and vigorous manner.

General relations and economical importance of the Southern Carboniferous Tracts. In taking leave of the southern coal country, we may be permitted to offer a few observations as to the relative produce of its different parts, and of the capabilities which it seems to afford of future economical development.

The crystalline and granitic rocks which form the nucleus of the whole region being well exposed between the Dnieper and the Kalmiuss, on the banks of the river Voltchia, we have the clearest proofs that the carbonaceous strata, in their extension to the west and north-west, dwindle to thin zones which rest upon these older rocks. In these tracts the limestones and shales disappear and the few traces of coal are associated with sandstone and grit. All endeavours, therefore, to find coal in the drainage of the Dnieper, or within portable distances of that great river, so as to be of use to the manufacturers of Odessa or conveyed at small expense to the Black Sea, must be futile.

Towards the south-east, however, the Kalmiuss, as previously stated, exposes a succession of limestones, grits, shales, with some coal. As no works worthy of notice have yet been opened in this tract, it may seem presumptuous in us to offer any opinion respecting its mercantile value, but judging from the few traces which there occur of any considerable quantity of vegetable remains, and also from the very small developement of the seams, as well as from the nature of the coal itself (with the single exception of Alexandrofsk), we should be disposed to think, that few portions of the tracts watered by the Kalmiuss or its tributary brooks, will be found to contain sufficient carbonaceous matter to lead to works of any utility, beyond the mere supply of the adjacent inhabitants.

We have heard that the researches undertaken by the Russian engineers, and particularly those made under the auspices of M. Anatole Demidoff and conducted by M. Le Play, have afforded a similar conclusion, drawn not merely like our own, from what could be detected in natural outcrops and a few artificial openings, but also from borings at numerous points, as well as from the analysis of the coal-seams discovered.

To the east, however, of the north and south parallel in which the Kalmiuss flows, the carbonaceous matter increases considerably with the augmentation of masses of shale with limestone; and we think that the whole of the ridges south of Bachmuth, and on the east bank of the Toretz (the mines of Jeleznoe (p. 103) afford a good illustration), are well worthy of being largely excavated and carefully examined; for from the elevation of the hills it is evident, that in many of these places the mines could be drained by adits, at a small expense. In their extension to the south-east, the strata, becoming highly arenaceous and argillaceous, lose at the same time their carbonaceous and calcareous features, thin courses of limestone only being apparent; and with this lithological change the coal seams, diminishing in number, become gradually anthracitic, until they acquire in some parts the characters of true anthracite. This tract, particularly its south-easternmost angle, may, we presume, prove of still greater economical value than the district of the Toretz, both on account of the good quality of the anthracite and its comparative proximity to the Sea of Azof; whilst the same physical features, viz. broad undulatory ridges high above the drainage, will equally facilitate for some time the desiccation of the mines, without rendering steam-engines necessary.

By far the richest portion, however, of the coal region, is the north-eastern district, parts of which we have described at Uspensk and Lissitchia-Balka, and which is distinguished by some of the many anticlinal ridges into which this coal tract has been thrown. The strata plunging to the east and north are lost beneath the chalk, and to the south-west they pass beneath younger rocks, including the equivalents of the Zechstein. It is, however, most important to bear in mind, that the most productive portion yet known, is that which is directly in contact with the cretaceous rocks, and hence we may hope, that at some future day, when the coal shall have been exhausted on its outcrop or in the ridge of Lissitchia-Balka, it will be found beneath the adjacent chalk on the left bank of the Donetz, like the coal under the chalk at Valenciennes: and if so, we venture to predict, in less disturbed positions than in the anticlinal ridges on the right bank of that river, which are so instructively displayed between Lugan and Lissitchia-Balka.

We do not lightly throw out this anticipation. Our acquaintance with the phænomena in Russia and the analogies of Great Britain and France, enable us to support it. For as the carbonaceous matter increases in volume to the north-east, what is there, we ask, to prevent its extension beneath the chalk? From our experience in coal-fields (that of Dudley is a beautiful example), we know that thick beds of coal never disappear *per saltum*, and that when followed and regained beneath contiguous strata of more recent age, the coal is often in unbroken sheets, and is then of higher commercial value than where it has been thrown up to the surface by former convulsions of nature. Without such convulsions, man, it is true, might have long remained ignorant of its existence, but with increased knowledge he follows the coal from its disturbed outcrop, and is amply repaid by finding it at lower depths and often in great and uniform masses. Attention to this simple rule cannot be too strongly impressed upon the minds of the Russian authorities.

If, however, the working of these coal-mines beneath the cretaceous rocks is a problem not likely to be solved in our day, we may, at all events, suggest the safe experiment of boring through the masses to the west of Lissitchia-Balka, near the spot where the lowest beds of certain overlying deposits have been described. If correct in our belief, that such overlying strata are of the age of the magnesian limestone, there is every reason to conclude, from what we know of the general structure of Russia, that the carboniferous deposits beneath them will partake of the same slight inclination; and we need not add, that if coal seams, as productive as these of Lissitchia-Balka, were found under such favourable circumstances and so near to the town of Bachmuth, the discovery would be most important. The great impediment to the steady working of these coal-fields is their highly dislocated and contorted condition, and we therefore repeat, that the object of the Administration of Mines should be pointedly directed to the establishment of works wherever the beds are least disturbed.

The process of coal-mining has, in fact, been the same in the more advanced tracts of Western Europe. In the olden times of England no one thought of sinking for coal, except at spots where the mineral cropped out; and we can all remember when those geologists who recommended a search after it by penetrating the magnesian limestone (Zechstein) were treated with derision, and yet nearly half the fuel of London is now extracted from strata in that position The day may therefore come when the old works of Lissitchia-Balka having been exhausted, the coal-mines of Bachmuth shall render that town most flourishing.

But whether mining operations be confined, as at present, to the country where the carboniferous strata crop out, or hereafter extended by deeper shafts to other contiguous tracts, it is obvious that there exists in this region a quantity of coal of good and fair quality, which, if opened out with spirit and industry, will thoroughly justify the anticipation of Peter the Great, that it would benefit his descendants. Quantitative results, however, can only be measured by succeeding ages, when it may suit the interests of Russia to render the country in which the coal and limestone abound, the seat of mines and manufactures. In the mean time, though we have no desire to raise delusive hopes, and though we believe that this region will never be found to contain the same amount of mineral as any one of the productive tracts of Western Europe and America, we are justified in saying, that where steam-engines are not used (and with the exception of a small one at Lissitchia-Balka they are unknown) any coal-field must be considered in a virgin state when compared with the great carboniferous deposits of other countries. In the British Isles, at all events, we may affirm, that if no coals were extracted, except those which could be procured without the aid of steam, the natural supply would sink at once to a thousandth part of its present extent, and with this defalcation, Great Britain might quickly relapse into her condition of four centuries ago, little differing from that of the tracts in Southern Russia which we have been considering, and which at present are almost exclusively occupied by an agricultural people.

Having now described all the carboniferous districts in the central and southern regions, we will next give a brief sketch of the deposits of this age on the western flanks of the Ural, and then terminate our account of the Carboniferous system of Russia by a general review of its organic remains.

Postscript.—After the preceding pages were printed, we received a copy of the Fourth Volume of the splendid work of M. Anatole Demidoff, 'Voyage dans la Russie Méridionale,' which is entirely devoted to the description of the Carboniferous region of the Donetz. M. Le Play, an eminent French engineer, happily selected by M. Demidoff to ascertain the true mineral wealth of this tract, and to describe its physical and geological structure, has produced a work so replete with well-digested details, collected, not only from observations of the natural features of the region and the mines which have already been commenced in it, but also by numerous borings carried on by himself or his assistants during a period of three years, that the Imperial Government will doubtless feel grateful to the accomplished person who has so liberally fostered these inquiries.

In a large geological map, in which the demarcations of the carboniferous and crystalline rocks, and also of the overlying Secondary and Tertiary deposits are given, M. Le Play has grouped under darker colours, such parts of the tract as are known to be productive of coal, to distinguish them from those in which the mineral has not yet been discovered. This method, doubtlessly, carries with it a certain amount of information, but is deficient in stratigraphical meaning, for some of the beds so marked are in higher positions than others; in some the coal is interlaced with limestone, and in others it is almost entirely subordinate to sandstone and shale; in one tract anthracite exclusively prevails, in another bituminous coal. By reference, however, to the explanation, and, above all, to an admirable series of tables, this defect is obviated. These tables are, in fact, perfect models for the practical mining engineer; they give at one view the direction, inclination, thickness and quality of the coals at each locality, also the characters of the associated strata, as well as the state of the works, and their produce at each mine or spot of trial. To these is added another set of tables, in which the chemical analysis of the coals from forty-three different places is given by M. Malivaud, another agent of M. Demidoff.

Into such details, valuable as they are, it was not our province to enter, and we will now, therefore, merely offer a few remarks explanatory of those points in which our geological conclusions either agree or are at variance with those of M. Le Play.

We have stated that the fossils which he had brought to France, and which we inspected before our journeys to Russia (1840), first led us to believe, that the coal beds are chiefly subordinate to the carboniferous limestone. Of this, indeed, there could be no doubt, for the species were, to a great extent, the very same as those with which we were familiar in rocks of that age in Western Europe. On interrogating M. Le Play, however, we could not ascertain that he had arrived at any defined idea of *a succession* of strata, derived either from the stratigraphical order of mineral masses, or from their imbedded organic remains. In fact, he then distinctly acquainted us with what has now appeared in his work, that, owing to the disturbed and convoluted condition of the strata, the want of persistency of mineral characters, and the apparent existence of similar species of shells throughout the series, it was impracticable to assign a base line to the deposits, or to trace their uppermost limits, still less a passage into any superior formation. Now as we have ventured to effect these objects, we will here briefly state why we conceive M. Le Play did not arrive at similar results, although he had in his own hands some means of proof, which, through the hurried nature of our visit, we never obtained.

No geologist, however practised, can, we venture to say, explain the structure of a part of a complicated distant country, unless he has made himself master in undisturbed tracts, of the succession of its normal formations. Long as we have been occupied in the study of the Palæozoic rocks, we are confident, that had we been thrown suddenly into the chain of the Donetz, and had been desired at once to unravel its complexity, we should have reached no other geological result than that of M. Le Play. We had, however, by two years of extensive comparative researches, obtained an intimate acquaintance, not only with the older Palæozoic rocks of Russia generally, but in reference to the Carboniferous system, had convinced ourselves, that throughout the enormous area over which we had traced it, the upper or great coal formation of Western Europe was absent, and that the calcareous or lower group, occupying the whole carboniferous horizon, was by help of certain fossils divisible into three stages. Again, we had ascertained by numerous sections on both flanks of the Ural Mountains, that, in becoming part of a mountain mass, this system, so uniform and so peculiar over so vast a space, there put on many of its ordinary features so well known to those who have studied the carboniferous limestone only in the western parts of Europe.

We further learnt, that, in the absence of any deposits to represent our coal-fields, the Carboniferous system was there succeeded, in ascending order, by a vast series of red and cupriferous deposits to which we have assigned the name of Permian. It will not, therefore, be arrogant on our part to say, that we entered upon the examination of the territory of the Donetz possessed of elements of comparison which no previous travellers had acquired.

Our task was, therefore, less difficult. Knowing from the maps and instructions furnished to us by the Administration of Mines, that the major axis of this tract and the main direction of the strata trend from west-north-west to east-south-east, we resolved, after terminating our researches in Southern Russia, to examine the chain of the Donetz in parallel lines, transverse to its general strike, and, by carrying out this scheme, we arrived at the conclusion, that the oldest member of the series occupies its southern frontier, and that after a multitude of flexures the central strata dip under the upper Fusulina limestone, the whole group being surmounted in the valley of Bachmuth by the equivalents of the Permian system.

Our readers will have seen how much importance we attach to the presence of the large *Productus giganteus* as uniformly characterizing (over vast regions in Russia) the lowest beds of the carboniferous limestone, and we were aware, as before stated, that M. Le Play had collected this fossil in the chain of the Donetz, though the exact locality was unknown to us. We were, indeed, assured by Colonel Olivieri, that he had found this species in the great

Scar limestone, near Karakuba, though we did not ourselves detect it; and reasoning upon this fact together with evidences of an ascending order from south to north, and by acquiring proofs, unknown to previous geologists, of the existence of upper members of the series charged with Fusulinæ, we completed our section by expressing our belief in the passage of the higher carboniferous deposits into the Permian rocks.

We now learn from M. Le Play, that the *Productus giganteus*, of which he collected many individuals, occurs at Rubejnoi on the Lower Donetz, in the southern part of the region, and he thus completely confirms our idea of an ascending section from south to north. Though at one time at a short distance from that spot, we unluckily did not visit it, but M. Le Play's faithful detailed sections are quite sufficient for our purpose; for after describing the limestone as massive and important, he says, that the mineral associations with it are *different* from those limestones on *the north, in which many more seams of coal occur* than in the strata of the Lower Donetz.

In fact, the examination of the carboniferous region of the Donetz is one of the most striking examples which can be adduced, of the paramount importance to the practical miner, of the close study of organic remains in reference to the normal positions of the strata; for throughout deep sections in the northern part of this territory, there is not a trace of the great Productus, whilst all the fossils of the middle and upper strata are present. Any one, therefore, who had felt as confident as we do, that this remarkable fossil was as clear an indication of a lower band as the *Spirifer Mosquensis* and Fusulinæ were of an upper, could not have doubted of the general relations and order of the strata in the chain of the Donetz.

Nay more, the evidence now so clearly laid before us by M. Le Play, in substantiating the value of our stratigraphical tables, enables us also to speculate upon a parallel between the lowest anthracitic beds of this territory and the lower coal of the Valdai Hills, Tula and Kaluga (p. 71 *et seq.*). In the south-eastern limb of the country of the Donetz, the beds of anthracite and hard sandstone and schist which have a prevailing northerly dip, may fairly be supposed to rise out, like the thin coal of the Valdai, from beneath the limestone with great Producti, whilst the proximity of the crystalline axis of the southern steppes may well account for the indurated and metamorphic character of strata which we have described under such a very different lithological aspect in the Valdai Hills and in the governments of Tula and Kaluga, where they occur almost in their original condition of sand and clay, and are far removed from the influence of all intrusive rocks.

Agreeing in the correctness of the general parallel which M. Le Play has drawn between the carboniferous deposits of the Donetz and the carboniferous limestone of Great Britain, Belgium and France, we do not believe that beyond this point his comparisons can be sustained. The carboniferous deposits, "terrain houiller," for example, of the Low Countries and of Düsseldorf, with which we are well acquainted, do not offer, as he supposes, an analogy to those of the Donetz; for in the Rhenish provinces coal-seams are in no instance interstratified with the Mountain Limestone series of English geologists, but are invariably superposed to such rocks. Again, in these Prussian and Belgian districts, the mountain limestone with sands and shale, but void of coal, reposes on an elaborate succession of Devonian and Silurian rocks, loaded with typical fossils; whilst the group of the Donetz, unlike that of the north of Russia, is exclusively carboniferous to its base, and rests at once on very ancient crystalline rocks, or abuts against porphyries and other eruptive masses.

And even if we admit that there is to some extent an analogy between the carboniferous rocks of South Russia and the Low Countries, in both being overlaid by cretaceous deposits, we must also not omit to recognize, in the one case, the presence of intermediate strata of the age of the Zechstein, and in the other the total absence of that deposit.

The true foreign analogy, therefore, of the coal strata of the Donetz, considered in reference to other deposits of the same age, is to be found in the north-western or Lake districts of England, where some seams of coal lie below and others are interstratified with the mountain limestone series and its sandstones and shales. The coal-field of Berwickshire, or that below the mountain limestone, is much richer in contents than the south-eastern portion of the tract of the Donetz, which we believe to be on the same parallel; whilst in identifying the rest of the succession, or the great mass of the Donetz, with that of the Mountain Limestone group of Northumberland and the Yorkshire dales, the comparison, as to amount of produce, is largely in favour of the Russian deposits.

To considerations of theoretical importance concerning the changes which the surface of Southern Russia has undergone, and which are ably put forth by M. Le Play, we shall not at present advert, reserving our views on these points for the concluding chapters of our work, when all the elements which we can bring together shall have been laid before our readers, to enable them to see the grounds upon which we come to our conclusions.

For the present, then, we take leave of this volume of M. Le Play, which, though it contains views from which we differ, we regard as an important addition to the records of physical science, and as possessing infinitely more the character of a good monographic description of one tract, than anything which, from the extensive nature of our researches, we are enabled to offer.—*February* 15, 1843.

CHAPTER VII.

CARBONIFEROUS ROCKS ON THE WESTERN FLANK OF THE URAL MOUNTAINS.

Section on the banks of the river Tchussovaya, showing a passage from Carboniferous Limestone, through Millstone-grit and Coal to overlying Conglomerate, Calcareous Grits, &c.—Section from Nijni-Serginsk to Sarana, exhibiting Goniatite Grits overlying Carboniferous Limestone.—Bands of Carboniferous Limestone near Sterlitamak.—Prolongation of Carboniferous Limestone along the South Ural and ascending Section from it through Goniatite Flags and Grits into Permian Deposits.—Review of the Organic Remains of the Carboniferous System.

HAVING detailed the succession of the Carboniferous strata in the northern and central parts of Russia, it might appear desirable to pass at once to the consideration of the next group in the ascending series. Believing, however, that the region to which we now call attention, contains within it certain peculiar upper beds of the Carboniferous epoch, not seen in other parts of Russia, we think that by describing them, we shall best convey a clear idea of the transition to the superior deposits or Permian rocks, the history of which is to occupy the two following chapters.

In a subsequent sketch of the Ural Mountains the carboniferous rocks will again come frequently under consideration, both as respects their relations to the lower formations, and the lithological changes they have undergone by plutonic action. Our present purpose is briefly to explain their structure and position in the country composed of the hilly grounds to the west of the Ural ridge, and to show how they dip under and are connected with the next overlying or Permian deposits.

By looking over the Map the reader will perceive, that towards the central portion of the Ural, the carboniferous limestone is divided for a considerable distance into two bands, one of which (the eastern or main zone) follows the sinuosities of the older rocks on which it rests. The outer zone is, in fact, the indication at the surface, of a line of upheaval parallel to the Ural chain, and as we shall revert to this subject hereafter, it is sufficient now to state, that as far as our own observations went, this band, running for the most part in a tract of little elevation, and much obscured by local detritus, seldom exhibits its relations to the superior deposits. We therefore commence our account of the carboniferous rocks of this region by describing the limestone on the west flank of the North Ural, where it forms one band only, as exposed on the banks of the Tchussovaya, a tributary of the Kama, and where it dips under deposits differing considerably from any which we have described in other parts of Russia.

Section of the Tchussovaya.—Carboniferous Limestone, Millstone Grit, Coal, Calciferous Grit, Flags, and Conglomerate (3 and 3' of Map).—The lowest member of the system, resting upon and passing conformably downwards into the Devonian rocks, is exhibited most distinctly, in several grand flexures on the banks of the Tchussovaya, to the east of its tributary the Coiva. It is there a light grey, crystalline, compact limestone of very great thickness, much resembling the great Scar limestone of the north of England, or the equivalents of that rock in the Bristol and South Welsh coal-fields, and is charged with large Producti and many characteristic fossils.

A few versts to the west of Kinofsk[1], the lowest beds of this limestone, or those in contact with the Devonian rocks on which that Zavod is situated, consist of great masses of amorphous structure, in some places forming troughs, in others rising up into precipitous peaks, the beds in which are occasionally vertical. These limestones are distinguished by containing many concretions of flint and chert, and at one spot, called Moultic, we collected the *Productus giganteus*, *P. comoides*, and other fossils characteristic of the lower strata.

No description of the geologist, still less a mere sectional drawing, can convey an adequate idea of the contortions and pictorial beauty of these wild gorges. The flexures on the Meuse may, in some respects, be compared with them, but the channel of the Tchussovaya being narrower, the rocks more rugged and diversified with foliage, and the defiles highly intricate, the Russian scene appeared to us to be more striking than that in Belgium[2].

[1] The property of Count G. A. Strogonoff.

[2] We very much regret that since our return to England, certain sketches of these gorges have been lost, or we should certainly have given lithographic illustrations of this grand scene of contortion, in

After various grand undulations, in which limestone, sometimes dolomitic, constitutes three-fourths of the river cliffs (schists and quartzose grit being rarely seen), the uppermost portion of the formation is admirably exposed in rocks on the right bank of the river, a little to the east of Ust-Coiva. The strata are there exhibited in beds inclined to the west at an angle of 70°, and by pacing across them, as far as they were visible, we estimated the thickness of this one member of the limestone to be not less than 1000 feet (*a* to *b* of section beneath).

Some of these beds are of light grey, others of brown colour; their fracture is conchoidal, and they contain among other fossils the *Spirifer Mosquensis*, which unquestionably refers them to the same age as the white limestone of Moscow.

The woodcut which is here annexed will give the reader an idea of the manner in which these limestones subside under hard quartzose sandstones, and afterwards emerge in anticlinal flexures, to the west of Ust-Coiva.

21.

At the spot where it dips under the grit, the limestone is in the condition of a yellow decomposing dolomite.

Millstone Grit and Coal.—The rock which immediately surmounts the limestone, on the Tchussovaya, is a hard siliceous sandstone, occasionally coarse-grained, which is undistinguishable from certain varieties of the millstone grit of English geologists, and is actually worked for millstones. This grit occupies the higher grounds or plateaus where the limestone has not been raised to the surface, and is seen in several troughs on the banks of the Tchussovaya, to the west of Ust-Coiva. It is of considerable dimensions, and when followed to the west is found to contain impressions of carboniferous plants.

At about twelve versts east of the village of Kalino, and on the property of the Princess Butera, beds of coal have been found subordinate to this formation. Two galleries have been driven into the rock at different levels. In the lowest of these works, the strata were found to plunge 40° to the west-north-west, a bed of coal of

which the rocks are beautifully decked with northern forest trees and many flowering plants, *Cypripedium calceolus*, *Orchis*, *Stachys*, *Vicia*, &c. Caverns are not unfrequent, and as usual in most countries bordering on Siberia, several of these are called the caves of Yermac, and in which the Cossack conqueror of the Siberian Tatars is supposed to have been concealed, after his early disasters.

middling quality being covered by yellowish grey, arenaceous shale and white siliceous grit. The upper gallery showed the strata to be inclined 25° to the north-east, with coal of good quality and of about three feet in thickness, intercalated between two bands of siliceous grit, the whole covered by shale and impure coal. The beds of coal which are known to crop out on the river Kosva in the property of Prince Lazaref, belong exactly to the same place in the series, and we have little doubt, that all the coal which has been spoken of as existing along the western flank of the North Ural, occurs in this member of the system. There is, indeed, in these gorges so clear and complete an exposition of all the beds of the carboniferous or mountain limestone, properly so called, from its junction with inferior Devonian rocks to its dip beneath the millstone grit, that we are assured beyond the possibility of doubt, that in this eastern region, coal is never found subordinate to or below the limestone, as in the other parts of Russia which we have described. England, indeed, affords within itself parallels to all these Russian examples and many additional cases. Her greatest coal-fields, for example, are all superior to the millstone grit, which in Yorkshire, however, does contain workable seams of coal, whilst Northumberland and Berwickshire contain numerous bands of good coal, both in the carboniferous limestone and inferior to it.

Goniatite Grits.—The limestone and millstone grit of the Tchussovaya above described, are succeeded to the west by coarser grits of greenish-grey and yellowish colours, and which, where we observed them, are as little inclined as the great Permian deposits which flank them on the west. At the mouth of the Usva, below Kalino, they appear in the form of coarse conglomerates. Still further to the west, near Gorodok, are deep pits which formerly furnished salt, and in a section of about 200 feet in thickness we observed the following order of beds :—

	Feet.
Conglomerate of rounded siliceous pebbles, imbedded in grey grit	15
Grit	40
Sandstone, finely laminated, with bluish shale and plants, chiefly Calamites, one of which resembles *C. remotus*, another *C. cannæformis* (Brong.)	8
Greyish grit, in strong bands, yellowish at the surface	10
White and yellow shale (marl), alternating with thin beds of grit	10
Grits, &c., resembling 4 and 5	5
Beds resembling No. 5	4
Calcareous grit, with calc-spar	3
Grit, like No. 4.	10
Marly shale, like No. 5	10
Dark-coloured fœtid limestone, with schistose grit	20
Blackish schist, somewhat marly	50

Though these beds are apparently horizontal when viewed in one section, they are, in fact, subject to considerable undulations, as may be seen about three versts from Gorodok, where they rise into a dome.

The same formation of grey grit (often a calcareous, yellow sandstone, with some shale and pebbly conglomerate) occurs on the sides of the high road from Kongur to Ekaterinburg. Flagstones and yellow sandstones with shale are seen near Yellim, where there are many impressions of plants, among others the *Calamites remotus* (Brong.). Between the post-stations of Bisserskaya and Klinova, the sandstones are succeeded by conglomerates composed of pebbles of quartz, felspar, and Lydian stone, with fragments of ancient fossiliferous limestone in a base of calciferous grit. These beds repose upon the same series of siliceous sandstone and carboniferous limestone which has been described upon the Tchussovaya. In fact, the overlying calcareous grits and conglomerates of which we are now speaking, are all members of the same group, which here occupies a wide and undulating trough, having the carboniferous limestone on either flank.

It is by following these strata to the south, viz. to the banks of the river Ufa and its tributaries, that we are best enabled to test their precise age, by finding them charged with characteristic fossils.

Section from the flank of the Ural at Nijni Serginsk to Sarana.—The traveller who follows our course, and descending from the western flanks of the Ural by Nijni Serginsk, directs his course towards Artinsk, traverses in the first instance a calcareous country of obscure relations. He will find one band of limestone (the red colour and No. 2. of our Map), charged with Devonian and Eifel fossils, thrown into reversed positions, like others to which we shall advert in our description of the Ural Mountains, whereby the younger beds are, in fact, bent under those of more ancient date,—a common phænomenon on the flank of eruptive chains. Leaving these picturesque Devonian limestones at the Zavod of Michaelofsk and crossing the Ufa, a band of crystalline carboniferous limestone is seen, and immediately above it are horizontal beds of a grit similar to that which has been described. We would here, however, observe that this tract is replete with rocks of intrusive character, and that sandstones, which we believe to be of the same age as the millstone grit before described, appear near Nijni Serginsk in the form of altered quartzose rocks, which will be described in the sequel. The overlying calcareous grit is highly fossiliferous, and contains Producti and corals. Occasionally, indeed, it passes into a very coarse conglomerate, made up of siliceous schist and black and white quartz, but sometimes containing fragments of the older Silurian and Devonian limestones with Pentameri and other fossils. This fossiliferous grit, generally known in Russia as the "Gres d'Artinsk," occupies a large surface of country: usually covered by verdure and little excavated, it is seldom exposed in good and deep sections. Upon the Ufa, however, ten versts from Artinsk, we met with a quarry which furnished us with four new species of Goniatites. One of these is very closely allied to known forms of the Carboniferous system, and holds a place intermediate between the *Goniatites striatus* (Sow.) and the *G. Listeri* (Sow.), combining the ornaments of the shelly covering of the former with the general outline of the latter. These Goniatites are, indeed, associated with unquestionable carboniferous fossils, one of which is the *Nautilus tuberculatus* (Phill.), fragments of Orthoceratites, &c., and thus all doubt concerning the age of the beds is removed.

The bands of grit in this quarry are of yellowish, brown and grey colours, from one to four feet thick, and are separated from each other and surmounted by shale. The grit is both fine and coarse-grained, and occasionally passes into a conglomerate, the whole having here a thickness of 100 feet. A quantity of plants, which we believe to belong to Lepidodendron and Calamites, but of which we regret not to have brought away good specimens, are interlaced with the Goniatites and other shells, among which is a small Orthoceratite. The most curious of the vegetable remains are numerous small fruits about the size of a large nut[1].

In continuing the section to the west of Artinsk, the same group of beds is prolonged to near the Zavod of Sarana, where a hill at least 500 feet high, is composed of strata of carboniferous limestone, which rise out at a sharp angle from beneath the basin of calciferous grit and conglomerate we have just described.

Let us for the present pass over the phænomenon of the unconformability of the Goniatite grit in this tract to the carboniferous limestone, due doubtless to local dislocation, since we shall adduce an example of complete conformability on the flanks of the South Ural. It is sufficient for our present purpose to point out, that this rock clearly overlies the limestone and millstone grit, and that by their fossil contents, all these deposits must be grouped in the same system The carboniferous limestone on the banks of the Ufa (we are now speaking of the western

[1] Some of these nut-like remains of plants were brought away. They resemble certain fossil fruits which we have since obtained through Mr. J. Walker of Calderstone House, near Liverpool, from the gritty sandstone of Wickersley, east of Rotherham, and near the junction of the coal measures with the overlying red sandstone and magnesian limestone.

band before alluded to) occupies cliffs 400 feet in height, and is filled with *Spirifer Mosquensis*, *Productus antiquatus*, and *P. concinnus*.

Carboniferous Limestone near Sterlitamak.—The inner and outer zones of carboniferous limestone which we have sketched, are probably confluent a little to the south of Ust Simsk. Our survey, however, of the western flanks of the Ural was not sufficiently detailed, to enable us to ascertain this point precisely, nor yet to trace a continuous zone of Goniatite grits and flags, to the west of the outer band of limestone. In emerging from the Ural, by a traverse from Ufinsk to Ufa, we found ourselves suddenly in a low, obscure tract occupied by red deposits. In quitting the chain, however, by another parallel traverse from Verch-Uralsk to Sterlitamak, the same carboniferous limestone is again seen to range upon two lines from north to south, inclosing between them a small trough of Permian deposits, composed of gypsum, limestone, red marl, &c. The innermost of these bands forms the boundary of the mountainous region, being a calcareous fringe which hangs upon the red conglomerates and older rocks of Devonian and Silurian age. Whatever inversions and contortions may be seen in the Northern Ural, we here distinctly perceive the lower beds of the carboniferous limestone, with *Productus striatus* and other fossils, reposing upon a quartzose series of beds of reddish colour, spotted with green, and in many parts much resembling the Old Red Sandstone of Scotland; like which it contains pebbles, and is in parts a conglomerate. These relations are seen on the western flanks of Akritau, as is expressed in the coloured transverse section from the Ural to the west (Pl. IV. fig. 1.). In their range to the east, or among the mountains, these calcareous beds are subject to many dislocations, but where they terminate by a great fault against the low country watered by the rivulet Ziganofka, they are in almost horizontal positions. In these cliffs the limestone is both of light grey and black colours, with white veins, is often flaglike and fissile, with numerous thin courses of black flint, and contains the *Spirifer Mosquensis* and many carboniferous fossils.

The outer zone of limestone which rises from beneath the trough of Permian rocks, running nearly from north to south, and close along the left bank of the river Bielaya, is marked by four subconical hills, which appear like volcanic elevations in the flat district, in which they are protruded to the surface. The hill of Tchekatau, immediately to the east of Sterlitamak and the third of the peaks counting from the north, may be described as a good example of the ridge. It is a rugged, bare rock of some height, with a double top, which rising abruptly from the banks of the Bielaya and its tributary the Salaüst, is exposed in a most instructive anticlinal form, the strata dipping sharply to the east and west. To the east they plunge at a moderate angle beneath other flaggy limestones with gypsum; whilst to the east the beds are almost vertical, and terminate in a great fault or depression, in which the Bielaya runs from north to south (see coloured section, Pl. IV. fig. 1.).

The limestone is of light grey and brownish colours, and is in part a mass of shells. Among these we identified *Productus antiquatus*, *P. lobatus*, *P. punctatus*, *P. spinulosus* (Sow.), *Spirifer lineatus* (Sow.), *P. quadriradiatus* (nob.), *Leptæna sarcinulata* (Hüpsch.), *Terebratula pleurodon*, *Orthis Michelini*, *O. arachnoidea*, Orthoceratites, and the little Trilobite of the Valdai Hills, *Otarion Eichwaldii*. On the whole, the beds which are exposed, may be of rather younger age than those to which we have just alluded, as occupying the western flank of the mountains, but there are no traces of the overlying Goniatite grits.

To the south of the parallel of Sterlitamak, the outer zone of carboniferous limestone soon subsides, but the direction of an anticlinal line is continued far to the south of Orenburg, as will be hereafter explained, in describing the Permian rocks at Grebini, &c.

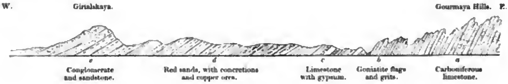
We did not follow the inner carboniferous zone, which is marked upon the Map, as continuous from the south-east of Sterlitamak to the gorges of the Bielaya, where that river escapes from east to west; but if the ridges be continuous from north-north-east to south-south-west, it is evident that the strike of the strata must be very oblique to the course of the hills,—a phænomenon, indeed, by no means peculiar. To the south, however, of the Bielaya, the carboniferous limestone occupies a number of small ridges parallel to each other, and all trending from north to south, as beautifully and correctly expressed in a MS. map presented to us by General Perofski, and a slight expression of which is attempted in our small general map of the Ural. In these ridges, however, the geographical outline is in perfect harmony with the strike of the strata. Occupying a zone of some breadth, this carboniferous limestone, in which we found fossils characteristic of both its highest and lowest members, ranges down to the Sakmarka, where that river flows transversely to the chain[1].

[1] It is in the midst of this band of parallel ridges of limestone that the country quarters, (Katchufka) of General Perofski are situated, amidst some of the many beautiful landscapes which the South Ural affords.

In the annexed woodcut the spectator is supposed to be looking from near the Ural river on the south, towards the edges of the strata which are washed by the river Sakmarka, and the section explains how these calcareous rocks pass conformably under the Permian deposits which overlie them to the west (see Map).

From the post-station of Verchni Ozernai, we made an excursion to the edges of the adjacent mountains, there known under the name of the Gourmaya Hills, and near the Baschkir village of Kundrofka, on the right bank of the Sakmarka, we found the following ascending series, clearly exhibited in beds highly inclined and dipping to the west.

22.



The rocks forming the mass of mountains to the right, consist of carboniferous limestone, which graduates upwards into a flagstone series. The latter is succeeded by bands of calcareous grit and flagstone, many of which have the same composition as the grits of Artinsk, and contain Goniatites, Encrini, and other small fossils, together with plants, &c.

As these strata plunge directly under other calcareous rocks with gypsum, followed by cupriferous red sandstones and conglomerates, all of which partake of the elevation of the chain, and dip more or less sharply to the west, we hailed this section as the most important which we had observed, in showing the passage from lower to higher carboniferous strata, and from the latter into another system characterized by a different group of fossils. These overlying deposits will be taken into consideration in the following chapter.

General Remarks on the Fauna of the Carboniferous system of Russia.—The reader who has followed us in our preceding enumerations of the carboniferous fossils, in different parts of the empire of Russia, will be not less struck with their general resemblance to those of the same age in Western Europe, than with the marked differences between them and the forms in the older palæozoic rocks of this region. One or two species, only, of the Devonian fauna have been detected among the numerous carboniferous types to which we have referred; and even these may, upon a strict scrutiny, prove to be distinct varieties. If, indeed, the *Leptæna sarcinulata* (Hüpsch), which is very prevalent in the carboniferous strata of Russia, should eventually be pronounced to be the same species as the *Leptæna lata*, so typical of the Silurian rocks of Britain—an opinion which is already entertained by no less an authority than M. L. Von Buch, and also by one of us[1]—it offers a very puzzling problem in the distribution of marine remains, for of this shell there is not a trace in the well-examined Silurian deposits, nor even in the Devonian deposits of Russia; whilst, on the other hand, as will be shown in the sequel, it has in these regions been first brought into existence in the carboniferous age, and has been continued into its uppermost members. Such a striking anomaly as is offered by this singular exception, may therefore render us cautious in identifying all species by their external forms.

Without, however, dwelling upon a solitary exception, we invite attention to the remarkable proofs which Russia affords, of an almost completely new creation of species in the carboniferous epoch; a fact which is the more remarkable, when we know, that by far the larger portion of the vast area under review has not, during these ancient epochs, been the theatre of any violent catastrophes; but that, on the contrary, the deposits have there succeeded to each other in the most tranquil manner. Enormous tracts, however, it must be admitted have been periodically raised from beneath the sea by grand oscillations, of which the central dome of Devonian rocks (p. 53) is a striking example; and parts of the bottom of the carboniferous sea have then been added to this continent, to form, in their turn, the shores of newer accumulations, which will hereafter be described under the name of the Permian system.

The Carboniferous rocks of Russia are rich in characteristic organic remains, and though the lists which we have to offer are not so copious as those which have been derived from the more diligently explored rocks of similar age, in other parts of Europe, they completely answer the views of the geologist. In a word, many well-known species represent exactly the fauna of this epoch, and serve as a sound basis for reasoning, which future discoveries may slightly modify, but cannot destroy.

Of ichthyolites, so remarkably abundant in the Devonian epoch, there are very few traces in the carboniferous limestone; a fact which may be theoretically ex-

[1] M. de Verneuil. See the reasoning on this point in Part III.

plained on the principle of certain peculiar submarine conditions, to which allusion has already been made (see p. 64). The few which have been discovered, including a fine ichthyodorulite[1] and some small teeth, are, however, quite distinct from the remains of fishes of the preceding period. Trilobites, so profuse in the Silurian epoch, and so very rare in the Devonian, are also but little developed in the carboniferous age; two small species only having been found, which are very closely allied to the trilobites of the mountain limestone of England and of Belgium. A Cytherina, or minute marine crustacean, also found in those countries, has been detected at two or three places in Russia, where, as will have been observed, the genus is not limited to rocks of this age, but commencing life in the later days of the Devonian epoch, its existence was prolonged, as will hereafter be shown, into deposits of the age of the Zechstein.

The Cephalopoda, so numerous and of such varied forms in the carboniferous deposits of the West of Europe, are, on the contrary, very rare in Russia. Of Orthoceratites we are as yet acquainted with two or three distinct species only, and Goniatites, unknown throughout the great mass of Russia in Europe, are found in certain upper strata only, on the flanks of the Ural chain. To some of these we have already alluded, as existing in the grits of Artinsk, but when we come to explain the structure of the Ural, and to show the nature of the carboniferous limestones on the Asiatic side of that chain, it will then appear, that at a spot distant upwards of 2500 miles from the British Isles, Goniatites are there found (with many other shells) absolutely identical with those of the English and Belgian carboniferous rocks. The Nautili are as scarce as other Cephalopods. We identified, however, the *N. tuberculatus* as common to the Ural mountains, Vitegra and the Valdai Hills; and the country of the Donetz affords the *Nautilus Leplayi* (Nob.). Bellerophons are indeed pretty plentiful, but, for the most part, their shelly matter has disappeared, and they are to be observed in the form of casts only. A good exception to this remark is that in the Valdai Hills, the *Bellerophon clathratus* (D'Orb.) and *B. depressus* (Eich.) were both found in complete preservation, the former being undistinguishable from British and Belgian species.

The Brachiopods, and particularly the Producti, abound to such an extent, that the mountain or carboniferous limestone, here as elsewhere, might well be called "Productus Limestone." And what is still more remarkable, the species are almost

[1] This ichthyodorulite was found by Colonel Helmersen.

everywhere the very same as those of our own countries. Among the most common of these shells are the *P. giganteus* and *P. striatus* (both characterizing the lower beds), the *P. antiquatus* and *P. punctatus*; all well known as the most common forms of the British mountain limestone.

The Spirifers offer less variety than those of England, and we are not able to enumerate more than seven or eight species. The most remarkable and most generally diffused is the *Spirifer Mosquensis*, which invariably characterizes the central mass or white limestone of Russia, and is never found in the lower stratum.

The most prevalent corals are the *Chætetes radians*, *Lithostrotion floriforme*[1], the undescribed species of the English mountain limestone to which we have often referred, the *Gorgonia retepora*, and *Retepora laxa*. In the Ural Mountains and on their flanks, the two latter polypifers are highly useful in enabling us to distinguish the carboniferous from the Devonian limestone, when these rocks graduate into each other, and are subjected to the same flexures. Gorgonias and Retepores, we may observe, are evidently of the latest creation among the corals of the palæozoic rocks, for they occur even in the overlying Permian deposits.

Encrinites are not wanting in the carboniferous limestone of Russia, but they seem to be less abundant in it than in England, and the heads or stomachs of these animals, by which alone their specific characters can be well determined, are exceedingly rare.

Lastly, the creatures which, approaching to the lowest scale of organization, particularly attract our attention as peculiar to the carboniferous deposits of Russia, are the Fusulinæ, foraminifers closely allied to the genus *Nonionina* of D'Orbigny[2]. Russia is the only country in Europe in which such minute beings are found so low in the series of deposits, and there they so abound, that, like the Nummulites of the older tertiary and youngest secondary deposits, they constitute thick masses of rock; and from the fine lamination ot the strata, seem to indicate the existence of a very tranquil sea, during the long time throughout which they were accumulated. We have described such rocks upon the Volga near Samara,

[1] Mr. Lonsdale had not completed his examination of the corals whilst these pages were in the press, and his account of them will appear in Part III. In the mean time he has decided, that the *Lithostrotion floriforme* must be called *L. emarciatum*, Fischer having described it as *Astræa emarciata*.

[2] Whilst these pages are passing through the press, M. Alcide D'Orbigny, having examined the Fusulina, has enabled us to correct our comparison of this foraminifer (p. 87) with the Alveolina, which it very much resembles in external form. See description, Part III.

where, associated with a few other well-known fossils of the system, they almost exclusively occupy its upper division; though in another locality, a few have been detected in the middle beds, with *Spirifer Mosquensis*.

On the whole, the review of the Carboniferous fauna of Russia indicates numerous forms which are identical in deposits of the same age in the British Isles, North America and Russia; thus affording the strongest proofs, that the conditions of equable climate which prevailed over enormous areas, during the Silurian and Devonian epochs, were continued, in quite as great intensity, during the succeeding age.

As to the bearing of these organic remains upon public utility, we may confidently say, that by exactly comparing fossils from different and distant localities, we have assured ourselves of the precise position of various coal-bearing strata; and by pointing out that the *same* deposit in one region is entirely void of coal and in another is richly charged with that mineral, we have, we trust, helped to solve a problem of some national importance.

CHAPTER VIII.

PERMIAN SYSTEM.

Introduction.—Explanation of the word Permian.—Eastern Limits of the Permian System along the Slopes of the Urol Mountains.—Lower Limestone and Gypsum near Perm.—Copper, Grits, Sandstones, &c.—Ascending Series of Strata from the south-west flank of the Ural to the Environs of Orenburg.—Permian Rocks around Orenburg.—Limestones of Grebeni, &c., shown to be the equivalent of the Zechstein, &c.—Conglomerates, Copper beds and Sandstones north and west of Orenburg.—Kargalinsk, Obschey Sirt, &c.—Transverse Section from Sterlitamak, near the Ural, to the Volga on the west, including the Mines of Nijni Troitsk, Bielebei, &c.—Country between Perm and Kazan.—Sections on the Kama, Volga and Sviaga.—Sections of Gypsum and Limestone on the Piana (Barnàkuva, Arzamas, &c.).—Western Limits of the System.—Origin of the Copper Sands, &c.

HAVING worked our way upwards through Silurian, Devonian and Carboniferous rocks, we have now to describe the next succeeding natural group. Spread out over a larger surface than any other Russian system, the rocks in question, with certain overlying red deposits which we cannot yet well separate from them, occupy the greater part of the governments of Perm, Orenburg, Kazan, Nijni Novogorod, Yaroslavl, Kostroma, Viatka and Vologda, a region more than twice the size of the whole kingdom of France!

Very different opinions have prevailed concerning the age of these rocks, due doubtlessly to the varied aspect which the same strata assume in their range over so broad an area, and to the limited scale of observation from which conclusions have been drawn. The red sandstone and conglomerate of certain districts, with small seams of subordinate coal, have led to a comparison with the "rohte-todte-liegende," whilst the lighter-coloured sands have suggested the idea of the "weiss liegende" of German geologists. Again, the variegated marls and sandstone, with salt and gypsum, which abound in other parts of the region, have induced the belief, that these deposits belonged to the New Red Sandstone or Trias. Long ago, indeed, the German miners, who first developed the value of the copper ores which are so widely distributed through the sands and grits of Perm and Orenburg, observed an analogy between those beds and the "Kupfer schiefer" with which they were familiar, as well as between the associated Russian shelly limestones and their own "Zechstein[1]." These analogies, however, were little mentioned among geologists, and were forgotten with the lapse of years. The fossils, indeed, had never been compared, and recently Professor Kutorga, grounding his opinion on the character of the plants, had referred the beds in which they are contained to the true carboniferous æra.

Such was the state of the question when we entered upon the survey of Russia. To arrive, therefore, at a sound conclusion respecting the age of these rocks, it became essential to traverse, as far as possible, the countries over which they extended, and compare the phænomena which had led to such contradictory opinions. The result has been, that though these deposits are of very varied mineral aspect, and consist of grits, sandstones, marls, conglomerates and limestone, sometimes inclosing great masses of gypsum and rock-salt, and are also much impregnated with copper, and occasionally with sulphur, yet *the whole group is characterized by one type only of animal and vegetable life.*

Convincing ourselves in the field, that these strata were so distinguished as to constitute a system, connected with the carboniferous rocks on the one hand, and independent of the Trias on the other, we ventured to designate them by a geographical term, derived from the ancient kingdom of Permia, within and around whose precincts the necessary evidences had been obtained.

With the highest respect for the labours of German geologists upon the Zechstein, and for the researches of those authors who have placed the Magnesian Limestone of England on the same parallel, we are convinced, that neither in Germany nor in Great Britain do the same accumulative proofs exist, to establish the independence of a geological system. If mineral characters be appealed to, no German writer will contend, that the thin course of "Kupfer schiefer" is of like importance with the numerous strata, which in Russia constitute many bands of

[1] When we examined this tract we were quite unaware that any German miner had compared its limestones with the Zechstein, and we only became acquainted with the circumstance through M. A. Erman, when he visited England in 1842.

various structure; rendering, in fact, the Zechstein itself a mere subordinate member of a vast cupriferous series. Subordinate, however, as it is in some tracts of Russia, the Zechstein is so magnificently displayed in others, in masses of both limestone and gypsum, that it more than rivals the finest sections of that deposit, whether in the Hartz or in Thuringia. We object, however, to a lithological name, hitherto reserved for one portion only of a complicated series; and as the Germans have never proposed a single term for the whole group, which is based upon the rohte-todte-liegende and is surmounted by the Trias, we have done so, simply because we first found in Russia the requisite union of proofs.

We will not occupy time in showing, that the English synonym "Magnesian Limestone" is a term, the employment of which could only have led to false inferences; for our readers who have followed us already know, that both the Devonian and Carboniferous rocks of this country contain large and continuous masses of magnesian limestone, often indeed more dolomitic and magnesian than the limestone of the rocks we are about to consider.

For these reasons, then, we were led to abandon both the German and British nomenclature, and to prefer a geographical name, taken from the region in which the beds are loaded with fossils of an independent and intermediary character; and where the order of superposition is clear, the lower strata of the group being seen to rest upon the Carboniferous rocks.

And now a word or two upon the fossils. Neither German nor English geologists have yet proved that the Zechstein or Magnesian Limestone contains within it a Flora of its own; few distinct and well-characterized species having been found in the Kupfer schiefer and Zechstein of Germany, and none having been detected in the Magnesian Limestone of England. A few species of Calamites and Ferns, with fucoid-like plants, are, indeed, cited in the tabular list forming part of a recent work which has just fallen into our hands[1]. The geological habitat assigned to several of these German plants—"Zechstein-Sandstein"—may, however, be offered as another valid reason for the use of a general name, as applied to this group.

We may add, that even whilst we write, the high authority of M. Adolphe Brongniart has confirmed our early impression of the intermediary character of the

[1] Gea Von Sachsen. Dresden and Leipsick, 1843, in which a commentary by Dr. Adolphe Kurze, with figures of two plants, is quoted. See also Münster's Beiträge, Part I. pl. 4. fig. 5. Some of the species referred to in the 'Gea Von Sachsen' are unpublished.

Flora which we collected in Russia, and to his views we shall appeal, in a review of the Permian organic remains, with which the ensuing chapter will be concluded. In the mean time it may be affirmed that the existence of plants, approaching rather to Carboniferous types than to those of the Triassic period (which is the opinion of M. Brongniart), is in harmony with the evidences derived from the animal remains, which, whether Mollusca, fishes or Saurians, constitute a group perfectly analogous to that which occupies the same geological horizon in Western Europe.

Such then is our apology for the introduction of a new synonym, and in the ensuing chapters we shall support our reasons for its use. To render, however, the term Permian acceptable to German and English readers, we have placed the words Zechstein and Magnesian Limestone as equivalents in the Table and Map, thus to point out, that beds similar in structure to them, form part of the diversified "Permian System."

In our first announcement of this system we believed that it might comprehend the rohte-todte-liegende of Germany[1]; but we have since seen reason to modify this view, and to exclude (for the present) that German deposit from our Russian natural group. For, if the rohte-todte-liegende should be found to contain (and we believe this to be the case) some of the same species of plants as the coal-fields of the surrounding countries, that deposit must certainly be considered the representative of the Carboniferous system in that portion of Northern Germany, where no other coal-fields exist. At all events, English geologists have not yet been able to point out any natural distinctions between the plants of their Lower Red Sandstone and those of the subjacent coal measures; and as the identification of this red sandstone with the rohte-todte-liegende has been admitted, we are compelled to avow, that a deposit so characterized can form no part of a system in which the plants belong to a *peculiar type*. In a word, therefore, our Permian system em-

[1] See Mr. Murchison's Letter to Dr. Fischer, Moscow, Sept. 1841, when the term "Permian" was first proposed; also Phil. Mag. vol. xix. p. 417. In suggesting this name, we had, we confess, forgotten that our distinguished friend M. D'Omalius D'Halloy had employed the word "Penéen" to characterize all the strata between the "terrein houiller" and the "bunter sandstein." We adhere, however, to our geographical name, not only because it was adopted on the same principle which led to the use of "Silurian and Devonian," but also from our having found in the Permian deposits undescribed organic remains and much mineral wealth (copper, sulphur, salt, &c.); thus rendering the word "Peneen" or "sterile" quite inapplicable in the present state of our knowledge.

braces everything which was deposited betweeen the conclusion of the carboniferous epoch, and the commencement of the Triassic series.

After this preliminary explanation, we have great pleasure in expressing our thanks to several scientific friends who aided our labours in the examination of the region under review. In the mining tracts near Perm we acquired a knowledge of the sequence of the strata through the efforts of Colonel Völkner, the director of the Imperial Zavod of Yugansk, and his officers. In the district around Bielebei (equally rich in copper ores) we were cordially assisted by Major Wangenheim Von Qualen. Shortly previous to our visit, that gentleman had published[1] a geological sketch of the country around his residence, which too plainly indicated the doubts under which, in common with all his predecessors, he then continued to labour. He had also furnished the Museum at Moscow with a valuable collection of fossil shells, plants, fishes and Saurians, and he further contributed liberally to our scientific wants. We are bound, indeed, to say, that without his labours and the co-operation of our learned and kind friend Dr. Fischer, to whom the best of these fossils had been communicated, (and who had indeed published or prepared many of them for publication,) we could not have arrived at so clear and satisfactory a conclusion respecting the age of the Permian deposits.

In describing the Permian rocks we shall commence with their eastern limits on the flanks of the Ural Mountains, and having pointed out their base or junction with the carboniferous limestone, we shall then describe parallel, transverse sections from the Ural on the east, to the Volga on the west, concluding this chapter with an account of the deposits on the right bank of that river.

Eastern limits of the Permian System.—By inspecting the Map it will at once be seen, that the rocks of which we have briefly spoken (and which are there coloured light-red, and marked by the figs. 4 and 5), are to a great extent surrounded by strata of the carboniferous æra, on which, in fact, they repose in the form of a vast trough. On the western side of this enormous basin, the country is so low and the subsoil so obscured by detritus, that it is difficult to ascertain the order of superposition in any direct section. The geologist, however, who advances from west to east, convinces himself by independent proofs, that he has reached a zone of younger age than any which he has examined on the west and

[1] Bulletin de la Soc. d'Hist. Nat. de Moscou, 1840. Adopting, however, our views of classification, Major Wangenheim Von Qualen has published another account of the rocks of his neighbourhood, since we left Russia, and he now places them on the parallel of the Zechstein.

north. He finds, it is true, several lithological analogies between the great country of Old Red Sandstone which he has left to the north and west of the carboniferous limestone, and the vast red region in which he is at first bewildered; but with the discovery of fossils, he ascertains, that zoologically the one red region is wholly dissimilar from the other. Comparing the fossils with those of Western Europe, he assures himself, that he has entered into a formation higher in the series than the carboniferous limestone.

His next object, therefore, is to explore those tracts wherein the elevation of the older strata with which he had previously made himself well acquainted, has been such, as clearly to expose a passage from them to the newer strata in question. Such proofs were, indeed, obtained to some extent in our first visit to Russia, by ascending the great Dwina; but as the beds are there very horizontal, we shall appeal to that section in the next chapter, and in corroboration only of the succession which is more clearly exhibited on the western flanks of the Ural Mountains. The slight sketch which has been given of the carboniferous rocks which occupy the hills on the western flanks of that chain, will enable our readers to understand how they rise out from beneath the Permian deposits, and referring to the coloured section (Pl. II. fig. 1.), as affording a general view of the order observed along the flanks of that chain, we shall at once proceed to detailed descriptions of different tracts, in the governments of Perm and Orenburg.

Lower Limestone, Gypsum and Copper Deposits near Perm.—The oldest beds of this system, or those on the western slopes of the Ural Mountains, which succeed to the upper carboniferous strata, are well developed to the east of the city of Perm, on the banks of the rivers Sylva, Babka, Sira and Gromotucha, where they consist of finely laminated, calcareous flagstones, sometimes inclosing small concretions of white gypsum, at other times charged both with large concretionary masses and thin flaglike beds of the same mineral. Some of the calcareous beds resemble chalk marl, others are dark-coloured, hard, and somewhat bituminous, with courses approaching to chert, and the whole pass upwards into calcareous grits, sandstones, conglomerates, &c.

At Verkni Podvolodchie, the cliffs on the right bank of the Sylva show an ascending section, from flaglike limestones, through concretionary grey calcareous rocks, into overlying flagstones and grits, which are surmounted by shales and flagstone with plants.

Near Tchelkanova, on the same river, amorphous masses of gypsum appear on both banks; and at Savorochino, gypsum is seen in one cliff, and limestone in the other. Again, at Goruchky on the Sylva, there is an ascending section of limestone, gypsum and calcareous grit; whilst in other spots, both on the Sylva and Sira rivers (Votiaky, Gromotucha, &c.), large masses of grit and marl repose upon limestone without the intervention of gypsum. We owe our acquaintance with these facts to our friend Col. Võlkner[1]. In ascending the Babka and Sylva rivers we found the gypsum still further developed. At Krisolova, the right bank of the Babka, 150 to 200 feet in height, is occupied in ascending order by—1. Large masses of gypsum. 2. Flaglike gypsum and calcareous flagstone. 3. Finely laminated, small concretionary gypsum, with flags of marly grey limestone divided both by gypsum and thin way-boards of white chalky marl. 4. Summit composed of a tufaceous dolomite passing into calcareous grit. Chert is seen at intervals in this neighbourhood, and some of the courses of limestone are pisolitic, whilst others are bituminous. These rocks also occupy the country around the town of Kongur on the high road from Perm to Ekaterinburg.

Like most formations, therefore, in which gypsum abounds, the lithological variations are considerable in very short distances, even where the strata are horizontal; masses or large concretions sometimes taking the place of calcareous flags, and *vice versâ*. It is somewhat remarkable, that strata containing so much calcareous matter should be so devoid of fossils; for in none of the localities which we examined, could we detect organic remains in these lower gypsiferous limestones, except at two places; viz. at Rapoymaya, between the Yugofsk Zavod and the river Sylva, where we detected minute *Cytherinæ* in a bastard limestone, and again near Gorodok in the Tchussovaya river. At the latter place the limestone, which is burnt for lime and occupies the plateaus, contains *Unionidæ*, shells much resembling forms to which we shall hereafter allude, in describing the country further west, and to the north of Bielebei.

In one place, however, where the ground rises into a little eminence, called Tchalpan, a limestone is loaded with small shells, among which the *Modiola Pallasii* and the *Terebratula elongata* are abundant. Although we did not visit this locality, and owe our knowledge of it to Colonel Völkner and Captain Platanoff, we can only say, that we believe the rock may prove to be an overlying mass, similar to fossiliferous limestones we shall presently describe, and which are clearly of the age of the Zechstein.

[1] Then director of the Imperial Zavods or mining establishments of Perm.

Whilst the limestones, flagstones and gypsum here described are seen in the valleys on the east, the plateaus to the west are occupied by cupriferous grits, sandstones and shale, which have been largely excavated at several places. These rocks have been particularly developed at the Zavods of Yugofski and Motovilika, and as we were accompanied through them, as well as the adjacent country, by Colonel Völkner, who furnished us with sections and specimens, we at once acquired an acquaintance with them. These beds, which are pierced by shafts from 35 to 130 feet deep, consist of thick, flaglike grits of grey and dingy colour, rarely ferruginous, sometimes of greenish hue, and occasionally slightly calcareous, with courses of red and grey ribboned marl and shale. The ores of copper, chiefly the green carbonate, are disseminated at intervals through all the beds, but in this district the grits are the most cupriferous. On the whole, the lower beds are more grey and dark-coloured, and the upper strata redder. Plants of at least twenty species (some of which are figured and will be described in Part III.) diversify the series in this locality, and in some of the lower strata they are so numerous as to have given rise to thin seams of coal, occasionally from two to three feet thick. Concretions, often cupriferous, six to eight inches long, occur here and there, and they have been generally formed around carbonized stems of plants. Both here, and in other places which we shall hereafter describe, the copper ores are very frequently found to be arranged in the interstices, and around the fossilized stems and branches of plants, exhibiting passages from the common oxide of copper to the grey sulphuret or copper pyrites, and occasionally to the finer varieties of bright green acicular malachite, mixed with crystals of the blue ore (Kohlen-Salz Kupfer) [1].

All these beds are as near as possible horizontal, and consist, we repeat, in

[1] The cupriferous beds contain 2½ per cent. of ore only, but from the wide dissemination of the ore throughout vast masses, its extraction is profitable, though by no means so much so as in the copper works of the Ural, particularly those of M. A. Demidoff, where it is quite in another condition, occurring in rich veins and masses amid metamorphic strata, associated with igneous rocks, as will be described in Part II. In the districts near Perm, 108 cubic feet of wood are consumed to extract a poud, or about 37½ lbs. English, of copper ore; and the cutting and converting the wood into charcoal cost 2½ roubles. The poud of copper sells from 32 to 34 roubles, and costs the Government 23, whilst individuals whose establishments are not so expensive, produce it at 18 roubles. The Imperial Zavods near Perm afford 16,000 pouds per annum, and as the net gain per poud is 10 roubles 60 copecks, the Government profit is 160,000 roubles, or about £8000 sterling per annum, after defraying all costs, pay of officers included.

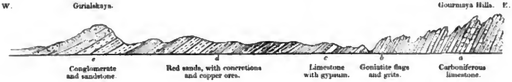
ascending order, of grey and dark-coloured shale with plants and coal, grey grit and ribboned shale, red and greenish grey grits, and argillaceous marl.

The whole country is, indeed, of a red colour, and the surface is usually covered with fine gravel arising from the decomposition of a conglomerate *in situ*. Such decomposed conglomerate is made up of various crystalline rocks derived from the adjacent Ural chain, among which quartz rock and quartz prevail, with syenite, greenstone, &c., and some fragments of the palæozoic limestones. Masses of this age, that have been decomposed *in situ*, are, in fact, very common over wide spaces in the governments of Perm and Orenburg, and though in general the imbedded fragments are small, we have met with examples (one in particular at Eralskaya-gora, between Ust Kataf and Simsk) where they were large, and which, the cementing detritus having been washed away, might almost have been mistaken for erratic blocks of a more modern period.

On this eastern frontier of the Permian system we did not extend our researches further to the north than Solikamsk, a country composed of grey-coloured, flag-like limestone, marls and gypsum, surmounted, here and there, by red sandstone and conglomerate, occasionally cupriferous. These rocks are rich in salt-sources, which have been followed down to such great depths beneath the surface, that we are constrained to believe, either that they issue from the very base of the Permian system, or even from the carboniferous rocks. The analogy of a great mass of rock-salt at Illetzkaya Zastchita, south of Orenburg, and which will be described in the next chapter, might indeed lead to the belief, that these saline sources have their origin in the body of the Permian rocks. When, however, we remember that at Starai-Russa, salt-springs, equally copious, rise through the Lower Devonian strata, and possibly even from the Silurian rocks (p. 45), we are compelled to desist from attaching any value to the presence of salt as a geological constant. It occurs, in fact, in beds of all ages, and of the truth of this remark Russia offers excellent examples (see further observations on salt in the next chapter).

Western Flank of the South Ural.—Ascending Series near Orenburg.—Rocks of similar composition to those we have described near Perm, and having the same prevailing red colour, succeed to the carboniferous beds all along the western edges of the Ural chain. Wherever the nature of the country and the limited time at our disposal enabled us to make researches, we found the lowest strata of this system to consist of calcareous flags with large masses of gypsum, similar to those upon the Sylva and Babka near Kongur. We shall presently describe the succession in the neighbourhood of Sterlitamak, but as the uppermost carboniferous strata, viz. the Goniatite grits and flags, are not there visible, and the line of junction is marked by violent dislocations (the lower carboniferous limestone being thrown at once into immediate contact with the gypseous strata), we prefer to transport our readers to the southern extremity of the chain, and to point their attention to a very clear ascending order, the lower part of which has been already alluded to. It has been shown (p. 132), that at the south-western flank of the South Ural the upper-

22 *bis.*



most beds of the carboniferous limestone (*a*) occupying the hills called Gourmaya, near the Bashkir village of Kundrofka, are highly inclined, dipping to the west. The Goniatite grits and flags (*b*) are succeeded by other grey and thin calcareous flags with large concretionary masses of white gypsum (*c*), in which we observed no fossils, and which perfectly resembled the deposits of the Sylva and Kongur. A country composed of red ground follows, and still further to the west, are hard, red and green sandstone and flagstone, in parts calcareous, in parts a conglomerate, with disseminated copper ore (*d*). All these strata dip to the west beneath other red beds, and in the hill of Girialskaya, the whole group is distinctly overlaid by a coarse, red sandy conglomerate (*e*), having a base of dull red sandstone. The materials of this conglomerate have been derived from the older rocks of the Ural chain, and vary from the size of peas to that of melons. All these masses are inclined at high angles and dip conformably to each other to the west; on the mountain sides at 60° to 70°, and in the lower hills of Girialskaya at not less than 35° to 40°, the inclination gradually diminishing as the hills descend into the low country. This section is therefore most clear, in showing a perfect conformability between the Permian rocks and the carboniferous strata upon which they repose; a phænomenon the more remarkable, as in considerable tracts connected with the Ural these deposits are unconformable.

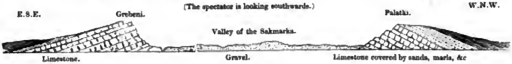
Between these hills and Orenburg the country subsides into an undulating steppe, in which it is very difficult to trace any regular succession, though dark red sandstone with some gypsum occurs, a little out of the high road, and other strata contain concretions of impure limestone not unlike "cornstone." These concretions, and the matrix in which they occur, are indeed more like the Lower New Red Sandstone of the central counties of England than any other rock to which they can be lithologically compared, and in approaching Orenburg we again saw them at the little station of Nejinskaya, where the rock is a dull, brown-red sandstone with purple streaks.

At Orenburg, the right bank of the Ural river exposes cliffs of red and light-coloured marly incoherent sandstone, and this system of red beds extends over a very considerable area to the south, north and west of the city.

Zone of Zechstein, or Magnesian Limestone.—Having conducted our readers to some distance from the edge of the carboniferous limestone, as seen on the flank of the Ural Mountains, and having ascertained, by their high inclination, that many of the intermediate strata are of great thickness, we may now state, that on this parallel we met with a band of limestone which is dissimilar in mineral aspect from that which is associated with the gypsum near the mountain flanks. Some courses of this limestone are perceived near to Orenburg, about four versts west of the city, and near the mouth of the river Sakmarka. The upper beds are thin, and of light grey colour, but they thicken downwards to courses of eight and ten inches of whitish colours. The strata exposed (and they have been quarried to shallow depths only) form probably the upper part of the Zechstein, properly so called, and they contain *Terebratula elongata* and another species, with some reed-like plants and serpuloid bodies. This rock is here evidently upon a line of undulation or elevation, for the beds plunge to the south-south-west at 25°.

About sixty versts, however, to the north, the same limestone is admirably exposed at a place called Grebeni, and is extensively quarried as a building stone for the use of the surrounding country. The hill of Grebeni is on the left bank of the river Sakmarka, to which it presents an escarpment of not less than sixty feet in height, from which the beds dip to the east-south-east at an angle of 20° to 30°. This portion of the valley of the Sakmarka evidently marks a line of elevation and dislocation, for on traversing this low ground to the hill of Palatki, about six versts from Grebeni, we found the same limestone in a reversed position, and dipping eastwards at 20°. The annexed woodcut will convey a tolerably correct idea of the transverse section across this valley.

23.



The best beds of this limestone are so copiously charged with broken shells, and when worked assume so white a colour, that they somewhat resemble the calcaire grossier of Paris, and, like that stone, they are easily chiselled and ring under the hammer. The fossils of Grebeni are *Productus Canncrini* (nob.), *Orthis Wangenheimi* (nob.), *Avicula Kazanensis* (nob.), *Modiola Pallasii?* (nob.), *Retepora flustracea* (Phil.), &c.

In several places along the west flank of the South Ural we met with a succession similar to that which is given in the above woodcut. Thus at Visilki, two versts north of Gorodok-Sakmarsk, limestone with the same fossils as at Grebeni, and in which the *Retepora flustracea?* abounds, dips at 20° to the west and by north, under grey grits and sandstone, the lowest beds being calcareous and containing shells (*Productus*, &c.). In following this section a little to the west, the next succeeding beds are found to be composed of red siliceous conglomerate, slightly dipping off at first, but soon becoming horizontal, in which copper ore being largely disseminated, has given rise to the mines of Kargalinsk. As in other places where copper ore abounds, fossil trees and plants are also of frequent occurrence, and although at the time of our visit we were not so fortunate as to procure them, this spot has also afforded many remains of fishes (*Palæonisci*), with *bones of Saurians*, &c. To the north of Sakmarsk, at about twenty-five versts towards Yemangulova, a section exposes a similar succession from an inferior limestone through grey grits into red overlying ground, and here the direction is transverse to the prevalent strike, and instead of dipping to the east or west, following the line of the chief anticlinal which is parallel to the Ural, the strata plunge 20° to the north, exhibiting a fracture, at right angles to the main elevation, and in the line by which the river Sakmarka escapes from the mountains (see Map). At Yemangulova and to the west of that village, a whitish fossiliferous limestone occurs, which is capped by sandstone and layers of grey-coloured limestone, the whole dipping about 12° north-east.

In proceeding northwards from Sakmarsk to Sterlitamak, we no longer met with the limestone containing fossils of the Zechstein; but near the mines of Voskresensk (still nearer to the Ural), we were once more amidst cupriferous conglomerates, inclined to the west and reposing upon a white limestone without fossils.

Though our time did not permit us to make many transverse sections, still by ascending the Sakmarka, where its course lies from east to west (see Map), we ascertained, that a considerable tract of red country is there interpolated between the zone of limestone with zechstein fossils (just mentioned), and the flaglike and upper beds of the carboniferous limestone. The latter forms the outer or western edge of the picturesque hills, among which General Perofski, the Governor-General of Orenburg, has his summer residence. In our journey, however, from Orenburg to Voskresensk, we necessarily regained the flank of the carboniferous limestone, and in its vicinity we again obtained proofs of the existence of a white limestone without fossils, as above stated, dipping under and surrounded by copper grits and siliceous conglomerates. This excursion, therefore, confirmed our view of the existence of *two* calcareous zones, as proved by the section from the Gourmaya Hills to Orenburg. We shall presently offer similar evidences in a section from Sterlitamak to the environs of Bielebei, and in the next chapter a like sequence will be indicated in the account of our ascent of the great Dwina from Archangel to Ustiug.

In the parallel of Orenburg, we found a system of red grits, marls, conglomerates, &c., spread out over the whole country between that city and Samara on the Volga, with scarcely a trace of limestone. The higher part of this region, which divides those streams from the valley of the Ural, and is known as the Obschey Sirt, is not, as some authors supposed, a ridge of crystalline rocks, but simply a low and scarcely perceptible watershed, which is traversed by the road from Orenburg to Samara, where it consists of red sandstone, in parts hard, solid, and slightly micaceous, with subordinate, concretionary beds approaching to conglomerates.

To the east of the fort of Borsk a natural section of about 100 feet exposes in ascending order the following beds:—1. Solid red sandstone. 2. Red shale. 3. Red sandstone. 4. Red shale. 5. Reddish coarse-grained grit of some thickness. 6. Red shale. 7. Thin bed of red and green sandstone. 8. Course of conglomerate. 9. Red sand with concretions. 10. Red shale. 11. Conglomerate, with fragments and concretions of marl, &c., and bones of Saurians.

In the ensuing chapter we shall treat of the extension of the Permian rocks to the south of Orenburg, and into the steppes of the Khirghis, where they are characterized by masses of rock-salt and salt springs, and are overlaid by peculiar limestones unknown in other parts of Russia.

Sections from the Flanks of the Ural chain near Sterlitamak, to the Volga on the west.—In a traverse from Sterlitamak to Ufa we perceived nothing worthy of notice, except masses of gypsum and alabaster, subordinate to red sandstone, argillaceous limestone and marl. In the environs of Sterlitamak, the lower gypseous beds, to which we have adverted as forming the base of the Permian system, are not seen on the banks of the Bielaya, which river there meanders in a plain, flanked on the east by the outlying hills of carboniferous limestone previously alluded to, and which evidently constitute the last echellon, or parallel, of the older rocks of the Ural. Between these outliers, however (Tchekatau, &c.), and the main body of carboniferous limestone on the east, there is a fine trough of red and green marls, with vast masses of gypsum and thin-bedded impure limestone, in which we could discover no fossils. The lowest beds consist of flaglike, brown-coloured gypsum; in the middle strata occur large white concretionary masses; and the upper consist of thinly foliated, reddish gypsum, inosculating with red marl and courses of white and red marlstone. Separated from the main region of the Permian deposits and pierced by the anticlinal ridge of carboniferous limestone above alluded to (see coloured section, Pl. II. fig. 1.), the ascending series above these gypseous masses is necessarily truncated; though the strata we now describe are splendidly exhibited in the picturesque hills inhabited by the Bashkirs, on the right bank of the small stream Seleuk. To the west of the Bielaya, or on the left bank of that river, the beds are denuded or obscured for some distance; but to the south and south-south-east of that town, the carboniferous limestone receding eastwards with a partial change of direction in the Ural chain, the Permian rocks are largely spread out in undulations, upon both banks of the Bielaya, so far as that river flows from south to north.

After leaving the country of gypsum and flat-bedded limestone on the Seleuk, similar to that of the Sylva (p. 142), the first beds visible in the low plateaus to the west of Sterlitamak, are dull, red, earthy flagstones and sandstones, passing to purple and yellowish micaceous sandstone, from one inch to two feet thick, which are followed by others, composed of red or purple and grey sandstone and grit, undistinguishable from those near Perm, with occasional white conglomerate; the whole alternating, as seen in some ravines, with red and green marls or shale, in which courses of pebbly rock wedge out in one locality and expand in another. After passing over a barren steppe of considerable width, inhabited by Bashkirs, the surface of which is covered at intervals with much black earth or "Tchornozem," we first perceived on the sides of a ravine near the Bashkir camp of Ilchegulova, about half way between Sterlitamak and Bielebei, bands of impure limestone, in parts resembling English "cornstone," alternating with grey and red grit and shale. In these beds, most of which are flaglike, we found the *Modiola Pallasii*, the *Productus Cancrini*, and some corals, impacted in a dull red matrix, overlying other limestone flags of grey colour and compact structure, beneath which are thin bands of smoke-grey and greenish calcareous sandstone and grit. The beds exposed are in all about thirty feet thick, and they occupy the summits of the plateaus watered by the Nadir and other rivulets which flow into the Dioma. In our journey to the west we perceived that the calcareous matter thickened rapidly, inclining upon the whole to the west; for we shall presently see, that beds containing the same fossils which here occupy the plateau, occur at the bottom of the deepest denudations.

The reader will not fail to observe, that on this line of section, as on that of Orenburg (p. 146), limestone with fossils of the Zechstein is not met with, except at some distance from the edges of the carboniferous rocks.

On the banks of the Dioma, this limestone series thickens in fine escarpments, composed of strong bands of red and grey grits with plants; and the latter, sometimes calcareous, alternate with courses of fossiliferous limestone.

This is well seen at Nikefur, on the banks of the Zayakaya, a tributary of the Dioma, in cliffs of about 140 feet in height, which expose the following succession:—

Summit.—Bands of white and brownish compact flaglike limestone, with courses of yellow and greenish gritty sandstone, with *Productus Cancrini* (nob.), *P. horrescens* (nob.), *Terebratula concentrica*, small *Modiolæ* and plants, &c.
Calcareous grit, with thin courses of flint.
Grey marl with thin courses of limestone.
Sandstone and grits (with schists of conchoidal fracture forming the laminæ of deposit), containing many stems of plants.
Limestone, whitish and grey, in beds of one to two feet.
Dull red argillaceous beds.
Base.—Thick beds of purple and grey grit and sandstone.

In all this tract, the limestone seemed to prevail on the summits, and the grits towards the bottom of the valleys.

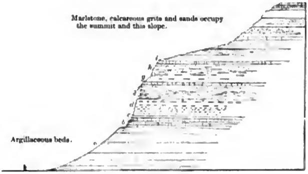
Further westwards, at Metaftamak, twenty-two versts from Bielebei and west of the Zavod of Ussen-Ivanofski (where we first met with our kind friend Major Wangenheim Von Qualen), the hills to the north of the little stream, rising to not less than 250 feet above its bed, expose so many alternations of limestone with sandstone and marl, that we are induced to impress the nature of the series on the mind of the reader by the following woodcut.

In ascending from the rivulet and plain, the first eighty feet (*a*) are observed in a slope which is evidently argillaceous; for springs burst out where it terminates against the escarpment of overlying rocks, just as in the Midland Counties of England the line of springs is seen, where the inferior oolite rests upon the lias.

Above this the following ascending section is observed :—

24.

i. White limestone.
h. Marlstone and grit.
g. Thin course of limestone (one foot).
f. Thick-bedded, fine-grained grey sandstone, with much false lamination.
e. Marlstone, with concretions of it in sandstone.
d. Marls and argillaceous limestone.
c. Grits with many plants.
b. Thin courses of shelly limestone, alternating with sandy grits, in which plants and carbonaceous matter are found, and in the uppermost limestone, Producti and other fossils. This band is loaded with detached spines of the *Productus Cancrini*.



Above this the vertical section ceases, and the slope which leads to the summit exposes, first, sandy beds with calcareous grits and argillaceous concretions, grey, compact, marly flagstone, thin, red, sandy and marly beds, covered by greyish and brownish flaglike compact limestone. From these sections it appears certain, that beds of limestone containing the fossils of the Zechstein, are interlaced with a copious development of sands, marls, &c., which are loaded with the peculiar plants we shall hereafter describe.

A high plateau, due probably to a great undulation of the strata, rises between the Dioma on the east and the Ik on the west, on which the town of Bielebei is placed, and to the north of which are situated the Zavods of Nijni and Verkni Troitsk[1]. In the neighbourhood of these Zavods the structure of the tract is admirably laid open on the banks of the river Kidash, which has a short and rapid course from east to west, until it falls into the Ik. In passing from Verkni to Nijni

[1] These Zavods are managed by our friend Major Wangenheim Von Qualen.

Troitsk, or from east to west, the beds with Producti are seen to be overlaid by a very considerable thickness (400 to 500 feet) of white marlstone, flaggy limestone, marl and sandstone ; the white marlstone occasionally predominating in the upper parts of the hills. We might offer many detailed sections of the structure of the hills around these Zavods. We could not, however, propose any one as a type of general succession ; for, as before said, no two sections, made even in the same parallel and at very short distances from each other, will be found to agree. As the beds throughout the whole of this tract are very slightly inclined, and approach as near to horizontality as may be, with very few signs of dislocation, and as the numerous watercourses which fall into the Kidash expose fine natural sections, we convinced ourselves, that, for the most part, the variety of structure was due to expansions and contractions of mineral matter upon the same horizon ; in short, to the system of inosculation represented in the coloured section, Pl. IV. fig. 1, and in the tabular view which accompanies the Map.

The Productus limestone, in its lowest and thickest beds, is sometimes a hard, thick, flaglike magnesian limestone, of conchoidal fracture, splitting into very large flags : in some places, strata containing the same fossils are calcareous grits, in others they are white limestones. Occasionally they are tufaceous, though usually the uppermost beds only assume the latter character, and they are then associated with a great thickness of whitish and greenish beds of marl and marlstone, with few fossils, except Modiolæ. Sometimes indeed (as at Metaftamak, see opposite section), the Producti are found in calcareous grits or sandstones ; at other times they are united together in matted masses, and form shelly, tertiary-like beds, six to eight inches thick, harder than the strata with which they are intercalated, and with which they alternate in escarpments from 150 to 200 feet high. Again, at Nijni Troitsk, the same shells occur in a brown shale surmounted by white limestone, but in no instance have they as yet been found in the overlying beds of cupriferous sandstone and conglomerate associated with the bones of Saurians. This group is also diversified by the presence of flint and chert, which occur both in the form of thin continuous layers and small concretions, like those of the chalk of Western Europe. The siliceous bands exhibit, indeed, all the shades of variety, from a coarse chert to the finest resinous silex, and as in the carboniferous limestone of Russia, they sometimes contain fossils.

The red argillaceous shale styled "leber thon" by Major Von Qualen, contains no organic remains, nor have the white marls and tufaceous limestones afforded any, with the exception of some beds containing Modiolæ, and very rarely a Productus. The grits, sandstones, shales and pebbly beds of this district very much resemble those near Perm, contain many plants of the same species, and also afford thin seams of coal, from one and a half, to three and a half feet in thickness.

The intimate connection of copper ore with the fossil vegetation, similar to that described at Perm, is most instructively displayed, particularly at the mines of Klutchefski near Bielebei, and at Kargala in the Steppes north of Orenburg. So general, in fact, is the connection of fossil wood and copper ore, that the discovery of the outcrop of the silicified trunk of a tree often leads the mining-agent to follow it into the rock and thereby to detect valuable cupriferous masses. Sometimes the copper ore interlaces with all the fibres of the silicified wood; at other times it is continuous through a mass of leaves, matted in sand, grit or marl, and thus a small nucleus of vegetable matter has often proved a source of considerable wealth. Where the copper permeates the coaly fibre, it is usually in the state of blue carbonate. As a general rule it may be said, that the sandstone, grit and shale beds in which plants occur, are the great matrix of copper ore, and that this mineral is much more rarely found in the white and green marls —never indeed in the same quantity, and never, as far as we know, in the pure limestone [1].

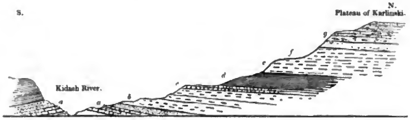
An examination of the section from the valley of the Kidash to the adjoining plateau of Karlinski, and from thence to the river Ik, must indeed convince any one, that the whole of the beds we have been describing constitute one complex mineral series, with copper disseminated at intervals; for at the base of the section on the Kidash, are beds containing *Productus Cancrini*, in the middle limestone and flagstones with Uniones or Anodons; then plants and traces of coal; and lastly, marl, sandstone, partial conglomerate and grit, with bones of Saurians.

The annexed woodcut will convey a tolerably correct idea of the succession visible in one part of these valleys, where the mines are poor, but in which at least 500 feet of strata are exposed.

It was in these conglomerates and grits of the plateau of Karlinski (evidently in this spot superior to the great calcareous bands with Producti) that some of the Sauroid remains described by M. Fischer were found by Major Von Qualen [1]. The *Rhopalodon Mantellii* (Fischer), on the other hand, was detected in the conglomerate

[1] See our explanation of the connection of the copper ore with plants at the end of this chapter.

25.



a. Shale and calcareous flagstone, with *Productus Cancrini* and other fossils overlaid by and subordinate to grey sandstone and grit (*b*).—*c*. Thin-bedded white marlstone passing to tufaceous limestone.—*d*. Yellowish calcareous shelly beds, ten to fifteen inches thick, with white, red and green-coloured marls. These beds break into large rhombs or septarian masses, and the separating fissures are filled with shale. The chief bed is made up of a multitude of broken shells, and is divided from the marlstone above and below by a thin pellicle of shale. In the overlying marlstones are Unios or Anodons, with stems of fossil plants.—*e*. White marlstones of great thickness.—*f*. Dingy red and green incoherent sands, with some green marl and a little copper.—*g*. White marlstone with red and green argillaceous marl or shale. This section gives the details on the east side or left bank of the little rivulet Karla, which flowing from the plateau of Karlinski, falls into the Kidash, but he who passes even to the west side of this puny brook will find very different beds at similar levels. Thus, towards the summit on the west of the Karla, red sandstone, copper ore, grit and conglomerate abound adjacent to and in the very same horizon as the marlstone, &c. on the east bank.

at the mine of Klutchefskoi, in the arrondissement of Bielebei, forty versts south-east of the river Dwina, and near the village of Kargola. In the opinion of Professor Owen, to whom we have submitted specimens from these localities, the bones from near Troitsk, probably humeri, unquestionably belong to Thecodont Saurians, and are more closely allied to the *Thecodontosaurus* (Riley and Stutchbury), discovered in the dolomitic conglomerate of Bristol, than any known fossils. This analogy is, indeed, still more strongly supported by the more characteristic and better preserved jaw of the Rhopalodon, which approaching very near to the species of Bristol, is quite distinct, in Professor Owen's estimation, from the Cylindricodon of Jäger, which belongs to the Trias.

These conglomerates and grits with fossil wood and copper, occasionally contain quartz pebbles as big as turkeys' eggs, imbedded in a cement which is essentially the same as the grey grits of Perm, occasionally a little calcareous; and in the detailed sections, where the mines are much worked, they overlie grey and green shale with some plants and coal.

Believing that most of the phænomena are to be explained by inosculations and undulations, as expressed in the coloured section (Pl. II. fig. 1.), still we are not prepared to say, that the tract we are now speaking of, and which has been described in detail by Major Von Qualen, is entirely void of faults. The very section

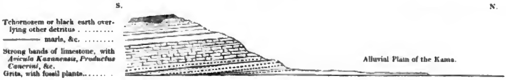
[1] When we were in this district none of the shells of the limestone had been found in the same beds with the Saurian bones, but subsequently our friend Major Wangenheim Von Qualen has detected them in intimate association, thus leaving no doubt that all these strata belong to one geological epoch.

above given indicates some amount of upheaval proceeding from east to west, in the valley of the Kidash; and we know, indeed, that north and south dislocations, and of which we shall presently speak, have affected the region further to the north. We could not, therefore, observe the rapid change, in a very short horizontal distance, which takes place in this line of hills, viz. from marlstone and limestone to grit and sandstone, without supposing, that some upcasts and downcasts may exist. We still however adhere to the belief, that the great lithological complexity of the series is mainly due to frequent inosculations of different mineral layers.

In pursuing our examination westwards we observed great concretionary masses of gypsum with spacious caverns, beneath escarpments of white limestone, in the deeply excavated valley watered by the river Ik. Between the Ik and Bugulma, on the contrary, we saw sections of copper grits and sandstones *beneath* white and yellow limestones, containing corals and minute fossils, which are referred to Cytherinæ. Towards Bugulma, however, gypseous masses reappear in force near the base of the hills.

A line drawn from Tchistopol upon the north, to Bogoroslan on the south, may serve as the western limit to which the chief plant-bearing and cupriferous grits extend, for to the west of it no plants have been found, no copper ores are worked, and the whole Permian system, with few exceptions, is represented by limestones, with shale and marl, or marlstone. Near Tchistopol, for example, when we travelled from the west, we learnt our first lesson respecting the intimate connection between the grits of Perm containing plants and carbonaceous matter, with bands of Productus limestone, as represented in this woodcut.

26.



We there saw how such beds of grit pass distinctly under limestone with Producti, and how to the east of this, viz. to the embouchure of the Kama and at Kazan, gypseous white limestone, marlstone, shale and marl constitute the whole system. That these rocks are, however, precisely of similar age to those we have been describing, is quite evident, for they contain the same species of fossils.

Between Bugulma and Samara wide undulations of arable ground, void of trees, and composed of red and green marls, inclose at intervals flag-like beds of white and yellow magnesian limestone; and in them near Klevlina, in the valley of the little Tcheremcham river, we observed small Lingulæ, which we cannot distinguish from the carboniferous species *Lingula parallela* (Phill.). From thence to the westward the limestones expand, and occupy, for a considerable space, the whole country. On the banks of the Sok there are escarpments of white and yellowish magnesian limestone, 100 to 120 feet high, exposing beds from four to ten inches thick, the streams flowing from which are as limpid as the rivers which issue from chalky rocks in Western Europe; and lastly, the structure of all these western plateaus is clearly displayed at the town of Sergiefsk, where this magnesian and gypseous series is exposed in the cliffs impending over the river.

Again, at the Imperial Baths of Sergiefsk, eight miles east of the town of that name, the sections of the hill sides, to the east of the baths, are very clearly exposed. At the base of the hill issue the very copious mineral sources, a brief analysis of which by Dr. Clauss, and given to us by Dr. Flisch, one of the physicians of the establishment, is herewith annexed[1]. These springs issue from bands

[1] If we were permitted to judge of the quantity of sulphuretted hydrogen by the smell, we should say, that we never met with such strong evidences at any other sulphureous baths, for even at the distance of a mile and when the place was concealed from our view by a hill, our noses announced to us the proximity of this great healing source, to which 1500 patients were attracted during the summer of our visit. Pallas, in describing the chief sulphureous pool of this neighbourhood, speaks of the fœtid smell occasionally extending three or four versts.—1st Voyage, vol. i. p. 156. Issuing from four sources, the waters are collected in a large open reservoir, which is surrounded by ornamental trees.

The following is the analysis of Dr. Clauss, of the University of Kazan, of a pint of the water.

Gas, hydrog. sulfurat.	1·464
Acid. carbon	2·653
Azot.	0·477
Carbonat. calc.	1·987
——— magnesiæ	0·987
Muriat. magnesiæ	0·893
Sulphat. calcariæ	12·920
——— magnesiæ	1·573
——— kali	0·360
——— natri	0·173
Silici	0·173
Principii extractivi	0·054
Summa	20·12 gr.

of whitish limestone, charged with the *Productus Cancrini*, *Avicula Kazanensis*, and other characteristic forms. Thick bands of magnesian limestone with yellow surfaces, in beds of three, four, and five feet each, appear on the side of the hill, and are overlaid by a dolomitic tufa containing gypsum and siliceous agate-like concretions, the summit being composed of marlstone, and white limestone as expressed in this woodcut :

27.

As sulphur was formerly extracted from these hills, we may take this opportunity of saying, that the whole of the tract between Bugulma and Sergiefsk which is watered by the river Sok, has been minutely described by Pallas[1] as the seat of some copper ore, much gypsum, marl and limestone, with native sulphur, sulphureous and asphaltic sources and lakes. The deposits most charged with sulphur occur on the left bank of the Sok and around the spot now fixed upon as the site of the baths, but they also extend from the town of Sergiefsk to the confluence of the Sok with the Volga, near to which great quantities of native sulphur were formerly extracted from the strata, and extensive works were in activity at Sernoi-Gorodok. In his description of that locality, Pallas distinctly acquaints us, that the sulphur was regularly deposited in marly and gypseous horizontal strata, subordinate to limestone, exactly similar to that which we are now describing at the baths of Sergiefsk. This circumstance, and the copious issue of highly sulphureous as well as asphaltic sources at many points from these rocks, which are regularly bedded and in a wholly *unaltered condition*, may have an important bearing upon geological theory. Viewed under one aspect only, these facts might lead us to believe that the phænomena were entirely unconnected with igneous or volcanic phænomena. In fact, the district of Sergiefsk is not less than 400 versts distant from any eruptive rock, and, as above said, the strata which contain the sulphur or emit the mineral waters are unbroken and unchanged.

According to a recent examination of the sulphur deposits of Sicily, by M. Paillette, a French engineer[2], showing that the beds in which the sulphur is contained

[1] Vol. i. French Edit. p. 142 *et seq.*

[2] See ' Comptes Rendus à l'Institut,' May 1843, and an able report of M. Dufrenoy.

are of the lower tertiary age, he infers that its origin is due to the decomposition of gypsum and the liberation of sulphuric acid; effects produced under the influence of the igneous phænomena to which Sicily has been subject. If this reasoning be admissible in regard to the Mediterranean deposits, it may also, doubtless, be applied to our Russian strata, in which gypsum, marls, salt, and asphalt are similarly associated. We think, however, that the explanation of the origin of the sulphur of Sergiefsk, which we suggest at the close of this chapter, is, on the whole, more satisfactory. Leaving, then, for the present, the consideration of this theoretical point, we simply remind our readers, that as geologists we have done our practical duty in proving, that the sulphur beds of Russia, the lithological characters of which were long ago so well described by Pallas, are included in strata formed at the close of the palæozoic period.

We did not examine the banks of the Volga throughout the whole of the remarkable elbow which that river makes between Stavropol and Sysran. We have already stated (p. 86) that its right bank consists for the most part of lofty cliffs of carboniferous limestone, and from the details of Pallas we apprehend, that the same formation extends (though for a very short space only), to the left bank of the great stream and to the right bank of the Sok (see Map). Pallas, indeed, states, that the limestone, which is described by him as containing bodies like seeds of wheat (our Alveolinæ), forms a promontory in that situation. We much regret not to have traced the junction which is probably there visible between the gypsiferous, sulphureous and saline Permian deposits, and the upper member of the carboniferous limestone, and we invite our successors to develope these relations.

At all those points, however, at which we touched upon the edges of the Volga, viz. at and to the east of Sysran, at Samara, at the mouth of the Ussa, and at Ussolie opposite Stavropol, we perceived that the right bank only of the stream was composed of cliffs of carboniferous limestone, the left shore being for the most part a slightly undulating plain or steppe, which (with the sulphur hills described by Pallas, a continuation of those of Sergiefsk) we place in the Permian system. At Ussolie a portion even of the right bank of the Volga, consisting of low grounds, the property of M. Davidoff, is also, we believe, referable to the Permian rocks, since salt springs issue from the spot. We are further disposed to include among the Permian strata a calcareous conglomerate or regenerated rock, which covers the carboniferous limestone of the picturesque promontory of Ussolie. This conglomerate, seemed to us to be plastered irregularly upon the flanks of the older limestone, and thus reminded us of the junction of the dolomitic conglomerate with the mountain limestone near Bristol and in the Mendip Hills. A heavy storm, however, prevented us from satisfactorily deciding this point.

Country between Perm and Kazan.—In receding from the Ural chain in a more northern parallel than that which we have just described, i. e. from Perm to Kazan, the geologist equally traverses a great cupriferous region, the western limits of which are about 100 versts east of the latter city.

In this region limestone is much less developed (at least within short distances of the high road) than in the tracts before mentioned. To the east of Ochansk we perceived a hard, greyish limestone, and at the village of Nosdri, six versts north-east of Soskofskaya, we met with another variety, a white and somewhat compact limestone, but neither of them seemed to contain fossils. In all the tracts east of the Kama, the same red marls and grits prevail as at Perm, and the surface is here and there covered with the disintegrated materials of the conglomerates before alluded to. Copper ore occurs in a deposit similar to those described at Perm, and of these we inspected collections at the Zavod of Yugoshansk, chiefly brought from the mines of Mola-lashioskaya. In these were some of the finest specimens of plants, particularly the *Calamites gigas* (Brongn.). In the low undulating country between Okansk and Malmish, towards the western limit of the copper region, little of interest is to be observed, and the surface is uniformly occupied either by red marls and sands, or by an occasional pebbly rock, which we found undecomposed at one place only, near Sassnobskaya, where it formed the cap of a hill and was quarried to a depth of thirty feet. To the east of this the same materials, viz. pebbles derived from the Ural Mountains, arising from the breaking up of these conglomerates in place, are strewed about at intervals, just as the detritus of the central counties of England has been formed out of the degradation of the pre-existing conglomerates of the New Red Sandstone[1].

Towards the Viatka river, all traces of the conglomerate gradually disappear, and the cupriferous zone is succeeded by marls, marlstone and limestone. From what we observed in the portion of the government of Viatka which we passed through, we were not induced to extend our researches northwards to the city of that name; the more so as we were informed, that the country around it contained strata precisely analogous to those we are now describing; and in a previous journey from Ustiug to Nikolsk, we had indeed seen specimens of limestone, derived from Koteloitch near Viatka. In descending the Viatka to Malmadish, dark red sandy grits, with much false bedding, and containing many flattened concretions of slightly calcareous grit, are interlaced with red marls.

These rocks, extending to the Kama, are there associated with limestone containing Zechstein fossils, as described near Tchistopol (p. 156). Midway between Malmadish and Malmish, flaggy limestones overlie the red rocks, and in the same district, at the Taischoffski Zavod, we met with a fine section of Magnesian Limestone with Producti and Aviculæ, of which fifty to sixty feet are exposed, covered by red and white and greenish marls, in which some small amount of

[1] We were informed by the Golova, or chief tradesman of Sassnobskaya, that limestone also occurred six versts south of his little town.

copper ore occurs. This is the westernmost copper Zavod with which we are acquainted[1].

Between Malmish and Kazan, the sandstone and grits are exposed in many places. At the Tatar village of Salaouch they have evidently been subjected to dislocations. The beds of marl at this place, and of hard sandstone at the station between it and Malmish, though four versts apart, are both sharply inclined to the east-south-east at an angle of 32°. It also appeared to us, that certain bands of thinly laminated white limestone and marlstone which form the summits of these hills, were horizontal, and consequently unconformable to the subjacent grits and marls. The dislocation of these lower beds is an important fact in teaching us the westernmost limits to which the disturbing causes connected with the elevation of the Ural chain have extended. The horizontality, also, of overlying beds of white marlstone and limestone is no less important, in enabling us to speculate upon the age of certain strata, which are widely spread out in the centre of this great red basin, of which we are treating. There is a considerable accumulation of these overlying materials of marls, sands and tufaceous limestone or marlstone near the town of Arsk, offering a section of about 100 feet, in which, however, we found no fossils.

Rocks around Kazan.—The city of Kazan is built upon a succession of thin courses of impure limestone, reddish-brown marly shale, &c. Some beds containing fossils are seen in a white limestone under the citadel, though the vast denudations and enormous accumulations of clay, drift and sand for the most part obscure the fundamental rock: it again rises, however, from the plain of the Volga in an isolated hill on which a monastery is built, on the right bank of the Kasenka.

On the right bank of the Volga, however, at a distance of a few versts from Kazan, fine bold cliffs from 250 to 300 feet in height are seen, which will be presently described. In the mean time we would advert to the sections on the Kama and Volga, to the south of Kazan.

The section at Smeof, near Tchistopol, alluded to p. 156, clearly exposes beds of grit like those of Perm, and charged with similar plants, *underlying* magnesian limestones containing Producti and Aviculæ, and surrounded by green and

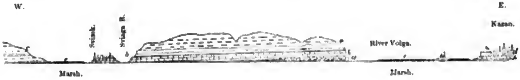
[1] This copper work is the property of M. Yartsoff, and is worked by M. Sakaloff, who gave us a cordial reception. The ore which was formerly extracted at this spot, is now chiefly brought from the more arenaceous tracts upon the east, the smelting being continued here on account of the value of the buildings and the proximity of the limestone, &c.

white marls and marlstone, approaching to a chalky consistence. In following the course of the Kama from Tchistopol towards its mouth, a considerable change, however, takes place in the structure of the country. The beds of grit with plants disappear, large masses of gypsum succeed, and at Shuran the cliff on the right bank of the stream, about eighty feet high, consists in the lowest part of yellowish cream-coloured and spotted marly limestone with small spinose Producti (*Productus Cancrini*). The central portion is made up of limestone as white as chalk, of conchoidal fracture, with Modiolæ, and thin courses of gypsum covered by a sub-brecciated, small concretionary, marly limestone. The upper part contains white, greenish and reddish marls and marlstone, with a few thin plates of yellowish and greenish grit; upon this lies the ordinary reddish-coloured argillaceous detritus, which covers large parts of this district, where it is not occupied by the black earth or Tchornozem.

Near the village of Cliutziski on the Volga, below Kazan, the limestone is seen to rise in horizontal beds from the level of the river to a height of fifty or sixty feet, and in it we observed many fossils. Among them are *Productus Cancrini*, *Avicula antiqua* (Münster), *Modiolæ* and a small bivalve like a Corbula. Gypsum does not show itself in this locality, but is found in abundance lower down the stream, and also higher up at Verkni Uslon. The fossiliferous limestone here, as in all other parts of this neighbourhood, is surmounted towards the west, where the country rises, by red and white and green marls, with courses of marly tufaceous limestone, which beds are void of organic remains.

The finest, however, of all the examples of the limestone and its passage upwards into the overlying deposits, is offered in the cliffs exposed in the promontory which forms the right bank of the Volga at Verkni Uslon, and extends to Sviaga near Sviask. This woodcut exhibits, in fact, a transverse section from Kazan[1] to

28.



[1] Borings and sinkings to a considerable extent had been carried on before our arrival at Kazan, in the hope of obtaining a purer water than that now in use, and these works passed through various beds of limestone, argillaceous marl, sand, &c. This was one of the many improvements which were pursued

Sviask, a distance of nearly thirty versts. At Verkni Uslon[1] gypsum (*a*) occupies the lower portion of the cliff in thick sub-concretionary bands, with thin courses of fossiliferous white limestone. These are succeeded by impure limestone and shale, and these by bands of grey-coloured harder limestone (*b*), both strong-bedded and flag-like, which rise to a height of seventy or eighty feet above the Volga, and are loaded with many fossils, including *Productus Cancrini*, *Avicula Kazanensis* (nob.), *Av. cheratophaga* (Schloth.), *Modiola Pallasii* (nob.). The limestone is surmounted (as upon the Kama) by red, green and white marls and sands (*c*), but they are here of a great thickness (150 to 200 feet). They contain thin courses of white tufaceous limestone, in one of the lower beds of which, only, we observed Modiolæ.

These overlying marls (*c*) occupy the whole of the upper portion of this promontory; for on examining its western face, as you descend upon the river Sviaga, the same succession is offered as that which is exposed on the eastern side, or the Volga cliffs. The view near the little village of Shevalagheena, a little above Sviask, is indeed very striking, as it exposes, in a steep ravine, a thick mass of limestone, covered by upwards of 200 feet of finely laminated green, white and red marls and sands. Some beds of this limestone are cream-coloured, cavernous, and in parts magnesian; others are grey, even lightish blue, and become, in parts, so siliceous as almost to resemble chalk-flints. Greenish-coloured calcareous flagstones also occur, and near the summit of the calcareous mass is a thin course of fœtid, dark-coloured, bituminous limestone passing into tufa. The fossils are the same as at Verkni Uslon, and among these the *Avicula Kazanensis* and the *Productus Cancrini* are the most abundant.

Sviask, upon the river Sviaga, is built upon an outlying mass of the limestone, as represented in the preceding woodcut. The hills to the east or on the right-hand of the spectator are those to which we have just alluded, where the limestone forms the bottom of the cliffs; whilst those on the left and in the distance, *i. e.* to

with vigour in this beautiful and well-regulated city, in which we were so kindly received, and of which we retain the most vivid and agreeable recollections. Alas! that many of its fine buildings should have been recently destroyed by fire! We rejoice, however, to learn that the calamity did not seriously affect the University, which contains most valuable records, antiquities and collections. Under the able direction of M. Mussin Puschkin, seconded as he is by some of the ablest professors in the Russian empire, this establishment is destined to play a noble part in the advancement of knowledge among the population by which it is surrounded.

[1] Verkni Uslon is the post-station nearest to Kazan on the Moscow road, and just opposite the mouth of the river Kazanka, which flowing by Kazan, here empties itself into the great stream.

the south and west, the limestone having sunk beneath them, are entirely composed of the overlying marls and sands, which occupy so vast a space to the west and north, and of which we shall treat hereafter. The cliff exposed on the west side of the town of Sviask, and under the chief monastery, exhibits about forty feet of limestone, covered by about ten to twenty feet of sand and detritus, viz.

1. Strong beds of dark grey, bluish limestone, in parts earthy and fœtid, with courses of flint. 2. Grey limestone. 3. Marly argillaceous beds. 4. Impure limestone. 5. Concretionary strata of yellow magnesian limestone, with nodules of pure flint, in beds from three to fifteen inches. 6. Fissile marls. 7. Thin-bedded, cream-coloured, yellow and white marly limestone, with conchoidal fracture. This is the highest bed *in situ*. The fossils are the same as those of Verkni Uslon and Shevalagheena, in short, the characteristic forms of the deposit wherever we have examined it.

The examination of this limestone in the environs of Kazan affords some results of interest, for it proves to us, first, that in passing from east to west the lower beds with gypsum gradually disappear, and that the upper masses of the fossiliferous rock are eventually lost under a great accumulation of variegated marls and sands; secondly, that in this western portion of its range, the limestone no longer inosculates with sands, plants and copper grits, as in the districts nearer to the Ural Mountains, but is a more homogeneous mass of calcareous or pure siliceous matter; and lastly, it is evident, that even in the space of a few miles, the beds, though containing similar fossils, vary exceedingly in their lithological structure.

Western and Southern Limits of the Permian Rocks in the Governments of Nijni Novogorod and Simbirsk.—In reference to the eastern boundary of the carboniferous limestone, the beds of which with Fusulinæ are worked at the village of Schwetzi, in the district of Sudovo, thirty to forty versts north-west of Murom, we may now observe, that the nearest beds of Permian limestone which we could detect are at the little village of Teplova on the river Tiosha. Unfortunately the space between these two limestones of different age (about ninety versts) is so obscured by loose sand, that we found it impossible to discover the succession of strata which fill up this interval. In our journey from the west, it was at the village of Teplova, about fifty-six versts west of Arzamas, that we first met with the limestone of which we are now treating. The beds at this spot are yellowish (magnesian), marly, and spotted by manganese, with some disseminated concretions of flint. Though of no great thickness they are quarried for building purposes. The fossils are neither abundant nor well-preserved, but among these are the Retepores, generally found in the range of the system through Perm and

Orenburg (*Retepora flustracea?*), the small spinose Producti and casts of Turritella.

Whenever the sands which cover so large an area around Murom terminate, there the limestone shows itself, but as you approach Arzamas from the west, it is again hid by a wide spread of black earth (Tchornozem). This handsome town, surrounded by the limestone, is built upon an elevated terrace, that decreases in height towards the river Tiosha, on the banks of which are yellowish white, concretionary limestones, covered by red clay and marl. The river runs for a long space through similar strata, and it is only on reaching Nova Salki on the road to Penza (fifteen versts from Arzamas), that the section is of real interest. Here the limestone becomes harder and more regularly stratified, with some finely laminated, compact beds, separated by thick bands of marl. These upper rocks, about forty feet thick, repose upon white gypsum, and are covered by red marls like those before alluded to near Kazan.

Notwithstanding the concretionary character of the beds in one section, and their more regularly stratified appearance in another, it is quite evident, that all these masses belong to the same group; similar fossils being disseminated at intervals. At Novo Salki they are rare, possibly on account of the large masses of gypsum which take the place of the limestone, but around Arzamas we found a spinose Productus absolutely identical with a species not uncommon at Humbleton Hill in the magnesian limestone of England (Sunderland); a Terebratula closely approaching to the *T. Royssii* with indeterminable forms of *Spirifer*, *Arca*, *Sanguinolaria*, *Modiola*, *Avicula*, *Corbula*, *Turritella* and *Pleurotomaria*, and a Retepore scarcely distinguishable from *R. flustracea*.

The river Piana, to the north-east of Arzamas, affords sections not less instructive than those of the Tiosha. These localities, long ago described by Pallas and since adverted to by Mr. Strangways[1], are highly interesting. We followed the banks of the river for some distance by the villages of Itshalki, Kniaspavlova, and Barnùkova, and ascertained that throughout this district it runs in Permian limestones. The hills on its banks have often very irregular surfaces, sometimes presenting great cavities due to subsidences, caused by numerous natural caverns of gypsum which forms *the base* of all the limestone of this tract.

At Itshalki the limestone, near its upper limits, is so charged with fossils, that it has completely the aspect of a tertiary limestone, in which the shells are

[1] Geol. Trans., vol. i. p. 27.

scarcely cemented together. This analogy is still more striking when we find that the fossils are Retepores, Modiolæ, and *Ostreæ*, the latter not easily distinguished from the species of more modern periods. The loosely aggregated and detached shells which are strewed about as if recently abandoned by the sea, impressed us, indeed, so much with the idea of recent deposits, that we could not at first bring ourselves to reject the hypothesis of a tertiary basin in this central part of Russia. A comparison, however, of the beds of Arzamas with those on the Piana, soon convinced us that they were both of the same age and associated with the same masses of gypsum and red marl; and a closer examination taught us, that the Retepore, which from its colour, isolation and conservation had so fresh an appearance, was the same species as that found in the Permian system of other parts of Russia. Lastly, we observed Producti and Spirifers in the continuation of the oyster beds, containing also the same Retepore and equally lying between the gypsum and the red marls.

The interest attached to these highly fossiliferous strata induces us to offer a few more words upon the sections of the Piana.

Itshalki.—Beneath the red and white marls which occupy the summits of the hills at this spot, are seen the shelly beds which vary in very short distances, in the state of aggregation of the fossils, and it was in one spot only that we discovered them in the above-mentioned isolated condition. The lower beds appeared for the most part to be the more consolidated. The gypsum is not visible here, but from the rapid undulations and circular depressions of the surface, which reminded us of similar forms in the gypseous tracts upon the river Ik, in the government of Orenburg (p. 156), and also in tracts where the same rocks will be presently shown to abound near Pinega in the north, we had no doubt that the gypsum was immediately beneath us. This locality is unquestionably richer in well-preserved shells than any we are acquainted with in the whole range of the Permian system, and our successors who may be able to devote a few days to the collection of its fossils may probably add new and important forms to our lists. In the mean time we have discovered two species of Ostrea, one of which entirely disengaged from its hinge, leaves no sort of doubt of the genus to which it belongs. It is scarcely necessary for us to acquaint geologists that up to the present time the Ostraceæ have never been found below the Muschelkalk. The appearance therefore of this genus, whose species rapidly augment in the ascending order of formations, and no one of which has ever been discovered in the carboniferous limestone or inferior rocks, whether in Russia or in the west of Europe, is, together with the presence of Saurians, a good zoological reason for distinguishing the Permian system from all accumulations of higher antiquity.

Among the other fossils of Itshalki, the Modiolæ are so abundant, that the rock might be called "Modiola Limestone," and it is of great interest to observe, that the dominant species so closely approaches to one which occurs near Sunderland, that the only difference is in the lesser size of the English specimen. The Retepores are also abundant, and are all but identical with the *R. flustracea* of the English Magnesian Limestone. A smooth Terebratula near to *T. elongata* (Schlotheim), a Turritella, and a little Natica, very much resembling the *N. variata* (Phill.), are also found here.

Between Itshalki and Barnùkova, and on the opposite bank of the Piana, is the little village of Kniaspavlova, near which are hillocks of white gypsum and limestone, containing the small *Productus Cancrini*, with *Avicula*, *Terebratula elongata*, Retepores, &c. In ascending the stream the masses of white gypsum expand considerably, as you approach Barnùkova, where they form a cliff not less than eighty feet high[1]. The succession of the strata is precisely similar, however, to that of Arzamas. The caverns in this fine mass of alabaster have been accurately described by Pallas and Strangways. Though larger, they are, as before said, alike in kind to those upon the Ik, and similar cavities will be mentioned in the next chapter near Pinega, in the government of Archangel. They have always excited the curiosity of the inhabitants and attracted the attention of naturalists, but notwithstanding their celebrity, no one had attempted to define the geological age of the rocks in which they occur, before the period of our visit. The gypsum, in its pure white and saccharoid condition, appears to have a great development at this place, for besides the vertical wall of seventy or eighty feet, the spacious caverns which have been opened out in it do not reach to the extremity of the great concretion. In a word, this rock of alabaster is identical with masses in other parts of Russia, and also with those of the same age on the south-eastern and southern flanks of the Hartz. It is covered by a calcareous breccia inclosing angular fragments of a reddish limestone, and this bed is followed by others, of friable marly limestone filled with shells, particularly Modiolæ and Ostreæ.

[1] This cliff is a little distant from the river, and in the grounds of M. Kissileff, now the Imperial Chargé d'affaires at Paris.

The ascending section terminates, as is usual in all these districts, with red argillaceous marl, containing some small concretions of gypsum and courses of marlstone. The whole of the beds are perfectly horizontal.

We could have wished that our time had permitted us to examine the range of the Permian deposits in all other parts of this district. By inspection of the Map, however, it will be seen, that they are covered to the south by secondary formations (Jurassic and Cretaceous), a fact which we ascertained by passing southwards to Simbirsk and Sysran.

Origin of the Copper Sands and Marls.—It has been more than once stated in this chapter, and a reference to the Map on which the boundary is defined explains the fact, that the portion of the Permian strata which is cupriferous, extends for a certain distance only to the west of the Ural chain (on the average from 400 to 500 versts)[1]. In all the Permian tracts more distant from these mountains, no trace of copper ore is to be found. These circumstances alone would naturally lead to the belief, that the Ural mountains had afforded the sources from whence the mineral matter proceeded.

As we shall hereafter show that this chain was, in remote periods, the seat of processes of intense metamorphism, during which copper veins were abundantly formed in the older palæozoic rocks, we are naturally led to suppose, that such operations may have had some connection with the deposit of the adjacent copper sands and marls. But in what manner were the latter rendered cupriferous? Not certainly by the degradation of pre-existing copper lodes, and by the dissemination of their particles in the adjoining sea, for in no instance do we find such fragments; the fact being, that beds composed of similar materials are so impregnated with the mineral in one spot and so void of it in a contiguous locality, as to exclude the hypothesis, that this locally saturated mineral condition can have resulted from the grinding down of the detritus of other cupriferous rocks. We are inclined, therefore, to believe, that when the Permian deposits were accumulating in the adjacent sea, springs charged with salts of copper were flowing into it from the Ural chain, then undergoing a peculiar change of composition, and that such springs deposited the greater part of their metallic contents in those portions of the bottom of the sea which afforded to them the strongest points of attraction.

[1] In the marly, sandy and calcareous tracts forming the left bank of the Volga, copper ores were formerly extracted at no great distance from that river. These deposits were, however, much less rich in ore than those nearer to the Ural chain, and they have been exhausted. Pallas alludes to copper ores on the river Kinel, not far to the east of Samara.

Now we have stated, that the disseminated copper ore in the regions on the west flank of the Ural is invariably most abundant when it is associated with the stems, branches or leaves of fossil trees, which formerly growing on the contiguous mountains, were doubtless washed down from them before or during the same period. If this be a fair statement of the former existing conditions, we have accidentally been furnished with a modern analogy, which seems satisfactorily to explain why the ancient copper sources of the Ural acted so peculiarly upon the vegetables of that ancient æra.

Some years ago a peat bog near Dolgelle in North Wales was found to contain so much copper, that certain speculators dug out the peat, and burning it, extracted a small quantity of ore. Fortunately for science, some specimens of the cupriferous vegetables were given to that able geologist and good chemist Mr. A. Aikin, who has kindly furnished us with this account of the phænomena. "The peat was black, compact, and differed from the ordinary appearance of that substance, in containing a few small bits of bluish-green, compact carbonate of copper. The pieces of wood were cylindrical, each two or three inches long, and one inch or more in diameter, in a perfectly sound state, and seemed to be parts of a recent branch of oak. The transverse section of these specimens showed bluish or greenish stains, indicative of the presence of some salt of copper, and also grains of irregular form of copper in the metallic state. The copper contained in the bog probably originated from copper pyrites (a mixture or compound of the sulphurets of iron and copper), forming a vein, or dispersed in grains in some rock so situated, that rain-water falling on its surface and there dissolving them, the mixed sulphurets of iron and copper derived from the decomposition of the above-mentioned sulphurets, might flow down into the bog. Bog-water contains vegetable acid and extractive matter proceeding from the conversion of recent vegetables into peat, which substances, together with the carburetted hydrogen gas, evolved during such conversion, would be quite adequate to the production of metallic copper and its carbonate, especially when assisted by the action of the oxide of iron contained in vegetables."

This observation has thus, it appears to us, thrown a clear light on the origin of the most widely-spread cupriferous deposits hitherto observed in the crust of the globe. In no part of this vast copper region is there a trace of a true vein, which proceeding from beneath and traversing various strata, might be supposed to have been formed by igneous or metamorphic action upon strata previously consolidated. On the contrary, every portion of the ore being interlaminated with the beds, or irregularly diffused, at intervals, throughout them, the most rational and satisfactory explanation of its deposit is afforded by the modern analogy; the difference consisting in the Russian accumulations not having been formed under the atmosphere like that of the Welsh peat bog, but beneath an adjacent sea, into which the rivers and springs of the primæval Ural poured their mineral contents.

In adopting this hypothesis, we are, we confess, bound to admit, that a similar explanation may be applied to the origin of the native sulphur and also to the sulphureous and asphaltic springs which issue from the Permian rocks around Sergiefsk (p. 158); for as copper ores occur in the same horizon, so is it by no means unlikely, that whilst eruptions were in full activity in the Ural Mountains, some mineral sources, either connected with the igneous operations affecting that chain, or rising contemporaneously from fissures beneath the adjacent sea, may have deposited native sulphur and asphalt, whilst other springs and currents were impregnating with copper the surrounding sediments of the Permian epoch. We shall return to the consideration of this theoretical point in treating of the Ural mountains (see Part II.).

CHAPTER IX.

PERMIAN ROCKS OF THE NORTH ON THE RIVERS DWINA AND PINEGA.—OVERLYING RED DEPOSITS OF THE CENTRAL AND SOUTHERN REGIONS.—ORGANIC REMAINS AND CONCLUSIONS.

Sections of the Gypsiferous Rocks overlying the Carboniferous Limestone, on the Pinega and Dwina Rivers.—Zechstein of Ust Vaga and Kiriloff.—Sections of overlying red and green Marls and Sands, with Tufaceous Limestone from Ust-Vaga to Ustiug-Veliki.—Sections on the banks of the rivers Strelna and Suchona.—Totma and its Salt Springs.—Vologda, Ustiujnitz, &c.—Sections on the Volga below Kostroma, and from Jurievitz by Balachna, to Nijni Novogorod.—Relations of red Deposits on the Volga to the Limestone of Kazan and Sviask.—Red and Gypsiferous Sands and Marls of the Oka.—Fossiliferous red Marls of Viasniki on the Kliasma.—Rock Salt and Gypsum of Illetzkaya-Zastchita (Orenburg).—Detached Saliferous Rocks in the Steppes of Astrakhan.—Mount Bogdo and doubts concerning its age.—Review of the Organic Remains of the Permian System and associated Rocks.

HAVING indicated the relations of that member of the Permian series, which unquestionably represents the Zechstein, to gypsiferous and other masses beneath it and to a wide expanse of conglomerate, red marl and sand above it, in the governments of Nijni Novogorod, Simbirsk, &c., we shall in this chapter offer independent proofs of a similar succession on the banks of the rivers Pinega and Dwina. A sketch will then follow, of the overlying red deposits in the governments of Vologda, Kostroma, &c., showing that they are confluent with those of the Volga. Directing attention to similar rocks which extend into the southern steppes, we shall next indicate how the masses which are there highly saliferous, are overlaid by a peculiar and distinct fossiliferous limestone; the survey of the great red basin under review being concluded with a general account of the Permian organic remains.

The rocks which are exposed in ascending the river Dwina from Archangel to Ustiug-Veliki, a distance of about 600 versts, exhibit, with some modifications, a succession similar to that which has been described in proceeding from the western flanks of the Ural Mountains to the interior of the governments of Orenburg and Kazan. The great band of carboniferous limestone which traverses the Dwina above its embouchure, has already been spoken of, and our first point is to show, that it is succeeded by newer formations on the south [redacted]. In our journey up the banks of the Dwina, we naturally met with newer deposits; for even supposing that the strata, partaking of the very great flatness of this region, were entirely horizontal, still in ascending this great river for several hundred miles, we inferred, that as we gained a higher level, so should we arrive at newer formations. The stream is, indeed, known to have a pretty rapid descent, and Ustiug lies at about 300 feet above the sea. While one of our parties examined the coasts of the White Sea [1], the other (so limited was our time) explored the river Pinega or eastern tributary of the Dwina [2].

Section of the Pinega.—We will first briefly describe the order on the Pinega. In ascending this river, extensive masses of carboniferous limestone, with *Productus antiquatus*, appear at intervals through the drift and sand, and are succeeded at the village of Uksenskaya, by other bands of the same limestone in which many other carboniferous fossils occur. Although we had not leisure to ascertain the fact, we think it is highly probable that, by exploring the picturesque adjacent gorge of the Tinga, a junction might be detected between those carboniferous rocks, there very much developed, and certain overlying gypsiferous strata which we class with the Permian system. The road, as is usual in Russia, being carried over the higher ground and the river flowing in an alluvial valley filled with much detritus, we were prevented, throughout a space of about twenty-six versts, from tracing all the links of succession; but on rejoining the stream we observed, at four versts beyond the station of Kuzomenskaya, large masses of gypsum occupying the cliffs, to heights of thirty or forty feet. We ascertained that this gypsum, having a small course of limestone subordinate to it, is continuous from this point (fifty-five versts south-west of Pinega, to twelve versts above that town), and we have no doubt that it spreads over a considerable region to the north-east. At two or three versts above the station of Beschkom, on the right bank of the river, the gypsum, in the form of brilliantly white alabaster, forms cliffs, and alternates

[1] Mr. Murchison and Count Keyserling.

[2] M. de Verneuil and Lieut. Kokscharof.

with courses of limestone. In the latter we sought diligently for fossils, notwithstanding torrents of rain and the persecution of myriads of mosquitoes, whose numbers seemed to be greater than the drops of water in the storm[1]. The thickest course of dividing limestone at this spot never exceeds two or three feet, and the rock is very fissile, marly, and void of fossils. On the banks of the river above Pinega, the cliff[2] is composed in ascending order of—1. Ten to twelve feet of thin-bedded limestone, the bottom beds of which are charged with Turritellæ, Aviculæ, Turbo, and other forms dissimilar from carboniferous fossils. 2. Gypsum, with some thin courses of marly limestone. 3. Band of limestone two or three feet thick. 4. White gypsum. 5. Red crystalline gypsum. 6. Red and argillaceous sandstone, with small intermixed concretions of gypsum.

In a word, the banks of the Pinega clearly showed (all the strata being horizontal), that the carboniferous limestone was overlaid by the gypsiferous or lower bands of the Permian system.

Ascent of the Dwina.—Limestone with Gypsum, Marls and Sands.—Limestone with Fossils of the Zechstein.—Overlying Sands, Marls and Tufaceous Limestones.— In ascending the Dwina, from the same base of carboniferous limestone to which allusion has just been made, and after travelling over much sand and detritus, we fell in with cliffs of gypsum and thin courses of limestone, exactly similar to those of the Pinega. These first begin to show themselves on the left bank, at about three versts north of the post-station of Zaborskaya, where the gypsum is both red and white. First ranging on the level of the river, these bands rise gradually to about fifteen versts from Kaletzkaya, where they form cliffs from forty to fifty feet high. The red courses then disappear, and the whole being pure white, the effect upon the eye is that of a continuous band of snow or ice, surmounted by a dark green line of fir-trees, as seen on both banks of a noble river, two-thirds of an English mile in width, and for a distance of more than twenty versts. In a word, the Dwina here runs in a long gorge of alabaster.

This gypsum is then clearly subordinate to the Permian system, being precisely

[1] The case containing these fossils was unfortunately lost. We may here observe, that mosquitoes constitute the chief impediment to geological research during the hot summer months, in all these high latitudes, and particularly where wood and water abound. The hardy natives even are compelled to work in cowls, like those of Capucin friars, through which their eyes, nose and mouth only are seen; and we were driven to the use of masks and veils.

[2] In this cliff a large cavern exists, used by the peasants for cellarage and said to be two versts long.

in the same position in relation to the carboniferous rocks, as the great masses described in the last chapter, which flank the Ural Mountains. The following woodcut will convey an adequate idea of how these gypsiferous beds (*b*) overlying the carboniferous limestone (*a*) pass under other beds of the Permian system (*c* and *d*). The gypsum is occasionally seen to assume large concretionary forms, which rise up and cut in dyke-shapes through the horizontal layers. The layer of limestone in the centre of the cliff, though often not exceeding a foot in thickness, is very persistent, and is marked by containing one or two peculiar fossils, the casts of which are sometimes occupied with a pellicle of green earth. The shells are, for the most part, Aviculæ. These calcareous and gypseous courses are associated with and dip under red and green marls (*c*), which entirely occupy the banks higher up the stream, and on the Pianda, a western tributary of the Dwina, we found other small flattened concretions of pink-coloured gypsum, subordinate to spotted marls and a thick red soft sandstone.

29.

On the Dwina, near Schestozerskaya (where we first discovered overlying modern sea-shells hereafter to be described), the lower mass consisted of bands of gypsum, coloured by red marls, with white and pure thick-bedded gypsum. Still further to the south, other white limestones reappear, and these contain the same small Aviculæ as lower down the Dwina, with other shells, and finally another limestone (*d*) succeeds, which is exposed both at Shidrova on the Dwina, five versts below the mouth of the Vaga, and also on the south bank of that river immediately beyond the ferry.

The strata near the water's edge at Ust-Vaga, consist of impure sandy limestone, in parts almost a dingy, dark green calcareous sandstone, not much unlike some varieties of the Lower Greensand, covered by beds of dirty grey limestone, loaded with the following fossils, viz. ***Productus horrescens*** (nob.), ***Terebratula Schlotheimii*?** (Buch.), ***Calamopora fibrosa***, var. ***ramosa***, all of which belong to the true Zechstein division of the Permian system[1]. Independent, therefore, of the inference, *à priori*, that in ascending the Dwina to higher lands, we necessarily reach newer strata, it is clear that from the moment we quitted the

[1] We shall afterwards show how these ancient limestones are covered by bands of blue clay, sands and gravel, with existing species of shells of Arctic character, like those at Schestozerskaya.

great band of carboniferous limestone, we had been passing over strata dissimilar, both in mineral characters and zoological contents, from that well-known rock and all the inferior deposits.

A parallel transverse section across the calcareous zone to Kirilof, north of Vologda, establishes the same succession, to strata equally unlike the carboniferous types as those we have just described; for a little to the north of the former town, the Baron von Meyendorf and Professor Blasius, in a traverse from Vitegra to Ustiug[1], detected white marls and limestones charged with fossils, some of which are identical with those of Ust-Vaga, such as the well-characterized *Productus horrescens*; whilst others are peculiar to this locality, viz. *Pentamerus superstes* (nob.), *Spirifer Blasii* (nob.), and a Terebratula closely resembling *T. Royssii* (L'Eveillé).

We were unable to trace distinctly the steps of a further ascending series into deposits clearly characterized by fossils.

Red Series above the Fossiliferous Limestones.—In travelling up the Dwina, for 300 versts, we had been led, step by step, as above stated, through deposits unlike any of the inferior rocks of Russia, both in zoological contents and mineral structure, and on further ascending the stream, it became evident, so horizontal were the strata, that the red and green marls and sands which occupied its banks, must belong to still younger deposits. After long and fruitless journeys to detect any further order of superposition, or any new fossils between the Permian limestones and certain Jurassic strata, to be described in the next chapter, it is with great hesitation that we place (even provisionally) any portion of the strata in the interior of the province of Vologda and the adjacent governments of Kostroma, Nijni Novogorod, &c. in a newer system than the Permian, strictly so called (see lighter tint of Permian colour on the Map and Table marked No. 5.).

To enable our readers to judge of the amount of evidence we possess, we will now successively describe the natural appearances seen in the ascent of the Dwina to Ustiug-Veliki, in a traverse to Vologda by the Suchona and Strelna rivers, in an exploration of the northern and western limits of these deposits, and in a descent of the Volga, from Kostroma, to Nijni Novogorod. Lastly, we will show that all the masses near the last-mentioned city are continuous with the red strata which overlie the Permian limestones on the Volga, and extend to the Kliasma on the west.

[1] Whilst we were ascending the Dwina in 1840, from Archangel to Ustiug, Baron A. von Meyendorf, Professor Blasius and M. Zinovief passed direct from Vitegra to Ustiug, where we met them.

The road which leads from Ust-Vaga to Ustiug, runs for some miles at a short distance from the Dwina, and the great thickness of the drift sands which here encumber the surface prevented our seeing the fundamental rocks. Reddish cliffs, however, showed themselves as soon as we regained the river banks. At Zastrova, six versts north of Zaletzkaya, the beds consist of a dullish red and yellowish sandstone, in parts brick red, with traces of fucoid-like casts. These sandstones are subordinate to argillaceous red marls which have been, here and there, much broken up. The vegetation now begins to assume a more southern aspect. Hops are seen in cottage gardens, and the larch thrives well on the undulating sandy grounds by which you pass from Archangel into the vast government of Vologda.

Near Larionofskaya, a very poor hamlet, the banks of the Dwina exhibit red marls divided by a course of whitish marlstone[1], and the same features are continued in cliffs of some altitude. On reaching the river banks further to the south, we found them to be composed of marls having a conchoidal fracture. We regretted, for a time, that we had not further examined the cliffs near Larionofskaya; but we afterwards ascertained, that similar beds extend over nearly the whole province, and that we had already passed far beyond their line of junction with the inferior fossiliferous limestone. Again, for some distance to the south of Soiga, where the red marls appear, the country is more than usually covered up, the sands having given way to a covering of tenacious, light-coloured, drift-clay. In traversing this clayey tract, we speculated on the possibility that a district, in which arable land and rich meadows had taken the place of the northern forests, might contain some strata of a different nature; but when we again came upon a denuded portion, the same red and spotted marl peeped out again from beneath the fine alluvial mould of the surface, occasionally strewed over with northern boulders. The only new features were thin bands of a calcareous grit, in parts almost a conglomerate, with fragments of flinty slate, &c., which pass into an impure limestone or cornstone.

The country near the town of Krasnoborsk is much intersected by ravines which run from east to west, and in crossing them we examined several sections of the red marls, subdivided at intervals by courses of brownish red calcareous grit and conglomerate. If mineral character were to be taken as a proof of their age, we might say that these rocks much resemble some of the bands in the Lower New Red Sandstone of England, particularly in containing yellow magnesian

[1] To make a perfect section, we should recommend future geologists to embark at Ustiug, and *descend* the Dwina to its embouchure.

cavities, black flinty and quartz pebbles, &c. in a calcareous cement of brown, red and green colours. Such beds, in short, might represent some of the equivalents of the Dolomitic conglomerate in Worcestershire; and we must allow that, after all, they are not unlike certain strata which in the previous chapter we have enumerated as Permian.

In our examination of these conglomerates, we could detect no fragments of the carboniferous limestone, which might be expected to exist in accumulations of posterior age. Yet here we must caution our friends who have studied the earth's surface in the dislocated and elevated regions of the west only, where hard and crystalline rocks abound, against the adoption of such reasoning; for on the northern limits of this region, the greater portion of the carboniferous limestone is a soft and tertiary-like deposit, which, from its horizontal and unbroken condition, can never have afforded any quantity of solid detritus. It would, therefore, be unreasonable to look for fragments of it in the conglomerates which make part of the red deposits by which its edges are conformably overlaid. The great breaking up of the surface of this limestone and the transportation of its flints, to which we shall hereafter allude, took place long afterwards, and is connected with more recent geological phænomena.

The tracts around Ustiug, as laid open by the rivers Suchona, Dwina, &c., are all composed of sands, red and green marls, and white tufaceous limestones. Silicified trees, sometimes of great size, are found in the sands, and these, we believe, are similar in kind to those in Perm and Orenburg, to which we have previously alluded [1]. No copper ore, however, is associated with them.

Sections of the Strelna and Suchona rivers.—Salt Springs of Totma, &c.—The chief distinctions in the great masses of red and green marl, which are seen in ascending the banks of the river Suchona from Ustiug to Vologda, are thick bands of dull whitish, argillaceous limestone, very much resembling the bands which occur in the Lower New Red Sandstone, as well indeed as the cornstones of

[1] Though Ustiug is not yet a city of the first class, it seems well entitled to be so considered, both from its buildings, active population, fine situation, and as being the real metropolis of a vast country. In an instructive statistical chart of Russia, recently published by the Baron A. von Meyendorf (our companion in this portion of our tour), Ustiug is signalized as a mart of manufactures, particularly of cutlery, locks, ornamental boxes, and linen woven and printed by the peasantry. In very ancient times, the art of enamelling upon copper seems to have been practised here, derived probably from intercourse with China. But we must not enlarge upon such topics in this work, however we were gratified by our reception in the hospitable and flourishing town of Ustiug. For all such details we refer to the highly useful labours of Baron A. von Meyendorf (see his new Statistical Map of Russia).

the Old Red system[1] of the British Isles. The river Strelna offers vertical cliffs, 200 feet high, and the Suchona, into which the former falls, runs between banks not less than 240 feet high, of which the following may be taken as a generalized section in *ascending* order. Red flaglike marl with conchoidal fracture. Cornstone or earthy tufaceous white limestone, in irregular sub-concretionary thin beds, burnt for lime, but containing no traces of shells. Red and green marls alternating for a great thickness in a beautifully ribboned arrangement. Courses of very impure concretionary limestone. Red and green marls repeated. The whole is capped by drift and blocks. These diversified marls, with calcareous courses, occupy the whole territory, and to recapitulate sections would therefore be useless. They are invariably so void of fossils that they obtained from our friend Baron A. von Meyendorf the significant name of "calcaires muets" (mute limestones[2]).

At Totma and several other places, these red deposits are the source of salt springs, and gypseous strata are passed through in the sinkings. At Vologda the substratum is obscured by a vast spread of detritus, which extends over the western side of the government, and ranging up to the eastern water-sheds of the Valdai Hills, and the lakes near Vitegra on the north, hides all the subjacent rocks. It was in vain that we explored the country, in a long and laborious circuit, extending westwards from Vologda to Tcherepovetz and Vesegonsk, and thence to Mologa; for the whole of this tract is so covered by sand, gravel and northern detritus, that we never could detect the subjacent rocks. Red marls appear, however, from beneath this mass near Rybinsk and other places, and also on the Unja river near Makarief, though they are hidden again under detritus, at the beautiful city of Yaroslavl.

In descending the Volga from Kostroma to Nijni Novogorod, the red marls, though frequently covered by detritus, are seen to occupy the banks for long spaces, surmounted, here and there, by shale of the Jurassic series, which we shall presently describe. At Krasnoe Pojeni, near Ples, twenty to thirty feet of finely laminated and spotted red and green marls, with occasional geodes of harder green

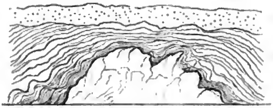
[1] See 'Silurian System,' p. 55. Similar bands have been just alluded to in the sections north of Ustiug, p. 170.

[2] A party of our first expedition, consisting of the Baron A. von Meyendorf and M. E. de Verneuil, traversed the country to the south of Ustiug by Nikolsk, and found it to be essentially the same as that which we are now describing, until they fell in with overlying Jurassic shales at Makarief on the Unja river (see Map). At the same time Mr. Murchison, accompanied by Lt. Koksharof, made the wide range by Vologda, Tcherepovetz, Mologa, Rybinsk and Yaroslavl, alluded to in the text.

marlstone, and some courses of sandy mottled flagstones, which from their concretionary tendency, run into the form of pot-stones, are covered by Jurassic shale, with Ammonites, Belemnites, &c. So conformably does the Jura shale here repose on red and green marls, that when we first saw this section (1840), we were led to consider the latter as the Keuper; but a further examination of the banks of the Volga below this point, by Ples to Kineshma and Yurievetz, convinced us that, on the whole, the surface of the red deposits is uneven and irregular, the Jurassic shale being at one spot on the level of the river, and at other places high above the red marl. We therefore concluded (independent of the non-existence of Lias in Russia), that there was no regular sequence of deposits, but, on the contrary, that a long interval had elapsed between the respective accumulations of the red ground and the black Jurassic shale.

At Christof on the Volga, below Yurievetz, and a little above the small town of Katungo, the marls fold around and dip away from a great concretionary mass of white limestone, which rises through the strata, to at least fifty feet above the stream. This limestone, which is almost pure white, is of subcrystalline structure, with a splintery and conchoidal fracture, contains here and there impure smaller concretions of marl and less pure calcareous matter, and in parts assumes a laminated structure. Slickenside polish and scratchings are frequent on the sides of the joints, which, together with the convoluted broken condition of the adjacent marls, through which the calcareous mass protrudes, demonstrate the great power of concretionary action in modifying the form of strata, and in producing all the appearances of upheaval and dislocation from beneath. Associated with this concretion are courses of rose and white coloured gypsum, numerous red and white, small, calcareous concretions, and occasionally brown and red calcareous grits, in which we searched long and fruitlessly for traces of organic remains. Some of the beds are micaceous, and thin courses of irregular concretionary flagstone are to be detected.

30.



At Balachna, still lower on the Volga, the red and green marls with gypsum, give rise to copious salt-springs, in the deepening of which the strata have been pierced to a depth of upwards of 400 feet. At Nijni Novogorod, where the Oka unites with the Volga, the right banks of both rivers offer splendid sections, in cliffs from 300 to 400 feet in height, of finely ribboned, red and green marls, with subordinate courses of soft gritty flagstone, and soft yellowish sandstone, almost in the state of incoherent sand. The magnificent new roads which descend from the Kremlin to the lower town or fair, and the formation of the grand esplanade overlooking the Volga, have admirably laid open the strata. But notwithstanding these advantages, rarely to be met with in Russia, we were not able, after an assiduous search, to observe any organic remains, except a very minute bone, probably belonging to a fossil fish. The extraordinary subsidences to which these incoherent cliffs are subject, and the deep transverse furrows (*avrachs*) which cut through the table lands, give the fullest insight into the mineral characters of these rocks.

Sections of Red Marls and Sands on the Volga below Nijni, and on the Oka and Kliasma Rivers.—The sections of Kazan, Sviask and the Dwina (see woodcut, p. 162), having proved that limestones with the Zechstein fossils subside under a group of marls, with courses of tufaceous and impure limestone, precisely similar to those of the governments of Vologda and Kostroma, we have now simply to state, that all these masses are confluent, and that they spread over the central part of this red region. They occupy, in fact, the whole of the high lands on the right bank of the Volga between Kazan and Nijni Novogorod, and are traceable still higher up that river as stated, nearly to the city Kostroma. In ascending the Oka, the great tributary of the Volga, the same rocks are quite as largely developed to the parallel of the town of Gorbàtof; and on the right bank of the river we find them ranging as far as Viasniki, beyond which they are lost upon the west, under heaps of detrital matter which obscure their junction with the inferior deposit of carboniferous limestone. These marls, sands and tufaceous limestone are obscured, as before stated, by the same detritus, all along the eastern limits of the great carboniferous region of the Northern Governments.

Let us first simply describe the features of such rocks on the Lower Volga above Kazan and on the banks of the Oka and Kliasma. Between Sviask and Tchebok-sar on the Volga, two and more courses of the tufaceous limestone, from twelve to fifteen feet each in thickness, and beds of two to three feet, are subordinate to ribboned and spotted marls, exactly similar to those described on the Suchona. One of these limestones differs only from the other, in being a little darker and more compact; for both are essentially what would be called tufaceous. The marlstone passing into limestone is pierced throughout by innumerable small cavities which branch and cross each other, and whose internal faces, invariably of a dark tint, contrast strongly with the white-coloured body of the rock. Occasionally these limestones are of a cream colour and a more compact structure, with conchoidal fracture, and they then very much resemble what in England would be called freshwater limestone of secondary and carboniferous dates. We can aver that we have broken countless specimens of these tufaceous limestones on the Volga, the Suchona, the Dwina, &c., and have never yet been able to detect the trace of a fossil in them, nor in the marls with which they are associated.

At Tcheboksar the section in ascending order consists of—

1. Red marls. 2. Greenish and chocolate-coloured concretionary calcareous grit, resembling on first inspection a conglomerate, but in reality more like those beds in England which both in the Newer and Older Red systems we know to have been formed by concretionary action (cornstones). 3. Marls, brick-red and green, of considerable thickness. 4. Marls in which the courses of tufaccous limestone and marlstone prevail. 5. Slightly micaceous sandstone with red marl, &c.

To the west of Tcheboksar some of the deep ravines expose cavernous limestones similar to those before described, surmounted by strong bands of brownish calcareous grits and flagstones, and thence to Nijni the same system is continued, exhibiting certain slight lithological variations only. At Nijni, as before described, the group becomes much more arenaceous.

At Nerinski on the Oka, sixteen versts south-west of Nijni Novogorod, the cliffs expose a band of thin-bedded gypsum, resting upon small-grained, finely laminated sandstone, the rippled surfaces of the strata being separated from each other by a thin pellicle of greenish grey marl very much resembling certain beds in England in the younger part of the Trias; whilst in the upper part of the cliff, ribboned, red and green marls and white tufaceous marlstone, sometimes of delicate pink tints, abound. The gypsum of Nerinski is very different in composition and aspect from any which we observed in the inferior strata of the governments of Perm and Orenburg, or on the Dwina and Pinega; some parts of it being lamellar, others fibrous, of various colours, from pure white to dark red. In other beds of flaglike sandstones, gypsum is disseminated in minute, brown, glassy concretions about the size of peas, which resemble small looking-glasses set in a dull matrix. When these flagstones are broken up for use (and they are the only solid stones around Nijni Novogorod), the small concretions glisten in the eye like fish-scales, and when they disintegrate, the surface of the rock has a pock-pitted appearance. A little further, however, along the cliff the gypsum swells out and forms masses a foot or two in thickness. Mineral milk, or fossil leather of mineralogists, formerly recognized in these tracts by Strangways, Fischer and other writers, occurs here, and was also observed by us at intervals between Gorbàtof and Viasniki.

At Viasniki on the Kliasma and in the ravines to the east of the town, there is a clear section of marls, sometimes slightly micaceous and sandy, with other beds of light red and green colours, very finely laminated, overlaid by blood-red, incoherent sands passing into sandstone, yellowish sands and marls, and variegated, highly calcareous grit. In the light red, variegated marls towards the middle of the cliff, and in a ravine to the north of the high road, we detected a profusion of microscopic crustaceans resembling Cytherinæ, associated with a small flattened bivalve shell, having the general form of Cyclas, and these, as before said, are the only organic remains with the exception of a very small (fish?) bone observed near Nijni and now unfortunately lost, which we have been able to detect in these widely spread red strata of such very persistent lithological characters.

After thus describing the chief distinctions of these marly deposits, it will be seen, that although they overlie the beds with Zechstein fossils, yet as they agree in position and mineral character with other members of the Permian group of the governments of Perm, Viatka and Orenburg, in which Permian plants and thecodont Saurians occur, we cannot rigorously exclude them from that system. We have not indeed any sort of evidence to prove, that the masses we are describing constitute a portion of the Trias of Europe, or that they can be placed in parallel with the New Red Sandstone of the British Isles; but knowing as we do, how long a period elapsed before any characteristic organic remains were discovered in the Bunter Sandstein of Germany, the gres bigarré of the French, or in the New Red Sandstone of England, and how much longer a term passed before that rock was separated from the Keuper, we think we act in the spirit of true observers by leaving this mass under the name of Upper Red Sandstone, thus simply considering it a great and copious cover of the Permian system. If, in the sequel, fossils should be found, which connect a part of these deposits either with the Permian system or with the Trias, we shall not have taken any step to prevent such collocation by merely stating the fact, that this variegated group overlies the Zechstein strictly so called. On the whole, however, we confess we are disposed to view these variegated sands and marls like those of Orenburg as a part of the Permian system.

Whilst we have noted the existence of rock-salt in the Permian system, as well as of numerous saline springs, the latter only are known in the overlying marls and sands, and we have before stated, that these saline springs rise from great depths, both at Totma in the government of Vologda and at Balachna on the Volga above Nijni Novogorod. It is well, therefore, to bear in mind this circumstance, since it induces us to believe in the probable existence of subterranean masses of rock-salt in deposits of higher antiquity than those in which they, for the most part, prevail in Western Europe. Hence also it is to be inferred that salt-wells may be sunk with effect on the Artesian principle, in many parts of a vast basin which we have shown to be surrounded by older deposits (see Map).

Permian Rocks south of Orenburg.—In the south-eastern region where rocks of this age occur, we perceived that along a certain line, Permian limestones similar to those we have before described, are thrown up in isolated hummocks or cones, the strata of which are often highly inclined. Such a line of disruption has been traced from north-north-east to south-south-west, and slightly divergent from the chief axis of the Ural. The hills of Grebeni afford, as before said, a good example of these dislocations, and to the south-south-west of Orenburg, in the steppe of the Kirghis, we met with a fresh example of them upon the same line at Mertvi-sol (or the dead salt) (see Map). This little elevation is also interesting, as it afforded us the best means of forming our conjectures respecting the geological age of the great adjoining masses of rock-salt and gypsum which occur at Illetzkaya-Zastchita.

These hills present beds of limestone perfectly undistinguishable from the Permian limestones (*a*) of Grebeni and other places, and which plunge to the east under the red grit of Orenburg (*b*), with traces of copper ores. Beds of white gypsum occur, partly in the form of Selenite (*c*) and partly dark-coloured and compact. From these gypsum beds a brine spring issues, which, as it cannot be derived from waters traversing the overlying red strata, probably rises from rocks of the same age as those which we have described at Sergiefsk as the seat of so much saline matter.

31.

This limestone of Mertvi-sol contains the same fossils as that of Grebeni, viz.

the *Modiola Pallasii*, *Retepora flustracea*, var.? closely allied to a species of the Magnesian Limestone of England, &c. &c.

Rock-Salt at Illetzkaya-Zastchita in the Steppes of the Kirghis.—Freezing Cavern. —Our readers of this chapter having been already fatigued with lithological details, we will now endeavour to relieve such monotony by a short episode, which embraces an account of a very remarkable phænomenon.

It was in the early days of an unusually hot and parching month of August that we travelled from Orenburg to visit these famous salt-works, and were driven at a furious pace over the parched up and undulating steppe to the south of that city. Passing through caravans of Bukharians and Chivans, journeying to and from the great Russian entrepôt, the pretty little green oasis of Illetzkaya-Zastchita at length broke upon the sight. Its groves of trees, its fort, and well-arranged buildings (diversified by mounts of gypsum not unlike, in miniature, the "buttes de Montmartre" near Paris), announced the most remote of the Imperial establishments in this wilderness.

With the exception of the fossiliferous limestone in the adjacent hills (and of which we have just spoken), the whole of the tract is made up of reddish, sandy marl and whitish gypsum, amid which materials, the rock-salt appears as a vast, irregularly formed mass. The protrusion of certain points at the surface, had long ago led the Kirghis, or original nomadic inhabitants of the soil, to use the salt; but it is in latter years only that the Russians, regularly occupying the spot, have laid bare a large portion of the mineral. By sinkings in the neighbourhood they have further ascertained, that undulating at slight depths beneath the surface, the rock-salt extends over an area having a length of two versts and a width of rather more than an English mile. Selecting one of the most favourable situations within this space, for the open work; i.e. where the ground rises to a little height above the ordinary drainage, the Russian miners have now exposed a broad surface of salt and have cut into the rock to the depth of about seventy feet. This mass is crystalline, of white colour, without a stain, and so pure, that the salt is at once pounded for use without any cleansing or recrystallizing process. Upon first viewing this bright white mass from above, we were impressed with the notion that it was composed of horizontal beds; but on descending into the quarry, we found that this appearance was caused by the method employed to extract the salt.

The reader who would bring these features to his mind, must first imagine an open quarry, from which the upper portion of the salt had been removed, with men at work on different horizontal stages. Long lozenge-shaped pieces in process of extraction at different levels are seen to be divided from the mass, by lateral, vertical joints, which have been cut open with the hatchet. The block, thus squared, is then completely separated from the body of the rock beneath, by heaving against its free end a huge beam of wood, which swings upon a triangle and is worked to and fro by a company of the miners. Owing to the crystalline and brittle nature of the substance, a few violent jars only of this battering ram are required to sever the mass from the parent rock, and thus a vast amount of labour is saved, which at Wieliczka and other salt mines is employed in the extraction of the mineral[1]. This process of side-cutting and horizontal battering necessarily produces in the body of the salt a direct resemblance to many stone quarries, with their natural joints and floors.

Other external circumstances, resulting from existing causes, are worthy of notice in this great salt quarry. The upper surface of the salt having been corroded by long-continued atmospheric action of the rain-water and melted snow which percolates through the thin cover of red sand and marl, the result has been the formation of a number of needles, which are good miniature representatives of the snowy " Aiguilles " of the Alps. Again, on that side of the quarry which has been worked to the greatest depth, and is now abandoned, the atmospheric action, smoothing away every irregularity, has left a vertical glassy cliff fifty to sixty feet high; and, lastly, the water lodged against its base during the spring period of Russian debâcle, has excavated and dissolved the salt to the height of the spring-floods, leaving a dark cavern, over which the saline mirror seems suspended, and hanging from the bottom of which are stalactitic crystals of salt.

Having stated that the floor of this immediate district consists of rock salt, it is natural that every pond of water, supplied either by springs which rise up from beneath, or by rain-water which rests upon or communicates with the salt, should be intensely saline. Such is the case, particularly in a natural pool of bright, transparent, greenish water, which is used by the natives as a salubrious bath[2], and in which myriads of small animals, peculiar to brine springs, are seen in lively agitation.

[1] It is well worthy of notice, that Russian ingenuity accomplishes by a sudden stroke, a line of clean separation similar to that which an Austrian miner labours to effect during many days with his pickaxe and other tools.

[2] We bathed in this natural pellucid brine-pit, and had great difficulty in sinking the body.

Freezing Cavern.—Besides the floor of salt, this spot is marked by two or three gypseous hillocks, one of which, on its south side, assisted by artificial excavation, is employed by the inhabitants as a cellar[1]. This cavern has the very remarkable property of being so intensely cold during the hottest summers, as to be then filled with ice, which disappearing with cold weather, is entirely gone in the winter, when all the country is clad in snow.

Standing on the heated ground (the thermometer in the shade being then at 90° Fahr.), we can never forget our sensations, when the poor woman to whom the cave belonged, unlocked a frail door, and let loose a volume of such piercing cold air, that we could not avoid removing our feet from the influence of its range.

We afterwards, however, subjected our whole bodies to the cooling process, by entering the cave, which, it must be recollected, is on the same level as the road-way or street of the village. At three or four paces from the door, on which shone the glaring sun, we were surrounded by the half-frozen quass and provisions of the natives, and a little further on, the chasm (bending slightly) opened into a natural vault about twelve to fifteen feet high, ten or twelve paces long, by seven or eight in width. This cavern seemed to ramify by smaller fissures into the body of the little impending mount of gypsum and marl. The roof of the cavern was hung with undripping solid icicles, and the floor might be called a stalagmite of ice and frozen earth. As we had no expectation of meeting with such a phænomenon, we had left our thermometers at Orenburg, and could not, therefore, observe the exact degree of cold below the freezing point. The proofs of intense cold around us were, however, abundantly decisive for our general purpose, and we were glad to escape in a few minutes from this ice-bound prison, so long had our frames been accustomed to a powerful heat.

In considering the peculiarity of the circumstances attendant upon this freezing cavern, we are not yet, we admit, sufficiently provided with accurate data. If, as we were assured, *the cold is greatest within* when the *external air is hottest and driest*, that the fall of rain and a moist atmosphere produce some diminution of the cold in the cave, and that upon the setting in of winter the ice disappears entirely, then, indeed, the problem is very curious. All the inhabitants positively

[1] This phænomenon ought, correctly speaking, to have been considered in the concluding chapters, where the existing causes are referred to; but it is so intimately linked on, we conceive, to subterranean influence and the subsoil of the tract, that we prefer to speak of it in this place.

adhered to this statement, and the expression of the peasants was, that in winter they could sleep in the cave without their sheepskins.

In our hurried visit we could do no more than request the authorities to look carefully to this point during ensuing winters, and to preserve thermometric registration of the changes in the cave, in relation to the external air. In the mean time, the simple fact which was presented to our senses was quite sufficient to create the utmost surprise.

Our first attempt to afford an explanation of the phænomenon, was by supposing, that the chief fissure opening downwards, communicated with a floor of rock-salt, the saliferous vapours of which might be so rapidly evaporated or changed in escaping to an intensely hot and dry atmosphere, as to produce ice and snow. If this or some such subterranean process were admissible, then the apparent connexion between the intense cold within the cave and the great heat without, might, we thought, be explained. Finding, however, that our geological chemistry was doubted by some persons, we submitted the case to Sir John Herschel, and he kindly endeavoured to solve the problem by reference to ordinary climatological causes only. The following is an extract from a letter addressed by him to Mr. Murchison :

" That the cold in ice-caves (several of which are alluded to in a part of this letter not published) does not arise from evaporation, is, I think, too obvious to need insisting on. It is equally impossible that it can arise from condensation of vapour, which produces heat not cold. When the cold (by contrast with the external air, *i. e.* the difference of temperature) is greatest, the reverse process is going on. Caves in moderately free communication with the air are dry and (to the feelings) warm in winter, wet or damp and cold in summer. And from the general course of this law I do not consider even your Orenburg caves exempt; since however apparently arid the external air at 120° Fahr. may be, the moisture in it may yet be in excess and tending to deposition, when the same air is cooled down to many degrees beneath the freezing-point.

" The data wanting in the case of your Orenburg cave are *the mean temperature of every month in the year of the air*, and of thermometers buried, say a foot deep, on two or three points of the surface of the hill, which, if I understand you right, is of gypsum and of small elevation. I do not remember the winter temperature of Orenburg, but for Ekaterinenburg (only 5° north of Orenburg), the temperatures are given in Kuppfer's reports of the returns from the Russian magnetic observatories.

If any thing similar obtains at Orenburg I see no difficulty in explaining your phænomenon. Rejecting diurnal fluctuations and confining ourselves to a single summer wave of heat propagated downwards alternately with a single winter wave of cold, every point at the interior of an insulated hill rising above the level plain will be invaded by these waves in succession (converging towards the centre in the form of shells similar to the external surface), at times which will deviate further from mid-winter and mid-summer the deeper the point is in the interior, so that at *certain depths* in the interior, the cold-wave will arrive at mid-summer and the heat-wave in mid-winter. A cave (if not very wide-mouthed and very airy) penetrating to such a point, will have its temperature determined by that of the solid rock which forms its walls, and will of course be so alternately heated and cooled. As the south side of the hill is sunned and the north not, the summer-wave will be more intense on that side and the winter less so; and thus though the form of the wave will still generally correspond with that of the hill, its intensity will vary at different points of each wave-surface. The analogy of waves is not strictly that of the progress of heat in solids, but nearly enough so for my present purpose.

"The mean temperature for the three winter months, December, January, February, and the three summer months, June, July, August, for the years 1836, 7, 8, and the mean of the year, are for Ekaterinenburg as follows :—

	Winter.	Summer.	Annual Mean.
1836.	− 10°·93 R.	+ 11°·90 R.	+ 1°·22 R.
1837.	− 12°·90	+ 12°·93	+ 0°·30
1838.	− 12°·37	+ 12°·37	+ 0°·60
Mean.	− 12°·07 R.	+ 12°·40 R.	+ 0°·70 R.
	+ 4°·83 Fahr.	+ 59°·9 Fahr.	+ 33°·57 Fahr.

"The means of the intermediate months are almost exactly that of the whole year, and the temperature during the three winter as well as the three summer months most remarkably uniform.

"This is precisely that distribution of temperature over time which ought under such circumstances to give rise to well-defined and intense waves of heat and cold; and I have little doubt therefore that this is the true explanation of your phænomenon.

"I should observe, that in the recorded observations of the Ekaterinenburg observatory, the temperatures are observed two-hourly, from eight A.M. to ten P.M., and not at night. The mean monthly temperatures are thence concluded by a formula which I am not very well satisfied with; but the error, if any, so introduced must be far too trifling to affect this argument. The works whence the above data are obtained are 'Observations Météorologiques et Magnétiques faites dans l'Intérieur de l'Empire de Russie,' and 'Annuaire Magnétique et Météorologique du Corps des Ingénieurs des Mines de Russie,' works which we owe to the munificence of the Russian government, and which it is satisfactory to find thus early affording proofs of utility to science in explaining what certainly might be regarded as a somewhat puzzling phænomenon, as it is one highly worthy of being further studied and being made the subject of exact thermometric researches on the spot, and wherever else anything similar occurs."

"P.S. Thermometric observations in the steppes, of the mean monthly temperature of the soil at different depths from one to 100 feet (at Forbes's intervals), would be most interesting. At Ekaterinenburg the mean temperature of the air being 36°·6 Fahr., no permanently frozen soil would probably be reached, but a very little more to the northward that phænomenon must occur.

"The 'thinning out' of the frozen stratum would be most interesting to trace, but in thinning out by decrease of latitude it might possibly at the same time 'dip' beyond reach, all above it being occupied by soil subject to the law of periodic frost and thaw, and giving room under favourable circumstances to ice-caverns, pits, or galleries. What determines the distinct definition of the hot and cold alternating layers is the exceedingly peculiar form of the curve of the monthly temperatures as given in the tables above referred to."

In thanking Sir John Herschel for his efforts (amid his numerous important researches) to explain the wonders of our cave of Illetzkaya, we think it right to state, that even his explanation has to contend with some strong local objections. The little hillock of gypsum, for example, not exceeding 150 feet in height, and of an irregular *conical* form, is the seat of other rents and openings, no one of which, as we were informed, contains snow or ice. Why therefore does our cave present this exceptional phænomenon? How indeed are we to imagine that a six months' wave of cold shall affect a cavern in a small mount, and not the subsoil of the surrounding country[1]? Again, if there be no connection between the hot

[1] Although they have no direct application to our case of Illetzkaya, we may state that the phæno-

and arid external air and the formation of the ice, why is the latter lodged so near the southern face of the hill on which the rays of the sun (very powerful in this latitude) are beating for some months?

The observations of Pallas throw some light upon the problem. In visiting Illetzkaya-Zastchita, he described this mount of gypsum, and stated that the Kirghis inhabitants of his day were in the habit of throwing votive offerings into a large open fissure of great depth which formerly existed *at its summit*. This opening was, it appears, closed up before the visit of the great naturalist, though he fails not to record a saying current among the people, that when open, a man (tempted by hope of gain or from curiosity) was let down by cords and *experienced insufferable cold beneath*. The accuracy, therefore, of the account given to Pallas by the natives has been in great measure substantiated through the phænomenon made known by a lateral opening at the base of the mount, which evidently did not exist at the time of his visit, for he makes no allusion to it.

We may also state, that this author mentions similar caverns at Indersk, still further to the south, in which he experienced intense cold; and far from being surprised like ourselves at such a phænomenon, he simply adds, that it is one of usual occurrence *in caves of gypsum*. On this point, however, we must observe, that as far as our experience goes, there is no natural connection between gypsum in its natural state and cold, for neither the large caverns in that rock described by us upon the Pinega in latitude 64°, nor the caves of the Ik and Barnùkova (pp. 156, 165, and 173, note 2), contain ice or snow in summer.

But to revert to our own case, has solid ice existed for ages in this mount of gyp-

mena of the permanently frozen soil at Yakutsk, to which Admiral Wrangel and M. Baer directed attention, have not yet been adequately inquired into. In travelling through Ustiug, in 1840, we met with the engineer who conducted the sinkings of the shaft and from him we learnt—1st. That with the exception of about sixty feet of alluvial soil, the pit, to a depth of 350 feet, was sunk through strata of limestone and shale with some coal—the limestone being *peculiarly hard* and in beds *from two to six feet thick*. 2nd. That none of the sinkings took place in the summer months on account of the foul air. 3rd. That when Admiral Wrangel descended the shaft, the surface being then burnt up by the summer sun, the thermometer below was 6° Reau. below zero. As new inquiries into this interesting phænomenon have been instituted by the Imperial Government, we shall merely state, that in reference to our case, there must be a striking difference between the climate of Yakutsk and that of the steppes south of Orenburg, both as to the length and heat of the summers and the intensity of winter cold. Yakutsk, situated in N. lat. 62½°, suffers under a winter cold of 39° 2′ cent. below zero. See the valuable table of climatology published by Baron Humboldt, 'Asie Centrale,' vol. iii. p. 102. The eminent geographer states, however, that he has no sure data for Orenburg, vol. iii. p. 556.

sum both when open from its summit and without such aperture? Is it, on the contrary, a phænomenon which changes with the seasons, as the inhabitants declare? If so, is it susceptible of explanation by climatological changes, as attempted by Sir John Herschel? or is it to be accounted for by an union of meteorological and chemical causes? Avowing our incompetency to explain the true nature of the changes by which the result was produced, we were about to state, that in clinging to our original belief, or some modification of it, we left the problem to be solved by others. Whilst, however, these pages were passing through the press, the facts having been accidentally mentioned to our friend Dr. Robinson[1], he expressed an opinion which induced us to elicit from him the following ingenious explanation:—

"Your revise has reached me, where I am luckily able to refer to the account of Monte Testaceo which I mentioned to you at Parsonstown, and which you will find in the first volume of Nicholson's Journal, 4to series, page 229. If you examine it, you will, I think, agree with me in thinking that the principles applied by Nicholson to explain these phænomena, nearly as you appear to have done in the first instance, are sufficient for Illetzkaya." . . . . "First suppose the hill rifted with fissures so as to let air percolate all through it, and that this net-work of air-passages communicates with the cave below, and above with vertical fissures communicating towards the summit of the hill with the external atmosphere. During winter the air contained in these fissures is warmer than that without, it will therefore rise and escape, being replaced by an equal mass of cold air. This being warmed by the rock with which it is in contact, will escape in its turn, and thus an inward current will be felt in the cave till all the rock which it can reach or influence is cooled down to the winter temperature. In spring the current will be reversed; it must still be of the temperature of the rock through which it passes, and will thus reproduce in summer the cold which had been stored up in winter, till the rock attains the summer temperature and the action is intermitted. Some cold must be lost, as I have hinted, by the transmission of central heat, but still a very small mass of rock will supply an immense mass of cool air. I do not know whether the *specific heat* of gypsum has been ascertained; but suppose it the same as of lime, and every cubic foot of it in the hill will cool 150 cubic feet of air to the same degree. Assume the hill to be a pyramid whose base is a quarter of a mile and 150 feet high, this would supply eighty-five feet every second for six months, which seems more than sufficient. But secondly, this hill may communicate with extensive caverns or fissures full of air, extended horizontally, and within the reach of the transmitted influence of winter and summer. In the former they and the air they contain will be cooled; but when the influence of the latter reaches them, it will expand the air, and this escaping by the cave will add its cooling powers. Such seems to be the case in some of the Italian caves, but I think the supposition scarcely required at Illetzkaya. As to the degree of refrigeration, it obviously depends on the winter temperature; but I would expect it to be increased by the evaporation. The materials of the hill, saliferous gypsum, must dry the included air completely, as their affinity for water is considerable; on the other hand, after a spring thaw, we must expect to find the earth of the cave which is near the surface saturated with moisture; and it is easily shown that arid air, even at or below 32°, will be

[1] Astronomer of Armagh, and Member of the Royal Irish Academy.

cooled still lower under such circumstances, besides that some heat may also be absorbed by its expansion. De Saussure, in a calcareous cave, found, June 29, 1771, the external thermometer 79½° Fahrenheit, while that in the cave was but 37¼°; and as this was in Italy, I think we may assume that a much greater depression would have been produced had the climate been like that of Orenburg. Whatever you may think of my attempt at explanation, it is at least to be hoped that your Russian friends will ere long obtain for you the necessary data as to climate and conduction, without which we are but guessing in the dark. A couple of thermometers sunk in the ground, and a journal of the state of the cave, seem especially necessary."

Ingenious as are the explanations of Sir John Herschel and Dr. Robinson, we still think that they do not completely solve the problem. Some persons have, indeed, thought that very different explanations might be proposed, by reference to the artificial production of ice and snow, one very remarkable example of which occurs in the mines of Schemnitz in Hungary[1]. But we are not yet sufficiently acquainted with all the features of the case of Illetzkaya, and apologizing to our two distinguished friends for having drawn forth their opinions before such data had been got together, we pass to other subjects, in expressing our hope, that the Russian authorities will soon procure for us the knowledge of the facts, without which no accurate induction can be made.

Saliferous Rocks and overlying fossiliferous Limestone of the Southern Steppes.— In the lower steppes adjacent to the Caspian, or in that wide expanse which we shall afterwards describe, as having a surface covered with sea-shells, the older rocks similar to those of Illetzkaya rise to the surface like small islands. These islets are composed of red sand, marl, gypsum and limestone. Saliferous sources also rise to the surface at their feet, and occasion the formation of adjacent salt lakes and saline incrustations—even forming deposits of rock-salt in some of the deeper depressions.

As examples of these isolated hills we may cite Mount Indersk and its associated salt lake, the gypseous elevations near Gourieff, the saliferous hills of Arsagar, the Great and Little Bogdo, and the gorges of red grit from which the salt rivulet flows, which supplies the Lake Elton, so useful to Russia as a great storehouse of salt[2].

The Indersk Hills, which we did not visit, extend for about forty versts along the left bank of the river Ural, and are composed, like all the other hillocks which emerge from beneath the steppes of Astrakhan, of gypsum, marl and sandstone with saliferous springs. Near the lake of the same name, Pallas also remarked

[1] See Ure's Dictionary of Chemistry, 2nd edit., p. 290. Art. 'Caloric.'

[2] For an account of the source of Lake Elton, consult the Researches of M. Göbel the chemist.

beds of grey colour, containing Ostreæ and Belemnites, and recently Colonel Helmersen has distinctly ascertained, that these strata are of the same age as the Jurassic formation, to which we shall presently advert as occurring in many parts of Russia.

Mount Bogdo.—Having already stated, that we have no proof of the existence of rocks of the age of the Trias in the central region of Russia, it becomes our duty to ascertain, if there be not a representative of some member of that system in the rocks of Mount Bogdo, which rise up as isolated hills in the steppe of the inner horde of Kirghis, on the left bank of the Volga.

No locality has undergone more changes in the estimate of its age than this famous mount, and it was therefore visited by one of us[1] with the view both of making a correct section and to collect the fossils which it contains The graphic description of Pallas, had the fossils which he collected been preserved, might have long ago enabled geologists to form nearly as accurate a conjecture concerning the age of these hills as that which we are now enabled to make; for he informs us that their base, composed of saliferous masses, salt lakes, red and green sands, &c., is surmounted by limestone charged with shells and ammonites.

Notwithstanding this ancient description, we find the most recent authorities exceedingly at variance in interpreting the age of these deposits. From an examination of a chambered shell which they contain, M. Von Buch surmised that they might prove to belong to the Muschelkalk, and more recently Professor Eichwald has referred the deposit to the Silurian system!

We shall first endeavour to show that the latter opinion is untenable, and that, though not yet fully established, the opinion of M. Von Buch is much more likely to prove correct.

Great and Little Bogdo.—The two contiguous hills of Bogdo are pretty nearly similar in composition. The little Bogdo is a low ridge stretching from north-north-east to south-south-west. At its northern extremity, a natural section exposes red sandstone dipping to the east at about 30°, surmounted by a whitish limestone, composed of angular, breccia-like fragments of a compact and hard nature, and forming masses so like ruined buildings, that the simple inhabitants seriously believe them to be such. The calcareous beds are covered by greyish coloured gypsum, and in their eastward dip, these strata are met and cut off by limestone

[1] Count Keyserling.

inclined to the west, thus showing a transverse line of fault; the gypseous mass occupying a symmetrical depression.

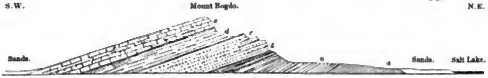
The greater Bogdo presents analogous phænomena of succession, but on a larger scale. Being the highest point in all this region, and also remarkable for its peculiar vegetation and living animals, it has attracted both the superstitious worship of the nomadic tribes who live around it, and the special attention of every scientific traveller who has approached it, including Falk, Pallas, Göbel and Eversmann. Modern geologists, however, are chiefly acquainted with it through a few of its fossil remains. Pallas, who visited it three times, describes the succession of the beds and their neighbourhood, with an exactness which we cannot too much admire in the 'De Saussure of Russia,' and he cites a remarkable *Ammonite* which has recently been described by M. Von Buch. The resemblance of this fossil to a characteristic Ammonite of the Muschelkalk, seemed to the latter author to indicate the existence of that formation in Russia.

Professor Eichwald (who has not visited the spot) has recently published a short memoir, in which, in addition to an extract from Pallas, he gives the description of a true Orthoceratite supposed to have been collected at Bogdo by M. Göbel, a fact to which Colonel Helmersen had previously alluded. As the very circumstantial and minutely detailed voyage of Göbel makes no allusion to the finding of any such body, and as the collection on which Professor Eichwald has formed his conclusions was sent from Dörpat, we cannot but think that one of the true Silurian Orthocerata of Esthonia, so abundant in the collection at that university (see p. 33), has been transmitted to the Professor at St. Petersburgh through mistake or inadvertence. We searched most carefully for fossils on the spot, and the result of our labour was the acquirement of about twelve specimens of the *Ammonites Bogdoanus* and other shells, none of which resemble in the least the Orthoceras described by Eichwald. In describing the matrix or rock in which his Orthoceras is imbedded, that author mentions the existence of green grains, which is to us a convincing proof, that he had simply before him a portion of the chloritic Silurian limestone of Esthonia; for we can positively assert, that the limestone of Mount Bogdo contains no such matter. Hence we presume, that the common *Orthoceratites vaginatus* of the Silurian limestone of Esthonia was not found at Bogdo, and consequently that Professor Eichwald's conclusion, that this mount is of Silurian age, is without foundation. With all respect for his authority, we are also bound to state our conscientious belief, that Professor Eichwald is in error, when he supposes that the *Ammonites Bogdoanus* has a ventral siphon, an opinion which induced him to name the shell *Clymenia Bogdoana*. We have distinctly ascertained, that the siphon is placed exactly as in the Ammonites and Goniatites.

But to resume our account of these singular outliers of the steppe. According to the Baron V. Humboldt, the summit of the greater Bogdo, of which the annexed woodcut is a section, is 537 English feet above the ocean, and hence upwards of 600 feet above the Caspian Sea. The beds dip south-west about 30°, and therefore in an opposite direction to the chief masses of the Little Bogdo.

The base of this hill consists of saliferous strata of argillaceous marl (*a*), from which brine-springs issue and deposit solid banks of salt in the adjacent lake; beds of the thickness of a foot being sometimes formed in a single year. Gypseous

32.



courses occur, and marl so red that it is used as paint by the natives. To these succeeds a considerable thickness of sandstone, the lower part of which (*b*) is soft, friable, and thin-bedded, and the upper (*c*) is a reddish grit, occasionally coarse-grained and hard, and containing rose-coloured quartz, Lydian stone and small striated concretions. Above these strata is a sandy, red and white argillaceous marl (*d*), which, from the alternation of courses of white marl, has a ribboned aspect, and this rock, in which Pallas found some salt, has a thickness of about 200 feet. The summit is composed of a grey-coloured limestone (*e*) of about 100 feet thickness, which divided into flags, has certainly very much the aspect of Muschelkalk. Near its base it is loaded with a great Gervillia; and higher up with casts of a Perna, which in the general outline has some analogy with the *Inoceramus rostratus* of the Jura limestone (Goldf. pl. 115. fig. 3.).

On the opposite side of the hill we found, in addition to the *Ammonites Bogdoanus*, a compressed Mytilus somewhat resembling the *M. eduliformis* of the Muschelkalk, and small bivalves which may be referred to the genus Donax. The general character of these fossils, so very different from those we have observed in any other part of Russia, and the entire absence of palæozoic forms[1], seem to conspire with the order of the strata, to lead us to consider this limestone of the steppe of Astrakhan, as a stage in the geological series superior to the Permian system, and which has not been observed in any part of Russia properly so called (see Map).

We are very far from believing that these upper beds are Jurassic, both because we have not found among them any of the fossils which characterize the strata of that age in Russia, and also because the limestone of Bogdo is very dissimilar to any beds of that epoch with which we are acquainted.

If, after all, the exact geological horizon of the limestone of Mount Bogdo is uncertain, our researches have, we trust, limited the range of formations to which it can be referred; for it is now ascertained to be younger than the great body of the Permian and older than the Jurassic strata. Looking, therefore, to the "facies" and dominant character of the fossils, and seeing that the limestone in which they lie passes gradually downwards into saliferous rocks which form a part of the Permian system, we are disposed to approach very nearly to the opinion of M. Von Buch, and to think that if not the equivalent of the Muschelkalk, these beds must at all events approach to that age.

Origin of the Salt of the Steppe of Astrakhan.—In previous chapters it has been shown, that salt sources rise out of different deposits in Russia, from the base of the Devonian system to the red rocks associated with the Zechstein; and as the largest and best-developed masses of rock-salt are of the latter age, and the saline sources of the steppe of Astrakhan issue from the foot of Mount Bogdo, we believe that they have their origin in similar masses of rock-salt. It is, indeed, quite evident, that these and similar saline sources are due to subterranean causes of an ancient date, and are in no way dependent upon the recent desiccation and retreat of the Caspian Sea; for it is only where the mounts of red sandstone rise out in this wide plain, that permanent salt-springs are known. In other parts of the same steppe, abounding as the surface does in marine shells, the finest fresh water is obtained, by boring to a few feet into the sand and gravel.

[1] Although the *Ammonites Bogdoanus* has not serrated lobes, like those of the Ceratites of the Muschelkalk, and ought, according to strict generic definition, to be placed among the Goniatites, it offers, nevertheless, by the form of its chambers, a very strong analogy to the Ceratites. The inclination of the folds of the lobes towards the interior edge of the whorls, and their comparative narrowness, recall forcibly to the mind of the geologist the *Ceratites nodosus* of the Muschelkalk (see Part III.).

We shall hereafter show, that all this low tract was once occupied by a Caspian Sea, and endeavour to give some proof of the high level at which its waters once stood; but we again insist, that the salt springs to which we have alluded, are completely independent of any such comparatively recent cause, and are derived from a subsoil formed in the earlier zones of the earth's crust. If we mistake not, a great number of the saline lakes of Eastern Russia and Siberia will be found to owe their qualities to the lodgement of water in depressions fed by salt springs or communicating with masses of rock salt[1]. However this may be, the facts to which we have adverted in Russia proper, may be turned eventually to national advantage, in a country where nearly horizontal strata occupy vast, regular depressions; for wherever salt sources have their natural outbreak at the edges of such basins, we may feel certain, that artesian wells sunk in favourable places within their area, might raise salt to the surface, in districts removed at inconvenient distances from the usual marts of this indispensable commodity. A hint on this point is sufficient for the intelligent administration of the Imperial Mines.

[1] We have been recently informed by M. Hommaire de Hell, an enterprising French engineer, who has prepared for publication a Map of Southern Russia, that, in the southern steppes which we did not visit, between the Black and Caspian Seas, there is a very general occurrence of clay impregnated with saline particles, though the ordinary sandy superficial covering of the country yields fresh water. In dry seasons no salt is procured; but when the inferior clay has been saturated by heavy rains, lakes are formed, which, on evaporating, leave considerable saline incrustations. The saliferous property of this steppe is considered by M. Hommaire to be a residuary phænomenon, due to the desiccation of the once submarine tract which connected the Black and Caspian Seas (see Map). We may return to the consideration of this subject in a future chapter, when we treat of recent changes; and, in the mean time, we simply remark, that if the inferences of M. Hommaire be admitted, they do not in any way interfere with our geological facts, as to the ancient origin of the permanent salt sources to which we have adverted.

Formation of Ice in the Cave of Illetzkaya-Zastchita explained.

Since the preceding pages were printed, Professor Wheatstone has called our attention to a memoir of Professor Pictet of Geneva, explanatory of the formation and conservation of summer-ice in natural caverns[1]. These caverns, near Besançon and in the Jura, occur in tracts where the mean cold is above the freezing point, and it is also said of them, as of Illetzkaya, (p. 186), that the hotter the summer the greater is the quantity of ice they contain. The grotto of La Baume near Besançon presents, indeed, a close analogy to our Russian example, as it lies

[1] See Edinburgh Phil. Journ., vol. viii. p. 1, and Bibliothèque Universelle.

within the lower part of a hillock of about the same height as the little mount of Illetzkaya. Seeing from their position, that such masses of ice cannot be the residue of a winter deposit, Professor Pictet accounts for their formation by extending the views of De Saussure, respecting the descending currents of cold air, which in hot summers traverse the artificial mound of broken pottery at Monte Testaceo near Rome, as well as the sides of certain rifted calcareous hills in Italy and Switzerland. Professor Pictet argues, that in his ice-caves (as in certain mines with vertical shafts above them and horizontal galleries on the lower sides of the hills) the downward current of air during summer must acquire, during its descent, the temperature of the vertical portion of the crevices through which it passes; that temperature being in general at least as low as the mean temperature of the place. He also supposes (with De Saussure), that the air descending through the fissures in the strata, must be still further cooled by the refrigerating effects of evaporation, derived from the moistened materials which it encounters in its progress.

If this explanation be applicable to the ice-caves near Besançon and in the Jura, it applies, we conceive, much more strongly to our case in Russia, where the numerous icicles pendent from the roof of the cavern and the stalagmitic crust of ice on the floor, equally indicate a previously wet and damp roof, affording a passage to water; whilst the *excessive dryness of the external air of these southern steppes*, to which we have specially adverted, must contribute most powerfully to the refrigerating effects of evaporation. We may add, that this view is supported by reference to the climate of the plains of Orenburg, in which the great wetness of spring caused by the melting of the snow, is succeeded by an intense and dry Asiatic heat. These conditions, cooperating with the form of the grotto, the fissures above it, and the horizontal opening into it at the foot of the hill—features quite analogous to the vertical shafts and horizontal galleries of mines, referred to by the Genevese Professor—seem to us completely to explain the phænomenon of Illetzkaya, and with it all those examples of ice-caverns mentioned by Pallas in still more southern latitudes.

P.S. We intended, as announced, to terminate this chapter with a review of the Organic Remains of the Permian strata, but feeling that this important subject could not thus be done justice to, we have devoted an entire chapter to its consideration, giving at the same time our ultimate view of the correct equivalents of the Permian deposits in Western Europe.

CHAPTER X.

Equivalents of the Permian System in Germany and other Parts of Europe.—Analytical Review of its Animal Contents.—Permian Flora.—Close of Palæozoic life.—Table of the Permian Fauna.

In this chapter we will first give the results of our recent comparisons in Germany, and our general view of the equivalents of the Permian System in Western Europe, and next a detailed analysis and tabular view of its organic remains.

Since the earlier chapters of this work were written, the visit to Germany before alluded to (p. xii.), has led us to form a more correct view respecting those deposits of Western Europe which might be placed in parallel with the Permian system. We have now learnt, that the opinion which till recently prevailed, that the "Rohte-todte-liegende" formed a natural member of the carboniferous group, has been abandoned, and that these deposits are known to be separated from and unconformable to each other. Of this fact we became convinced by visiting the territory around Zwickau in Saxony, and we have obtained the authority of Professor Naumann for adhering to it. In that tract, Captain Gutbier having largely collected the plants belonging to both deposits, his specimens enabled us to see, that the Flora of the Rohte-todte-liegende, which is there well preserved, in finely levigated white claystones, contains certain forms which are either identical with, or closely allied to, our Permian plants; whilst among them, though they are all of carboniferous genera, there is not one of the characteristic species so abundant in the subjacent coal-field. On the other hand, though the Rohte-todte-liegende is there unconformable to the coal-measures, and is distinguished by peculiar plants, it passes conformably upwards into the Zechstein, and thus forms a natural group with that deposit.

A similarly close connexion exists in Upper Silesia. In the mountainous tracts which range by Waldenburg towards Glätz, a small productive coal-field is overlaid by a series of red sandstones, conglomerates, and shale, in the upper part of which, particularly near Friedland and Rupersdorf on the Bohemian frontier, a black, bituminous limestone occurs. This calcareous rock, thus interlaced with red deposits which represent the Rohte-todte-liegende, and immediately overlying the coal-measures, contains Zechstein fishes, associated with plants closely resembling those of our Permian types. Of the fishes, the *Palæoniscus Wratislaviensis* (Ag.) and the *P. lepidurus* (Ag.) are the most abundant; and among the most common of the plants we may cite a *Neuropteris* (*Odontopteris*), which is never found in the underlying coal-measures, but is very characteristic of the Permian deposits of Russia. This identification is established on the authority of that excellent fossil botanist, Professor Göppert, who subscribed to our opinion, that the other plants of the limestone and flagstone of this red group, are distinct in species from those of the carboniferous strata. Now, as the fishes also, are referred to the same type as the Ichthyolites found in the Zechstein of Western Germany and in the parallel rocks of Russia, there can be no doubt, that these Silesian beds of red sandstone, shale, marl, and conglomerate, with an included limestone, not only represent the Permian system, but are singularly interesting, in indicating a closer approach to the Russian form of the deposit than their representatives in the west of Europe. We, therefore, confidently revert to the view which we expressed in proposing the term Permian, and we unhesitatingly include the Rohte-todte-liegende in this natural group[1].

Having thus indicated the strata which are the lower members of the Permian series in Germany, can we pursue the parallel upwards, and show, that, as in Russia, some of the beds overlying the Zechstein are also to be grouped with that rock? This question is one of considerable importance; for, as by its organic contents the Zechstein is now admitted to be of palæozoic age, we are called upon to decide, whether its uppermost natural limit was completed when the last beds of limestone were accumulated. What then are the facts in Germany to support this view? The answer is, that the Bunter Sandstein or next overlying rock, forms there as conformable a roof to the Zechstein, as the latter does to the Rohte-todte-liegende. That limestone, therefore, with the Kupfer-schiefer and its dependences, is thus simply the fossil-bearing centre of a great deposit of red conglomerates, shales, and sandstone. Wherever, indeed, the Zechstein occurs in a tract in which its relations to the overlying sandstone can be traced, the two

[1] See Letter of Mr. Murchison to Dr. Fischer von Waldheim, Sept. 1841, Moscow. Leonhard and Bronn's Jahrbuch for 1842, part 1. p. 91; and Phil. Mag. vol. xix. p. 418.

are found so intimately united, that the discovery of any Permian fossils in the overlying rocks, would at once compel geologists to place both series of beds in the same natural group. Now, in Germany, this next overlying mass of rocks (the Bunter Sandstein) is divided into two members, the lower of which is composed chiefly of sandstone, and the upper of marl; and in the lower of these, as far as our knowledge goes, no fossil remains have yet been found, with the exception of the *Calamites arenarius*, a plant which has been supposed to have a close affinity to, if indeed it be distinguishable from, one of the carboniferous forms.

Under these negative circumstances in Germany, and with the positive evidences derived from Russia, that the palæozoic type of the Zechstein *is continued into sandstones and conglomerates above that rock*, particularly through certain imbedded plants, we think that the lower part of the Bunter Sandstein in Germany (occurring as it does in exactly the same stratigraphical position as the upper conglomerates, marls and sands in Russia) must be separated from the Trias and united with the Zechstein.

In throwing out this suggestion, we by no means wish to abstract from the Trias the whole of the lowermost of its three members. We long ago examined *in situ* those sections near Strasburg and other places, which, by means of a continuous series of animal and vegetable remains, unquestionably connect certain underlying red marls and sands with the Muschelkalk. We simply point out, that as the thick deposit of Bunter Sandstein is, according to the newest German authorities, divisible (lithologically[1]) into two members, the lowest band, or a part of it, may be placed on the parallel of beds occupying a *similar position* in Russia, and in which palæozoic types prevail; whilst the upper Bunter marls and the "Grès bigarré" properly so called, will doubtless continue to form the true base of the Trias or secondary rocks (see woodcut, p. 204). The state of the case, when fairly put, seems to be this. The region of Permia has first afforded proofs of the palæozoic shells and plants being extended upwards into red deposits *above* the Zechstein, whilst the strata occupying a similar position in other parts of Europe have not yet contributed any opposing evidence, either as regards stratigraphical arrangement or fossil contents.

In England there is, we apprehend, little difficulty in grouping the various members above the coal-measures, which constitute or represent the Permian system. The most important of them were long ago ably described by Professor

[1] See Table prepared by M. Cotta, attached to the geological maps of Saxony prepared by Professor Naumann and himself. We may add, that in a letter to us, Professor Naumann sees no objection to our proposed classification.

Sedgwick, when he showed, for the first time, that the Lower New Red sandstone[1] was the equivalent of the Rohte-todte-liegende (Pontefract rock of Smith),—which overlaid conformably by the Magnesian Limestone or Zechstein (the latter rock with flags representing the Kupfer-schiefer), was associated with red marls, gypsum and sands. His section, indeed, of the succession near Kirkby in Nottinghamshire, exhibiting a lower and an upper red sandstone, with beds of shale and limestone between them, the whole overlying the coal-measures (in this instance conformably), is a very good illustration of our united group[2]. In other parts of England adjacent to the Silurian region, we place in parallel with the Permian system, all those red sandstones and conglomerates, which immediately surround and overlie the coal-fields of the central counties, and in which the Magnesian Limestone or Zechstein is represented simply by a calcareous conglomerate, occasionally dolomitic[3].

In respect to Germany we may further state, that besides visiting in 1843 certain tracts in and around Saxony, including the Thüringerwald (with the environs of Halle we were previously acquainted), we also examined that part of Hesse Cassel of which Riechelsdorf is the centre, in all of which districts we perceived a conformable succession from the Rohte-todte-liegende and Zechstein into the lower Bunter Sandstein. In Hesse Cassel, indeed, M. Althaus of Rothenburg, an intelligent geologist and a director of mines, has distinguished in his district, a lower from an upper Bunter Sandstein, the former constituting, as in other parts of Germany, the regular cap of the Zechstein.

Now, whilst this lower Bunter Sandstein of Central Germany is unproductive of animal remains, a similar negative character pertains to the rocks of the same age which range up to the valley of the Rhine south of Frankfort, and extend from

[1] Scarcely any plants of the Lower New Red of England have yet been made known. The "Pontefract Rock" of William Smith, which is not unlike one of the varieties of our Permian grits, contains, as we are informed by Professor Phillips, some obscure plants, one of which was described by Professor Lindley. Fossil Flora, vol. iii. pl. 195. We cannot mention the name of so distinguished a geologist as Professor Phillips without stating, that he has long been of opinion, that the shells of the Magnesian Limestone are of the true palæozoic type; and, although Mr. Murchison was formerly opposed to this classification, chiefly on account of the Magnesian Limestone containing Saurians—vertebrata unknown in the older palæozoic divisions—he has since become completely convinced of its accuracy. It is right on his part to state, that his colleagues, M. de Verneuil and Count Keyserling, were always of the same opinion as Professor Phillips.

[2] Geol. Trans., New Series, vol. iii. pp. 56, 57, 80 and 81, plate 5. fig. 1.

[3] See Silurian System, pp. 54 *et seq.*, 466 *et seq.*, and plates 29 and 37. See also new Geological Map of England by Mr. Murchison, published by the Society for the Diffusion of Useful Knowledge, in which the Permian classification is for the first time applied.

Heidelberg to Baden-Baden. At the latter place, the formation assimilates to its type in the Vosges mountains on the opposite bank of the Rhine, where it has been admirably described by M. Elie de Beaumont under the name of "Grès de Vosges," and clearly separated by him from the overlying Trias. As in the Vosges, the Zechstein is omitted at Baden-Baden, and the series consists, in ascending order, of a conglomerate often composed of granitic, porphyritic and older slaty rocks, succeeded by sandstone and shale, both red, white and mottled. Though we entertained no doubt when on the spot, that these strata, as well as those of the Vosges mountains, through which we passed, were the equivalents of our Permian rocks, it is a high gratification to be able to state, that upon consulting M. de Beaumont, we find this eminent geologist is quite of our opinion, and that he adopts with us the classification by which our Permian group, comprehending the Rohte-todte-liegende, the Zechstein and the lower Bunter Sandstein, is represented in the Rhenish country and in France by the "Grès des Vosges[1]."

In the comparison, however, with Central Germany, it is well to state, that the Russian succession presents few or no traces of the thick development of red sandstone and conglomerate which is distinctly intercalated between the carboniferous rocks and the Zechstein[2], as might be expected in a flat and undisturbed region. In some Russian tracts, indeed, we have shown, that the Zechstein or Permian fossils imbedded in marlstone and limestone succeed, with scarcely any other intervening rocks than bands of gypsum, to the great mass of the carboniferous limestone. In other districts, however, grey grits and sandstones underlie as well as overlie those courses of limestone which represent the Zechstein, whilst the conglomerates chiefly cover the calcareous zone. But we must not attach undue importance to the identification of mineral structure in establishing a succession in synchronous deposits of distant countries. We have already seen, that with a most striking similarity in the general distribution of life, between each great palæozoic system of Russia and its equivalents in Western Europe, the examination of Russia has revealed to us very considerable discrepancies in the nature of the imbedding rocks. To recede, for example, no further than the immediately subjacent deposit, we learn that the great masses of the coal-fields of

[1] See M. de Beaumont's view of the Grès de Vosges, Mém. pour servir, vol. i. and "Déscription de la Carte Géol. de France," vol. i. p. 391 *et seq.*

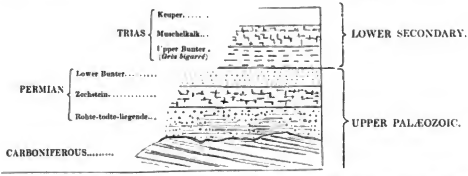
[2] It is very probable that certain sandstones and conglomerates (not the goniatite grits of Artinsk), on the western flank of the Ural Mountains, may represent, as before said, the Rohte-todte-liegende, a point to which we shall revert in Part II. See Table with the Map.

England, France, Belgium and America have no well-marked equivalents in Russia, nearly the whole of the carbonaceous matter in the empire being included in the lower or calcareous member of that system.

We repeat, then, that the Permian rocks of Russia consist of an assemblage of sandstones, grits, conglomerates and marls, with subordinate bands of gypsum and limestone, which, without exactly following the *same detailed mineral sequence* as the deposits of similar age in Germany, is bound together by certain natural links; and we are thereby induced to propose the word Permian, to designate a natural group in Europe, hitherto undistinguished by any common name.

To dispel all uncertainty from the minds of our readers concerning the equivalents of the Permian system in Western Europe, and their prevalent relations to the strata beneath and above them, we annex the accompanying woodcut.

33.



In exhibiting this diagram, we do not mean to assert, that the carboniferous strata are everywhere unconformable, as here represented, to the base of the Permian rocks. Sections in England have, indeed, already been cited, which show a perfect conformity between these deposits; though many other cases in the same country may also be appealed to, where they are as discordant as in Germany, and where the surface of the carboniferous strata has undergone denudation as well as dislocation anterior to the accumulation of the overlying deposits[1]. On the other hand, there is no example, in any part of Europe, of the slightest unconformability between the upper part of the Palæozoic or Permian rocks and the lower secondary or Trias; and yet the carboniferous and Permian fossils have that striking community of character which we shall develope in the succeeding pages, whilst the Permian and Triassic fossils *are entirely distinct*.

[1] See memoir of Professor Sedgwick, *ut supra*, Geol. Trans. vol. iii. plate 5. fig. 3. plate 6. fig. 1, &c.

This is an important fact[1], and we dwell upon it as a proof, that the most marked distinctions between the fossils of succeeding formations cannot always be referred to violent physical revolutions of the surface, by which, as it has been supposed one group of animals was annihilated anterior to the creation of another. In the previous chapters we have, indeed, demonstrated, that throughout vast regions of Russia, the older deposits are most clearly separable from each other by means of their respective fossils, although they are all apparently conformable.

We will now strengthen our conclusions respecting the independence and true relations of the Permian system, by some general observations on its organic remains, and by showing in a tabular view their distribution, as far as it is known, in various parts of Europe.

Review of the Organic Remains of the Permian System.—Though less copious than that of the inferior palæozoic rocks, the fauna of the Permian System, being less known, well merits a detailed examination. It constitutes, in fact, the remnant of the earlier creation of animals, the various developments of which we have followed through the three preceding ages; and exhibits the last of the partial and successive alterations which those creatures underwent before their final disappearance. The dwindling away and extinction of many of the types, produced and multiplied in such profusion during the anterior epochs, and the creation of a new class of large animals, the Saurians, clearly announce the end of the long palæozoic period and the beginning of a new order of zoological conditions.

The two greatest revolutions in the extinct organic world are those which separated the palæozoic from the secondary age, and the latter from the tertiary. Viewed as the conclusion of the first of these epochs, the Permian deposits must, therefore, excite in the minds of geologists an interest, not inferior to that connected with the upper chalk, in displaying a similar apparent termination to a series of organic bodies.

The species which characterize the Zechstein or Magnesian Limestone and the Kupfer-schiefer having hitherto been mentioned in a number of detached works only, we have thought it advisable to group them together with our newly-discovered forms, in a synoptical table, in which we indicate the authors who have described each species, its synonyms, and the beds in which it has been found.

[1] In reference to this generalization, we must, however, bear in mind, that the "Grès des Vosges," which we have included in the Permian system, has been shown by M. Elie de Beaumont, to have been elevated *anterior* to the accumulation of the "Grès bigarré" and Keuper.

This inventory of an assemblage of submarine animals, which modern researches have taught us were about to pass away, has the advantage of enabling us to compare the whole Permian fauna with that of the preceding epochs, and also the special fauna of this epoch in Russia, with that of the corresponding deposits of Western Europe. Under these two points of view, we shall now successively consider the subject.

The total number of Permian species cited in our table, including four or five which are doubtful, is about 166. In this estimate, on the other hand, we do not reckon a few forms alluded to by some authors, the bad state of preservation of which or other causes have prevented their being precisely determined. This number is really small, when we compare it with that of the fauna of the Carboniferous or Devonian epochs, in each of which more than 1000 species have been either figured or described. Of the 166 known species, 148 are exclusively characteristic of the Permian system, whilst 18 only are found in the whole underlying series of Silurian, Devonian and Carboniferous rocks. If we dissect these numbers, in order to deduce the various elements of their composition, we easily discover the characteristic features which distinguish the Permian from the subjacent Carboniferous system.

The corals, which in the carboniferous epoch amount to more than 100 species, are, in the Permian system, reduced to fifteen, and even of such forms three or four only are abundant, and these, acording to Mr. Lonsdale, are chiefly species of Fenestella[1]. This sound naturalist also informs us, that not one of the Permian corals actually *examined by him* has been found satisfactorily referrible to carboniferous or older species, though they belong to genera which have a marked palæozoic character.

The Crinoidea are extremely scarce, and of the seventy to seventy-five species which inhabited the carboniferous seas, one only, the *Cyathocrinites planus* (Mill.), appears to have lived during the Permian epoch. Even this solitary species is extremely rare, and we are as yet unacquainted with it in Russia.

[1] Since the two previous chapters were printed, we have been favoured by our valued friend Mr. Lonsdale with a corrected list of the Permian corals, founded not only on the examination of all the Russian specimens we collected, but also on a rich assemblage of English species submitted to him at our request by Mr. King of Newcastle-upon-Tyne. The new names in the table at the end of this chapter are those of Mr. Lonsdale, and his explanation of the changes he has found it necessary to make in the names of previous writers, will be given in Part III.

Among the shells of the ancient formations, the Brachiopods are those to which, in common with other practical geologists, we attach the greatest importance; and it is by their evidences that we are best enabled to trace the close connexion between the Carboniferous and Permian systems. Ten out of the thirty Permian species are common to the two systems, whilst the genera Productus and Spirifer, both characteristic of the carboniferous epoch, are continued throughout the Permian deposits; the first offering six, the second eight species. All the Permian Producti are very spinous, and the prominent species is the *P. horridus* (Sow.), (*P. aculeatus* (Schloth.). Two only of this genus are ornamented with regular longitudinal striæ, viz. the *P. Cancrini* (nob.) and *P. Leplayi* (nob.), the first of which has a very singular distribution. Occurring profusely through the Permian strata of Russia, and serving there as an infallible mark of their age, it is completely wanting in the corresponding deposits of Western Europe, but is found in one well-known locality of carboniferous limestone at Visé in Belgium [1].

The Spirifers of the Permian system, being all plaited, have much analogy with those of the inferior strata: two species appear to be common to this and the carboniferous series, one of which, however, referred by us to the *S. hystericus*, is still doubtful.

The Orthis, one of the earliest forms of Brachiopods, and which we have shown to be so eminently characteristic of the first or Silurian period, decreases in the number of its species as it ranges through the Devonian and Carboniferous zones, and in the Permian it has but three representatives, one of which occurs in Russia and two in Germany.

The small genus *Chonetes* (Fischer), the importance of which is chiefly due to the wide distribution of one of its species, the *C. sarcinulata* (*Leptæna lata*, V. Buch), may be said, in its European distribution, to rise from the Silurian into the Carboniferous system; and if our views respecting the gypsiferous tracts near Bachmuth be correct, into Permian deposits also. It is so abundant in the Ludlow rocks (Upper Silurian) of England, as to be one of the best types of that formation, and in Sweden it seems to occur in beds of the same age. In the palæozoic rocks of Great Britain and Belgium, indeed, it continues to the Carboniferous series inclusive; whilst in Russia, being entirely absent in the Silurian and Devonian systems, it appears for the first time in the Carboniferous, and more abundantly than in the corresponding deposits of the west! This fact, though

[1] See De Koninck. Descrip. Foss. Belg. p. 179, pl. 9. f. 3. 1842.

remarkable, is not inexplicable, even by reference to such laws of distribution as must have resulted from repeated changes of the configuration of the bottom of the sea, and other submarine phænomena, by means of which this species of Chonetes may have been displaced from its western habitat at an early period, and propagated towards the east, where, under favouring conditions, it subsequently assumed a great development; thus offering the rare example of a species, which, changing its region, lived through three great palæozoic epochs, and was partially in existence during a fourth.

The genus Pentamerus, so characteristic of the Silurian epoch, and which begins to be very rare in the Devonian strata, has not hitherto been found in the Carboniferous deposits, and does not reappear in the Permian epoch. Conformably, however, with the prevailing evidences of the development of nature, which in the modifications of beings at successive periods, seems often to retain some feature of the preceding types, the Silurian and Devonian Pentameri are represented in the groups which next followed by forms of Terebratulæ, which offer in their internal arrangement a part of the structure of Pentameri[1]. We here allude to the *Terebratula Schlotheimi*, V. Buch, and *T. superstes* (nob.). In these species, in fact, the dorsal valve is furnished, as in the Pentameri, with two oblique, dividing *plates*, which unite at their base, and are fixed on to a vertical septum that is attached longitudinally to the central portion of the shell. These singular Terebratulæ of the Carboniferous and Permian deposits, which thus replace the Pentameri, disappear in their turn at the close of the Palæozoic age. The *Terebratula Schlotheimi*, we may here observe, presents the remarkable peculiarity, that in Russia it belongs exclusively to the Carboniferous rocks, in two localities of which it has been detected; whilst in England and Germany it is a characteristic fossil of the Magnesian Limestone and Zechstein.

The Permian deposits do not contain more than nine species of Terebratulæ which have been correctly determined, five of which are found in the lower Palæozoic formations. The prevailing species are smooth with concentric striæ, one only, the *T. Geinitziana* (nob.), which is allied to the *T. Thurmanni*, being plaited.

In effect, if the Brachiopods be viewed as a whole, we believe that of upwards of 200 species which prevailed during the carboniferous epoch, ten only prolonged

[1] Mr. King, Curator of the Natural History Society of Newcastle-upon-Tyne, with whom we have been in correspondence upon this subject, proposes to establish a new genus for these shells under the name of Camerophoria (see his forthcoming Description of the fossils of the Magnesian Limestone of England).

their existence into the Permian æra, whilst twenty new species complete the total number which researches have shown to have occurred in this last period.

Passing now to the Conchifers of the order Dimyaria, we may state, that whilst upwards of 120 species have been detected in the Carboniferous strata, their number is reduced to twenty-six in the Permian system. Among the most characteristic of this family, the genus Modiola is extensively found through Russia and England. In the former country, our *Modiola Pallasi* is as certain a type of the age of the rocks in which it occurs, as the *Productus Cancrini* (nob.): in England the characteristic Modiola is the *M. costata*. The genus Axinus[1], so very abundant in the Magnesian Limestone, and so peculiar to that rock, has its Russian representatives in the *A. Rossicus* (nob.), and in the *A. pusillus*.

Among the Monomyaria the genus *Avicula* is nearly as important as the *Modiola* in the Dimyaria. It contains eight species, all of small size and generally smooth. The best known in Western Europe are the *Avicula keratophaga*, *A. antiqua*, and *A. speluncaria*. One of the valves of the last mentioned has a gryphoid form, and bears a great resemblance to our Russian type, *A. Kazanensis*.

The number of the Monomyaria, amounting to about seventy-five in the Carboniferous epoch, is reduced to sixteen in our system, and fifteen of these are peculiar to it. The *Avicula antiqua*, found by ourselves in the carboniferous limestone of Vitegra and of Malayoraslovetz, between Kaluga and Moscow, is the only species of the genus which is common to this and another palæozoic zone.

The Gastropods appear to have undergone much diminution in the formation of the Permian strata, and to have had great difficulty in accommodating themselves to new conditions. For, if we pass over the seven minute species of *Turbo* and *Rissoa*, occurring in one locality only near Manchester[2], the number of Gastropods known throughout England, Germany and Russia, in rocks of this age, amounts but to fifteen species, a number which must appear still more insignificant, when we reflect, that as many as 225 species of this class are known in the Carboniferous system. These fifteen Permian species are almost all new; three only having been able to live on from the Carboniferous to the Permian epoch. The rarity of individual Gastropods which are met with in the strata, seems to combine with the

[1] *Schizodus*, MSS., King. See Observations, Table, p. 224.

[2] This deposit is described by Mr. Binney, 1st vol. Trans. Geol. Soc. Manchester, and the shells are determined by Mr. Brown.

paucity of species to make us presume, that the causes which were opposed to their free development produced very extensive effects.

The Cephalopods, which under the forms of Goniatites, Nautilus and Orthoceras were so numerous during the Carboniferous period, that 160 species have been already described from its strata, were almost entirely annihilated previous to or at the commencement of the Permian æra. At all events, notwithstanding our keen researches, we have been unable to obtain the smallest trace of a Goniatite or Orthoceratite in any of the Permian tracts of Russia, the only specimen of Cephalopod which we could detect being a fragment of a doubtful Cyrtoceras, in the limestone of Shidrova, near Ust-Vaga. A Nautilus, figured by Dr. Geinitz[1], is the only specimen of a Cephalopod with which we are acquainted in the Zechstein of Germany. The museum of the Natural History Society of Newcastle possesses also some fragments of a Nautilus, to which Mr. King refers the portions of a chambered shell, assigned to an ammonite by Professor Sedgwick, in his Memoir on the Magnesian Limestone. Now if the chambered fragments which we found in Russia, and supposed to belong to a Cyrtoceras, should prove to be portions of a Nautilus, the Cephalopods are reduced to a solitary genus of very rare occurrence.

This scarcity of Cephalopods at the close of the Palæozoic æra has a remarkable parallel in a subsequent geological period; for as these animals were reproduced in vast abundance and under many new forms in the Triassic, Jurassic[2], and Cretaceous systems, so towards the termination of the last of these, we perceive a second and similar disappearance of the greater number of shelly Cephalopods. The extreme reduction in the number of Gastropods at the close of the Cretaceous period is, indeed, an additional feature of resemblance between these two epochs; for twenty-four species of this class only have been discovered by M. d'Orbigny in

[1] Neues Jahrbuch, Leonhard, 1841, pl. 11. f. 1. Whilst we write Professor Sedgwick has discovered a Nautilus in the Lower Silurian rocks of Bala in North Wales, and thus Cephalopods of this generic form, have existed from the older Palæozoic or Protozoic to the present period, however they may have been obliterated at certain epochs.

[2] The recent researches of M. Alcide D'Orbigny have led him to believe, that the close of the Jurassic period bears a strong analogy to the termination of the Palæozoic and Cretaceous æras in the notable diminution of the number of chambered shells. In the Portland rock he admits but three species of Ammonites, which certainly seem to be of small value when contrasted with the prodigious numbers of species of these creatures on the one hand in the lias, lower and middle oolite, and on the other in the succeeding greensand and cretaceous rocks. English geologists, however, cannot forget that in the frequent occurrence of the same species and in the extraordinary size of the individuals, the Portland rock is eminently *Ammonitic*.

the upper chalk, whilst he describes 134 in the lower member of the formation (*craie chloritée*).

If future discoveries and a more perfect acquaintance with the zoology of these epochs, should oppose no evidence to conflict with that which is now accumulated, some persons might be led to perceive in this grand and intermittent phænomenon, the recurrence of a general law. Whilst, however, our present acquaintance with their respective faunas would certainly lead us to conclude, that the Permian and Cretaceous systems have each preceded an almost entire renovation of animal life, it is right to state, that judging from many of their generic forms, the upper secondary rocks seem to have prepared the way for the sequence of the tertiary strata. In short, some geologists, including ourselves, who have contended for this view, are still disposed to think, that with increased observation, a zoological passage may be discovered between the upper chalk and the lower tertiary deposits.

But after all, we are far from wishing to draw wide conclusions from limited and insufficient data; and we are too well aware of the recency of the discovery of multitudes of species in the older Palæozoic rocks, not to be alive to the necessity of much caution in deducing general zoological inferences. We have still, however, great reliance on the fact, that few strata have been longer or more assiduously examined, than the Zechstein and Kupfer-schiefer of the Germans and the Magnesian Limestone of the English; and, as the activity of modern collectors has added little to our stock of knowledge of the animal remains of these rocks, we have a fair right to reason upon the general character of their fauna. Yet more have we authority to take this view, when by traversing the vast basin of Russia, occupied by synchronous strata, we find the same group of fossils and the same species extending from the mouth of the Petchora and the country of the Samoyedes upon the Northern Ocean, to the south of Orenburg, or over upwards of 18 degrees of latitude[1]!

[1] Whilst we write we have received intelligence from our friend and colleague, Count Keyserling, that in an expedition during the last summer with M. Krusenstern, to determine the geographical outlines, geological structure, and natural productions of the region around the embouchure of the Petchora, he has there traced the Permian strata occupying the plateaux on its left bank; the depressions being occupied by Jurassic and post-pleiocene deposits. He has further discovered an undescribed low chain of mountains called the Timans, forty to fifty versts wide, which, trending from the sources of the Vitchegda to the north-north-west, forms the eastern limit of the Permian deposits, and is separated from the Ural by the very broad intervening trough of the Petchora. In this ridge and trough, as in the North Ural, the Permian rocks do not exist; the only sedimentary strata being the Lower Palæozoic, which are associated

If we extend our review to the higher orders of creatures in the Permian system, we perceive that Trilobites are entirely wanting. Schlotheim alone has spoken of a fragment of a Trilobite in the copper slate of Saxony, but Count Münster has ascertained that this supposed Crustacean is an ichthyolite, belonging to his genus *Janassa*. The entire disappearance of these beings, so characteristic of the most ancient formations, is one of those striking phænomena to which we attach great importance. In the study of the palæozoic succession we see, indeed, that the disappearance of this race is regularly announced, by a gradual diminution of its numbers during the preceding epochs. Appearing among the earliest forms of life and having their maximum of development in the Silurian period, Trilobites decrease very sensibly in the Devonian strata, and in the carboniferous deposits are reduced to some few small species, of which the *Phillipsia* and *Griffithides* (Portlock) are the last expiring forms. And here we are presented with one of those beautiful links in natural history, of which the strata forming the earth's crust have afforded so many proofs; for, with the final extinction of a family destined never more to reappear, its place is taken by an allied Crustacean, the Limulus, the earliest form of which was created during the formation of the great coal-fields, and was followed, in our Permian system, by the large and remarkable species as yet peculiar to Russia, the *Limulus oculatus* (Kutorga). Unlike the Trilobite, the Limulus has survived all the numerous revolutions which have followed its creation, and some of its species, far different indeed from the earlier types, are co-existent with our own race.

Unfavourable as the conditions of life in Europe seem to have been, during the Permian æra, to many orders of Mollusca, and notably to the peculiar crustaceans called Trilobites, they were not antagonist to the propagation of aquatic Vertebrata. The fishes, which, commencing in the Upper Silurian rocks, obtained a great development in the Devonian and Carboniferous æras, hold a considerable proportion with reference to other classes in the Permian fauna. They are represented by sixteen genera including forty-three species, all of which, save one, are peculiar to the Permian deposits. The solitary exception is the *Palæoniscus Freislebeni* (Ag.), which it is right to observe, has been detected at Ardwick,

with granitic, eruptive and metamorphic rocks. This subject, embracing the discovery of many well-characterized Silurian fossils not hitherto observed in the Baltic provinces, together with well-recognized Devonian fishes and Carboniferous types, is mentioned at greater length in our Introduction, and will be again alluded to in the subsequent pages. (See Map).

near Manchester, and in the uppermost coal-measures only; beds, in fact, immediately subjacent to strata of the Permian age[1]. Whilst, therefore, fishes, considered as a class, were propagated throughout the æra of which we are treating, we see in the solitary presence of this species, and in one district alone, the confirmation of that law generalized by the researches of Agassiz, that these vertebrata serve to mark with extreme precision the age of the deposit in which they are found; there being the rarest example of any one species having lived beyond the duration of the waters and the peculiar sediment in which it was called into being.

Above all, the Permian epoch is remarkable in being the most ancient, in which the labours of geologists have as yet brought to light the existence of Saurians. The bones of this class of large Vertebrata occur, both in beds beneath the Zechstein and in the upper portion of the system,—we speak of the Thecodont Saurians, Palæosaurus and Protosaurus. This striking fact, which is in parallel, if we may so speak, with the annihilation of Trilobites, indicates the incessant action of that law of improvement and partial alteration in the animal kingdom, the effects of which are slow and successive, and appear to be often independent (specially so, indeed, in Russia) of those great physical mutations which have affected the surface of the planet.

Having reviewed the Permian fauna as a whole, and having brought prominently forward the relations by which it is connected with those of the preceding period, it is now necessary to consider it under another point of view, and to ascertain the nature of the modifications which it undergoes in distant geographical regions. In the first instance we have followed it back *in time*, and have compared the whole fauna of the period with that which preceded it We are now called upon to study it *in distance*, or in its horizontal extension, to compare its different parts with each other, the fossils of Russia with those of Western Europe; and to see whether zoological deductions confirm the parallelism which we establish, between the vast Permian basin of Russia, and the more circumscribed deposits associated with the Zechstein and Magnesian Limestone of our own countries.

In Russia, as in all other parts of Europe, the Permian fauna is poor in its variety of species. The shells are for the most part found in the calcareous bands which occupy its lower and central divisions, constituting, like the Zechstein and Kupferschiefer of Germany, or the Magnesian Limestone of England, the great centre of

[1] Silurian System, p. 89.

the animal life of the epoch. Yet here again, as in the preceding and subsequent ages, we can by no means bring the Russian succession of Permian strata into a detailed stratigraphical analogy with that of Western Europe. Thus, for example, as we have before explained, the calcareous courses of Russia occasionally inosculate with great thicknesses of fossiliferous grit; but the Saurians, fishes, certain Producti and Modiolæ, with most of the plants, unquestionably occur in conglomerates, sands, tufaceous limestones and marls which *overlie* the beds with Zechstein fossils. In Germany, on the other hand, the Protorosaurus, so long known there in the deposits of this age, occurs in the Kupfer-schiefer or beds *beneath* the Zechstein. It is true, that over enormous areas of Russia, we were enabled to detect fossils in the superior strata at wide intervals only[1]. Long-continued and minute labours to discover fossils were indeed incompatible with the chief object of our researches, which was necessarily directed to the general classification of the deposits, which in Russia are spread over such wide districts. Still, in justice to ourselves, we must say, that in overcoming the obstacles which we encountered, in order to arrive at a true estimate of the equivalents of the Permian group, we neglected no means within our reach. In proof of this we may state, that our list contains fifty-three Russian species, a greater number than that of any preceding author who has described deposits of this age in Western Europe, where they have been so long under examination. This fact, considering the rapid nature of our journey and the very few fossils of this age known in these regions, before we traversed them[2], proves, as we might indeed expect, that the number of Permian fossils will be found to be in proportion to the *extent* of the sea of that epoch, the bottom of which has been explored.

To enable our readers to form their own conclusions on this point, let us cast a rapid glance over the various fossil lists which have been published by authors who have described the Zechstein of Germany or of England.

Schlotheim[3], who first paid attention to the organic remains of this group, describes fifteen species only.

[1] Terebratulæ have been since found by Count Keyserling on the banks of the river Suchona, in beds wherein we did not detect fossils. (See Map, and p. 177.)

[2] Our excellent friend Major Wangenheim Von Qualen is the only person of our acquaintance, who residing in the heart of the Permian region, occupies himself in collecting fossils. To him is due the discovery of the Saurians described by Fischer and mentioned by ourselves, and we learn whilst we write, that he has found an almost entire skeleton of one of these animals.

[3] Denkschriften der Mün. Akad., 1817, vol. vi.

Professor Sedgwick [1], in his memoir on the Magnesian Limestone of the North of England, indicates thirty-three species distributed in the following manner:—Fishes, 8; Cephalopod (fragment of); shells, 22; of these 8 only are determined; and 2 Retepores.

M. Quenstedt [2], in a careful comparison of the fossils of the Zechstein of Thuringia with those of the Magnesian Limestone of England, enumerates 10 fishes, 16 shells, 1 encrinite, and 4 corals.

M. Kurtze [3] and Professor Germar [4], in describing the organic remains of the Kupfer Schiefer of Mansfeld, have made us acquainted with 8 or 10 fishes only; but Professor Agassiz and Count Münster have amply supplied the deficiency [5].

Mr. Binney and Mr. Brown [6] have recognised 17 species of fossils, many of them microscopic, in the red marls of Manchester, which we consider to be of this age.

Lastly, the list of the remains of the Zechstein of Saxony, recently prepared by Dr. Geinitz [7], includes 11 fishes, 1 Nautilus, 7 Gasteropods (3 only determined), 8 Conchifers, 11 Brachiopods, 1 Encrinus, and 5 corals—in all 41 species.

The number of species, as we have just said, which we collected in Russia, amounts to fifty-three, *i. e.* about a third of the total number composing the whole of the known Permian fauna. Of these thirty-two are peculiar to Russia. Among the 21 species which remain, 16 are known in the Zechstein of Germany or in the Magnesian Limestone of England, and 5 only appear to be absolutely identical with species which have hitherto been found in the more ancient palæozoic deposits. If we analyse this number of 16, which is common to the Permian system of Russia and the rest of Europe, we perceive that four of the species existed at the preceding or Carboniferous period; and if to these, five others be added, which in Russia are peculiar to the Permian strata, whilst they are identical with carboniferous forms of other countries, we learn that among 21 Permian species common to Russia and Western Europe, 9 have lived on during both epochs. When, however, we restrict our view to Russia, it is found that of these 9, 3 only of the 53

[1] On the geological relations, etc. of the Magnesian Limestone (Transact. Geol. Soc. of London, 2nd series, vol. iii. part 1, 1829).

[2] Über die identität der petrificate der Thüringischen und Englischen Zechsteines (Wiegm. Archiv, 1839, p. 79–89, pl. i.).

[3] Kurtze; commentatio de petrefactis quæ in schisto bituminoso Mansfeldensi reperiuntur. Haliæ, 1839.

[4] Germar; die Versteinerungen der Mansfelder Kupferschiefers. Halle, 1840.

[5] Agassiz, Poissons Fossiles, and Münster's Beitrage, Heft 1, 3, 5 and 6.

[6] Transactions of the Manchester Geological Society, 1841, vol. i.

[7] Gæa von Sachsen (Dresden und Leipzig, 1843).

Permian species of that country descend into the palæozoic rocks. These results prove, that there necessarily exists a relation between the greater or less duration of the existence of species and their propagation or extension to distant parts, and it confirms, in a remarkable manner, that law previously announced by one of us[1], viz. "*that the species which are found in a great number of localities, in very distant countries, are almost always those which have lived during the formation of several different systems.*"

Let us now take a rapid view of the species found in Russia, in order to compare them, in each class, with those of other parts of Europe, and thus to bring out in strong relief the contemporaneity of the deposit in distant countries.

By the study of ichthyolites Palæontology seemed to teach us, as we have before said, that in proportion to their elevation in the animal kingdom, fossils are most characteristic of given deposits. But much caution is required before we can reason from this doctrine inversely, and infer that the lower the order of animal the more uncertain criterion is it of the age of the stratum. From the existence of some species of corals, both in Silurian and Devonian rocks of great thickness, it is ascertained, that under certain conditions these creatures lived on through very long periods. But can we apply this view to the Permian rocks? Are Polypifers of the pre-existing Carboniferous age found in them, and to what extent? Had our own imperfect knowledge been appealed to, we should have said with our precursors, that several forms of this low class of beings were common to the two systems. The philosophic researches, however, of Mr. Lonsdale have convinced this great authority on such a subject[2], that when examined under a lens of high power, nearly all the Permian corals are seen to be distinct in species from those of the Carboniferous æra.

Concerning the Brachiopods we may venture to express our own opinion. Of twenty species eight are peculiar to Russia, and twelve are already known elsewhere. These twelve species are thus distributed: two, viz. *Terebratula pectinifera* and *T. plica*, belong exclusively to the Zechstein of Western Europe; a third, *Spirifer undulatus*, is doubtful; three, viz. *S. cristatus*, *Terebratula elongata* and *Lingula Mytiloides*, are common to the Zechstein and the older formations; one, the *Terebratula Schlotheimi*, occurs in carboniferous rocks in Western Europe, and in the Permian strata of Russia: and lastly, five others, *Terebratula Royssii*,

[1] De Verneuil and D'Archiac, Trans. Geol. Soc. Lond. 2nd series, vol. vi. p. 335.

[2] See Mr. Lonsdale's Description of the Corals of the Silurian and Devonian rocks in Murchison's 'Silurian System;' also in the Geol. Trans. vol. v. p. 734; vol. vi. p. 227 *et seq.* See also his Description of the Russian Corals in an Appendix.

T. concentrica, *Spirifer hystericus*, *Chonetes sarcinulata* and *Productus Cancrini*, are peculiar, in the west, to the carboniferous or subjacent formations. The comparison of these twelve species of Brachiopods with those of Western Europe, appears, at first sight, to be indecisive of the question, as to the stage in the geological series in which we ought to place the Permian deposits of Russia. But without even quitting this class of Brachiopods, the consideration of their other species shows an amount of parallelism, in the modifications they have undergone simultaneously in both countries, which in itself excludes all doubt. The *Productus horrescens*, for example, however distinguishable from the *P. horridus*, is evidently the analogue of this shell so characteristic of the Zechstein; and the disappearance of all the large carboniferous Producti with longitudinal striæ, and their replacement by small spinose species, as well as the striking diminution of every species of Orthis, both in Russia and in the West of Europe, are strong negative characters, which clearly establish the contemporaneity of distant strata, accumulated under the influence of analogous organic laws.

The Dimyaria present eleven Permian forms in Russia, of which eight species are peculiar to the country, and three others to the rest of Europe. Among the shells of this class the *Modiola* is the most abundant genus in Russia,—a fact which is in perfect harmony with the distinguishing features of the system in other countries.

The Monomyaria are less numerous, and are represented in Russia by seven species, four of which are peculiar to the empire, and three are already known in the Magnesian Limestone of the West. These three species all belong to the genus *Avicula*, which in Russia, as in all the other regions of the same geological age, offers several small smooth species, and is, above all, rich in specimens. Among the species peculiar to Russia, we may cite the *Avicula Kazanensis*, which there replaces the *Avicula speluncaria* of Germany, the existence of which in Russia is problematical.

The Gastropods do not present any interesting result, except that of the very limited number of their species, which is in conformity with the general law we have remarked in the relations of the Permian fauna. So is it with the Cephalopods and Trilobites; for the entire absence of the latter and the extreme rarity of the former, are completely in harmony with the facts observed in the other Permian regions of Europe.

The small number of fishes enumerated up to the present day in Russia might at first seem to be less accordant with what has been observed elsewhere; but we must remark, that it is rather to the want of sufficient researches, and also to the deficiency of adequate identification and description, than to the non-existence of such forms, that the poverty of our list is due. In proof of this it may be stated, that we have visited one of the chief localities only, Kargala, where the remains of fishes are associated with those of thecodont Saurians, whilst we inspected other specimens from near Menselinsk and from the district of Bielebei, as well as from various places (some of the best of which are now deposited in the Museum of the School of Mines), which convinced us, that many species have already been discovered in true Permian strata[1]. On this subject, however, we must refer to the description preparing by Professor Agassiz and which has not yet reached us, of the few fragments of fishes of which we obtained possession. (See Part III.)

Lastly, we repeat, that there appears in Russia, as well as through Western Europe, in the deposits of which we now treat, a class of large and peculiar vertebrata as yet unknown in older rocks; and this striking coincidence between the eastern and western extremities of a great continent is one of the best proofs, that the laws, which in ancient epochs, presided over the first appearance of new classes of animals, exercised a simultaneous influence over vast territories, if not over the whole surface of the globe.

This synchronous development of the chief phænomena of organic nature appears to us to afford additional demonstration of the contemporaneity of the deposits which occupy so large a portion of the surface of Russia, and which we have termed Permian, with those strata never previously grouped together upon geological and zoological evidences; viz. the Rothe-todte-liegende, Kupfer Schiefer, Zechstein, or Magnesian Limestone, and the lower part of the Bunter Sandstein, or Grès bigarré (Grès Vosgien) of M. Elie de Beaumont. The number of Russian species identical with those of Western Europe is, indeed, pretty nearly what we might expect to meet with in this remote portion of Europe, where these deposits, not separated from each other by chains of older rocks, or interfered with by any ridges of intrusive character, constitute the most enormous basin ever yet described by geologists, the uniformity of which may be well explained, by its having been accumulated in a sea of such very large dimensions.

General remarks on the Permian Flora.—In the preceding pages we have more

[1] Fossil fishes of more than one species were also procured by Baron Humboldt and his associates Rose and Ehrenberg, from the copper sands of Verchni-Moulinsk near Perm, and they are deposited in the Royal Museum of Berlin, where we inspected them. They are mentioned by M. G. Rose in the description of the journey of Baron Humboldt, vol. i. p. 117, and will be described by Dr. Girard of Berlin. One of them seemed to us to be not very distant from *Palæoniscus catopterus*, Ag.

than once alluded to the plants of the Permian system found in Russia, and fortunately before this chapter is closed, we are enabled to give their general character from the pen of M. Adolphe Brongniart.

These plants were first submitted to the examination of our friend Mr. Morris, under whose direction four plates of them were prepared, but like ourselves he felt desirous to obtain the opinion of M. Brongniart. That great authority in fossil botany, whose detailed description will be given in Part III., recognises the following genera and species, from the form of their leaves, viz. *Neuropteris salicifolia* (Fischer), *N. tenuifolia* (Ad. Brong.), *Odontopteris Strogonovii* (nob.)[1], *Adiantites Strogonovii* (Fisch.), *O. Permiensis* (Brong.), *O. Fischeri* (Brong.), *Pecopteris Göppertii* (nob.), *P. Wangenheimii* (Brong.), *Neuropteris* (Fisch.), *Sphenopteris lobata* (nob.), *S. erosa* (nob.), *S. incerta* (Brong.), *Hymenophyllites* (Fisch.), *Nöggerathia cuneifolia* (Brong.), *Sphenopteris* (Kutorga), *N. expansa* (Brong.). Without having reference to the original specimens of some of the ferns, M. Brogniart remarks, that it is impossible he should adopt a decided opinion respecting such forms as those which have been termed by Fischer *Adiantites Göppertii*, *A. Brownii*, and *A. Brongniartii*; whilst he has no doubt, that the *Sphenopteris cuneifolia* of Kutorga is certainly a portion of a Noeggerathia, of which genus there may, he says, be more than one species.

Judging from the stems which he has examined, M. Brongniart adds to the list *Lepidodendron* (species doubtful), *L. elongatum* (Ad. Brong.), *Calamites* (n. sp.?), closely allied to several species of the coal fields, and particularly to *C. Suckowii*?

In conclusion, M. Brongniart observes, "If, after having thus passed in review[2], all the specimens of this system (Terrain), which I have examined myself, and those which are adequately figured, we compare this group of plants, as yet of small numbers, with the floras of the periods nearest to your Permian rocks, I remark,—1st. That two species appear to be identical with the plants of the Carboniferous deposits (Terrain houiller), viz. *Neuropteris tenuifolia* and *Lepidodendron elongatum*; whilst a large Calamite approaches to *C. Suckowii*?. 2nd. The other species, to the number of eleven, have not been observed up to this day in any other formation, neither in the coal-fields nor in the Trias. These are, *Neuropteris salicifolia*, *Odontopteris Strogonovii*, *O. Permiensis*, *O. Fischeri*, *Pecopteris Göppertii*, *P. Wangenheimii*, *Sphenopteris lobata*, *S. erosa*, *S. incerta*, *Noeggerathia cuneifolia*, *N. expansa*. 3rd. All these *genera* are common to the Permian and the Carboniferous systems, whilst up to the present time, the Lepidodendron, Noeggerathia, and Odontopteris have been found in the latter only, the true Neuropteris having been rarely detected in any other deposit. 4th. No one of these Permian fossils can be compared with the plants of the Trias. The absence of the characteristic Conifera of the lowermost division of these rocks (the Voltziæ), and those even (such as the Walchiæ) which are found in the upper stages of the coal-field and in the schists of Lodéve, indicate a very marked difference between the Flora of the Permian system and that of the New Red Sandstone or Trias. 5th. Botanically, the plants of the Permian system seem to be a continuation of

[1] The new species marked nobis are named by Mr. Morris.

[2] These details are given in Part III.

vegetable life of the same nature as that which prevailed during the Carboniferous æra. 6th. The fossil plants (few in number no doubt) which are contained in the Kupfer Schiefer and Zechstein of Germany[1], being for the most part marine, are necessarily very different from land plants of the Permian rocks of Russia."

The results of the inquiries of the botanist are therefore completely in accordance with those of the palæontologist. They clearly prove that the Permian system is the uppermost stage of that long Palæozoic series, which commencing with the lowest Silurian rocks, presents a connected succession of animal and vegetable life, the last traces of which passed away with the termination of the strata under review. Until Russia was explored, this upper member of these ancient rocks had scarcely afforded a trace of terrestrial plants. Neither in the British Isles nor in Germany had there been found more than one or two species of land plants in deposits of this age, no one of which has yet been fully identified or described. Now in reference to our Russian species, such of them as had been previously alluded to by other writers, were placed by some in the carboniferous rocks, by others in the New Red Sandstone[2]. Our sections, however, have shown that neither of these views is correct; and as the Russian plants to which we have called attention, occur for the most part in strata distinctly *overlying* beds containing the fossils of the Zechstein, it is clear that certain red sandstones, marls and conglomerates, above that rock belong to our Permian group, are wholly distinct from the Trias, and are truly Palæozoic.

We repeat, therefore, that we have now adduced ample botanical as well as zoological and stratigraphical evidence to vindicate the application of the collective word Permian, to a succession of strata which had not been previously united through their geological relations and organic contents.

These proofs will, we trust, be considered as still more strongly borne out by the grandeur of the phenomena to which we have appealed; for the Permian deposits of Russia repose upon Carboniferous strata throughout more than two-thirds of a basin which has a circumference of not less than 4000 English miles.

[1] The species of plants, ten or twelve in number, which have been found in the Kupfer Schiefer or the sandy beds associated with the Zechstein in Germany, are chiefly marine fucoids, and have been termed Caulerpites. According to M. Adolphe Brongniart, the only terrestrial plants of these German strata are the *Tniopteris Eckardi* (Germar), and a Neuropteris mentioned by Naumann, which not being determined is doubtful.

[2] See a very recent memoir by M. Yasikoff, Bull. de Moscou, 1843, part ii. p. 237, in which he refers an interesting portion of the Permian rocks described by us upon the Kama, and between that river and the Sok, either to the *New Red Sandstone or the Carboniferous Limestone.*

TABULAR LIST OF THE ANIMAL REMAINS OF THE PERMIAN SYSTEM IN EUROPE.

Note.—The abbreviations Sil., Dev., Carb., and Perm., and the letters S., D., C., P. after the localities, refer to the Silurian, Devonian, Carboniferous and Permian systems. The letters R. and E. respectively indicate that the species has been found in Russia, or elsewhere in Europe. The Russian localities are printed in Italics. The letters MS. King, refer to a monograph of the Magnesian Limestone fossils of England, about to be published by Mr. King, Curator of the Museum at Newcastle-upon-Tyne.

No.	Genera and Species.	Authors and References.	Palæozoic Systems.				Localities.	Observations.
			Sil.	Dev.	Carb.	Perm.		
	POLYPARIA.							
	Scyphia	Goldf.						
1	— undescribed	King, MS.				E.	Humbleton near Sunderland (K.)*.	
	Petraia ?	Münst.						
1	— undescribed	King, MS.				E.	Ibid (K.).	
	Cyathophyllum	Goldf.						
1	— profundum	Germar, Geinitz, N. Jahrb. 1842, p. 579. tab. 10. f. 14 *a*.				E.	Ilmenau, Mansfeld (G.)	Introduced on the authority of Geinitz.
	Anthophyllum ?	Goldf.						
1	— incrustans	Lons. *posteà*, pt. iii.				R.	*Ust-Vaga, Kirilof* (De V.).	
	Tubuliclidia	Lons.						
1	— spinigera	Lons. *posteà*, pt. iii				R. E. ?	*Ust-Vaga, Orenburg, Ilchegulova, Itschalki* (De V.); *Grebeni* (De V.), Humbleton. ?	
2	— crassa	Lons. *posteà*, pt. iii.				R.	*Ust-Vaga* (De V.).	
	Aulopora	Goldf.						
1	— undescribed	King, MS.				E.	Humbleton (K.).	
	Fenestella	Miller.						
1	— anceps	Lons. *posteà*, pt. iii. Ceratoph. id. Schl. Mün. Ak. vi. pl. 2. f. 7; Gorgonia, id. Goldf. tab. 36. f. 1; Schl. Syst. Verg. Pet. Samml. p. 19; Quenstedt, Wiegm. Archiv, 1835; p. 92; Geinitz, N. Jahrb. 1841, p. 641; and Gæa v. Sachsen, p. 98.				E.	Glücksbrunn (Sc. Gf.); Konitz (G. K.); Pösneck, Kamsdorf, Corbusen, Schwaara, and Dinz near Gera (G.); Humbleton (K.)	
2	— antiqua	Gorgonia, id.; Goldf. p. 98; Geinitz, Gæa v. Sachs. p. 98; Kutorga Verh. M. G. Petersb. 1842. pl. 6. f. 6.	E.	E.	R. ?	E.	Dudley, S.; Eifel, and Devonshire? D. (Gf. P.); *Ural*, C. (Gf.); *Sterlitamak*, C. (De V.); Konitz, Kamsdorf, &c. P. (G.).	Introduced as Zechstein species on the authority of Schlotheim.
3	— ? dubia	Gorgonia, id. Schl. Mün. Ak. vi. pl. 2. f. 4; pl. 3. f. 1. (Encrinites ramosus, pl. 4. f. 16.) Gorgonia id. Goldf. pl. 7. f. 1; Quenstedt, Wiegm. Archiv, 1835, p. 91; Geinitz, Gæa v. Sachs. 1843, p. 98.	E.	E.		E. ?	Glücksbrunn (Sc. Gf.); Konitz, Pösneck, Corbusen (G.).	
4	— flustracea	*posteà*, pt. iii.; Retepora id. Phillips, Geol. Trans. 2nd series, iii. p. 120. pl. 12. f. 8; Gorgonia infundibuliformis? Goldf. tab 10. f. 1 *a* (*exclusis aliis*).				E.	Humbleton (S. K.); Konitz (K. G.); Glücksbrunn (Gf. G.); Pösneck (G.).	
5	— infundibuliformis	*posteà*, pt. iii.; Gorgonia id. Goldf. pl. 36. f. 2 *a* (*exclusis aliis*).				R.	*Ural* ? (Gf.), *Ilcheguleva, Tchagestrova* on the *Dwina* (De V.).	
6	— ramosa	*posteà*, pt. iii. Hornera ? id. King, MS.				E.	Humbleton (K.).	
7	— retiformis	*posteà*, pt. iii. Escharites id. Schloth. Mün. Ak. vi. pl. 1. f. 1, 2; Eschara id. Schloth. Syst. Verz. Pet. Samml. p. 19; Gorgonia infundibuliformis Goldf. pl. 36. f. 2, *b. c*; Quenstedt, Wiegm. Archiv, 1835, p. 89; Geinitz, Gæa v. Sachsen, p. 98.				R. E.	Glücksbrunn (Sc. Gf. G.); Konitz, Pösneck (G.); *Itschalki*; *Grebeni* (De V.).	
8	— virgulacea	*posteà*, pt. iii. Retepora id. Phillips, Geol. Trans. 2nd series, iii. p. 120. pl. 12. f. 6, 7.				E.	Humbleton (S. K.).	
	ECHINODERMATA.							
	CRINOIDEA.							
	Encrinites	Mill.						
1	— ramosus	Schl. Beitr. pt. ii. pl. 2. f. 8; pl. 3. f. 9–15; Geinitz, Gæa v. Sachsen, p. 98; Cyath. planus, Miller, p. 86.			E.	E.	Bristol, Ireland, C.; Glücksbrunn, Kamsdorf, Pösneck, Mansfeld, Humbleton, P.	A species of an undescribed Cidaris has been found at Humbleton by Mr. King.

* In the class Polyparia the authority for the locality is given, as specimens from each have not, in all cases, been inspected by Mr. Lonsdale. De V. signifies De Verneuil, G. Geinitz, Gf. Goldfuss, K. King, M. Murchison, S. Sedgwick, Sc. Schlotheim.

No.	Genera and Species.	Authors and References.	Palæozoic Systems.				Localities.	Observations.
			Sil.	Dev.	Carb.	Perm.		
	CONCHIFERA. Brachiopoda.							
	Terebratula	Brug.						
1	— elongata	Schl. (non Sow.) Pet. pl.20. f.2; Nachtr. 20. f.2; id. Mün. Akad. vol. vi. pl. 7. f. 7; V. Buch, Ub. Ter. p. 106; Geinitz, Gæa v. Sachs. p.97; Römer Verst. des Harz. pl. 5. f. 18, 19, 20; T. Qualenii Fisch.; Bull. de Moscou, 1842, p. 466; id. Kutorga, 1842, Verh. M.G. St. Petersb. p.26. pl.6. f.2; T. hastata? Phill. (non Sow.) Pal. Foss. pl. 35. f. 168; Tab. nost. IX. f. 9 *a, b, c, d.*		E.	E.	R. E.	Grund, Harz; Newton Bushel? D.; Yorksh. C.; Schmerbach, Glücksbrunn, Corbusen, Pösneck, Humbleton, *Itschalki, Nikefur, Santangulova*, 2 versts from the *Dioma, Tchelpan, Yemangulova*, mouth of the *Sakmara* near *Orenbourg, Ilchegulova*; river *Suchona*, P.	T. lata, complanata, intermedia, Schl., Mün. Ak. vol. vi. pl.7. f.12–14. (according to M. Geinitz.)
2	— id. var.	T. plica, Kutorga, 1842, Verh. M. G. St. Petersb. p. 26. pl. 5. f. 11.			R.	R. E.	*Sterlitamak*, C.; *Kirilof*, Humbleton, Corbusen, P.	Variety with a dorsal sinus; according to M. de Buch, sometimes the *T. elongata* has the dorsal valve sinuated.
3	— sufflata	Schl. Mün. Ak. vi. pl. 7. f. 10, 11; Mém. Soc. Géol. Fr. vol. iii. pl. 19. f. 12 *bis*.				E.	Glücksbrunn, Schmerbach, Humbleton.	Closely allied to the preceding variety.
4	— concentrica	V. Buch, Ub. Tereb. and Mém. Soc. Géol. Fr. vol. iii. p. 216. Tab. nost. VIII. f. 15.		R. E.		R.	Eifel, Boulonnais, *Lake Ilmen*, D.; *Nikefur*, P.	
5	— Roissyi	Bull. Soc. Géol. Fr. vol. xi. pl. 3. f. 1 *b, c, d.* Sp. *id.* l'Eveillé, Mém. Soc. Géol. Fr. vol. ii. pl. 2. f. 18–20; De Kon. Foss. Belg. pl. 20. f. 1. pl. 21. f. 1.			E.	R.	Tournay, C.; *Kirilof, Arzamas*, P.	
6	— pectinifera	Atrypa, Sow. Min. Conch. vol. vii. pl. 616; Tab. nost. VIII. f. 16 *a, b.*				R. E.	*Kirilof, Tioplova, Bielebei*, Humbleton.	
7	— Geinitziana	nob. Tab. nost. X. f. 5 *a, b.*				R.	*Shidrova*; river *Suchona*	This species is nearly allied to *T. Thurmanni*.
	— inflata?	Schl.					Schmerbach, Röpsen	These three species are mentioned in M. Dechen's translation of De la Beche's Geol. Manual, but not described.
	— paradoxa?	idem					ibid.	
	— pygmæa?	idem.					Leimstein.	
8	— lacunosa?	Von Buch, Ter. p. 49; Zieten, pl. 41. f. 5; Geinitz, Gæa von Sachsen, p. 96.				E.?	Ilmenau (Geinitz), Humbleton (V. Buch).	We believe that this Jurassic species has never been found in the Zechstein.
9	— superstes	nob. Tab. nost. VIII. f. 5 *a, b, c, d*, e				R.	*Kirilof.*	
10	— Schlotheimii	Tab. nost. VIII. f. 4 *a, b, c, d, e*; T. lacunosa, Schl. Mün. Ak. vol. vi. pl. 8. f. 15–20; T. Schlotheimii, Von Buch, Mém. Soc. Géol. Fr. vol. iii. pl.14. f. 7; Geinitz, Jahrb. Min. 1841, p. 640; id. Gæa v. Sachsen, p. 96.			R.	E.	*Sterlitamak, Sarana*, C.; Humbleton, Schmerbach, Ilmenau, Corbusen, Könitz, Gera, P.	Mr. King proposes for this and the preceding shell a new genus under the name of *Camerophoria*.
	Spirifer	Sow.						
1	— undulatus	Sow. Min. Conch. 562. f. 1; Ter. alatus, Schl. Min. Tasch. VII. pl. 2. f. 1, 3, 9; Petref. p. 250; Quenst. Wiegm. Arch. 1835, p.79; V. Buch, Ub. Delth. p.37; Gein. Gæa v. Sachsen, p. 97.				R.? E.	Midderidge, Humbleton, Gera, Röpsen, Könitz, Schmerbach, *Bielebei*? (Fisch. Bull. Mosc. 1842, p. 466.)	
2	— multiplicatus	Sow. Geol. Tr. 2nd ser. t. iii. p. 119				E.	Humbleton	
3	— hystericus?	Schl. Pet. p. 249. pl. 29. f. 1; De Kon. Foss. Belg. p. 236. pl. 15. f. 3; Delthyris micropterus, Goldf.	E.	E.	E.	R.?	Kaysersteinel, S.; Eifel, D.; Tournay, C.; *Kirilof*? P.	
4	cristatus	Schl. Mün. Ak. 1817, t. vi. pl. 1. f. 3; S. octoplicatus, Sow. Min. Conch. 562. f. 2, 3; V. Buch, Uber Delth. p. 39. and Mém. Soc. Géol. Fr. pl. 8. f. 9; Gein. Gæa v. Sachsen, p. 97; De Kon. Foss. de Belg. p. 240. pl. 15. f. 5.			E.	R. E.	Derbyshire, Visé, C.; Glücksbrunn, Könitz, Ilmenau, Humbleton, *Arzamas, Itschalki*, P.	
5	— curvirostris	nob. Tab. nost. VI. f. 14 *a, b.*				R.	*Kirilof.*	

No.	Genera and Species.	Authors and References.	Palæozoic Systems. Sil.	Dev.	Carb.	Perm.	Localities.	Observations.
6	Spirifer Blasii	nob. Tab. nost. VI. f. 9 *a, b, c, d.*				R.	*Kirilof.*	
7	— rugulatus*	Kutorga, 1842, Verh. M. G. St. Petersb. p. 22. pl. 5. f. 5.				R.	*Santangulova*, distr. of *Bielebei.*	
8	— ind. spec.	Tab. nost. VI. f. 13.				R.	*Santangulova.*	
	Orthis	Dalm.						
1	— pelargonata	Ter. id. Schl. Mün. Ak. vi. pl. 8. f. 21–24; O. Laspii, V. Buch, Mém. Soc. Géol. Fr. iv. p. 210.				E.	Röpsen (V. Buch), Könitz (Dechen), Schmerbach (Quenstedt).	Aff. *O. crenistria.*
2	— Wangenheimi	nob. Tab. nost. XI. f. 5 *a, b.*				R.	*Grebeni.*	
3	— excavata	Geinitz, N. Jahrb. für Min. 1842, p. 578. pl. 10. f. 12, 13; Gein. Gæa v. Sachsen, p. 97.				E.	Altenburg near Pösneck.	This shell, which we have not seen, is said to have a concave ventral valve. It may be a *Leptæna?*
	Chonetes	Fischer.						
1	— sarcinulata	Ter. id. Schl. 1820, Petref. p. 256. pl. 29. f. 3; O. striatella, Dalm.; id. His. Leth. Suec. 20. f. 7; Lept. lata, V. Buch, Berl. Akad. 1828, pl. 3. f. 1 et 2; Orthis Hardrensis, Phill. Pal. Fos. 60. f. 104.	R.E.	E.	R.E.	R.	Ludlow, Ems, Daun Prüm, Gothland, *Pokroi*, S.; Berry, Pomeroy, Eifel D.; Hardrow, Yorkshire, Tournay; *Vitegra, Dwina, Donetz*, C.; neighbourhood of *Bachmuth*, P.	
	Productus	Sow.						
1	— horridus	Sow. Min. Conch. pl. 319. f. 1; P. calvus, pl. 560. f. 2–6; Gryphites aculeatus, Schl. Min. Taschb. vii. pl. 4. f. 1, 2, 3; Pr. id. Quenstedt, Wiegm. Arch. 1835, pl. 1. f. 2; Bronn. Leth. pl. 3. f. 1, 2; Gein. Jahrb. 1841, p. 640; id. Gæa v. Sachsen, p. 97; P. Hoppii, Kön. Icon. Fos. Sect. pl. 9. f. 108.				E.	Glücksbrunn, Eisenach, Kamsdorf, Ilmenau, Röpsen, Schmerbach, Humbleton, Durham.	The name of *P. aculeatus*, given in 1813 to this shell by Schlotheim, was previously used in 1809 by Martin for another species.
2	— horrescens	nob. Tab. nost. XVIII. f. 1 *a, b, c, d*; P. calva, Kutorga (non Sow.), Verh. M. G. St. Petersb. p. 17. pl. 5. f. 1.				E.	*Ust-Vaga, Kirilof, Krasnoborsk, Nikefur*, several localities in the district of *Bielebei.*	
3	— Cancrini	nob. Tab. nost. XVIII. f. 7. et XVI. f. 8 *a, b, c*; De Kon. Fos. Belg. p. 179. pl. 9. f. 3; Fisch. Bull. Moscou, 1842, p. 466; P. spinosus, Kutorga *loc. cit.* p. 18. pl. 5. f. 2. (non Sow.)			E.	R.	Visé, C.; *Arzamas, Itschalki, Kniaspavlova, Ustlon* and *Sei-ask* near Kasan, *Kliutziski, Kidash, Nikefur, Ilchegulova, Metaftamak, Grebeni*, P.	
4	— Leplayi	nob. Tab. nost. XVI. f. 4 *a, b*				R.	*Bielagorskaia* near *Bachmuth.*	*Productus*, with a small area as in *P. horrescens* and *subaculeatus.*
5	— Morrisianus	Strophalosia Morrisiana, King (MS.)				E.	Humbleton	
6	— spiniferus†	Strophalosia spinifera, King (MS.)				E.	Humbleton	With an area like that of the preceding.
	Lingula	Brug.						
1	— mytiloides	Sow. Min. Conch. pl. 19. f. 1, 2; Portlock, Rep. Londond. p. 444. pl. 32. f. 7.			E.	R.? E.	Wolsingham, Co. of Durham, Tyrone, C.; Thickley, *Cleveline* on the *Tcheremsham*, P.	The Russian specimen approaches to *L. parallela*, Phill.
	Orbicula	Lam.						
1	—? speluncaria	Schl. De la Beche's Manual, German edition, p. 459.				E.	Glücksbrunn	A very doubtful body.
	Conchifera dimyaria.							
	Solemya	Lam.						
1	— biarmica	nob. Tab. nost. XIX. f. 4 *a, b.*				R.	*Kniaspavlova* near *Barnukova*; *Gorodok* on the *Tchussowaya*; *Karla*, district of *Bielebei.*	
	Allorisma	King (MS.).						
1	— elegans	King (MS.)				R.? E.	*Arzamas*; Humbleton.	
	Osteodesma	Deshayes.						
1	— Kutorgana	nob. Tab. nost. XIX. f. 9				R.	*Arzamas, Sergiesk, Nikefur.*	

* Besides these seven species, several other *Spiriferi* are quoted in the Zechstein, but without any details, such as the *S. minutus*, Sow. (Sedgwick, Geol. Trans. vol. iii. p. 119), the *S. multicostatus*, Dechen (Geinitz, Gæa von Sachsen). It is also very doubtful if the *S. trigonalis* has been really found in the Zechstein, though it is mentioned in the German translation of De la Beche's Manual.

† The *P. rugosus* (Schl.), *antiquatus* (Sow.), *spinosus* (Sow.), and *longispinus* (id.), are quoted in the German edition of De la Beche's Manual as found in the Zechstein, but new and more accurate researches have proved the non-existence of these species in this deposit.

No.	Genera and Species.	Authors and References.	Palæozoic Systems. Sil.	Dev.	Carb.	Perm.	Localities.	Observations.
	Unio	Brug.						Believing that the *Axinus* of the Magnesian limestone differs essentially from the *Axinus angulatus* of the London clay, Mr. King proposes the new generic name of *Schizodus*.
1	— umbonatus	Fischer, 1840, Bull. de la Soc. des Nat. de Moscou, p. 489; Tab. nost. XIX. f. 10.				R.	*Karla*, district of *Bielebei*.	
2	— indet. spec.	Kutorga, 1842, Verh. M. G. St. Petersb. p. 27. pl. 6. f. 4; Unio acuta, Sow. Fisch. *loc. cit.*				R.	Do. do.	
	Axinus	Sow. *partim*. Schizodus, King (MS.)						
1	— obscurus	Sow. Min. Con. pl. 314				E.	Garforth near Leeds.	
2	— parallelus	King (MS.)				E.	Coast between Shields and Sunderland.	
3	— truncatus	King (MS.)				E.	Humbleton.	
4	— Schlotheimi	Cucullæa id. Geinitz, N. Jahrb. 1841, p. 638. pl. 11. f. 6; Tellinites dubius, Schl. Mün. Ak. vi. pl. 6. f. 4, 5; Gæa von Sachsen, p. 96.				E.	Eisenach, Glücksbrunn, Gera	Specimens given by M. Geinitz have convinced us that his *Cucullæa Schlotheimi* had such a dental apparatus as is seen in the *Axinus Rossicus*, nob.
5	— Rossicus	nob. Tab. nost. XIX. f. 7 *a*, *b*.				R.	*Itschalki*, *Klintziski* on the Volga 30 versts below *Kazan*, *Cleveline* on the *Tcheremsham*.	
6	— rotundatus	Brown, Manch. Trans. vol. i. pl. 6. f. 29.				E.	Newtown near Manchester.	
7	— parvus	id. ibid. p. 65. pl. 6. f. 30.				E.	ibid., allied to E. Schlotheimi?	
8	— undatus	id. ibid. pl. 6. f. 31				E.	ibid.	
9	— pusillus	id. ibid. pl. 6. f. 32				R.?E.	ibid. *Cleveline*.	
10	— minimus	(Lucina minima) id. ibid. pl. 6. f. 33				E.	ibid.	
	Nucula	Lam.						
1	— Kazanensis	nob. Tab. nost. XIX. f. 14.				R.	*Sriask*.	
2	— Vinti	King (MS.) Astarte, Sedgw. Trans. Geol. Soc. 2nd series, vol. iii. p. 119.				E.	Whitley, Durham.	Identical with the *Cucullæa sulcata*, Geol. Tr. 2nd ser. vol. iii. p. 119.
	Arca	Linn.						
1	— tumida	Sow. M.C. pl. 474. f. 3				E.	Durham, Humbleton.	
2	— antiqua	(Münst.) Goldf. pl. 122. f. 8; Myt. striatus, Schl. Mün. Ak. vol. vi. pl. 6. f. 3.				E.	Glucksbrünn.	
3	— Kingiana	nob. pl. XIX. f. 11				R.	*Ilchegulova*.	
	Mytilus	Linn.						
1	— acuminatus	Mod. id. Sow. Geol. Tr. 2nd ser. iii. p. 119; Myt. Hausmanni, Goldf. pl. 138. f. 4.				E.	Humbleton, Durham, lower beds at Gera, Schwarzfeld.	
2	— septiferus	King (MS.)				E.	Durham.	
	Modiola	Lam.						
1	— Pallasi	nob. Tab. nost. XIX. f. 16, *a*—*k*				R.	*Arzamas*, *Itschalki*, *Barnukova*, *Ustlon*, *Klintziski*, *Sergievsk*, *Tchistopol*, *Ilchegulova*, *Nikefur*, *Grebeni*, *Tchelpan*, *Tchagestrova* on the *Dwina*.	
2	— costata	(Arca costata) Brown, Manch. Tr. vol. i. pl. vi. f. 34, 35; Pleurophorus costatus, King (MS.).				R. E.	*Itschalki*; Humbleton, Newtown near Manchester, Yorkshire, Neustadt?	Mr. King proposes the new genus *Pleurophorus* for these two fossils.
3	— modioliformis	Pleurophorus modioliformis, King (MS.)				E.	Humbleton	
	Pinna	Linn.						
1	— prisca	Laspe, Münst. 1839. Beitr. heft 1. p. 45. pl. 4. f. 4; Gein. Gæa von Sachsen, p. 96.				E.	Glücksbrunn, Merzenberge near Gera, Neustadt.	
	Monomyaria.							
	Avicula	Lam.						
1	— speluncaria	Quenst. Wiegm. Arch. 1835. pl. 1. f. 1; Gein. N. Jahrb. 1841, p. 639; Gryphites id. Schl.; A. gryphæoides, Sow. Geol. Tr. 2nd series, p. 119; Omal. d'H. Prec. Elem. de G. 1843.				R.? E.	Roschitz, Könitz, Pösneck, Glücksbrunn; *Arzamas*?	
2	— keratophaga	Quenst. Wieg. Arch. 1835, p. 86; Mytil. keratoph. Schl. Mün. Ak. vi. pl. 5. f. 2; Goldf. pl. 116. f. 6; Gein. N. Jahrb. 1841, p. 639; aff. to A. lunulata, De Kon. Gæa von Sachs. p. 96.				R.E.	Glücksbrunn, Könitz, Pösneck, Kamsdorf, Humbleton, *Ustlon*, *Kargala*.	According to Mr. King, these two shells have two well-defined adductor muscular impressions.
3	— antiqua	Münst. Goldf. 116. f. 7; non Avic. id. Goldf. 160. f. 9.			R.	R. E.	*Mala Yaroslavetz*, *Mary's Canal*, C.; Glücksbrunn, Humbleton; *Tioplova*, *Klintziski*, *Pinega*, *Barnukova*.	

No.	Genera and Species.	Authors and References.	Palæozoic Systems. Sil.	Dev.	Carb.	Perm.	Localities.	Observations.
4	Avicula Kazanensis	nob., *posteà*, pt. iii.				R.	*Ustlon* near *Kazan*, *Sergiesk*	Allied to *A. speluncaria*.
5	— sericea	nob., *posteà*, pt. iii.				R.	*Ustlon* near *Kazan*, *Arzamas*.	
6	— inflata	Brown, Manch. Trans. vol. i. p. 65. pl. 6. f. 25, 26.				E.	Newtown near Manchester.	
7	— Binneyi	id. ibid. pl. 6. f. 27				E.	ibid.	
8	— discors	id. ibid. pl. 6. f. 28				E.	ibid.	
	Gervillia	Defr.						
1	— ? tumida	King (MS.)				E.	Humbleton.	
2	— ind. spec.	Gein. N. Jahrb. 1841, p. 639. pl. 11. f. 2.				E.	Altenburg, Sommeritz, etc.	
	Pecten	Linn.						
1	— pusillus	Pleuronectes pusillus, Schl. Mün. Ak. vi. pl. 6. f. 6.; Lima pusilla, Quenst. Wieg. Arch. 1835, p. 81.				E.	Glucksbrunn, Humbleton.	
2	— Koksharofi	nob., *posteà*, pt. iii.				R.	*Shidrova*.	
3	— indet. species	Sow. Geol. Trans. 2nd series, iii. p. 120.				E.	Humbleton.	
	Spondylus	Lam.						
1	— Goldfussii	Münst. 1839, Beitr. heft 2. p. 44. pl. 4. f. 3; Gein. Gæa von Sachsen, p. 96.				E.	Röpsen near Gera; Corbusen.	
	Ostrea	Linn.						
1	— matercula	nob., *posteà*, pt. iii.				R.	*Itschalki*.	When we discovered it, this *Ostrea* was the most ancient example known of the genus; but whilst we write, M. de Koninck has discovered another species in the Carboniferous limestone of Belgium.
2	— ? pusilla	King (MS.)				E.	Coast between Shields and Sunderland.	
	MOLLUSCA. GASTEROPODA.							
	Melania	Lam.						
	— several ind. spec.	Phill. (MS.) Geol. Tr. 2ᵈ s. vol. iii. 118.				E.	Hawthorn hive, Durham.	
	Natica	Adanson.						
1	— minima	Brown, Manchester Trans. vol. i. pl. 6. f. 22, 23, 24.				E.	Newtown, Humbleton.	
2	— ind. spec.	Allied to the preceding.				R.	*Itschalki*, *Ilchegulova*.	
	Euomphalus	Sow.						
1	— planorbites	Münst. (Collect. of Dr. Schmidt at Jena); Gein. Gæa v. Sachsen, p. 94.				E.	Kamsdorf.	
	Pleurotomaria	Defr.						
1	— carinata	Phill. G. Yorks. ii. pl. 15. f. 1.; Helix id. Sow. Min. Conch. pl. 10.			E.	E.	Settle, Yorkshire; Castle Isl., Ireland, C.; Humbleton, P. (King).	
2	— penea	nob., *posteà*, pt. iii.				R.	*Arzamas*, *Kliutziski*, *Meteftamak* on the *Dioma*.	
3	— nodulosa	King (MS.)				E.	Humbleton.	
	Trochus	Linn.						
1	— antrinus	Schl. Mün. Ak. pl. 7. f. 6. (Trochilites).				E.	Glücksbrunn.	This shell seems to be a *Pleurotomaria*.
2	— helicina	Trochil. helic. Schl.; Quenst. Wiegm. Arch. 1835; Turbo hel. Gein. Jahrb. 1841, p. 638; Troch. id. Gein. Gæa v. Sach. 95.				E.	ibid., Altenburg	
	Turbo	Linn.						
1	— Mancuniensis	Brown, Manch. Tr. vol. i. pl. 6. f. 1, 2, 3.				E.	Newtown, Humbleton.	
2	— minutus	Brown, ibid. pl. 6. f. 4, 5				E.	Newtown.	
3	— ind. spec.	Gein. Gæa v. Sachsen, p. 95.				E.	Saara, Zehma, Sommeritz near Altenburg.	Small and conical.
	Macrocheilus	Phill.						
1	— symmetricus	King (MS.)				E.	Humbleton.	
	Loxonema	Phill.						
1	— rugifera	Phill. Pal. Foss. pl. 38. f. 188; Melania, id. Ph. Geol. Yorks., ii. pl. 16. f. 26.		E.	E.	E ?	Brushford, D.; Otterburn, *Valdai*, C.; Humbleton? (King MS.), P.	
2	— ? Urei	Turritella Urei, Flem. Brit. Anim. p. 305. Ure Ruth. pl. 14. f. 7.			E.	E. ?	Lanarks C.; Humbleton? (King MS.), P.	
	Turritella	Lam.						
1	— biarmica	Kutorga, Verh. M. G. St. Petersb. 1842, p. 28. pl. 6. f. 3.				R.	District of *Bielebei*, *Itschalki*.	
	Murchisonia	D'Arch. et De V., Bul. S. G. de Fr. xii. p. 154.						
1	— subangulata	nob., *posteà*, pt. iii.				R.	*Itschalki*, *Arzamas*, *Kliutziski*, *Tchistopol*, *Nikefur*.	
	Rissoa	Fréminville.						
1	— pusilla	Brown, Manchester Trans. vol. i. p. 63. pl. 6. f. 6, 7, 8.				E.	Newtown near Manchester.	
2	— Leighii	Brown, Man. Tr. vol. i. p. 63. pl. 6. f. 9, 10, 11.				E.	Newtown near Manchester.	
3	— minutissima	id. ib. pl. 6. f. 12, 13, 14.				E.	ibid.	
4	— Gibsoni	id. ib. pl. 6. f. 15, 16, 17.				E.	ibid.	
5	— obtusa	id. ib. pl. 6. f. 19, 20, 21.				E.	ibid. Silksworth, Co. of Durham.	

No.	Genera and Species.	Authors and References.	Palæozoic Systems.				Localities.	Observations.
			Sil.	Dev.	Carb.	Perm.		
	Cephalopoda.							
	Nautilus	Linn.						
1	— Freieslebeni	Gein. N. Jahrb. 1841, p. 637. pl. 11. f. 1; id. Gæa v. Sachsen, p. 95.				E.	Gera, Ilmenau.	
2	— ind. spec.	nob.				R.	*Shidrova* on the *Dwina*..........	Perhaps a fragment of *Cyrthoceras*.
3	Ammonite? (fragment).	Sow. Geol. Tr. 2nd ser. iii. p. 118.				R.?	....	This fragment belongs to a *Nautilus* (King.)
	ANNELIDA.							
	Serpula	Linn.						
1	— ind. spec.	Geinitz, N. Jahrb. 1841, p. 638; id. Gæa v. Sachs. p. 95.				E.	Corbusen, Altenburg.	
2	— traces of Serpula	Sow. Geol. Trans. 2nd Ser. vol. iii. p. 118.				E.	Humbleton; coast between Shields and Sunderland.	
	CRUSTACEA.							
	Limulus	Müll.						
1	— oculatus	Kutorga, Beitr. z. Kenntn. des Kupfers. der Ural, 1838, p. 22. pl. 4. f. 1, 2, 3.				R.	*Government of Perm.*	
	Cytherina	Lam.						
1	— ind. spec.	nob.				R.	*Rapolnaia* near the river *Sylva*; *Akbash* near *Bugulma*; *Viasniki.*	
	PISCES.							
	Placoides.							
	Janassa	Münst.						
1	— angulata	Münst. Beitr. heft 1. 1839, p. 46 & 114. pl. 4. f. 1, 2; id. heft 3. pl. 3. f. 5; Kurtze, Comm. p. 20; Gæa v. Sachsen, p. 95.				E.	Glücksbrunn, Eisleben, Riechelsdorf.	
2	— bituminosa	Münst. heft 1. p. 116; Schl. Nachtr. 2nd part, pl. 22. f. 9; Gæa v. Sachsen.				E.	Schmerbach, Riechelsdorf.	*Trilobites bituminosus* (Schl.) var. of the *J. angulata* (Geinitz).
3	— dictea	Münst. heft 1. 1842, heft 5. p. 39. pl. 15. f. 10–16.				E.	Riechelsdorf.	
	Dictea	Münst.						
1	— striata	Münst. Beitr. heft 3. p. 124. pl. 3. f. 1. f. 1 & 2. pl. 8. f. 3—10; id. 1842. heft 5. p. 51; Acrodus larva, Agas. vol. 3. pl. 22. f. 23—25				E.	Riechelsdorf, Thalitter.	Is not the *Dictea Humboldti* (Münst.) an additional species?
	Wodnika	Münst.						
1	— striatula	Münst. Beitr. heft 6. p. 48. pl. 1. f. 1 *a*—*d*.				E.	Riechelsdorf.	
	Byzenos	Münst.						
1	— lati-pinnatus	Münst. Beitr. heft 6. p. 50. pl. 1. f. 2 ...				E.	Riechelsdorf.	
	Radamas	Münst.						
1	— macrocephalus	Münst. Beitr. heft 6, p. 52. pl. 14. f. 1.				E.	Riechelsdorf.	
	Strophodus	Agass.						
1	— arcuatus	Münst. Beitr. heft 3. 1840, p. 123. pl. 3. f. 7. pl. 8. f. 11. heft 6. p. 50. pl. 1. f. 3.				E.	Riechelsdorf.	
	Acrodus	Agass.						
1	— Althausi	Münst. Beitr. heft 3. pl. 8. f. 5. pl. 3 et 4. f. 6.				E.	ibid.	
	Gyropristis	Ag.						
1	— obliquus	Ag. 3. p. 177.				E.	Near Belfast.	
	Ganoides.							
	Palæoniscus	Agass.						
1	— Freieslebeni	Ag. Poiss. Foss. v. 2. p. 66. pl. 11 & 12; Germ. Verst. d. Mansf. p. 12. f. 9–14; Kurtze, Commentatio, 1839, p. 12; Knorr. 1755, pl. 17–19; *Synon.* Ichthyolithus Eislebenensis, Palæothrissum æquilobum, Huot; Palæot. blennioides, Holl.; Acipenser bituminosus, Germ.; Palæon. Freieslebeni, Blainv.; Palæot. macrocephal., Blainv.; Clupea Lametherii, Blainv.			E.	E.	Ardwick, C.; Mansfeld, Hessia.	According to M. Germar his *P. megacephalus?* may be a variety of this species with a large depressed head.
2	— macropomus	Ag. Poiss. Foss. v. 2. p. 81. pl. 9, f. 6, 7.				E.	Ilmenau.	
3	— magnus	Ag. v. 2. p. 78. pl. 13 and 14. Germ. Verst. p. 18; Kurtze, Comm. p. 13.				E.	Mansfeld.	
4	— comtus	Ag. v. 2. p. 97. pl. 10 *b*. f. 1–3; Paleot. magnum, P. macrocephalum Blainv. Geol. Tr. 2nd ser. iii. pl. 8. f. 1, 2. pl. 9. f. 2.				E.	E. Thickley; Ferry Hill, Co. of Durham.	

No.	Genera and Species.	Authors and References.	Palæozoic Systems. Sil.	Dev.	Carb.	Perm.	Localities.	Observations.
5	Palæoniscus elegans	Ag. 2. p. 95. pl. 10 *b*. f. 4, 5; Palæot. id. Sedgw. Geol. Tr. 2nd ser. iii. pl. 9. f. 1.				E.	E. Thickley; Midderidge, Co. of Durham.	
6	— glaphyrus	Ag. 2. p. 98. pl. 10 *c*. f. 1, 2				E.	E. Thickley; Ferry Hill.	
7	— longissimus	Ag. Poiss. Foss. 2. p. 100. pl. 10 *c*. f. 4.				E.	Ferry Hill.	
8	— macrophthalmus	Ag. 2. p. 99. pl. 10 *c*. f. 3.				E.	E. Thickley.	
9	— Tchefkini*	Fisch. Bull. Nat. de Moscou, 1842, pl. 4.				R.	District of *Bielebei*, *Steppe of Kargala*.	
10	— lepidurus	Ag. 2. p. 64. pl. 10. f. 3, 7, 8, 9				R. E.	Scharfeneck, county of Glatz; Ottendorf, Silesia.	
11	— Vratislaviensis	Ag. v. ii. p. 60. pl. 10. f. 1, 2, 4, 5, 6				E.	Neudorf, Ruppersdorf, Silesia.	
12	— catopterus	Ag. Poiss. Foss. and Proc. Geol. Soc. vol. ii. p. 206.				E.	Rhone Hill, Ireland	We consider the Red Sandstone of Rhone Hill to be the equivalent of the above-mentioned Silesian rock.
	Tetragonolepis	Fisch.						
1	— Murchisoni	Fisch. Bull. de Moscou, 1842, p. 463				R.	*Troitsk*.	
	Platysomus	Ag.						
1	— gibbosus	Ag. 2. p. 164. pl. 15; Germ. Verst. d. M. p. 25; Kurtze, Comm. p. 22; Stromateus gibbosus, Blainv.; Strom. angulat., Germ.; Rhombus diluvian., Wolfarth.				E.	Mansfeld.	
2	— rhombus	Ag. 2. p. 167. pl. 16; Germ. *l. c.* p. 26; Kurtze, p. 24; Knorr, p. 1. pl. 20. f. 1; Stromateus major, Blainv.; Strom. Knorri Germ.; Rhombus diluv., Wolfarth.				E.	Mansfeld.	
3	— macrurus	Ag. 2. p. 170. pl. 18. f. 1, 2; Geol. Tr. 2nd ser. iii. pl. 12. f. 1, 2.				E.	E. Thickley.	
4	— parvus	Ag. 2. p. 170. pl. 18. f. 3; Geol. Tr. 1st ser. iv. pl. 2.				E.	Low Pallion, Durham.	
5	— striatus	Ag. 2. p. 168. pl. 17. f. 1–4; Geol. Tr. 2nd ser. iii. pl. 12. f. 3, 4; Uropteryx striatus (Walchner.).				E.	Whitley; Durham (*Sedgw.*), East Thickley.	
6	— intermedius	Münst. Beitr. heft 5. 1842, p. 43.				E.	Riechelsdorf.	
7	— Althausi	Münst. ibid. p. 44. pl. 5. f. 2.				E.	ibid.	
8	— Fuldai	Münst. ib. p. 45. pl. 6. f. 1				E.	ibid.	
	Dorypterus	Münst.						
1	— Hoffmanni	Germ. Münst. Beitr. 1842, heft 5. p. 34. pl. 14. f. 4.				E.	Mansfeld.	
	Acrolepis	Ag.						
1	— Dunkeri	Palæon. Dunkeri, Germ. Verst. d. Mansf. p. 19. f. 1–5; Kurtze, Comm. pl. 1; Münst. Beitr. heft 5. p. 40; Acr. asper, Ag. Jahrb. 1841, p. 614; id. Gæa v. Sachsen, p. 94.				E.	Mansfeld, Eisleben, Riechelsdorf.	
2	— exculptus	Gein. Gæa v. Sachsen, p. 94; Pal. exculptus, Germ. *loc. cit.* p. 21. f. 6–8; Kurtze, ib. p. 19. pl. 2; Münst. Beitr. heft 5. p. 42. pl. 6. f. 2.				E.	Mansfeld, Schmerbach.	
3	— Sedgwicki	Ag. 2. p. 11. pl. 52; Geol. Tr. 2nd ser. iii. pl. 3. f. 3.				E.	Ferry Hill, Riechelsdorf.	
4	— angustus	Münst. Beitr. heft 5. p. 40.					Riechelsdorf.	
5	— gigantens	Münst. Beitr. heft 5. p. 41.				E.	Riechelsdorf.	
6	— intermedius	Münst. Beitr. heft 5. p. 41.				E.	Riechelsdorf.	
	Pygopterus	Ag.						
1	— Humboldti	Ag. 2. p. 10. pl. 54, 55; Germ. Verst. d. M. p. 22; Kurtze, Comm. p. 25; Esox Eislebensis, Krüger; Münst. Beitr. heft 5.; p. 48. pl. 5. f. 1.				E.	Mansfeld, Riechelsdorf, Neudershausen, Glücksbrunn.	The genera Acrolepis and Pygopterus are of the Sauroid family, Ag. The Globulodus is of the Pycnodontes fam., Ag., and the Cœlacanthus of the Cœlacanthes fam. Ag.
2	— mandibularis	Ag. 2. p. 10. pl. 53 and 53 *a*.; Geol. Trans. 2nd ser. iii. pl. 10, 11; Nemopteryx mandibularis and Sauropsis Scoticus (Walchn.).				E.	Ferry Hill.	
	Globulodus	Münst.						
1	— elegans	Münst. Beitr. heft 5, 1842, p. 47. pl. 15. f. 7.				E.	Riechelsdorf.	
	Cœlacanthus	Ag.						
1	— granulatus	Ag. 2. pl. 62.				E.	Ferry Hill.	
2	— Hassiæ	Münst. Beitr. heft 5. p. 49.				E.	Riechelsdorf.	

* Three species, very probably belonging to this genus, were found in the *Steppe of Kargala near Orenburg*, and are now in the collection of the Corps des Mines at St. Petersburgh.

No.	Genera and Species.	Authors and References.	Palæozoic Systems.				Localities.	Observations.
			Sil.	Dev.	Carb.	Perm.		
	Saurians.							
	Protorosaurus	Herm. v. Meyer.						
1	— Speneri	id. in Münst. Beitr. heft 5. p. 1. pl. 8. f. 1; Monitor antiquus, Holl; Mon. Foss. de Thur. Cuvier; Miscell. Berolinensia, 1710, p. 99; Link Act. Erudit. Lipsiæ, 1718, pl. 11; Gein. Gæa v. Sachs. p. 93.	......	......	......	E.	Mansfeld, Glücksbrunn, Eisleben.	
	Thecodontosaurus	Riley and Stutchb.						
1	— antiquus	Riley, Geol. Tr. 2nd ser. v. p. 349.	......	......	......	E.	Redland near Bristol.	
	Palæosaurus	Riley and Stutchb.						
1	— cylindrodon	Riley, Geol. Tr. 2nd ser. v. pl. 29. f. 4	......	......	......	E.	ibid.	
2	— platyodon	id. Geol. Tr. 2nd ser. v. pl. 29. f. 5	......	......	......	E.	ibid.	
	Rhopalodon	Fisch.						
1	— Vangenheimi	Fisch. Bull. Soc. d. Moscou, 1841, p. 460. pl. 7.	......	......	......	R.	*Klutchefskoi* near the river *Dioma* (*Bielebei*).	
	Brithopus	priscus } Kutorga, Beitr. zur Kenntn. Ural, 1838.	}	......	......	R.	*Government of Perm*	These 3 genera require further examination.
	Orthopus	primævus						
	Syodon	biarmicum						

RECAPITULATION OF THE FAUNA OF THE PERMIAN SYSTEM IN EUROPE.

Classes.	Genera.	Total Number of Species in Europe.	Species exclusively peculiar to the Permian System in Europe.	Species found in older formations.	Species found in Russia.			
					a. Peculiar to that country.	b. Previously found elsewhere.		
						b'. In the Permian and older formations.	b''. In the Permian beds exclusively.	c'. In older formations exclusively.
Polyparia	7	15	13	2	3	1 ?	2	
Echinodermata	2	2	1	1				
Conchifera, Ord. Brachiopoda	7	30	20	10	8	3	4	5
——— Ord. Dimyaria	10	26	26	...	8	...	3	
——— Ord. Monomyaria	5	16	15	1	4	...	3	
Mollusca, Ord. Gasteropoda	11	22	19	3	3			
——— Ord. Cephalopoda	1	3	3	...	1			
Annelida	1	2	2					
Crustacea	2	2	2	...	2			
Pisces	16	43	42	1	2			
Reptilia	4	5	5	...	1			
Total	66	166	148	18	32	3 or 4	12	5

We much regret that this table has been drawn up without the benefit of the long-promised assistance of Professor Agassiz. His observations on a few of the Permian ichthyolites of Russia which we submitted to him, may increase the number in that class of fossils.

SECONDARY ROCKS.

JURASSIC OR OOLITIC SYSTEM.

CHAPTER XI.

Jurassic System of Russia.—Range and uniformity of Composition of the lower Division, from the Northern Sea to the Lower Volga.—Basins of the Middle Volga, the Oka, and the Moskwa.—Iron Sands and Grits with Plants in Russia and Poland compared with their equivalents in England.—Large Basin of the Lower Volga, Simbirsk, Saràtof, &c.—Jurassic Rocks of Orenburg, and their peculiar mineral aspect.—Upper Division of the Group on the river Donetz in Southern Russia, and at Cracow in Poland.—The whole of the Jurassic Rocks of Russia on the parallel of the Oxford Clay, Calcareous Grit and Coral Rag of England, or "Terrain Oxfordien" of France.—Suppression of the Trias, Lias, and Lower Oolite in Russia.—Occurrence of the Oxford Formation in Asia and Africa.—Conclusion.

THROUGHOUT the Palæozoic series of which we have just taken leave, there exists, as has been shown, a vast succession of deposits, which, covering an enormous superficies, are linked on to each other by regular transitions and organic contents. Far different is the system which next presents itself upon the surface of Russia. Occurring at remote intervals only, the strata immediately overlying the red formation last described, contain a class of organic remains entirely distinct from any hitherto named, and occupy isolated basins, patches, or stripes, the beds of which have no natural connection with the deposits beneath them. As the rocks of these countries are less disturbed than those of any portion of the globe which geologists have examined, and as the Palæozoic series is complete, we were at first naturally induced to look also for a full succession of secondary deposits, similar to that with which we were acquainted in other countries. In vain, however, we sought for fine escarpments, like those of our oolites in England and the north of France, with valleys of clay and lias. In their place we found low masses only of slightly coherent shale, with sands and concretions; which being superposed to the Palæozoic rocks, and containing Ammonites and Belemnites, clearly belonged to some member of the great secondary division of deposits.

In our first exploration of the Volga below Kostroma, where such Ammonite beds occur, we were indeed disposed to refer some of them to the Lias, because we were then led to think (as previously stated, p. 179), that the red deposits in that neighbourhood might represent the Keuper of Germany and France. More extended researches, however, induced us to adopt other views; for whilst we could obtain no sort of proof that any of the red deposits in question belonged to the Trias, so we found distinct evidence, that the overlying strata of which we are now treating, though resembling the Lias in mineral character, were, in fact, by their organic remains, the representatives of the Oxfordian or middle oolite.

All these detached masses of Jurassic (Oxfordian) strata have a surprising uniformity of character, whether found near Moscow, on the Oka, on the Lower Volga, or in the remote district of Ust Sisolsk, in the government of Vologda. To these districts, examined by ourselves in the years 1840 and 1841, we may add three still more distant and northern tracts, where strata of the same character, and containing the same fossils, have been discovered through the enterprize of Major Strajevski, an officer of the Imperial School of Mines, by M. Ruprecht, the botanist, and since we left the country, by Count Keyserling, our own associate. The first of these is on the east flank of the North Ural, in N. lat. 64°, and on the banks of the little rivers Tchol and Tolya; the latter in N. lat. 68°, on the shores of the White Sea, east of Mezene (see Map). The third is in the depression by which the great river Petchora passes to the Icy Sea, and has been made known to us whilst we write by Count Keyserling, who in the past summer (1843) led an expedition into those wilds, inhabited only by Samoyedes, and which were previously an entire blank, even upon all Russian maps. We shall hereafter, as well as in our Introduction, point out the agreement of the general succession in this northern region with the strata in other parts of Russia. Of the Jurassic deposit which now concerns us, Count Keyserling thus speaks:—" It is a widely spread and low formation in the north, which forms the ' tundra ' or mosses, and occurring in all the depressions of the more ancient rocks, occupies extensive, marshy, wooded tracts. It is, for the most part, composed of grey or black clay, with calcareo-arenaceous concretions, disposed along the lines of bedding, and is rich in Ammonites and Belemnites. Towards the base of the formation only, are found some continuous beds of an impure arenaceous limestone. As far as I can determine the fossils, they seem to me all to belong to the middle Jura (*Terrain Oxfordien*). The *Belemnites excentricus*, and the forms which approach that species, such as *B. Puzotianus*, *B. Beaumontianus*, are the most frequent remains. On the river Cisola I also found the rib of a Saurian[1]."

To demonstrate, however, the truth of our statement, that the Palæozoic deposits are at once succeeded by strata of the age of the Oxford formation, we now pass to the detailed description of these Jurassic masses, in the chief tracts where we examined them during the years 1840 and 1841.

Jurassic Basin of the Middle Volga.—We will first describe the strata of this age which occur midway upon the course of the Volga, because being there, as we believe, incumbent on rocks of less antiquity than in the other part of Central Russia, in which we could detect a junction, an ascending series might be best looked for, which, if any such passage existed, would show the connection between the Palæozoic and secondary formations. To the east of Kostroma the Volga winds, as already described (p. 178), through masses of red sandstone and marl, which we are unable to separate from the Permian system. In the greater part of this tract, the substrata are obscured by a thick cover of detritus, which is chiefly composed of the regenerated materials of the adjacent red rocks. But at about eight versts north-west of the village of Crasnoe Pojeni, deep red and finely laminated beds with geodes of harder marlstone, to which allusion has been already made, are seen to rise upon the right bank of the Volga to the height of thirty feet above the stream. These beds are surmounted, and as it then appeared to us, in perfect conformity, by dark-coloured (greenish black) clay, in which occur small crystals of selenite and concretions of indigo-blue, argillaceous limestone. In the clay or shale, which is in absolute contact with the red rocks, we observed but few organic remains, though a large Belemnite was abundant. In other beds, however, which occur at intervals along the banks of the river, we found the *Ammonites cordatus* (Sow.), *Turbo muricatus* (Sow.), with several species of Belemnites, including the *B. absolutus* (Fischer), which M. D'Orbigny has identified with a species found in Oxford clay at the Vaches Noires in Normandy[2].

[1] Letter of Count Keyserling to Mr. Murchison, 6th November 1843. (See Map.)

[2] The new species of Belemnites will be described by M. D'Orbigny in the Third Part of this work.

Seeing (in 1840) the conformable junction of these dark-coloured strata with the inferior red beds at Ples, and thinking, when on the spot, that one of the Gryphæ was not the *G. dilatata*, but rather the *G. MacCullochii* of the Lias, we were then disposed to believe, that these strata might represent both the Keuper and Lias. We mention this fact to show how extremely difficult it is to decide from an isolated case and one or two fossils, upon what may be termed conformity of succession, particularly in a country where the strata are apparently horizontal, and are to a great extent unsolidified. In all those tracts, indeed, where the oscillations of the land have been of such a nature as to leave the strata in positions more or less horizontal, it is evident, that the observer cannot expect to detect much appearance of unconformity in the planes or surfaces of any strata which happen to be in collocation, even though they have been deposited at very different epochs. When such junctions, however, occur, he may reasonably look for the effects of abrasion on the lower of the two sets of dissociated strata, whether by the action of former waters, or by other denudations to which the earlier beds were subjected before the succeeding strata were accumulated. We did not, indeed, descend the Volga from Ples by Kineshma to Juriavetz, without observing decided proofs of such a condition of things. We found, in fact, that instead of occupying a regular overlying platform, the Ammonite and Belemnite shales, of whose exact age we were at first in doubt, occurred at different levels, sometimes on the higher part of the cliff, at other places in depressions, and even descending beneath the waters of the stream, as represented in this woodcut, in which *a* marks the underlying red strata, *b* the Jurassic beds, and *x* the general cover of drift.

34.

This woodcut relates to about thirty miles of country in horizontal extension.

We saw therefore, in the general contour of these shales and the various strata of red marl and sand on which they repose, exactly the same relations as those which occur, between the beds containing the same fossils near Moscow, and the carboniferous limestone upon which they there lie. In fact, the woodcut which has already been given, p. 80, explains a similar case; though the underlying rocks at Moscow are of older age than those upon the Volga. The Ammonite and

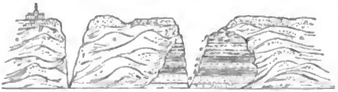
Belemnite shale of the Volga having no stratigraphical connection with the inferior strata, it follows necessarily, that their age can be determined by their fossil contents only. Between Ples and Kineshma, the black shale is surmounted by thin courses of a ferruginous, concretionary marlstone, in the form of a rude oolite, passing here and there into a compact rock, and exposing on the whole a thickness of about fifty feet. At Kineshma, these marlstone beds disappearing, the black pyritous shale alone occupies the cliff in a thickness of about thirty or forty feet. Wherever we detected these beds of shale, whether upon the Volga or upon its tributary the Unja, the banks of which we examined in a journey from Ustiug-Veliki by Nikolsk to Kostroma, we found that they were characterized by the same organic remains.

Near Makarief, on the Unja, the shales, more bituminous than upon the Volga, and equally reposing upon red marl and sand, are loaded with a vast profusion of flattened and iridescent Ammonites, chiefly the *A. cordatus* and *A. virgatus*, associated with Belemnites, all of them characteristic fossils of the Oxford oolite and clay. The same forms of Ammonites and the same Belemnites in abundance were observed at various spots along the Volga, and with them we also found the *Gryphæa dilatata.*

Jurassic Basin of the Oka.—On the banks of the river Oka, at Oksevo, the first post station north of Jelatma, in the government of Vladimir, we met with a strong ledge of fossiliferous Jura rocks. The lowest beds visible consist of black pyritous shale containing the *Gryphæa dilatata*, with Belemnites. Intercalated with these strata are spheroidal concretions of calcareous sandstone, occasionally two to three feet long, which, when split up by the peasants as flagstones for their doorways, expose micaceous surfaces. The overlying masses consist of numerous concretions of yellowish, marly sandstone, and the whole are conformably surmounted by *ferruginous sands with concretions of ironstone.* In these upper strata we did not observe organic remains; but by the analogy of similar beds near Jelatma and Moscow, of which we are about to speak, we believe they belong to the group in question.

The best natural sections of these strata are laid bare in several deep ravines on the left bank of the Oka, four versts above Jelatma and near the village of Inkino. Here, as in the adjacent tracts, the superficial cover of detritus is very thick, but wherever this matter has been removed by falls of the cliff, as represented in the annexed woodcut, we met with the following beds in ascending order, and occupying a thickness of about 120 feet.

35.



a. Shale and sands. *b*. Black shale, with calcareous concretions and fossils. *c*. Thickly laminated sandy marl and greensand. *d*. Dark shale. *e*. Yellowish ferruginous sands, with concretions of calcareous grit or sandstone loaded with Ammonites, Belemnites, and other fossils. *f*. Dark-coloured marls, followed by others of yellowish tint and sandy and ferruginous structure, with courses of marlstone, &c. These regular beds are covered by argillaceous drift (*o*), which for the most part obscures the section.

The fossils found midway in this cliff are clearly those of the Kelloways rock of England or lower beds of the Oxford group, viz. *Ammonites Gulielmi* (Sow.), *A. peregrinus* (D'Orb.), allied to *A. Lamberti* (Sow.), *A. Fournetianus* (D'Orb.), and *Gryphæa dilatata*, which occur generally through the lower Oxford oolite of France and England. With these are found three species of Belemnites, a Mya resembling *Mya depressa?*, Terebratula allied to *T. socialis*, with unpublished Corbulæ, Pectens, Serpulæ, which will be described in the sequel.

The river banks which expose these beds of the middle oolitic group, are within three miles of the iron-works on the cliffs of the little river Unja [1], on which we have described the carboniferous limestone (p. 84.); and from the beds being horizontal, it is almost certain that these rocks, though of such dissimilar age, must, if their relations were seen, be in contact as at Moscow, without the intervention of any other strata. In other words, we thus learn, that the edges of the great red (Permian) basin have here thinned out; for the fundamental rock near Jelatma, as already shown, is the carboniferous limestone.

Though we had not sufficient time at our disposal to follow the whole course of the river Oka, we have examined the fossils collected from various localities upon its banks by Colonel Olivieri of the Imperial School of Mines, which lie between Jelatma and Kolomna, and also from some places on the Moskwa, and we have no hesitation in saying, that they all indicate precisely the same group [2].

[1] The same name is often repeated in Russia as elsewhere. This river Unja, on which the iron-works are placed, and where carboniferous limestone appears, is in the government of Vladimir, and very distant from the stream of the same name before mentioned north-north-east of Kostroma.

[2] Among these intermediate localities (and probably many others will be detected), we may cite Zaraisk on the Oceter, a tributary of the Oka, forty versts from Kolomna, and where the Jura beds lie on carboniferous limestone; Petrofskaya, seventy versts east-south-east of Moscow; Ochrinka, near Bronnitza, fifty-fiveversts from Moscow (very beautiful fossils); Miatchkova, Bieseda, Kolomniskaya and Koroskaya, all in the vicinity of the ancient capital. The last-mentioned localities have long been known through the researches of Dr Fischer de Waldheim, and the first of them we examined personally.

Jurassic strata around Moscow.—The sections of Jurassic beds in the immediate neighbourhood of Moscow exhibit similar relations to the next inferior strata with those which prevail near Jelatma and other places on the Oka and at Zaraisk upon the Oceter, viz. they are at once incumbent upon one or other member of the carboniferous limestone, a fact we have already alluded to in describing the deposit at Inkino. And here we cannot but rejoice, that our visits to Moscow seemed to impart new energies to our excellent friend the veteran naturalist Dr. Fischer de Waldheim, ex-President of the Society of Natural History of Moscow, who has subsequently described some new species, of which we shall speak in the analysis of the organic remains[1]. We must also in this place specially acknowledge that we owe our acquaintance with many of the details of the Jurassic strata near Moscow, as well as the best fossils we possess, to Mr. Frears, an intelligent English gentleman resident at that city.

At Miatchkova, where the great quarries in the white carboniferous limestone have laid bare their relations, black shales, differing slightly if at all in lithological composition from those upon the Volga and the Oka, form the cover of the magnesian beds of the older limestone, as represented in this woodcut, which though

36.

e. Detritus and drift, with northern blocks.
d. Siliceous grits and ferruginous sands with *Pterophyllum Murchisonianum* (Göppert), and other plants.
b, c. Lower shale (*b*) with Ammonites, Belemnites. Sands and shale (*c*) with Jurassic fossils.
a. White and yellow magnesian carboniferous limestone with *Spirifer Mosquensis*.

previously given, we now repeat, not only to convey a general idea of the manner in which the overlying beds succeed to the palæozoic rocks[2], but also to define the members of this Jurassic group.

At a spot within the city of Moscow, and on the right bank of the Moskwa, these Jura beds were discovered by Mr. Frears to be incumbent on certain peculiar red and sandy beds with limestone, which we have shown to form an integral part

[1] Bull. de la Société des Nat. de Moscou, tom. xv. p. 118, et tom. xvi. Revue des Fossiles du Gouvernement de Moscou.

[2] In the great quarries of Miatchkova the incoherent black shale has frequently subsided or has been washed down, after the melting of the snow, into the hollows or excavations, and thus in many instances the shale beds seem, at first sight, to underlie the carboniferous limestone. In the description of the above woodcut at page 80, the word tertiary has been erroneously applied to the overlying siliceous grits.

of the carboniferous series of Russia. In ascending the Moskwa, accompanied by that gentleman, to about six versts beyond the city and near to the village of Shelapika, we found its left bank to consist of finely laminated, slightly micaceous, incoherent black shale, occasionally pyritous, and rising to heights of forty to fifty feet above the stream. These shales are seen at intervals for six or seven versts along the Moskwa.

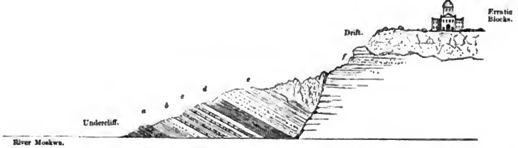
Among the prevailing fossils here we could not avoid remarking specimens of the same *Ammonites virgatus* found at Ples on the Volga, at Makarief on the Unja, and at Jelatma on the Oka, many of them preserving their shells with a beautiful iridescence, and associated with the same Belemnites as in those localities. With these, however, were many other forms, such as Trigonia, Astarte, Modiola, Pecten, Amphidesma, &c., which we had not collected upon the Volga: some of them have been recently described by Dr. Fischer. After crossing a neck of land which is peninsulated by the river, the same beds are traceable in its banks under the village of Koroshovo, where they are overlaid by hard siliceous grits (*d* of previous section), to which we shall hereafter refer. Near the church or western part of this long village, the shales are diversified by large, irregularly formed concretions of sandy marlstone, containing very numerous organic bodies, many of which, a well as little nacreous Ammonites, preserve their shelly covering and are beautifully iridescent. In this group Dr. Fischer cites the *Terebratula acuta*, *T. ornithocephala*, and *T. digona*, with Avicula, Astarte and other shells, among which we were very much struck with two forms so closely resembling well-known fossils of the greensand formation, viz. *Pecten orbicularis* and *Inoceramus sulcatus*, that on the spot we believed them really to represent those species [1].

Unwilling as we were to admit lithological composition only, as an evidence of the age of a rock, we could not avoid being much influenced by such considerations, when we saw fossils so closely resembling lower cretaceous types, imbedded in sandstone, often of a ferruginous colour, in which green grains and the oxide of iron were disseminated, just as in the greensand of Western Europe. Some of the overlying courses resemble, indeed, as nearly as possible, the ferruginous bands of the lower greensand, termed "clinkers" in England, whilst beneath them the strata are made up of whitish sand passing into harder grit.

[1] On showing this Pecten to M. A. D'Orbigny, he convinced us that it is distinct from the *P. orbicularis*; Dr. Fischer has since published it under the name of *P. nummularis*. It will be described by M. D'Orbigny, together with the other fossils, in Part III.

Whatever doubts, however, we at first entertained as to the age of these overlying beds, were removed by examining another section on the right bank of the river, under the Sparrow Hills and directly opposite to Moscow, whither we were also conducted by Mr. Frears. Here the cliff (the highest point in the immediate vicinity of the capital) rises to the height of about 200 feet above the stream, and presents, with some subsidences, a highly inclined talus towards the rich alluvial plain in face of it, on which stands the Devitchi monastery. This cliff occupies the segment of a circular sweep formed by the river, at the east end of which are the noble edifices of the Mamonoff palace and the Donskoi convent—on the west the church and village of Vorobleia. Within this space of about an English mile, large portions of the cliff have sunk down and form undercliffs, as shown in this diagram, and the edges of the beds are thus clearly exposed from beneath the overlying drift of sand and northern boulders. The section of the uppermost beds is best seen in the lateral ravines, which here, as in so many other parts of Russia, open out from the river banks into the adjacent country. The relations of the whole were rendered still more clear, at the period of our visit, by excavations and levellings on the summit of one of the chief subsidences, with the view of forming a terrace on which a large new church was to have been placed. This diagram explains the case.

37.



The lowest beds, seen only in the dry summer months at the river edge, and in a small islet, are of the Black Ammonite and Belemnite shale (*a*). These are overlaid conformably by whitish sands with green striæ (*b*). Then follow strong bands (*c*) from one to three feet thick, of highly ferriferous sandstone, in parts running into concretions like those at Koroshovo, and with numerous white grains appearing in the base. These iron-shot sandstones are occasionally so loaded with Inocerami that we may call them "*Inoceramus Grit*," and it will presently be shown, that they are most characteristic of strata of this age in very distant localities of Russia. Next follows dark-coloured marly shale alternating with sands (*d*), afterwards passing up into other ferruginous sands, white and green (*e* and *f*).

The strong bands (*c*), often of concretionary forms, are most charged with fossils, some species of which also occur in the underlying black shale, such as Pecten, Avicula, and Cardium. We also detected some of these forms in the higher beds (*d*).

2 I

After making this section we could not entertain a doubt, that the whole of the strata of shale, sand, marl and marlstone which we had seen near Koroshovo, belonged, like those of the Sparrow Hills, to one and the same Jurassic formation.

A collection of the fossils from Koroshovo was sent by Mr. Frears, at our request, to Professor Phillips, who identified a few of the forms. Aware, however, that M. Alcide D'Orbigny was exclusively engaged in a general examination of all the Jurassic remains of France, and believing that the continental Jurassic deposits would be found to present a greater number of analogies to the Russian fossils than the series of the same age in the British Isles; and knowing further that the latter were still far from being thoroughly described[1], we submitted all our Jurassic shells from Russia to that author, requesting him to place them in parallel with those of France. The divisions of the French series being, M. D'Orbigny has convinced himself, the exact counterparts of England, as described by the English authors, Smith, Conybeare, and others, he has assured us, that the group of animal remains from the central and northern tracts of Russia, including all these strata at Moscow, belong to the lower part of the central division of the Oolitic system, which he terms the "Terrain Oxfordien." We shall offer a few remarks upon this comparison at the close of the chapter.

It yet remains for us to describe the overlying siliceous grits (*d*) of the general section of the country around Moscow which are represented in the woodcut at p. 235. With no other guide than their lithological character and overlying position, we were at first disposed to place these beds (though with much hesitation) on a parallel with the greensand. A subsequent exploration of Southern Russia, in which we became acquainted with siliceous sandstones (not exactly similar it is true) in deposits above the chalk, induced us to suppose that the Moscow grits might, after all, prove to be of tertiary age. Geologists who have not worked amid the obscurity of Russian stratification must not feel surprised at this oscillation in our minds. They will recollect that proofs have been already adduced of the apparent conformity of succession being in truth no criterion of contiguous beds forming

[1] We happen to know, from Professor Phillips himself as well as from Sir Henry De la Beche, that a very considerable number of unpublished oolitic species have been discovered by the British Ordnance surveyors. From our knowledge, indeed, of the numerous additions made to this fauna in one district only by Mr. Buckman of Cheltenham, we are quite ready to admit, that additional monographs must be brought out before this important system is thoroughly illustrated in the British Isles. In the mean time we refer our readers to a promised new edition of Murchison's 'Geology of Cheltenham,' with additions by Mr. Buckman and Mr. H. E. Strickland.

parts of a connected series. In the absence of clear sections and junctions, and unprovided with any fossil evidences, we continued, therefore, to remain in doubt concerning these upper siliceous grits of Moscow, when we received a letter from Mr. Frears, who, in sending us drawings of fossil plants recently found in them, has happily enabled us to come to a distinct conclusion respecting these hitherto ambiguous strata. Before we advert in greater detail to these plants, we must say a few words on the position and structure of the rock in which they have been discovered.

As the Jura shales and sands which have been described, occur in depressions of the carboniferous limestone (woodcut, p. 235), and occasionally rise to certain heights upon the banks of the Moskwa; so are they *conformably* surmounted by the siliceous sandstones and grits in question, which occupy the plateaux and summits of the country, where they are not covered with drift and detritus. For the most part they are ferruginous sandstones, occasionally containing green grains and somewhat earthy, but in their lower parts they exhibit large subconcretionary masses of hard siliceous grit, usually of a white colour, which are extracted for building purposes and also for millstones, and form a regular article of export from Moscow to distant parts of Russia[1]. On the high grounds at Celo Nikilofskaya, between Bronnitzi and Miatchkova, considerably to the south of Moscow, we examined quarries opened out from beneath yellow, white and reddish-brown drift, in which the upper beds of this rock consisted of greenish argillaceous sand, the central of ferruginous sandstone with ironstone concretions, and the lower of the compact white grit in question.

The best sections, however, are seen in ascending the Moskwa for a few versts above the metropolis. We have already described the manner in which the fossiliferous Jura shales and calcareous grits and sands are exposed at Koroshovo, on the left bank of that stream. They are there covered by the sands and grits which we are considering, but the bank being low and much eroded, the chief visible remnants of the overlying mass are hard blocks of siliceous grit, which, owing to their isolated and weathered aspect, appear at first sight to be boulders. But their true relations are observed by passing to the opposite and higher bank of the river. It is in this plateau, and near the hamlet of Tatarova, that the most extensive quarries have been laid open in the overlying sandstone, parts of which are identical with the blocks at Koroshovo. The escarpment there presents to the river valley a section, in which 30 to 40 feet of sandstone have been cut into, surmounted

[1] We met with the Moscow millstones at Nijny Novogorod, and even at Ustiug-veliki.

by a mass about 12 to 15 feet thick of reddish-coloured detritus. The upper stone beds are rusty-yellow, slightly coherent, sandy grits, with occasional flattened geodes of black and brown oxide of iron. In these respects, indeed, they are not very different from the upper ferruginous beds under the Sparrow Hills, a continuation of the same plateau. The whiter grit extracted for building and millstone occurs in subconcretionary masses or flattened ellipsoids from two to four feet thick, and forms the lower part. If prolonged across the Moskwa, these horizontal beds would be directly superposed on the Jurassic strata of Koroshovo, and we thus learn, that the detached blocks of grit in the loose overlying sands of that village, are simply the harder beds *in situ* which have resisted denudation.

For a long time the only fossil we had obtained from these sandstones was a cast of a shell evidently marine, and apparently belonging to the genus *Lucina*. The plants above mentioned have therefore proved to be a most important addition.

Two of the best-preserved specimens of these plants were discovered in the ferruginous sandstone of Tatarova. On sending the drawings of them to Dr. Göppert of Breslau, that eminent botanist has referred two of these specimens to the genus Pterophyllum of the family Cycadeæ, and his description of the best-preserved species, which he has named *Pterophyllum Murchisonianum*, will be given in Part III. of this work. Other closely allied plants, belonging either to the same genus or to Calamites, with traces of Coniferæ, have been found by Mr. Auerbach[1] in a white siliceous grit near Klin, which, from the lie of the country and nature of the rock, Mr. Frears has no doubt is of the same age as that of Tatarova. These will also be described in the sequel. Again at Troitskoi on the Moskwa, three versts above Tatarova, Mr. Frears has found similar sands to be associated with a deposit of calcareous shale and marl, also highly ferruginous and full of equisetaceous plants. As no drawings of these last-mentioned remains have yet been sent to us, we are unable to reason upon them, except by general analogy; whilst it is very interesting to find, that they are there associated with fishes' teeth and a quantity of scales of fishes, which, when adequately examined, will no doubt enable geologists to place these beds still more precisely in their geological position[2].

[1] One of these plants has been named by M. Auerbach *Scolopendrites pectinatus*.

[2] In respect to Jurassic fishes, it is important to state, that a fish-palate found on the banks of the Volga having been sent to Dr. Mantell, he is about to publish it in his new work, 'The Medals of Creation,' under the name of *Gyrodus Murchisoni*; expressing also his opinion, and that of Agassiz, that it is *an oolitic form*.

It would further appear that Professor Rouiller, of the Imperial Academy of Moscow, has examined the substance of this rock very carefully under the microscope, and has discovered in it an extraordinary quantity of siliceous sheaths of Infusoria, among which, besides some unknown genera, he has recognised Bacillaria, Fragillaria, Cosconema, Galionella, &c.

Regretting that we have not had it in our power to inspect the remains of the fishes, infusoria and plants, from the last-mentioned locality, we still think that we can form a tolerably correct decision as to the age of these beds, from the drawings of the plants of Tatarova and Klin only, when coupled with our personal acquaintance with the succession and relations of the strata. It is, indeed, quite evident that these plants, for the most part Cycadeæ and Ferns, with fragments of stems, which, if not those of Calamites, probably belong to Zamiæ, are from their facies of at least as high antiquity as the upper and middle oolite, and having referred them to Dr. Mantell and Dr. Lindley, those competent authorities are of opinion that they more naturally pertain as a group to the Flora of the Jurassic than to that of any other system. No such plants have ever been found in Cretaceous rocks, and it is needless to add that they are wholly unlike any forms of vegetation of the Tertiary age.

The geological relations of the strata in which the plants are contained, are completely in accordance with this view; for we have shown that they constitute the conformable roof of beds with many Oxfordian shells, and that in one locality (the Sparrow Hills), the latter are seen to pass upwards into white and ferruginous sands scarcely to be distinguished from those of Tatarova.

We shall afterwards point out other sections on the Volga where a similar ascending order is observed, and where, as at Moscow, it is impracticable to separate the overlying iron sands from the inferior Ammonitic shales; and towards the close of the chapter we shall indicate how in the south of Russia, sands, with plants and lignite, which we believe to be similar, are overlaid by limestones of the age of the Coral Rag.

A recent excursion to Poland, to which allusion has been made when treating of the Permian rocks, also enables us to throw collateral light on this question. By reference to the geological map of Poland by M. Pusch, it will be seen that he considers a large tract of sandstones between Warsaw and Kielce to be either of the æra of the lower Lias (*Grès du Lias*), or of the Keuper. Having previously convinced ourselves that there were no representatives of the Lias or Keuper in the adjacent plains of Russia, we were naturally anxious to satisfy ourselves if the so-called Lias sandstone of Poland was really of that age. Accompanied by Professor Zeuschner and our kind friend Mr. D. Evans, the proprietor of its mines, we examined this tract. To the south and west of Jevitze, sandstones of yellowish and white colours are overlaid by a subcrystalline limestone, in parts having a coarse oolitic structure, and which, from certain imbedded species of Echini and fragments of shells, we had little hesitation in referring to the Coral Rag. The inferior rocks which rise to the south, and there form undulating wastes, at once struck us forcibly by their lithological resemblance to the sandstones of the eastern moorlands of Yorkshire, like which they are in parts highly ferruginous (concretionary iron ores being worked in them), and also contain some thin seams of poor coal, used in smelting the iron. In fact, just as in our English example, these members of the oolitic series, consisting of sand, grit, shale, and some carbonaceous matter, have much the mineral aspect of a true coal-field. Possessing an intimate acquaintance with similar deposits in Yorkshire and at Brora, we had little hesitation in placing these Polish sandstones on their true parallel; and we were further strengthened in our conclusion by finding some plants, which, if not identifiable with known species of the coast between Scarborough and Whitby, appear to belong to the same group.

But to connect the Polish with the Russian case. The plants found at Rosvadi in Poland occur in sandstone similar to that of Tatarova, and evidently belong to the same series; and we have now no longer any doubt, that they are all of younger date than the Lias, and are on the general parallel of the middle oolite. To attempt to establish a closer comparison would be unsafe with our present amount of knowledge; and it is enough for our purpose to say, that without pretending precisely to identify each continental subformation with a corresponding stratum of the British Isles or of France, we believe, that the arenaceous strata so copiously developed around Jevitze and Rosvadi in Poland represent, *as a whole*, the series of sandstone and shale beneath the Coral Rag, and extending downwards through the middle oolite; whilst from its well-defined horizon, as immediately covering a formation charged with Oxford fossils, we consider the arenaceous grits of Tatarova and the adjacent plateaux of Russia to be of the age of the sands beneath the Coral Rag.

We have previously shown that at Oksevo and Inkino upon the Oka, beds containing Oxfordian fossils pass upwards into iron sands, and we have now no doubt that the latter, as well as similar beds at Unja near Jelatma (p. 84), in which iron ores are worked, belong to the same division of deposits as the sandstones of Moscow. Lastly, in reference to many other parts of the governments of Moscow, Vladimir, and the adjacent tracts[1] (in which, it is to be remarked, no trace of any cretaceous or tertiary fossil has yet been found), we venture to suggest, that nearly all the ferruginous sands with ironstone concretions will also be found to belong to the same member of the Jurassic series,—the youngest formation which has yet been proved to exist beneath the drift and recent accumulations of this central region. This conclusion is, we think, sustained by fair analogy, and by the fact, that all the Russian deposits preserve an uniform lithological character over very wide areas.

Great Jurassic Basin of the Lower Volga, and of the Governments of Simbirsk, Tambof, and Saràtof.—The Jurassic rocks of Russia, as already explained, occupy detached basins only, and are therefore of less continuous extension than the systems of Palæozoic age. When viewed upon the map, these masses appear of much less horizontal extension than even the cretaceous deposits which overlie them. This view, founded as it is upon the knowledge we at present possess, must not, however, be exaggerated. It is very true that in the tracts of the Middle Volga, the Oka, and the Moskwa already described, as well as in the isolated patch discovered by one of us near Sisolsk, to the north-east of Ustiug-veliki[2], these deposits are narrow stripes of very limited extent. They resemble, in fact, detached relics of a sea, the deposits of which were probably separated by undulatory movements of the more ancient rocks. When, however, we follow the southern limit of the Permian strata from the banks of the Alatyr, south of Arzamas, to Simbirsk upon the Lower Volga[3], or when we interrogate the deep denudations on the banks of that stream, to ascertain the nature of the base of the plateaux to the south of the governments of Simbirsk, Saràtof and Penza, it is seen that everywhere, from their northern boundary to Saràtof, Jurassic rocks have extended and are visible beneath the cretaceous and tertiary deposits. To the south of Saràtof the great thickness of these overlying strata does not permit us to reach the Jurassic beds in any natural section, and their future prolongation in that direction

[1] We met with similar slightly coherent, ferruginous sandstones, in ravines on the right bank of the Oka at Piskavadi, between Mtzensk and Bielef, where they rest on the corroded surface of Devonian rocks. We may also state, that a proprietor of iron mines in the government of Vladimir informed Mr. Frears, that he had discovered Ammonites in the beds from which his iron ores are extracted.

[2] By Count Keyserling. (See Map.)

[3] We designate as Lower Volga all the course of that river below Kazan.

becomes of course problematical. In tracing their western limit, we discover it in the bed of the river Alatyr and its affluents, and we have already shown that these strata reappear on the Oka near Jelatma. In that parallel the Jurassic strata have certainly not spread out so far to the south as the meridian of Saràtof, for they are entirely absent in the government of Voroneje, where we saw cretaceous strata reposing at once upon Devonian rocks. Lastly, the northern limit of the great Jurassic band we are now considering, is defined by a line which, passing from about twenty versts below the source of the Piana, terminates upon the Volga about fifty to sixty versts north of Simbirsk, and a little below Tetiushi. We infer that Jurassic beds are to be found on the road from Arzamas to Simbirsk, because we observed Belemnites in the bed of the Piana. Near Barnùkova, indeed, these beds are seen *in situ* in the banks of the rivulets around the village of Kamarinof, about twenty-five versts east of Ardátof, and they continue to range without interruption to the river Sura, where they disappear beneath the chalk, and only emerge from beneath that formation in the deep valley of the Volga at Simbirsk. If, as we presume, there is no objection to the idea, that the argillaceous beds with Ammonites, mentioned by Pallas in so many places on the Alatyr, near Vassili-Maïdan, &c., and which we refer to the Jurassic age, are prolonged beneath a vast detrital cover, and are united with the strata described by us upon the Oka, it will readily be admitted, that this basin having the form of a triangle, the acute point of which extends to near Jelatma, and the two sides of which range to the Volga, is the largest continuous mass of this age in the centre of the Russian empire. (See Map.)

After thus seeking to trace the limits of this great Jurassic mass, we may now speak of its composition and fossil contents. It is a fact, to which we must again advert, that the Jurassic formation of the north and centre of Russia is everywhere composed of dark-coloured pyritous shale or clay, and of sands, sandstone and marlstone, and very seldom contains solid and calcareous beds. Thus, for example, in all the basin of which we are treating, we know of no calcareous matter except in the concretions or discontinuous courses of impure argillaceous limestone, of greyish and blue colour, which we can best compare with the cement stones of the Lias. In his journey from Arzamas to Penza, Pallas pointed out these concretions near Vassili-Maïdan, in an affluent of the Alatyr, and at other places. They are, in fact, well known to modern geologists as occurring in many argillaceous deposits of very different age. The country between the Piana and the Sura contains a considerable number of them, and they are prolonged to the Volga. At Goroditche, below Simbirsk, they appear to lie in the upper part of the formation, *i. e.* above "Inoceramus sandstone," like that which has been described at Moscow. On the other hand, they are found in the great cliffs of Saràtof, rather low in the series; and there they have no longer the form of ellipsoids, but more frequently of truncated cones applied base to base.

One of the most interesting beds of this Jurassic system, at Simbirsk and Goroditche, is the Inoceramus sandstone. This band has already been noticed at Moscow, and we now allude to it, to show the remarkable persistence of the same strata over wide areas, and also to demonstrate, that all these Jura deposits of Russia, however distant from each other, belong to one stage in the series. At Simbirsk this sandstone is almost on the level of the Volga, whilst at Goroditche, twenty-five versts to the north of this town, it is nearly at the summit of cliffs 150 or 160 feet above the stream. This difference of level, in a band of such persistence and which marks so distinct a horizon, indicates in the deposits of that tract a regular inclination to the south, although it is as imperceptible to the eye as the dip of the Silurian and Devonian rocks upon the Volkof (p. 30). But slight as it is, this inclination is still adequate to cause the whole of the Jurassic rocks to disappear at some versts below Simbirsk, where they are replaced by the chalk, which descends to the water's edge and occupies the river cliffs. The rise of the carboniferous limestone in the peninsula of the Volga near Samara (p. 86), again brings to day the Jura beds in the neighbourhood of Sysran, and with exceptions they thenceforward form the bottom of the valley of the Volga as far south as a promontory below Saràtof. Another band worthy of notice, because it occurs in several localities and serves to mark a fixed place in the deposit, contains beds of combustible matter or lignite. These are the bituminous schists of Goroditche [1], and of Kaschpoor near Sysran, which contain Ammonites and Belemnites described by M. Eichwald, and which Colonel Helmersen has shown to re-occur at Khvalinsk [2].

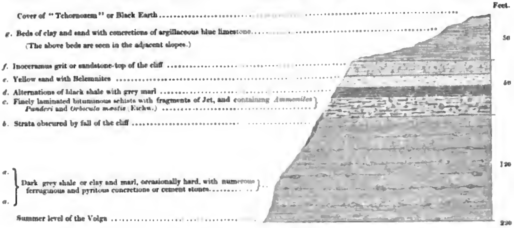
Sections on the Lower Volga.—We will now give in detail the section of the right

[1] The Jurassic shale we have described contains in parts of its range, as we have shown, some courses of bituminous schist and impure lignite, notably at Goroditche and at Khvalinsk on the Volga. One of the chambered shells from the last-mentioned locality having been described by Professor Eichwald as a goniatite, these strata were considered to belong to the carboniferous system until we visited the locality. As the character of the shale had led some persons to think that lignites fit for use might be extracted in this region, we beg to state, that we dissent entirely from this surmise, and believe that in an economical sense the bituminous shale of the Volga is worthless.

[2] See a Geological Map of Russia by Colonel Helmersen, published before we visited these parts, anno 1841.

bank of the Volga at Goroditche west-north-west of Simbirsk, because it shows the relative positions of several of the beds to which allusion has just been made.

SECTION AT GORODITCHE ON THE VOLGA. 38.



To the north-east of Sysran, or in the hills above the Ussa and Volga rivers, the lower Jurassic shale is seen in mouldering cliffs and sloping hills loaded with characteristic Ammonites and Belemnites, and reposing, as at Moscow, upon the carboniferous limestone [1]. To the south of Sysran the same black shale, with greenish and ferruginous sandstone and concretions, extends into the promontory of Kashpoor and occupies the base of nearly all the sections down to Saràtof. At Feodorofskaya and Khvalinsk these beds are capped by cretaceous rocks and white chalk.

After several denudations and obscurations, the Jurassic rocks appear in great force in the cliffs of the Volga at Saràtof, and to the north of that city exhibit a greater development of the formation than we have seen at any one place in Russia, the vertical thickness not being less than 300 to 400 feet. The ascending section from the Volga under the hill of the suburb called Sakalosfkie, offers—

1. Towards the river edge, a vast succession of rolling subsidences of clay, sand and grit, the detritus of the cliff above, which rise in a rude talus, the concretions of cement stone with septarian divisions exposing here and there very beautiful Ammonites and other fossils, often highly iridescent. The *Ammonites cordatus* of the Oxford clay is one of the species we were enabled to identify upon the spot. 2. Dark pyritous shale with many concretions of ferriferous and argillaceous limestone of light indigo colour, some as large as bee-hives, easily exfoliating and breaking to pieces under atmospheric influence (iridescent Ammonites abundant). 3. Sands of yellowish colours and of considerable thickness. 4. Shale. 5. Yellow sandstone with bands of cherty character. 6. Dark shale, with concretions passing into whitish stone bands. 7 Yellow, ferruginous sand and ironstone bands. 8. Dark shale. 9. Yellow and whitish sands.

[1] The vertebra of a Saurian has also been found here, and was described by Professor Eichwald. Über Icthyos. und Cerat. Russl. 1841. The *Orbicula mæstis* above mentioned, is described by the same author. Urwelt Russland, 1840. Heft 1. pl. 4.

Though we had no time to seek for many fossils, our readers cannot fail to perceive in this section a close analogy to the succession at Moscow and other places, and will readily admit with us, that as at the ancient metropolis and at Inkino on the Oka so at Saràtof, ferruginous and white sands form the upper part of the deposit. We shall presently see how these sands connect the strata we have been considering with the next overlying formation in the south of Russia.

Eastern tract of Jurassic Rocks.—It is a remarkable proof of the value of palæontological evidence, in identifying strata before they have been examined by field geologists, that certain fossils sent to M. Von Buch from the government of Orenburg, enabled him anterior to our visit, to assert that the same band of Jurassic rocks which occurs at intervals in the plains of Russia and near Berlin, appeared also in the steppes which lead from Europe into Asia. Whilst our own observations completely confirm this view, we must state, that however uniform is the composition of the rocks of this age in the central and northern regions of Russia, yet as they approach to the Ural chain and the Asiatic steppes, they put on lithological characters dissimilar from their ordinary matrix. The higher grounds which rise above the cupriferous strata of Kargala and the Saragula Hills, are covered by very siliceous beds, in which the same Jurassic fossils as at Moscow, such as *Ammonites cordatus* and *Gryphæa dilatata*, occur in nearly pure silex. On the river Vitlanka, not far from the salt mines of Illetzkaya-Zastchita, the same formation is well seen in open quarries of about fifteen feet in depth, where the stone is of light yellow colour, sonorous under the hammer, and is composed of minute, white siliceous grains cemented in a calcareous paste, which still more prevails in other beds which become calcareous grits. Here are again found fossils which are common in the Jurassic shales of Moscow, such as a *Lima* closely allied to *L. proboscidea*, *Ammonites cordatus*, &c. &c. In two ridges, called Tatchilnoi Gora and Jornavoi Kamen, the same rock becomes a complete siliceous grit, and is even quarried for millstones and grindstones. Near the fort of Isabelnoi upon the Ilek, similar beds occur and have furnished osseous remains, which we did not see, but probably belonging to a large Saurian; and they are also seen at the sources of the river Kamenko on the slope of the Obstchey Syrt, forty versts north of the fort of Baratinski.

We may here remark, that the surface of these Jurassic districts is often covered with rolled pebbles of white quartz and Lydian stone, both on the river Vitlanka and on the adjacent hills, and among this detritus are large blocks of quartz. Near the small river Tchorni Retchki, to the north of Novo Illetzkaya, we discovered beds of conglomerate *in situ*, made up of similar materials resting on red Permian sandstone. It is probable, therefore, that all the rolled stones having the same characters which are spread over parts of the tract of the high steppe of Illetzkaya-Zastchita, have been derived from a disintegration of the Permian conglomerates which were re-arranged by the sea in which these Jurassic rocks were accumulated. Let this theoretical point be as it may, the lithological composition of the Jurassic rocks in the southern part of the government of Orenburg is highly interesting, in showing how similar mechanical submarine operations have been repeated in distant countries during former epochs, whenever the strata approach to hilly and disturbed tracts like the Ural, the surface of which has been much disturbed. In these strata, different as they are in their stony features from their equivalents in fossil contents through other parts of Russia, we see both siliceous and calcareous grits assimilating in aspect to certain beds of the Oxford oolite at Brora in the Highlands of Scotland[1]. Again, the conglomerate which appeared strange to those of our party who had only observed the Jura beds of northern and central Russia, has also its analogy to certain conglomerates and grits, which in Britain mark the base of the oolitic series, in tracts where the vibrations of the surface have been intense, and where coarsely aggregated and detrital beds stand in the place of the finely laminated lias shale of other portions of the island[2].

Upper Jurassic Group in Southern Russia.—We have shown that a great axis of Devonian rocks divides central Russia into two zones of very different lithological composition (p. 53). To the south of this axis there are no traces of Jurassic strata resembling the great mass of those we have described, nor indeed can any considerable development of strata of this age be observed in journeying southwards, until they are found to constitute, and under a very different mineral aspect, the rocky crest of the Crimæa. Visited by one of us for a short time only, we necessarily leave the description of that remarkable peninsula to the able authors, M. Dubois, M. Huot, and M. Hommaire, who have so thoroughly explored it, the first of whom has permitted us to consign to our own map its chief geological features, as well as those of the Caucasus, from illustrations prepared by himself.

[1] See Geol. Trans. N. S. vol. ii. p. 296, siliceous grit of Braambury Hill.

[2] On the northern shores of the estuary of the Severn, Conybeare and Buckland were the first who made us acquainted with lias conglomerates, and Mr. Murchison detected similar rocks in the north-western Highlands of Scotland, alternating with true lias limestones. In the latter situation there are also white grits, which might very well be employed as millstones, like the Jurassic grits of Orenburg. (See Geol. Trans., 2nd Series, vol. i. p. 303, and vol. ii. p. 361.)

In fact, the Jurassic rocks of the Crimæa, lying to the south of the granitic and porphyritic steppe, to which we have alluded, and much perforated by eruptive rocks, belong distinctly to another mineral region. They assume the Caucasian aspect of the strata of that epoch, and from their imbedded masses of hard and crystalline limestone, they might at first view seem to be referable to the same Jurassic limestone which is spread over Southern Germany, including the Alps and Carpathians, and which bounds the shores of the Mediterranean Sea,—a series which unquestionably includes in descending order all the strata, to the inferior oolite and lias inclusive[1].

On this point, although we do not yet pretend to have the means of forming a correct decision, we are bound to state, that, judging from the fossils which have been as yet submitted to him, M. D'Orbigny is of opinion, that even there, the lias does not form a part of the group as in the Alps and Carpathians; but on the contrary, that, differing as it may in lithological character, the Jura of the Crimæa and the Caucasus represents, like that of Russia, the "Terrain Oxfordien." He has convinced himself, that the Ammonites of the Crimæa, when not identical, approach closely to forms which are common near Dignes in the Lower Alps and at the Mont du Chat; whilst the northern species are evidently those of a separate basin, characterized by the distinct species to which we have before alluded.

But to consider the tracts with which we are personally acquainted: the only deposit of the Jurassic or oolitic age hitherto observed between the Devonian axis of Voroneje and Orel and the Sea of Azof and the Black Sea, was first discovered by Major Blöde on the banks of the Donetz near Izium. Accompanied by that persevering geologist, we were enabled to satisfy ourselves of the accuracy of his observations; and although we slightly extend the limits of the group, we admit with him, that it occupies a tract of very limited dimensions. It is, in truth, a minute patch upon the great surface of Russia; for to the south it is entirely cut out near Bachmuth and Lugan, where the chalk reposes on Permian and carboniferous strata, without the intervention of a single bed to represent any member of the Jurassic series. Still the deposit is geologically important, both from its peculiar character and as marking a higher stage in the series than any other beds of this epoch in Russia.

[1] To mark the exceeding difference between the synchronous rocks of the north and south of Europe, M. Von Buch has graphically distinguished the latter by the term "Mediterranean Type."

The right bank of the Donetz at Izium presents steep escarpments which expose interesting sections of these Jura rocks, both at that town and at several localities above and below it. The uniform composition of these strata leaves no doubt, that they belong to one and the same division of the series; and they pass under cretaceous rocks, of which we shall treat in the next chapter. We shall not employ many words in describing these different localities, though we must enter sufficiently into detail to render apparent the characters which unite them, and the marked differences which separate them from the basins already described.

Sviatagora.—In advancing to the north, after our examination of the great carboniferous tracts of the Donetz (p. 89 *et seq.*), the point at which we first observed any strata of Jurassic age was at Sviatagora, about eight versts below Izium. Near the celebrated convent of that place these beds rise up very gradually from beneath picturesque masses of white chalk which have weathered into "needles," and resemble the light and airy spires of a Gothic church[1]. The strata which immediately lie beneath the white chalk, are sandstone and sand, intermixed with some courses of clay, analogous to, but not identical with, certain great masses of grit which a little higher up the Donetz are invariably inferior to the white chalk, and seem, as we shall hereafter show, to form a part of the cretaceous system. These sandstones are of greenish-grey colour, and disintegrate readily. The alternating clays are reddish and compact, passing to shale, in some parts plastic and highly argillaceous, in others sandy. The white Jurassic limestone which is surmounted by the sands and sandstone, is in parts oolitic, and towards its base pisolitic; but the chief mass is not so distinguished, and simply resembles many of the earthy white limestones of La Rochelle in France and of Portland in England.

In the middle part of this section we found a fragment of a *Terebratula* resembling *T. spinosa* and some indistinct corals. The thickness of the white limestone at this spot is about forty feet, and the beds dip at an angle of twelve to fifteen degrees to the south, whilst the overlying chalk is rather less inclined but in the same direction.

Kamenka.—The second locality in ascending the banks of the Donetz, at which the Jurassic formation crops out, is about three versts below the little village of Kamenka. The beds are here less inclined than at Sviatagora, not exceeding three or four degrees in their dip to the south. The brook Kamenka, which flows

[1] In early times the cells in the chalk beneath these natural spires were used as convents by the monks.

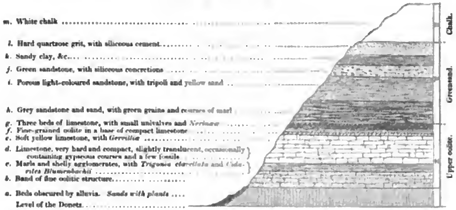
into the Donetz, three versts from the village of the same name, lays bare on its banks a very instructive succession. In the upper part are courses of sub-concretionary or brecciated white limestone with Terebratulæ, resting upon an agglomerate of shells, and a band of very fine oolite: in the lower are yellowish calcareous sands, or rather disintegrating sandy limestones, with ferruginous oolite and yellow sand. The whole of these beds may have a thickness of about forty feet. The fine-grained oolite and the shelly agglomerate are the beds most worthy of attention, and they are also by far the most constant; for we traced them northwards by Izium to Donetzkaya near the military colony of Petrofskaya. The shelly beds contain in great abundance the *Trigonia clavellata*, a small Ostrea, Nerinæa, Astarte, Terebratula, and a Turbinolia. To these beds at Kamenka, and a little higher up the Donetz, lower beds of friable and soft limestone succeed, *reposing upon ferruginous sandstone with plants and some lignite*, which have been observed in one point only, and described by Major Blöde. We did not see the plants in question, which ought to be compared with the recently discovered flora of the ferruginous sandstone of Moscow. Judging from their position beneath these white fossiliferous or Upper Jura limestones, there can however, we conceive, exist but little doubt, that the lowest beds on the Donetz are the equivalents of the highest beds at Moscow, or sands above the Oxford clay. They are, therefore, of high interest in bringing the Jurassic series of North and South Russia into geological connection.

The presence of the Nerinæa and of a coral unknown in the other Jurassic formations of Russia, the absence of Belemnites and the great scarcity of Ammonites (we shall presently, however, allude to a striking species), are points which seem to indicate a very notable change in the distribution of the fossils of the Jurassic epoch, so regular and uniform in all the central and northern parts of Russia.

Izium.—The most instructive of the sections on the Donetz in ascending order is certainly that of Izium; for, besides affording a very complete development of the uppermost Jurassic division, it also clearly shows that a considerable thickness of sand and sandstone (greensand) is there interposed between the Upper Jura and the white chalk. In this section the inferior beds are not visible beneath the river alluvia, and the ascending order commences with the fine-grained oolite, the shelly agglomerate with *Trigonia clavellata*, and a compact hard limestone. The succession is explained in the accompanying diagram. The uppermost Jurassic strata are divisible, it will be observed, into five beds, each peculiarly characterized, and the group is then overlaid by green sandstone, sands, &c., which in their turn are surmounted by chalk. To the consideration of the last-mentioned deposits we shall return in the next chapter.

39.

SECTION AT IZIUM.



There is, then, as we have shown, the most perfect agreement between these sections in different parts of the Donetz. The higher inclination of the strata visible in one spot near Kamenka, is proved to be, after all, a mere local derangement, since at distances of ten and more versts apart, we observed the same beds in nearly horizontal positions. The persistence of the shelly agglomerates with *Trigonia clavellata* and the fine-grained oolite, afford, in short, as clear a line of geological horizon, though on a smaller scale, as the Inoceramus sandstone in the lower Jurassic division of other parts of Russia. We again detected these beds occupying the right bank of the river, in low cliffs from fifteen to thirty feet high, at Donetzkaya, near Petrofskaya, where, in addition to the *Trigonia clavellata* and *Nerinæa elegans* (Fischer), the *Ammonites biplex* also occurs: there is also present a remarkable Ammonite of undescribed species, which M. D'Orbigny informs us exists in the coral rag of France[1].

From the details here given, and from the section which shows that these strata repose upon ferruginous sands with plants, and are overlaid by green sand and chalk, our readers can have no doubt that the group which we are describing, is of age posterior to the dark Jurassic shales and sands of the central and northern regions. But can we refer them with precision to any one known formation or subformation of the oolitic series of England, or of the Jura limestone of the Con-

[1] This Ammonite approaches to the *A. biplex*.

tinent? Even whilst on the spot, we were led rather to group them with the coral rag than with any inferior stratum. We subsequently confirmed this view by a visit to Poland, and can now state, that the rocks of the Donetz may be well compared with the white limestone on which the citadel of Cracow stands. Forming a low ridge along the banks of the Vistula near that city, the upper mass is there a white, compact limestone, about 300 feet thick, which, as it contains lines of flint exactly resembling those of the English chalk, was formerly placed on the parallel of that formation. The lower strata are yellowish, sandy, calcareous grits. In the white or superior beds, Professor Zeuschner, with whom we recently examined the rock *in situ*, has identified the following fossils of the coral rag,—viz. *Scyphia clathrata* (Goldf.), *Ammonites biplex*, *A. triplex*, *A. polyplocus*, *A. annularis*, *A. flexuosus*, *A. vertebralis*, *Lima proboscidea*, *Terebratula biplicata*, and *T. subsenilis*. The lower mass, from 100 to 150 feet thick, contains *Pecten fibrosus*, *P. lens*, *P. textorius*, *P. vimineus*, *Terebratula varians*, *T. concinna*, *T. bullata* or *globata* (V. Buch), *T. perovalis*, *Lima proboscidea*, and *L. pectinoides*?, with some broken Belemnites and Fucoids.

Judging from these organic remains, Professor Zeuschner correctly places the beds which contain them, in parallel, as a whole, with the coral rag. We may add, however, that, in our opinion, the lowest of these bands also truly represents the calcareous grit of Oxford and the Malton oolite of Yorkshire, since it contains some of the most characteristic species of that subformation,—a very remarkable coincidence, when we consider the distance which separates Malton and Oxford from Cracow. But to resume and apply this reasoning to Russia, we may say, that the Polish beds of Southern Poland serve as a valuable connecting link between England and Russia, since they possess, in common with the limestones of the Donetz, the same characteristic *Ammonites biplex*, and we therefore believe, that they both belong to the same group—the upper Oxford oolite.

Conclusion.—In terminating this chapter, we may repeat, that our observations have established and extended the view first taken by M. Von Buch, from an inspection of the fossils only; that in a broad zone, extending from the plains of Prussia into the distant tracts of Russia, all the Jurassic strata belong to the Oxfordian formation of that series. We have further ascertained, that in Central Russia, as in Poland, there exists an arenaceous deposit, with plants and occasional lignite, which represents the sands in and above the Oxford clay; whilst in Southern Russia a small upper member of the series is the equivalent of the white limestone of Cracow in Poland, and is, we conceive, of the exact age of the coral rag and calcareous grit of England.

Detailed examination of the fossils derived from the lowest and larger formation has convinced M. D'Orbigny, that they belong to two stratigraphical divisions first established by William Smith, viz. the Kelloway rock and Oxford clay; and judging from the remains we laid before him, he thinks it possible to distinguish, with as much precision as in France or England, the lowest Oxfordian or Kelloway rock, from the overlying beds of the Oxford clay. Thus, according to M. D'Orbigny, the fossils from Moscow, Jelatma on the Oka, the North Ural and the tracts near Simbirsk and in the government of Orenburg, contain similar assemblages of forms, which he classes with the remains of the Kelloway rock of England or the lower stage of his "Terrain Oxfordien"; the *Ammonites Gulielmi* (Sow.) and the *A. Fournetianus* (D'Orb.) being the characteristic fossils. On the other hand, M. D'Orbigny believes, that the beds at Makarief on the Unja, near Ples on the Volga, and at Saràtof, represent the middle beds of the "Terrain Oxfordien," or simply the Oxford clay of England; of these the *Ammonites cordatus* is characteristic[1].

Adopting invariably those views of classification, which agree with the distribution of organic life, we have never, we trust, undervalued the importance of clear evidences of superposition. Now, in Russia the facts (as we have related them) are, that the Jurassic beds which are in *contact with inferior rocks*, are those near Ples, Makarief and Moscow. Unquestionably, therefore, in a country void of all great dislocations and with little variation in the level and inclination of the strata, such beds may naturally be supposed to lie low in the Jurassic series. Judging from the few fossils we could collect in the vicinity of those junctions, M. D'Orbigny is led to believe, that two of these masses belong to his middle stage of the "Terrain Oxfordien," whilst a third (that of Moscow) is on the parallel of his lower stage. In relation, however, to the sections on the Volga near Ples, it must be stated, that in the Jurassic shale in contact with the red Permian rocks, we obtained Belemnites only; whilst the other fossils were gathered from mouldering slopes and at intervals along the river banks, where no such junctions are visible. Among these fossils, the *Gryphæa dilatata*, as already said, was not unfrequent, and it was associated with *Ammonites cordatus*, *Turbo muricatus*, &c. Again, in the Jura beds upon the Oka (near Jelatma), referred by

[1] In England this fossil is usually found in the "calcareous grit."

M. D'Orbigny to the "étage inférieure," we find the same Gryphæa, associated with different species of Cephalopods, which are common in the Kelloway rock or lower stage; and hence it might be inferred, that the beds containing them must also be the lowest Jurassic stratum in Russia. This however is not the case; for the section at Inkino near Jelatma (p. 234) exhibits the same fossiliferous beds resting upon a considerable thickness of Belemnite shale; and a similar order of superposition is seen at Moscow. Whether, therefore, this shale be in contact with the red marl and sand of Ples or the carboniferous limestone of Moscow, or whether, as near Jelatma, the subjacent rocks are hidden from view, it is quite manifest, that it forms the lowest Jurassic stratum of Central Russia: and it is also equally certain, that this lower stratum contains few fossils, and that the shells cited as types of the Kelloway rock are found, both at Inkino and at Moscow, in central or overlying beds.

But these facts are not at variance with our general views of the identification of distant deposits; for all the Jura rocks of Central and Northern Russia put together, are not of greater vertical thickness than one formation only of Western Europe, and their fossils belong, as an united group, to the Oxford clay and Kelloway rock of England, or "Terrain Oxfordien" of France. We cannot, it appears to us, push the parallel further, and expect invariably to find in Russia an exact equivalent for the little English band of Kelloway rock. We may, indeed, rest satisfied with proving, that certain strata of Northern and Central Russia contain species which characterize the Oxford clay and its sub-formation in England and France,—that other beds with plants represent the sands of the calcareous grit, whilst the white limestone in Southern Russia is the equivalent of the Coral Rag.

Without the knowledge which we possess of the country, a theorist, whilst defining more precise geographical limits than we can hope to assign to the different parts of this great Jurassic basin, might endeavour to indicate its littoral and pelagic deposits. But no such separation can be admitted so long as we know, that lithologically and zoologically the strata at Jelatma on the Oka, are undistinguishable from the very distant rocks of the North Ural and the basin of Petchora, on the one hand, and from those of Moscow on the other.

At the same time we are quite ready to admit with M. D'Orbigny, that the fossils from Makarief, Ples and Saràtof have generally the aspect of the Oxford clay, and that those of Moscow, Jelatma, North Ural, Simbirsk and Orenburg, present the "facies" of the Kelloway rock.

The extension of this one member of the oolitic series from the plains of Prussia to the frontiers of Asia, is not less remarkable, as evidence of the wide operation of the same general causes in ancient epochs, than as demonstrating the great "hiatus" of formations which is shown to exist between the Palæozoic rocks and the Jurassic deposits; there being in these countries an entire absence of the Trias, properly so called, and also of the Lias and inferior oolite. This omission of formations, so important in Western Europe, and there indicating so long a lapse of *time*, might lead us to presume, that the bottoms of the ancient seas had, to a great extent, been raised above the influence of the waters, during the periods which passed whilst these deposits were forming in other parts of the world, and that they were not again submerged until the period of the middle oolite. We might perhaps explain the absence of so much inorganic matter and so many animal remains, by supposing, that the tracts thus distinguished had been submerged to vast depths, and placed beyond the reach of any sedimentary influence. But whatever theory we adopt, it is evident that such uprisings or depressions took place equably over a very wide area; for in the region where they occur, no sort of eruptive agency has ever been in play. The operation, therefore, was probably one of general intumescence at one æra, and of subsidence at another, without the production of any of those great fissures and dislocations so common throughout countries affected by plutonic outbursts.

But, putting aside speculation as to the cause of this suppression of the intermediate deposits, and looking only to the actual geological succession, is our wonder to cease, we may ask, with the announcement, that these Oxfordian strata extend from the plains of Prussia to the Icy Sea of the Samoyedes, and to the Siberian or Asiatic flank of the Ural? Certainly not, for we have ascertained that they are much more widely diffused. When we first saw the fossils of this grand Russian deposit, we were struck by their resemblance to forms collected by English travellers in the Himalaya chain, a series of which was presented to one of us[1] a few years ago by Lady Sarah Amherst[2], and found by herself upon the spot.

[1] Mr. Murchison. The black Ammonites collected in the Himalaya are used as charms by the Hindoo Fakirs.

[2] Now Lady Sarah Williams.

Our surmise has been confirmed by M. Alcide D'Orbigny, who, having examined the Himalayan fossils of this age which we have submitted to him[1], acquaints us, that the most common of the Hindoo Belemnites is identical with the very common Russian species *Belemnites absolutus* (Fischer); whilst among the Ammonites are the *A. interruptus* (Schloth.) and the *A. triplex* (Sow.), which in France and Germany are highly characteristic of the Oxford clay! We are not yet sufficiently acquainted with the details of East Indian geology to be able distinctly to assert, whether, as in Russia, the "Terrain Oxfordien" there prevails to the exclusion of other members of the oolitic series; but the fact is very remarkable, that from whatever locality of Northern or Southern India fossils of this age have hitherto been brought home, they all have the "facies Oxoniensis." Thus in the Runn of Cutch and the adjacent lands at the mouth of the Indus, English geologists have already shown, that *Gryphæa dilatata* is associated with fossils very similar to, if not identical with, the Ammonites and Trigoniæ of the Oxford formation[2]. The same inference has, indeed, been drawn from similar fossils collected in Southern Africa, on the Orange river, considerably to the north of the Cape of Good Hope[3].

So far, then, we are assured by the evidence of organic remains, that the Oxfordian strata occur in other quarters of the globe; but how are they there distributed? Do they occur in great continuous zones or isolated patches, and are they, as in Russia, the sole representatives of all the oolitic series? Where, again, are their eastern limits in Asia? may they not range from the Himalaya mountains, through Nepaul[4], even into the Birman and Chinese empires?

Though future explorers alone can answer these queries, our readers will, in the

[1] These Himalayan fossils included the collection of Lady Sarah Amherst and one made by Major D'Arcy, and presented by him to Dr. Buckland.

[2] See the memoir of Captain Grant, Geol. Trans., vol. v. p. 289, and the notice by Colonel Sykes of collections made by Captain W. Smee and Colonel Pottinger, ibid. p. 715. The oolitic fossils of the Runn of Cutch, and also of the desert to the north-east (Balmeer, Joonah, &c.), have quite the character of the middle oolite. See figure of *Gryphæa dilatata*, Geol. Trans. vol. v. p. 719.

[3] Silurian System, p. 583. These African species were collected by Dr. Smith.

[4] The late General Hardwick, of the East India Company's service, brought home, together with his splendid collection of natural history, certain fossils from Nepaul. Among these were three species of Ammonite, named and figured but not described by Mr. J. E. Gray; viz. *A. Nepaulensis*, *A. Wallichii*, and *A. substriatus*, all evidently forms of the oolitic series, but whether distinct from those of the Lias cannot well be determined. (See Hardwick and Gray's Illustrations of Indian Zoology. Fol. vol. i. last plate.)

mean time, we trust, be satisfied that we have proved, in no ambiguous terms, the vast range of this Oxford deposit. Our own survey has, indeed, shown, that it is one of the most important members of the secondary rocks of Eastern Europe; for whilst in Great Britain it constitutes a small portion only of the oolites, not there occupying above a fifth part of the space covered by that series, in Russia it spreads over considerable tracts, to the entire exclusion of the Great and Inferior Oolite and Lias beneath, as well as of the Kimmeridge clay and Portland rock above it. In a word, the Oxford formation of Russia is the only deposit which there exists, between the palæozoic rocks upon which it reposes, and the cretaceous strata by which it is succeeded.

P.S. As this sheet was passing finally from our hands to the press, we received a letter from our zealous friend Mr. Frears of Moscow, which announces, that M. Jasikoff of Simbirsk, to whose observations on the Cretaceous and Tertiary rocks of that government we shall presently refer, has discovered in the Jurassic strata a few bones of *Ichthyosauri*. These remains occur in black calcareo-bituminous schists, which seem to pass on the one hand into a limestone, and on the other into greenish sands. These beds near Simbirsk are, however, of the same age as those of Moscow; for they contain some of the same species of fossils. Among others which will be noticed in Part III. M. Jasikoff cites *Gryphæa dilatata*, *Inoceramus dubius*, *I. lævigatus*, with Avicula, Terebratula, Orbicula, six species of Ammonites, two species of Belemnites, &c.

In reference to what has been said of the sands with plants which overlie the fossiliferous shale of the Moskwa, p. 240 *et seq.*, it ought to be stated, that the cast of the Lucina which is mentioned as occurring in these sands and grits, was found in the overlying beds south of Miatchkova, no such shell having ever been detected at Tatarova. We see no reason, however, to doubt our conclusions, that all these sandstones in the Government of Moscow are of the same age, and belong to the upper part of the Oxford formation. Whether the beds at Troitskoi really constitute, as we suspect, the uppermost limits of this series in the Government of Moscow, must be decided hereafter.

CHAPTER XII.

CRETACEOUS SYSTEM.

I. *Prefatory Sketch of the Variations in Mineral Character of the Cretaceous System of Northern Europe in its range from West to East.—Succession in England, France, Germany, Poland and the Carpathians.*—II. *Cretaceous Rocks of Russia in the drainage of the Donetz and the Don.—Thinning out of the white Chalk in the Governments of Kharkof, Kursk, &c.—Eastern mass of Chalk on the River Ural.—Cretaceous Rocks of the Lower Volga extending from Simbirsk to the Southern Steppes.—Peculiar mineral development of the Cretaceous system of Russia and its apparent Passage into the Tertiary Rocks.—Country between the Volga and the Don.—Conclusions.*

DEVOTING our chief attention to the Palæozoic rocks of the northern and central districts of Russia, we had no great difficulty in mastering the relations of the Jurassic or next succeeding deposits, which exhibit well-defined characters and occupy limited spaces. A much shorter period, however, was spent by us in the vast region of the south, which, with the exception of the granitic steppe, a small patch of Palæozoic rocks and the carboniferous tract of the Donetz, is exclusively occupied by cretaceous and tertiary deposits. Under these circumstances it is evident, that we must be unprepared accurately to define the boundaries and relations of the superior systems. In the following pages, indeed, we shall give other cogent reasons, which prevent us from separating the Cretaceous from the Tertiary rocks, with the same decision as in England and France. To render this point more intelligible to our readers, and also to convey to them a clear view of the general range and features of the cretaceous deposits of Northern Europe, we shall commence this chapter with a sketch of the changes which they undergo, in passing from the British Isles on the West, to Russia on the East.

In some parts of England the oolitic series is well known to be separated from the Cretaceous rocks, by a considerable estuary and freshwater formation called the

Wealden. This deposit, feebly represented in France, but clearly recognizable in Hanover[1], is not traceable throughout Eastern Germany; and has no representative in Poland or Russia. In reference to our subject, therefore, it is unnecessary to enter upon the discussion which at present occupies geologists, as to the precise marine equivalents of these estuary and freshwater beds in other parts of the European basin. The Wealden group of the British Isles is surmounted by a thick Cretaceous system, divided, in ascending order, into the following formations: —1. Lower Greensand. 2. Gault. 3. Upper Greensand; and 4. Chalk. As the lowermost of these masses, of considerable dimensions and of varied structure has been recently found to contain in England many fossils characteristic of the "Terrain Neocomien" of Swiss and French authors, it is clear that the latter formation, which extends through the south of France, is simply a largely developed inferior member of the Cretaceous system, under a certain mineral type, and with some peculiar fossils. With this deposit we have, however, a little more concern than with the Wealden, for although its lower and peculiar part does not, as far as we know, exist in Eastern Germany or Poland, it appears in the Crimæa and southern limits of Russia[2]. But putting aside the lowest greensand of English geologists, which with its continental equivalent the Neocomian must be considered the true base of the Cretaceous system, it may be stated, that even within the kingdom of France it has been ascertained, that the cretaceous subdivisions in the south of that country are essentially distinct from those of the north. In the latter, as in England, the white chalk is *underlaid* by bands which respectively represent the Upper Greensand and Gault, with some development of a Lower Greensand; whilst in the southern provinces the last-mentioned deposit, containing much calcareous matter, is at once surmounted by white limestone, which passes under tufaceous marlstone, the whole series terminating upwards in yellowish-white and gray chalk. And yet, notwithstanding this great discrepancy in

[1] See Roemer's Versteinerungen des N. Deutsch. Oolith. Geb. 1836.

[2] It is right to observe, that some Neocomian shells, similar to those which occur in the lowest beds of the greensand of the Isle of Wight, have been found near Kislavodsk, at the northern foot of the Caucasus. We state this on the authority of our colleague Count Keyserling, with whom we examined the coast-section at Atherfield in the Isle of Wight in the spring of 1842, and thence suggested that it would prove to be the equivalent of the Neocomian strata of foreign geologists. (See Proc. Geol. Soc., vol. iv. p. 112, and the memoirs of Mr. Austen and Dr. Fitton, Proc. Geol. Soc. vol. iv. pp. 170 and 198.) M. Dubois de Montpereux had previously ascertained the presence of Neocomian strata in the Crimæa. His detailed sections of the whole cretaceous series, as exhibited in the cliffs of this country, are most instructive. (See Voyage au Caucase, &c., Fifth Ser. pl. 10. f. 13.)

detailed mineral succession, the system, as a whole, in France is characterized throughout by certain fossils, some of which have a great vertical range when followed from one part of that country to another[1].

With a strong general analogy, if not identity as a geological group, derived from stratigraphical and zoological evidences, the Cretaceous system of Germany differs, in the lithological arrangement of its parts, both from that of England and of France. In England, as already stated, the upper half is calcareous, the lower arenaceous and argillaceous; and if in the North of France the same general succession may be said to exist, the South presents, as just mentioned, a group more or less calcareous throughout. In Central and Eastern Germany, on the contrary, the whole system is much more siliceous, calcareous matter being very sparingly distributed. To that country, therefore, we now invite a little preliminary attention, seeing that it is intermediate between the best known western types and the chalk of Russia.

In Central and Eastern Germany, then, the upper part only, as we believe, of the English lower greensand, is well represented by the Quader Sandstein, which constituting rocks of picturesque forms on the northern flank of the Hartz and in Saxony, spreads over a wide area in Bohemia, Silesia and Moravia, where with Alcyonia and some fossils of the west, it contains many new species of animal remains, some of which have been published, and also a copious Flora[2].

In Saxony the "Lower Quader" is a light-coloured siliceous sandstone, with occasional green grains and spots of black oxide of iron. The next superior band, or "Lower Pläner-kalk," is a marly grit, sometimes a chert, at others a conglomerate, and even a white, incoherent and ferruginous sand. The latter rock contains a few peculiar fossils, and some which in Britain have been found only in the white chalk, such as Hippurites, sharks' teeth and palates of fishes, with *Terebratula gallina*, *T. ovoides*, &c. The next, or third group, ascending, termed the "Middle Pläner-kalk," varies from a white and ferruginous sandstone containing some green grains, to a highly calcareous grit, in which the well-known fossils *Inoceramus con-*

[1] See D'Archiac, Études sur la Formation Crétacée, 1844; also the instructive descriptions of M. Dufrénoy, Déscript. de la Carte Géol. de France, and La Paléontologie Française of D'Orbigny.

[2] See the Gæa von Sachsen, by Dr. Geinitz; also the memoir of M. Göppert on certain plants. Another work is preparing on the deposits of this age in Moravia, by Professor Glocker of Breslau, in which many new forms of plants are figured. The fossil contents of the cretaceous rocks of Bohemia are said to exceed 500 species, part of which have been made known by Dr. Reuss (Kreide-gebilde des Westlichen-Böhmens, Prag. 1844). It is not our province here to allude to the Northern German types described by Römer.

centricus and *Ostrea vesicularis* are most abundant. The fourth division, the "Upper Pläner," is a dull gray, sandy, calcareous rock, containing sometimes as much as 75 per cent. of carbonate of lime. This band is peculiarly characterized by *Hamites* and *Scaphites* with *Terebratula carnea*, *T. Mantellii*, certain large Inocerami common in the chalk of England, numerous fishes; and altogether 160 species, at least, have been collected from it in Saxony alone, of which the *Spondylus spinosus* (*Plagiostoma*, Sow.) is perhaps the most abundant of the forms well known in the chalk of other countries. Lastly, the fifth or highest division, termed the "Uppermost Quader," is a siliceous building-stone, often occupying the table-land of lofty hills, which containing very little calcareous matter, has not afforded many fossils, though among them are Hamites which distinctly connect it with the underlying band; and others, such as *Pecten asper* and *Lima multicostata* (Geinitz), which some observers might consider to be characteristic of the greensand below the chalk.

Geologists can scarcely hear of this Saxon succession[1] and compare it with that so lucidly pointed out by Fitton and other English authors[2], without perceiving that whilst the group of organic remains of both countries is on the whole the same, the detailed lithological order in which the beds succeed each other, and the fossils by which they are distinguished, are essentially different.

In Saxony and the surrounding tracts of Germany, where there is no true chalk, we see several species running through the whole series. The *Pecten 5-costatus*[3], for example, is found in every one of the five German subdivisions, and the *Inoceramus Mytiloides* of the lower chalk (never yet seen in the English greensands), occurs in the lowest and one of the highest of the Saxon beds. Valuable, therefore,

[1] This succession is given on the authority of Dr. Geinitz of Dresden, who has just added to his former publications an interesting description, with figures, of the fossils of certain cretaceous rocks upon the frontiers of Saxony, Bohemia and Silesia, which were recently traversed by Mr. Murchison (Heuscheurgebirge near Glätz, and Kieslingwalda near Habelschwerdt). In his list are enumerated many species well known in England, as characteristic of the lower greensand series, among which are *Trigonia alæformis*, Sow., *Pecten quadricostatus*, ib., *Cardium Hillanum*, ib., *Venus faba*, ib., *Terebratula sella*, ib., *Cucullæa glabra*, ib., *Littorina conica*, ib., *Turritella granulata*, ib., *Ostrea macroptera*, ib., &c., &c. Others, from the same localities, and which do not there appear to lie in higher positions, are, on the contrary, in England, characteristic of the chalk only; viz. *Terebratula striatula*, Mantell, *T. octoplicata*, Sow., *T. Mantelliana*, ib., *T. pisum*, ib., *T. ovoides*, ib., with *Hamites ellipticus*, Mantell, several fishes, &c., &c.

[2] See Fitton's memoir on the strata below the chalk, Geol. Trans. vol. iv. p. 103; and Mantell's Geology of the South-east of England.

[3] M. D'Archiac also shows that the *Pecten 5-costatus* ranges through all his four divisions of the cretaceous formation of the south-west of France.

as species are in designating the limits of sub-groups within given distances, the distribution of the fossils of the Cretaceous system of France and Germany shows, that forms which some geologists might consider as characterizing one division only of a system, there pervade all its members. We have alluded to the divisions of the Cretaceous system of the east of Germany, in order to lead our readers to admit, that as in a country not midway between the shores of Britain and some of the tracts to which we are about to allude, there are already such striking deviations from the local types with which they are familiar, so might we, when transported to the eastern extremities of Europe, expect to find still less agreement in character between more widely-separated cretaceous deposits. Nevertheless all observers will not fail to be struck with the fact, that however the detailed lithological and zoological succession of the subformations vary, the pure white chalk reappears in Russia with exactly the same aspect and composition as in their own countries, associated with certain greensands; whilst the cretaceous series, as a whole, is eminently marked by the same group of organic remains.

If our observations had been adequate, we should have conducted our readers, step by step, from the Silesian and Saxon deposits to which we have briefly alluded, through Poland into Volhynia and Podolia, those western governments of Russia in which cretaceous rocks occur. Not having, however, personally examined a great portion of that area, we must dismiss this subject in a few paragraphs, relating to tracts with which we have so slight an acquaintance, and then proceed to describe those parts of Russia in which we made more accurate observations[1].

Covering portions of the south of Poland, the cretaceous rocks extend in great force into Volhynia, and are extensively exposed on the banks of the Vistula and its tributaries. Thence they range by Lublin into Podolia, where they surmount the Palæozoic rocks (Devonian? and Silurian) on the banks of the Dniester (environs of Kamenetz-Podolsk, and Moghilev).

In that tract of Poland which lies to the south of Kielce, and between that town and Cracow, the cretaceous rocks have a very uniform aspect, and consist of thin-

[1] In the Royal collections at Warsaw we noticed the small *Exogyra calceola* in a greensand from Denischin near Marionufka on the Dniester; *Gryphæa annulata* and *Nautili* from Kasbisch on the Vistula; large Inocerami with Scaphites and Echini in flints, from gray chalk in a tract extending from Kharkuf by Novi-miasto to Kortchin, where those fossils are associated with sulphur and gypsum; Belemnites from Udritza near Yamstock; Alcyonia in large branches from Lublin and the country extending to Zamosch and Kasmisch. At the latter place the zoophyte, Choanites of Mantell, occurs, and will be pointed out as re-appearing at Khwalynsk on the Volga, and at Kursk in the heart of Russia.

bedded, dingy white, and cream-coloured marlstones, occasionally very like the more chalky beds of the upper greensand, or "craie chloritée." They there contain Inocerami with *Spatangus cor-anguinum*, *Terebratula carnea*, and other well-known chalk fossils; and the basin, both at its northern and southern extremities, rests upon Jurassic strata. The rock, for example, on which the citadel of Cracow stands, which, from its white colour and imbedded flints, was long considered to be chalk, is, as we have before mentioned, the southernmost of these Jurassic zones.

But as we have not had leisure to decipher the relative age of the different members of the Cretaceous system of Poland, we must refer to the works on that subject by M. Pusch, and also to the recent labours of Professor Zeuschner, who has thrown new light upon the fossil contents of the secondary formations of his native country. There is, however, one great geological feature which cannot here be passed over in silence, viz. the widely-diffused sandstone and shale which occupies so prominent a space upon our Map on the northern flank of the Carpathian chain, and is coloured by us as cretaceous. In so classifying the Carpathian sandstone, or "Grès des Carpathes," we adopt the conclusions of the leader of German geologists, M. Von Buch, and of our precursor M. Boué, and are necessarily at variance with the newly-published opinion of M. Zeuschner, who accompanied one of us in a traverse across these outer ridges or "contre-forts" of the Tatra Mountains. In stating our own view, we must at the same time admit that, as a whole, the "Grès des Carpathes" is very different in mineral composition from the Quader Sandstein of the adjacent low countries of Silesia, Moravia, &c.; and that, as yet, it has offered no distinct organic remains beyond those fucoids which have been considered as marking the lower stage of the Cretaceous system. We adhere, however, to our opinion for this plain reason; that in our transverse section to the Tatra, we found the lowest beds of this Carpathian sandstone composed of sand and dark shale, reposing upon a limestone[1] loaded with Nummulites, Pectens, Echini, &c., which rock is clearly incumbent upon the Jura or Alpine limestone,—with its characteristic fossils, and including in its lower beds some well known Lias species. In fact, we found the Tatra chain and its dependencies upon the north to be a repetition, as nearly as possible in all its parts, of the Austrian Alps, with the survey of which one of us was formerly much occupied. The sandstone and shale of

[1] These Nummulites are distinct in specific characters from those occurring in rocks, which in the Pyrenees, the Crimæa and other countries, constitute the uppermost cretaceous or lowest tertiary stratum.

the sub-Alpine eminences near Vienna (the Flysch of Keferstein and Studer), which are interposed between massive and lofty mountains of limestone (Alpen or Jura Kalk), and the tertiary accumulations of the plains, are in fact undistinguishable from the "Grès des Carpathes" both in structure and position, and in the fucoids which they both contain[1].

Whatever may be the exact equivalent of the "Grès des Carpathes," there can, however, be no doubt that to the north and north-east of that peculiar formation, there exists an enormous development of true cretaceous deposits, including much white chalk. For the account of these beds in Podolia and on the Dniester, we refer to the writings of Eichwald, Dubois, Blöde and others, and we now at once transport our readers to similar rocks in those regions of Southern Russia, where we have personally examined them.

Chalk of the Donetz, or Country of the Don Cossacks.—One of the finest displays of white chalk we saw in Russia, occurs in the southern steppes of the Don Cossacks, on the right bank of the river Donetz, which there flows for some distance in denudations of this rock. On the right bank of that stream, to the south of the Lugan iron-works, the white chalk occupies basins or undulations, which, as already explained (p.108), are occasionally separated from each other by protruding masses of highly inclined carboniferous strata. To show the very great thickness of the white chalk in parts of this region, we may state, that at the period of our

[1] In justice to our friend M. Zeuschner, it should be stated, that he has been led to group the "Grès des Carpathes" with the Jurassic series, because he observed in it what he supposed to be an *intercalation* of rocks containing Jura fossils. See section in a work, written in the Polish language, "Rzut Oka na budowe Geologiczna Tatrow przez L. Zejsznera. Warszawa, 1842." But we examined the very sections which led him to adopt this view, and cannot agree with him. We believe that the appearance of limestone with Jurassic fossils (inferior oolite, &c.), forming part of the series of the Carpathian sandstone at Zaflary, is simply due to an upcast, upon a line of eruption parallel to the granitic axis of the Tatra, by which the lower Jurassic strata have been forced up or wedged in amidst these sandy cretaceous formations, which, according to our view, are thrown off both to the south and north. This is indeed proved by the rise *en masse*, as above stated, of the *Jurassic group of the great Tatra from beneath these same sandstones*. An Aptychus ?, Ammonite, and Pecten have, it is true, been found in a portion of an outer zone of rock, very distant from the Carpathian mountains, and about one post south of Cracow, which is referred by M. Zeuschner to the same sandstone: but the relations of the strata are there much too obscure to enable us, as yet, to draw any rational conclusions from them. Until the detailed relations of the undulating region, extending far from the flanks of the Carpathians, are better worked out, and all its organic remains made known (a task which we trust M. Zeuschner will accomplish), it would obviously be unfair to express any opinion or decision concerning this tract, although the evidence is decisive at Zaflary and on the north flank of the Tatra.

visit (1841) Artesian sinkings had been made at Lugan to a depth of 630 feet without any indication of a change of rock.

At Uspensk in the same district, where the chalk lies in hollows of the carboniferous strata, we found *Inoceramus crista galli*, *I.* (*Catillus*) *Cuvieri*, *Lima semisulcata*, *Ostrea vesicularis*, *Belemnites mucronatus*, &c. &c. Courses of flint, of white, gray, resinous and black colours, are there numerous. The whole of this cretaceous mass, though unconformable to the subjacent coal strata, seems to have been simultaneously affected by a movement of elevation, for it dips with them to the north-north-east, though not by any means at so high an angle. But besides the pure white chalk, there occur in this same district, particularly to the north of Lugan, and between that place and the great coal-works of Lissitchia-balka, some small tracts in which greensands, apparently rising from beneath the chalk, are loaded with Exogyræ, as well as with the *Ostrea vesicularis*. These portions of greensand extend to the right bank of the Donetz, in depressions of the older rocks, at Serebrianka and Verknaia. At the bureau of the mines at Lissitchia-balka, we inspected several fossils in a matrix of *greensand* derived from these localities, but none of them had the facies of the remains of lower greensand, all of them (including the *Ostrea vesicularis*) being species of the white chalk and upper greensand of Western Europe.

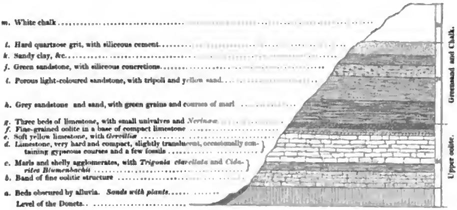
Before we leave the overlying deposits around these carboniferous tracts, we must further state, that on their southern frontier they are also surmounted by a narrow band of chalk, which, with a slight interruption, extends from the confluence of the Donetz and the Don on the east, to the rivers Miuss and Krinka on the west[1]. Again, on the eastern limits of this coal country we observed numerous instructive sections of white chalk, notably at Kamenskaya and on the little streams Slaboka, Glaboka, &c., tributaries of the Donetz. In several other localities, which it is unnecessary now to specify, as their names do not appear upon our map, the white chalk is distinctly and conformably surmounted by a peculiar, white clay-stone, with marlstone and sands, the whole being perfectly analogous to strata in the government of Kursk, which we shall presently show to be an integral part of the Cretaceous system.

In tracing the cretaceous rocks from these southern coal regions in their course

[1] This band of chalk is correctly laid down by Captain Ivanitzki in a geological map of this region, with which we were furnished by General Tcheffkine, and of which a reduction has been published in the 'Annuaire des Mines de Russie.' We have somewhat extended Captain Ivanitzki's band.

to the north, we must specially revert to the admirable section at Izium on the river Donetz (p. 252). There, as above remarked, is seen a clear order of superposition, which shows the upper Jura limestone or coral rag covered, by light-coloured sandstone and sand with green grains, inclosing thin courses of marl. These beds pass upwards into porous sandstone with tripoli, the whole of this lower cretaceous or greensand group, of about 70 feet in thickness, being surmounted by pure white chalk.

SECTION AT IZIUM. 39 *bis*.



The structure of the country in the governments of Kharkof and Kursk convinced us, however, that thick as it may be at Lugan and in the upper steppe of the Don Cossacks, the white chalk dwindles out to one thin bed in the adjacent regions upon the north, and plays a very subordinate part only, amid argillaceous and siliceous masses which there represent the Cretaceous system.

The important and flourishing city of Kharkof[1] stands in the centre of deposits which, from their light colours alone, might lead to the impression of their being cretaceous; for, consisting of whitish, greenish, and light yellow argillaceous beds, which, at first sight, very much resemble chalk marls, they become white in weathering, and leave chalk-like streaks when rubbed upon any other substance. This rock is, however, nothing more than one of the varieties of a deposit we shall in the sequel describe, as existing in great force on the banks of the Volga and the Don; being a very light, minutely micaceous and fine-grained earthy sandstone, which derives its colour and character from a large proportion of white felspar. It contains no lime, at least in most places, it does not effervesce with acids, and is

[1] This city, little known in Europe, contains an university and a population of upwards of 40,000 persons.

what Major Blöde has designated "Kiesel-thon." We consider it, however, to be of the Cretaceous epoch, for the following reasons. Three or four versts to the east of Kharkof, these white rocks are overlaid by regularly bedded, ferruginous sands, sometimes almost flagstones, but in other parts appearing as concretions in fox-coloured sand. Such beds occur in certain ravines, where a passage is seen into the whiter masses through strata of green sandstone, in which grains of chlorite are disseminated in a sandy argillaceous paste. Being the only hard beds in the country, they are much used for building and paving purposes.

These rocks, extending to the northern frontiers of the government of Kharkof, offered us no organic remains, nor has Major Blöde, who has examined them much more than ourselves, been able to detect any traces of such, even where they range over a wide space westwards into the government of Pultava. In that direction, indeed, the hard ferruginous masses often form isolated hills. At Bielgorod, about sixty versts to the north of Kharkof[1], a mass of true chalk reappears high above the town, and therefore, as we conceive, overlying some members of the great arenaceous development of the Cretaceous system which we detected under the drift, in the lower slopes of the adjacent hills. The ascending section here, in proceeding from the valley to the hill above the town upon the north, exhibits— 1. Sands, &c.; relations obscured in the slopes. 2. White chalk without flints, in horizontal beds about 100 feet thick. 3. Greenish friable sandstone, about ten feet, containing siliceous flags, and separated from the chalk by a course of gray laminated marl. 4. Superficial black earth or "Tchornozem."

At Oboyan on the river Psol, the white chalk disappears, and the cliffs have exactly the same appearance as those near Kharkof; for what seemed to us to be chalk under the first rays of an autumnal rising sun, proved on closer inspection to be non-calcareous, and nothing more than a white variety of the "Kiesel-thon," or sandy marlstone, in which a very little calcareous matter was disseminated; and thus the rock began to assume the real characters of the upper greensand, the Pläner-kalk of Germany, or the "Malm rock" of England. At the stage north of Oboyan, called Selikof, rocks of the same general aspect become still more calcareous, and exhibit strata (in the ravines) which show a distinct passage from dirty white, sandy, argillaceous marl, to chalk marl,—and even into what could not be distinguished, at first sight, from chalk, but which in reality, however, is not so, as is well known to the natives, who transport their "meol" or true chalk from a distance of forty or fifty versts. It may be remarked, that in proportion as these

[1] The White City.

marlstones become calcareous, they have less of the conchoidal fracture of the "Kiesel-thon," are on the whole whiter, are occasionally iron shot, and contain certain corals (Choanites), which are certainly of the Cretaceous age, since they occur in the white chalk of England. Having already noticed these last-mentioned corals in Poland, we shall hereafter advert to them, as associated with other cretaceous fossils in white chalk, at Volsk upon the Volga.

In following these beds to the city of Kursk, we became convinced that the whole of the argillo-siliceous and marnose group we had been examining, must be included in the Cretaceous system. In their range from Kharkof to Kursk, the beds becoming gradually more calcareous, show traces of animal life in proportion to an increase of lime. At Kursk we found, indeed, fossils in them which leave no doubt of the age of the deposit, such as a Belemnite, two species of Terebratulæ, and the same Choanites already alluded to. This mass of chalk marls, having much the character of the upper greensand of England, is seen, on the banks of the rivers Sem and Tuskar, distinctly to overlie a course of pure white chalk without flints, of about seven feet in thickness, and containing Terebratulæ, one of which resembles *T. carnea*. The detailed section from the banks of the Sem to the high ground on which stands the city of Kursk, is thus most valuable in clearly demonstrating, that *the white chalk thins out* in a system of sands and marls which are thus exhibited.

GENERAL SECTION AT KURSK. 40.

The ironstone (section of *b*) consists of a floor about four feet thick, of irregular mammillary concretions, so matted together as to form thick paving-stones, the internal structure of which somewhat resembles that of the clinkers in the lower greensand of English geologists (the car-stone of Norfolk, Bedford, &c.). A portion of this band is extensively quarried in galleries beneath the white chalk, and is usually charged with *Ostreæ*, the species of which is unknown to us. This bed of concretionary ironstone (the paving-stone of the city) does not exceed six inches to one foot in thickness, and occasionally lies in a mass of true greensand, *i. e.* yellowish, incoherent, yellow sand, in which green particles are disseminated.

Whatever horizon may hereafter be assigned to the uppermost sands, or (*e*) of this section, we can have no hesitation in considering the three underlying members as Cretaceous, and from their stratigraphical and lithological connection we believe them to be also part of the same system; their composition and relations have also convinced us, that the strata over wide surfaces to the east and south of Kursk, of which they are prolongations, may owe their paucity or absence of organic remains to the lithological composition of the rocks. It is, indeed, certain, that with the exception of containing a little calcareous matter, the argillo-siliceous marls of Kursk, are identical in colour, aspect, composition and manner of bedding, with the white siliceous clay-stones of Kharkof, and the formation is continuous between these places.

The establishment, therefore, of the age of the marls of Kursk by their interlacement and connection with white chalk, ironsand and greensand containing fossils, is a point of considerable importance, in clearing up the obscure question, as to what is or is not to be included in the Cretaceous system of Russia. Major Blöde, who had closely defined the lithological character of these strata in the government of Kharkof, not having, when we left the country, seen the proofs we discovered at Kursk, was unable, from zoological or other evidence, to assign such beds to their correct place in the series; but we must do him the justice to say, that arguing from their aspect and composition, as well as from the entire absence of tertiary fossils (which, he contended, if the deposit were younger than the chalk, would be found in them), he always considered the strata around Kharkof as belonging to the secondary rocks.

Cretaceous Rocks of the Don.—On referring to the Map, it will be seen that cretaceous rocks occupy very wide spaces upon the Don. These masses may, indeed, be considered as the eastern prolongation of the deposits in Southern Russia, to which we have just adverted.

In passing from the Donetz to the Don, and particularly on the banks of the Kalitva, we found sections, in ascending order, analogous to those of Kursk, from white chalk, through whitish marls and "Kiesel-thon" to siliceous sand. The same order is seen on the left bank of the Don at the station of Matiushenskaya. Again, much further down that stream, below the great elbow which it makes towards the Volga, we met with a similar succession between Golabinskaya and Piattisbianskaya, to the south and east of which last place the white chalk with its superincumbent and associated marls, marlstone and sandstone sinks beneath the tertiary limestone of the steppes. To this point we shall again refer. In ascending the Don, we perceived that the chalk was continuous to the neighbourhood of Voroneje, where it overlaps the Devonian rocks before described. We would not unnecessarily multiply sections which exhibit merely lithological succession, but we beg to offer one which we made in the neighbourhood of that city, because it is as valuable in showing a full development of the sands, &c. beneath the white chalk as some of the preceding sections have been in respect to the overlying strata. The following ascending succession, then, is seen on the river Veduga, two versts below the village of Indovistye, and to the west of Voroneje.—

V. White chalk, 20 feet. Above this the regular succession terminates, and the surface of the chalk is covered by the reddish alluvium or drift common to large tracts of Russia, and by black earth and northern blocks.

IV. Ferruginous, siliceous, concretionary band, exactly like that of Kursk, beneath the chalk (woodcut, p. 269), mixed with some greensand, 4 feet.

III. Greensand, 100 feet in thickness, divided into the following courses in ascending order:—*a*, white and yellow sands alternating, and containing flaggy grit, 20 feet; *b*, yellow ferruginous grit, 3 feet; *c*, alternations of yellow and white sands, containing concretions and flags of hard grit of irregular surface, 20 feet; *d*, coarse-grained greenish sandstone spotted yellow, 40 feet; *e*, coarse-grained micaceous green sandstone, spotted grey and weathering into elongated fragments.

II. Black schistose clay, 30 feet.

I. Lowest beds, ferruginous sandstone, 7 feet.

So far then we do not hesitate to place all the strata, alluded to in the preceding pages, in the Cretaceous system; but we admit we have some embarrassment in even rudely determining the limit between the cretaceous rocks of the south, and those ferruginous sands and grits between Mtzensk and Bielef, which we have for the present classed with the Jurassic sandstones of Moscow and Vladimir[1]. We can only state our impression, that in those regions, true cretaceous rocks do not extend northwards beyond the great dome of Devonian rocks which constitutes the axis of Russia. In the absence of fossils it is, indeed, difficult to form a correct opinion concerning the age of sandy deposits occurring at wide intervals only and in small patches, and which from their lithological composition might be considered as Jurassic, Cretaceous, or even Tertiary. We have already seen reason to allow, that the siliceous grits of Moscow are truly Jurassic, though they much resemble other grits which in the south of Russia certainly lie above the chalk. If the simple analogy of the mineral or external character of certain sands and grits to those which overlie the white chalk could be assumed as an in-

[1] We leave the classification of the isolated masses which occur between the southern basin and that of Moscow open till the discovery of fossils.

dication of their belonging to the same epoch, we could easily have solved such a question, by placing all the sands, clay-stone, &c. of the southern regions in the tertiary series. But the clear sections of Kursk and numerous other places contradict such a classification; whilst the structure of Saxony and the adjacent parts of Germany support the view which we have adopted, by distinctly proving, that the very uppermost beds of the Cretaceous group are often siliceous sandstones. In describing the tracts of this age along the Lower Volga, we shall presently show how, as at Kursk, siliceous sands with beds of marlstone and claystone are interlaced with the white chalk, and form with it one inseparable series. In the mean time let us say a few words on the chalk of the far-distant south-eastern steppes, on the banks of the river Ural.

Chalk on the banks of the Ural.—The most remote country in which we observed true chalk, was on the banks of the river Ural, about 150 versts south-west of Orenburg, where it forms a zone of about 160 versts in width, extending from the junction of the Utva with the Ural on the north-east, to the country beyond Uralsk on the south-west. The greatest length of this zone, we had no means of determining, in that wild region of Kirghis and Cossacks, the extreme boundary of the Russian empire; but from what we could ascertain, the chalk ranges from the banks of the Ural, where we examined it, to beyond the sources of the Kamelik, a tributary of the Volga on the west, and on the east towards the rise of the Utva. It may, indeed, have a much wider range than we have assigned to it on our Map, for Pallas has spoken of chalk on the European side of the Ural, near the sources of the Busuluk river[1], and it *may* therefore occur to a small extent on the north side of the Jurassic rocks which are laid down upon our Map. For our own part, we observed chalk at the hill of Semipolatnoi on the river Utva, and also on the opposite bank of the Ural river, at the Cossack outposts of Baratinskoi, Zenuarzof, and Rubeshnoi, where it is white, without flints, in horizontal beds, and contains *Inoceramus Cuvieri* and *Belemnites.* The alluvial plain on which is placed Uralsk, the chief town of the frontier Cossacks, is almost surrounded by chalk (see Map), which to the south sinks under the tertiary sands of the steppes of the Kirghis.

Cretaceous rocks of the Volga below Simbirsk.—In describing the range of the

[1] We so much respect the authority of Pallas on every point, that we scarcely dare to express a doubt respecting this chalk near the sources of the Busuluk. As, however, in passing from Orenburg to Samara, we traversed the Obschey Sirt (see Map), and saw nothing but Permian rocks, we venture to surmise, that the rock supposed to be chalk, may prove to be one of the white marlstones, or limestones so abundant in the red Permian deposits?

Jurassic rocks on the Lower Volga, we have already informed our readers, that they are overlaid by cretaceous deposits. If we had had sufficient time we might probably have obtained clearer evidences of the exact order of these strata, in the governments of Simbirsk and Saràtof than in any other part of Russia; for in that region the right bank of the Volga is composed of plateaux of considerable altitude, the beds composing which are occasionally well exposed both on the banks of that great river and its tributaries, as well as in numerous ravines.

In respect to the cretaceous beds near the city of Simbirsk, we can say that they are of considerable thickness, and that we observed in them the following fossils: *Terebratula octoplicata*, identical with that of Meudon near Paris, *T. Defrancii*, *T. carnea*, *Ostrea vesicularis*, *Pecten serratus*, *P. undulatus*, *Inoceramus Cuvieri*, *Belemnites mucronatus*, *Lenticulites Comptoni* (Nils.), and *Frondicularia complanata* (Defr.). M. Jasikoff of Simbirsk, who has made a most interesting collection of the fossils of this tract, which we inspected in his absence, states, that the Cretaceous system there presents a descending succession of white chalk, gray and chloritic chalk, and chalk marl[1].

Ill-provided as we are with the means of defining the geographical limits of the cretaceous rocks of this tract, we must, in truth, leave all such efforts to be made by M. Jasikoff and geologists resident in the country, and in the mean time simply speak of phænomena lower down the Volga which fell under our own notice.

In travelling from Simbirsk along the right bank of the Volga, towards its mouth, we found that the white chalk, wrapping round the Jurassic beds, ranged

[1] Whilst these pages are passing through the press, a letter received from our friend Mr. Frears of Moscow, explains the most recent views of M. Jasikoff respecting the geological succession in the environs of Simbirsk. The uppermost cretaceous beds (covered by tertiary clays and sands) consist of white chalk with courses of chert, occasional deposits of tripoli, and masses of ferruginous ochre; beneath these is chalky marl with bands of chloritic chalk; and thirdly, marls with nodules of phosphate of lime. The group, about 250 feet thick and containing in all nearly forty fossils, is evidently the equivalent of the chalk properly so called, for in its central and lower bands of "craie chloritée" are well-known chalk species, such as *Inoceramus Cuvieri*, *Belemnites mucronatus*, &c., associated with zoophytes, &c., whilst in the upper beds are found *Terebratula carnea*, *T. subrotunda*, *Spatangus cor-anguinum*, *Plagiostoma* (Lima) *Hoperi*, *Belemnites mucronatus*, *Scaphites æqualis*, with Zoophytes, Crustaceæ, and teeth and vertebræ of fishes. Beneath this formation, however, M. Jasikoff has discovered variegated clays 300 feet thick (near Simbirsk and at Shilovka on the river Uren), in which he has detected one fossil only, viz. *Ammonites consobrinus*, a species which M. D'Orbigny places in the "couches supérieures Néocomiennes," or upper part of the lower greensand of English geologists. The fossils enumerated by M. Jasikoff will be mentioned in Part III. of this work, but we shall presently revert to the deposits by which the white chalk is covered in the environs of Simbirsk.

in low hills a few miles on the west of our route, and then advanced to the promontory of Kashpoor. The rock is well seen in the descent which the road makes from a plateau, obscured by black earth and detritus, to the Volga at Kwalynsk, where true chalk having a thickness of upwards of 200 feet, reposes on Jurassic beds (sands and shale, &c.) with *Ammonites Panderi*. As we moved with great celerity, being anxious to employ the chief remaining portion of the fine autumnal weather of 1841 in the survey of the coal country of the Donetz, we had not the means of accurately ascertaining either the horizontal or vertical limits of the cretaceous masses. We believe, however, that certain marls and marlstone, porcellaneous and sandstone bands with which the white chalk is associated, must, as at Kharkof and Kursk, be contained in the Cretaceous system. At Kerza the white chalk is seen in a promontory on the Volga, and the higher hills, ranging into the interior, are occupied by sands and sandstones.

At Volsk, indeed, there is a clear section in which at least 200 feet of chalk with Belemnites, a Pecten resembling the *Pecten quinque-costatus*, and fragments of the coralline Choanites, are capped by an equal thickness of whitish yellow sand, which passes upwards into bands of hard, compact, siliceous grit.

The higher hills or superior strata to the south-west of Volsk are chiefly composed of bluish-gray, sandy, slightly micaceous psammitic shale of conchoidal fracture, which is here and there porcellaneous (Kiesel-thon), and which passes into finely laminated, ferruginous and white sandstone with green grains. If the general arrangement of the masses, in a country which is composed essentially of horizontal strata, be our guide, we should say, that these strata must overlie and form the upper part of the chalk exposed at the adjacent town of Volsk. We detected, however, in these beds imperfect casts of Nucula, Lucina, Turritella and other shells, which we were disposed at the time to consider tertiary. But our materials are too vague, and the intermediate strata too little known, to enable us to decide the point, which we leave to be settled by our successors, simply noting by the way, that these beds may very probably indicate a passage from the Secondary to the Tertiary deposits.

Similar siliceous claystones and sands protrude at intervals through the drift at many places, and give rise to a sterile country. They range, in fact, over all the higher lands north and south of the city of Saràtof, and are largely developed throughout the government of that name. In ascending from the lower grounds at Saràtof, where we have described high cliffs of Jurassic shales and sands, we passed in succession through beds of whitish, bluish-gray and yellowish sands, for the most part incoherent, but containing concretions of silicified sandstone with Alcyonic bodies, and corals, &c., which are overlaid by siliceous mottled claystone of porcellaneous character, in parts including green grains, and resembling many varieties of the greensand series of Britain, or of the Quader Sandstein and Pläner-kalk of the Germans, where those members of the series are not calcareous.

The annexed woodcut and the accompanying description, will convey a general idea of this succession.

41.

N.E. S.W.

i. Sands—base of Tertiary deposits.

CRETACEOUS.
- *h.* Siliceous beds.
- *g.* Claystone and porcellanite. } (With flinty Kiesel-thon.)
- *f.* Dull grey argillaceous marlstone. } (With flinty Kiesel-thon.)
- *e.* Whitish, grey, and bluish marls.
- *d.* White and yellow sands and sandstone, with Alcyonia and corals.

JURASSIC.....
- *c.* Alternations of shale and sand, with Jura fossils.
- *b.* Ferruginous sands of great thickness.
- *a.* Dark pyritous shale, with concretions of argillaceous limestone, *Ammonites cordatus*, &c.

In the walls of the farm-houses of the German colonists at some distance to the south of Saràtof, we met with earthy, yellowish sandstones, having green grains diffused, which so completely resembled some of the secondary greensands of England, more particularly in containing long branching bodies like Alcyonia, that however indisposed to admit lithological identity and imperfect fossil proofs to guide us, we could not avoid believing, on the spot, that these rocks formed a part of the Cretaceous system.

In pursuing our course still further to the south, we were presented with other evidences which at once convinced us, that although the higher plateaux might, to a great extent, be cretaceous, the depressions, at all events, were certainly occupied by tertiary rocks; for to the north-west of the town of Kamischine, we found, in a siliceous grit, mineralogically very much resembling the Lower Quader of the Germans, beautifully preserved impressions of dicotyledonous leaves, which are unquestionably of tertiary age. Of these we shall treat in the next chapter. These siliceous rocks appeared to us distinctly to overlie the porcellaneous shale and greensand with Alcyoniæ which we have been considering, as represented in this section.

42.

TERTIARY.... { d. White quartzose siliceous grit, with leaves of dicotyledonous plants.
c. Sands, clay and marl,—beds obscured in sandy slopes.

CRETACEOUS. { b. Sandstone, sand and white marlstone, with Alcyonic forms and ironstone concretions.
a. Hard, porcellaneous, bluish-grey claystone and marlstone (conchoidal fracture).

But here it is essential to point out to our readers, that the same siliceous marlstone and sandstone with Alcyonia, which near Saràtof we have shown to occupy a plateau, descend at Kamischine to low cliffs upon the Volga, where they are surmounted by tertiary grits. In these relations, therefore, as well as in the gradual disappearance of the Jurassic strata beneath the chalk, we have the clearest proofs, that in following the course of the Volga from Saràtof, or from north to south, the older formations successively disappear beneath the younger.

The beds of this series, which have the most persistent character, are dingy white claystone of very low specific gravity, with ferruginous concretions and some grains of greensand, which are seen to repose on a similar rock of equally compact structure and conchoidal fracture,—a porcellanite, in which greensand concretions occur at intervals. In a word, these rocks on the level of the Volga at Kamischine, are undistinguishable from the beds which near Volsk and Saràtof are several hundred feet above that stream; for they contain Alcyonic-like bodies having stems and heads, usually in very decisive green sandstone and with some imperfect corals. We may also remark, that Exogyræ imbedded in greensand occur in this region, specimens of which were sent to Professor Eichwald, who submitted them to our inspection on our return to St. Petersburgh[1].

Still further to the south we found similar argillaceous and sandy beds, with concretions of greensand and mottled, porcellaneous, greenish marlstone, in parts having a cretaceous aspect, with overlying sands and quartzose sandstone; and at the post-station of Bielaya-glina, thirty versts south of Kamischine, we again met with pure white chalk, rising into hills and exposed in ravines, at nearly the same level, and at a very short distance from the sandstone, claystone and marl we have been considering. In these chalk beds were several fossils, including corals and *Terebratula carnea*.

[1] It was stated that these Exogyræ were found between Kamischine and Tzaritzin; but the locality was not mentioned. One of the Exogyræ bears certainly a strong resemblance to a species common in the Maidstone grits or upper part of the lower greensand of England, and is associated with a small Plagiostoma, a Pecten very near to *P. orbicularis*, *Vermetus*, &c.

Seeing, therefore, in a country which has been subjected to few or no great dislocations, that the white chalk reappears at intervals upon the same level as certain beds of white and gray claystone and sandstone, we came to the conclusion, that the latter must here constitute the dominant portion of the Cretaceous system, in which the white chalk occurs in large occasional masses only. Led as we were to this conviction by the general structure of the country on the Lower Volga, we were still more impressed with it, when in our examination of the Steppes of the Don and the governments of Kharkof and Kursk we found, as already stated, an abundant development of similar rocks, in none of which could we detect the trace of any tertiary shell, but in which, to the evidences collected on the Volga, we added, as already stated, that of a Belemnite with Terebratulæ and Polypifers, unquestionably of cretaceous age.

A traverse which we made from the chalk of Bielaia-glina to Antipofka[1] on the Volga, also confirmed us in our views of the order of superposition. Leaving the denudations in the white chalk, we there passed over a plateau of sandy and quartzose character, the beds of which, distinctly overlying the chalk, seemed to incline gradually upon a long slope, so as to form the base of certain shelly beds, which upon the Volga are loaded with fossils of Eocene age, the whole as represented in this drawing.

SECTION SHOWING THE GENERAL RELATIONS OF THE CRETACEOUS AND TERTIARY STRATA.

43.

d. Tertiary sands.
c. Clay and sand with shelly concretions (Bognor and London clay-shells).
b. Sands and claystone, &c., forming the passage from cretaceous to tertiary rocks.
a. White chalk, with Terebratulæ and other fossils.

The tertiary sands and marlstone of Antipofka very much resemble the beds we have been considering as cretaceous, and though we had not time to make detailed researches, we have very little doubt, that a thorough exploration of the adjacent ravines will afford evidence of a passage from the white chalk, through a group of claystones, sands, &c., into true tertiary deposits, the lower portion of which have to a great extent the same mineral characters as the upper cretaceous.

From sections, then, as well as from the general structure of large provinces, we are impressed with the belief, in a gradual mineralogical and stratigraphical trans-

[1] We were of course led to Antipofka by the well-known description of Pallas.

ition between the secondary and tertiary rocks of Southern Russia, and we the more adhere to this view, because we never yet have seen an instance of *the surface of the white chalk of Russia, or of any beds which we could call cretaceous, having been eroded as in Western Europe*. On the contrary, at Volsk, Kursk and other places cited on the Donetz and the Don, the white chalk seemed to form a part—often indeed a central part—of a continuous series of sands and argillaceous strata to which it was subordinate; and when in addition it is stated, that the lower tertiary fossils occur in beds of nearly a similar character, we think our inference is well sustained.

But if their succession be truly indicated, there is still the greatest difficulty in assigning precise relative boundary-lines upon a map, to the cretaceous and tertiary deposits. Should our opinion be correct, that nature has not placed any clear barriers between them, such lines can be laid down only after many years of elaborate survey. And even then, very extensive districts occupied by white and grey claystones and sands, with marls, in which no fossils can be detected, must be subject to doubtful interpretation. In certain districts, it is true, the evidence is clearer. To the west of Simbirsk, near Drechetilofka, for example, there are strata incumbent upon the chalk, in which M. Jasikoff has detected characteristic tertiary fossils. It would also appear that the so-called cretaceous strata near Saràtof are overlaid by patches of the same age, just as it has been shown, that the white chalk is surmounted by the shelly beds of Antipofka. To the south and west, however, of that place, in the tract extending by Tzaritzin to Sarepta, and in all the space in that latitude, between the Volga and the Don, the white chalk receding far to the west, we have great hesitation in asserting that the upper steppes between Sarepta and the Don, are truly tertiary, as represented on our Map[1]. We have, however, stated, that at Piattisbianskaya to the south of Golubinskaya and on the right bank of the Don, we met with escarpments of white, grey and green, minutely micaceous claystone, marlstone and sandstone, &c., which we group with the chalk. The formation there occupies arid hills, 200 or 300 feet in height, which present a

[1] That our readers, unacquainted with the vast distances which must be travelled over in Russia, may not think we omitted any means within our reach to arrive at sound conclusions in classification, we may state, that we were compelled to travel most rapidly (often day and night), and in excessively hot weather (August 1841), through these tracts of the Volga and the Don, in order to be able to reach and examine the steppes of the sea of Azof and the coal-field of the Donetz, before the bad weather of the autumn. In fact, being much hurried and compelled to view some districts with less accuracy than others, we naturally sacrificed the cretaceous and tertiary to the palæozoic and carboniferous rocks, particularly as the Imperial Government attached more importance to our report upon the latter.

striking contrast to the wide and flat grassy steppes of the Kalmucks from which we emerged. These rocks appeared to us to be identical in composition with those of the Volga, the Kalitva and the environs of Kursk. In truth they have been proved to be cretaceous, since M. le Play has detected the *Pecten quinque-costatus* in their south-western prolongation[1].

In concluding this brief and imperfect sketch of the Cretaceous deposits we may remark, that they have a very wide extension in Southern Russia (probably more extensive than is indicated in our Map), notwithstanding the comparatively small number of points where white chalk appears at the surface[2]. We would also further remind our readers, of the agreements and discrepancies which this system exhibits in different parts of its range, when compared with deposits of the same age in Western Europe. If examined in detail the Russian type differs, for the most part considerably, in lithological distribution from that of England and Northern France. It agrees, however, with that of Southern France, of Germany and parts of Poland, in the pure chalk being less equably deposited in thick masses. Thus at Lugan, in the south of Russia, the chalk having a thickness of 600 or 700 feet, possesses all the characters of the English and French white chalk, and contains some of its characteristic fossils; whilst at Kursk, as we have shown, it is reduced to a band only seven feet thick, intercalated between greensand and ironsand beneath, and earthy marls and sands above, which, however, occasionally contain true cretaceous fossils. In this mineral arrangement we perceive, however, that sort of *general* parallelism between the beds deposited in Russia and those in Western Europe (particularly with those of Eastern Germany), which we ought to expect to find in strata of the same epoch, separated from each other by wide intervals. Some persons may conclude, that the greensand beneath the white chalk is the exact counterpart, though on a small scale, of beds which are fully developed in the British Isles and Hanover, viz. the ferruginous or upper strata of the lower greensand. Though we cannot affirm it, we would not reject this analogy, because the last researches of M. Jasikoff have shown the existence of variegated clays, inferior to the chalk properly so called, which contains an Ammonite of the upper part of the lower greensand (see note, p. 273). Additional detailed surveys may therefore, bring to light other lower greensand or Neocomian species in Russia

[1] See Voyage dans la Russie Méridionale et la Crimée sous la direction de M. A. Demidoff, par M. le Play.

[2] The exact limits of the white chalk may indeed be easily defined by those who have the means of traversing the southern governments in various directions; for in that country the superficial detritus is not very thick, the ground is undulating and hilly, and the peasants are invariably acquainted with the nearest points where the "meol" or chalk is found, with which they whitewash their houses and churches.

proper, the more so as they have been found both on the northern flanks of the Caucasus and in the Crimæa, where the whole Cretaceous system, from the Neocomian to the upper chalk and from the latter to Nummulitic strata, with shells of tertiary age, has been fully described by M. Dubois[1] and M. Huot[2].

It has been stated by us, that we cannot truly recognize in the ascending order an upper greensand on which the white chalk rests. On the contrary, where we saw the white chalk thinning out amid other strata, the beds which *most resemble* the "pläner kalk" of Germany or the malm rock of England, and which at Kursk contain Terebratulæ and a Belemnite, lie above and not below it. These lithological discrepancies are, however, no greater than those which exist in the distribution of the different members of the system when followed from England to Eastern Germany, or from the north to the south of France, whilst the organic remains assure us, that all these deposits belong to one natural system.

The distribution of certain types of animal life through varied and distant masses of inorganic matter, is doubtless of great geological interest, and compels us to be cautious in not attaching too much weight to mere details of mineral sequence. At the same time it appears, that mineral characters, under the limitations which we have endeavoured to define, are not to be neglected even in geological classification; for we have ascertained, that in the remotest regions of the Volga, greensand, ironsand, chalk and chalk marl occur, in which the same group of fossils prevails, as in rocks of Britain and France which hold the same relative place in geological succession; and we have shown the extension, at intervals, of pure white chalk containing some characteristic organic remains, from the British Isles to the confines of Asia.

Doubtless, therefore, these facts demonstrate, that during the cretaceous as in all the preceding geological epochs, there existed a most widely-spread diffusion of similar agencies which produced this general uniformity of result.

[1] Consult the letters of M. Dubois de Montpéreux to M. Elie de Beaumont; Bull. de la Soc. Géol. de France, vol. viii. p. 371; and his Table, *ib.* p. 385. Also the great work of the same author, Voyage en Caucase, en Arménie, en Crimée, &c.; and see particularly Serie V. and VI. pl. 13 and 14; where the Neocomian and chalk formations are given in detailed sections. The last eighteen plates of the fifth series offer a complete résumé of the geological history of the Crimæa.

[2] Voyage dans la Russie Méridionale et la Crimée sous la direction de M. A. Demidoff, vol. ii. p. 398; Partie Géologique de M. Huot. This author divides the Cretaceous system of the Crimæa into three stages, Neocomian, greensand and chalk, classing the overlying Nummulitic beds as tertiary, a point to which allusion will be made in the next chapter.

N.B. Erratum.—For *Inoceramus crista galli*, p. 266, read *Ostrea crista galli*, and for *Frondicularia complanata*, p. 273, read *Ananchytes ovata*.

CHAPTER XIII.

TERTIARY DEPOSITS.

General Remarks on the Tertiary deposits of Northern Germany and their extension into Russia.—Division of the Tertiary rocks of Russia into three great zones:—Eocene, Miocene, and Aralo-Caspian.—Older Tertiary or Eocene deposits on the Dnieper and the Volga.—Miocene Oceanic deposits of South Poland, Podolia, Bessarabia, &c.—Aralo-Caspian or brackish water Accumulations, and their enormous Eastern range from the borders of the Black Sea and Sea of Azof, through the Crimæa to the shores of the Caspian and Aral Seas, and into the high plateaux of Khwarezm in Asia.—More recent desiccation of the Caspian in the Lower Steppes of the Volga and the Caucasus.—General Reflections on the Aralo-Caspian deposits and their desiccation at separate periods.—Raised Sea-Bottoms of the North of Russia in the Valleys of the Dwina and Petchora.—Conclusion of Part I.

HAVING endeavoured in the preceding chapter to show how the cretaceous rocks of Russia are linked on to certain tertiary deposits, we now proceed to consider the latter. Their perfect description must, however, constitute at some future day, an important work by other geologists, which for want of data cannot yet be submitted to the public. We have already explained, that our first object in visiting Russia, was to point out with clearness the succession of her ancient or Palæozoic strata. If, in addition, we have been enabled to give general sketches of the Jurassic and Cretaceous systems, which in both cases are susceptible of countless improvements, still more must we plead our inability to do justice to the tertiary deposits, which are so widely spread out in the southern parts of the Russian empire, and of which we have ourselves examined some portions only.

Even in those countries of Western Europe where the relative ages of each tertiary substratum are much better known, the task of fully describing them would be yet attended with many difficulties. Take, for example, the tertiary series of the North of France, and endeavour to apply it to the southern tracts of that country,—try to register along the flanks of the Pyrenees the equivalents of the lower beds of the basin of Paris, and many of the best geologists will still be found at issue. In England, it is true, a close parallel was long ago established between the calcaire grossier and the London clay; but how long a period elapsed before the overlying mammiferous beds of the Isle of Wight were put into exact comparison with the gypsum beds of Paris! How much reasoning upon the distribution of animals in contemporaneous basins was employed before the Faluns of the Loire and the Crag of England were proved to be of similar age[1]! If such be the case in countries where this class of deposits has been well studied, we need scarcely say, that in the present state of our knowledge of Russia, it would be idle to draw too closely the terms of comparison between her tertiary deposits and their equivalents in Western Europe. Even in extending our view from the British Isles to Eastern Germany, we are arrested midway by unanswered difficulties. Thus, the characters of the very numerous fossil contents of the great tertiary basin of Mayence have recently led us to infer, that some of its lowest beds, consisting of sand with brown coal and lignite, may represent the plastic clays of the Paris and London basins, because the shells in the overlying sands, if not absolutely the same as certain forms of the calcaire grossier, have among them, at all events, very few species indeed, approaching to those of existing nature; whilst the numerous vertebrata in the upper beds of the same deposit are considered to be analogous to those of the gypseous strata of Paris, which are classed in the Eocene group[2].

If this view be sustained, it may have a great influence in determining the age of the adjacent fields of brown coal which cover such wide areas in Prussia and Northern Germany. Clear fossil evidences are, however, still wanting in regard to these deposits. Mineralogically, and in general structure, like the lowest beds of Mayence, they present strong analogies to the plastic clays and sands of England and France. M. v. Buch has, indeed, stated, on the authority of Count Münster,

[1] See Lyell on the Faluns of the Loire. Proc. Geol. Soc. vol. iii. p. 437.

[2] This view of the age of the basin of Mayence is drawn from the researches of M. Herman V. Meyer, M. Kaup and Prof. A. Braun. M. v. Meyer is of opinion, that the very numerous and peculiar vertebrata of this basin, whether described by himself or M. Kaup, may be compared with those of the gypsum beds of the Paris basin. They are, therefore, of the same age as the Anoplotheria beds of the Isle of Wight. Prof. A. Braun having classified and determined the very numerous shells, has found that a very small percentage can be referred to existing nature. See Memoir by Mr. Murchison, Trans. of the Brit. Assoc., Anno 1843.

that certain shells which occur in strata near Mecklenburgh, above the brown coal, may be referred to the calcaire grossier. On the whole, therefore, we are disposed to believe, that a large portion of Northern Germany and Poland is covered by strata of the same age as those which are considered Eocene in the basin of Mayence. The western portion of our Map is coloured upon this principle (No. 8).

In relation to Russia, there seems to be no doubt that strata of the older tertiary age range up to the city of Kief on the Dnieper, where one of us has observed them. Thence, if not continuously prolonged to the east, upon the Dnieper they reappear at Butschak, lower down the same river, where they were detected by M. Dubois[1]; and in the environs of Simbirsk they have been noticed by M. Jasikoff. By our own observations we show the presence of fossiliferous deposits of like age upon the Lower Volga, and thus, it is clear, that the oldest tertiary deposits strictly so termed, do exist in Russia, though their exact boundaries and limits have yet to be defined.

Of the existence of Miocene deposits (No. 9.) there are also abundant examples, in broad horizontal expanses of limestones, marls and sands, which ranging from the upper part of the valley of the Vistula on the west, spread out in vast sheets over the governments of Volhynia, Podolia, and Bessarabia, to near the western shores of the Black Sea and the low country north of Odessa, where they subside beneath other deposits of a younger age. With the detailed relations of such masses throughout the greater part of this low region, our acquaintance is chiefly limited, to the southern districts of Poland on the west, and to the neighbourhood of Odessa and the edges of the Black Sea and Sea of Azof on the east, including parts of the Crimæa.

A glance at the Map will show the general line of separation between the older tertiary (No. 8.) and the miocene deposits (No. 9.). In Poland they are divided by an axis of ancient rocks, chiefly Devonian, which ranges from west-north-west to east-south-east in the environs of Kielce; in Podolia and Volhynia by the granitic steppe, and still further to the east by the coal-field of the Donetz. Agreeing with M. Dubois de Montpéreux, who has pointed out the distinctions in Volhynia and Podolia, between these two great tertiary zones, we regret that it has not been in our power to lay down their exact geographical limits throughout their entire range. We simply propose to indicate natural groups, the exact boundaries of which can

[1] See a letter of M. v. Buch, Bulletin de la Soc. Géol. de France, vol. vii. p. 157; and Neues Jahrbuch von Leonh., &c. 1836, p. 359.

be defined only by numerous competent observers. If in the table of superposition (and in the Map), we have endeavoured to separate the miocene (No. 9.) from another group, Pliocene ?, which we term Aralo-Caspian (No. 10.), we must beg our readers to understand, that in a few districts over which the colour of the younger deposit is extended, the older beds are also present in the same natural sections. This point will be explained in the sequel, when we come to separate the deposits of oceanic character from those named Aralo-Caspian, which cover such immense tracts in Asia.

With these prefatory remarks, we may now say a few words upon each of these Russian accumulations.

I. *Eocene or older Tertiary (No. 8. of Map).*—Sections have already been cited, in which beds equivalent to the calcaire grossier and London clay, are seen in connexion with strata which we refer to the upper part of the Cretaceous system. Amid vast spaces of Russia as yet little explored by geologists, there is every reason to hope, that notwithstanding the superficial detritus which obscures the rocks, and the small comparative elevation of the land, other sections will yet be found, to show more completely, both the order of superposition and the sequence of organic life, and to indicate the existence in these undisturbed regions, of a passage from the cretaceous to the tertiary system.

In the Crimæa, indeed, and particularly near its southern shores, where the rocks are much more elevated and clearly exposed, the first beds in natural ascending order above the white chalk, are those which contain Nummulites, with *Ostrea latissima*, and a gigantic Cerithium: they are classed by M. Dubois with the Cretaceous system, but, according to M. Huot and other geologists, are included in the tertiary series. These intermediate beds are, it is believed, of the same age as certain strata along the northern flanks of the Pyrenees, the relative antiquity of which has recently undergone much discussion; MM. Dufrenoy and E. de Beaumont claiming them as appanages of the chalk, because they have undergone some of the great elevatory movements by which that deposit was affected, whilst their opponents contend, that as they contain some of the characteristic fossils of the lower tertiary beds of the basin of Paris, they must be classed with that formation. As one of us only has some personal acquaintance with the Crimæa, we do not consider this a fit occasion to enter much into a controversy, which cannot be determined without a very circumstantial appeal to facts and fossils. Reference will, however, be again made to this subject, and a thin band is left in the table appended to the

Map, to show, that such Nummulite rocks occur in the Crimæa, where they were first described by one of us, subsequently by M. Dubois[1], and also by M. Huot, though we are ignorant of their existence in the continent of Russia.

Let us pass then to the consideration of beds which every one will admit to be of tertiary age. We regret that in travelling through the northern part of Poland we had not time to make adequate researches among the tertiary rocks which lie between the Prussian frontier and Warsaw, where deposits of brown coal and clay are associated with white calcareous claystones (Kolin to Kolá), in which we observed casts of Pectens and other shells. There can, indeed, be little doubt, that the accumulations of this zone, often highly argillaceous, are connected with the tertiary deposits of the Russian frontier upon the same parallel of latitude, which, occurring in the environs of Grodno and around the marshes of Pinsk, extend to Kief and to the south-east of that city. In the tract between Grodno and Kremenetz they have been described by M. Eichwald[2], as plastic clays and sands with brown coal, and beds with freshwater shells, which immediately surmounting the white chalk, are succeeded by shelly limestones.

The banks of the river Styr near Lutsk, and of the Goryn, offer numerous examples of these beds. M. Eichwald compares them with the plastic clays and sands of the Paris basin, but as he gives no specific names to the organic remains, we must pass at once to the adjacent country around Kief, where clear evidences have been observed.

In and about the city of Kief itself, clays, sandstone and shelly bands, which have been described by Professor Hoffmann[3], are characterized by a Cerithium closely allied to the *C. giganteum*, and an Ostrea which we cannot distinguish from the *O. callifera* (Goldf.), and hence we are led to believe, that they belong to the older tertiary age.

This inference is, indeed, completely sustained by the contents of similar strata at the adjacent place of Butschak on the river Dnieper, where M. Dubois collected many shells which have been accurately determined by M. v. Buch, according to the following list which the latter has kindly communicated to us.

[1] See Voyage au Caucase, en Arménie, en Crimée, etc., vol. v.; and Series v. of Illustrations, pl. 14. Also Voyage dans la Russie Mérid. et la Crimée, vol. ii.; and Mémoire sur la Crimée, par M. de Verneuil, Mém. de la Soc. Géol. de France, vol. iii. p. 17–25.

[2] Naturhistorische Skizze von Lithauen, Volhynien und Podolien. Wilna, 1830.

[3] We have not with us whilst we write the publication of M. Hoffmann. The Kief section was, however, examined by one of our own party, Count Keyserling.

Fossils of Butschak on the Dnieper, in the Government of Kief, collected by M. Dubois and named by M. von Buch.

1. Terebellum fusiforme (Grignon). L.C.[1]
2. Cassidaria carinata (Grignon). L.C.
3. Buccinum stromboïde (Grignon).
4. —— Desnoyersi. Bast. sp. Bordeaux, Touraine.
5. —— reticulatum. Bordeaux, Gallicia.
6. Rostellaria fissurella. Paris Basin and L.C.
7. Tritonium pyraster (Grignon).
8. Pyrula clathrata s. condita. Dax, Cassel.
9. ——— lævigata. Paris Basin, L.C.
10. Fusus Burdigalensis,—a variety of the F. clavellata of Grignon.
11. —— funiculosus (Grignon).
12. Cerithium Lima (Desh.). Paris, Podolia[2], also living in the Mediterranean and N. Atlantic.
13. Turritella imbricataria. Paris Basin, L.C.
14. Trochus agglutinans (the angle of the carina is very sharp). Paris Basin.
15. —— monilifer. Paris Basin, L.C.
16. —— striatus (Gmelin). Touraine, Sicily, also living in the British and Mediterranean Seas.
17. Solarium plicatum. Paris Basin, L.C.
18. Voluta costaria (Grignon).
19. Natica epiglottina. Paris Basin, L.C.
20. Fissurella neglecta. Touraine, Italy, also living in the Mediterranean.
21. Calyptræa trochiformis (Grignon). L.C.
22. Bulla cylindrica (Grignon). L.C.
23. Pectunculus pulvinatus. L.C. and Paris Basin.
24. Arca barbatula. Paris Basin.
25. Lucina radula (Lam.). Exists in the British seas.
26. Crassatella compressa? Paris.
27. Psammobia muricata, et parvensis,—varieties of the same species (Dubois).
28. Corbis lamellosa. Paris Basin.
29. Corbula nucleus (Lam.). Italy, Sicily, Mediterranean and British Seas.
30. Venericardia elegans (Grignon).
31. Cardium oblongum Gmel. vel sulcatum (Lam.). Fossil in Italy, living in Mediterranean.
32. —— semigranulatum. Paris Basin, L.C.

This group, adds M. von Buch, differs essentially from the shelly beds spread out over Podolia, particularly those of Bielazurska, all of which correspond with the Sub-Apennine formations of Brocchi in Italy.

The determinations and inference of M. von Buch are of high value when coupled with the general description of the region by M. Dubois. The latter has assured us, that nothing can be more dissimilar in lithological aspect than the tertiary formations which lie respectively to the north and south of the great granitic plateau of Volhynia and Podolia; the northern zone being in general siliceous and talcose with clay, the southern eminently calcareous. " This difference," adds M. Dubois, " drawn from lithological characters, is still more striking as based upon the fossils. According to my view, it is an ascertained fact, that the tertiary rocks of the Ukraine and of the banks of the Dnieper (upper part) are analogous to those of the basin of Paris, or what is termed the lower tertiary stage; whilst that of Gallicia (Poland), Podolia, Volhynia, &c. is of the age of the Sub-Apennine regions, or of the middle tertiary epoch." (Letter to Mr. Murchison, 1843.)

[1] The letters L.C. indicate that the species occurs also in the London clay. Many of these shells were named by M. von Buch at an earlier period. See Bull. de Soc. Géol. de France, vol. vii. p. 157.

[2] See Neues Jahrbuch, 1836, p. 83, and Karsten's Archiv, vol. vii. p. 311. Schneider's Journey in Volhynia and Podolia.

The researches of M. Dubois have thus given us a clear line of demarcation between the older and middle tertiaries in respect to those regions which he has traversed.

Though unable to continue with accuracy the comparison, from the western provinces described by M. Dubois, through the Ukraine, we may say from personal knowledge, that the same contrast exists between these northern and southern tertiary zones at the western and eastern extremities of the great region under consideration. At the western end, we have observed the siliceous and argillaceous tertiaries of the plains of Poland to be strikingly different from the calcareous shelly strata to the south of the axis of the Palæozoic rocks around Kielce (see Map). Again, far to the south-east, where we have no longer an intermediate granitic plateau, and where we may consider the great coal region of the Donetz to be the barrier of separation, all the younger deposits to the north of it are sandy and argillaceous, whilst those of the high steppe to the south are eminently calcareous. Here, however, geological distinctions, founded upon fossil evidences, are still wanting, for in the northern zone no naturalist has supplied them, and it was only in a country much further to the east, viz. upon the Volga, below Saràtof, that we obtained proofs of the existence of an older tertiary formation as rigidly determined by its organic remains.

Unacquainted personally with any shelly tertiary deposits in the vast region lying between Butschak upon the west and the Volga on the east, we cannot pretend to draw the line of separation, except by general mineral characters, and we will now terminate our brief sketch of the older tertiary beds of Russia with an allusion to certain deposits in the neighbourhood of Simbirsk, and a description of the shelly strata at Antipofka on the Volga.

For an acquaintance with deposits of this age near Simbirsk we are entirely indebted to M. Jasikoff, who states, that throughout a great portion of the government of that name, the white chalk is covered by siliceous clays and argillaceous sandstones, which are surmounted by sandstones, grits and quartzose sands, the whole having a thickness of about 150 feet. In the lower or argillaceous portion of these deposits M. Jasikoff cites one or two known Eocene fossils, such as *Turritella imbricataria* (Lam.), *Nucula comta* (Goldf.), and *Turbinolia elliptica* (Brongn.), with new species of Nucula, Ostrea, Pholadomya, &c. The overlying sands and sandstones contain *Pectunculus pulvinatus*, with Cythereæ and Dentalium, and much silicified wood, often bored through by cylindrical bodies (Pholades ?).

Antipofka near Saràtof on the Lower Volga.—The lowest beds of the tertiary rocks containing fossils in the east of Russia, with which we are personally acquainted, occur at intervals along the right bank of the Volga, below the city of Saràtof, and notably at the large village of Antipofka, where they were formerly noticed by Pallas as constituting a " conglomerate of shells." From the description of that author, we were disposed, on approaching the spot, to think, that these shelly beds, forming as they do the western edge of the low steppes of the Kirghis, would prove to be of very recent age, and represent simply the consolidated shingle and shells of a former Caspian Sea which advanced to this boundary, but examination soon taught us that their organic remains belong to the oldest tertiary period. At the base of the low cliffs on which Antipofka stands, or rather protruding through a talus of sand exposed in summer by the subsidence of the Volga to its lowest level (forty feet below the high watermark of spring floods), the beds most abundant in fossils are distinguished by a number of large concretions from six to eight feet long and four and five feet thick; marking strata perfectly horizontal, which are made up of a profusion of shells, cemented in a gray sandy marlstone. The accompanying woodcut explains the succession. These shelly beds (*a*) are overlaid by yellowish iron-shot and whitish sands (*b*), with bands of compact, dark-coloured chert, from eight inches to one foot thick. Some of the alternating courses consist of greensand, others are made up of a devious net-work of siliceous, tubular forms which cross each other, and in some of the softer sandy layers are casts of shells. The low cliff terminates in ascending order in beds of light blue marl passing into beds of sand (*c*), which in many parts are surmounted by drift and local detritus (*x*).

LONGITUDINAL DETAILED SECTION AT ANTIPOFKA.

44.

Level of the Volga.
Horizontal distance 2 to 3 versts.

x. Drift of finely laminated clay and sand of brown colour, and with no foreign detritus. Bones of Mammoth, Bos and Rhinoceros occur in this deposit in the low steppes on the opposite bank of the Volga.

Tertiary.
- c. Siliceous sands with irregular concretions.
- b. Bluish-gray marly beds, in parts sandy, with casts of shells.
- a. Large ellipsoidal concretions of sandy calcareous grit subordinate to clay and sand, with Eocene fossils (Bognor and London clay).

Among the fossils we collected are *Cucullæa decussata* (Sow.), *Pectunculus brevirostris* (Sow.), *Venericardia planicosta* (Sow.), *V.*——— (n.s.), *Calyptræa trochi-*

formis (Lam.), *Crassatella sulcata* (Sow.), *Turritella edita* (Sow.), together with several unpublished forms of *Venericardia*, *Lucina*, *Venus*, &c.

In citing these species, we should not have relied upon our own powers of identifying fossil shells from a distant part of Russia with forms well known in England, had we not been supported by Mr. James Sowerby, who is intimately acquainted with the fossils of the London clay, and who, in addition to those which he recognises as decidedly the same species published in his 'Mineral Conchology,' has assured us, that an unpublished Venericardia which we brought from Antipofka, occurs at Barton in the Hampshire cliffs. We may add to this zoological evidence, that there is a remarkable lithological agreement between the Russian and English beds, for in their concretionary nature and matrix, these shelly beds of Antipofka are *really undistinguishable from the masses of the Bognor rocks in which the very same shells occur.*

We have previously expressed an opinion (see p. 276 and woodcut) respecting the relations of these lower tertiary beds to the chalk and cretaceous strata in their immediate vicinity. We repeat our belief, that the shelly beds of Antipofka are connected with the white chalk in the manner represented in that woodcut, viz. by sands and grits which occupying an intermediary place, may in their lower members be classed with the cretaceous rocks, whilst their upper parts graduate into the lower tertiary rocks under consideration. A great portion, therefore, of the sandstones, which are exhibited in the cliffs of the Volga below Antipofka, and extending by Tzaritzin to Sarepta, are probably of the older tertiary period.

It is also well to observe, that the inferences we have drawn from the structure of this part of Russia, of a passage from the Cretaceous to the Tertiary system (p. 276 *et seq.*), appear to be sustained by the independent testimony of M. Dubois and of M. Huot[1], concerning the succession, structure and contents of the upper secondary and lower tertiary rocks of the Crimæa, though neither of these authors seem to be of our opinion concerning a passage or transition, which, indeed, we suggested long ago in reference to that tract[2]. They state, however, that in a tract full of dislocations, cretaceous rocks having a peculiar mineral character, are *conformably* overlaid by a series of beds charged with Nummulites and other shells, which, by M. Dubois, are grouped with the chalk; by

[1] Voyage en Caucase, en Arménie, la Crimée, etc., par F. Dubois, vol. v. and Voyage dans la Russie Méridionale et la Crimée sous la direction de M. A. Demidoff, par M. Huot, vol. ii. The first of these authors has ascertained the existence of true Eocene (Paris and London) shells in the tertiary basin of Akhaltsikhé in Armenia! See Von Buch, Bull. de la Soc. Géol. de France, vol. vii. p. 157.

[2] See Mém. de la Soc. Géol. de France, vol. iii. p. 25.

M. Huot, with the tertiary. On the one hand, besides Nummulites, these beds contain, according to MM. Dubois and Huot, the *Spondylus striatus* (Goldf.), *Podopsis id.* (Brongn.), a cretaceous shell, and a Terebratula, very closely approaching to *T. carnea* of the chalk; and on the other, many species of shells absolutely identical with well-known fossils of the Paris and London basins, viz. *Ostrea latissima* (Desh.), (*O. gigantea*, Brander), *Cerithium giganteum, Turritella imbricataria, Ovula tuberculosa, Cardium porulosum, Voluta luctator, Ampullaria crassatina,* &c. Seeing this assemblage of fossils, we cannot but agree with M. Huot, that these Crimæan beds must be classed as tertiary. On the whole, we consider their uppermost portion to be of the same age as our shelly sands of Antipofka, whilst the lower beds seem most clearly to indicate a passage between the so-called secondary and tertiary rocks.

II. *Middle Tertiary Rocks (Miocene, &c.)*.—We have said that deposits of limestone, sand and marl, charged with sea-shells, are largely spread over the southern tracts of Russia, and that some of them have been compared by M. v. Buch with the Sub-Apennine strata of Italy. The latter constitute, in fact, the great accumulations of Podolia and Volhynia, explored by MM. Eichwald and Dubois, whence they extend into the southern parts of Poland on the west, and are prolonged into Moldavia, Bessarabia, and New Russia on the south and east.

Salt Deposits of Wieliczka.—Judging from their position on the flanks of the outer or lower Carpathian chain, and from their passing under the sands and shelly beds which we are about to describe, we think that the saliferous deposits extending along the outer edge of the Carpathians, from Wieliczka to Bochnia and Stara-sol, constitute the lowest stage of this group. In a work devoted to the geology of Russia, it does not perhaps strictly fall within our province to treat of these saliferous deposits; for they are all included within the Austrian dominions; but as from their contiguity to the Russian frontier they are noted upon our Map, and as we examined them *in situ*, in order to place them in relation with the adjacent shelly tertiary deposits of Poland and Russia, we may be permitted to express our own opinions concerning them; particularly as the fact of their thinning out to the north must be considered of some practical importance. So long as the presence of rock-salt was supposed to be an indication of the age of the strata in which it occurs, the saliferous strata of Wieliczka were grouped with formations of much higher antiquity, in which that mineral most abounds (New Red Sandstone, &c.), but the discovery of certain shells in the matrix of the salt of Wieliczka has, for some years, led geologists to consider the deposit as of tertiary epoch, though its exact place in the series has not been determined. A perfectly correct view can, however, now be taken, both from the character of the shells, and from the fact, that the saliferous strata graduate into and form part of the tertiary deposits of the Upper Vistula, of the age of which there can be no doubt. We indeed convinced ourselves upon the spot, that these masses of salt, worked at great depths beneath the surface, are simply great concretions, subordinate to thick masses of clay, which have been accumulated along the external edge of the younger secondary rocks (Grès des Carpathes), and formed subsequently to the elevation of the Carpathian chain. In tracing their outlines in the extensive subterranean works of Wieliczka, it has been ascertained, that these masses of salt (which are of great diameter near the principal shafts) range from west and by north to east and by south. They constitute, in fact, a narrow band only, which runs out in thin courses or strings towards the north, where it is surmounted by and inosculates with the shelly sands upon the banks of the Vistula.

A general idea of these saline concretions and their relations to the older rocks upon the south, as well as to the tertiary shelly sands upon the north, is sufficiently explained by the accompanying transverse section.

45.

But whilst the salt forms, as here represented, dome-shaped concretions which are lost in short spaces when followed to the north or south, it is more or less continuous in ellipsoidal masses for many leagues in a direction from west by north to east by south. In other words, the salt, by whatever cause produced, has been formed along an *ancient coast* of the Carpathian mountains, the lower hills of which, consisting of greensand (Grès des Carpathes), advance and form their southern boundary.

Among the shells of Wieliczka the *Nucula comta* (Goldf.) is abundant, and is associated with Milliolites and other very minute forms with which we are not acquainted, as well as with teeth of fishes and fossil wood. Again, the *Ringicula buccinea* (Desh.) was pointed out to us by Professor Zeuschner in the very body of the salt [1], and as this shell occurs in profusion in the adjacent sands of the Vistula, deposits to which we shall presently allude, there can be no doubt that the salt of Wieliczka is not only

[1] Professor Zeuschner having sent a mass of rock-salt with shells in it to Professor Philippi, the latter dissolving the matrix discovered in the residue forty species of animal remains! viz. 5 Zoophytes, 14 Polythalamæ, 1 Echinus, 1 Serpula, 7 Conchifers, 8 Univalves, and 3 Crustaceans. Neues Jahrbuch, Leonhardt and Bronn, 1843, p. 568. Professor Philippi identifies a Cerithium with the *C. Lima* (Brug.) now living in the Mediterranean.

of miocene age, but perhaps even of the upper portion of the Sub-Apennine group, as the *Ringicula buccinea* which it contains is a pliocene and recent as well as a miocene species. More accurate comparisons may indeed prove these salt deposits to have been formed at precisely the same period as the upper blue marls of Savona and other parts of Italy.

Shelly Sands of the Upper Vistula and its Tributaries, Korinitza, &c.—We did not trace in detail the various beds containing tertiary shells which occur at intervals upon or near to the banks of the Vistula below Cracow, where they form low hills, for the most part composed of sandy and incoherent strata. Guided by Professor Zeuschner, we at once repaired to a good and well-known shelly locality called Korinitza on the Nida, a tributary of the Vistula. Here we observed that the sands are more calcareous, passing occasionally into cream-coloured sandy limestone, which seemed to rest upon marls and clays. There are, however, few good vertical sections of these slightly coherent and irregularly distributed masses, which rise on the whole to heights of 150 to 200 feet above the adjacent river Nida, reposing upon Jurassic strata of white limestone, which is loaded with fossils. The tertiary shells lie about in profusion on the surface of the arable land, and are also found in calcareous marlstones and sands in small ravines to the north and west of the little village.

Though we might at once satisfy our readers concerning the age of these tertiary shells by referring them to the works of Pusch[1], in which some of the species are published, we think it desirable to confirm and extend his authority by annexing the following list of the shells we procured upon the spot; in naming which we have had the assistance of M. Deshayes and Mr. Morris.

Shells found at Korinitza in Poland.	Other Localities.
Natica glaucina, *Linn.*	Vienna, Bordeaux, Volhynia.
— olla, *Mar. de Serres*	Bordeaux, Italy, Perpignan, living in the Mediterranean.
Turritella Archimedis, *Brong.* t. 2. f. 8	Bordeaux, Vienna, Volhynia.
— turris, *Bast.* t. 1. f. 11	Bordeaux.
Ancillaria conoidea, *Desh.* Ency. Méth. p. 44. No. 8. A. coniformis, *Pusch*, t. 11. f. 1	Vienna, Touraine.
Ringicula buccinea	Vienna, Bordeaux, also living.
Voluta magorum, *Brocchi*, Pusch, t. 11. f. 2	Vienna, Sub-Apennines.
Buccinum obliquatum, *Dubois*	Volhynia.
— reticulatum, *Brocchi*	Vienna, Sub-Apennines, living in the Northern and Mediterranean Seas.
— reticulatum, *Dubois* (non Brocchi nec Linn.)	Volhynia.

[1] Polen's Palæontologie. Warsaw, 1837.

Shells found at Korinitza in Poland.	Other Localities.
Buccinum semistriatum, *Brocchi*	Vienna, Sub-Apennines. English crag. Sicilian beds. Still living in Mediterranean.
— costulatum, *Brocchi*	Vienna, Sub-Apennines.
— serratum, *Brocchi*, t. 5. f. 4	Sub-Apennines.
Nassa columboides, *Bast.* t. 2. f. 6	Bordeaux, Vienna.
Cassis texta, *Brown*. Dubois, t. 1. f. 4, 5	Vienna, Volhynia?
— Italica, *Desh.* (Bucc. Ital. Brocchi)	Sub-Apennines.
Rostellaria pes-carbonis, *Brong.* t. 4. f. 2	Vienna, Bordeaux, Volhynia.
Cancellaria varicosa, *Brocchi*	Vienna, Sub-Apennines.
— uniangulata, *Desh.* Encycl. Méthod. p. 181. No. 5.	Asti.
— mitræformis, *Andreiofsky*, Bull. de Moscou	Volhynia.
Murex spinicosta, *Brug.*, M. tricanthus, *Linn.*, Pusch, t. 11. f. 20	Vienna.
— plicatus, *Brocchi*	Sub-Apennines.
Triton affinis, *Desh.*	Morea.
Ranella marginata, *Linn.*	Vienna, Bordeaux.
Fusus Stutzii, *Partsch.*	Vienna.
— Zahlbruckneri, *Partsch.*	Vienna.
Fasciolaria Polonica, *Pusch*, t. 12. f. 2	Vienna.
Pleurotoma tuberculosa, *Bast.* t. 3. f. 11	Vienna, Bordeaux.
— interrupta, *Brocchi*	Sub-Apennines.
Pyrula rusticola, *Bast.* t. 7. f. 9	Bordeaux, Vienna.
Cerithium aleucoides, *Brocchi*	Vienna.
Cytherea multilamella, *Lam.*	Vienna, Rome.
Arca diluvii, *Lam.*	Vienna, Bordeaux, Volhynia, Touraine.

In addition to these thirty-three species, all well known in other parts of Europe, one or two forms only of our collection, including a Natica, seem to have been undescribed, and the list therefore most clearly establishes, that the tertiary accumulations of the Upper Vistula, Wieliczka, &c., which range along the northern flanks of the Carpathians, are of miocene age, and perfectly analogous to certain deposits of the Sub-Apennines in Italy and the basins of Vienna and Bordeaux.

Miocene Deposits in Southern Russia.—Strata similar to these just mentioned, and containing a similar group of fossils, extend through Volhynia, Podolia, &c., where they have been described by MM. Eichwald, Dubois, and other geologists, and have more recently been observed by M. Hommaire de Hell in Bessarabia. M. Dubois, however, was the first author who showed, by the publication of his work[1] upon the fossil conchology of the plateau of Volhynia and Podolia, accompanied by illustrative plates, that this great mass of shelly deposits was the equivalent of the beds of the Sub-Apennines and of Bordeaux. In sustaining this view by the examination of adjacent and similar strata in Poland and along the

[1] Conchiologie Fossile du Plateau Wolhyni-Podolien. Berlin, 1831.

northern shores of the Sea of Azof, we would also extend the parallel to the basins of Vienna and Hungary.

M. Dubois divides his tertiary deposits into four stages in the following ascending order. 1. Clay and plastic clay. 2. Marine sand and sandstone. 3. Oolite and Cerithium limestone. 4. Serpuline limestone, with marine calcaire grosier, lignites and freshwater limestone being occasionally associated. Of these bands the sandybeds No. 2 appear to be in that region by far the richest in organic remains; since out of 110 species of shells which he describes, ninety-two are found in them, among which are many of those which we have cited from Korinitza in Poland. From M. Dubois's description, we are strengthened in our belief, that the oolite is merely a dependent member of the same group; for although it contains Cerithii and species which he did not detect in the underlying sands, it is evident, that it is a continuation of the same marine series.

The fourth member above mentioned, Serpuline limestone and marine calcaire grossier, is called by M. Dubois a quaternary formation. As he shows that this is clearly an overlying deposit, occasionally of great thickness, and as it contains *Cardium lithopodolicum*, with Mytili and other forms closely approaching to those of the Black Sea, it is probably of true pliocene age, and ought in any detailed work to be separated from the miocene rocks under consideration. In our general Map, however, we group together such tertiary deposits, whether miocene or pliocene, so long as the oceanic character prevails in each of them.

To beds of probably the same age as the upper marine division of M. Dubois, we shall hereafter allude, in mentioning certain deposits of the Crimæa and of Bessarabia.

In the Museum of Warsaw many specimens were pointed out to us by Professor Yarocki, from various localities in Podolia, which served to convince us, that all the tertiary deposits of that region are of the same age as those of the Vistula and the Nida. Many of these shells occur in the tract between Yampol and Vienitza, at Machnufka, &c. They lie for the most part in earthy greensand, and have often preserved their colours like recent specimens [1].

The oolite of this age often becomes, as in Lower Styria [2], a fine-grained mass, lithologically undistinguishable from English and French varieties of the great oolite of Jurassic age. Our former description of this rock in Styria, written thirteen years ago, may, indeed, serve to explain its nature in the south of Russia. "Some of the spherules are hollow, but others are arranged about grains of semicrystalline calcareous matter, or particles of sand. The beds of true oolite are overlaid by irregular concretionary masses, partly oolitic, which alternate with unctuous sandy marl. Some of these concretions are amorphous; some assume

[1] According to Professor Yarocki, these fossils were chiefly collected by the Polish naturalists who assisted Professor Eichwald in his survey of Volhynia and Podolia; M. Zborzewski a fossilist, and M. Andrzejowski a zoologist. In mineralogy and botany, Professor Eichwald was assisted by MM. Jakowicki, Gorski and Zienowicz.

[2] Geological Transactions, vol. iii. p. 397 *et seq.*

contorted tubular forms; others are finely laminated." Like the tertiary oolites of Styria and Hungary,—which from a profusion of fossils we then showed to belong to the upper tertiary group of Austria, so are those of Bessarabia and Southern Russia, simply an eastern prolongation of deposits formed at the very same period, and in a sea which must then have had a very wide diffusion. In Styria and Hungary these oolites inosculate with calcareous sands, clays and marls through thicknesses of several hundred feet; but there volcanic action has been rife, and the strata have been heaved up and clearly exposed, whilst in the undisturbed plains of Russia we can scarcely surmise what their vertical thickness may be, judging from a few partial sections only on the banks of the chief rivers.

M. Hommaire de Hell, a French engineer, has shown us specimens from Kichenef in Bessarabia, which are identical with those of Yampol in Podolia, or of Poppendorf and Radkersberg in Lower Styria, and we know that similar tertiary rocks extend to Taganrog and even into other tracts beyond the region of our own researches. We do not pretend to say that this peculiar rock occupies a well-defined place in the tertiary series. Indeed we are disposed to think, that like the oolitic masses in the secondary rocks, which in some places are of great vertical dimensions, and in others disappear, this oolite occurs in concretions only, expanding and contracting within certain horizontal distances; but we are convinced, that wherever it has been observed, whether in Austria, Hungary, or Russia, it is included in deposits which belong to the miocene group, sometimes the upper part.

On the Dniester in Podolia the tertiary strata in question repose at once (according to M. Hommaire) upon the older or palæozoic rocks, and are covered by *gypsum*. Major Blöde, as we understood him, seems, on the contrary, to connect the gypsum of those regions with the chalk rather than with the tertiary deposits, and this also is the view of M. Pusch. Not having visited Podolia our opinion must go for little; but having satisfied ourselves that the salt of Wieliczka is of as recent an age as the great gypsiferous masses of Sicily, we confess that we lean to the opinion, that the gypsum of the Dniester belongs also to that epoch.

Limestone of Taganrog.—Allusion has already been made to the difficulty of neatly defining upon the Map, the line of separation between the beds of which we are now speaking, and certain younger shelly beds and limestones of the steppes. In the enormous space of Southern Russia as yet unexamined, numerous junctions may be detected, between these inferior and often oolitic members of a sandy calcareous group, and the beds we are about to describe. Such an order of superposition, exposing strata of different age in the same vertical section, is seen at Kichenef in Bessarabia[1].

But, to confine our remarks, in the first instance, to tracts which we have visited, it may be stated, that even with our limited time, we observed certain natural junctions in the tertiary series which distinctly proved, that the purely marine beds of which we are treating, lie beneath the peculiar steppe-limestone to which we shall next call attention. The sections of the low hills to the north of the Sea of Azof establish this succession. The strata exposed at the level of the Sea of Azof on its northern shore and at the town of Taganrog, are unquestionably of date anterior to the shelly limestones of the adjacent hills of Rostock and Novo Tcherkask, by which they are distinctly overlaid, as expressed in the woodcut of the following page.

46.

d. Clay drift with Mammoths' bones. } Terrestrial deposits.
c. Sands with fluviatile shells.
b. Aralo-Caspian or steppe limestone. } Tertiary deposits.
a. Upper miocene limestone.

In this woodcut the miocene limestone of Taganrog is seen to be overlaid by fluviatile shells in sand and by detritus containing the bones of Mammoths, &c. The geologist will at once see, that these last-mentioned deposits have no connection with the tertiary succession under review; they will necessarily be considered in a separate part of this work.

The lowest and perfectly horizontal beds (*a*), as seen along the quays of Taganrog, are light buff-coloured limestone, in beds from two to three feet thick. This rock, in parts cavernous, and in parts *oolitic*, is there so stained with ferruginous matter as to resemble the hard beds of English crag, whilst in other examples it may be lithologically compared to the best white building-stones of the calcaire grossier of Paris. Among the fossils, which are very abundant, we observed three species of Cardium, one of which we will describe under the name of *C. Fittoni*,

[1] There seems to be no doubt, that the fossils collected by M. Hommaire from Kichenef and that part of Bessarabia, some of which we have seen, differ to some extent from those from Poland, Volhynia and Podolia, of the true miocene type. Like the shells of Taganrog, they appear to form a passage from miocene to pliocene, and to be immediately subjacent to the Aralo-Caspian deposits. The exact limits, therefore, between the two formations throughout this western region, cannot be precisely laid down upon our Map, and in referring to it our readers must understand, that over a considerable area in Bessarabia and the adjacent countries, the miocene marine strata are occasionally overlapped by and pass into what we consider Aralo-Caspian or its equivalent.

and with them *Buccinum dissitum*, *Mactra ponderosa* (Eichw.), two species of *Turbo*, and some minute marine univalves.

Upon the whole, the aspect of these shells conveyed to us the idea that they are not of remote age, and probably upper miocene; but being all of marine or oceanic origin, and not approaching very nearly to existing forms, they are clearly to be distinguished from those remains which occur in the higher limestone of the adjacent hilly steppe. To this deposit, which borders the Sea of Azof and Black Sea, and extends over a prodigiously large region upon the east, we now beg specially to direct the attention of our readers.

III *Aralo-Caspian or Steppe Limestone—the Relic of a great former Eastern Mediterranean.*—The tertiary strata we have been considering, whether of Eocene and Miocene age, or passing from the latter into Pliocene, are to be viewed on the whole as widely spread marine formations which have been accumulated in true oceanic seas or their estuaries. The formation we have now to contemplate is strikingly dissimilar, in offering throughout one of the largest basins in the world, an uniformity of peculiar characters which separates it decisively from any tertiary deposits of Western Europe. This peculiarity consists in the imbedded fossils being analogous and to a great extent identical with those of the present Caspian Sea, in which the univalves (with the exception of one doubtful species of *Rissoa*) are of freshwater origin, associated with forms of Cardiaceæ and Mytili which are common to partially saline or brackish waters.

This distinguishing feature, then, of the present Caspian prevails throughout all the enormously developed tertiary formations of the southern and south-eastern steppes (European and Asiatic), and leads at once to the conviction, that during long periods antecedent, as will be hereafter explained, to the historic æra, a vast region of Europe and Asia was covered by a Mediterranean Sea of brackish water, of which the present Caspian is the diminished type. (See Nos. 10 and 10′ of Map.) To render the distinction between these accumulations and all others clear and unambiguous, we have adopted the term Aralo-Caspian, first applied in a geographical sense, by our great precursor Humboldt, to this region of the globe.

With the remoter limits of this former Mediterranean we are necessarily unacquainted. Judging from the recital of travellers and from specimens of the rock, we have no doubt that it extended to Khivah and the Aral Sea; beyond which the low level of the adjacent eastern deserts would lead us to infer, that it spread over wide tracts in Asia now inhabited by the Turkomans and Kirghis, and was bounded only by the mountains of the Hindoo Kusk and Chinese Tartary. On the north-east, north and north-west, however, we have ourselves to a great extent traced its boundary, as constituted by the palæozoic and secondary rocks of Orenburg, the extremity of the Ural chain, the cretaceous and older tertiary deposits on the right bank of the Volga, and the low hills of the Don Cossacks: whilst, along the northern shore of the Sea of Azof and the northern and western coasts of the Black Sea, the Aralo-Caspian strata are here and there seen to be underlaid, as at Taganrog, by the tertiary oceanic beds which have just been described. Of the southern boundary of this eastern Mediterranean, our personal knowledge does not range beyond the northern slopes of the rocky ridge of the Crimæa and the peninsula of Taman.

Pallas, the first propounder of the belief in a great inland retired sea, as well as several of his successors, have ascertained that similar deposits occupying the northern edge of the Caucasus, cover a great part of the isthmus between the Black and Caspian Seas, and we now know from MM. Eichwald and Dubois, that they spread over the country of Daghestan, a part of the low region east of Tiflis, and form the southern coasts of the present Caspian, beyond the limits of our Map. Throughout this enormous area scarcely any other strata are visible, except those which are charged with the relics of a former brackish sea, analogous to and often identical with species now inhabiting the present Caspian.

By examination of the eastern tract of the Crimæa (Kertch, Taman, &c.) and the shores of the Black Sea, we satisfied ourselves that the chief strata of these localities were formed beneath the same waters: and judging from the organic remains collected from numerous points of the whole area, there can be no sort of doubt, that all the masses of water now separated from each other, from the Aral to the Black Sea inclusive, were formerly united in this vast pre-historical Mediterranean; which (even if we restrict its limits to the boundaries we already know, and do not extend them eastward, amid low regions untrodden by geologists) must have exceeded in size the present Mediterranean!

If towards the close of this work we venture to throw out a few speculations concerning the more active causes by which the relations of land and water have been changed, and by which this former expanse of water has been since converted into dry land, and separated into distinct seas now occupying different levels, our present object must be to describe the nature of the strata, their imbedded contents, and the altitudes at which they now lie. In so doing we shall also endeavour to show, by the physical features of this region, that such desiccation must have resulted from at least two great movements of upheaval; by the first of which the limestones which occupy the hilly coasts of the Black Sea, Sea of Azof and Caspian, and large tracts between that sea and the Aral, must have been consolidated and left dry; so as to form the shores of an inland sea of posterior date, which though separated from the Aral, still spread over the great steppe north of Astrakhan, and covering the low steppe of the Caucasus and the isthmus of Perecop, connected the sea of Azof and the Black Sea with the present Caspian. We have, indeed, endeavoured to mark this succession upon the Map[1], first, by a rich yellow colour No. 10., to indicate the earliest period of this Aralo-Caspian brackish sea when it covered its greatest area; secondly, by a diminished tint of the same colour (10′), showing a more recent period of desiccation, when the Caspian and Black Seas were still united, but when the Caspian and Aral were separated by the high intervening plateau of the Ust-Urt.

Aralo-Caspian or Steppe Limestone.—It is to this formation, for the most part we presume of Pliocene age, that we refer the strata, which occur at Novo Tcherkask, and under the name of Steppe Limestones occupy a large portion of the hills before referred to, at heights of 200 or 300 feet above the sea (see woodcut, p. 296). Novo Tcherkask, the new and spacious capital of the Don Cossacks, is to a great extent built of a rock of this age, which is there excavated to a depth of twelve or fifteen feet, showing sands both above and beneath it. This rock is of a gingerbread colour, and is made up of a mass of broken shells, so as still more to resemble the English crag than the inferior marine beds of Taganrog. It may also be compared in lithological aspect with the large cavernous shelly secondary oolite of Barnock, near Peterborough in England, like which it may prove a durable and good wearing stone though full of cavities[2].

The shells which characterize the rock at Novo Tcherkask are—the same small *Cardium sulcatinum* and *C. incertum* (Desh.), described by one of us from Odessa

[1] In defining the range of the steppe limestone on a Map of the scale which we have prepared, it is to be again observed that along the edges of the younger deposit a few localities are included at or near which the antecedent marine formations are also occasionally apparent as *subjacent rocks*; for example, in the low cliffs of Taganrog, where the steppe or younger limestone occupies the adjacent cliffs or hills. Similar examples of superposition or passage may, for aught we know, occur at numerous other localities, and all that we have it in our power to effect, is an approximation to the real borders of the vast area in Russia, over which the brackish or Aralo-Caspian waters once extended.

[2] This steppe limestone, whether extracted at Novo Tcherkask or Odessa, is easily cut in the quarries, but hardens in the atmosphere.

and Kamiusch Burun at the eastern extremity of Crimæa,—another species of Cardium of this steppe-limestone—undistinguishable from the *C. pseudo-cardium* (Desh.), which we found living in the Lake Akerman near the Dniester, and a very small *Mytilus* (Dreissena), which with a *Paludina* constitute whole bands of stone, the shells being in general triturated and cemented into a porous mass.

From the character, then, of its imbedded shells, it is evident that this limestone was deposited in brackish waters, and from its occurrence at numerous places, where it forms the shores of the lower steppes, it must have occupied a vast area. Within the limited scope of our own researches, we observed it ranging eastward as far as Lepatinsk on the Don, about 100 versts from Novo Tcherkask, where it caps a cliff about 120 feet high, and where, having a thickness of thirty-six feet, it reposes upon incoherent sands with yellow courses of about forty feet, beneath which are beds of siliceous sands and sandstones, undistinguishable from those we have before mentioned as covering the white chalk in other parts of Russia. Such sandstones, generally yellowish-white, and crumbling into fine glassy sand, occupy the promontories on the right bank of the lower part of the Volga, and from Sarepta extend along the right bank of the Sarpa where we examined them. Associated with some marls and occasional limestone, they constitute, in fact, the western and northern shore of the vast lower steppe of the Kalmucks, and in that sense we shall hereafter allude to them. We have before us a manuscript description of these sandstones written by Mr. Strangways many years ago, in which their eroded surface and concretionary structure are well described. Whether near Sarepta on the Volga, or on the southern edge of the granitic steppe of the Dnieper extending westwards to Poland, they seem to constitute the oldest portion of these tertiary rocks, and to be succeeded by the steppe limestone. In some instances, near Sarepta, as Mr. Strangways well observed, they present striking appearances of false stratification or cleavage oblique to the chief horizontal beds. From our own acquaintance with them we are unable to assign the relative age of *all* these sandstones, occurring as they do at remote distances from each other. In the absence of organic remains, we cannot presume to decide, whether they ought to be classed with the Miocene or Pliocene deposits, or whether they occur in both of these subdivisions. Some of them have, indeed, been already alluded to as being of the Eocene or older Tertiary age. In truth we have already stated, that in many districts the development of both the cretaceous and tertiary rocks is so arenaceous, that we are incapable of drawing clear lines of separation between them.

To return, however, to the true Aralo-Caspian strata, we consider the chief masses of white limestone occupying the low hills to the south of the coal region of the Donetz, and ranging by Mariopol to Odessa and thence into the lower country of Bessarabia on the western shores of the Black Sea, to be of this age. We place upon the same parallel the upper shelly strata described in the Crimæa, including the chief limestones around Kertch, and the deposits of the cliffs of Kamiusch Burun and Taman, and also the limestones on the northern and western shores of the Black Sea.

We would here refer our readers who seek for the details of the formation in that region, to a memoir by one of us upon the Crimæa, in which we have described these deposits, as being there composed of courses of argillaceous marls, clays, calcareous marls, concretions, ferruginous bands, agglutinated shells (faluns), and soft, spongy, shelly limestone[1]. The soft limestone, usually white, is the best type of the whole formation, and largely used as a building-stone both at Odessa and in the Crimæa, it has afforded a great number of organic remains. In some bands associated with it we found an infinite quantity of small Paludinæ; but at Taman, as at Novo Tcherkask, the most abundant forms are the small and peculiar Cardiaceæ, and the *Mytilus polymorphus* (Dreissena of Van Beneden). Of the former M. Deshayes described twenty species, and whilst these are associated with Mytili and a Modiola which must have lived in brackish waters, we remarked the almost total absence of Gasteropods of marine origin; the Paludinæ, Melanopsidæ and Limneæ which were then enumerated, being unquestionably of freshwater origin, and one of them undistinguishable from species now inhabiting the embouchure of the Dniester (*Neritina Danubialis*).

In addition to these decisive conchological facts, an independent proof has recently been obtained of the manner in which beds of a purely marine character passed into these brackish steppe limestones. Pallas and Rathke had both alluded to the bones of certain Cetacea found in the peninsula of Taman; and Professor Eichwald had referred the head of one of these animals to a Dolphin, and named it *Ziphius priscus*. Obtaining possession of this specimen for the Museum of St. Petersburgh, Professor Brandt worked the head of the colossal creature out of the rock in which it was imbedded, and pronouncing it to belong to a new family of whales, has described it under the name of *Cetotherium Rathkii*. This fossil genus appears to form a new link in the animal kingdom, and is more nearly allied to the

[1] M. E. de Verneuil, Mém. de la Soc. Géol. de Fr. vol. iii. with 6 plates.

herbivorous Cetaceans than to the Dolphins. Its position in the geological series is most striking; for the rock in which it occurs near Taman, contains casts of sea shells similar to those of miocene age, which extend from Volhynia and Podolia to near the shores of the Black Sea and to the Crimæa. It is also very remarkable, that along with this herbivorous cetacean, the other, and as we think overlying, organic remains (among which, however, banks of corals occur) have more the character of the inhabitants of a brackish sea than those of the subjacent rocks.

These relations are, however, in accordance with modern conditions, and are, indeed, explained by an analogy in Scotland, for an acquaintance with which we are indebted to Professor E. Forbes. The lake of Stennis, in the Orkney Islands, celebrated in the writings of Sir Walter Scott, has actually been converted, within a very recent period, whether by elevation of the land or other cause, from a salt-water loch into a freshwater and marshy tract; and with this great but gradual change, certain marine genera (Cardiaceæ and Mytili) have continued to live on amid their new associates of land and fresh water (Limneæ, Neritinæ, &c.), whilst others have perished. That which is taught on a small scale in the Scottish lake must, therefore, have formerly occurred on the edge of the great Aralo-Caspian Sea,—which in consequence of separation from the ocean, was converted into a brackish state, and in which, as in Scotland, the same hardy and time-serving marine genera continued to exist with new associates in their altered abode! In a word, the miocene deposit of Taman, with its herbivorous cetaceans and marine shells, intermixed with and succeeded by brackish water relics, is only an example, in an earlier period of the world, of a formation along the edge of a great Caspian, the creatures in which necessarily differed from those of the pure marine period which preceded them.

In describing the geological succession of the Crimæa, M. Huot[1] has divided the tertiary series (supercrétacé) into lower, middle and upper stages. The first of these is unquestionably of the same age as the calcaire grossier of Paris or London clay, with which, as before explained, it has several species in common. We do not, however, coincide with this author in his method of grouping fossils from several localities to form his second stage: so far as he places in it species which are identical with or analogous to those of Bordeaux, Dax or Touraine, it is evident that such remains belong to the true miocene deposits to which we have already alluded, as being so widely spread over the continent of Russia. Such shells (ob-

[1] Voyage dans la Russie Méridionale et la Crimée sous la direction de M. A. Demidoff, vol. ii. p. 425.

served by this author at Sevastopol, the convent of St. George, Simpheropol, Kertch and Enikalé) must not, we contend, be placed on the same parallel as the remains which occupy a portion of the cliffs of Taman and of Kamiusch Burun, in which one of us found the twenty species of peculiar Cardiaceæ before alluded to[1], mixed up with Mytili of brackish water forms, and with Limneæ, Paludinæ and the *Neritina Danubialis*. Seeing that in the western and central portions of the vast area of Southern Russia which are covered by oceanic miocene deposits, there is nowhere such a predominance of brackish and freshwater over marine shells, we must consider the beds of Kamiusch Burun to be more naturally linked on to the Aralo-Caspian or steppe limestone than to miocene deposits. Throughout the cliffs of Taman we observed nothing but remains similar to those of Kamiusch Burun, *i. e.* the Cardiaceæ of the steppe, with Mytili and freshwater univalves. At the same time we believe, that to the east of Kertch, lower strata have been brought to the surface, particularly in a tract which has undergone considerable movement along the line of eruption of the adjacent mud volcanoes. The very few shells and corals imbedded in compact limestone, which we collected at Enikalé, for example, are marine; and in our specimens from thence there is no sign of mixture of miocene with Aralo-Caspian shells. But admitting that the herbivorous cetacean found at Ak Burun occurred in beds of this age with marine shells, why are we not to look upon them as inferior to the brackish water accumulations of Kamiusch Burun, and if so, what is there in such collocation to interfere with our general views? Such facts indicate nothing more than a passage from one formation to another, and our inference is even sustained by referring to M. Huot himself; for in speaking of his middle tertiary group he admits that, in one part, its *upper beds* contain Trochus, Phasianella and other marine genera difficult to determine, *mixed up with land and freshwater shells*.

Natura non facit saltum, said our forefathers, and in tracts where there has been a gradual change from purely oceanic to brackish water deposits, spots must naturally be detected, which expose evidences of the transition from one set of conditions to another. Now a glance at the Map will serve to convince geologists, that the deposits under consideration are just in that geographical position where such a passage ought to be looked for; since they not only lie towards the western limits of the former Aralo-Caspian Sea, but also form part of a tract *singularly disturbed*, and in which all the tertiary strata, from the lowest or Eocene beds, have been

[1] De Verneuil, Trans. Soc. Géol. de France, vol. iii. p. 47–58. M. Huot and his associate M. Rousseau have since augmented the number of these Cardiaceæ to twenty-seven.

thrown up and exposed in succession. Here then we presume the elevation of submarine beds into land, produced one of those natural barriers, by which the Western Ocean of that day was eventually shut out from all communication with the great internal Aralo-Caspian; and here, therefore, we might expect to detect the remains of such animals as the herbivorous cetacean, associated with sea shells and followed by the inhabitants of brackish water. In such a conterminous tract, where the waters must have undergone a gradual change, a few hardy marine animals might have lived on for a time; and thus can be explained the existence of coral reefs, composed entirely of the *Eschara lapidosa* (Pallas), which there seem to rise up through the brackish water strata. But with a further separation from their original seat, the oceanic types would necessarily dwindle away, and when the isolation of the Aralo-Caspian Mediterranean was completed, the result would be a simplification of the animals which lived in it, and the establishment within it of a fauna perfectly distinct from that of the ocean. This view is, indeed, strongly sustained by an appeal to facts. Partial intermixtures of shells, or rather such transitions as that at Taman, and of which we believe there are also evidences (though of a much less decisive nature) in Bessarabia, and around the Sea of Azof and the Black Sea, are peculiar to the western boundaries of the Aralo-Caspian deposits. In following these strata to the east no such phænomena have been detected, and the central portions of this widely-spread formation, around the Caspian Sea, present exclusively the true and persistent types of an inland sea, the beds of which were formed under widely extended and uniform conditions, and in which there are no vestiges of corals, marine shells or herbivorous cetaceans. The great uniformity of composition and fossil contents which pertain to these Aralo-Caspian rocks over such enormous eastern regions, a point on which we shall presently dilate, compels us therefore to differ from M. Huot in the theory of their origin; for whilst he attributes them to the desiccation of numerous shallow brackish lakes or lagoons, left here and there by the retirement of the ocean, we, on the contrary, are convinced *that all the Aralo-Caspian deposits were accumulated under one vast inland sea*, the inhabitants of which differed as essentially from those of the ocean of that day, as the animals of New Holland now differ from those of the rest of the world.

Before we quit the consideration of the uppermost deposits of the Crimæa, Kertch and Taman, we cannot avoid alluding to another opinion expressed by M. Huot, from which we still more strongly dissent, viz. the presence of great fossil extinct Mammalia (*Elephas primigenius* and *Mastodon angustidens*) in his middle tertiary formation of this tract. If this fact were established, it would be at variance with all our knowledge of the distribution of such animals over enormous surfaces of Russia and Siberia, as well as in other parts of the world; but as M. Huot has never seen these remains imbedded in the same strata with marine remains of miocene or even pliocene age, but simply collected them at the foot of the cliff, the natural inference would seem to be, that they had fallen from an overlying mass of sand, clay or other superficial detritus, occupying a position similar to that in which we found them at Taganrog (see p. 296), and were lodged in their present position, just as similar remains subsiding from river banks in inland tracts are carried into the beds of the present streams. In corroboration of our own opinion it also may be stated, that no remains of these Mammalia are cited by any author in the solid tertiary formations of Russia, not even in the Aralo-Caspian or uppermost stratum; and since M. Huot himself describes them in another place, as really occurring in the superficial detritus or earthy covering of these tracts, we shall now simply state, that such is in our view their only true habitat. This terrestrial subject, which is not strictly connected with that under discussion, will necessarily be considered in a subsequent part of this volume.

Though unable from our own researches to describe the continuation of the steppe limestone, from the peninsula of Taman along the northern edge of the Caucasus, we believe from the descriptions of others, that the rock is continuous. We think that it ranges along the low country by Stavropol towards the advanced Caucasian spur called the Beshtau. However this may be, the recent publication of Professor Eichwald distinctly enables us to synchronize with it all the widespread horizontal shelly limestones of the Daghestan, Derbend and Bakù, which form low hills on the western shores of the Caspian Sea. There again we are presented with agglomerates of Cardiaceæ and Mytili, with Paludinæ and other freshwater shells. The labours of M. Eichwald have indeed a special value in determining the age and origin of these limestones, for in describing the very limited existing fauna of the Caspian Sea, he has ascertained, that at least seven species of the fossil shells are now living in it. In these rocks the same phænomenon is repeated as in those which we have examined on the shores of the Black Sea and Sea of Azof, viz. that with the exception of some traces of Rissoa, there *are no marine univalves*.

The following table of the Caspian shells, recent as well as fossil, will show better than pages of writing, to what degree the tertiary deposits around that sea coincide with those we have been mentioning on the shores of the Sea of Azof and Black Sea, and how they more fully exhibit the true and unmixed Aralo-Caspian type.

Table of Caspian Shells, fossil and recent, chiefly compiled from M. Eichwald's 'Zoologia Caspia-Caucasia.'

GENERA AND SPECIES.	WHERE LIVING.	FOSSIL IN THE STEPPES.
Paludina variabilis, *Eichw.*	In the Caspian near Astrakhan and Derbend.	Rocks of Daghestan.
— Triton, id.		Ditto.
— exigua, id.		Ditto.
— pusilla, id.	Near Derbend among the fucoids; Black Sea, near Odessa.	
Rissoa Caspia, id.	Caspian Sea	Rocks of Daghestan.
— Conus, id.		Province of Derbend, mixed with the preceding Paludinæ.
— dimidiata, id.		Daghestan, and near the naphtha springs, with agglutinated fragments of Neritina, Cardium and Dreissena.
Neritina liturata, id.	On the sea-weeds of the coasts of Derbend, Balkan and Astrakhan.	Rocks of Daghestan; Gulf of Karabogas.
Bullina Ustuertensis, id.		Ust-Urt, mixed with Cardiaceæ and Paludinæ.
Mactra Caspia, id.		Promontory of Tük Karagan; Bakù.
— Karagana, id.		Ibid.
Cyclas Ustuertensis, id.		Plateau or isthmus of the Ust-Urt. Eichwald justly remarks, that the presence of these Cyclades in thousands, with a great profusion of Paludinæ, clearly announces a mixture of fresh and salt water.
Dreissena polymorpha, *Van Ben.* (Mytilus) Mytilus edulis, *Lin.*	Embouchure of the Volga; Caspian and Black Seas, and Baltic.	Near Astrakhan, and in all the low steppes extending to Tzaritzin, with Cardium, Adacna and Monodacna, thus indicating the presence of an ancient sea. Of these the Dreissena is much the most abundant and forms immense agglomerates. Entire islets are composed of Dreissena and Cardium, as well as all the coast between Bakù and Derbend, and tolerably high hills towards the town of Takhn.
— rostriformis, *Desh.*		Crimæa, Taman and low steppes of L. Elton.
Donax priscus, *Eichw.*		Tük-Karagan promontory, with *Cardium edule* and *Mytilus edulis.*
Cardium edule, *Lamk.*	The existing species in the Caspian is very small.	Both coasts of the Caspian. In Daghestan, with Rissoa and Paludina. Near the Gulf of Karabogas, with *Didacna crassa, Monodacna Catillus, Mytilus polymorphus, Neritina liturata,* &c.
— rusticum, id.	In every shore of the Caspian.	
Didacna trigonoides (Cardium), *Pall.*	Generally in the Caspian, and according to M. Hommaire in the Sea of Azof.	Lower steppe of the Volga. Smaller varieties of this species are found at Bakù mixed with Mytilus, Rissoa, &c.
— crassa (Cardium), *Eichw.*	Caspian, Nikolaieff (Black Sea).	Small variety in Daghestan, Karabogas.
Monodacna Caspia (Cardium), *Eichw.*	Caspian.	
— pontica, id.	Black Sea.	
— propinqua, id.		Bakù.
— intermedia, id.		Bakù, near to *Cardium paucicostatum,* Crimæa.
— Catillus (Cardium), id.		Bakù, Karabogas, Lower steppes of the Volga.
Adacna colorata (Cardium), *Eichw.*	Gulf of Nikolaieff, Volga, Don, and *Palus Mæotis.*	
— edentula, *Pall.*	Caspian.	Near Lake Elton and steppes of Astrakhan, with *Mytilus polymorphus, M. rostriformis, Adacna protracta, Monodacna Catillus,* and *Didacna trigonoides.*
— protracta, *Eichw.*		Steppes near Lake Elton in argillaceous hillocks.
— plicata, id.	Gulf of Asterabad, Freshwater lake of Akerman near Odessa.	
— læviuscula, id.	Gulf of Asterabad and Bakù.	
— vitrea, id.	Ibid.	

In seeing the wide extension of the most common species of the fossil shells enumerated in the preceding table, no one can fail to be convinced, that whether imbedded in the rocks forming the shores of the Black, Azof or Caspian seas, they once all lived under the same waters. Throughout all that sea of ancient times, certain peculiar forms of the genus Cardium[1] constitute the characteristic feature of the fossils, and also, it will be observed, of the present Caspian. In fact, of the fifteen species enumerated by Eichwald[2], seven are still living exclusively in the Caspian, two in the Black Sea, two are common to both seas, and eight are fossil; whilst of these last eight species, four are identical with living forms, and four seem to be lost. But even the species presumed to be lost are so closely allied to those now inhabiting the Caspian, that we cannot avoid recognising in them the same peculiar Aralo-Caspian type, unknown in all other regions of the globe. It is worthy of remark, that one species, the *Adacna colorata* (Eichw.), which has been found living in the rivers Volga and Don, as well as in the gulf of Nikolaieff and the *Palus Mæotis*, offers a good analogy to explain the habits of the Cardiaceæ of the steppe limestone. It is further remarkable, that the *Adacna plicata*, which Eichwald cites from the gulf of Asterabad in the Caspian Sea, has been found by us living in the freshwater lake Akerman[3], near Odessa, and within forty to fifty versts above the mouth of the Dniester. This fact, added to those cited by Eichwald, of the coexistence of numerous Paludinæ with Cardiaceæ, and analogous to those inhabiting the present Caspian, would lead us to believe, from zoologicai data alone, that the Caspian of our day is simply the residue of the great Aralo-Caspian Sea, whose fauna was so dissimilar from the oceanic deposits of the æra in which it was accumulated.

But notwithstanding all previous researches, our knowledge, it must be allowed, is yet too limited to enable us to reason very closely upon the relative change in the inhabitants of the former and present Caspian. In the lists of M. Eichwald we see, indeed, that several species are now living which have not been found fossil,

[1] Deshayes retains entire the genus Cardium for all these forms, but Eichwald forms for them the genera Adacna, Monodacna, and Didacna.

[2] The work of M. Eichwald here cited must be considered as the verification and support of many of the opinions contained in his former volume, Alte Geographie des Kaspischen Meeres, des Kaukasus und des Südlichen Russlands. Berlin, 1838.

[3] In the same lake we found the *Cardium pseudo-Cardium* (Desh.), (Mém. Soc. Géol. de France, vol. iii. pl. 1. f. 1 and 2.), which by a total absence of lateral teeth and other characters is very nearly allied to the Cardiaceæ of the Caspian.

and that others which are abundant as fossils are unknown in existing nature. Yet here we must observe, that as the bottom of the Caspian has never, we apprehend, been explored by that searching instrument *the dredge*, nor its contents fully laid open by it, like those of the Ægean Sea through the labours of Professor E. Forbes, it must be impossible to say to what precise extent the submarine fauna of the former and larger Caspian agrees or disagrees with that of the present sea.

We have already endeavoured to account for the partial intermixture of purely marine shells with brackish water remains in some of the rocks of the isthmus of Taman; and explaining the phænomena by a modern analogy, have sought to lead our readers to understand, how the inhabitants of our ancient Aralo-Caspian being shut out from the ocean, may have lost the oceanic and assumed the brackish water type. The present Caspian, for example, isolated and excluded from all communication with the ocean, is so slightly saline, that even in a part of it far removed from rivers and streams, its waters are said to be potable[1]; and, according to Eichwald, as stated in his Fauna, the greater number of its fishes

[1] Lieutenant Felkener (Annuaire des Mines de Russie, année 1838, p. 155) states, that in the Isle of Tcheleken, which is saturated with saline springs, the Turkoman inhabitants drink no other water than that of the adjacent Caspian Sea. With such a fact before us we cannot subscribe to the view of M. Hommaire (Bulletin de la Soc. Géol. de France, vol. xiv. p. 263), drawn from a belief that the Caspian of the present day is more saline than the Black Sea. M. Hommaire has, indeed, a theory to sustain, which, in our opinion, is at variance with the geological and physical structure of the surrounding regions. That author contends, that the Caspian is simply a portion of the ancient Black Sea, which since its separation has been lowered to its present level through a diminished supply of fresh water from the rivers Volga and Ural, and also by *evaporation*; and *hence* its supposed greater saltness. Granting that the Volga and the Ural, no longer flowing through vast undrained and uncultivated forests, do not afford so great a volume of fresh water as of old, and that the level of the Caspian may consequently have somewhat subsided, there is no reason to apprehend that this cause can *continue* to operate to any great extent. In regard to the alleged excessive saltness of the Caspian, the statements of M. Göbel, the chemist, (who makes the water less salt than that of the ocean) are at variance with those of M. Hommaire. We venture, however, to believe, that both analyses may be true, and that they depend upon the portion of the sea from whence the samples were taken. We have, indeed, no difficulty in understanding why such parts of this sea as happen to be fed with intensely saline springs issuing from beds of rock salt, may not be exactly as they are represented by M. Hommaire; but whilst he attributes this excess of salt in the water to evaporation, we distinctly refer it to *ancient geological causes*, viz. rock-salt and salt springs of previous epochs. Our readers will, in truth, perceive, that the theory of M. Hommaire requires no other refutation than the simple fact, that Caspian shells lie in rocks 700 feet above the Caspian Sea. Would that author lower the great Aralo-Caspian Sea from such heights by evaporation? We shall presently assign geological reasons which exclude the possibility of such former high levels of that sea, and which at once destroy the reasoning of Pallas and many of his successors, as to certain *historical* deluges in Greece and the rupture of the Dardanelles being due to the letting off of these inland bodies of water.

belong to freshwater genera and species. In another memoir, however, by the same author [1], an opinion is expressed, that though it is now, and has ever been but slightly saline, the Caspian is daily becoming more so, both through evaporation and the dissolution of masses of salt which occur in or below its bed. To this cause M. Eichwald seems to attribute the poverty of its fauna, and the disappearance of several species which are supposed to have been in existence at no distant day. Even our present amount of acquaintance with the subject would, however, induce us to reject this reasoning; for, in the first place, no valid proof has been given of an increase in the saltness of the Caspian; and secondly, judging from all the fossil collections, there is no reason to believe, that the former vast Aralo-Caspian possessed a greater variety of species, or that its shells partook more of a marine character, than those of the present sea. The truth, indeed, seems to be, that in the ancient as in the modern period, the relative proportion of organic contents has been perfectly maintained. Now in sheets of fresh water of our own æra the number of genera and species is small, but that of individuals great, whilst in the ocean their variety is countless,—a result probably due to the great diversity of conditions produced by strong currents in vast and open seas, and to the removal of species from distant countries brought into contact with each other. The persistent and almost monotonous zoological character of the Aralo-Caspian limestone is, therefore, the best possible proof of the insulated position and uniform, brackish nature *of the one great inland sea* in which it was accumulated.

This Aralo-Caspian limestone occupies the summits of the extensive isthmus between theCaspian and the Aral. M. Eichwald has, as it will be perceived in the prefixed table, named two species of shell after this isthmus, the Ust-Urt. Owing to the great difficulty of travelling far inland among the wild Turkomans who inhabit it, we presume that M. Eichwald has not much examined the interior; but by connecting his zoological determination of the species, which so exclusively occupy the shelly limestone forming the eastern cliffs of the Caspian, with the independent description of other travellers, there can be no doubt, that the same deposit spreads over the whole of the plateau between the two seas, extending to Khivah and even far beyond that city [2].

[1] Ergänzung seiner früheren Aüsserangen über das Verhältniss des Caspischen zur Schwarzen Meere, Erman's Archiv für Russland, 1843.

[2] Older tertiary and even secondary and ancient rocks doubtless form the nucleus of the Ust-Urt (see note, p. 313). We are now merely speaking of the shelly limestones, marls, &c. of the surface deposits.

Judging from the sketch of the country between Balkh and Khivah left to us by the adventurous and lamented Burnes, we can scarcely doubt, that on the east the Aralo-Caspian deposits range continuously to the edge of the elevated plateau of Pamir (Bolor chain of Humboldt), and on the south to the foot of the western prolongations of the Hindoo Kush ; for he describes all the plain of Turkistan, which is watered by the Oxus, as consisting of soft yellowish limestone, with clay, gravel, sand and occasional springs and deposits of salt[1].

Respecting the Ust-Urt we had, indeed, come to the same conclusion from personal communication with M. Eversman, who accompanied the expedition of General de Berg, which passed, in the winter of 1826, from the Caspian to the Aral, and determined the heights of the Ust-Urt, as well as from the travels of Muravief, when our opinion was strikingly confirmed by the perusal of the Appendix to a recent work by the enterprizing British envoy Captain James Abbott. After travelling from Khivah to the promontory of Tük Karagan, by a route seldom if ever previously taken by a European, he distinctly says, " the basin of the Caspian is a shell limestone precisely similar to that which forms the plateau between its shores and Khivah. It is remarkable that the whole of this immense mass, often elevated to more than *one thousand* feet[2] above the level of the Caspian, contains but the three shells, the cockle, muscle, and spirorbis, which are the production of the waters of the Caspian. Hence (he well observes) had these vast strata of shell limestone been the deposit of the ocean, they must have contained other shells than those which they yield to research. They are therefore the deposits of the Caspian." In alluding to these relics of a former Mediterranean, the same traveller goes on to speak of them as proofs of that sea having once stood at a vastly higher level, and thereon builds a theory for the wearing away by these higher waters of the gorges of the Hellespont. Here, however, he shows himself to be unacquainted with the true principles of geology, which would have taught him, that if ever the Caspian stood above the level of the highest points at which the steppe limestone is now found, it must have covered Russia in Europe and the plains of Germany ; but of such a phænomenon there are no traces. Geologists will, therefore, naturally conclude, that such positions

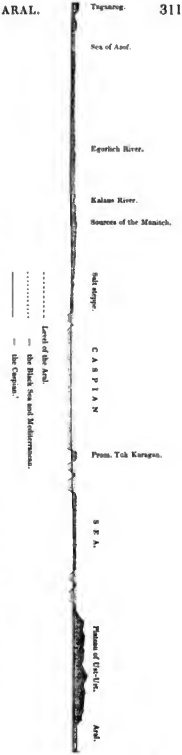
[1] Trans. Geol. Soc. vol. iii. p. 494.

[2] As Captain Abbott's most remarkable journey was performed during a period of the greatest danger (the war between Khivah and Russia being then at its height), and as in traversing this very steppe, which he so graphically describes, he was robbed, captured and severely wounded by the Turkomans, we are not to expect from him an accurate estimate of heights.

of the steppe limestone (even if they do not exceed 700 or 800 feet, the ascertained heights of the Ust-Urt above the sea) must be referred to unequal elevation of the bottom of an ancient Caspian, and not to its depression.

To give to the reader a clear view of these great oscillations of land, we here subjoin a general section, from the hills of Aralo-Caspian limestone above Taganrog upon the Sea of Azof, to the Aral Sea. In this diagram, which is founded on the Russian determinations of the relative altitude of the different tracts of land and inland seas, the dotted line represents the level of the Sea of Azof and the Ocean; a glance, therefore, will show how the Aralo-Caspian deposits have been heaved up to different heights in the hills of the Don Cossacks, on the eastern shores of the Caspian, and in the Ust-Urt. Again, whilst it has been demonstrated, that these inland seas were once united, the Caspian, and with it large portions of the adjacent lower steppe, to which we shall hereafter advert, are seen to be depressed beneath, whilst the Aral Sea is above the level of the ocean.

In the opposite woodcut no very great precision must be looked for, an observance of which is obviously impracticable, where the horizontal line extends over near 900 miles of country. Again, if in giving the height of the Ust-Urt above the Caspian, the same proportions were followed, as in the height of the Ocean or Sea of Azof above the Caspian, that plateau would appear extravagantly mountainous. The sole object of the section is to convey a *general approximate idea* of the relations of the masses of land and water. (For the level of the Caspian, see note, p. 321.)



47.

The relative changes between land and water within the historic æra will be considered towards the conclusion of the work, on which occasion we shall endeavour to indicate, how those recent modifications of contour to which Baron Humboldt referred, are distinct from the phænomena so clearly ante-historical which occupy us; for though we now offer proof, that the Aral and the Caspian were to a great extent separated in the tertiary period, by the elevation of the Ust-Urt and the great isthmus of Khivah, we may take the opportunity of discussing with our illustrious contemporary, whether in the early periods of history the Aral and the Caspian *may* have been connected in their *southern* parts, and whether the Oxus may not have flowed into both seas [1].

Another author, Lieutenant Felkener, of the Imperial Russian Mining Corps, may, indeed, be cited in support of the view, that the masses of land to which we have been alluding were formerly the bottoms of an inland sea.

In exploring the eastern edges of the Caspian from Asterabad to the Cape Tük Karagan [2], he describes the southern portion of the coast, extending from the river Karasù to Postchanoi Ugol, as a low alluvial sandy plain, which rises insensibly to the east, and is flanked on the north and north-east by the great plateau of the Ust-Urt, and on the south and south-east by the chain of Khorassan. This lower desert of Khivah (Khwarezm), inhabited by lawless Turkomans, and with which geographers are only slightly acquainted through the adventurous travels of Muravief and Conolly, would seem, therefore, to offer the same relation to the Ust-Urt which the low steppes of Astrakhan and the Caucasus bear to the adjacent raised tertiary strata which surround them, a subject to which we shall presently advert. Though little versed in the specific distinctions of fossil shells, Lieutenant Felkener is sufficiently clear in his narrative to permit us to doubt, that an elevatory process has been going on from remote antiquity to a very recent period, if not to the present day, by which the mountains, hills and banks on the coasts of the Caspian have been successively heaved up. Connecting effects with their causes, his description of the raised beds of the Caspian, often inclined and dislocated in the neighbourhood of the eruptive rocks of the Balkhan, and their horizontal position at great altitudes where placed at some distance from such lines of disturbance only, tend to confirm our belief, that with a little more attention of competent observers, these tracts, particularly in the meridian of the eastern prolongation of the Caucasus, will afford still more distinct proofs of different epochs of elevation.

In making this remark, however, we are fully alive to the very great difficulties which must encompass any traveller who seeks minutely to examine the interior of a tract, inhabited by wild and lawless Turkomans, and in which for a distance of 800 versts, from south to north, one well only of fresh water is known. Even from the pages of Lieutenant Felkener we learn that, upon the same parallel along which porphyries and other plutonic rocks were formerly ejected, and which threw up the more

[1] Asie Centrale, vol. i. p. 421 *et seq.*, and vol. ii. p. 221 *et seq.* Muravief, Voyage en Turcomanie, and Journey to the North of India overland from England, through Russia, Persia and Affghanistan, by Lieutenant Conolly. London, 1834.

[2] Annuaire du Journal des Mines de Russie de 1838, p. 130.

ancient tertiary deposits, other uprisings and ebullitions have been continually in activity. Among the prominent features of the latter are the fountains of naphtha and the hot saline springs (an eastern continuation of those of Bakù and its sacred fires), which bursting out in some spots from the bottom of the sea, rise up through all the adjacent lands, penetrating the Isle of Tcheleken and the adjoining coast. In that tract, the strata composed of clay, sand and shelly agglomerates, all evidently formed under the waters of the Caspian, are so saturated with naphtha, salt springs and iron ores, and are so altered, hardened and thrown about at various levels, that they acquaint us in terms too plain to be misunderstood, *how* these former sea-bottoms have been placed in their present position, and brought into their peculiar actual condition; whilst huge masses of the coast cliffs (exceeding 100 feet in height), remote from such lines of eruption, are seen to be composed of horizontal layers of unaltered shelly limestone of the Aralo-Caspian date[1]. In alluding to the naphtha springs, we are, however, touching upon phænomena which, ancient as may have been their origin, are agents now actually effecting changes; so dismissing for the present their consideration, we may revert to them towards the close of this work, as the last of a long series of causes of alteration in the outline of the earth.

In the mean time we further glean from the travels of Captain Abbott, that in one district near the eastern shore of the Caspian, where the ground rises to considerable altitude (1500 feet according to this author), viz. in the ridge between the Gulfs of Munghis-lak and Tiuk-kara, the hills are chiefly composed of *red sandstone*. Having shown how Permian rocks of that character trend far to the south of Orenburg, and that they have been observed by other travellers near the sources of the Emba, where they are associated with igneous rocks, we cannot avoid suggesting, that the hills of Munghis-lak, constituting a portion of the Ust-Urt, may be considered one of the terminal embranchments of the Ural. Baron Humboldt has, indeed, previously expressed his opinion, that the Ust-Urt is the direct prolongation of the Mughodjar and Airuk hills, the southernmost rocky masses of that

[1] Whilst we write, we are informed by our friend Colonel Helmersen, that another Russian traveller, M. Basiner, a botanist, has very recently explored the banks of the Aral Sea to Khivah, and that having there collected both fossil and recent shells, he will throw new light upon this interesting subject. Count Keyserling adds in another letter, that M. Basiner has brought back to St. Petersburgh shells of different tertiary age; the *Voluta ambigua* (var. *V. luctator*) for example, found in the deep valleys, seems to indicate the presence of the London clay; the *Mactra ponderosa* in an oolite must represent our miocene, p. 294; whilst the superior masses are the steppe or our Aralo-Caspian limestones.

chain in which plutonic rocks appear. The existence of red sandstones, probably palæozoic, but at all events long anterior to the tertiary deposits, supports his view, whilst the presence of the recent steppe or Aralo-Caspian limestone over nearly the whole surface of this isthmus, proves decisively, that sea-bottoms of that age, elevated from north to south, and directly in the line of upheaval of the Ural Mountains, effected a great change in the physical outlines of these regions, at a period which, though geologically recent, must have been long antecedent to the historical æra.

Having before stated that the Aralo-Caspian deposits repose, along their north-western frontier, upon older oceanic strata, it is clear, that subsequent to their accumulation, these last-mentioned beds and other submarine masses must have been heaved up and formed into barriers which prevented the spread of the ancient inland sea. It is also evident, that at a later period, a large portion of that sea was thrown off, and its bottom raised into great plateaux of steppe limestone. We venture to believe, that these results are distinctly referable to at least two periods of vibration between land and water, which took place before the earth's surface was inhabited by our race. For as the steppe limestone above alluded to, has all the appearance of having been the shore of certain low and sandy steppes to which we now invite attention, so do we believe that the latter was still the abode of the same ancient, eastern Mediterranean, when its waters being considerably diminished, entered into deep recesses, and united the present insulated seas by straits and channels, the bottoms of which have since become dry land.

In thus carrying on the attention of the reader to this branch of inquiry, we beg, however, to guard him against the inference, that other changes of sea and land in the North of Russia, particularly those which involve the great phænomenon of the erratic blocks, *may* not have been effected *anterior* to some of the last desiccations of these lower steppes. We have merely deemed it expedient, when explaining the successive retirements of the Aralo-Caspian Sea, to consider in the same chapter the whole series of changes of adjacent sea-bottoms into continents, and to show that all such grand mutations are, properly speaking, geological phænomena, which ought to be considered apart from superficial detritus not clearly proved to be submarine, as well as from minor undulations between land and water which have taken place within the historic æra.

Lower Steppe deposits of the former Caspian.—Our readers will perceive that we have distinguished upon the Map, a large portion of Southern Russia by a lighter tint of the colour used for No. 10. and by the sign 10'. This region includes the whole of the lower steppe of Astrakhan between the rivers Ural and Volga, which, passing down the western shores of the Caspian, extends, in a strait, to the west, over the low grounds of the Kalmucks, between the Caspian and the Sea of Azof, and again from the western shores of the latter by the isthmus of Perecop to the Black Sea below Kherson. The whole of this vast area was, we conceive, covered by the waters of the inland sea to which reference has just been made, at the comparatively modern period when the Aralo-Caspian limestones had been so elevated as to form its shores. Our own acquaintance with the boundaries of this great area is limited to portions of its western and northern shores. Of the southern or Caucasian boundary, our knowledge is, of course, derived from Pallas and his numerous successors. Among the latter we must mention Mr. Strangways, who traversing many years ago the low steppe between South Russia, the Crimæa, and the Caucasus, visited the mineral sources and baths of Kislovodsk, and the group of mountains of which the Beshtau is the principal: Mr. Strangways has put into our hands some manuscript notices of the lower region, which it is very much to be regretted were not formerly published.

Other travellers and naturalists have since visited that country, and those who desire to make themselves masters of the whole subject, particularly in reference to the tracts around the Sea of Azof and between that sea and the Caspian, will doubtless first study the works of Pallas, and then endeavour to synchronize the various elements of his details with modern geological science, by reference to the recent works of M. Kupffer, M. Dubois and M. Hommaire de Hell. For our own parts, we shall chiefly dwell upon the portions of those low countries which we have seen, and on which, as they have been visited by few modern geologists, we hope to be able to throw some light. Though a good notion of a large portion of the outline of these lower steppes was first put forth by Pallas, the great naturalist seems to have entertained vague ideas respecting their eastern boundary. A few years ago it was, indeed, commonly supposed, that these same lower steppes extended far to the east of the river Ural, and that coasting the southern termination of the Ural chain, they spread over vast tracts in Siberia, and possibly communicated with slightly elevated deserts adjacent to the northern seas. A glance at our Map will show that this view cannot be entertained; for, however we may yet be unable to define the whole of their eastern boundary, many Russian observers, including Professor Eichwald, have ascertained, as before stated, that hilly grounds, composed of various strata, occupy the left bank of the Ural and its tributaries, and that these are succeeded on the east by a band of Jurassic rocks extending across the river Emba, and pointing towards the Sea of Aral.

Steppe of Astrakhan.—The whole of the low steppe between the Ural and the Volga, and which ranges from the watershed of the Obschey Sirt upon the north to the Delta of Astrakhan on the south, is (with the exception of the islets of Bogdo, Arsagar, &c.) apparently nothing but a desiccated sea-bottom. It is, in fact, entirely composed of sand, with occasional heaps of fine gravel, is rarely argillaceous and loamy, and is almost everywhere strewed over with shells or the debris of species, some of which are now living in the adjacent Caspian Sea, such as *Mytilus polymorphus*, *Adacna edentula* (Eichw.), and *Didacna trigonoides* (*Cardium*, Pall.): others have not been found living, such as *Mytilus rostriformis*, *Adacna protracta*, and *Monodacna catillus*. The mean elevation of this steppe above the level of the Caspian does not exceed fifty feet, and as that sea is 83·6 feet below the level of the ocean, as will be hereafter explained, it follows, that if the water of the Black Sea should, by any subsequent change of level of the intermediate land, find access to this region, nearly the whole steppe in question would be again submerged. The shelly sands, however, ascend insensibly to the north, or towards the Obschey Sirt. They also rise where they approach the isolated hills of Bogdo, whilst at Tchornoyar on the right bank of the Volga above Astrakhan, and near the western shores of the desiccated area, beds with Caspian shells are seen to occupy a thickness of about sixty feet above the stream, and in the following ascending order:—*a.* Lowest beds, sands in various courses, 35 feet. *b.* Bed with Caspian shells. *c.* Brownish sandy clay or silt, which, on drying, scales off into irregular laminæ. *d.* Yellowish argillaceous sand.

Though one of us[1] traversed this steppe from north-east to south-west, *i. e.* from Uralsk, to the banks of the Sarpa below Sarepta, and therefore in its greatest diameter, we have nothing else to state concerning its monotonous internal structure. Of its northern and western shore, which was followed by the remainder of our party, we have yet a few words to say. On the north it is com-

[1] In traversing this steppe, which could not have been accomplished without the kind and active assistance of General Perovski, Count Keyserling visited the Khan of the Inner Kirghis in the heart of the steppe, who is tributary to Russia. Oases affording very tolerable sustenance for cattle occur at intervals, and the *best fresh water* is found by digging holes in the sand. This fact serves to substantiate the belief, that the steppe is saliferous in those spots only where springs rise from subjacent rocks containing salt.

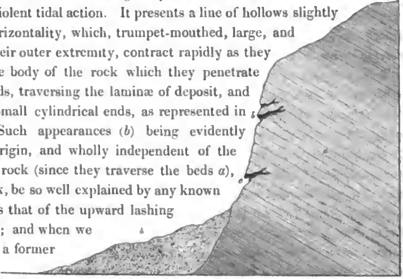
posed of palæozoic rocks rising gently into the Obschey Sirt, and forming the southern limb of the great Permian basin. The western coast is most decisively marked by the high grounds and promontories constituting the right bank of the Volga, which consisting, as we have shown, of Jurassic and cretaceous strata, rising several hundred feet above the stream, decline near Kamischine, under the tertiary strata. The latter ranging by Tzaritzin to Sarepta, occupy the left bank of the Sarpa, and there form the coast of a former Caspian (see Map), amid the desiccated and incoherent beds of which the Volga now finds its way to Astrakhan. No one, in truth, can have stood upon the promontories of the Volga and the Sarpa, and have observed their salient and re-entering angles, so like the worn coasts of the sea, nor have gazed, as we have done, over the vast expanse of lower steppe at his feet, covered with marine exuviæ, some of them identical with forms now living in the Caspian, and others closely allied to them, without being convinced, that there was a period,—and at no very distant time in the history of the planet,—when the waves of a former Caspian washed against these shores.

This, indeed, was the idea of our precursor Pallas, though he did not attempt, as we do, to refer this desiccation to epochs anterior to the historical æra. In illustrating his view, we must also say, that Pallas has made use of one argument which seems to be irrelevant. Observing towards the summit of the escarpment on the Sarpa near Sarepta, irregular concretions of agglutinated sand, which did not penetrate far into the body of the soft sandstone, he imagined them to be the remaining evidences of a peculiar action of the sea (by which such forms are occasionally produced), when it stood at between 300 and 400 feet above the present level. As, however, we have repeatedly found similar, short and irregular sandy concretions in the tertiary sandstones of the South of Russia, to which, indeed, we have alluded—often far removed from any coast line—and as we could when on the spot discover no difference between them and the examples in the cliffs of the Sarpa which Pallas cites, we cannot admit that such configuration has any reference whatever to the action of a former Caspian.

We shall now adduce other evidence derived from Mount Bogdo, and to which Pallas has also partially adverted, which in itself is a convincing proof, either of a former higher level of the Caspian, or of the elevation of the ancient cliffs of that great inland sea. In the Little Bogdo the sands with Caspian shells rise up in slopes, and so obscure the hill, that we may suppose it formed a shoal in the former sea. In the Great Bogdo, however, the same sand and shells reach only a certain distance on its loftier sides, the upper portion of which might, therefore, from this circumstance alone, be set down as an islet of the former Caspian; but we will now give independent reasons for our belief on this point. The chief escarpment of this hill which faces to the east, has been before described as consisting in ascending order of argillaceous marl, soft thin-bedded sandstone with harder siliceous reddish grit, red and white argillaceous marl, and a cap of grey-coloured limestone (p. 195 and woodcut).

The marly and easily decomposing beds, occurring between the hard limestone summit, and the sandstone and grit which form the shoulders of the hill, are necessarily much ravined and worn by ordinary action; but beneath them, and at a moderate height above the talus of sands with Caspian shells, the nearly vertical face of the sandstone has been so singularly eroded, that we can attribute it to nothing but violent tidal action. It presents a line of hollows slightly devious from horizontality, which, trumpet-mouthed, large, and much worn at their outer extremity, contract rapidly as they advance into the body of the rock which they penetrate obliquely upwards, traversing the laminæ of deposit, and terminating in small cylindrical ends, as represented in this section. Such appearances (*b*) being evidently of mechanical origin, and wholly independent of the structure of the rock (since they traverse the beds *a*), cannot, we think, be so well explained by any known natural cause, as that of the upward lashing of the sea-surge; and when we see the shells of a former Caspian (*d*) lying in an inclined talus precisely like those of a sea-shore, and at a few feet beneath the line of erosion on the rock, we can scarcely doubt that such has been the agent[1].

48.



In another portion of the hill, but on the same eastern face, a similar line of holes (*c*) is seen at a lower level, and beneath it is also a talus of sand and shells; and from this we were led to infer, that the retreat was accomplished by at least two great oscillations of the surface.

[1] Mount Arsagar in this steppe, which we did not visit, is also considered by Pallas to have been washed by the waves of the sea, as he found Caspian shells and rolled pebbles upon the summit of its alabaster rocks.

Whilst considering this phænomenon it is worthy of remark, that the erosion is on the *eastern* face of the hill; since from all we can learn this is still the point from which the most violent winds of these regions still proceed—the great land winds, in fact, of continental Asia. If not mistaken, we could adduce examples of indentations in sandstone, nearly similar to those of Mount Bogdo, made by the present sea upon the British cliffs; and for ancient analogies we would refer to the deep cylindrical erosions of the surface of the chalk so common all over Western Europe.

Whilst then we have indisputable proofs, from the general configuration of the masses of land which flank this lower steppe, that the bottom of a former Caspian was raised, the lines of water-worn holes in the vertical face of Mount Bogdo (evidently from its composition an islet in this former sea) are striking confirmations of the view, that such elevations were effected during two periods.

Low Steppe of the Caucasus.—We wish it were in our power to give some sketch, from personal observation, of the southern extension of the tract above described into the low steppe of the Kalmucks, which constitutes, in fact, its southern prolongation, and spreads over a large portion of the region between the Black and Caspian Seas. Although, however, we only trended a portion of its northern shore along the Sea of Azof, we know enough of it from Pallas and our precursors, as well as from Strangways, Eichwald and Hommaire, to feel certain, that to a great extent it is of the same composition, and contains the same shells as the steppe we have described, and of which, indeed, it is the continuation. In some parts, the low Caucasian steppe, particularly along the course of the Kuma and for some distance from the Caspian, is more argillaceous than the larger portion of the Kirghis steppe; resembling rather the deposits at Tchornoyar. It is further remarkable in containing so much salt disseminated in the earth, that after the wet seasons, the water having evaporated, the desiccated surface throws off coats or efflorescences of muriate of soda. In reference to this phænomenon, we must draw a distinction between the saline productions of the steppe north of Astrakhan and those of the lower steppe of the Caucasus. The former (as we have already seen, p. 196) are the products of subjacent and very ancient rocks (Permian, &c.), whose included masses of rock-salt give off perennial and copious springs, which, issuing through the overlying sandy beds of the desiccated Caspian, form highly saline pools and lakes. The latter, on the contrary, even where they are most saline (as along the banks of the Kuma), seem to be derived from troughs or cavities occupied by marine mud or mire, in which a certain amount of salt is disseminated, and it is after copious rains only and in certain seasons that they give off a saline effervescence. In many cases they appear to be the mere residue of salt marshes, which had been formerly overflowed by the sea. Pallas has, indeed, pointed out the distinction between these two classes of salt deposit. "None of the salt lakes and marshes on the western coast of the Caspian Sea have such a stratified incrustation of salt, gradually increasing, as may be observed in the lakes of Bogdo, Elton and Indersk, near the river Yaik. *There* the ample store is continually supplied and increased by rich salt springs; whilst all the saline particles of the *other* salt lakes are completely dissolved by the rains of autumn and winter[1]."

To the clear distinction thus drawn by the great naturalist, before geology was a science, we have to add, that the copious perennial springs of the steppe of Astrakhan are derived from residual subterranean phænomena of oceanic character, accomplished during the palæozoic æra, when intense mutations were brought about, and vast masses of crystalline rock-salt were formed, whilst the saliferous efflorescences of the marine mud of the steppes of the Caucasus are simply what we might expect to find in the retentive portions of the bed of a retired sea[2], particularly in the contiguity of the great eruptive chain of the Caucasus[3].

We believe that all the lowest part of this vast steppe of the Caucasus bears the same relations to the younger tertiary rocks of the Crimæa and the Caucasus, as the low steppe of Astrakhan to the adjacent promontories in the south of Russia. We have therefore laid these tracts down upon our Map under one common tint (10′), intending thereby to convey the idea, that the waters once covered a sinuous tract between the Caucasus and Southern Russia, uniting the Caspian with the Sea of Azof and the Black Sea on the one side, and the Caspian with the Aral on the other, at a period when other beds of the same inland sea (the steppe limestones) had been elevated and formed to a great extent their shores. At the same time we are ready to admit, that a portion of the steppe of the Caucasus may have

[1] Pallas's Travels through the Southern Provinces. English edition. 4to. p. 305.

[2] In the expedition of General De Berg from the Caspian to the Aral, the greatest obstacles to the passage of the guns and heavy baggage were similar *oases* of marine mud to the north of the Ust-Urt, which were not frozen hard, even when the thermometer stood many degrees below zero.

[3] In his work upon the Caucasus, M. Dubois has shown, that masses of rock-salt have been formed even in the tertiary deposits, by a conjunction of volcanic eruptions with the desiccation of ancient sea bottoms. The same results are indicated in the Isle of Tcheleken in the Caspian, where the springs of naphtha and salt issue from beneath the marine mud. (See Felkener *ut supra*, p. 310.)

been desiccated at a more recent period than the steppe of Astrakhan. To what extent our colour representing the period *intermediate* between the elevation of the steppe limestones on the one hand and the true historic æra on the other, may be correct, particularly in the eastern portions to which we have extended it, must be hereafter the subject of critical research. But both these divisions of the former or great Aralo-Caspian epoch were, we doubt not, antecedent to historic records.

The old opinion of the eastern extension of a vast Caspian[1] of all but historical

[1] The exact and definitive results of the operations carried out by the Imperial Government to determine the true level of the Caspian, executed by the able mathematicians Fuss, Sawitch and Sabler, have been recently communicated to us by M. Struve, the distinguished astronomer, under whom the observations were compared. Four trigonometrical levellings, between the Sea of Azof and the Caspian, were made, independently of each other, and the results of each were as follows:

The levelling of M. G. Fuss gave the depression of the Caspian = 85·0 English feet.
Sawitch „ „ = 83·2
(1st) Sabler „ „ = 83·9
(2nd) Sabler „ „ = 83·0

The combination, therefore, of these very closely agreeing observations, gives a mean result of 83·6 English feet, and reduces the possible error to 1·3 foot of more or less depression.

The operations commenced on the shore of the Sea of Azof near the village Kagalnik (see Map), and the following table explains the position and height of the ground at the places where observations were made:—

	Approximate distance from the Sea of Azof.	Height above the Black Sea.
Kagalnitskaya (station)	70 versts	112 English feet.
Novo Egorlich (village)	120	348
Sredny Egorlich (village)	150	237
Letnitskoi (village)	200	184
Novo-Troitskaya (station)	250	495
Stavropol (city), on the highest ground between the two seas	300	1688
Alexandrov (borough)	380	1020
Georgievsk (city)	440	970
Ekaterinograd (station, formerly a city)	520	613
Mosdok (city)	560	432
Navur (station)	610	308

The steppe is cut by the level of the Black Sea at the distance of seventy versts from the Caspian and eight versts to the west of the station Sukhoborosdiask. 0

Kisliar (city) fifty versts from the Caspian — 27°

Tchernoi-Rinok (village) three versts from the Caspian — 71°

The two last mentioned places are, therefore, 27 and 71 feet below the level of the Black Sea.

In saying that we confidently rely upon the high authorities above-mentioned, it is right to state, that M. Hommaire de Hell having made a series of levellings from the mouth of the Kuma on the east to that of the Manitch on the west, *i. e.* along the low banks of these two rivers, the result of his operation is, that date, was, indeed, likely to prevail, at a period when it was not ascertained, whether the fossils of the steppe limestone differed or not from the shells of existing nature; and when, from the want of accurate admeasurements of the relative heights of land and water it was imagined, that the whole of this region was a depression on the surface of the earth; the present Caspian Sea being supposed to be more than 300 feet below the level of the ocean. The Russian researches, to which allusion has been made, have, however, removed this obscurity. They have taught us that the Caspian is 83·6 English feet only beneath the Black Sea. It has been further ascertained, that the Caspian and Aral are separated by the broad and lofty isthmus of the Ust-Urt, which from its condition and contents must have been formed long antecedent to the historic æra; and lastly, it is now supposed by other observers, that the Aral being 117 feet above the Caspian, is consequently 33·4 feet above the Black Sea, Mediterranean and ocean (see section, p. 311).

These great differences of level in masses of water, whose shores are occupied by limestones which must have been accumulated under the same inland sea, were clearly effected in very ancient periods; for independent of the prodigious alteration in the physical outline of these countries, caused by the elevation of former sea-bottoms and their erection into barriers which now separate the Aral and Caspian seas, we find that a considerable proportion of the fossilized shells are no longer living in the adjacent Caspian, and thus, independently of the great mutations of surface, we are compelled to believe, that the steppe limestones are, in relation to our own age, of high antiquity. In like manner, though to a less extent, we draw the same inference concerning the greater part of the low steppes; for although from their relations and "facies" these sands have evidently been desiccated at a period subsequent to the elevated steppe limestone which constitutes their shores, they contain *some of its shells, and among them species now unknown in the Caspian.* The calcareous hills, and the low, sandy and argillaceous bottoms of the steppe, we consider, therefore, to be *signs of two retreats of the same pristine sea,*

the Caspian is 18 met. 30 cent., or 60·04 English feet only lower than the Sea of Azof! (See Bull. de la Soc. Géol. de France, vol. xiv. p. 322.) This determination, with many other admeasurements, is about to appear in a work entitled "Les Steppes de la Mer Caspienne," some livraisons of which, already before us, do great credit both to the artistical and literary accomplishments of Madame Hommaire, who accompanied her husband in his laborious survey of these Kalmuck steppes. With every respect however for this author, we really consider it impossible that his one line of observations can be placed in competition with the quadruple and closely compared data of the Russian mathematicians, to whose results, in common with Baron Humboldt, we attach implicit confidence. See this line of levels on Map.—May 1844.

whose relics have been mentioned, or as we would express it, of two elevations of the land, during the long period whilst the surface was assuming its present outline. In reference to the former Eastern Mediterranean, we can well imagine how similar species should have exclusively prevailed over so vast an area, so long as the same waters covered all the low tracts from the low country south-west of Orenburg to the Black Sea, and how a sensible change of animal life should have accompanied the diminution of the Caspian to its present dimensions and the union of the Black and Mediterranean Seas.

General view of the Caspian Deposits.—In terminating our reflections upon the Aralo-Caspian deposits, we beg to impress upon the reader, that without attempting to enter into details, our principal object has been to demonstrate the existence of a former vast, interior brackish sea, the remains of which have an uniform, limited and peculiar physiognomy, which cannot fail to be regarded as one of the most singular features in the ancient condition of the surface of the globe which modern researches have brought to light. Though the effort to synchronize precisely these Caspian deposits with oceanic marine strata of other parts of the world is obviously no easy matter, we have still good grounds for believing, that on the whole they are the equivalents of Pliocene and Post-Pliocene deposits; for on the one hand they clearly overlie strata of Miocene age, and on the other are intimately linked on to the inhabitants of the present Caspian.

In respect to the actual degree of saltness of the Caspian, the analyses of M. Göbel, on which we rely (p. 308), are strengthened by the opinion of M. Eichwald, who thus writes:—" I can assure you that the Caspian is much less salt than the Black Sea, and possesses one-sixth part only of the saltness of the ocean. Its water, however, is very acrid and disagreeable to the taste on account of the bitter salts and naphtha which it contains in such quantities that few animals can now exist in it[1]."

We have already explained, that we believe the great saltness of *some parts* of this sea is due to brine springs issuing from the bowels of the earth—often from rocks formed long anterior to the earliest Caspian deposits. But whether this be so or not, we base our general inferences upon the simple fact, that shells identical with those now living in the Caspian—*to the exclusion of nearly every oceanic species*—are spread over the lands of vast countries, and have been left at dif-

[1] Letter to M. de Verneuil, in which M. Eichwald, extending this reasoning, infers, that the former Caspian probably contained more species than the present sea (May 1844).

ferent and considerable altitudes. Whilst, therefore, we specially invite the attention of geologists to the grandeur and peculiarity of this former internal sea, we think that its diminution to the size of the present Caspian and Aral seas, is mainly due to oscillations of its former bottom. The eruptive rocks which range along the Crimæa, the Caucasus and the Balkhan of Khwarezm, are fortunately at hand to explain, that as igneous matter in various forms has sought an issue at many points in those contiguous mountains, partially raising up sedimentary deposits, and changing their mineral aspect and condition; so probably have internal, widely acting expansive forces, derived from the same deep-seated source, heaved up, in broad horizontal masses, to the different levels at which we now find them, the beds of the former great Caspian Sea. Such elevations would very naturally, we contend, be accompanied by adjacent depressions, and thus we would explain the low position of the Caspian Sea, and such portions of land around it, as are admitted by all observers to lie beneath the surface of the ocean.

Lastly, by the tint upon our Map (10′), which extends over the lower steppes, we merely seek to indicate a period, when the great and earlier Caspian had, by the elevation of its bottom, undergone a very notable diminution in size. Our conclusion, that this intermediate condition—when such large tracts of our present dry lands were still covered by water,—was antecedent to our own æra, is, we may observe, strengthened by the absence of all traces of man or of his works in any of the most recent or lower, sandy deposits of these steppes. The remains of Mammoths occur, indeed, in the sands and mud of the most recent of these desiccated Caspians with Mytili and shells adherent to them, showing by what races the adjacent lands were inhabited, when the waters of a Caspian covered the steppe of Astrakhan. On these terrestrial subjects, however, we shall not now dilate, though in the sequel we shall endeavour to explain the nature of the agency by which all these changes of land and water were brought about, and to indicate how the same causes, operating with much less intensity than in the preceding epochs, have produced comparatively small relative oscillations only within the historic age.

Northern extension of a former Caspian.—M. Jasikoff has just communicated to us the interesting fact of the extension of Aralo-Caspian deposits considerably to the north of the limits with which we were acquainted. The most southern of these masses occurs in the low steppe on the left bank of the Volga, opposite the cities of Volsk and Sysran, and probably communicating with the same deposits in the large steppe of Astrakhan, ranges northwards to the junction of the Motsha and Kundurstsha rivers. The northern Aralo-Caspian tract, called by M. Jasikoff the " Basin of Bulgar," is, according to him, quite insulated and separated from that of the south by the carboniferous rocks described p. 85, which form the promontory of the Volga near Samara, and by the Permian deposits; from whence it ranges northwards on the left bank of the Volga beyond Simbirsk, to the environs of Tetushi and Spask. Throughout these tracts, which are sandy steppes, reposing, as we believe, upon our Permian rocks, M. Jasikoff has found the *Mytilus polymorphus* and other Aralo-Caspian shells, and has thus added proofs of another arm, perhaps a detached bay or fiord ?, of a former Caspian Sea, into which the Volga of that day emptied itself in 55° north latitude (see Map).

Oceanic Deposits in the Ust-Urt.—Uncertainty as to the real Level of the Aral Sea.— In the absence of any geological survey of the Ust-Urt or wild plateau between the Caspian and the Aral, the description of its southern portion by Captain Abbott, the presence of a shell described by Eichwald as *Cyclas Ust-uertensis*, as well as the account of the monotony of the tract given by the party which accompanied General De Berg (see p. 310), have all led us to infer, that the older Caspian deposits which unquestionably form the cliffs of the Sea of Aral as well as of the Caspian, extended continuously over the whole tract which rises to a maximum height of 731 feet. An excursion to St. Petersburgh since the preceding sheets were printed has induced Mr. Murchison to modify this opinion. After inspecting certain fossils collected on part of the higher grounds of the Ust-Urt by M. Basiner, to whom allusion has already been made, and submitted to him by Colonel Helmersen, he had no hesitation in agreeing with the latter, that these shells and the oolitic marly limestone in which they occur are of oceanic character, and synchronous in age with the uppermost Miocene deposits of Podolia, Bessarabia, and Taganrog already alluded to.

According to M. Basiner, these beds appear to have been upheaved into a plateau, which formed the western shore of a former Aral Sea. In our view, which supposes the previous union of that sea with the Caspian, we would suggest that these upraised oceanic deposits may have constituted an island in the great Aralo-Caspian brackish sea. Future surveys must determine this point, and decide whether the earliest Caspian waters may have communicated with those of the Aral by a northern strait; for to the south there must have been a communication over the low steppes and one of a very broad character. In the mean time, the facts before us compel us to reduce to more moderate limits than we assigned to them, the oscillations to which the bottom of the old and extended Caspian has been subjected. According to M. Basiner, the deposits charged with true Caspian shells, as seen on the western shores of the Aral, do not rise to more than 150 or 200 feet above that sea, and form a sort of undercliff or low buttress between it and the higher plateau of the Ust-Urt. This elevation agrees with that of the steppe limestone which we observed on the shores of the Sea of Azof and Black Sea.

We willingly take this opportunity of thanking Colonel Helmersen for his timely correction of our ideas concerning a region as yet unknown personally to any practical geologist; and in referring to a memoir which he is preparing, in illustration of the geological fruits of M. Basiner's journey, we also beg to say, that to his friendly communication we owe our first acquaintance with the existence of a band of eruptive rock (Shik Djeli) on the right bank of the Oxus, to the north-east of Khiva. To this important feature a reference will be made when we come to consider the true southern prolongation of the great Uralian chain.

In reference to the real level of the Aral, it is right to observe, that some Russian travellers, particularly M. N. Khanikoff, who has obligingly communicated to us his views, are of opinion[1], that the determination of the height of that sea by mere barometrical observation is not to be depended on[2]. From a general survey of the surrounding regions, including an estimate of the fall of the Oxus from its sources to its mouth, and from the level of the country between its western bank and the Caspian, M. Khanikoff is of opinion, that there is no material difference between the level of the Aral and the Caspian, and that the former, like the latter, will be found to lie in *a depression* of the earth's surface In our previous reasoning we took the usually recognised data, and simply followed Humboldt. But even should M. Khanikoff's view be substantiated, our general reasoning respecting the oscillations of the bottom of the great former Caspian, and its brackish inhabitants, will not be affected, though the intensity which we have assigned to such vibrations must be diminished.

[1] See M. N. Khanikoff's work on Bukhara, with maps. St. Petersburgh, 1843.

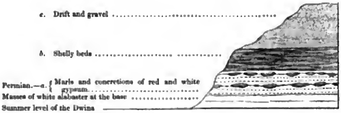
[2] There is a prevalent opinion among those who have travelled into the steppes, that the barometer is not to be there trusted as a test of height. Without again alluding to the error into which geographers were led as to the real depression of the Caspian, it is said that from a mean of twelve observations in the Siberian steppes, an observer recently obtained for a result, that the ground between the Ui and the Tobol rivers was *beneath the ocean*, and yet these streams have a course of hundreds of miles before they reach it!

In throwing his eye over our Map, the geographical reader will not fail to distinguish some slight new contours of the shores of the Aral, particularly towards the north. For these, and the extension of the plateau towards the north-eastern angle of the sea, we are indebted to Captain Romanoff, of the Imperial Staff-Corps, who surveyed the ground. According to this intelligent officer, the island of some size which has so long found a place in our maps is a fable, which probably originated in the allegorical style of the Kirghis inhabitants of the steppes, who spoke of it as a spot "from whence no man returns." Numerous low islands, however, occur near the mouth of the Sir or Jaxartes, and all the northern shores exhibit low cliffs of marl and steppe limestone.

Shelly Sea-Bottoms—Post Pliocene or Pleistocene Beds in North-eastern Russia in Europe.—Let us now transport our readers to the north of Russia, and introduce to their notice certain raised bottoms of the Arctic Sea. Throughout a vast region of Northern Russia no traces have been detected of tertiary deposits of Eocene, Miocene or Pliocene age. We have, indeed, already shown, that the whole of the subsoil of an enormous northern area, with the exception of some patches of Jurassic strata, is occupied by Palæozoic rocks, the surfaces of which are, to a great extent, obscured by sand, clay and blocks of northern origin. To the consideration of these last-mentioned superficial accumulations we shall hereafter advert, and we now proceed to describe certain true sea-bottoms which we ourselves discovered.

That beds of sand and mud, containing marine shells, the most of which are undistinguishable from existing species, occur at various levels above the sea, and particularly near the eastern shores of Sweden and the western coasts of Norway, has long been known; but it was still a problem whether this phænomenon extended eastwards into Russia. No deposits of this age had ever been found in Finland, or near St. Petersburgh and the adjacent Baltic governments; but in ascending the banks of the Dwina from Archangel, it was our good fortune to observe certain beds, which from their structure, fine lamination and thickness, indicated the action of slow and long-continued deposit, whilst the shells abounding in them (almost undistinguishable from those of the adjacent White Sea) announced that this tract was submerged during a very recent period. We first noticed these beds on the right bank of the Dwina opposite the post station of Schastozerskaya, about 240 versts above the city of Archangel. At this spot we were much surprised to find a profusion of shells having a very modern aspect, regularly imbedded in clay and sand of about ten feet in thickness, which, covered by about twenty feet of the coarse gravel and detritus of the country, reposed at once on bands of red and white gypsum, subordinate to red marls, which form a part of the rocks we have called Permian. The annexed woodcut conveys an idea of this order.

49.



We afterwards found similar beds on the right bank of the Vaga two stations further to the south. At the latter they rest on strata of the Permian limestone which we have before described, p. 174. As both these localities were seen to be in the valley of the Dwina or in one of its indentations, we had not at that time (1840) an opportunity of ascertaining, whether these shelly deposits extended continuously to any distance east and west; but our colleague, Count Keyserling, having retraversed the tract during the summer of 1843, has discovered, that in the sections on the river banks of the upper portion of the Vaga, such shelly beds are not visible. We might, therefore, view them as relics of the sea, when the present embouchure of the Dwina was a bay or estuary which entered for upwards of 250 versts southwards into the adjacent low lands. At the same time it is necessary to remember, that these shelly beds are covered by sand and gravel, which we should have great difficulty in separating from the superficial northern drift. A recent excursion through Sweden has, indeed, convinced us, that in the neighbourhood of Upsala, marine post-pliocene deposits containing the *Tellina Baltica*, are there covered by coarse gravel and large erratic blocks, as stated by Mr. Lyell[1].

Some of the shells on the banks of the Dwina and Vaga, which have been preserved in the blue clay or marine mud, and thereby totally excluded from atmospheric influence, have retained all the freshness of their original colour, with their

[1] See Phil. Trans. 1835, Part I.

valves often adherent; and the whole, even when blanched, are generally in an excellent state of preservation. The collection we made (the work of two or three hours) has been examined by Dr. Beck of Copenhagen, Mr. Smith of Jordan Hill, Scotland, Mr. Lyell and Mr. G. Sowerby, all of them well versed in the forms of shells which occur in raised sea-beds.

Dr. Beck considers all the species examined by him (fifteen in number) to be identical with those now existing in northern seas which range from 42° to 84° north latitude. Mr. Smith, on the contrary, believes that though many of these species are recent, some are of peculiar varieties now found in desiccated and elevated sea-beaches only, such as those to which he has given so much attention on the banks of the Clyde and the western shores of Scotland. Mr. Lyell entertains the same view, and at once recognizes the group as identical with that which he had described from Uddevalla in Sweden. Lastly, Mr. G. Sowerby, differing from Mr. Smith in a few specific identifications, is also of opinion, that the shells of which we now subjoin a description, though on the whole an association of existing species, have yet among them forms seldom, if ever, found except in raised sea bottoms of a sub-fossil character.

List of Shells found upon the Dwina and at Ust-Vaga, named by Mr. Smith and Dr. Beck, with remarks by Mr. G. Sowerby.

1. *Saxicava arctica* (*Striatella arctica*, Linn., *Mya byssifera*, O. Fbr.).—May be regarded as a distinct species from *S. rugosa*; but it is also found living from the Arctic regions to 54° north latitude.
2. *Mya truncata*, Linn.—Recent in northern seas; fossil in many localities. (Uddevalla, &c.)

2 *a*. *Mya* ——?.—It is difficult to decide whether or not this should be regarded as merely a variety of the last, or a distinct species. It is found fossil in several localities, but I doubt if it has been found recent.

3. *Littorina littorea*, Ferr.—A very abundant recent species between 74° and 42° north latitude.
4. *Pecten Islandicus*. — { *Recent*; Newfoundland, and to 56° north latitude. *Fossil*; Clyde, Bute (Uddevalla).
5. *Nucula rostrata*, Lam.—A living northern form = *N. oblonga* of Mr. Smith's list.
6. *Tellina calcarea*, Chemn.—Also living in northern latitudes, towards 60° north latitude. (Fossil at Uddevalla, &c.)
7. *Tellina Grœnlandica* }
8. *Mytilus edulis* } Both these fossil species of Ust-Vaga are widely diffused in a living state. (Fossil at Uddevalla, &c.)
9. *Cardium ciliatum* ?, O. Fbr. Faun. Gr. (*C. Islandicum*, Chemn.)—If this be the *Cardium ciliatum*, we are entirely unacquainted with that species in England. The form, as far as may be judged from the very incomplete specimens, approaches nearer to some Australian than to northern forms. It is very different from any northern form that I am acquainted with.
10. *Cardium Grœnlandicum*.—Probably the same as the recent species.
11. *Cardium edule*, Linn.—Ranges to 42° north latitude.
12. *Astarte Borealis*, Nilsson (*Crassina Withami*, Smith).—Recent northern species, 60° north latitude; fossil but not recent in the Clyde (Dr. Beck identifies it with *A. semisulcata*, Gray).

13. *Astarte sulcata*, Nilsson (not *Venus Scotica*, De Montf.), but very near to, if not identical with, the recent *Astarte Garensis*, Auct. Scot. These specimens, which are marked *A. Garensis* by Mr. Smith, together with those marked *A. elliptica* by him, are positively identified with the fossil Astarte of the Clyde, which he also calls *A. Garensis*. (Dr. Beck identifies it with *A. Scotica*.)
14. *Astarte Damnoniensis*, Lam.—Living in 55°, 56° north latitude. Among the species of Astarte submitted to me there is no one to which this name can properly be attached.
15. *Astarte compressa* (*Venus compressa*, Mont.).—Why Mr. Smith has called this *A. depressa* I know not, since it must be considered identical with our British recent *Venus compressa* of Montagu. These fossils are even closer in resemblance to the recent species than the Clyde fossils.
16. *Astarte multicostata*?, Smith.
17. *Astarte depressa*?, Smith.—Those shells which Mr. Smith has called *A. Damnoniensis* are essentially different from that species, as well as from every other recent Astarte known to me. This species seems to me identical with the fossil named *A. depressa* by Mr. Smith.
18. *Natica clausa*.—Recent in northern seas and fossil in the Clyde. (Fossil at Uddevalla, &c.)
19. *Buccinum undatum*.—A rather slender variety.
20. *Fusus carinatus*, Lam.—Same as the recent species.
21. *Balanus sulcatus*, Linn.—Ranges to 54° north latitude.
22. *Nucula rostrata*, Lam. nec Sow.—65° to 54° north lat.
23. ———— n. s.—Recent at Spitzbergen.

(21–23) —These occur in Dr. Beck's list only[1].

After the opinions of such naturalists (however the identity of a species or two may be contested), there can, we presume, exist no doubt, that our deposits of the Dwina and the Vaga are analogous to those described by numerous authors as forming ancient raised beaches (Post-Pliocene) at different levels in the British Isles, Sweden, Norway, &c.

Deposits also of a precisely similar nature occur, here and there, on the coasts of the Gulph of St. Lawrence. They have been observed by Captain Bayfield, R.N. in the environs of Quebec, at heights varying from 50 to 200 feet above the sea[2]. Mr. Logan has followed them inland towards Montreal, where they reach an elevation of *four hundred and sixty feet* above the Atlantic[3]; and it is very remarkable, that they contain very nearly the same group of shells as the deposits of the North of Europe, the most frequent species in both countries being *Mya truncata*, *Saxicava rugosa*, *Tellina calcarea*, *T. Groenlandica*, *Mytilus edulis*, *Pecten Islandicus*, and *Natica clausa*. The wide distribution of these Arctic shells is a most remarkable fact, and one from which we may infer, that if the climate was then colder than it is at the present day, the distribution of temperature over a large portion of the

[1] That Dr. Beck may have seen some species not examined by Mr. G. Sowerby is very probable, as the former was supplied with a collection from the same locality in the possession of M. E. de Verneuil, the latter by one brought to England by Mr. Murchison.

[2] Geological Proceedings, vol. iii. p. 119, and Trans. Geol. Soc. 2nd ser., vol. vi. p. 135.

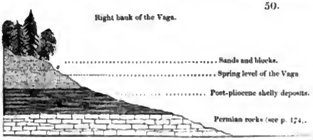
[3] Proceedings of Geol. Soc. vol. iii. p. 769.

northern hemisphere was nearly the same. To this point, however, we shall return in a concluding chapter of Part II., when we consider the transport of erratic blocks.

In previous pages we have more than once adverted to the strict conformity with which deposits of very different age succeed each other in various parts of Russia, and we have guarded our readers against the inference, that such relations should be taken as any proof of the overlying stratum having been formed *immediately after* that which is subjacent. We now adduce still stronger evidence, that great oscillations between land and water must have taken place, without in the slightest degree deranging the position of the strata of anterior epochs, which, formerly depressed beneath the sea, were raised to the surface, and now form part of the continent.

A section near the mouth of the Vaga exhibits the same post-pliocene beds perfectly conformable to limestones with Producti and corals of the Permian rocks, as expressed in this woodcut. If unacquainted with the great distinctions between the Palæozoic shells beneath, and those of post-pliocene age above, an observer might indeed, be here led to view them as parts of an undivided or unbroken series; but geology teaches us, that an enormous interval elapsed between their formation, during which the older Permian strata, first elevated and removed from the influence of marine deposits, were, after a long lapse of ages, submerged and covered by the sand and mud with post-pliocene shells, and afterwards raised into their present position. And yet with all this oscillation, these shells being now about 150 feet above the sea, the most perfect parallelism between the two sets of strata is preserved[1].

50.



In speaking of this amount of elevation, it is important to recollect, that the beds at Uddevalla, 1000 miles distant from those of the Dwina, and in which some of the same species are found, are about 200 feet above the sea, and that similar beds

[1] Considering that the Dwina descends from Ust-Vaga to Archangel, a distance of about 240 versts, it is not unreasonable to suppose, that the pleistocene beds at the former place lie at the height of 150 feet, and barometrical observations of Count Keyserling lead to the same inference.

in Norway and America occur at various levels from 40 to 600 feet[1]. Now as we necessarily infer, that waters containing identical *oceanic* species must have stood at the same level, and cannot have lain at such different heights within the *same* recent period, no reasonable hypothesis can be entertained, except that to which we have alluded in speaking of the former Caspian deposits, and which refers these different levels of the same sea-beds to different degrees of elevation. It is, indeed, almost unnecessary, in the present state of geological science, to sustain by our northern examples, that which has been so clearly demonstrated around the coasts of the British Isles and North America, and of which such decisive proofs have been already adduced in this work from the South of Russia.

The nature and origin of the superficial detritus which covers these Arctic shells will be hereafter explained; but we may here, however, remark, that the coarse gravel and sand, which surmount the beds of shells upon the Vaga and the Dwina, and which we cannot well separate from the erratic block phænomenon, must all have been accumulated under water.

We may now say a few words upon the nature of the other recent marine deposits in the north-east of Russia, to which allusion has previously been made, though we are not yet furnished with full details. Fragments of sea-shells, apparently of existing Arctic forms, have been observed by Count Keyserling (1843) in many parts of the valley of the Petchora, extending inland to upwards of 3° of latitude south of the mouth of that river (68½ to 65¼ north latitude), on the banks of which they are strewed about upon argillaceous slopes, for the most part composed of Jurassic shale. They do not, however, show themselves in regular beds, like those of the Dwina or the Vaga.

This observation of our friend is valuable in enabling us to form a more correct opinion now than during our first tour, respecting the relations of some of these sea-bottoms to other superficial detritus. He has remarked, that the shells are found in the depression of the great valley of the Petchora only, and never on the plateaux, nor even in the tributaries of that river which descend from and cut through such plateaux, and hence he believes, that such shelly deposits were formed in an estuary of the northern ocean, which penetrated into a continent that had already, to a great extent, assumed its present contour. In fact, we

[1] For more details upon the subject of the elevation of the coasts of Norway, we recommend our readers to peruse the highly instructive memoir of M. Elie de Beaumont, entitled "Rapport sur un Mémoire de M. Bravais" (Extrait des Comptes Rendus à l'Acad. des Sciences, 31 Oct. 1842).

distinctly learn from him, that whilst these modern shells extend along the valley of the Petchora or its slopes, the higher grounds are occupied by sand, gravel and clay, containing here and there the bones of Mammoths. His inference, therefore, is that bays of the sea (such as that of the Petchora), in which the Arctic shells lived, entered far into low lands, the interior of which were then inhabited by great extinct Mammalia; and thus it would appear, that these last raised shelly oceanic deposits of the north are probably in the parallel (as to time) of the desiccated steppe of Astrakhan, into which the remains of similar mammals were washed from the adjacent lands of those regions. For, as no regular beds with subfossil shells, covered with gravel and sand, like those upon the Dwina and the Vaga, have been observed upon the Petchora, it may, after all, be maintained, that the broken and superficial shells in the latter tract are marine residue of a still more recent elevation.

Upon this point, however, some uncertainty must prevail, until a greater number of species of shells be collected and the tract be more examined.

Conclusion of Part I.—If we at once proceeded to complete our geological sketch of Russia in Europe, we ought now to enter upon the discussion of the relative antiquity of other superficial deposits in which no sea-shells occur, such as the coarse detritus with foreign blocks, the "black earth," the Mammoth alluvia, &c. Before we do so, however, the structure and outlines of the great regions inhabited by lost species of mammals, as well as the relation of the Ural Mountains to the adjacent parts of Siberia and Russia, must be explained, both anterior to and during those comparatively recent periods. Although, therefore, wide tracts in Northern Russia are covered with varied detritus of sand, clay, erratic northern blocks and black earth, nearly all of which were, we believe, deposited *under water*, we think it expedient, for the better comprehension of the whole subject, to defer that discussion.

Some naturalists have, indeed, regarded the phænomenon of erratic blocks as one of a purely terrestrial nature, and have connected their transport with the movement of enormous glaciers over the surface of the earth. Differing as we do entirely from such a hypothesis, in reference to the detritus of Russia, we beg to argue that case separately and entirely upon its own merits. Before, however, we venture upon this difficult question, the whole of the data must be got together; for unless the reader shall have previously obtained a clear conception of the antecedent changes by which the relations of land and water were established, he will have great difficulty in following our reasoning upon the origin of certain great surface-accumulations which are yet undescribed.

In the part of the work which we now conclude, we have, indeed, purposely avoided any interference with our main object, of presenting to the reader a clear description of the materials which have been progressively accumulated under the waters.

This first division of the geological history of so large an empire is simply, therefore, to be viewed as an effort to describe the long *submarine* succession[1] which is exhibited in the solid frame-work of European Russia,—a succession which we have now traced from the earliest animal epoch, to a period in which the shelly remains of the sea approach very closely to those of our own æra.

[1] See Tabular View attached to the Map.

END OF PART I.

PART II.

THE URAL MOUNTAINS

AND

TIMAN RIDGE,

SUPERFICIAL DEPOSITS OF RUSSIA,

AND

CONCLUSION.

CHAPTER XIV.

THE URAL MOUNTAINS.

Introductory Remarks.—General Sketch of the Ural Mountains.—Difficulties opposed to their complete exploration.—The colonized or Russian portion of the Chain the chief object of the present Work.—Prevalent physical features.—Practicable routes and navigable streams.—Zavods or Mines, and their inhabitants.—Maps and Sections.—Method of developing our geological views.

THOUGH the Ural Mountains have been examined during more than a century and a quarter, and although many of their rocks and minerals have been described by men of science, their true geological structure has not yet been sufficiently explained. This statement should not, however, excite surprise. Considering the short space which has elapsed since the conquest of Siberia, and up to how recent a time these mountain tracts remained in a state of impenetrable forest, inhabited by idolatrous Voguls and Ostiaks upon the north and Mahomedan Bashkirs on the south, we ought rather to feel astonishment at the rate with which the region has been cleared and civilized through the introduction of European manners and mining industry.

When Peter the Great, with a keen perception of the surest methods of advancing his empire, selected the first Demidoff, to explore the iron-ores of these mountains, he laid the foundation of the great native mineral wealth, which now so conspicuously distinguishes Russia from all the surrounding nations. The earliest mining establishments or Zavods planted by that great sovereign are still the centres of activity, and have served as models after which numerous other works have been formed, both by the government and private speculators.

In the days of Pallas, geology was so little understood (a few gold-mines only being known and a great portion of the country unreclaimed), that the descriptions of the great naturalist are chiefly to be viewed as vivid portraits of living nature. As such, indeed, his observations have well stood the test of time, and small gleanings only have remained for those who followed him.

Since that time, the Russian miners, learning their first lessons from foreigners, have become a well-informed class, independent of extraneous aid, and their directors (officers of the Imperial School of Mines) have described the lithological and mineral characters of the country, around their respective posts, with great fidelity. Some of these works, to which we shall hereafter allude, are illustrated by maps, and for a further acquaintance with them we request our readers to consult the instructive volumes of the Mining Corps. Among these authors they will not fail to distinguish Colonel Helmersen, for his determination of the chief heights, for his graphic sketch of the general features of the mountain range, as contrasted with the remote Altai, and for many geological and lithological distinctions, made in conjunction with his associate Professor Hoffman[1].

In our own day, Humboldt, however, is the individual who has given a cosmical importance to this chain, by showing how, in common with other mountains which have, what he terms, a *meridian* direction, it possesses auriferous and peculiar metalliferous characters. By his comprehensive general views, the illustrious traveller and his enlightened companion, Mr. G. Rose, have also gone far towards rendering the task of geologists both light and easy, for they have clearly indicated the principal forms of a large portion of these mountains, the direct dependence of the metamorphism and mineralization of sedimentary masses upon the intrusion of plutonic matter, and have acquainted us minutely with the nature of the crystalline rocks and simple minerals of the chain. Again, judging from organic remains sent to him by the Russian authorities, or brought back by Baron Humboldt and his associates, M. von Buch had asserted the existence of Silurian and carboniferous rocks in the Ural.

After such results, what then, it may be asked, remained to be accomplished? We answer—To identify the broken masses of those mountains with their types in other countries—to compare them with deposits in the plains of Russia whose age we had determined—and to produce, if practicable, a general geological view and map of the whole chain.

[1] We do not here specify all the authors who describe the structure of the Ural, but besides those above cited and others (of whom hereafter), we highly esteem the merits of Hermann (Min. Beschr. des Ural Erzegeb., &c.), Kupffer (Essai d'un Tab. Géogn. de l'Oural), and Ad. Erman (Reise um die Erde).

Baron Humboldt, we may add, was among the first to urge us onwards in this work, and has throughout our labours afforded us every assistance.

But even when so encouraged, our task would have been hopeless, had we not previously made ourselves well acquainted with the nature and order of the strata which occupy the great adjacent regions on the west. It was only therefore, after we had learnt our lesson amid the slightly consolidated and unbroken deposits of Russia in Europe, whose history and succession have been explained, that we ventured to decipher the intricate relations of rocky masses, which in the Ural are thrown about in much apparent confusion. Before, however, we enter upon the details of this survey, we would explain a few of the difficulties which are opposed to the establishment of clear results; and in doing so, throw a glance over the general contour and external condition of the chain.

Viewed as the great barrier which separates Europe from Asia, and pertaining to both, the Ural Mountains, in a limited view, have been usually said to range from the Arctic Ocean on the north, to the parallel of Orenburg on the south, or throughout 18° of latitude.

Though no travellers have yet continuously explored these tracts of the chain which lie between 65° north latitude and the Northern Sea, there is little doubt, from what has been detected in the Isle of Vaigatz, where Silurian and other palæozoic fossils occur, that the geological system of the Ural is continuous to that point[1]. We know, indeed, from the explorations of Captain Strajefski to 65° north latitude, that the axis of the chain, at least its eastern flank, is composed of rocks essentially similar to those of the Ural of the Russian miners, and from that point to the Northern Ocean other proofs have been obtained that the chain is persistent in its characters[2]. Again, by the recent explorations of one of our own party (Count Keyserling) to 66½° north latitude, we have ascertained, that the western flanks of the chain (near the sources of the river Ussa) are composed of the same palæozoic rocks which we are about to describe in the colonized and mining districts.

But in a wider geographical and geological sense the Ural Mountains have

[1] That the central axis of the Ural is prolonged to the isle of Vaigatz, was recently ascertained by the observations and collections of the naturalists Schrenk and Lehmann. See also Hermann, Mineral. Beschreib. vol. i. p. 4; and Humboldt, Asie Centrale, vol. i. p. 464.

[2] We have already alluded to the discovery of Jurassic strata in latitude 64° on the east flank of the Ural by Captain Strajefski (p. 230), and of the same on its western flank by Count Keyserling in a still higher latitude. These sedimentary flanking deposits have obviously no connection with the structure of the chain.

even a much more extended range. From the prevalence of Orthoceratites, Producti, and other fossils, as well as from carboniferous matter in their rocks, M. Baer has suggested that the large islands of Nova Zemlia, stretching out so far northwards into the Arctic Ocean, are in truth also a prolongation of the Ural and its dependencies[1]. A reference to a general map of Northern Asia might lead any one to believe, that Nova Zemlia is in fact simply a continuation of the chief or central mass of these mountains.

An eastern limb, radiating to the north-north-east from 65° north latitude, passes into the Obdorsk mountains and the great promontory which separates the gulf of the Obe from that of Kara. First explored by Sujeff under the directions of Pallas, the correct geographical position and altitude of these mountains were only determined by the enterprising geographer Adolphe Erman, who fixed their direction to be 35° east of north, and their loftiest summit to be 5286 feet high. Lowering gradually as it trends to the south-west, this Obdorsk ridge unites with the Ural in 65°. (See General Map, Pl. V.)

Viewing then the Obdorsk mountains as a great north-eastern embranchment, and the line of Vaigatz and Nova Zemlia as marking the extension of the central chain, we might geographically, almost consider a newly discovered line of elevation on the north-west, as a third range of the Northern Ural.

This western chain is one which has been made known by the recent labours of our colleague Count A. V. Keyserling and his associate Lieutenant Krusenstern, and which rising near the main Ural or middle chain in latitude 62°, trends in a north-north-westerly direction for the space of about 500 English miles, and exposing all the edges and succession of its rocks on the east side of the gulf of Tcheskai, finally disappears in the headland of Kanin-nos near the extremity of our Map. This range, the chief part of which is called the Timan, is however, strictly speaking, separated from the Ural by a trough of Jurassic deposits, and traversing in its northern part a region occupied by Samoyedes, extends beyond the limits of the growth of forests in these parallels of longitude. It was, indeed, wholly unknown to geologists and scarcely known to geographers, except through old works of the sixteenth century[2], till the close of the summer of 1843, when its

[1] Bull. Scient. de l'Acad. de St. Pétersbourg, tom. iii. No. 10.

[2] Humboldt cites an old map engraved on wood in 1547 at Nuremberg, on which the courses of the Petchora (Peczora), Ussæ and Sosva (Sossa) are approximately laid down. The chief ridge of the Ural is termed "Montes dicti Cingulus terræ." Asie Centrale, vol. i. p. 456.

geological explorer, Count Keyserling, returned to St. Petersburgh (see General Map, Pl. V.). His survey shows, that forming the western flank of the great valley of the Petchora and the eastern limit of the great Permian basin, this ridge, though composed of palæozoic and metamorphic deposits which have been pierced by igneous rocks, ought to be dissociated from the Ural in a geological sense, and must rather be viewed as the stony girdle of Russia in Europe, which extending from Scandinavia on the north-north-west, envelopes and forms the natural mural portion of the adjacent European formations. This ridge, whose strata contain organic remains which throw great light on the palæozoic fauna of Russia, will be considered in a separate chapter.

The extreme southern limits of the Ural are viewed by Humboldt as extending considerably to the south of the parallel of Orenburg, viz. by the mountains Mugodjar to Mount Airuk, whilst its extreme southern end is considered by him to lie in the higher grounds between the Aral and Caspian Seas. The recent discovery of a ridge of eruptive rock to the north of Khivah, to which we have before adverted, to say nothing of a better acquaintance with the structure of the crystalline chain which trends southwards from Mount Airuk towards the Aral Sea, seems even to extend the generalization of Humboldt, and to lead us to believe in a great southern prolongation of igneous and palæozoic rocks, which, ranging into Central Asia, beyond the depression of the Aral, constitutes the high ground on the right bank of the Oxus[1]. In this extended sense, then, a grand meridian elevation, of which the Ural Mountains, properly so called, is the distinguishing central feature, has a length of nearly 30° of latitude.

For a knowledge of the north-eastern flank of the chain, extending from 60° to 65°, we shall appeal to Russian authorities; whilst our own acquaintance with some features of the western flanks within the same latitudes, enables us, as above said, to speak personally of a tract (the Timan ridge) not previously visited by any geologist. Our chief observations are, however, restricted to that part of the chain which is colonized and accessible; viz. from Bogoslofsk in 60° to Orsk and Orenburg in 51°, or throughout 9° of latitude.

Within these parallels, the average altitude of the mountains does not exceed

[1] Our acquaintance with the structure of the southern prolongation of the Ural, beyond Mount Airuk, is due to M. N. Khanikoff, Captain Romanoff, and the researches of M. Basiner obligingly communicated to us by Colonel Helmersen.

from 2000 to 2500 feet, though their outline is diversified by groups which rise from 3000 to near 6000 English feet above the sea.

Throughout that portion of the tract which is situated between Bogoslofsk on the north and Kishtymsk on the south, or in reference to the names of separate peaks between Konshakofski Kamen and Jurma, there is but one dominant mountain ridge, with low parallel counterforts both on its east and western flanks. To the south, however, of Jurma, the chain branches out into fan-shaped masses. The most western of these, comprising several ridges, terminates in a low region towards Orenburg, and is to some extent prolonged in the slight undulations of the Obschey Sirt. The central masses of this southern Ural may be spoken of under two heads; those which bifurcating from the lofty Iremel range into the plateau of Preobrajensk on the west, and into the sharp ridge of Kyrkty and Irendyk upon the east; whilst the Ilmen and its southern extension, the Kara Edir-tau, constitute the eastern or flanking ridge of Siberia.

Enlarging upon the determinations of Hermann, Helmersen and Hoffman, Baron Humboldt has seized upon this southern expansion of the Ural, and illustrating it with his usual felicity, has shown how from a single chain in the central portion, it passes into a trifurcation which is persistent from 51° to 55½° north latitude[1]. Having crossed and recrossed this southern portion, where it is most expanded, we think that, whether their mineral constitution or physical features be considered, these masses, when viewed in detail, are more numerous. To this point, however, we shall subsequently revert.

In the following remarks we shall first treat of the northern and afterwards of the southern portions of the chain which we examined.

When approached by the usual high road from its western or European flank, the North Ural of the Russian miners appears little more than a low hilly ridge, for the most part densely wooded; and although a line of rock appears at intervals, the Ural Mountains of the traveller's imagination are reduced, when they appear in sight, to a mere range of mounts, seldom exceeding in apparent height the Vosges between Metz and the Rhine. Their real height is, however, more considerable, the deception being produced by the traveller having already gradually ascended to some altitude above the sea, before he obtains a view of the chain. Those persons, indeed, who have only passed over it by the route to Ekaterinburg, at the

[1] Asie Centrale, vol. i. p. 433–439.

rapid rate of Russian travelling, might almost doubt the existence of a chain, for the road is there carried over the watershed at the point of its greatest depression, and where the outline is round-backed and featureless. The same may be said of the central crest between Blagodat and Serebriansk, and also of the pass near Katchkanar in the parallel of Verkhoturie, by both of which we travelled, except that upon these lines the "divortia aquarum" is enlivened, at intervals, by bold and serrated crags. From certain localities, however, on the Siberian side the traveller can form a more adequate conception of these mountains. In travelling by the ordinary route, from Europe, he gradually approaches them from undulations, amid which the central ridge is often nearly lost; whilst to many parts of the lower plateau of Siberia they present themselves as a serrated, mural and naked ridge, which peering through the forests, has the aspect of a mountain escarpment. Of the nature of this central crest, composed of quartzose and metamorphic rocks, the view at the head of this chapter affords a characteristic idea, and in the sequel other sketches will be given of the appearance of the chain, whether examined in its most elevated portion or on its Siberian flank.

The width of the mountain region may be variously computed, according to the definition of the geographer. Humboldt places the average at twelve to fifteen French leagues, or at about the width of the Pyrenees. The true ridge, however, or Ural-tau, whatever local names may be given to it by the natives in different parallels, must simply be considered as the dividing crest which parts the waters of Europe from those of Asia. But as throughout a considerable space the flanking ridges are, as before said, insignificant, though in other parts they rival the watershed itself in height, it is not easy to define the breadth of ground which should be included in the term Ural Mountains. This remark specially relates to what, for our present purpose, we shall call the North Ural; viz. from Petropaulosk and the most northern Russian mines—from the point, in fact, where colonization ceases northwards, to the cluster of summits before alluded to, and which radiating from Jurma or Yurma, pass to the south-west and south by Zlataüst and Miask.

In the northernmost part of this tract, dense forests and impassable marshes very frequently obscure the watershed, which is diversified solely by occasional stony peaks, lifting their heads through monotonous and silent woodlands, which would to this day have been peopled by a few wild Voguls only, had not the precious ores led the Russians to colonize and clear them. Yet with all the progress which has been made, the only good carriage road completely across the North Ural is in the parallel of Ekaterinburg. Two other transverse roads to the north of that town are, indeed, practicable, but they run for a certain distance only; the one serving as the line of communication between the Imperial Zavods of Kushvinsk and Serebriansk, to effect through the latter a junction with the Tchussovaya river; the other passing from the Zavod of Nijny Tagilsk by Vissimo Shaitansk to Ilinsk on the same stream, which, from the point where it is navigable, becomes the medium for the transport of the heavy merchandize that passes from Siberia into Russia. Still further to the north lay the old high road from Perm, Viatka and Solikamsk to Verkhoturie, or that by which in earlier days the Russian exiles were transported to Siberia, but being disused it has now relapsed into an impassable wilderness[1].

Checked in our wish to traverse the chain by that line, we were enabled, through the kindness of our deceased friend the Prince Butera[2], to pass it on horseback by a track which had not been used for many years, and which leading us by the picturesque and lofty rocks of Katchkanar, placed us in communication with the Imperial Zavods on the east, in the parallel of 58° north latitude.

Enough has already been said of the impediments in the North Ural to rapid scientific researches; but our readers, who have seen how in the flat regions of Russia, we acquired a knowledge of the subsoil by interrogating the river banks, might naturally ask, Why not resort to the same method in the mountains? In truth we did so, to as great an extent as our limited time and the nature of the region would permit; but a glance at the Map will show how rarely, in the absence of roads, we could avail ourselves of such facilities.

Though on the whole a very low chain, the Ural completely plays the part of the Alps and some great mountains, by throwing off its waters to either flank of a central axis; for throughout its whole range, from the uncolonized and savage wilds of the North to the parallel of Orenburg, the "divortia aquarum" are nowhere cut through by any great transverse fissure, and are not, therefore, crossed by any stream. In the neighbourhood of the central depression and to the south of Ekaterinburg, it is true, that in its upper part, the Tchussovaya, where it is very small, winds obliquely through the central hills; and a similar example, as cited by Hum-

[1] A still more northern route is marked upon the Map of Humboldt and Rose, viz. from Tscherdyn to Petropavlosk, but we apprehend that it also is not passable, except in winter.

[2] Married to the Russian proprietress of these mines, cited by Baron Humboldt as Countess Polier in a previous marriage.

boldt, occurs in an upland valley north-east of Zlataùst, which sends one rivulet to feed the Miass upon the east and another to the river Ai upon the west; but these are mere exceptional streamlets, and are not navigable by the smallest boat or canoe.

Nor can the Ural or Yaik itself be said to cut through the chain, for it flows southwards along the eastern flank of the mountains, so long as they maintain their lofty character. It is only when they apparently terminate, by subsiding for a considerable space into the low tracts of the Kirghis, that this river finds an issue to the west in a wide transversal valley, and passing in which from Orsk by Orenburg to the Caspian, it is prevented from flowing southwards to the Aral, by the high grounds which in the broad sense before stated form the southern prolongation of the Ural Mountains.

We conceive, indeed, that nearly all transverse gorges by which rivers escape across ridges from one water basin to another, are nothing more than ancient apertures in the crust of the earth which have resulted from former oscillations and consequent disruption and denudation of the rocks. For although cases are known in which the strata on either side of a gorge do not exhibit signs of unconformability or dislocation (and such may be cited as examples of pure denudation only), still we believe that even in such exceptions, the transverse chasm has been mainly produced by a great vibratory movement, giving rise to a fissure, the depth and size of which has been augmented by powerful denudation when the land and waters were changing their relations. We maintain that *highly inclined* or *torrential* streams only can have made a perceptible impression in laying open mountain gorges which were not natural fissures; or, in other words, that rivers, properly so called, have never *cut sections through chains*, but simply flow in chasms prepared for them. Remarkable examples of such phænomena are to be seen on the flanks of every great mountain chain from the Alps to the Andes, and on a smaller scale in numerous parts of the British Isles[1].

But if the crest of the Ural chain be not rent by distinct transverse gorges, its flanks and counter-forts, both on the east and west, expose many such, in which flow streams, some of them navigable. We therefore took advantage of the Serebrianka and the Tchussovaya on the west of the ridge, and of the Issetz and Sosva on the east; and as these rivers flow respectively from east to west and west to

[1] See Silurian System, pp. 236, 422 *et passim*, and the Memoirs of Mantell, Fitton, Martin and Hopkins on the Wealden, &c., in the Transactions and Proceedings of the Geological Society of London.

east, we were naturally enabled to read off upon their banks the true relations of the strata, on either side of the crystalline meridian axis.

In the northern mining tracts, or in all the country between Ekaterinburg and Bogoslofsk, considerable facilities for inquiry, indeed, exist; since they abound not only in good communications between the Zavods[1], but also in lines of intercourse with their detached mines.

In these districts all difficulties have, in truth, vanished before the perseverance and energy of the Russian miners, whose labours have thinned the forests, erected commodious and often splendid buildings, drained the marshes, filled the gorges with lakes (for water is their great mining power), and rendered the tracts around their Zavods the residence of a population more advanced in knowledge than any with which it was our lot to meet in the greater part of the Russian Empire. Yet in no work of geography or statistics can the general reader acquire an adequate conception of the highly flourishing condition of these centres of industry, each more populous and thriving than many towns which are marked on maps in large letters; and though it is not our object on this occasion to enter into economical details, we cannot avoid stating, that these establishments, both Imperial and private, often contain many thousand industrious workmen, whose houses and essential comforts we have seldom seen surpassed in the manufacturing towns of Europe. When once the inmate of these hospitable establishments, the geologist can effect with comparative ease any inquiry which lies within the circuit of their jurisdiction; and under the powerful recommendations with which we travelled, obstacles were overcome, which, if unprotected travellers, we could not have attempted to face.

The Southern Ural of our Map, i. e. all the mountainous region extending from $55\frac{1}{2}°$ north latitude to the parallel of Orenburg, being much less densely wooded and much less marshy than the Northern Ural, is necessarily more accessible to geological research. Near the northern end of this division of the chain, lie Miask on the east and Zlataùst on the west; the former the most important auriferous Zavod of the south; the latter, as its name (gold-mouth) implies, a débouché for the metal into Europe. An excellent road is necessarily kept up between them, which affords a most instructive transverse section[2], and supplied us with

[1] Upon our Map all the Zavods are engraved in a strong character, in order to mark their statistical importance.

[2] See Pl. III. f. 1.

the characteristic sketch of the central crest rocks represented at the head of this chapter. Whilst Ekaterinburg, the chief town, is celebrated for water-works, which polish the hard porphyries and precious stones of the Ural, Zlataùst has become the great Imperial workshop of the chain. Under the direction of the able engineer and metallurgist General Anòsoff, this establishment, whether for the superiority of its blades of damasked steel or its richly embossed ornaments, may truly be called the Sheffield and Birmingham of Eastern Russia.

As few tracts far to the south of Miask have been found to contain productive gold alluvia, and as the country, though rich in soil and vegetation, is chiefly inhabited by poor and pastoral Bashkirs, no strong reasons have existed for rendering it easy of access. Two practicable routes, however, exist across this southern portion of the chain (besides that from Orsk to Uralsk), both of which we were enabled to follow, through the obliging arrangements of General Perovski. The one called the *starai-tract*, or old road, traverses obliquely from Orenburg to Verch Uralsk, passing by the plateau of Sakmarka and the Irendyk Hills (here the Ural-tau or crest); the other, the *commerzi tract*, or commercial road, in great part completed by orders of General Perovski, crosses the numerous high ridges of which the western flanks of the chain are there composed, and among which the picturesque river Belaia threads its course into the lower countries on the west.

In concluding this introduction it may be stated, that besides making lateral excursions, we traversed the Ural Mountains in seven different parallels, the geological features of which we have endeavoured to represent by as many coloured sections. Divided into two parties of research, and meeting occasionally at the chief places only, we were thus enabled simultaneously to examine the European and Asiatic flanks of the chain, and accordingly to accomplish nearly as much in one season as any single party could have brought to light in two. In addition to the traverses of the chief ridge, we made many lateral and longitudinal excursions, and extended our travels eastwards as far as Kaltchedansk and Troitsk, in order to make ourselves acquainted with the essential distinctions of the subsoil of Siberia as contrasted with that of European Russia. Again, as before indicated, we extended our researches in a subsequent year to the Timan ridge, a great north-western appendage of the chain, hitherto entirely undescribed.

But notwithstanding every exertion in our power, we are fully aware that our results must on many points be defective, in the distinctions which ought to characterize a well-digested geological memoir. We profess, however, simply to offer a general sketch of these mountains, which, imperfect as it may be in details, and particularly in the demarcation of the outline of the formations, will still, we trust, be found to assign the chief rocks of the Ural chain and Timan ridge to their proper places in the geological series.

Provided with the useful geographical map compiled by Humboldt and Rose, it was at first our intention not to attempt any other definition of the Ural than that which is given in our general geological map of Russia (Pl. VI.). The Imperial countenance with which we were favoured, led, however, to the acquisition of some geographical data with which our precursors were not furnished, and we, therefore, caused a separate map to be prepared of all the Uralian regions from the north of Bogoslofsk to the south of Orenburg, which we have endeavoured, however imperfectly, to colour geologically[1] (Pl. VII.).

In the following descriptions, therefore, the reader will do well to consult both the general map, in which the Ural forms the eastern boundary, and also the detailed map in which the relative positions of places can be better traced. The geographical materials for the construction of the latter are chiefly derived from the Prussian map, and on it we have inserted the knowledge we obtained from local surveys of Russian officers at the Zavods of Bogoslofsk, Ekaterinburg and Zlataüst, as well as what we could derive from the writings of Helmersen, Hoffman, Humboldt, &c. The chief additions, however, in our map appear in the southern divisions of the chain, and are taken from original field sketches executed by the staff under the orders of General Perovski, late Governor-general of Orenburg, and kindly presented to us by that distinguished officer. Lastly, the coloured sections which we have prepared (Plates II., III., IV. and V.), may, we trust, explain better than pages of writing, the dominant structure of the Ural Mountains, as seen in a number of parallels throughout nine degrees of latitude. With due attention, therefore, to these coloured sections, and an occasional glance

[1] Both maps have been prepared in London by Mr. Arrowsmith, under the direction of Mr. Murchison, who has published the larger one in the last volume of the Royal Geographical Society. The original map of the South Ural, as compiled by order of General Perovski, from the surveys of the Russian staff under General Rakosofski, and now deposited in the Apartments of the Royal Geographical Society, is a work highly creditable to the officers, who prepared it from their field sketches. The last corrections of the Map, Pl. VII. are taken from the labours of Mr. J. Khanikoff, who is preparing a Russian map of these territories, and we refer with pleasure to a new geographical memoir by him upon the Southern Ural and adjacent regions, which Mr. Murchison has communicated to the Royal Geographical Society of London.

at the maps, woodcuts and scenic sketches which are annexed, we hope that the following explanations may be considered adequate to the sole object we have in view,—a general acquaintance with the age and relations of the masses composing these mountains, and the mutations they have undergone. We beg, therefore, that our efforts may simply be viewed, as a continuation and extension of the important researches of Humboldt, Rose and Helmersen, to whose views of metamorphism and mineral structure we seek to add a few clear, general geological results.

We were for some time undecided as to the plan we should adopt in describing the Ural. If, indeed, we had simply transcribed and enlarged our notes made upon the spot, we might have rendered the work more lively and palatable to most readers, but this was felt to be inconsistent with the method pursued in other parts of the volume, though after all we have imparted much more of the character of a personal narrative to the chapters upon the Ural, than to those which relate to Russia in Europe. In one respect we regret that our journals have not been fully printed; for they are replete with heartfelt expressions of gratitude to our kind friends of these mountains, of whom we may truly say, that they generously and hospitably carried out the wishes of their Emperor, in His Majesty's desire to foster and advance geological science.

CHAPTER XV.

NORTH URAL OF THE MINERS.

General View of the Geological Structure of the Ural.—First transverse Section of the Ural Mountains and their Dependencies, by the Route from Perm to Ekaterinburg, with an Account of the Eruptive Phænomena and Mineral Springs of Nijny Sergiefsk.—Continuation of the transverse Section along the Banks of the Issetz, from Ekaterinburg to Kaltchedansk in Siberia.—Sketch of the region North of Ekaterinburg.—Character of the Rocks around the Zavods of Neriansk and Nijny Tagilsk.

THE Ural Mountains have long been known to be made up of crystalline and slaty rocks, replete with ores and simple minerals, but their chief component parts have not yet been sufficiently defined, as consisting of certain sedimentary palæozoic strata, which have, to a great extent, been metamorphosed by the agency of intrusive or eruptive rocks. From the presence of organic remains traceable at intervals along both flanks, and even close to the axis of this chain, we have, indeed, convinced ourselves, that some of their central ridges, whether in the garb of chloritic, talcose, micaceous or quartzose rocks, are scarcely, if ever, of higher antiquity than the unsolidified Lower Silurian shale on which St. Petersburg is built, whilst others, sometimes also in a crystalline state, are of the Devonian and Carboniferous age. But though we saw abundant proofs of the presence of unaltered palæozoic strata in some spots, and of their metamorphism in others, it was obviously impossible without much more continuous labour than we could bestow on their examination, to separate the formations as distinctly from each other, as in the flat and undisturbed regions of Russia: nor could we trace with accuracy the outlines of every mass, which fossiliferous in one part of its range, in another is either cut off by some outburst of eruptive matter, or has through subterranean agency assumed a peculiar lithological aspect. Yet whilst the axis of these mountains, and the greater part of their eastern sides, are in such a broken and mineralized condition, that the age and nature of the strata can be recognized at intervals only, we have but to descend to their western or European slopes, to learn how very distinctly they regain their depositary character and graduate upwards into well-recognized Devonian, Carboniferous, and Permian deposits. In fact, by travelling from the mountains, to the comparatively low grounds in the governments of Perm and Orenburg on the west, whether along the banks of the Tchussovaya or Bielaia rivers, or even by some of the roads, any practised geologist may satisfy himself, that notwithstanding numerous contortions and even inversions towards the axis of the chain, the lower palæozoic strata (Silurian and Devonian) are eventually overlaid by carboniferous, and the latter by Permian deposits. Still more beautiful examples of the development of the oldest of these palæozoic rocks will be made apparent, when we come to explain the structure of the more northern or Arctic Ural.

From our previous pages (pp. 137–168 *et seq.*) the reader will have gathered, that the Ural chain, must have been to some extent elevated into dry land at a very early period, or immediately after the formation of the carboniferous limestone; for it has been shown, that the Permian accumulations of the adjacent lower country are, to a great extent, made up of the debris of the older Uralian rocks, that they contain fossil vegetables which must have grown on these mountains, and also have derived their singular cupriferous character, either from mineral springs connected with the metamorphism of the Ural, or from the wearing away or destruction of the numerous masses of copper ore which were formed in that chain at a period of high antiquity.

Whilst the features of the western slopes of the chain thus enable us to connect the obscurer masses of the Ural with unequivocal and well-known strata, whose position is established, the Siberian flank, on the contrary, exhibits no such clearness of order: even there, however, we were enabled to decipher a disjointed succession, from Silurian to carboniferous strata, though at rare intervals only, and amid occasional deviations from natural sequence. Instead of occupying continuous zones, as on the west, the strata containing organic remains on the Asiatic side of the crest, are alone traceable at wide intervals, their fragments being cut off by and almost buried under bands of eruptive and crystalline character, which running from north to south and parallel to the chief chain, corrugate and embellish the surface by numerous asperities of outline. (See the Maps, Pl. VI. and VII.)

It is on this eastern flank, where eruptive agency has been so active, that with rare exceptions, all the richest metalliferous ores are to be seen, whether occurring in veins, masses or deposits, the gold alluvia being found in the depressions between the elevations or on their flanks.

The low region of Siberia into which these folds or corrugations pass, is to a great extent occupied by granitic rocks With very limited exceptions, true granites seem never to enter into the higher portions of the Ural, the culminating points of which generally consist of altered palæozoic strata, usually in the state of quartzose and chloritic rocks, sometimes as mica schists, with saccharoid marble ; whilst promontories of greenstone, porphyry, and sienite indenting and breaking in, as it were, upon the central and subcrystalline ridge, often constitute the highest peaks.

Notwithstanding, however, the striking contrast which is presented by the opposite sides of the Ural chain, we convinced ourselves that in the earlier periods, there had taken place all over this region, and probably extending far into Siberia, a deposition of Silurian, Devonian, and Carboniferous strata, which by the linear outbursts of granitic rocks on some lines, and of porphyries and greenstones on others, in lines from north to south, were thrown up into and formed this chain, *anterior* to the accumulation of the Permian deposits. As the latter have not been observed on its eastern flank, we may be permitted to surmise, that in those early periods a large portion of Siberia adjacent to the Ural, was also raised from beneath the sea, and put without the reach of these waters, under which the copper sands and their associated marine animals were accumulated.

On its western flank Jurassic rocks occur abundantly towards the northern and southern extremities of this chain, but as on its eastern flank true Jurassic strata occur in northern and southern patches only, and there is scarcely a trace of them in the intermediate country, nor, indeed, of any beds of secondary age throughout many degrees of latitude, we may infer that, at all events, a very large region of Siberia (including that portion of the eastern flank of the Ural) was not subjected to marine deposits during the long interval which elapsed between the formation of the carboniferous limestone and the accumulation of certain tertiary deposits of which we shall presently speak. In short, we hope to show, that there is no evidence to gainsay the hypothesis, that during the greater part of the secondary period, and afterwards during a long tertiary epoch, a very large region of Siberia may have been a continental mass far above the waters. To this point we shall necessarily again refer, when we come to treat of the tracts inhabited by the lost races of quadrupeds.

After this short view of the general nature of the chain, we will now lay before our readers a series of descriptions of transverse sections which we made across it in various parallels of latitude. These descriptions will, indeed, follow pretty much in the order in which we travelled, and by attention to the coloured sections (Plates II., III. and IV.), we trust that our readers will perfectly comprehend our general views. But although the description of the sections will sufficiently explain the leading geological features, there is one phænomenon on which we must afterwards dwell separately, viz. the nature of the gold alluvia; both to show that such accumulations were formed in one of the most recent periods of change which the earth's surface has undergone, and also to connect it with the destruction of the large Mammalia, at a time when our continents were beginning to assume their present form.

We need not say that those who seek for detailed lithological distinctions and elaborate descriptions of mineral structure will not find any such in our pages: on such points it is alone necessary to refer to the lucid writings of M. Gustaf Rose[1].

General Section across the Ural by the route from Perm to Ekaterinburg, with an account of the eruptive Rocks and Mineral Springs of Nijny Serginsk (Pl. II. fig. 1.).—It has been previously shown that the Permian strata, occupying the regions watered by the Kama and its tributary the Sylva, sweep over large low tracts at the western slopes of the Ural Mountains, from whence many of their component parts have been derived (p. 168). Extending to Kongur, these red and cupriferous deposits becoming highly gypsiferous, are lost under an extensive cover of black earth between Kongur and the post-house of Morgunnof. Thence to the station Zlataustsk the base of the country is calcareous, exhibiting here and there, particularly in the environs of Saksomsk[2], cavernous, white and yellow, dolomitic limestone forming low hills, which, from the few remains detected in it, and more particularly by subsequent examination of its southern prolongation near Krasno Ufimsk, we considered to be carboniferous[3].

[1] Reise nach dem Ural, dem Altai und dem Kaspischen Meere von A. von Humboldt, G. Ehrenberg und G. Rose. Berlin, 1837 and 1842.

[2] An iron-work of M. Alex. Demidoff.

[3] The heat was intense as we passed this tract, our thermometer in the shade of the carriage, even when exposed to the rapid current of air, being from 94° to 99° Fahrenheit. Late in the evening it fell to 88°, and at sunrise was 69°.—June 12, 1841.

To the east of Zlataustsk the carboniferous limestone disappears under certain flagstones and grits occasionally calcareous, the extension, as we believe, of those of Artinsk (p. 127 *et seq.*), which give quite a different aspect to the country. Woodlands and wilds there take the place of arable and pastoral undulations, and a heavy clay for the most part occupies the surface. On emerging from these woodlands the advanced posts of the Ural which begin to show themselves, nowhere present a bolder feature than the Surrey hills as viewed from the valley of the Thames.

At this point, or near the post-house of Altschitska, commences the coloured section (Pl. II. fig. 1.). Hence to Yallim, soft yellowish sandstones predominate, and upon the banks of a small stream they contain casts of Calamites and alternate with layers of argillaceous schist, which occur both in thin beds and also in oblate spheroidal forms. These strata have the aspect of carboniferous deposits, and they unquestionably overlie the true Carboniferous limestone. Allusion has already been made to strata probably approaching to those in age on the banks of the Tchussovaya, and we shall afterwards have to speak of them on the western flank of the Arctic Ural. In approaching Bissersk they incline 15° to 20° to the east, and containing plants (including ferns), become somewhat calcareous, their lamination being marked by plates of yellow mica.

In this parallel the hilly wooded character more distinctly sets on, and the tract diversified by rivulets and pools of water, having somewhat the aspect of the Lower Jura[1], may be viewed as the first appanage of the Ural chain[2]. At Bissersk the carbonaceous sands and grits are partially obscured by loose sand and clay,

[1] We could not learn that any Russian nobleman or country gentleman ever resides on his property in this very pretty tract. In fact, the whole of the Casino or club of the nobles at Perm was placed at our disposal by the kind and hospitable governor M. Ogaref, and we learnt that in all his vast government (as large as the kingdom of France) three or four noble proprietors only were ever resident.

[2] Humboldt has the following excellent observation when speaking of this very point on the western flank of the Ural:—"Comme presque partout les chaines de montagnes s'élèvent sur un terrain déjà bombé, et que des contreforts plus ou moins étendus marquent l'étendue latérale des soulèvemens, il n'est pas facile de circonscrire l'area des montagnes et des plaines. Cette difficulté augmente lorsque, comme dans l'Oural, la chaine n'est élevée à de grandes distances que de 3 à 4 cents toises de hauteur, et que loin de former toujours une digue rocheuse, elle se présente plutôt comme un aggroupement de montagnes et de hauts plateaux disposés dans la direction d'un méridien. Comment, par exemple, fixer les points où commence et où finit l'Oural dans la route qui conduit de Perm et de Kongour, célèbre par ses cavernes de gypse, par Catherinenbourg à Tobolsk; on est incertain si ce sont les changemens si lents de niveau qui doivent décider la question, ou s'il ne faut pas ajouter la considération *de la nature de la roche* aux considérations rélatives au relief."—*Asie Centrale*, vol. i. p. 451.

but at Mayaskaya and Klinofskaya Gora, between that place and Klenofsk, the beds rise into rapidly undulating hills, the last-mentioned or culminating point being (according to Humboldt) about 1062 English feet above the sea. In these hills the same basis of gray calcareous psammite or grit with plants, is diversified by containing numerous pebbles from the size of nuts to that of fists, consisting of porphyry, quartz, felspar, Lydian-stone or altered slate, and occasionally with fragments of the palæozoic limestones of the Ural, in which the fossils are still visible. These strata, sometimes horizontal and very thick-bedded, seem to fold gently over with the outline of the ground. From sections hereafter to be adduced from other parallels, there is, indeed, no doubt, that the carbonaceous beds with plants and pebbles are clearly separated in all the region of the Ural, from the inferior carboniferous limestone properly so called, to which they are in fact *unconformable* ; and if they are also to be considered of the carboniferous age, it must be admitted, that great elevations and dislocations of this chain took place during the formation of sediments which in other parts of Europe constitute the carboniferous system.

The height of these hills increases as you advance from west to east; for the hill of Berosovskaya Gora, between Klinofsk and Kirghishansk, is (according to Humboldt) 1230 feet above the sea. It is from that hill, west of Klinofsk, that the best view of the central or Ural ridge is obtained, and although of slight altitude in comparison with other mountain chains, the intermediate succession of wooded parallel valleys and lower hills, terminated by a long and slightly broken ridge of rocks, embodies a vista by no means unpicturesque.

In the hills east of Kirghishansk the grits and conglomerates above described (which with the exception of the plants much resemble the tertiary nagelflue of Switzerland) are succeeded by whitish, hard and brittle, highly ferriferous sandstones, not unlike some varieties of the millstone grit of England (see Section, Pl. II. fig. 1.). These beds dip rapidly both to the east and west, and, as we soon ascertained, are upon the outermost lines of eruption of the Ural in this latitude. Towards the station of Grobovo great accumulations of very finely shivered, crystalline limestone are accumulated in the valleys, and in the bed of the little rivulet, three versts west of that station, we found strata of compact, yellow limestone, alternating with others of dark indigo colour, which containing *Productus gigas*, *Orthis arachnoides* and Encrinites, left no doubt in our minds, that the rock is truly of the carboniferous age.

These beds, sharply inclined to the east and by north, seemed also to participate, like those of Kirghishansk, in some movements dependent on eruptive forces, and having heard that the mineral springs of Nijny Serginsk were situated at one stage only to the south of the great route, we at once deflected from it to examine the rocks in their vicinity.

Mineral Springs and eruptive Rocks of Nijny Serginsk.—Having repeatedly had opportunities, both in the Silurian region of England, in the Rhenish provinces, and other parts of Europe, of proving, that mineral springs frequently rise to the surface at those points where rocks of igneous or plutonic origin have pierced through sedimentary deposits, our drive over rich but wild fields and pastures along one of the longitudinal valleys to the west of the chain, to the Zavod or mining establishments of Nijny Serginsk[1], was made in the full conviction, that both the origin of the wells and the dislocations we had seen on the sides of the high road (one of the first marked disturbances of the subsoil met with between that spot and St. Petersburgh) would be similarly explained. We were not disappointed. In the environs of Nijny Serginsk many of the greater phænomena which we afterwards witnessed in the chief ridge of the Ural, are clearly exhibited on a small scale; and as epitomes are more easily comprehended than extended and discursive statements, we will, for the present, interrupt the narrative of the first long transverse section of the Ural chain with the following short illustration.

The flourishing iron-works of Nijny Serginsk are situated on the river Sirga, by the barring up of which, an artificial lake about six versts long and one verst wide, is made to fill the lower part of one of the numerous wooded valleys, recently purchased from the former Bashkir inhabitants, and as yet only partially reclaimed. By the aid of this water-power, as in other parts of the Ural, wealth and comfort are here diffused through an increasing and prosperous community.

To the south of the chief Zavod are thick-bedded, quartzose and highly altered sandstones, occasionally quartzose rock, but still regularly bedded and alternating with schists. These masses strike north-north-east, south-south-west, and dip 25° east-south-east. They are evidently a part of the same series of strata seen on the high road in the valley near Kirghishansk. At the north end of the village

[1] The ground around this Zavod was bought from the Bashkirs by one of the Demidoff family, and sold to the brothers Gubin of Moscow. The population of Nijny Serginsk is 2609, that of the adjacent establishment of Aligsk 450. They are both iron-works, are admirably managed, and the workmen and their families most comfortably lodged, well-fed and neatly dressed.

they pass, however, into amorphous masses of quartz rock, in which nearly all traces of bedding are obliterated, whilst points of intrusive greenstone appear at intervals.

He who disbelieves in the theory of metamorphism may here be convinced of its truth. In the short space of a mile, since he can walk upon the edges of the partially altered beds of grit and schist, until he finds them converted into amorphous quartz rock, in contact with highly crystalline greenstone, a rock which, from its composition and from the part it plays in all parts of the world, is now admitted to be of igneous and intrusive character.

We came to the conclusion, that this sandstone and quartz rock are of the age of the millstone grit, because certain limestones which rise up behind them are clearly referable to the carboniferous limestone. In the environs of this Zavod we could not, it is true, discover any clearly definable organic remains, so very much had the rock been altered; but the strata having a persistent strike from south-south-west to north-north-east, we observed that in following the same calcareous courses from Nijny Serginsk to the north, they became less altered, and regaining in a few miles the character they present upon the high road near Grobovo, contained many carboniferous fossils (*Bellerophon*, *Pecten*, *Cyathophyllum*, &c.). By tracing these calcareous fossiliferous masses to the south-south-west or towards the points of eruptive matter, the changes are most marked. In the quarries where the limestone is extracted as a flux for the iron ores, it is first found to become highly fetid, veined and heavy, and next it is thrown over in arches and domes, the angles of inclination varying at every step. In this condition, though the rude outline of organic bodies is discernible, no distinct forms can be traced. Passing on to the south of Nijny Serginsk, the limestone, in a metamorphic amorphous state, rises abruptly into a low ridge which presents a rude escarpment to the river Sirga, from the base of which the mineral spring issues.

A close analysis of mineral waters formed no part of our scheme, and we therefore contented ourselves with tasting the spring, which is very copious, and much resembles that of Harrowgate in Yorkshire, being equally, we believe, saturated with sulphuretted hydrogen. The chief geological interest, however, consists in the fact, that whilst the limestone from which the spring issues is a highly crystalline amorphous mass, in which all traces of bedding and fossils have disappeared, and angular joints and rifts pass through it in all directions, hills of porphyry and greenstone rise up beyond and almost encompass this altered rock, as represented in this woodcut.

51.

Having thus we hope clearly explained the causes of the dislocation on the high road, which have been produced upon a line of eruption from south-south-west to north-north-east, or parallel to the adjacent portion of the Ural, we may now return to the main section across the chain, merely stating by the way, that we traced for some distance westward or down the affluents of the Ufa, a pebbly calcareous grit with plants, similar to that which has been described on the high road from Perm to Ekaterinburg, and that we found it to overlie the carboniferous rocks of this tract[1]. We may also mention, that already the difficulties of making any traverses of the Ural except by practised roads became apparent; for upon expressing a desire to travel on horseback or on foot across the Ural from this point to Ekaterinburg, distant in a straight line little more than sixty versts, we were informed by the manager of the Zavod that no Russian ever attempted it, and that by no effort could we accomplish it.

Section across the Ural resumed.—To the east of Grobovo, the road runs in one of the lateral depressions, and little stony matter is to be seen. The absence of all coarse detritus is, however, a phænomenon which cannot but surprise every geologist

[1] In a journey made by Count Keyserling, subsequent to that which we now describe, many fossils were collected which throw the clearest light on the age of the grits of Artinsk. See ante, p. 128, where we describe a section, including an undulation of Devonian rocks, from Nijny Serginsk to Sarana.

accustomed to other mountain chains, for he has now absolutely reached the foot of the central ridge of the Ural, in which there are many lofty peaks, and yet not a single far-transported block can be detected.

At Tcheremtsal, twelve versts east of Grobovo, the rocks are found to have participated in the altered character of the chain; for the low counterfort between this station and the river Tchussovaya is composed of shivery, slaty, crystalline limestone, in which no stratification is apparent. This stream, so useful in transporting ores and merchandise from the Ural and Siberia to the Kama, and thence to the Volga, becomes navigable near the point where it is traversed by the road (north of Bilimbayevsk). As stated in the introductory pages, it is one of the only rivers of the chain with which we are acquainted, which in its origin seems to flow through the central ridge. The rocks, amid a depression of which it winds obliquely from the uplands, are evidently a fair sample of the structure of the axis in this parallel.

Facilitating our examination on every point by his admirable and clear arrangements, General Tcheffkine, the chief of the staff of the School of Mines, had directed Captain Karpinski to survey the banks in this upper part of the Tchussovaya previous to our arrival, and this able engineer showed us the specimens of each band of rock on our arrival at Ekaterinburg. This proved the more interesting to us, as the high road over the ridge offers very little of interest. Proceeding from the sources of the river, these rocks consist, according to Karpinski, of—

1. Bosses or bands of granite, the direction of which is from south-south-east to north-north-west. 2. A broad band of schistose chloritic rocks, separated from the granite by porphyritic hornstone. 3. Varieties of schistose, slaty, porphyritic felspar rocks with serpentine. 4. Gneisose and micaceous schists. 5. Quartz rocks and grits; on the rivulet Kurganova associated with iron ores, and at Makarova with kidney iron ores (hematite), and decomposed felspar. 6. Black, shivery, pyritous, slaty schist. 7. Whitish-grey and greenish, granitoid greenstone (syenite). 8. Chloritic and quartzose rocks with vein stones. The preceding rocks are found in the course of the stream from south-east to north-west. 9. Marble in contact with and in proximity to greenstone. This rock is seen near the point where the river first turns to the north and west. 10. Serpentinous schist and finely laminated chloritic schist and sandy grauwacke schist, not unlike many Silurian or Devonian beds. 11. Talcose schists and greenstone.

These rocks continue northwards to Bilimbayevsk before alluded to, on the high road, and from the above succession therefore, the reader may apprehend the nature of the whole nucleus of this part of the Ural, which cannot be well seen without following the gorge of the Tchussovaya.

Having thus learned, that no strata with organic remains were visible near the axis, but that all the limestone, sandstone and schists there associated with the greenstone, porphyry and other igneous rocks, were highly altered and crystalline, we resolved to complete our survey by descending the Tchussovaya from near the spot where it becomes navigable, and where the sedimentary rocks, receding from the great lines of eruption of the Ural, resume their ordinary characters.

As this examination of the banks of the Tchussovaya was, however, connected with a traverse of the Ural on another parallel, and also with a descent of the Serebrianka river, we shall postpone our account of that operation until we have completed our first general section to the most eastern point explored.

We therefore return to our general section. Near Bilimbayevsk (a Zavod of the Strogonoff family), the Tchussovaya, where the high road crosses it, flows in reddish alluvia, but immediately to the east of the stream talcose schists with granular limestone and iron ore[1] announce that you are already in a portion of the crystalline axis. The gentle ascent of the road, over which Russian horses travel nearly as fast as in descending, is conducted on a smooth talus on which no rocks protrude, and it is from the detritus only that the geologist can suppose he is passing over the talcose, quartzose and metamorphic rocks, so apparent in other central parts of the chain. To the east of Vassilivrask, asbestiform, serpentinous schists mount into a round knoll, and near the post station of Talitza, greenstone is apparent at the surface; but from the latter place to the summit no rock whatever is seen *in situ*. The summit level of the road (the lowest pass in the whole range of the Ural) is not 1400 English feet above the sea, and does not exhibit any marked asperities, the rocks being only discernible in openings amid the fir-trees on the sides of the road, where they are seen to consist of a large-grained hornblendic greenstone or syenite, which, as far as we could judge, seems to have pierced through chloritic and talcose schists[2]. Shortly beyond and at the station of Reshetsk or Reshety, where the water already descends to the east, granite rises above the surface in low masses, which, from the decomposing felspar, have assumed in weathering the appearance in miniature of the tors of Cornwall. Thence to Ekaterinburg the sloping route exposes little else than blocks of granite, which disintegrates into a sandy soil.

We do not profess to have examined all the varieties of rock in the environs of this metropolis of the Ural. We could not, however, avoid noticing, that talcose and chloritic grauwacke schist and clay-slate are thrown about in the eastern

[1] M. Rose describes crystals of magnetic iron ore as being disseminated in this talc schist.

[2] The Volshaya or Bolshaya Gora, or summit above the road, is stated by Humboldt to be from 377 to 380 French toises, or rather less than 2500 English feet above the sea.

part of the town at various angles of inclination, that the observatory is built upon a boss of serpentine, whilst hummocks of that rock and greenstone protrude here and there even in the streets. As to many of the rocks in the immediate precincts, we should say with M. Rose, to whose admirable description we must refer, that with the exception of unquestionable igneous rocks, such as granite, greenstone, porphyry and serpentine, they have often the undecided character of altered schists, preserving still some imperfect traces of their original structure, and not having assumed any specific form[1]. Numerous other varieties of rock, including varieties of aventurine, might be cited, and many beautiful and peculiar simple minerals. Of the latter, indeed, our associate Lieut. Koksharof has prepared for the use of English readers a list which will be given in the sequel[2]. Among the phænomena exhibited in or close to Ekaterinburg, it is however important to remark, that crystals of magnetic iron are disseminated both in the serpentine and adjacent chlorite schist; and that the granite which cuts through the serpentine in dykes, is the youngest intrusive rock of this neighbourhood. (See Rose, vol. i. p. 172 *et seq.*)

Descent of the Issetz River to Kamensk and Kaltchedansk (Siberia) (continuation of Section, Pl. II. fig. 1.).—In the great flat regions of Russia, whether in Europe or in Siberia, the truest method of ascertaining the nature of the subjacent rocks and their relations is to descend the rivers, or frequently to examine their banks. In Russia—even on the noble Volga—whenever we put this in practice, our patience, indeed, was sorely tested, so uniform and wide-spread is one formation only, over such vast countries do the very same beds extend, and so hidden are they in numberless places by vast mounds of superficial detritus. Very different is a river section on the Siberian flanks of the Ural. There, though the country is equally flat, the surface is never more than slightly encumbered with clay, sand or local debris, and never obscured by far-transported numerous blocks or boulders; whilst its subsoil, composed of hard and crystalline rocks, presents new features at every step. Such, at all events, we found to be the case in boating down the river Issetz.

[1] A stratified rock which M. Rose describes in the neighbourhood of Ekaterinburg, near the polishing works, parts of which contain lime with crystals of hornblende, and other parts have the characters of an augite porphyry—exhibiting a transition from a whetstone slate to porphyry—is what we should call schaalstein. See on pp. 363 *et seq.*

[2] At Ekaterinburg we were cordially assisted by the chief authorities, General Glinka and Colonel Tchaikovski, as well as by the head mechanical engineer, Mr. Tait. Among kind private friends we must specially mention M Borisdin, M. Arsenieff, and their agreeable families.

Convinced that a true acquaintance with the substrata could best be acquired in this manner, we requested General Glinka, the commander of the North Ural mining country, to make arrangements to enable us to accomplish our wishes, which he most obligingly and effectively carried out, by entrusting us to the charge of M. Schultz, the chief of the forests of this arrondissement. This excellent and judicious administrator, forewarning the authorities and inhabitants of our approach, prepared canoes at each little village on the banks of this stream, from the point at which we proposed to begin our descent.

Looking back from Ekaterinburg to the Ural, the traveller can scarcely recognise the chain he has passed, so imperceptible is the slope; the gay spires and towers of the town itself, 850 feet above the sea, seeming simply to rise out of a slightly inclined woody region. For some leagues to the east of Ekaterinburg, the base of this tract is essentially granitic, with aventurine and other metamorphic rocks, the granite very frequently assuming a thin-bedded or jointed structure.

We travelled rapidly over that space in our "tarantasses[1]" and joined the Issetz near the station of Loginof, forty-seven versts from Ekaterinburg, and where the river becomes deep enough even in dry weather for the navigation of small boats. Here taking to the canoes, we soon learnt to how much trouble we had exposed a whole population in order to satisfy our geological inquiry. Flowing with some rapidity from the eastern slopes of the Ural and through a thickly peopled tract well covered with grain, the inhabitants naturally avail themselves of this stream to grind their corn, damming it up to establish the necessary mill-races. At each village, therefore, often not more than a mile asunder, we were compelled to disembark and walk round the dam, whilst the boats were lifted over by numerous peasants assembled at each station for the purpose. The opposite lithograph will afford some idea of the scene at Volchof, of which we shall presently speak, and where the river escaping from the higher defiles enters into the flat country of Siberia.

Following, in this way, the windings of the Issetz for two days and examining all the rocks on its banks, we made the section which is given on the right-hand or eastern end of Pl. II. fig. 1, *i. e.* from Ekaterinburg to Kaltchedansk.

The rocks we first observed on the banks of the stream, after quitting the granitic plateau, were green micaceous chlorite schists, which are again succeeded

[1] The "tarantass," which is the carriage of Eastern Russia, has the body of a calèche on long elastic poles which serve as springs. In a subsequent view one of these vehicles is sketched.

GEOLOGISTS DESCENDING THE RIVER [illegible] by strong reefs of rose-coloured granite. This system of micaceous rocks, occasionally exhibiting intrusions of granite, syenite, &c., continues to beyond the mill of Paulkin and the village of Mamniskaya (about twelve versts by the turnings of the Issetz), where it is succeeded by another class of rocks. The chief masses at Mamniskaya consist of bluish calcareous flagstones, with veins of white felspar, which apparently graduate into and alternate with a contemporaneous bedded trap-rock, not unlike the "schaalstein" of German geologists, so largely associated with the palæozoic strata upon the rivers Lahn and Rhine[1]. These trappean rocks, increasing in volume as you descend the stream, have, however, a peculiar aspect. They are very felspathic, approach, here and there, to the character of serpentine, contain much disseminated carbonate of lime, and after all leave the observer frequently in doubt, as to whether they really are sedimentary strata or not. At the hamlet of Tiomna they are boldly displayed. At Bielobor these bedded rocks (schaalstein), contemporaneous, we believe, with the limestones, rise up at a high angle against an *intrusive* porphyritic greenstone, which is succeeded by black limestones of considerable thickness, inclined at a very high angle to the west, and resting upon carbonaceous shale. These beds, the first in which we saw fossils in Siberia, unequivocally belong to the carboniferous limestone, for we found in them *Productus gigas*, *Spirifer striatus* (Sow.), and several characteristic corals. The schists which followed are contorted and afterwards thrown off around a nucleus of trappean amygdaloid, which is succeeded by a considerable development of highly crystalline greenstone, some of which, from the predominance of felspar, may be called "graystone"[2]. These eruptive rocks occupy both banks of the river at Smolino (our station for the night), and also for some versts below it, where rising to rather greater altitude than the contiguous strata, they constitute a rugged and picturesque defile, as at Bielobor.

A point of compact felspar porphyry (eurite) protrudes among the blue schists, which are next observable, and which alternating with grits, often resemble the culm beds of Devonshire, like which they fold into numerous flexures dipping both to the east and west. We detected nothing in these schists but minute fossil plants —chiefly grasses—another point of analogy to the culm strata of Devonshire and the "flötz-lehrer-sandstein" of the continent; whilst the occurrence of *Productus gigas* and *P. pustulosus*, in an adjacent rock at Zaimskaya, further indicated the continuance of the carboniferous deposits. At Kadinskoi, however, a limestone

[1] See Trans. Geol. Soc. vol. vi. p. 249.

[2] See Scrope, Geol. Trans. vol. ii. p. 214.

rises in an arch from beneath these schists and grits, and as it contained the *Terebratula reticularis*, a shell never found in the carboniferous rocks, associated with casts of large Euomphali, we consider it to be Devonian. The courses of limestone and schist which extend to the mill of Tcherdinsk seemed to be repetitions, and we could not resist the impression, that the great masses of rapidly undulating limestone and schist near the village of Swagba, as well as certain black calcareous schists by which they are covered, were also of the true Devonian age, for they are covered by other limestones, schists and grits, which are clearly carboniferous. Whether the same neat division between the Devonian and Carboniferous limestones can be read off upon the Issetz, as that which we shall presently indicate upon the Tchussovaya on the west flank of the chain, must be determined by longer observation and a further discovery of fossils. Nor can we pretend to decide, whether the siliceous conglomerate and sandstone with some traces of coaly matter, which overlie the black schists and underlie the carboniferous limestone, ought to be grouped with the one or the other of these systems. For the present we must content ourselves with expressing our belief, drawn from the analogy of succession in other parts of the Ural, that the lower black schists and limestones on the Issetz are Devonian.

Adopting this view from the order of superposition upon the river, we were the more disposed to adhere to it, when in subsequently extending our researches into the interior, we found other schists and sandstones, sometimes red and green, with coarse grits and conglomerates, flanked at Bagaratz by true carboniferous limestone containing large Producti. A tract like this, perforated at numerous points by porphyry, greenstone and other eruptive rocks, cannot be expected to offer a regular sequence of ascending or descending order of deposits; the necessary result of such intrusion being, that in the numerous contortions and breaks to which the invaded strata have been subjected, they are often so bent back, that the older strata are placed above the younger,—a phænomenon now so clearly pointed out in other disturbed countries, that it is unnecessary here to dwell upon it[1].

A few versts to the south of the Issetz, we found, indeed, distinct proofs that sedimentary strata, older than any we saw in the gorges of the Issetz, had been forced up into the adjacent plateau. On the banks of a little stagnant streamlet called the Istok, and at the villages of Crasnoi-glasnova and Gashin-novo, three or four versts asunder, a small dome of light-coloured, whitish-grey, crystalline

[1] See Silurian System, pp. 421, 423 *et passim*.

limestone, rises in low protuberances through the rich black earth. This is most probably an Upper Silurian rock, for it is absolutely made up of Pentameri, some of which, of great size (a variety of our *P. Vogulicus*), are closely allied to the *Pentamerus Knightii*. It will afterwards be shown, that such a rock appears in other parallels of the Ural, even in the richest mining tracts, in describing which we shall more specially advert to the specific forms of the shells, since those at Crasnoi-glasnova were so welded into the rock, that good specimens were not to be obtained. In the mean time, this short digression has been made in order to show, that even in this tract there was once a palæozoic succession from Upper Silurian to carboniferous strata, however difficult is the task of now putting together their disjointed fragments.

Returning to our traverse by the river (Pl. II. fig. 1.), the lower black limestones, schists, grits, &c. on the Issetz, which we consider Devonian, are succeeded on the east by a very copious development of limestone, which is unquestionably carboniferous. For some distance this rock is almost in a crystalline condition, its surfaces are much eroded, and numerous indentations and fissures are loaded with the hydrate of iron. Near the gorge called Petersgal (Peter's gate), this limestone rises up into serrated and picturesque forms, about 200 feet in height, amid which the river winds, the cliffs exposing caverns at heights of upwards of 100 feet above the water. Though much thrown about and contorted, this rock occasionally resumes the ordinary aspect of the English mountain limestone, and contains characteristic fossils[1].

To the west of the shale which flanks this mass, the banks of the river become lower, and the first visible strata near the village of Bayanova are altered limestones, with bedded trap, or schaalstein, in which copper ore occurs, with some nests of malachite; whilst the chief rock of the track is a red quartzose porphyry, somewhat different from any seen in the higher part of the Issetz, and which passes here and there into eurite and compact felspar rock. To the north of this point lies the Imperial Zavod of Kamensk[2]. When thrown off by the porphyries exposed on the Issetz, the carboniferous limestone occupies four or five distinct ledges, and as along the Issetz, reposes on conglomerates and grits, which constitute, therefore, either the base of that system or the upper part of the Devonian.

[1] *Productus gigas*, *P. striatus*, Fisch. (*anomala*, Sow.), *Spirifer striatus*, *S. glaber*, Sow., *Caryophyllia fasciculata* (Flem.). Another coral seen by Mr. Lonsdale seems to be a new species of Lithodendron.

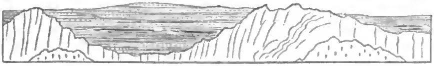
[2] At Kamensk we were hospitably entertained by Major Barotzi, director of the Zavod.

Tertiary Millstones of Kaltchedansk.—Having satisfied ourselves of the existence in this part of Siberia of a palæozoic succession from a metamorphic axis, which had been broken up by porphyry and other intrusive rocks, we next wished to ascertain the nature of a deposit, which we had heard of as yielding the finest millstones of the region, and also some traces of coaly matter. We accordingly re-embarked and descended the Issetz to the village of Volchof, where the river begins to quit the plateaux and wander in the wide plains of Siberia.

From Bayanova to Volchof (the village represented in the lithograph facing p. 358), the cliffs are essentially composed of porphyry, which occurs both in vertical and laminated masses, and also in bosses which peer out irregularly at intervals, the former conveying to us the idea of having, like the schaalstein, been formed contemporaneously with the palæozoic rocks, the others being of the age of the greenstones and porphyries which have thrown up the Ural chain.

The hills of Krasnoi-gora on the left bank of the stream, about 150 feet high, offered us a clear section of the porphyries, and also of the millstone grit of which we were in search, and at once taught the origin, age and structure of all the strata which cover the adjacent plateau of Kaltchedansk; as shown in this woodcut.

52.



These grits are, in fact, part of what we believe may prove to be wide-spread tertiary accumulations in Siberia, and they owe their peculiar character to having been derived from the quartzose, porphyritic and other intrusive rocks on which they rest, and out of whose materials they have been entirely composed. Thus, some of these courses consist of white and greyish clays, arising from the decomposed felspar—often by no means a bad potter's clay, in which leaves and remains of wood have occasionally been transmuted into a poor brown coal, with which small portions of amber are here and there associated.

The grits which occupy the highest part, range from the banks of the Issetz into an arid plateau, and to the north side of the high road to Tobolsk, are cut into by a number of shallow pits (twenty to thirty feet deep), the beds being everywhere perfectly horizontal. The extracted blocks of millstone cover the surface for about a square mile. The best millstones occur in beds from two to three feet thick, and are worked from beneath a roof of less valuable grit, where though perfectly horizontal, they have somewhat of a concretionary shape, and are brought out in lumps from six to seven feet long, which have often a rusty-ferruginous, occasionally a green exterior. Thin beds of sand and clay (wayboards) fold irregularly round these concretions, which to some extent reminded us of the tertiary "meulières" of the Paris basin. If we had not first viewed the section at Krasnoi-gora on the Issetz, where these beds, regularly and horizontally stratified, lie upon the igneous rocks, we should have had some difficulty in believing that they were entirely of aqueous origin, so much has the detritus of these quarries a trachytic and vitreous aspect[1], and so much did the grating of the debris under our feet remind us of some of the trachytes of Auvergne. Hand specimens may, indeed, be selected which approach to the character of pitchstone and the trachytic grits of Hungary.

Though the section at Krasnoi-gora on the Issetz exposed the millstone grits near the upper surface, yet the ravines at the village of Kaltchedansk showed them to be overlaid by forty to fifty feet of thick and thin beds of grey mudstone or claystone somewhat compact, of conchoidal fracture, and covered by a bluish and softer finely levigated mudstone. In a pile of detritus lodged in an adjacent hollow, and derived from these beds, we found several fragments of amber.

From the horizontal and undisturbed condition of all these overlying strata, it is evident they have been accumulated after the most violent agitations which the Ural chain has undergone. Similar beds extend, in fact, far to the north along the lowermost slopes of the Ural chain. At Verkhoturie, where they also surmount igneous rocks, they have been described by M. Rose, but neither in that tract, to which we shall hereafter advert, nor at Kaltchedansk, could we detect organic remains in them. On our Map, therefore, we have simply inserted them (under a yellowish colour) as tertiary deposits, of the age of which we are ignorant. Some persons, on account of their imbedded lignite and amber, might argue for their assimilation to the German strata of clay and sands with brown coal. Others may conceive they were accumulated in a vast basin of fresh water, which separated

[1] These rocks were inaccurately described by M. Tchaikovski as containing Olivine and Leucite. They are simply grits made up of fragments of porphyry, and grains of quartz of different colours, in a felspathic base. See Journal des Mines de Russie, 1830.

from the other tertiary and oceanic deposits, may have occupied a great space in Siberia during a more recent period. But we cannot here wander into such speculations, and having completed the description of one complete traverse of the Ural Mountains and their dependencies, from the low country of Europe on the west, to that of Asia on the east, we would now transport our readers to other tracts and sections of the North Ural, there to fill up the lacunæ in this first sketch, which simply narrates the leading features detected by passing geologists in one journey across a tract, having a width of upwards of 300 versts.

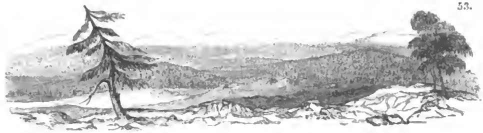
Chief Phænomena in the Districts immediately to the north of Ekaterinburg.—In journeying from Ekaterinburg to the northern mines, the tourist passes along the lateral eastern valleys of the chain in which, and on the banks of their lateral streams, gold alluvia have been largely deposited and much worked[1]. Neviansk, the oldest Russian Zavod, established by an ancestor of the Demidoffs, is the first pleasing relief offered to the eye of the traveller, who has passed through a half desolate tract between it and Ekaterinburg, in most of which the forests have been exhausted for the use of the contiguous mines, whilst culture has not yet made much progress[2].

Small hills, composed of porphyry, serpentine and other eruptive rocks, range to the east of the Zavod, which, with its large buildings and gay churches, lies in a depression between the low trappæan ridge and the eastern counterforts of the Ural. Where exempt from the local alluvia and detritus (often auriferous), this depression consists essentially of limestone, which from several corals discovered in it (*Favosites polymorpha*, Devonian variety of *Amplexus tortuosus?*, *Caunopora ramosa?*, &c.) we may consider Devonian. These limestones, with associated schists, strike north and by east, south and by west, or exactly parallel to the axis of the adjacent portion of the chain. The Ural, as seen from this comparatively low tract, has no longer the dim and scarcely perceptible outline which it assumes in the parallel of Ekaterinburg, but appears as a narrow, bare ledge, rising up in the distance, and separated from the spectator by subconical undulations covered with wood, as represented in this hasty little sketch.

[1] These gold alluvia, including those of Berezofsk near Ekaterinburg, will be considered in the sequel.

[2] The foreigner who is making his first excursion in the Ural, cannot but feel when he arrives at Neviansk, that he is in a land of true hospitality; for a large and comfortable house is kept up by the proprietor of the mines for the use of all strangers, from none of whom is any exaction demanded.

53.



When examined in detail, where any quarries or openings have been made, the relations of the intrusive rocks to the sedimentary are very instructive, even around Neviansk; for whilst the coralline limestone in the valley is little altered, yet nearer to the eruptive hills it is in the state of crystalline white and green marble, from which a statue of the late proprietor has been constructed.

Again, in the hillocks forming the fore-ground of the sketch, the igneous rocks, graduating from greenstone to porphyry and felspar rocks associated with serpentine, are seen traversing talcose schists, much dislocated and altered, with occasional coatings of magnetic iron ore [1].

Nijny Tagilsk.—Besides the coralline Devonian limestone, which is traceable for about twelve versts, chloritic schists and quartzose rocks, with various eruptive masses, lie on either side of the route between Neviansk and Nijny Tagilsk. The latter, the chief Zavod of the Demidoff family, with a population of 22,000 souls, is truly a well-ordered town, in which the comfortable dwellings of the workmen, the capacious hospitals for their relief, the schools for the education of the youth, the elegance of the public buildings and houses of the chief managers, and above all the skill with which the machinery, forges and works are conducted, would reflect the highest credit upon any European establishment [2].

If mineralogical details and all the shades of transmutation which sedimentary rocks have undergone during former operations of nature had been our object, a residence of a whole summer, instead of two or three days, might have been well and instructively passed in this most remarkable spot, the centre of a vast property; and where, by the instructions of M. Anatole Demidoff, we were received as if he had himself visited his mines, and were treated with overflowing kindness by his accomplished agents MM. Danilof and Schwetzoff. Baron Humboldt and M. G. Rose have however, to a great extent, supplied what may be deficient in

[1] The population of this Zavod is 17,000, and the inhabitants have a fine rural healthy appearance.

[2] The artificial lake for working the mills is of very graceful form and of some extent, and a little *steam-boat* was employed upon it.

our brief survey of Nijny Tagilsk, particularly in reference to the structure of the adjacent ridge of the Ural, which we did not visit, though we traversed it on two parallels further to the north.

The chief features which arrested our attention here were, first, the geological age of the strata; secondly, the chief metamorphoses they had undergone, and the agencies by which such changes had been effected.

Like many other Zavods along the eastern flank of the Ural, Nijny Tagilsk is situated amid low hills of eruptive rocks with interjacent masses of sedimentary strata, most of which have undergone great alteration, and which usually have a crystalline or sub-crystalline character. The junctions of these two classes of rock or their immediate neighbourhood, are the seats of the chief veins and masses of mineral ore which render this locality so productive; whilst alluvia with gold and platinum choke up some of the adjacent transverse valleys that radiate from the central mountains.

Notwithstanding the numerous points of eruptive rocks (for the most part hornblendic greenstone or amphibolite), and the great diffusion of altered rocks in their vicinity, patches of limestone are wedged in at intervals, which not having undergone much change, contain sufficient organic remains to enable us to say, that the rocks in which they occur are of Upper Silurian age. This limestone, which is both of dark grey and whitish or cream colours, according to the lesser or greater amount of alteration it has undergone, contains a Pentamerus closely allied to if not identical with *P. Vogulicus*, a turriculated shell which can scarcely be distinguished from the Gothland species *Murchisonia cingulata* (*Turritella*, Hisinger), and a fragment which we refer to the *Orthoceratites calamiteus* (Münst).

Magnetic iron and its relations.—The limestones above-mentioned appear to have been rent in twain by a narrow ridge or wedge of intrusive hornblendic rock (greenstone), which extending from the Zavod to the north, rises into the Vissokaya-gora or high hill, on the summit and flanks of which magnetic iron ore has long been extracted. From the short time we employed in the examination of this magnetic rock we cannot pretend to offer a satisfactory explanation of the relation of the iron ore to the adjacent greenstone[1]. We may, however, add a slight contribution to what has been already published, particularly as the mines were much

[1] Hermann, who first described these rocks, speaks of this trappean ridge as barren (of mines) "taube,"—a sort of porphyry passing to jasper, and containing white felspar and a little quartz. Miner. Beschr. des Ural, b. i. ss. 306, 309, 312. Rose did not examine this rock, but adds, that from the analogy of other rocks of magnetic iron, and what has been written concerning them, it is probably an augite porphyry with Labrador. Reise, vol. i. p. 311.

more laid open at the period of our visit than when they were inspected by Baron Humboldt and his associates. On the summit and slopes of the Vissokaya-gora patches of the ore (usually compact and with a conchoidal fracture) have been extracted from a very remote period; but whether these metallic masses are merely the upper portions of veins which traverse the surrounding rock, like those in the magnetic hill of Blagodat described as dykes by Colonel Helmersen[1], or mere adherent superficial patches which occupied cavities and clefts in the greenstone, we could not ascertain. However this may be, the chief mass of the ore is now seen to occupy the valley on the western side of the hill, for it has been deeply cut into by open quarries. The refuse stuff or capping of decomposed felspar and mixed matter with hydrate of iron having been cleared away, an enormous body of the iron ore (fer oxydulé), rudely bedded and traversed by numerous joints, is exposed by great works along a face which, including the useless overlying materials, has a height of nearly a hundred feet and a length of several hundred. When on the spot it seemed to us possible to account for the appearance presented by this metallic accumulation, most of which is now but little solidified, either by supposing it to have been of plutonic origin, and that, issuing from fissures on the hill side, it had flowed, when in a molten state, into the hollow where it lies; or that it was formerly a mass of sedimentary materials which had been altered and mineralized by heat and vapours, which making use of parts of the surrounding limestones as a flux, had elaborated this metallic substance. A feature pointed out to us by M. Schwetzoff may serve to throw some light upon the question of the origin of the iron. In opening out the side of the valley nearest to the hill of greenstone, irregular knobs or points of that rock were met with, on stripping which it was found, that the iron ore had accommodated itself to the inequalities of their surface, and that at such points of contact the ore was not only harder and more crystalline than usual—in fact almost unmanageable by the workmen—but also much more magnetic than at a short distance from the greenstone. Now, if the observer were furnished with no other data than these, he might, reasoning from the countless analogies of metamorphism which result from the eruption of igneous though sedimentary matter, infer that the greenstone intruding into ancient materials had, in producing a change throughout their whole mass, rendered those

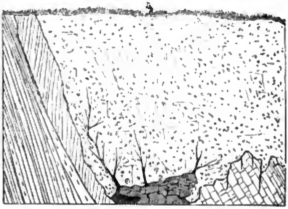
[1] Der Magnetberg Blagodat am Nordlichen Ural, von G. Helmersen, 1837. Colonel Helmersen in this memoir has very properly corrected the errors of previous authors, one of whom had spoken of the iron ore at Nijny Tagilsk as overlying the limestone, a second as associated with grauwacke, and a third as a mass in chlorite schist.

parts only which were in contact with it the most crystalline and metallic, by the development at such points of the most powerful electrical action.

We leaned, we confess, when on the spot, to this opinion; but, after having read the memoir of Colonel Helmersen upon the origin of the magnetic iron ore of Blagodat (which we regret we were unacquainted with when we examined this tract), we are bound to admit, that the phænomena at Nijny Tagilsk may possibly be explicable in accordance with his views, and that the metallic iron ore may have penetrated the pre-existing greenstone of the hill and thence have flowed as submarine lava or volcanic mud into the contiguous depressions. The facts that the ore expands in width, thickness and dimensions as it is followed into the lower parts of the valley, and that it fills up all the sinuosities of the subjacent rock, seem, on the whole, to favour this view, to the consideration of which we shall recur in the next chapter.

Copper ores and great mass of Malachites.—In the adjacent cupriferous ground at Nijny Tagilsk, nests and veins of copper ore have been found in the hollows between the eruptive rocks; and although the largest mass of cupriferous ground lies at some little distance (nearly an English mile) from the chief mass of iron ore, igneous rocks arise on all sides of it. Here, however, the matrix is very different from that of the iron ore. Instead of overlying and associated clay, the copper ground is flanked on one side by a rock much resembling the schaalstein or bedded trap of which we have spoken upon the river Issetz, and which highly inclined and sometimes vertical, seemed to be affected by powerful faults as represented in this woodcut.

ROUGH VERTICAL SECTION OF THE COPPER GROUND AT NIJNY TAGILSK.



54.

The ore being worked in shafts, and not like the iron in open quarries, we are by no means certain that this rough drawing, which we made when we descended the mine, represents the whole case with precision. Our sole object is to show, that in a space between ridges of eruptive rock, and bounded by a wall of schaal-stein, which is itself to some extent impregnated with copper, a considerable mass, in a much more incoherent and broken condition, is the chief mining ground[1]. This cupriferous deposit may be nothing more than a broad vein, though it seemed more to resemble a slightly consolidated heap of detritus which had been tumultuously aggregated in this hollow, at a period of convulsion, when the subjacent rocks were invaded by some sort of igneous action, and all the strata were broken up and re-arranged. In proof of this, points of limestone, the surfaces of which are irregularly eroded, polished and worn into depressions, as if by water, protrude from beneath into the matrix of copper stuff, in the manner described in the previous sketch. Though nearly all traces of bedding are obliterated, this limestone is still sufficiently characterized by the large Pentameri which it contains, to enable us to consider it of Upper Silurian age. That the copper has been accumulated subsequent to the consolidation of the adjacent palæozoic strata, is, indeed, evident; since, independent of their dislocated condition, rolled pebbles of the limestone have been found in the heart of the mining stuff. We were also assured by M. Schwetzoff that rounded and rolled lumps of the magnetic iron-ore also occur in this cupriferous mass; a fact which must induce the belief, that the agency which developed the copper ore, though probably also connected with the evolution of mineral springs, was in play at a different and posterior epoch.

The copper ground we have been describing having been excavated by shafts, an enormous mass of malachite was recently detected at the depth of 280 feet. Thin strings of green copper ore occurring at intervals were followed downwards, when increasing in width and value, they were found to terminate, at the base of the present mines, in an immense, irregularly shaped botryoidal mass of solid malachite, the form of which, as far as its lower part has been laid open, is represented in the preceding drawing[2].

The base of this valuable mass has not yet been traced, but when we examined

[1] For all the varieties of copper ore and other minerals which occur here, see the work of M. Rose, which has completely superseded the faithful but now rather antiquated descriptions of Hermann.

[2] Mr. Murchison brought a model of this mass from Nijny Tagilsk, which was presented to him by the Directors.

it, the surrounding matrix had been cleared away from its summit and sides; and if our notes taken on the spot are accurate, the summit alone has a length of about eighteen feet and a width of about nine feet, an enormous bulging mass being exposed beneath, the extent or base of which was not fully ascertained. The whole of the surface, however, which had been uncovered was calculated to contain not less than 15,000 poods, or upwards of half a million of pounds of pure and solid malachite.

The geological interest attached to this mass lies in the indication it affords, that the substance called malachite has been formed by a cupriferous solution which has successively deposited its residue in the stalagmitic form. "Mutatis mutandis," this mass has only to be viewed as formed of calcareous spar, and it presents every one of the features so well known to those who have examined stalactitic grottos with their stalagmitic floors in the clefts and caverns of limestone, or still more those large masses of tufa which have proceeded from calcareous wells. Wherever a portion of the malachite has been broken off, the interior is seen to consist of a number of fine laminæ (a fasciculus of radio-concentric globules), which invariably arrange themselves equably around the centre on which they have been formed, and are adapted to every sinuosity of the pre-existing layer; here presenting a dark line, there a bright and light one; just as the solution of the moment, the day or the hour, happened to be more or less impregnated with colouring matter. Besides round concretions, sometimes almost spherical, and also depressions of the surface, the under sides of this malachite are singularly analogous to that of any large mass of calcareous tufa, in presenting pendent, finger-shaped stalactites, which are also composed of concentric laminæ. The external surfaces of these concretions are frequently covered with a black ore of manganese which usually falls off on being touched.

When we examined this mass of malachite, much of the surrounding matrix had been removed, and it presented precisely the aspect of having been deposited in a depression of the limestone and schaalstein. On the whole, we are disposed to view it as having resulted from copper solutions emanating from all the porous, loose, surrounding mass, and which trickling through it to the lowest cavity upon the subjacent solid rock, have in a series of ages produced this wonderful subterranean incrustation. We would not, however, wish our readers to infer, that we have any authority for believing in the formation at the present day, of such cupriferous stalagmites, though it is *possible* that nature may in some tracts be still carrying on a similar process. Throughout all the great cupriferous region to the west of the Ural, we know, indeed, that the chief formation of copper was coeval with the close of the palæozoic æra, as proved by the similar structure of the Permian rocks, which, it has been shown, were themselves formed out of the detritus of a pre-existing Ural chain, and at a period when the surface of the earth and the bottom of the sea were affected by waters probably hot and charged with cupriferous matter [1]. At the same time it may be observed, that the geologist can occasionally as surely detect the relative ages of mineral masses by their mechanical condition, as if he were guided by superposition and a tabular order of organic beings. Thus one of the earliest changes which has been accomplished, is the metamorphism of the palæozoic strata, for at Lela Istostchinsk in the immediate neighbourhood of Nijny Tagilsk, a fossiliferous limestone is seen to pass into white granular limestone and talc schist, and fragments of such rocks are found in the cupriferous agglomerate. Again, magnetic iron is proved to have been one of the first of the great metalliferous products of the mountains, since rolled lumps of it are found in the copper ground, whilst the accumulation of the latter, coeval as we believe with the impregnation of the great Permian deposits of Russia, must in its turn have been anterior to the process by which the malachite exuded from the surrounding matrix, and was arranged in its present stalagmitic form.

These are the chief points to which we directed our attention at Nijny Tagilsk, to the country around which M. Anatole Demidoff is now applying so much scientific research, that we doubt not he will render it a school where some of the most curious metallurgical processes of nature can be best studied.

By reference to the Map it will be observed, that Nijny Tagilsk, like Ekaterinburg and Neviansk, as well as Kushvinsk, Turinsk, Bogoslofsk, and other places, to be hereafter described, is on the low but rich band of rocks which lies to the east of the culminating ridge and slope of the Ural. This north and south tract is, it will be observed, eminently calcareous, and at the same time the seat of some of the richest veins and masses of copper and magnetic iron ore; facts which may lead geologists to speculate upon the probable influence exercised by the limestone as a flux in the great metallurgical processes which nature has here elaborated. The limestones which are now visible appear, in truth, as mere fragments which have been broken up, occasionally transmuted into crystalline marble, and isolated by the eruption of igneous rocks, mingled with much serpentine and left in detached strips parallel to the principal chain. Without visiting many adjacent locali-

[1] Ante, p. 168.

ties[1], the collection alone which had been brought from them to Nijny Tagilsk sufficed to lead us to believe, that all the surrounding limestones were either like the Pentamerus limestone of which we have spoken as of Upper Silurian age or the oldest part of the Devonian. This inference applies, however, to the comparatively narrow tract only in which the chief mining works of the Demidoff family are situated. On its west rise up great igneous and metamorphic masses, which constitute the crest of the mountains, and separate the region in question from the palæozoic unaltered deposits on the Tchussovaya and its affluents.

To the east of Nijny Tagilsk and also within the Demidoff lands, lies another and much broader metalliferous tract, which differs from any zone upon the west, in being essentially *granitic*, though amidst it are other low ridges of syenite, greenstone and serpentine, all trending from north to south. Amid these intrusive rocks palæozoic limestones occur at intervals, and are often highly altered. In one specimen, however, we detected the *Chætetes radians*, a true carboniferous coral, which led us to suppose that this eastern tract might be viewed as a prolongation to the north of the palæozoic group we have described in the same parallel of longitude upon the river Issetz, where it is also associated with granitic, porphyritic and metamorphic rocks, the whole of which subside gradually into the plains of Siberia, where they are overlapped by tertiary accumulations (see p. 366).

P.S. After these chapters were written, our friend M. Le Play, the able mineral surveyor and metallurgist of whom we have already spoken in relation to the coal country of the Donetz, was sent by M. Anatole Demidoff to examine his Uralian mines. We had great pleasure in furnishing this gentleman with a copy (not then finished) of our general geological Map of Russia and the Ural, and particularly requested him to employ his leisure moments in verifying or correcting the observations we had made. Whilst these sheets were going through the press, M. Le Play addressed a letter to Mr. Murchison, which, in addition to some remarks concerning the different ages of the eruptive rocks, the limits of the unaltered palæozoic deposits on the Tchussovaya, and those of the more crystalline limestones around Nijny Tagilsk, contains a very clear account of the real nature and origin of the magnetic iron ore of these mountains. We are very glad to perceive that, both in the letter to ourselves, and in the one addressed to M. Elie de Beaumont,

[1] From the collections made at Nijny Tagilsk we recognized the Pentamerus limestone at the following localities:—Leba, and other places between it and Tchornoi Istostchinsk: Laisk, eighteen versts north of Nijny Tagilsk, where the *Favosites polymorphus*, *Stromatopora concentrica*, and stems of *Cupresso crinites* having been found, render it probable that the limestone there is Devonian. Again, at Vissimoshaitansk, near to which platinum alluvia have been described by Humboldt and Rose, and which, though in direct communication with and dependent upon Nijny Tagilsk, is on the western slope of the axis, Pentameri occur in a black dolomitic limestone mineralogically undistinguishable from rocks upon the Tchussovaya, which will be spoken of hereafter as Devonian.

(see Comptes Rendus de l'Institut, October 1844), M. Le Play states in the most unambiguous manner, that all these magnetic iron ores are of igneous origin, thereby confirming the view applied to Mount Blagodat by Colonel Helmersen, to whose observations we shall refer in the next chapter. M. Le Play shows, that as great accumulations of this ore are often essentially composed of felspar and hornblende and traverse other rocks, they must be considered igneously-formed masses, which, where the above-mentioned materials diminish and the magnetic iron prevails, constitute (particularly when half-decomposed) the productive mines of the Russians. The observations of so good an authority as M. Le Play, who has extensively studied the position of magnetic iron ore (fer oxydulé) in Spain, and who has found this ore to be more or less disseminated in the very body of many of the igneous rocks of the Ural, is of great value in the decision of this question.

CHAPTER XVI.

NORTH URAL OF THE MINERS—(*continued*).

Environs of Kushvinsk and Mount Blagodat.—Transverse Section from thence across the Chain to Serebriansk.—Descent of the River Serebrianka to its Mouth.—Descent of the Tchussovaya from Ust-Serebriansk to Ust-Koiva.—Transverse Section across the Ural from Ust-Koiva by Bissersk, Chrestovodsvisgensk and the Katchkanar, to Turinsk and Verkhoturie.—Environs of Bogoslofsk with Sections.—Descent of the River Kakva.—Conclusion.

THE same general character of rocks which prevails in the tract between Ekaterinburg and Nijny Tagilsk, extends northwards to Kushvinsk, and thence along the eastern flank of the Ural to Bogoslofsk and Petropaulofsk. Reverting to the consideration of the most northern of these districts at the close of this chapter, we will first take a rapid survey of the principal geological features around Kushvinsk, as a prelude to a second general traverse across the chain from thence to Serebriansk.

Brief Sketch of the Environs of Kushvinsk.—Immediately to the east of the Imperial Zavod of Kushvinsk[1] rise up the hills called the Greater and Lesser Blagodat (see Pl. II. fig. 3), upon and around which much magnetic iron ore has been extracted during a century. It was upon the higher of these mounts (described by numerous writers[2], from Pallas in former days, to Humboldt, Rose

[1] Colonel Galahofski of the Imperial School of Mines, Director of the Zavod of Kushvinsk, at the period of our visit, afforded us every assistance in his power to facilitate our examination of the environs, of which his officers had prepared a detailed lithological map. Kushvinsk has a population of 6000 souls. The establishment is now directed by the able mining engineer Colonel Völkner, who was so serviceable to us at Perm (see p. 144).

[2] This mount, as well as many other of the North Uralian rocks, has been described by Hermann, Kupffer and Ad. Erman, and Hoffmann. See Hermann's Mineral. Beschreibung und Erzählung meiner Reisen, &c.; Kupffer's Essai d'un Tableau Géognostique de l'Ourel; and Erman's Reise um die Erde.

and Helmersen in our own time) that the Vogul chief Tchumpin was sacrificed and burnt by his wild countrymen, for having introduced the Russians to the tract, pointing out to them the site of the ore.

According to Colonel Helmersen, who has given an admirable geological description of these environs, this mount is about 500 feet[1] above the adjoining lake, and its summit is rendered conspicuous by a monument which records the barbarous sacrifice. Differing somewhat from the rock which is associated with the magnetic iron at Nijny Tagilsk, the chief eruptive rock in the Great or Lesser Blagodat is felspathic augite porphyry. This rock is fully displayed between the Zavod and the higher summit, on approaching which, upright masses with metallic surfaces are seen to rise out, as it were, from the porphyry, indicating the ancient quarries from which the iron ore has been extracted. As far as they have been worked down, these excavations exhibit a continuous mass of the same fine-grained magnetic ironstone, with flakes of yellow and pink felspar and brown mica. Referring to Colonel Helmersen's very valuable details of the variation in structure of these rocks in different parts of the hill, it is enough for our purpose to state, that this author seems to have satisfactorily proved these felspathic ironstone masses to be portions of dykes of eruptive character which have traversed the augite porphyry, a fragment even of that rock having been found in one of them which rises up from near the base of the hill.

In our very hasty survey we descended from the summit of the higher Blagodat into the adjacent depression on the east, in which the greatest masses of the iron ore have been accumulated; and though when on the spot we were not led to entertain the opinion of Colonel Helmersen, and were rather disposed to view the great lateral and rudely stratified accumulations as sediments which had been metamorphosed by the influence of the contiguous eruptive rocks, we were then ignorant of the fact, that dykes of really intrusive character, made up of crystalline and igneously-formed minerals, and clearly formed posterior to the body of the

[1] Helmersen states, that the Zavod of Kushva (or Kushvinsk), being about 800 French feet above the sea, the absolute height of the summit of the greater Blagodat is 1260 French feet. Calling the lesser hill Blagodatka, the same author mentions, in addition to other variations in mineral character, that on the south side the rock passes into an amygdaloid with nests of quartz, that on the north side of the hill blocks of fine-grained limestone occur, and that Colonel Josse had found nests of limestone in the body of the rock. (Der Magnetberg Blagodat am Nordlichen Ural, 1837.) Again, according to Hermann, portions of beds of limestone were in his time detected in the ferriferous mining masses. (Rose, vol. i. p. 346.)

mountain, contained similar iron ore. Now that we are acquainted with this fact, which so clearly demonstrates the magnetic iron ore to have been erupted[1], we have no hesitation in agreeing with our skilful cotemporary, who has so closely studied the rocks of Blagodat, that these great masses of iron ore have flowed into this depression from fissures in the adjacent hill, and that they have since been cut through by other dykes of similar matter. In our description of the Katchkanar we shall adduce independent proof of the igneous origin of magnetic iron.

Besides the porphyry and magnetic iron of the Great and Little Blagodat, the environs of Kushvinsk are surrounded by a vast number of other eruptive rocks differing in mineral composition, the outlines of which were laid down by the Russian mining engineers in a detailed map of the rocks around the Zavod, which had been prepared for our use. These intrusive rocks so predominate, that the original sedimentary strata are only to be detected in very small and isolated fragments, or in bands of highly altered chlorite schists. The important point, however, for geologists like ourselves to dwell upon was, that whether composed of hornblendic greenstone as at Nijny, or of greenstone porphyry as at Laisk and Blagodat, all the intrusive rocks *on this zone* are upon the same line of eruption, and all, according to our view, have produced varied metamorphic and mineral effects upon the stratified deposits.

But still amid this chaos of eruptive and metamorphic rocks, well-known sedimentary strata are to be detected at intervals. Thus we observed fossiliferous limestones a little to the north of Kushvinsk in a highly cultivated tract through which the road to Bogoslofsk passes[2]. To the west of that route, about fifteen versts south of Nijny Turinsk, in the midst of the forest, and on the banks of a rivulet known among the Russian settlers as "Retchka Isveostka," or limestone brook, we met with strong beds of limestone striking to the north-north-west,

[1] See M. Le Play's confirmation of this view, ante, p. 376.

[2] In writing to us concerning the igneous origin of the magnetic iron ore, M. Le Play, after stating that Nijny Tagilsk and Blagodat are not the most appropriate localities for this inquiry, thus expresses himself:—" La question se résout surtout par l'étude des roches crystallines, qui forment de si grandes masses, soit dans le centre de la chaine de l'Oural, soit dans les contrées qui s'étendent vèrs l'est, du côté de la grande steppe de Sibérie. Le fer oxydulé y est, pour ainsi dire, un occupant constant des roches crystallines, *à la manière de l'albite et de l'amphibole*; et ça et là il y forme des montagnes où le fer abonde plus que les autres éléments : en beaucoup de points il forme des gites spéciaux, où les autres éléments disparaissent presque complètement, et qui suffiraient seules à alimenter des hauts fourneaux pendant des centaines d'années."—*Extract from a Letter to Mr. Murchison dated Ekaterinburg, August* 30, 1844.

and dipping 30° to the east. Among their fossils were a Pentamerus, closely allied to *P. Baschkiricus* (nob.), the large *Leptæna Uralensis* (nob.), with *Orthis striatula*, *Terebratula reticularis*, corals, &c. These beds of limestone are of a dark colour, alternate with shale, and have altogether an unaltered aspect. Surrounded by eruptive and metamorphic rocks, they constitute one of those "oases" or fragments of the original deposits, which occurring at intervals along this chain, serve to explain its original character.

It would, however, be presumptuous in us to attempt to define too precisely the age of this isolated calcareous fragment, the Pentamerus of which led us at the time to consider it of Upper Silurian age; but as we afterwards found the *Leptæna Uralensis* associated with Devonian fossils (on the Serebrianka), the rock under consideration may perhaps be classed as Devonian, particularly since its corals, *Caunopora ramosa*, *Stromatopora concentrica*, and *Favosites polymorpha* (var. Dev.), are very indicative of that age[1]. The limestone is to a great extent covered by coarse detritus derived from the adjacent hills, in which some calcareous specimens occur, amid many of an eruptive and metamorphic character, and from which grains of platinum have been extracted.

Transverse Section across the Ural from Mount Blagodat and Kushvinsk to Serebriansk.—Between the Zavod of Kushvinsk and the first counterforts on the eastern flank of the Ural-tau or ridge, no natural sections are visible, and the road passes over undulations of various igneous rocks, which, according to the Russian engineers, consist of porphyry, greenstone, aphanite, serpentine, &c.

At the small Zavod of Verchny Barantchinsk, talc schists are seen to be thrown off from a mass of greenstone, which rises into a hill called the Limetree Hill. From the depression to the west of this eminence, the ascent of the real Ural-tau or water-shed commences. The rocks discoverable on the sides of the route are finely laminated micaceous schists, in parts, indeed, somewhat carbonaceous, with occasional quartzose bands and veins of quartz[2]. The whole of the tract between the summit of talcose and chlorite schists and the environs of Serebriansk is, it must be admitted, as uninteresting and monotonous a mountain side as we ever

[1] Though the above-mentioned rock is little if at all altered, other limestones near Kushvinsk are in the state of white crystalline granular marble. In one of these we detected the form of *Favosites Gothlandica*; so that this rock may be true Upper Silurian.

[2] Colonel Helmersen states that he found specimens of the quartzose micaceous schist called "Itacolumite" near this axis. We shall hereafter advert to this rock as the matrix of diamonds. (Reise nach dem Ural und der Kirgisen Steppe, part ii. p. 199.)

traversed. Poor gold washings, now abandoned, were formerly worked at Kedrofka in a depression near the axis, and deposits of brown iron ore between that and Rabina Gora, slightly diversify the features of the subsoil, which invariably present the facies of metamorphic rocks, amid which one band of white crystalline limestone is apparent, and has, like all the other strata, a persistent strike from south to north. At the village of Lukovka, thirteen versts from Serebriansk and on the western slope of the chain, small greenstone protrusions were first observed by Colonel Helmersen, the position of which is highly interesting in exhibiting a central axis of metamorphic rocks enclosed between eruptions of igneous matter[1].

It was, indeed, very gratifying to see, that in proportion as we receded from the igneous zone upon the east, the sedimentary strata gradually parted with their talcose, quartzose and chloritic character, and assumed the appearance of ordinary argillaceous schist, with bands of grauwacke, grit and psammite, all parallel to the crystalline axis of the chain. Arrived at Serebriansk, the appearance of the strata at the edges of the excavations around the Zavod and along the banks of the artificial lake and of the river Serebrianka, led us to suppose, that the strata were not of higher antiquity than the Uppermost Silurian, particularly as we found the *Leptæna Uralensis* and *Terebratula aspera* in a band of impure limestone.

Descent of the Serebrianka River to its Mouth.—The Zavod of Serebriansk is established for the purpose of catching the waters of the Serebrianka river before they enter into a narrow and tortuous defile of some length, by which they escape to the Tchussovaya. A large lake is thus established above the works, by the water of which the ores of Blagodat are to a great extent worked. Having expressed our desire to descend the Serebrianka to its junction with the Tchussovaya (for we saw by the Map that its banks must expose good sections of the strata), it was most mortifying to perceive, that the river beneath the water-works was nearly dry. The Imperial instructions, however, for the fulfilment of our wishes were not to be slighted, and by daybreak after the evening of our arrival at Serebriansk the worthy Director of the establishment, M. Moskvin, having let off a large body of water from the upper reservoirs or lakes, had in one night created a river for our use, on which by daybreak a few canoes and a larger boat were already afloat and manned!

In this little flotilla we descended the wild and uninhabited gorge, though not with

[1] M. Le Play also speaks of hornblendic rocks on the western slope of the axis, but to the south of this section. (Comptes Rendus, October 21, 1844, t. xix. p. 853.)

facility. The body of water was insufficient for our larger boat, laden with provisions and baggage, and even in the smaller canoes it was difficult to avoid the rocks; so that after descending for some hours, one of them was upset and the geologists were well drenched in the rapid stream[1]. The large boat, often lifted through the rapids by our hardy and cheerful boatmen, was at length worn through by the rough treatment of the projecting rocks. When within two miles of the mouth of the river we were compelled to abandon the flotilla and endeavour to force our way by night along the edges of the wild, untrodden and virgin forest on the banks of the Serebrianka, not reaching the warm and dry huts of the peasants at Ust-Serebriansk until two in the morning.

Such privations were, however, amply repaid by the knowledge we obtained in this long day's work, of the true structure of the band of country between Serebriansk and the Tchussovaya, through which the river Serebrianka meanders in a deep gorge, for a distance of nearly seventy versts. All the strata around the Zavod of Serebriansk had (as we have already remarked) lost their crystalline characters, and had passed into palæozoic rocks of ordinary sedimentary characters. They are still, however, exceedingly convoluted and much dislocated. Numerous examples of this condition may be seen around the Zavod, and the annexed diagram representing their appearance a few versts below it, where they constitute the rocky banks of the Serebrianka, will sufficiently illustrate the flexures and faults to which the whole tract has been subjected.

55.

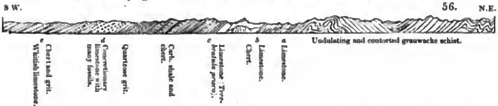
Thinly fissile schists, often of purple plum colours, roll over and over with courses of quartzose and psammitic sandstone, the grauwacke sandstone of authors, occasionally highly ferriferous; and these beds are frequently repeated by countless flexures.

At about forty versts (following the bends of the river) beneath the Zavod of Serebriansk, the grauwacke schists fold under the first limestone we observed; and about twenty-six versts from its mouth, we met with other limestones (a little above the junction of a brook called Shuroska). The annexed woodcut will sufficiently explain the relations and succession. The rock here (*a*) is a dark grey, hard, impure limestone, subordinate to schist or shale, is much contorted, and striking to the north-north-west, contains no determinable fossils. To the west,

[1] Our whole party was reunited at Serebriansk, and continued together in the descent of the rivers Serebrianka and Tchussovaya, and also in traversing the Ural by the Katchkanar.

Relations of underlying Silurian Grauwacke to Devonian Limestone on the Serebrianka.

56.



or further down the stream, the calcareous bands expand into highly fractured, slaty limestone, which is subordinate to hard sandstone. Up to this point the limestones and schists, *a* and *b*, may be Silurian; but at two versts lower down, the beds acquiring more regularity (strong-bedded black limestone), we found in them several fossils which convinced us that they were of the age of the South Devonshire, or Eifel strata. For besides the *Leptæna Uralensis* and *Terebratula reticularis*, both of which descend into strata which may prove to be of Silurian age, we may cite a *Clymenia*, *Cyrtoceratites*, closely resembling an Eifel species, *Strygocephalus Burtini*, *Orthis striatulus*, *Terebratula concentrica*, with two new species of Spirifer and several corals.

The beds of limestone, separated from each other by black carbonaceous courses, are here overlaid by highly quartzose, flat-bedded grit, which passes into chert, the whole undulating at low angles of inclination 15° to 20°, and followed by beds slightly differing from the above in being sometimes more, sometimes less cherty or flinty and carbonaceous. In one spot indeed (*d* of woodcut), these calcareous rocks, containing corals, assume very much the lithological facies of the Upper Silurian rocks of England, in which small calcareous concretions predominate. But notwithstanding all convolutions, we were evidently making an ascending section, as the prevalent dip was to the west, and the same *Terebratula reticularis* was more abundant in these uppermost beds than in the lower. We came therefore to the conclusion, that the fossiliferous portion of the calcareous zone between the Zavod of Serebriansk and the river Tchussovaya is Devonian. In descending the latter river we met with repeated and rapid undulations, by which these Devonian rocks are seen to support true carboniferous limestone of very dissimilar characters.

Descent of the Tchussovaya from Ust-Serebriansk to Ust-Koiva[1].—The same calca-

[1] In Part I. we printed the word Koiva with a C, but the orthoepy to which we have adhered in our Map induces us to prefer the K. In partially alluding to this tract in a previous page, 125, we also spoke of the loss of certain sketches, which having since been recovered, the illustrations, pp. 386, 387, 388, are taken from them.

reous Devonian rocks which are near the mouth of the Serebrianka, also occupy the cliffs of the Tchussovaya near the union of these rivers. It is useless to describe in detail all the reversals of dip or flexures of the various black and schistose limestones, marked by irregular white veins, which alternate with thin-bedded black chert or flint. The bends and breaks of these limestones are indeed quite as numerous and as remarkable as those of the grauwacke sandstone and schists upon the Serebrianka. There are, however, lithological varieties a little below Ust-Serebriansk which require notice. These are saccharoid dolomites, both white and black, which, here and there, are detected amid the convoluted and partially altered limestone strata. The *black dolomite* (a rock unknown we believe in Western Europe) is occasionally seen in very thin beds, perfectly interstratified with the ordinary subcrystalline limestone, and in highly inclined positions. The white dolomite occurs at a point of great disturbance, and where the dip is reversed.

By reference to the Map it will be seen, that these dolomites, which range along the great north and south fissure of the Tchussovaya, lie between two lines of igneous eruption, one of which has been already noticed at the mineral springs of Sergiefsk; the other (it will be subsequently mentioned) ranges northwards from Bissersk, a tract in which black dolomite also largely occurs.

After various undulations, in which masses of limestone many hundred feet in thickness, occasionally highly fetid and containing bands of dolomite, are arched over grauwacke grits, these Devonian rocks, for the most part inverted or dipping *towards* the Ural chain, though in other places away from it, are again most instructively exhibited in regular sequence, at the Kinovski Zavod, on the left bank of the Tchussovaya. Here a transverse ravine exposes the following section in ascending order from the western buildings to the edge of the stream, the whole dipping about 50° to the east. 1. Strong-bedded grey limestone, with *Terebratula prisca*. 2. Black beds with geodes and concretions of chert. 3. Dolomitic sandy limestone, followed by courses of clay and thin flat beds of white dolomite, the whole covered by impure limestone passing into quartzose calcareous grit. These rocks are Devonian; for they contain *Terebratula reticularis* (*prisca*), *Spirifer Murchisonianus* (De Kon.), with *Favosites spongites*, *F. polymorpha*, *Stromatopora concentrica*, *Lithodendron cæspitosum*, and *Caunopora favosa*, &c.

By this high inclination of the strata at Kinovsk on the west, and that of similar strata towards Oslankoi Pristan on the east, a vast trough is formed, in which appears a great mass of amorphous light-coloured limestone, called by the Russians

Stina voi, or the wall. Though we did not discover fossils at this spot, there can be no doubt that this is true carboniferous limestone, both from its lithological identity with rocks a little lower down the river, which contain characteristic remains, and from being similarly superposed to true Devonian rocks. In fact, after various contortions of the inferior beds, the very same limestone, *i. e.* a light grey uniform rock, like the prevalent carboniferous limestone of England, and very different from the dark-coloured and white-veined Devonian limestone, rises up into the bold and lofty cliffs called Multik, 300 feet high, the beds of which plunge towards the Ural, and in which we found the *Productus Scoticus*, *Caryophyllia fasciculata* (Flem.), with other mountain limestone forms[1].

57.

These masses of limestone are, indeed, distinctly seen to lie in a trough; since on proceeding somewhat eastward by a bend of the river towards Oslanski Pristan, we again met with precipitous peaks of Devonian limestone (Igluvostroi-kamen), for the most part in highly broken and grotesque forms as represented in this woodcut.

The older members of the Devonian system, or the upper part of the Silurian (where there are few limestones and fossils it is impossible to draw neat lines of division in a rapid survey), are thrown about with an inverted inclination, often plunging towards the Ural, and occupy low domes and undulations around the station of Oslanski Pristan. These deposits are composed of purple, red and greenish and grey schists and grits, with

[1] *Productus gigas*, *P. antiquatus*, *P. Scoticus*, *Spirifer Mosquensis*, with *Caryophyllia fasciculata* (Flem.); *Harmodites reticulata* (*Syringopora*, *id.* Goldf.), *H. ramulosa*, *Favosites spongites*, and other carboniferous fossils occur at Ilink and further up the stream. Several of the corals mentioned in this and other pages had not been seen by Mr. Lonsdale when these sheets were going through the press, and they may under his scrutiny be occasionally distinguished by other names. (See in subsequent part Mr. Lonsdale's description of the corals.)

courses of impure limestone, on the whole resembling the older beds upon the Serebrianka, p. 383.

In proceeding thus far, by the devious turns of the Serebrianka and Tchussovaya, we had therefore learnt, that the whole region was chiefly made up of lower palæozoic rocks, the folds of which opening out in proportion as they receded from the chief axis of the Ural, at length throw off troughs of carboniferous limestone—that we had, in short, advanced from older to younger deposits.

This inference was completely confirmed by a further descent of the Tchussovaya from Oslanski Pristan[1] to Ust-Koiva, which occupied us two days. In this space (of not less than thirty English miles in a straight line, and perhaps double that distance by the stream), in which the river Tchussovaya meanders nearly transverse to the strike of the strata, we passed over striking flexures, in which true Devonian masses, one of them exhibiting bands of hard, thick-bedded dull red sandstone, with greenish spots and blotches very much resembling the old red sandstone of the Highlands of Scotland, are associated with and overlaid by impure and other limestones, with characteristic Devonian fossils, whilst these are in their turn surmounted by great masses of true carboniferous limestone.

Further to the west we took leave of the older schists and psammites, and thenceforward were in a more purely calcareous tract. At Tchismar there is a striking anticlinal, where Devonian limestone and calcareous shale dip off to the east and west from underlying reddish rocks. In the upper strata near this place we collected the *Lithodendron cæspitosum* in as great profusion as at Lustheide on the Rhine, together with *Favosites polymorpha*, *Stromatopora concentrica*, *Spirifer Murchisonianus*, &c. From this point, indeed, to Kinish, or Kumuish, on the left bank, the river flows in limestones for the most part Devonian, and often in the state of dolomite, and which are surmounted by carboniferous limestone, of which we traced a few characteristic fossils at intervals, though usually the latter rock seemed to contain Encrinites only. Although the natural sections convinced us that two limestones, the lower dark and white-veined, containing Devonian fossils, and the upper light grey, containing carboniferous fossils, are occasionally in juxtaposition on the banks of this river, we cannot pretend accurately to define each junction. We will simply say, that the one, if not directly incumbent on the other, is separated only by a few bands of grauwacke grit.

[1] This place is the port on the Tchussovaya for the mineral produce transmitted from Kushvinsk and Serebriansk.

A more picturesque river gorge was certainly never examined by geologists. Between the hamlet of Kinish and Ust-Koiva we passed through scenes even surpassing in beauty those higher up the stream, and to which it would have required the pencil of a professed artist to do justice. The river runs in a limestone gorge, in which cliffs of every variety of form, occasionally exposing large caverns along their vertical faces, with trees and flowers grouped about in the clefts: rocks, varying in colour from black to white, in structure from amorphous dolomite to plane-bedded limestone, and twisted about into basins and anticlinals—here rising into serrated and broken peaks, there bending into graceful slopes—appeared in a continual succession[1]. We offer to our readers a sketch, taken at a point where the river is very tortuous, and must leave it to his imagination to conceive how beauteous are these scenes in all their summer glory. In the opposite lithograph a large bowl of carboniferous limestone, presenting a lofty precipitous face and covered with foliage, is seen in the distance, on the opposite or left bank of the stream; whilst highly-inclined and contorted rocks, which we believe to be Devonian, occupy the foreground.

The local name of the most remarkable of these basins, as represented in this woodcut, flanked by a striking mural mass of limestone (*a*) 300 or 400 feet in

57.

height, has escaped us; but certain peaks were known to our boatmen as the "four brothers," and another fine face of rock was termed "Güselny Kamen," or the musical stone. Some of the caverns, like those before mentioned on the Issetz, are said to have been inhabited by Yermak, the Cossack conqueror of Siberia, and therefore the great hero of the Ural Mountains[2].

In approaching Ust-Koiva these grand calcareous flexures begin to cease, and a long ledge of the upper limestone, loaded with true mountain limestone fossils,

[1] The most prevalent fir-trees are the *Pinus abies* and *P. picea*, here and there a gigantic *Pinus cembra* and a larch, with birch, aspen, &c. &c. Among a profusion of wild flowers we were specially struck with the beauty of the *Cypripedium calceola*, and many species of *Orchideæ*, *Vicia*, *Stachys*, &c.

[2] It was from the adjoining Zavod belonging to the Strogonoff family, then almost exclusively possessing this region, that Yermak the Cossack first proceeded in his expedition into Siberia. In that establishment he found a sure retreat and centre of operations between his first exploits and his final conquest of Siberia—a conquest scarcely less wonderful than that of Mexico by Cortez.

dips to the west, under the millstone grit, in the manner previously described, and represented in the woodcut, p. 126.

Here then the geologist has reached the western term of the more violent disturbances due to the outburst of the plutonic rocks and the upheaval of the Uralian axis, and from this point to the west the carboniferous limestone simply folds over in broad undulations capped by millstone grit, occasionally containing a little coal; whilst all these more ancient palæozoic rocks subside beneath conglomerates and deposits of the lower country. Such conglomerates arranged in horizontal strata we met with at the mouth of the river Usva and opposite the village of Komasino, where they alternate with beds of sandstone. They are entirely made up of fragments of the adjacent palæozoic rocks on the east, and certain fragments of carboniferous limestone, from the size of a child's head to that of the fist, mingled with pebbles of quartz, sandstone, chert, Lydian stone, &c. Such beds, similar to those observed in the same position on the route between Kongur and Ekaterinburg (p. 354), tell an unambiguous tale, and assure us that one of the great elevations of the Ural chain took place after the formation of the carboniferous limestone and millstone grit, the fragments of which have been deposited at the foot of the highly-inclined and broken formations which have been described.

Transverse Section of the Ural from Ust-Koiva on the west by Bissersk and the Katchkanar to Turinsk and Verkhoturié on the east (Pl. II. fig. 5).—Having endeavoured to explain the nature of the deposits on the western flank of the North Ural, as exposed in the gorges of the rivers Serebrianka and Tchussovaya, we now beg our readers to repass with us into Siberia, on a more northern parallel,—one by which we could not have travelled without the united assistance of our lamented friend Prince Butera and the Imperial Government. A part of this journey only, viz. to the gold mines of Chresto-vodsvisgensk, can be accomplished in the tilegas and light carts of the country, the central ridge being with difficulty passable on horseback.

To the east of Ust-Koiva, a plateau of millstone grit is succeeded by carboniferous limestone, similar to that on the Tchussovaya, on which is situated the Zavod of Alexandrofsk. Undulating and unaltered strata, chiefly carboniferous, continue a little to the east of that place, when the older grits and grauwacke (Devonian?) with subordinate limestone are found penetrated by intrusive rocks.

These intrusive rocks stretch out in a zone from north to south in the meridian of Bissersk, the chief Zavod of the tract, and are most apparent about twelve versts to the north of that place, where they are specially distinguished by containing that beautiful green mineral "Ouvarovite," so peculiar to the Ural Mountains and Siberia. This line of eruption, it will be observed (see Map), is parallel to the crest of the Ural. In looking at these rocks of Bissersk and those of Nijny Serginsk as two north and south[1] lines of eruption, the geologist may well account for the great breaks and occasional metamorphism of the intermediate strata, of which we have just treated as exposed upon the Tchussovaya. But between these small lateral and western lines of eruption and the chief ridge of the Ural, where other eruptive rocks appear, many sedimentary deposits occur, and just as in other traverses we perceived, that in proportion as the strata approach the grander lines of igneous protrusion, so are they more metamorphosed and crystalline.

For a few versts to the east of Bissersk no rocks appear through the deep and heavy alluvia and morass, but on reaching the little depression in which gold and diamond alluvia occur (twelve versts east of Bissersk), strong ledges of black dolomitic limestone have been laid open, which strike from 35° west of north to 35° east of south. In some places, where the alluvia have been removed, the beds are seen in highly inclined positions, sometimes vertical and at others inclining 70° to 80° towards the Ural. These dolomites, in the least altered parts of which we detected a few imperfect organic remains (Corals, Terebratulæ, Spiriferæ, &c.), have much the aspect of those on the Tchussovaya, except that they are still more crystalline. They are flanked on the west, and in fact pass into talcose schists, with bands and flattened concretions of quartz, and as both these rocks have clearly been altered, we conclude that the same causes have affected each of them. In fact, we observed between the beds of the dolomite, laminæ of talc schist similar to those which occur in the talcose and quartzose rocks of the adjacent mountains.

Throughout the greater portion, however, of the tract around Chresto-vodsvisgensk, the subsoil is completely hidden from view by thick mounds of gravel, for the most part very coarse, in which the gold ore occurs, and in which a few diamonds have been detected. To these a future reference will be made, and we now proceed to describe the passage of the Ural by the mountain of Katchkanar.

Passage of the Ural by the Katchkanar to Turinsk and Verkhoturié.—The road by which we were to pass the Ural (for the greater part a mere horse track), not having been used for some years, it was necessary to send workmen in advance,

[1] See page 354.

both to open it out where obstructed by the growth of trees and branches and to order guides and horses to meet us from the Imperial Zavod of Turinsk on the Siberian side of the chain to which we were proceeding[1].

The country between the great alluvial depression in which these gold mines are situated, and the real water-shed of the Ural is featureless. Dense foliage obstructing all lateral view, nothing is seen beneath the feet of the traveller save bog and marsh plants, and no vista whatever can be obtained through the dark and gloomy forest, in which his horse flounders, amid half-rotten and broken logs, occasionally sinking to the saddle flaps in mire. The few points of stone which protrude through the detritus and vegetation, are barely sufficient to acquaint him, that here, as between Kushvinsk and Serebriansk, the substratum is a chlorite schist, which not being of a hard nature, has been worn down into inconspicuous rounded slopes. The ascent of these hills is, indeed, so gradual, that our guides had some difficulty in persuading us we had reached the summit level (see section, Pl. II. fig. 5).

Immediately to the east, however, of the orographical axis, a very different scene awaited us. Scarcely had we begun to descend with the waters to the east, when turning sharply to the right by a narrow pathway, we were suddenly in a new world. A large chaotic assemblage of loose angular blocks lay around us, from amid which rose the magnificent *Pinus cembra*, towering above all its associates of the forests, the rocks being overgrown with pæonies, roses and geraniums. Such rocky features alone would have led us to suppose that we were at the foot of the object of our exploration, when in a few minutes the broken and jagged outline of the Katchkanar burst upon the sight, under a fine bright sun, and amid the

[1] The Director of the mines of Chresto-vodsvisgensk, M. Graube, a most intelligent Saxon miner, made every arrangement for this expedition, consisting of twenty horsemen, and also accompanied us to the Katchkanar and bivouacked with us for the night in an open shed, "balagan," constructed on the moment and roofed in with birch bark by our handy Russian attendants, having taken care to send forward, according to hospitable Uralian custom, a supply of food and beverage. There, on the eastern foot of the Katchkanar, we met with horses and men sent on from Turinsk, who conducted us to the high road between Ekaterinburg and Bogoslofsk, having previously cut away the obstructing boughs along the narrow pathway. Lying in the "balagan" before mentioned, with our feet towards a large fire, we may remark, that scarcely could the smoke defend us from the myriads of mosquitoes of these northern forests, which in the height of the summer overpower the strongest man, and render geological observation difficult, *even in such gauze masks* as we wore. Next morning, bidding adieu to the kind and intelligent M. Graube and his followers from the west, we quitted the Katchkanar and passed on to the banks of the Is and the Imperial mines of Turinsk.

merry song of birds. The dull, wet and marshy woodlands were now exchanged for sunshine, rocks and gorgeous vegetation. At length, then, we had found out a true mountain in the Ural, and leaving our horses at the first buttress which rises above the forest, we ascended the impending crags. Accustomed as we have been to the wildest features of the western Highlands of Scotland and the Alps, we are unacquainted with any scene presenting a finer foreground of abruptly broken rocks and never certainly had we looked over so grand and solitary a trackless forest as that which lay around us, and from which some straggling distant peaks (those on the north only being still capped with snow) reared their solitary heads. The accompanying sketch, slight as it is, may convey some idea of these primæval forests and the desolate rocks which they envelope.

A great portion of the rock around the Katchkanar, particularly near its base, consists of white and green felspathic greenstone, both coarse and fine-grained.

The chief summits, however, have a peculiar aspect. In scrambling over their dark surfaces, the crystals of augite so stand out from the felspathic mass, that in external aspect they reminded us of the crags of Coruisk in the Isle of Skye, where the hypersthene rocks[1] pass into greenstone. The upper masses of the Katchkanar, though unquestionably of igneous origin, are regularly stratified (see coloured section, Pl. II. fig. 5). They occur, in fact, in distinct beds, which are as symmetrically traversed by joints as those of any sedimentary formation. The Katchkanar may be compared in its rugged form, as well as in its general geological relations, to the picturesque Welsh mountain of Cader Idris, which being of about the same altitude, is also for the most part composed of *stratified* igneous rocks (greenstones), porphyries, &c., which rise up through metamorphic and palæozoic strata, whilst the neighbourhood exhibits syenites and other rocks, like those of the Ural, intruding through slates which are now known to be of Lower Silurian age[2]. The prominent summits consist of a series of rugged, broken masses bare of all vegetation, which

[1] Pallas's description of the Katchkanar, which is neither geological nor detailed (vol. ii. p. 267), is chiefly remarkable for the account of the powerful magnets procured from this rock. Adolph Erman determined its altitude to be 460 toises, or nearly 3000 English feet, and fixed its longitude. Gustaf Rose, who did not visit it, simply describes three specimens sent to him as coarse-grained magnetic iron, granular iron ore and augite, and coarse-grained augite sprinkled with iron ore. It is the metallic lustre of some of the crystals which gives to this augitic rock the aspect of the hypersthene of the Western Highlands and of Radnorshire. (See Silurian System, p. 318.)

[2] See an excellent account of the structure of Cader Idris by Mr. A. Aikin, Transactions of the Geological Society, vol. ii. p. 273.

though apparently thrown about in confusion, when viewed from below, are found to be regularly bedded and traversed by two sets of joints, the one striking from north-west to south-east, the other from north-east to south-west. Courses of hard and pure magnetic iron ore, from one to a few inches thick, line the first-mentioned joints. This mineral is also so diffused through the body of the rock, that wherever we placed ourselves, the needles of our compasses vibrated in all directions, and we were only enabled to decide upon the true direction of the joints by the place of the sun, and the relative position of distant points of the chain.

Whilst gold alluvia have been derived from veins in the adjacent rocks both on the west and on the east, detritus containing platinum occurs at various points near the central ridge. Similar alluvia have been described by Humboldt and his associates at Vissimo-Shaitansk, near the crest of the Ural, in the parallel of Nijny Tagilsk, where the platinum is associated with greenstone and hornblende rock containing chromate of iron. From this association it has been inferred, that these hornblendic igneous rocks with magnetic iron, are probably the sources from whence the platinum has been derived. On this point we now merely note, by the way, that the igneous rocks of Katchkanar seem to have played the same part as those of Vissimo-Shaitansk, and to have produced like results. Considerable accumulations of platinum have indeed been found all around the base of this mountain, particularly in the adjacent river valleys.

If we had known nothing of observations in other parts of these mountains, to some of which we have already alluded[1], the examination of the Katchkanar alone would have led us to adopt the opinion, that magnetic iron ore is of igneous origin. But now that M. Rose and M. Le Play have observed crystals of this mineral in igneously formed rocks, and also in the metamorphic strata in contact with them, and that the latter author and Colonel Helmersen have shown that masses mainly composed of it have traversed other rocks in the form of dykes, the inference becomes irresistible. Partaking of the character of the igneous rock of which it forms a part, the magnetic iron ore of the Katchkanar is so hard and crystalline as to be very intractable, not only to the quarryman, but also to the smelter. This circumstance, coupled with the great distance to which it was necessary to transport the material, either to the east or to the west, has led to the abandonment of works formerly commenced. Unless that trial had been made, even our solitary

[1] See Rose, vol. i. pp. 125, 172 *et seq.*; and Le Play, Comptes Rendus, October 21, 1844.

pathway would have had no existence, and the wild Katchkanar could not have been visited by the geologist.

The essential base of all the lower country at the eastern foot of the Katchkanar, consists of greenstone or other igneous rock, which extends to some distance from the axis. As soon, however, as we reached the banks of the Is, an east-flowing tributary of the Tura, and emerged from the dark forest into the first reclaimed ground, we were rejoiced by the sight of a group of our oldest fossil friends. The banks of this little river are in fact composed for a considerable distance of white limestone thickly tenanted by large Pentameri, some Trilobites, and shells which we hailed as true Silurians, and worthy of the very region of Caractacus. Remembering the pleasure with which we first cast our eyes over analogous beautiful forms of the Ludlow formation in England, we were enchanted when we discovered myriads of them undistinguishable from the *Pentamerus Knightii*, so that seated on the grassy bank of the Is, we might for a moment have fancied ourselves in the meadows of the Lug at Aymestry[1]. These Silurian beds are here horizontal, a rare phænomenon in this convulsed region. They constitute, in fact, one of the little oases in a region of large dimensions, where the original surface has not been broken up and disturbed, like other beds already described near Kushvinsk.

All around the Zavod of Nijny Turinsk, igneous rocks are again rife, and all palæozoic evidences are blotted out. M. Rose has already described the varieties of porphyry, porphyritic conglomerates, with augite, uralite, &c. which we traversed; and little, indeed, offered itself as we travelled along the banks of the Tura, by which we could identify any of the strata there visible with unaltered deposits. About twenty-four versts east of Verkhoturié, however, micaceous sandstone and schist appeared on the edge of the stream which we believe to be a metamorphic deposit (mere altered sandstone and shale); the mass being thrown off to the north-north-east by syenite, veins of the latter were seen intruding into the micaceous slate, just as granite veins in many parts of the world penetrate what have been called "primary" schists. These strata are thrown about with devious inclinations, and whilst some dip to the east and north, others incline to the west and south, or away from the line of eruptive rocks, on one of which stands the fortress

[1] See Silurian System, p. 201. Reasons will be given for assigning a new specific name to these shells, which in external form are so thoroughly identical with the *Pentamerus Knightii*, that Mr. Sowerby and other English conchologists will not even now admit that the distinctions indicate a new species.

and town of Verkhoturié. M. Rose styles this rock of Verkhoturié a granite with occasional crystals of Bucklandite or black epidote, and although we find in our note-book that we considered it also to be a syenite[1], or what the Italians would call "granitello," (not unlike a dominant rock in the Malvern Hills of England,) we have no doubt that the definition of the learned Prussian is mineralogically more correct than our own. It is now, indeed, well known, that rocks having true granitic characters (as in the Isle of Anglesea, Norway and many other tracts) have enacted exactly the same parts as syenites, greenstones and porphyries in piercing, whether by masses or in veins, the pre-existing palæozoic strata. The geological agency therefore of all these rocks is to a great extent the same[2]; and all such comparatively modern granites must therefore be distinguished from the more ancient granites which are associated with truly primary rocks. Hence in our general map of Russia and the surrounding countries, we group the granites on the eastern flank of the Ural chain with the trap rocks of other countries, and distinguish them from the antecedent granites of Scandinavia.

In the annexed view the rock of Verkhoturié is seen to be surmounted by an old castle built by the Emperor Ivan Vassilivitch, with its accompanying monastery and church. Formerly one of the great keys of Siberia, from whence the Russians extended their conquest, colonies and trade, it is now merely regarded as a venerable relic of olden times, the bones of one of its monks being visited by numerous pilgrims. In the meantime, whilst Verkhoturié is in a dormant state because no ores are near it, recesses in the back woods, formerly tenanted only by Voguls and wild animals, have been cleared, and have risen into important mining stations, teeming with civilization and industry.

With the exception of the granite and crystalline rocks, the only deposit in the environs of Verkhoturié worthy of attention, is a coarse grit used for millstones, which lies in horizontal masses to the east of the town, and in a fertile plain. This grit, with which our section terminates, is, we believe, of precisely the same tertiary age as that of Kaltchedansk (p. 362).

Environs of Bogoslofsk.—The granitic rocks of Verkhoturié reappear at intervals

[1] To establish a distinction between old and newer granites, some English geologists are disposed to attach the word syenite to all granitic rocks which have been intruded through the palæozoic as well as the younger sedimentary strata. It would be well if correct terms were introduced to distinguish the modern from the ancient granites.

[2] Rose also speaks of a true syenite upon the Tura, probably the same rock which we saw, but he does not describe its relations to the adjacent schists. ('Reise nach dem Ural,' &c., vol. i. p. 388.)

to the north along the river Losva, and by travelling along their western edge, through a country chiefly occupied by greenstone, we came to the largest masses of palæozoic limestone which are known upon the eastern flanks of the chain. Though perforated on all sides by eruptive rocks (greenstone, greenstone porphyry, &c.), and in numerous places converted into metamorphic masses with mineral veins, such limestones (the normal palæozoic deposits of this country) are seen to occupy a long, narrow tract to the north and south of Bogoslofsk. These strata extend from the Lobva on the south to beyond the river Sosva on the north, or for upwards of 100 versts, and are traversed not only by those two streams, but also by the Kakva, Turya and Vagran. (See Map, Pl. II.) Our personal exploration of this long calcareous zone consisted in making traverses from the western edges of these palæozoic rocks, by Bogoslofsk, along the Turya, to the copper mines of Turyinsk on the east, and also by descending the river Kakva to the gold mines of Peschanka [1].

In the woodlands at the western end of the Zavod lake at Bogoslofsk we met with some bands of limestone (Pl. II. fig. 6), but owing to the intolerable persecution of mosquitoes, and the slight elevation of the rocks above the soil, we could discover few fossils sufficiently distinct to characterize the strata in this locality, which we believe to be Silurian. At the eastern extremity of the lake and on its southern side, strata of grey and white splintery limestone occur in highly inclined and vertical positions, in which we detected *Pentamerus Vogulicus*, (nob.) with a second species of this shell; and these inclining to the east are surmounted at a high angle by a reddish limestone, with *Orthis Arimaspus* (Eich.), *Terebratula nuda*, *T. prisca*, with *Favosites Gothlandica* and other corals. It is from this same band, as well as from the environs of Petropavlosk, that the fossils collected by Colonel Helmersen were communicated to M. v. Buch, which he has published as Silurian [2]. We agree with that author in viewing the chief limestone at the Zavod

[1] We were furnished on the spot with a very instructive geological map of this tract by Captain Karpinski, in which the outlines of the limestones and every intrusive rock are laid down. Towards the talcose and quartzose axis of the chain, the chief eruptive rock is marked by him as syenite, whilst the limestones are surrounded and cut off by greenstones, &c. The metalliferous zone is flanked on the east by serpentine, granite, &c. We can now however refer our readers to Colonel Helmersen's second part of his 'Reise nach dem Ural und der Kirgisen Steppe' (1833 and 1835), in which are given a map and sections descriptive of the same country around Bogoslofsk and Petropavlosk.

[2] See Von Buch's 'Beiträge zur Bestimmung der Gebirgsformationen in Russland.' Among the fossils identified and described by M. von Buch from the limestones near Bogoslofsk are,—*Terebratula prisca* (*Ter affinis*, Sil. Syst.); *T. nuda*, V. Buch; *T. didyma*, Dalm. (*Atrypa didyma*, Sil. Syst.);

of Bogoslofsk as Silurian, but we now proceed to show, how after being intruded upon by igneous rocks, these strata are overlapped by courses which must, we think, be included in the Devonian system. (Pl. II. fig. 6.)

The rock which immediately overlies the red limestone in the southern suburb of Bogoslofsk seemed to us, at first sight, to belong to the group of trappæan rocks formed contemporaneously with the sedimentary deposits, for it occurs in regular beds of about one foot thick and dips 45° to the east. By close examination, however, M. Rose has shown that, though effervescing with acids, and having some resemblance to compact augite porphyry or greenstone, it exhibits, when disintegrated, a true brecciated or conglomerate nature. He also mentions courses of associated jasper in it, and as we agree with him and Colonel Helmersen, that this stratum of "quasi" igneous rock is surmounted by an agglomerate or breccia of angular fragments of fossiliferous limestone, and that these and the associated grauwacke schists (often jaspidified) are succeeded by a mass of augite porphyry, there can be no doubt, that eruptions took place after the consolidation of the sedimentary strata; and that here, as in many other places, the igneous matter has for a certain space been injected in bands parallel to the laminæ of the pre-existing deposits. Whatever this rock be termed, though clearly of plutonic origin, it is regularly bedded and jointed, and alternating with the grauwacke schists, dips with them decisively to the east. By this inclination the whole group above mentioned is brought under another course of limestone upon the east, in which a specimen of *Brontes flabellifer* was observed. From the presence of this Eifel fossil and certain corals, we were therefore disposed to view the strata which overlie the Pentamerus limestone as Devonian. However difficult it may be to draw the line of separation between the Silurian and Devonian rocks, still this little section near Bogoslofsk seems to show, that whilst the great mass of the Silurian rocks may be metamorphosed towards the central axis of the chain, the uppermost beds at all events seem to pass into the Devonian strata in the environs of the Zavod[1]. If a section be made to the higher mountains of the Ural, which we

T. camelina, V. Buch; *Spirifer vetulus*, *S. superbus*, Eichw.; *S. rostratus*, V. Buch; *Orthis Arimaspus* Eichw.; *O. elegantula* (*O. orbicularis*, Sil. Syst.); *Pentamerus Knightii*, Sil. Syst. (since separated by us and named *P. Vogulicus*); *Pleurotomaria* (*Turritella*) *cingulata* (His.), with the corals, *Favosites Gothlandica*, *F. polymorpha*, *Astræa porosa*, *Cyathophyllum ceratites*, &c. From this assemblage M. von Buch considered this limestone to be Upper Silurian, and probably of the age of the Ludlow and Aymestry rocks.

[1] That Devonian rocks exist in the tracts north of Bogoslofsk and Petropavlosk, seems probable, judging from the fossils collected by Capt. Strajefski.

did not visit in this parallel, we learn from Captain Karpinski and Colonel Helmersen, that nothing occurs but highly metamorphic rocks (talc schist and quartz rock) flanked on the east by lofty culminating points of syenite and greenstone[1]. This, in fact, is the portion of the Ural chain in which the peaks rise to the greatest height, the Konshakofski Kamen being about 844 toises, or upwards of 5400 English feet above the sea.

The tract to the east of Bogoslofsk bristles with lower ridges and points of intrusive rock, which though slightly diversified in outline, possesses a great variety of mineral structure[2]. The copper mines of Turyinsk, fifteen versts east of Bogoslofsk, afford a fine illustration of metamorphism, and the effect produced on sedimentary strata by the eruption of plutonic rocks. These mines occur at a point where the limestone is intersected in a complicated manner by greenstone porphyry, between which and the limestone are not only masses of copper ore, but large bands of garnet rock. We specially notice the nature of this metamorphism, as the result of the intrusion of igneous upon sedimentary matter, because it confirms, upon a grand scale, a phænomenon which was admirably described many years ago by Professor Henslow, in a memoir upon the Isle of Anglesea[3]. In the Welsh case the altered rock is of the carboniferous age,

[1] Helmersen does not indicate any syenite towards the centre of the chain, but lays down all the highest peaks as greenstone and greenstone porphyry, which rocks are occasionally separated from the talcose and quartzose rocks by hornblende slate.

[2] Besides several ores of copper, these mines have afforded silver, zinc, lead, iron, &c., all of which are described by M. Rose.

[3] Trans. Phil. Soc. Cambridge, vol. i. p. 359–447. This very able memoir of Professor Henslow demonstrates, what is not so clearly exhibited in the Uralian case, that a rock containing analcime as well as garnets is absolutely nothing more than a metamorphosed mass of shale and limestone full of organic remains, which had, by the influence of an eruptive rock, been converted into hornstone, jasper, and the above simple minerals. It is indeed very remarkable, that so far back as the year 1821, when some of the ablest geologists of the present day were still "Wernerians," Professor Henslow's view of the whole structure of the Isle of Anglesea was such, that it may to a great extent be now applied to the Ural Mountains, like which its chief and oldest metamorphic masses are chlorite schists and quartz rocks, passing into greywacke (Silurian?) and overlaid by old red sandstone, carboniferous limestone, &c. In the Welsh case, as in the Uralian, the strata are penetrated by trappean rocks and also by granites, which, in addition to metamorphism and fractures, have given rise to a copious development of copper ores. The author describes in a very masterly manner every minute change which the sedimentary deposits undergo in the contiguity of the igneous rocks, and shows how the old red sandstone becomes crystalline, the very pebbles of its conglomerate having been fused in contact with granite. He further points out how, through the disappearance of one mineral ingredient and the substitution of another, certain intrusive masses of rock necessarily acquire different names, though in respect to age and geological operations they can seldom be separated. The reader who will take the trouble of comparing

and the intruding rock (dolerite) is not very different from this of Turyinsk. In the Uralian case, however, the grandeur of the operation must not be forgotten; for the garnet rock, loaded with very beautiful and large crystals, is in

GROUND PLAN OF A PORTION OF THE COPPER WORKS AT FRELOFSKI, TURYINSK.

59.

Obs.—In describing these phenomena, M. Rose has given a plan of the whole district around the Turyinsk mines, as taken from a map published by Colonel Protasoff in the Imperial Russian Mining Journal of 1836, and also a horizontal ground-plan and vertical section of the Frelofski copper-works. That ground-plan, drawn by the head captain of the mines, Beger, being more extended than our own, shows more distinctly how the porphyritic greenstone *d* cuts, *in dykes*, through the greenstone *e*, as well as through the other rocks. See Rose's Reise nach dem Ural, &c. vol. i. plates 8. and 9.

a. Limestone. *b*. Garnet rock. *c*. Copper zone. *d*. Greenstone porphyry. *e*. Greenstone.

the details of Professor Henslow with those of M. Gustaf Rose and Colonel Helmersen, will perceive a remarkable analogy in the Welsh and Russian examples of metamorphism. But however the facts may be similar, there is an important difference between the views of the Russian authorities and those of Professor Henslow, since the latter shows that the garnet rock of Anglesea is simply the fossiliferous limestone and shale, mineralized and altered by the action of heat and the protrusion of the trap, whilst Colonel Helmersen seems to regard the garnet mass itself as of eruptive origin. We must say we think the reasoning of Professor Henslow may also be applied to the case of Turyinsk, whose garnet rock is we consider metamorphic—that it is, in fact, like the changed mountain limestone of Anglesea, or the Silurian limestone near Drammen in Norway (equally charged with garnets), a *result* of igneous intrusion.

one part 350 fathoms long by twenty wide, and has been worked to a depth of fifty fathoms, the adjacent limestone being chiefly converted into crystalline marble. In parts of the latter, however, which are less altered, we detected bands of black chert and other lithological characters so common to the palæozoic rocks of the Ural; so that combined with fossiliferous proofs along the strike of the beds, to which we shall hereafter advert, we had no doubt that the real age of the limestone is Devonian. Some of the richest copper ore occurs in openings between the garnet rock and the limestone, or along their points of contact. In some parts it is enveloped by limestone, and in others by the garnet rock, which according to Helmersen is chiefly compact and tough, being crystalline only when in contact with the limestone[1]. The preceding diagram, taken from a coloured Russian plan of the works at Frelofski (one of the chief mines of Turyinsk), at seventy feet beneath the surface, will at once enable the reader to comprehend the relation of the garnet rock to the limestone rock, and how the intrusive rock has in parts not only cut off and isolated the limestone, but also the bands with garnets.

All the undulating and lower country to the east of Bogoslofsk which we traversed, abounds, indeed, in a singular variety of mineral appearances. Thus a very few versts to the south only of the copper-mine of Turyinsk and Frelofski, are the noted gold mines of the Peshanka, which, formed out of the detritus of eruptive rocks which here and there rise to the surface, will be alluded to hereafter, together with the auriferous phænomena.

Descent of the river Kakva.—When isolated among the garnets, copper and gold of this tract, the warmest advocate for metamorphic agency may well have his misgivings as to such highly altered schists and limestones having ever been marine sediments charged with organic life. But if he be disposed to doubt that such changes have been accomplished, and the environs of Bogoslofsk on the west will not satisfy him (though fossils are also there to be found), we beg him to descend, as we did, the river Kakva from the station of Kakvinski, south of Bogoslofsk, for a distance of fifteen or twenty versts. As this river flows in a gorge from west to east, and as all the strata of the region here strike north 15° east, and south 15° west, it is manifest that it thus offers a transverse section. Accompa-

[1] According to Colonel Helmersen, there are instances of the garnet rock branching off like trap dykes. The limestone is evidently the oldest rock: judging from the analogy of contiguous places, it was first invaded by the greenstone, and from the facts above cited, the greenstone porphyry was clearly the last formed rock.

nied by Captains Strajefski and Popoff, and our former companion Karpinski, we embarked in small canoes at the station of Kakvinski, and glided down the tortuous and rapid stream. We found the whole gorge to consist of rapid undulations of limestone, which thrown into a number of saddles and troughs, is occasionally much dislocated. Associated with it, we observed alternations of bedded trappæan rocks like those near Bogoslofsk. The limestone is usually of a dark grey colour with white veins, but in the vicinity of the bedded trap, as at Bogoslofsk, it is red and compact. Wherever it is cut through by igneous rock of directly intrusive character, the limestone is highly altered; and we met with one example, where, in absolute contact with a dyke of greenstone porphyry, it had been converted into a pure white, saccharoid, granular marble, which crumbled away under the touch. In short, this descent of the Kakva would satisfy any one, however opposed to the doctrine of metamorphism, that there can be no more certain method of accounting for the crystalline condition of limestones in contact with eruptive igneous rocks, which at certain distances therefrom are unaltered and contain organic remains. The limestones are thrown about in various flexures to the east and west, whilst the dominant strike, from north and by east to south and by west, is very clearly maintained. For long spaces where the limestone is not absolutely saccharoid or crystalline, it is often compact, amorphous, and without distinct traces of bedding, and constitutes picturesque cliffs. One of these, called by the boatmen "Bielaya-kamen," or the white rock, particularly attracts attention, when it peers out from umbrageous thickets and rich vegetation.

Amid such strata we had at first little hope of discovering fossils, but here and there we were fortunate enough to collect an adequate number to satisfy us of the age of the rock. Even in the associated bedded trap, which very much resembled "schaalstein," we found corals similar to those which we had collected in a somewhat similar rock upon the Lahn in Nassau; such as *Favosites polymorpha*, *F. ramosa*, and *Stromatopora concentrica*. These fossils, which with the *Terebratula reticularis* or *prisca* and a plicated Terebratula were also found on the vertical and weathered faces of the limestone, led us naturally to believe, that the greater portion of this rock may be considered Devonian.

We also detected, however, in a limestone, one of the Pentameri, common to the underlying rock of Bogoslofsk[1]. Our belief therefore is, that in the undula-

[1] M. Rose mentions the occurrence of a trilobite in this limestone of the Kakva, which was supposed to be the *Calymene Blumenbachii*.

tions and great breaks to which all the strata have been subjected in this tract, the uppermost beds of the Silurian are brought to the surface and throw off the lower beds of the Devonian, as in the vicinity of Bogoslofsk.

It was sufficient for our chief purpose to satisfy ourselves, that the limestones, however crystalline and altered in some parts of their strike, as in the adjacent tract of Turyinsk, were nothing but palæozoic rocks, and of this fact the section of the Kakva offered us the most convincing proofs. To have worked out the precise succession of the strata in so convulsed a region was wholly impracticable during our cursory survey.

Equally convincing and more elaborately detailed illustrations of this phænomenon are, indeed, given by Colonel Helmersen, who in extending his descriptions of it to the banks of the Vagran and Sosva near Petropavlosk, has shown how on these streams, as well as on the Turya near Bogoslofsk, the fossiliferous limestones[1] and their associated beds are variously dislocated, mineralized and changed (including passages into dolomites, saccharoid marbles, jaspers, hornstones, &c.) when in contact with or in the proximity of the greenstones and porphyries of those districts. His observations form a valuable geological illustration of this territory; whilst M. G. Rose fully explains the mineral distinctions throughout the eruptive and crystalline rocks around Bogoslofsk, and has pointed out that the greenstone porphyry traverses not only the sedimentary deposits, but also the metamorphic garnet rock which had probably resulted from a previous eruption of another mass of matter in fusion (greenstone). (Rose, p. 400.)

In concluding this chapter, it may be observed, that the transverse sections of the Ural which have been described, explain phænomena clearly which are obscurely seen only upon the route from Perm to Ekaterinburg. They show us, that if not throughout the chain, at least on both its flanks and wherever the strata are not highly altered and crystalline, their age can be recognized by organic remains. Whether we look to the uppermost Silurian and the Devonian limestones, cut off and left in isolated fragments amid igneous masses on the east of the chief ridge, yet succeeded by Devonian and (as on the Issetz) by carboniferous rocks, or

[1] In considering the fossils collected in the Sosva, Vagran and Tura, to be Upper Silurian, Colonel Helmersen has added, that they are probably of the same age as the limestone of Livonia, which lies between the Esthonian (Lower Silurian) limestone on the one hand and the Devonian rocks on the other. Judging from the corals he has seen from several of these localities, some of which he believes to be new species, Mr. Lonsdale thinks that Devonian rocks are prevalent in the region east and north of Bogoslofsk. (See his description in the sequel.)

to the Devonian and Carboniferous limestones of the Serebrianka and Tchussovaya rivers upon the west, a persistent strike and general conformity of succession from centre to flanks is seen to prevail throughout the range. With numerous breaks, curvatures, and even apparent reversals, all these strata, whether metamorphic in their centre, unaltered on the west, or highly altered amid the granites on the eastern flank of the chain, *are conformable to each other, and all have the same line of bearing* as the higher adjacent portions of the axis; the strike of the westernmost zone of carboniferous limestone being perfectly parallel to the most central band of chlorite schist and quartz rock, in the same latitude. The North Ural of the Russian miners is, therefore, to be considered as made up of *one great sedimentary series*, which originally accumulated in successive masses, has since been metamorphosed, pierced and broken up, on parallel lines of intumescence, eruption and dislocation.

In subsequent chapters we shall further develope the striking lithological distinctions between the rocks upon the opposite flanks of the central ridge of the chain.

CHAPTER XVII.

THE ARCTIC URAL AND THE TIMAN RANGE.

(MAP, PL. VI., AND COLOURED SECTIONS, PL. V.)

Eastern Flank of the Ural from 62° to 65° North Latitude.—Jurassic Deposits in 65° North Latitude.—Western Flank of the Arctic Ural.—Section of the River Iletsk, with fossiliferous Lower as well as Upper Silurian Rocks.—Carboniferous Limestone and peculiar Development of its overlying Whetstones.—Isolated Trappæan Ridge of Sabliù.—The Timan Range—Constitutes the North-eastern limit of the Great Permian Basin—Its Granite and Schists.—Upper Silurian Rocks with Pentameri.—The "Domanik" Schists shown to be of Upper Silurian age.—Devonian Rocks of the same type as in the Valdai Hills.—Carboniferous Limestone like that of Russia in Europe.—Eruptive Rocks of the Timan Range.—Large area between the Timan and the Ural occupied by Jurassic deposits.—Conclusions, and Results of the Survey of the Petchora.

QUITTING for a time the colonized portions of these mountains, let us now extend our view to wilder regions, which, as distinguished from the North Ural of the miners, may be termed the "Arctic Ural."

Eastern Flank of the Ural Chain Mountains, extending from Bogoslofsk by Petropavlosk to 65° North Latitude.—Our own researches between Ekaterinburg and Bogoslofsk having completely satisfied us concerning the true nature of the eastern flank of the Ural, a reference to an excellent geological map of these environs, prepared by Captain Karpinski, sufficed to convince us, that the same limestones and igneous rocks extended to Petropavlosk and its environs, the most northern establishment of the Russian mines. It was not, therefore, necessary to follow these deposits further northwards upon their line of bearing; for we had before us all the fossils and specimens of Petropavlosk, and from them we clearly perceived, that the limestone nearest to the Ural ridge contained Silurian Pentameri, whilst Devonian shells occurred upon the east. On the banks of the Sosva, as upon the Kakva, these deposits are interrupted, cut off and metamorphosed by the intrusion of igneous rocks.

The persistent strike of all the chief sedimentary masses of the Ural, whether metamorphic or unaltered, and the dominant lines of eruption from north to south, of various bands of igneous rock, might, *à priori*, lead any observer to suppose, that a similar structure would be found to pervade the eastern flank of the chain when followed into the Arctic wildernesses. That such is truly so, has however only been determined by recent discoveries of Russian observers.

The earliest expedition for this purpose was under the command of Colonel Protassoff, chief of the establishment of Bogoslofsk at the time of our visit to that place. This officer, aided by Captain Strajefski, had some years before explored the mines, copper veins, iron ores and auriferous alluvia on the river Tolya 200 versts north of Bogoslofsk. Subsequently, Captain Strajefski was placed at the head of the northern explorations, and in two summers of very arduous labour, he succeeded in reaching 65° north latitude. In this journey, often labouring for great distances through deep swamps and lofty forests, inhabited at rare intervals by wild Ostiaks,—tortured by swarms of mosquitoes, and obliged to force each step through thickets, he overcame the most trying difficulties. By this expedition, the rivers which descend from the Ural were defined, and their native names attached to them; the rocks on their banks were examined, and by occasional traverses towards the axis of the chain its structure was determined. Proceeding from the sources of the Losva above Petropavlosk, Strajefski passed over the Sosva, and afterwards in succession its northern tributaries the Nios, Bugalia, Tolya and Sigva. Supplied by him with a large sketch MS. Map of the whole region that he traversed, we have taken from it the few data which appear on our general geological map concerning this wild tract; and have, for the present, deposited his original MS. with the Royal Geographical Society of London.

Examining at Bogoslofsk the specimens which Captain Strajefski had brought back, we had no difficulty in satisfying ourselves, that Upper Silurian and Devonian, perhaps even some carboniferous strata (for schists with plants occur), range at intervals from south to north along all this eastern flank of the chain, and that there, as well as in the other tracts already described, these deposits, often entirely cut out for long distances, are usually rendered highly metamorphic, particularly towards the axis of the chain, by numerous intrusive rocks, of which greenstone is the most prevalent.

Another important geological result of the expedition of Captain Strajefski was the discovery, before alluded to (p. 230), of Jurassic strata replete with fossils in 64° north latitude. These beds on the banks of the little river Tol, were found to consist of greenish sand and dark shale, dipping to the east or from the Ural chain. Among the fossils are Pinna, Plagiostoma, Pholadomya, Modiola, &c., with Ammonites and Belemnites, forming altogether precisely the same group, with which we had become familiar on the banks of the Moskva, the Oka and the Volga.

The occurrence of Jurassic rocks in this position was at first a great source of surprise to us, particularly as we had then observed no decisive proofs of a similar deposit in any portion of the eastern slopes of the Ural[1]. Subsequently, indeed, we were led to believe, that a small patch of Belemnitic strata, surrounded by eruptive and metamorphic rocks, and detected by Colonel Helmersen and M. Hoffman on the plateau of the Southern Ural near Tanalysk, might also be of this epoch. The strata of the same age on the eastern banks of the river Emba and its feeders, approaching as they do towards the southern prolongation of the Ural chain (see Map, Pl. VI.), and apparently almost folding round it, would further lead us to conclude, that however the deposits are now separated, the sea in which the Jurassic shells were entombed must have wrapped round the northern and southern ends of these mountains, and at a period long after their earliest elevations. Our acquaintance with these deposits has, indeed, been greatly extended by subsequent discoveries on the western flank of the Arctic Ural, where the same Oxfordian strata have been largely found, a point to which we shall presently revert.

Western Flank of the Arctic Ural.—We now pass on to consider the structure of the boreal region, first laid open by our own researches[2], which ranges northwards from 62° north latitude, and constitutes the western flank of the Arctic Ural. The geological composition of the mountains, in these parallels, may be briefly explained, by describing the natural sections exposed on the banks of the rivers which descend from the crest of the mountains. In that crest is situated the lofty mountain whence the magnificent Petchora takes its rise, its chief source being called by the native Zyrians Petchora-ill-is (see Map). In summer this tract is frequented by a branch of the Ostiaks called Mantchi, who possess large

[1] In a survey so expeditious as that which we made, it is not easy to establish the non-existence of a deposit over a wide region. We may, indeed, say that we found an imperfect shell in a mass of limestone immediately south of Verch Uralsk, which had much the appearance of an Ammonite of the Jurassic series. Of this, however, in the sequel.

[2] See notice of the geological discoveries of our associate Count Keyserling, p. 230.

troops of rein-deer, and by whose aid we ascended the mountain. From the summit of Petchora-ill-is (about 3600 feet above the sea), the spectator casts his view eastwards into the wide and deep valley of the Sosva (see p. 405), occupied by dense dark forests, beyond which are ranges of heights[1], called Telbunniar by the natives. Still further to the east are green dark-wooded plains, in which a few lakes appear, and in the distance are the boundless, yellowish steppes of Siberia. To the west, on the contrary, the view is soon arrested by numerous rocky elevations, which surround the upper woodland depression in which the rivers Yegra-laga and Petchora have their origin. The crest itself is seen to range very distinctly from south to north, along a series of broken, rocky summits, whose sides are, for the most part, covered with debris or grassy slopes.

The mountain of Petchora-ill-is consists of chloritic and micaceous schists, often highly quartzose, in beds obscurely stratified, and approaching to verticality. These rocks occupy a broad zone, including another mountain, called by the Zyrians Balvano-is, or the Mount of Idols, which owes its name to a peculiar phænomenon. On its rounded verdant summit are seen certain grotesque and rude columnar masses of chloritic quartz rock, mostly attenuated towards their base, and occasionally attaining the height of 100 feet. These natural monolithes are eight in number, and as five of them lie in the same alinement, or from north-east to south-west, we might at first suppose that they were indications of a great vein. Their schistose and depositary character, however, and the irregular distribution of the other three pillars, render it more probable that they are simply the hardest portions of the rock, which have most effectively resisted destruction.

To the west, the geologist descends through similar quartzose, chloritic and micaceous rocks and marshy forests, into the vast alluvial plain of the Yegra-laga. This plain is much occupied by gravel and rounded blocks of medium size, *all derived from the adjacent chain.* A few deserted huts are to be found which formerly served as places of barter between the Zyrians and the Ostiaks.

Looking eastwards from this tract, we were struck with the conical form of a mountain named Cosis, which we supposed might be trappæan, but, judging from specimens brought to us by the natives, we found it to be composed of the same rocks as the Petchora-ill-is.

Lower and Upper Silurian Rocks.—In descending the Yegra-laga we observed on both its banks alternations of argillaceous slaty schist, with bands of black

[1] According to Strajefski these hills are trappæan.

encrinite limestone, traversed by veins of quartz. These beds, having a north and south direction, cover the country to the point where the river Yegra-laga empties itself into the Iletsk; and even in ascending the latter towards the north, they are traceable for some distance. The only lithological variation observable in these beds, is *when they pass into talc schist, and where they contain great flakes of mica*. Their usual inclination is 80° towards the east, by which position it may be supposed that they are inverted, like certain strata before alluded to, which approach the Ural ridge on more southern parallels.

In descending the river Iletsk, the same beds plunge westwards, and still present the same courses of fetid encrinite limestone, and apparently with no other fossils. Upon them rest thick masses of subcrystalline grey limestone (marble), occupying cliffs of about 400 feet above the stream. Though it is difficult to extract organic remains from this rock, we detected in it, besides turriculated, indeterminable shells (probably, like those of Nijny Tagilsk, of the genus *Murchisonia*), the *Pentamerus Ostiacus* and the *Calamopora alveolaris*. The two last-mentioned fossils are indicative of Upper Silurian age, and as the rock rests upon the slaty schists with encrinite limestone, the latter, we inferred, must represent a portion of the Lower Silurian, like other masses to which we shall now advert.

The upper or marble beds dip both to the east and west, at angles from 40° to near verticality, and form a great basin, from beneath the western side of which the same argillo-calcareous schists rise up, as on the east. In one locality near the river Jezem, these slaty schists constitute a rock, much resembling in lithological aspect that of the shelly portion of the mountain of Snowdon in North Wales, and like it containing true Lower Silurian species, such as *Orthis calligramma* (Dalm.), *O. testudinaria* (Dalm.), *O. inflexa* (Pand.), *Terebratula crispata* (Sow.), *T. pleurites*, n.s., *Leptæna trama*, n.s., a large indeterminable Orthoceratite, and the *Calamopora fibrosa* var. *Sphæra*.

The occurrence of these shells in beds which underlie Upper Silurian rocks, *and pass conformably into talcose and chloritic schists*, is of great importance in leading us to believe, that by far the greater portion, if not the whole, of the Ural must originally have been formed of true palæozoic deposits[1].

Still further to the west, Lower Silurian rocks with black encrinite limestone

[1] This Pentamerus, which is not to be found in Part III. of our work, will be figured and described by our colleague Count Keyserling, in a forthcoming publication, entitled "Reise in das Land der Petchora," the plates and letter-press of which being of precisely the same size as our own, will form a natural supplement to this work.

again prevail, when they alternate with fragile, argillaceous schists and grey quartz rock, all of which are in highly inclined or sub-vertical positions. On the left bank of the stream, brown and brittle argillaceous schists constitute a mountain called Pulnaya-Gora, or Ball Mountain, so called because it is charged with many argillo-ferruginous concretions of a perfectly spherical form, another Silurian analogy, well known to all geologists who have examined the gorge of the Severn above Madeley, or the banks of the Banw in North Wales. The quartzose schists terminate in ascending order, with an inclination of 20° towards the west or lower country.

Carboniferous Rocks.—The Silurian masses above described are directly succeeded, and without any apparent unconformity, by carboniferous strata; thus showing, that in this part of the Ural, at all events, no portion of the Devonian group exists (see Map and Section, Pl. V. fig. 3). Unable to trace any great fault, or any decisive unconformability along this line, we are disposed to think, that the highly incurvated basin into which the Silurian rocks are here thrown, was formed before the Carboniferous beds began to accumulate, and that the upraised strata were placed beyond the influence of those waters under which the true Devonian beds were deposited.

The base of the carboniferous rocks, formed of thick beds of dark compact limestone, containing concretions of chalcedonic chert, and alternating with black shale, constitutes a sub-formation very much resembling the lower mountain limestone of Northumberland, Yorkshire, the Isle of Man, and the lower slaty group of Ireland.

The characteristic fossils of these lowest beds are, *Spirifer expansus*, Phil. (*lævigata*, var.), *Orthis arachnoidea* (Phil.), *Chonetes fornicatus*, n.s., with *Caryophyllia* and *Cyathophyllum*; whilst in the strata which immediately succeed to them is the *Productus hemisphæricus*, Sow. (var. *minor*.)

This carboniferous limestone is powerfully developed on the banks of the Iletsk, and occupies heights of 500 feet above its bed, as far westwards as the gorge called Stone-gate, where the rock is exposed in vertical cliffs of about 200 feet in height, through which the river escapes. The stratification of these limestones is often obscure, and is chiefly recognizable by lines of corals; the beds are powerfully bent both to the east and west, and the strike is persistent from north to south.

The chief lithological character (that of the mountain limestone of many parts of England) is undistinguishable from what we have described in the previous chapter upon the banks of the Tchussovaya river. Certain bands of a red colour and fissile texture, which are loaded with encrinites, alone diversify the mass of grey limestone with which they occasionally alternate.

The dominant fossils of this upper portion of the limestone are corals of the genera *Cyathophyllum*, *Lithostrotion*, *Syringopora* (*Harmodites distans*, Fisch.), with *Productus hemisphæricus* (*minor*), *P. comoides*, var., and *Orthis arachnoidea*.

Whetstone strata.—It is probable that the above-mentioned masses represent the lower and middle portions only of the Carboniferous system of this Arctic country. They are, in fact, overlaid by a thick series of argillaceous sandy beds, here and there schistose, which in the vicinity of the limestone partake of all its great and sudden flexures, and are perfectly welded on to it. Further westwards, their inclination becomes less and more regular, their direction being north-east. The sandy beds are made up of grains of Lydian stone and of grey, green and red quartz rock, imbedded in a fine felspathic or argillaceous matrix of greenish-grey and whitish colour, the quantity of which is so minute that it cannot be discovered by the naked eye. The siliceous grains, more or less rounded, are sometimes very small, but occasionally so large as to form a conglomerate grit. The prevailing colour of the whole rock is that of pounded black pepper; and it is divided into numerous powerful beds, traversed by joints which are seldom continuous. Where-ever these beds alternate with strong courses of greyish and reddish shale (clay), they are rounded off into slopes covered by gravel and vegetation; and they present clear and good sections only, where they are hard and sandy. Near the village of Sariù, the conglomerate courses expand into a true "Nagelfluhe," not less than twenty feet thick, containing grains of carbonate of copper. Plants having the "facies" of the carboniferous flora occur, and the whole group, being as before said, quite conformable to the carboniferous limestone, must be included in the same system.

The section of the very symmetrical hill near the Petchora river (Pl. V. fig. 2.), from whence the whetstones are extracted which are used over nearly the whole of Russia, establishes, beyond contradiction, the correctness of that view. The little river Sophiusa washes the base of this hill, and exposes a dome of carboniferous limestone, divided into thin flagstones towards the base, and thick beds near the summit: on both sides of the dome, these limestones are equably and conformably overlaid by shale, and a pepper-coloured whetstone identical with that of the Iletsk. The bed extracted for whetstones does not exceed three to four feet in thickness.

These whetstones are very largely developed along all the western flanks of the Arctic Ural. The river Petchora traverses them between 64° and 65° north latitude, and the huge blocks of grit found near the mouth of the Ussa, where that river empties itself into the Petchora, prove their persistence beyond 66° north latitude. From its conformable junction with the inferior limestone, the plants which it contains, and its mineralogical identity with the grits of Artinsk, before described (p. 129), we consider this rock to be a true member of the Carboniferous system; and we unhesitatingly distinguish it from the Permian grits above the Zechstein, which, however, we admit sometimes much resemble it.

The same succession of rocks which has just been described, extends probably to more northern points of the Arctic Ural, at least we have seen specimens of slaty schists, grey limestones with *Catenipora escharoides* (unquestionably, therefore, Silurian), as well as carboniferous limestone from the banks of the river Ussa.

We may here request our readers to consult the Map, and remark that the *principal crest* of the chain changes its direction in north latitude 65°, and ranges to its termination north-eastwards into the high mountains of Obdorsk, containing powerful plutonic rocks to which we have before adverted, as having been explored and their geographical position fixed by M. A. Erman. By reference to the map it will be seen, that a ridge of mountains, probably igneous and metamorphic, extends north-north-west from the Obdorsk group towards the icy sea. It is still unknown, however, whether the meridian and palæozoic zone of the chain is expanded near that parallel, where it passes into the Isle of Vaigatz, or whether a particular and less elevated branch there extends to the sea-coast; though, as before said, we are assured by the researches of M. Baer, that the same rocks are largely developed in Nova Zemlia.

Mount Sabliù.—Before we quit the consideration of the Arctic Ural, we may now speak of a small trappæan crest of no great longitudinal extension, called Sabliù, which we found to range from between 64° 30′ and 65° north latitude, and perfectly parallel to the major axis of the chain. This ridge, rising to a height of about 4000 feet above marshy low grounds, formed out of the debris of the carboniferous shale and grits, is composed of a porphyritic breccia, absolutely undistinguishable from that of the Solominski-kamen, near Petrozovodsk, on the borders of Russian Lapland (see *ante*, p. 18). Ranging from south to north for about thirty-five versts, the ridge of Sabliù affects an Alpine form, its western slopes being so steep that no turf adheres to it, whilst the hollows and clefts near its base are filled with eternal snows. In summer the summit is, however, free from snow, though it even then fringes the slopes in zones.

In vain did we seek on the face of this abrupt Arctic mountain for any traces of striæ or polishing, though every torrential streamlet on its flanks is accompanied by *trainées* of immense angular blocks, all derived from the adjacent summits; a subject, to the consideration of which we shall hereafter revert, when treating of the transport of the detrital and superficial matter of Scandinavia and the north of Russia.

Several ranges of heights are seen to the east of Mount Sabliù, the nearest of which are rounded, whilst the more distant rocky and wilder peaks constitute the real axis of the Ural, the dominant mountain of which in this latitude, the Tol-pas-is, has a height of about 4500 feet above the sea.

The carboniferous grits and shale on the flank of the Ural are overlapped by alluvial and incoherent argillaceous deposits, the deep ravines in which expose clays occupying excavations in the older rock, and containing Belemnites and other fossils of Jurassic form; but before we enter upon the examination of these secondary strata we must introduce our readers to another range of elevations which plays so important a geological part in the great basin of the Petchora.

The Timan Range.—Disconnected from the Ural in 62° north latitude by the depression above mentioned, and in no part rising to a greater altitude than 1000 feet above the sea, the zone of elevations called Timan, having a width of about sixty versts, stretches from south-south-east to north-north-west for a length of not less than 500 miles, and terminates in the headlands of Svetoi-nos, Barmin-mis, Rumenishni and Suvoinof upon the glacial sea. Like the Ural of the Russian miners, it forms the eastern wall or boundary of all the Permian deposits, the limestones and gypsum of which repose upon the western faces of its carboniferous and older palæozoic rocks, and never enter into the great depression just adverted to, which lies between this range and the Arctic Ural. To the west of the Timan, great masses of gypsum occur in the upper portion of the river Vim, whilst on the Ukhta and Vitchegda limestones abound, which, sometimes grey and marly, sometimes oolitic, contain characteristic Permian species, such as *Productus Cancrini* and *Modiola Pallasii.*

Viewed, therefore, in its relation to the Permian deposits, and its proximity to the Ural Mountains, the Timan range may almost be regarded as a branch of the latter. When, however, the reader casts his eye over the Map, he will perceive that the direction of this line of mounts coincides rather with that of the crystalline masses of Lapland and of the north-eastern edge of the Scandinavian coast, and is strongly divergent to the main axis of the Ural. But besides this, none of the rocks of the Timan, whether sedimentary or eruptive, have the Uralian impress. On the contrary, they possess the lithological characters of the rocks of Russia in Europe, and we therefore conclude, that they must rather be regarded as one of the Finnish and Lappish elevations, like those near Petrozovodsk, for example, to which we have previously alluded, than a trifurcating branch of the Ural.

In some spots near the glacial sea, we have even seen a portion of the Timan ridge assume the contour and character of the Scandinavian rocks, exhibiting rounded and flat domes of rose-coloured granite, in which schorl replaces mica. This rock forms, in fact, the promontory of Ruménishni-nos, and is flanked to the east by argillaceous schists, which strike from west 22° north to east 22° south, and plunge rapidly towards the north. The schists occupy the cape of Barmin-mis, and are there pierced by greenstones (diorites), which derange their dip. Argillaceous and micaceous schists also constitute an elevated mural mass along the peninsula of Kanin; and, according to M. Ruprecht the botanist, and the natives, the same rocks are prolonged in the direction of the Timan range, *i.e.* from Mikulkin-mis to Kanin-nos. This fact therefore shows, that in the parallel extending from 68° to 69° north latitude, the axis of this chain trends more westerly, and conforms to the outline of Russian Lapland. Near the centre of the range we learnt, that the heights from whence the river Vim descends, are also composed of similar schists, and we saw them further south, on the river Vol and the Upper Vitchegda. These schists are either of a blackish colour, or of a ribboned-grey, and are occasionally traversed by a cleavage, independent of the lines of bedding, which are always very much inclined. The great dislocation and high inclination of these, the oldest stratified rocks of this tract, are not participated in by the next deposit which succeeds, and which we have no hesitation in considering Upper Silurian. On the river Vashkina, near the icy sea, these rocks (see coloured section, Pl. V.) are loaded with Pentameri, the remarkable shell Cytherina, very nearly allied to the species of Gothland, and also by numerous Upper Silurian corals, such as *Catenipora labyrinthica*, *Calamopora alveolaris*, *Stromatopora concentrica*, &c.

Domanik Schists.—Other Upper Silurian beds of a very peculiar aspect (called

Domanik by the natives) are seen on the banks of the river Ukhta. These consist of black, tender, argillaceous and siliceous schists alternating, which are saturated with naphtha. They contain simple lobed Goniatites, long and slender Orthoceratites and small Cardiaceæ, the whole reminding us of certain dark slaty beds, which at Wissenbach, in Nassau, have been shown to occupy the very uppermost limits of the Silurian system (see Geol. Trans. vol. vi. p. 414). Some of these black, flaglike beds are as flexible as the well-known band of sandstone in the magnesian limestone near Sunderland, or more so; and sounding under the hammer like wood, may be polished and carved as a substitute for ebony. The fossils are chiefly found in small calcareous concretions of grey colour, which mark the laminæ of deposit, and are entirely free from the naphtha which permeates the mass of the rock, and gives to it a bituminous character.

Devonian Rocks of the Timan.—The "Domanik" schists are flanked on either side of the range by red and greenish sands and marls completely resembling the typical Devonian rocks of the Valdai Hills, and of the government of Olonetz. These rocks play a most important part in this chain; and the northern river Tzilma exposes in a transverse section, nearly all the different beds of which they are composed. Further to the south, they are developed on the little river Vol, reposing upon inclined schists. They there contain the *Terebratula Meyendorfii*, whilst their most characteristic fossils are various remains of the well-known Ichthyolites of the system common to the Baltic provinces of Russia and the British Isles, together with the *Spirifer d'Archiaci* and the *Terebratula Livonica*. Towards the base of the system, the *Orthis striatula* and *Terebratula prisca* abound here, as in the same position in other parts of Russia. In a word, the whole series is made up of red and variegated marls, red and yellow sandstone, with courses of marly limestone, whilst gypsum of red and white and green colours is interlaced with the other beds in thin courses, and is specially developed on the banks of the Pijema or Pishma.

Carboniferous Limestone and Millstone Grit of the Timan.—Overlying these true Devonian strata, the outer flanks of the Timan present bands of white carboniferous limestone containing the *Spirifer Mosquensis*, and exactly resembling the rocks of the same age at Vitegra and other places in Russia. And here it is curious to observe, that these pure white limestones repose at once on the Devonian strata, without the intervention of any lower sandy beds, such as occur in the Valdai Hills and to the south of Moscow.

On the coast of the glacial sea, this carboniferous limestone occupies the two capes, on either side of the ridge, called Suvoinov and Svetoi-nos. The river Indiga traverses the carboniferous band on the eastern flank of the Timan at thirty-five versts above its mouth, and exposes cliffs 100 feet high, which contain thick beds near their summits, and flagstones towards their base. The river Bielaya, an affluent of the Indiga, also exhibits on its less lofty banks, courses of limestone charged with Fusulinæ, fossils, as we have before shown, which characterize the upper part of this formation.

The same calcareous zone is also traversed by the river Tzilma in north latitude $65\frac{1}{2}°$, and forms the mountain Stchipina. In this parallel, the axis of the ridge is composed of Devonian rocks, the carboniferous limestone being seen on its eastern side only, and not upon the west. Nor is this limestone continuous, even on the eastern side; for upon the river Ijema or Ishma, the Devonian rocks are at once surmounted by Jurassic shales. Towards the southern extremity of the Timân, the same carboniferous limestone constitutes the chief mass of the range, and is laid open on the banks of the rivers Vol, Tsher and Milva, as well as on those of their recipient the Vitchegda; and we believe that it again appears in the form of an outlier or outliers on the river Soiva, a feeder of the great Petchora.

The carboniferous system of these regions contains another member, which is only to be seen at the northernmost extremity of the Timan range. Such are certain whitish grits charged with pebbles of white quartz, and therefore resembling the millstone grit; like which they also contain coal plants. Seeing that these beds have the same inclination as the carboniferous limestone, we believe their geological position to be precisely similar to that of the millstone grit of the Tchussovaya (p. 126). This inference cannot, however, be distinctly proved in the North Timan, where they form the lateral cover of a remarkable band of igneous rock.

Eruptive Rocks of the Timan.—The chief eruptive zone of the Timan extends from the cape Tchaitzin-mis for seventy versts towards the south-east, is from four to five versts broad, and rises to the greatest heights of these latitudes, all of them being sharp-backed, like the "Serras" of Spain. The rock has, on the whole, what British geologists would call a trappæan aspect, resembling certain basaltic rocks of the Hebrides and the south coast of the Isle of Man, and in it are amygdaloidal masses which contain Heulandite and Stilbite, minerals unknown in the rich and varied crystalline depositories of the Ural Mountains. Usually, however, the rock is more or less basaltic, of a dark colour, compact structure, and conchoidal fracture, with rare grains of a black vitreous mineral, and little crystals of Stilbite. Numerous veins and dykes of chalcedony traverse it, and give rise to druses of amethyst. Occasionally the structure is prismatic, and at other places the mass is regularly stratified in thick beds traversed by joints. This eruptive rock is singularly well laid open in the deep gorge of the river Bielaya, where it occupies vertical cliffs, of 300 feet in height.

The carboniferous grit, resting against the western side of these elevations at different levels, is, as well as the carboniferous limestone, inclined *towards* the trap, and might therefore at first sight seem to indicate that though the basaltic mass has unquestionably cut through, and perhaps raised up these sedimentary rocks, it has not given to them their present general inclination. But numerous examples in the Ural Mountains and other parts of the world, where the sedimentary strata dip inwards towards the eruptive ridges, and not away from them, would rather lead us to infer, that in undergoing a great vibratory and undulatory movement, the ends of the sedimentary strata adjacent to the eruptive masses have been let down by a subsidence into cavities occasioned by the evolution of much igneous matter, whilst their other side has been tilted up.

Whatever theoretical explanation may be attempted, it is certain, that these carboniferous strata are highly inclined and dismembered in the vicinity of the basaltic rocks, and this suffices for our purpose. The granitic axis of this range seems, indeed, to have been constituted at a much more ancient period, for it is flanked on the east by highly inclined slaty schists. These schists rise, in fact, into little discontinuous crests all along the chain, even where the granite is no longer seen at the surface, and everywhere they are very highly inclined and uniformly plunge to the north-east. The palæozoic rocks (if this name be restricted to those in which we actually discovered organic remains) are unconformable to these older schists, being, indeed, very feebly inclined, and usually to the east. For all that we know, the eruption of the granite of this region may have either been confined to a period anterior to animal life; or the ancient schists may represent some portion of the Lower Silurian sediments, in which few or no creatures were entombed. But we will not attempt to reason further upon such negative evidence, nor do we even desire to imply, that the most ancient schists of the Timan may not be of the same age as the large mass of the old gneissose and slaty rocks of Scandinavia. At all events, if referred to the palæozoic age, it is almost certain that they must be of higher antiquity than the portion of the Lower Silurian rocks which we have shown to exist on the western flanks of the Arctic Ural, and which there succeed conformably to true Upper Silurian rocks.

Jurassic Rocks between the Arctic Ural and the Timan Range.—In the great hollow in the earth's surface formed by the elevation of the rocks which we have been describing, or, in other words, in the great basin between the Ural and the Timan, no other deposits are visible save Jurassic shales, which are filled with many of the same organic remains as those which have been brought to light in other parts of Russia, and these are partially overlaid by very modern marine accumulations[1]. The same species of Belemnites, the same small Aviculæ and the same Inocerami abound in the region inhabited only by Samoyedes, which we traversed towards the mouth of the Petchora; and the same fossils have been brought by M. Ruprecht, the botanist, from the argillaceous portions of the more northern peninsula called Kanin-nos.

The best section of these Jurassic beds with which we became acquainted, is exposed on the banks of the river Ijema, or Ishma. At its confluence with the Petchora, large masses of a grey calcareous grit or sandstone, with a yellowish surface, and subordinate to the clays, are charged with Ammonites and other shells, as well as fossil wood. Beneath these succeed clays of very great thickness, with little concretions of cement, stone or argillaceous limestone, and still nearer the base is a shale similar to that of Goroditche and Moscow, in which are interlaced many Posidonias, the whole reposing upon Devonian limestones. Some hard bands in these Jurassic shales, which we did not meet with in other parts of these regions, cause dangerous rapids on the rivers Ishma and Vim. The banks of the river Sisola, and of its affluent the Visinga, must, however, be cited as good Jurassic localities, not only because they have afforded a multitude of Oxfordian fossil shells, but also the rib of a great Saurian. Whether this bone may belong to the same Plesiosaurus, the vertebræ of which have been recently found[2] in beds of the same age near Moscow, is more than we can pretend to determine. We can here only dwell on the interesting fact, that although examined for so very short

[1] See account of these Jurassic tracts, p. 230, and of the tertiary deposits of the Petchora, p. 332.

[2] Having submitted a cast of one of these vertebræ and half of one of the originals found by Mr. Frears to Professor Owen, his opinion is thus expressed:—"The Moscow vertebræ belong to the *Plesiosaurus brachyspondylus* (Owen), Report of British Association, 1839, p. 78. They are both middle cervicals, equalling in size our ordinary English specimen from the Kimmeridge and Oxford clays."

a period, the Oxfordian shales of Russia have already afforded Saurian remains on the Moskwa, the Volga, and the affluents of the Petchora, and that one of the forms is identical with a British species.

In concluding this chapter, which pretends to be an outline sketch only of a newly explored region, a large part of which is to be more minutely described in a separate work, we beg our readers specially to consult the Map, Pl. VI., as well as the coloured sections, Pl. V. In the latter, the general succession from the axis of the Arctic Ural to the adjacent low country on the west is explained in fig. 1, whilst the other drawings will afford a general idea of the outline and structure of a country never before examined by a geologist, and which, from the rigour of its climate, the nature of its Zyrian and Samoyede inhabitants, the difficulties of access, and the absence of any great mineral wealth, may not for ages to come be visited by other men of science.

Among the important geological results which this survey has contributed, we dwell with pleasure on the very clear development of Lower Silurian rocks charged with characteristic fossils near the axis of the Arctic Ural; because amid the metamorphoses which that chain has undergone, it is extremely difficult to detect such good proofs of age towards the central portion of these mountains. The evidence, indeed, of Lower Silurian, distinctly underlying true Upper Silurian strata, is a link in the proofs of succession which the reader will have observed it was not our good fortune to be able to detect in the highly metamorphosed axis of the North Ural of the miners. The western flanks of the Arctic Ural have also been most useful in demonstrating the precise age of certain grey carboniferous grits (whetstones) which have a very great expansion along the western outskirts of the chain, and are represented by a particular tint upon the Map (3').

New as it is to the geographer, the Timan range is not less interesting to the inquiring geologist, who cannot have examined vast areas of land, without being convinced, that however widely certain deposits may seem to be marked by a peculiar lithological structure, such distinctions are invariably put an end to when we reach the ancient boundaries by which such sediments were encompassed. In exposing true Upper Silurian rocks (which we have shown are not discoverable in the government of St. Petersburgh), and in thereby filling up, like the western Baltic provinces and the Ural, the full measure of the palæozoic rocks of this continent, the Timan range also exhibits Devonian and Carboniferous rocks, which are identical in contents with strata of the same age in the flat regions of Russia, whilst they differ materially from synchronous rocks of the Ural. This fact has led us naturally to connect the Timan with the subsoil of the vast low Muscovite countries, of which it forms the north-eastern girdle, and to separate it from the Ural, which in our language, has already assumed the Siberian type. Even the eruptive rocks of the Timan are, as we have shown, very different from those of the Ural, and much more accordant with those of Scandinavia, with the eastern flanks of which country the range seems to be in intimate connection.

The survey of the Petchora has further determined the exact north-eastern limits of the enormous basin of Permian deposits, whilst an examination of the flanks of the Ural or the Timan have equally shown us, that though pertaining to the same series of palæozoic life, the Permian strata must unquestionably be distinguished from the old and altered rocks of the Ural, out of which they have, indeed, been formed, and to which they are usually unconformable. In that phænomenon alone then we see the proof, that certain groups of animals have not always been obliterated by the powerful local changes, which have separated one deposit from another.

CHAPTER XVIII.

SOUTH URAL.

(MAPS, PL. VI. AND VII., AND COLOURED SECTION, PL. III. & IV.)

Introduction.—Eastern Flanks of the Chain between the North Ural of the Miners and the South Ural of the Bashkirs, or between the river Issetz and the Zavod of Kishtymsk.—From Kishtymsk and Mount Sugomak by Soimanofski Zavod to Zlataùst.—Zlataùst, Taganai and environs.—Tract extending westwards to Simsk.—Transverse Section across the Chain, from the Palæozoic Strata of Pristan and the river Ai on the west, through the dolomitic and trappæan rocks of Satkinsk, across the Ural Tau, to the highly crystalline and Metamorphic Rocks of Zlataùst and Miask upon the east.—Tracts south of Miask.—Environs and Section of Cossatchidatchi.—Granitic Steppes between the Ural and Troitsk in Siberia.—Eastern edges of the Ural from Verch-Uralsk to Orsk.—Transverse Section from Orsk to Orenburg.—Oblique Section of the Chain from near Orenburg, by Preobrajensk and over the Irendyk to Verch-Uralsk.—Transverse Section of the Chain from Verch-Uralsk on the east to Sterlitamak on the west.—Concluding Observations on the original Structure of the Ural Mountains and the Changes they have undergone; on the inversion of the Strata and their direction in different parts of the Chain.

THE Southern Ural of the geographer may be said to be divided from the North Ural of the miners, in the parallel which the Russians have selected as the limit between the governments of Perm and Orenburg[1]. To the south of this boundary vegetation becomes richer, and fine streams flow longitudinally between important ridges, which expanding in their range southwards and south-westwards, finally occupy a region of considerable width. Light and running waters have access to beauteous glades, which, peopled by picturesquely-clad Bashkirs, cheer the sight of the traveller, who contrasts them with the gloomy and unpeopled thickets of the north. The Southern Ural is also distinguished by having its chief peaks upon the

[1] In the time of Pallas a great part of the region described in this chapter was the government of Issetsk, since abolished, and now divided between Perm and Orenburg.

western side of the watershed, whilst in the North Ural, as already shown, they rise up on its eastern flank. Thus in the tracts we are about to consider, the Taganai, Iremel, Yamantau and other great elevations, lie to the west, whilst in those previously described, the Katchkanar, Pavdinski and Konshakofski-kamen, are upon the eastern slope of the axis, or "divortia aquarum." We here speak merely of the lines of greatest altitude, for upon inspecting the Map it will be seen, that in a geological sense, many of the igneous rocks preserve their meridian direction, and occupy very nearly the same parallels of longitude, whatever may be their height.

The chief physical distinction, however, of the South Ural is, that unlike the North Ural, which has one dominant ridge only (see Map, Pl. VII.), it is composed of many bands, which, proceeding from the mountain Yurma, gradually open out fan-wise, and are divergent. For whilst the Ilmen Hills on one line, and the Kyrkty or Krykty and Irendyk upon another (the two latter forming a sharp "serra," which represents the chief water-shed), trend upon the whole, from north to south; other and loftier ranges proceed from the Yurma, Taganai and Urenga on the north-east, and swelling out on the western flanks of the lofty Iremel[1], expand into a succession of ridges, which trending from north-north-east to south-south-west, are watered and traversed by the rivers Inzer, Nugush and Bielaya, all tributaries of the Kama and the Volga. It is this south-western portion of the chain which has met with the least attention from geographers and geologists, and in referring to our Map, on which many new features are inserted, we shall in the sequel endeavour to point out the structure of some of these embranchments. Before, however, we enter upon the description of such portion of these southern mountains as we visited, we must say a few words concerning an intermediate tract on the eastern flank of the chain between Ekaterinburg and the South Ural properly so called.

Eastern Flank of the Ural south of Ekaterinburg.—The portion of the chain which lies immediately to the south of Ekaterinburg is of slight altitude, and is com-

[1] The knot of higher mountains around Iremel, or Eremell, the geographical features of which have been just described in detail by M. J. Khanikoff (Journal of the Royal Geographical Society, vol. xiii.), is not, of course, included in the allusion to accessible and picturesque districts. Helmersen and Hoffman have explained the structure of the highest peaks in this rugged Alpine tract, which, as in the Taganai and Ural-tau of Zlataüst, consist for the most part of quartz rocks, with passages into micaceous schists, &c.

posed of crystalline rocks, some of which have been already alluded to, and others have been described by Humboldt and Rose. Believing that a tract in which the copper mines of Gumachefsk and Polefsk, so well known for their imbedded minerals, including marbles, veinstones, &c., could afford few or no traces of organic life, we did not examine it, but deflected from the chain to make the section on the Issetz, already described, and did not regain the mountain slopes till we reached the environs of Kishtymsk[1].

Quitting the Issetsk and the little oasis of Silurian rock at Crasnoi-glasnova (p. 364), we bent our steps obliquely towards the eastern slope of the Ural. For a considerable space around Crasnoi-glasnova the surface is occupied by rich black earth, the "tchornozem" of the Russians, of which we shall treat hereafter, mentioning it in this place only, in order to note, that we are unacquainted with any such deposits on the flanks of the Northern Ural. In this tract is also situated the brackish lake of Shablish, which having scarcely any outlet, may possibly derive its saline properties from springs flowing through subjacent rocks. We perceived, indeed, another geological feature in the neighbourhood of this lake, which led us to infer, that saliferous deposits, similar to some of those of Russia in Europe, might exist beneath the superficial covering of black earth and local detritus. Being informed by the peasants, that gypsum occurred in a little mount about twenty-five versts south-east from Bagariatsk, we travelled from that place to examine it. Passing by the lake and village of Ognova, in a flat country covered by black earth, we found the gypsum exposed in a gentle rise on the right bank of the river Sinara, and not far distant from its junction with the Sinera. Though the quarry had not been worked for fifteen years, the open cuttings were still sufficiently visible, and a section of about thirty feet deep plainly exposed courses of thinly

[1] Whilst two of us, Mr. Murchison and M. de Verneuil, were thus employed upon its eastern flank, Count Keyserling repassed the Ural to Sergiefsk, and descended the streams to the banks of the Ufa, thereby ascertaining the junctions between the older palæozoic rocks and the grits of Artinsk (see ante, p. 128). After these independent explorations we again met at Zlataüst, whence, after some conjoined explorations, M. de Verneuil and Count Keyserling passed from the Ai to Satkinsk, Simsk, Ufa and Orenburg. From Zlataüst Mr. Murchison again took the Asiatic side, and, accompanied by Lieutenant Koksharof, re-crossed to Miask and the Ilmen Hills, examined the auriferous tracts there and at Cossatchi-datchi, from whence he traversed the steppe to Troitsk, and thence regained the Ural river, following it to Orsk and Orenburg. Afterwards, in company with M. de Verneuil, he made sections across the chain from Orenburg to Verch-Uralsk, and from that place to Sterlitamak, whilst Count Keyserling traversed the Kirghis steppe by Mount Bogdo, &c.

foliated, red and grey gypsum, subordinate to red sandy clay; the whole dipping slightly to the south-east. In the bed of the adjacent stream we found fragments of a reddish-coloured brecciated limestone and of eruptive rocks, but could not connect them with the gypseous mount; nor did we discover any organic remains by which we could satisfactorily determine its geological age. On the western flanks of the Ural, the Permian strata are, as we have shown, the great depositories of gypsum; but could we, from the mere presence of that mineral in red earth infer, that this isolated patch,—the only one so characterized along the eastern side of the chain—is of the same age? Certainly not, because there is no vestige of the Permian rocks on the Siberian side of the Ural, and we, therefore, consider that this gypseous mount must either be a portion of the older palæozoic rocks (Devonian for example) which abound in these territories, or an accumulation of tertiary age, like that of Kaltchedansk, formed out of the detritus of pre-existing formations (p. 366). At Bagariatsk, indeed, we met with a very instructive section, in which for nearly a mile, highly inclined beds of red and green schists (on the banks of an affluent of the Sinara) alternated with red and greenish coarse conglomerate and grit, the whole differing only from the Old Red Sandstone of Scotland, in containing a few courses of impure limestone. On the west, or up the stream, these rocks pass into highly altered amorphous cherty limestone; and on the east or down the river, into black schists, grey grits and limestone containing large carboniferous Producti and other fossils. Seeing, therefore, that the tract (as well as that of the adjacent Issetz) does contain rocks, which, rising from beneath the carboniferous limestone, must be considered of Devonian age, we are disposed to think, that just as at Starai-sol near Novogorod, such beds may contain the elements from whence the saline character of the Shablish lake has been derived, and that like the gypsiferous strata of similar age in Livonia, they may contain gypsum; the hummock on the Sinara being either part of them, or having been derived from their destruction during the tertiary epoch. We had now completely satisfied ourselves, both by following the Issetz to Kaltchedansk, and by examining the Sinera and its affluents, that palæozoic rocks, pierced at intervals by plutonic matter, constitute the subsoil of the low plateaux, which descend from the mountain slopes to the great Siberian plains.

In approaching the Ural (at a few versts to the east of Kanevsk), we observed that granite again usurps the surface. This is a southern prolongation of one of the bands of similar rock near Ekaterinburg, like which it splits into flagstones, which when laid down here for use are sometimes three to four yards square and three or four inches only thick. When treating presently of similar rocks near Miask we shall discuss the question of their origin.

Travelling over another low and undulating country of black earth to the west of Kanevsk, we traversed the most northerly of the grounds now frequented by the Bashkirs and reached the Zavod of Kaslinsk[1]. From Kaslinsk to Kishtymsk the road coasts, as it were, the very edge of the Ural ridge, passing through woodlands and by a succession of lakes. In fact, we journeyed somewhat obliquely over a succession of dwarfish ridges, thirty to 100 feet high, each in itself a crystalline mountain in miniature, and all perfectly parallel to the main crest. If the chief heights of the Ural be compared to highly agitated billows, these little flanking ridges may be likened to the last expiring waves which have derived their form and structure from the same causes of disturbance. We found them to be, in fact, the smaller lateral folds of highly metamorphic rocks, whose surfaces, uncovered by a single block and in many parts swept clean of all gravel and sand, were thoroughly exposed. Some of them are so micaceous that they might pass for primary mica schist; others may almost claim to be associated with gneiss, and with them are associated the dominant chloritic and quartzose rocks of these regions. Though both eastern and western dips prevailed in the outer folds, a western inclination is most common in the masses nearest to the mountains, indicating an inversion or reversal of the strata,—a phænomenon often observed on both sides of this chain, and other great linear eruptions. In short, we had beneath our feet miniature mountains, which a few years ago any geologist would have termed primary, but which (and we shall soon adduce additional proofs to those derived from the North Ural) we cannot but consider as metamorphosed palæozoic strata, or masses so associated with them, that we know not how to separate them, in any classification founded upon the age or succession of rocks.

The Zavod of Kishtymsk is placed amid the lower folds of these metamorphic rocks and on the edge of a picturesque lake, just where the eruptive rocks rise out in great and striking masses from beneath, and explain, as in other places already cited, the cause of so much alteration.

[1] In approaching Kaslinsk our horses were brought to a stand-still at the edge of a wood in which the Bashkirs of the environs had pitched their summer tents. The sun was setting behind the Ural Mountains and gilding the tents of these poor but joyous people, who, after regaling us with their "kumiss" or mare's milk, furnished us with fresh horses from their extensive herd.

The prominent mountain, which here forms a striking counterfort of the Ural, is called Sugomac. On ascending it we were amply repaid, both by finding the structure of its flanks and summit most instructive, and also by enjoying a most remarkable prospect. Between the Zavod and Sugomac, bosses of greenstone, for the most part quite a hornblende rock, throw off gneissose mica schists, and in ascending the hill we met with protuberances of syenite; whilst higher up and in the deep recesses of the woods, limestone constitutes isolated masses, in the altered condition of white marble, with large crevices and fissures, one of which constitutes a cavern, said to be 300 feet in length.

The summit of Sugomac consists of a rock[1], which, like some of those alluded to near Ekaterinburg, almost defies mineral classification. It is irregularly schistose and chloritic, but at the same time contains hornblende. It is, therefore, either an intrusive or an original depositary rock so much transfused by igneous matter that the distinction can scarcely be drawn. From this peak the panoramic prospect is very striking. To the west is a vast rolling surface of mountains, made up of ridges separated from each other by dark depressions, and all, with the exception of the distant stony crest or "Ural Tau," covered with the densest forest; in short a primæval woodland, similar to that seen from the Katchkanar (p. 392), but differing in offering a more wavy outline. On the east, Siberia lies absolutely at your feet, and minor inequalities of the surface being merged, looks like one vast plain. The lake and Zavod of Kishtymsk, with rich meadows around them, are in the middle ground, and the distance is composed of a woody and partially pastoral tract inhabited by Bashkirs, in which, as we were informed, at least a hundred lakes exist, ninety of which belong to the proprietor of Kishtymsk. Some of these are represented in the opposite landscape, which we offer as one of the most striking "peeps into Siberia" which we met with on the eastern flank of the chain[2].

[1] Sugomac may be considered the southern prolongation of the ridge which lies between the iron mines of Ufaleisk and the Zavod of Kaslinsk, a tract formerly described by Hermann (Mineral. Reisen in Sibirien, 1783), and which consists of clay-slate and mica schist, with syenite and granite. It is also a tract (particularly between Kishtymsk and Syssersk), in which, according to Rose, chromate of iron abounds, occasionally appearing in layers or intercalated with serpentine. (See Rose's Analysis of the Rhodochromate found with the chromate of iron.) Talc schists, greenstone, with albite and cyanite, also occur here, and probably the rare mineral Uvarovite. (Rose's Reise, vol. ii. p. 158 to 160.)

Though the gold mines in the neighbourhood of Kishtymsk were visited by Baron Humboldt and his party, it appears from M. Rose's narrative that bad weather prevented their seeing or ascending Mount Sugomac.

[2] The Zavod of Kishtymsk belongs to the Zuboff family, whose agent, M. Petrof, received us with great

Soimanofski Zavod, &c. &c.—After travelling along the flank of the chain for some distance to the south of Kishtymsk amid the woodlands, lakes, &c. seen in the preceding sketch, we followed the new road by Soimanofski Zavod to Zlataùst (see Map). We thus necessarily effected what was much to be desired, viz. both a longitudinal and transverse section of the chain itself, in tracts where its structure is exceedingly diversified. The first traverse, or that in the parallel of Soimanofsk, exposed in succession ridges like those of which Sugomac is the type, and in which limestones and serpentines also abound, together with decisive eruptive rocks, and altered quartz rocks, &c. Further on, and to the west of the Zavod of Soimanofsk, large masses of auriferous alluvia encumber the surface and inclined edges of the subjacent and regularly stratified limestone, which enters quite into the heart of the chain[1]. The great point of interest to be now adverted to is, that after following the beautiful pastoral and upland valley of the river Miass, with the granitic ridge of the Ilmen-tau on the east and the higher eruptive and metamorphic chain of the Ural-tau on the west; i. e. when fairly encased between two great parallels of eruption, we discovered *Encrinites* in pure white saccharoid limestone. So highly altered is the rock, that we could still less believe our eyes, than when many years ago in the Austrian Alps, with Professor Sedgwick, we discovered similar organic remains in the chloritic, primarized limestone in the Tauern Alp. (Geol. Trans., vol. iii. p. 306.) This limestone being precisely on the strike of the masses on the mountain of Sugomac and at Soimanofsk, left no option but that of admitting, that the associated stratified masses, however crystalline they may now appear, were once quartzose sandstones and greywacke, formed under the sea at a period when palæozoic life prevailed.

The great transverse section across the whole chain in the parallel of Zlataùst, which will be presently described, strikingly illustrates this point and demonstrates, how invariably the altered character of the rocks and the presence of mineral veins, with bunches of simple minerals, are connected with and dependent upon the eruption of igneous matter.

Group of Mountains around Zlataùst from whence radiate the ridges of the South Ural.—We had now passed along the flank of the Jurma (see Map), and

kindness. He presented us with a very remarkable ore of iron from the mine of Yurasamskoi, west of Schatinsk, which is in parts made up of fibres nearly as fine as the filaments of asbestos. The Zavods around Kishtymsk produce 250,000 poods of iron and seventeen poods of gold per annum.

[1] The gold alluvia and their relations to these subjacent rocks will be subsequently explained.

were already in the knot of mountains from whence the South Ural, properly so called, begins, and where the striking contrasts with the North Ural, alluded to at the head of this Chapter, may be said to commence. It is here that separate ridges of marked and mountainous characters set on, such as the Urenga and the Taganai on the west, the Ural-tau in the centre, and the Ilmen hills upon the east. Here it is also that the rivers Miass and Ai, gliding in depressions through the central portion of the chain, escape into the adjacent lower countries, the former by the Zavod of Miask to Asia, the latter by Zlataùst to Europe[1]. Availing themselves of the water of the Ai, just where that stream issues from the higher mountains, the Russians judiciously fixed their chief establishment of Zlataùst upon its banks. This very flourishing place is thus situated in a romantic valley on the western side of the watershed of the Ural, at the foot of the Urenga, and a little to the south-west of the Taganai. The latter, the most striking mountain of the tract, rises boldly from the well-watered vale into three summits, which have acquired for it in the Bashkir language the name of "tripod of the moon." The highest of these summits has been estimated by M. Kupffer at 3521 English feet, and by Colonel Helmersen at 3592 English feet above the sea.

[1] Zlataùst is the Birmingham and Sheffield of the Ural, and exhibiting high progress in the arts and a well-organized community, is one of the brightest spots in the Russian empire. We very much regret that the nature of our work does not permit us to speak at length of the superior manufacture of steel which has so distinguished Zlataùst since the Zavod has been directed by that skilful metallurgist and excellent administrator General Anòsoff, whose damasked scimitars and ornamental steel works excel everything of like nature with which we are acquainted. On this point, indeed, we willingly refer to Captain James Abbot of the Honourable East India Company's Artillery, a traveller well-versed in the processes of preparing steel in the East. "The general fault of European blades (says he) is, that being forged of shear-steel for the sake of elasticity, they are scarcely susceptible of the keen edge which cast-steel will assume. The genius of Anòsoff has triumphed over this objection, not in hardening the soft steel, but in giving elasticity to the hard; and it may be doubted whether any fabric in the world can compete with that of Zlataùst in the production of weapons combining in an equal degree edge and elasticity."—*Narrative of a Journey from Heraut to Khivah, Moscow and Petersburgh*, vol. ii. Appendix, p. 87. The exquisitely damasked daggers and a sword which we received on the spot from the General, fully sustain the truth of this eulogy, and a plateau of burnished steel, richly ornamented and diversified with gold *relievi*, since forwarded to Mr. Murchison by the Imperial Administration of Mines, has excited much admiration in England. We found in General Anòsoff and his amiable family, as well as in the various officers of the Imperial Mines (who are all attached to him in heart as well as by duty), the truest and most serviceable friend, and we took leave of him with sorrow. Attended by Major Lissenko, who had prepared a mineral map of the region, General Anòsoff accompanied us in two excursions, and insisted on travelling with Mr. Murchison across the Ural to Miask and the gold mines south of that place, ascending by the way the Ural-tau. We have spelt Zlataùst as it is pronounced; the German orthoepy of it is Slatoust (see Map of the Environs, Rose, vol. ii. pl. 5.).

Having ascended the Taganai, we found it to be composed of quartz rock, evidently of metamorphic origin, for in some parts the stone is seen to pass through distinctly stratified beds into grit and conglomerate, whilst in others it is so highly crystalline as even to assume the characters of avanturine. Rising up from amidst masses of micaceous and chloritic schists, and surrounded by granitic and other igneous rocks which are laid bare at lower levels, the Taganai is, in truth, identical in structure with the adjacent Ural-tau, of which it must be considered a western counterfort, though considerably higher than the true watershed of the mountains.

The Urenga is a great crystalline mass of micaceous and chloritic schist, which contains dykes and bands of quartz, and is traversed at many points by greenstone dykes, and is also, we believe, metamorphic. The Nazimskaya-gora, to the north of Zlataùst, which rises to near 2300 feet above the sea, may be considered a prolongation of the Urenga. From the eastern side of this mountain we took the opposite view of the Taganai, which thus appears as a short but lofty, isolated, ridge surrounded by dense woods.

On the western flank of the Nazimskaya-gora we collected some beautiful minerals from a point of rock which had been recently laid open by order of General Anòsoff. At this spot the matrix is a chlorite schist with some limestone, penetrated in a very irregular manner by points of greenstone, the calcareous matter being usually in the form of spar, and the greater number of the simple minerals being found between it and the face of the intrusive rock. Among these minerals was the newly-discovered repidolite, together with garnets, crystallized talc, &c. Wherever the rocks are exposed, immediately to the north or south of Zlataùst, or in the gorges to the west of it, they are seen to consist either of amorphous masses, like those just mentioned, or of regularly stratified micaceous and chloritic schists and quartz rock, with which are associated intrusive greenstones, often, to a great extent, assuming the form of beds and dipping with the strata.

Western Dependencies of the Mountains between Zlataùst and Simsk.—Before we describe our general section across the chain in the parallel of Zlataùst and Miask, we beg to give a brief sketch of the succession from the crystalline centre of which we have just been speaking, to the western edge of all the rocky region near Simsk. The crystalline and metamorphic ridges of Taganai and Urenga, with a subsidiary limestone at Kuvashi, are flanked by a basin-shaped mass of schistose calcareous deposits, of which the limestone of Kussinsk is the fullest type. These we are

disposed to consider of Upper Silurian age, for reasons which will be given in explaining the transverse section, Pl. III. fig. 1. The country which we would now describe, is that which lies to the south and west of the Zavod of Satkinsk, and is made of various ridges of palæozoic rocks, watered by the rivers Juriusen or Yurezen and Sim, and their affluents. Satkinsk, by which place our chief section passes, is distinguished by its black dolomites and contiguous greenstones; the two rocks being in contact. At eight versts to the south of Satkinsk is Mount Makarofka, composed of greenstone at its summit, and flanked by slaty, argillaceous schists, which strike about north-north-east, south-south-west, or to the east of north[1]. This mount, and that of Ballindisha, the summits of which consist of immense masses of quartz rock, form a little ridge extending from north-north-east to south-south-west, and parallel to a higher ridge on the west called Silkia, also composed of quartz rock; the valley between them being occupied by limestone and iron mines. Still further to the south-south-west, the easternmost of these branches assumes the name of the Tchuida, also composed of quartz rock, as well as the loftier Zigalga (see Map, Pl. VII.), which runs parallel to it on the east. The valley between these ridges, or that of the Bulanka, which we traversed, is made of clay-slate, which having a north-north-easterly strike, has a dip of 35° to 40° to the east-south-east. With the expansion of this valley, an argillaceous and fissile limestone is developed (at Perevanchina, fifteen versts east of Yuryusensk), which clearly forms a part of the schistose and quartzose rocks in which it is intercalated, and with whose bearing to the north-north-east it entirely coincides: the beds of this limestone are all inclined *eastwards* at various angles from 10° and 15° to near verticality.

Flanked on the east by a ridge of slaty schist, the little town of Yuryusensk is situated in a picturesque longitudinal valley, ornamented, like all the Uralian forges, with a Zavod lake, the north-western banks of which consist of abrupt faces of limestone, in which we detected *Stromatopora concentrica*, with Terebratulæ, in beds passing downwards into dolomites; the whole dipping to the east-south-east, and therefore under the more ancient slaty schists and quartz rocks

[1] A very productive iron mine (brown oxide?), which supplies the forges of Yuryusensk, Simsk and Ust Kataevsk, occurs at Bakalski. The mining stuff is traversed by a highly inclined band of siliceous grit or quartz rock dipping to the north-west, and the surface is covered with clay and sand. This iron ore is probably of the same age as that which is found in the clefts and in the interstices of all the palæozoic rocks on both flanks of the chain, and is evidently an aqueous deposit of much more recent date than the magnetic iron ore.

before mentioned. We believe that this slaty, quartzose and occasionally calcareous series, which is, in fact, repeated by upheavals and repetitions to the very heart and highest members of the chain,—the lofty Iremel itself being but a metamorphosed grit and sandstone in the form of quartz rock,—represents the great mass of the Silurian system, and chiefly its lower portion.

To the west, however, of Yuryusensk the natural features of the country change, the sharp and arid ridges of quartz rock and slaty schist disappear, as well as the eruptive rocks, and are succeeded by limestones, sandstones and shale. The strata exposed between Yuryusensk and Ust Kataevsk, consist of limestones, both thick, thin-bedded and concretionary, occasionally dolomitic, sometimes in the state of marble, of red as well as grey colours, with subordinate grits, conglomerates and schists[1]. Throughout this succession of calcareous beds, we could discover a few corals only, but in a limestone valley at Ust Kataevsk we met with a Spirifer, identical with one with which we were familiar in the unquestionable Devonian beds of Voroneje on the Don (see p. 60), and which we have named *S. Anossofi*, in honour of our esteemed friend the Director of the mines of Zlataùst. Here, then, we had a true horizon, which was soon shown to be correct; for in a few versts to the west of this spot carboniferous limestone succeeds. It is important to remark, that whilst throughout the whole of the slaty, quartzose and older calcareous groups of which we have been speaking, and which we class as Silurian, the strata invariably plunge to the east or south of east (the younger portion of these rocks thus unquestionably dipping *under* the more ancient), no sooner are we removed at a certain distance from the great convulsions which the chain has undergone, than all such inversion ceases. At Ust Kataevsk, where the surface is only gently undulated, the beds regain, in fact, their normal position, and the Devonian limestone, which to the east is inverted, dips steadily to the west-north-west, and is naturally overlaid by the carboniferous group. These rocks, whether in the form of limestone, grit or calcareous flagstone, are well seen at Yakina and Eraol; the former six, the latter fourteen versts west of Ust Kataevsk, and in it we collected the well-known *Productus striatus* (Fisch.), (*P. Valdaicus*), with other fossils. In travelling from Eraol to Simsk, the road first passes over a low hill called the Eraolski Gora, the eastern flank of which is remarkable in this region, so void of all coarse detritus, by being covered with rolled and rounded fragments of syenite,

[1] The chief elevation in this calcareous tract is called Mount Soliman, the body or flanks of which consist of limestone, though the summit is a grit.

quartz rock and other crystalline materials derived from the adjacent hills upon the east and north-east. The summit, however, (a plateau from whence the Iremel and higher mountains of the chain are well seen,) is composed of limestone and sandstone in nearly horizontal masses, impressions of Calamites and other plants being visible in the latter. The Carboniferous system occupies, in fact, a fine breadth of country in this parallel, extending to about thirty versts west of the flourishing Zavod of Simsk, where it is finally overlapped by the gypseous red rocks of the Permian system which surround the city of Ufa. Void of all traces of detritus derived from the chain, and apparently beyond the region of dislocation, Simsk is very remarkable in exhibiting picturesque and broken masses of the carboniferous limestone, which surrounding a circular lake, dip in various directions. In fact, the strike in one point where we observed it, is from west to east, or athwart the direction of the very same formation a little to the east. Such partial aberrations and eccentric breaks must be looked for in the outermost folds of a great series of mountain flexures, near their line of frontier with another group of deposits By reference to the Map it will be seen, that Simsk is probably upon one of those flanking lines of dislocation parallel to that singular line of eruption which traversing the Inser is marked by a long south-south-westerly bend of the Bielaya. It is upon this latter line that the remarkable outliers of carboniferous limestone north and south of Sterlitamak, before described, p. 130, have been upheaved to the consideration of which we shall hereafter return. Among the fossils at Simsk we may enumerate *Productus Martini*, *P. semireticulatus* (Mart.), *Spirifer lineatus* (Mart.), all well-known Derbyshire and British species.

General Section across the Chain in the parallel of Zlataüst and Miask.—The coloured section, Pl. III. fig. 1, will best explain the highly diversified character of this chain, which, so crystalline in its central parts, tells off in a remarkably clear manner on its western flank the original nature of those palæozoic deposits which have been sufficiently removed from the great centre of mineralization. On this occasion, reversing the method employed in explaining the succession from Zlataüst to Simsk, we will describe the deposits as they succeed each other from the low country on the west, across the mountains to the low plateaux of Siberia on the east.

On the banks of the little river Kiga (an affluent of the Ai) sandstones and grits occupy the low country, and constitute, as at Artinsk and other places where we have before described them, a wide trough in the carboniferous limestone on which they repose (see Map). To the west they are succeeded by true carboniferous limestone with its usual fossils, that rising out from beneath them is itself underlaid by calcareous and quartzose masses which, as developed at Alina, we believe to be of Devonian age. The next group, extending from thence to Pristan, is unquestionably Upper Silurian, for we found in it *Pentamerus Bashkiricus*, *Favosites Gothlandica*, and *Stromatopora concentrica*. To the east of Pristan, a great convolution is followed by a break, and schistose and quartzose rocks with some greenstone are thrown over with a reversed dip. We consider these rocks, extending from Silkia to Satkinsk, to be Lower Silurian, because although we did not detect in them any characteristic organic remains, they possess the original elements of rocks of that age and contain at intervals courses of limestone, as already explained in the traverse to Yuryusensk. Knowing, as we do, from the sections of the Arctic Ural, that unquestionable Lower Silurian rocks exist in this chain, it is a fair inference that these quartzose and schistose grauwackes, which here succeed to true Upper Silurian, are also of that older age. In continuing the section, to Satkinsk and to the east of it, we find that the rocks in question are there overlaid by copious calcareous masses, often in the form of black dolomite, which lie in a trough, associated with much greenstone and trap. Near the eastern limit of this trough is the Zavod of Kussinsk, where crystals of talc abound in the schist, and thus indicate an approach to the zone of high metamorphism.

The banks of the Ai, however, near this place expose fine cliffs of limestone, which, though we could discern nothing but Encrinites in them, we suspect to be of Upper Silurian age. The lower beds are thin flagstones, the middle beds are thick, exhibiting a singular concretionary structure and remarkable undulations in the joints; whilst rounded elliptical forms, as if derived from large obliterated fossils, Pentameri?, protrude at intervals from the surface. The uppermost beds are thin-bedded like the lower, of red, green and yellow colours, and have a hard schistose aspect. The associated shales are changed into finely laminated, hard argillo-calcareous schists, which are occasionally welded together into compact rocks, with gaping breaks transverse to the lamination, the whole formation having a strongly altered aspect.

These rocks constitute the external fringe of the still more highly metamorphosed masses, which occupying all the region around Zlataùst, have before been alluded to. Between the Zavods of Kussinsk and Zlataùst, other bands of altered limestone with quartzose grits occur at Kuvashi, associated with greenstone and micaceous schist, which has been converted into Lydian stone. As in many other places, both on the east and west flank of the chain, the strata are here inverted, and, instead of dipping away from the geographical crest, plunge directly under it, the inclination of the limestones near Kussinsk, in like manner with those of Yuryusensk (p. 430), being from 30° to 45° to the east and south-east.

By following the older palæozoic rocks from their external zone, as they fold over in the saddles and troughs described in this section, to the environs of Zlataùst, we see how they become more and more crystalline and dislocated as they approach the axis of the chain. The crystalline and mineralized axis is of considerable breadth in this parallel, and may be said to extend from some versts west of Zlataùst, to the eastern flank of the Ilmen Hills beyond Miask. Let us therefore continue the section across it (Pl. III. f. 1.)

The ridges of the hill called Kossatur, immediately to the east of Zlataùst, consist of mica schist, with garnets, and here, as at Turinsk near Bogoslofsk, these crystals appear in strata which have been penetrated by greenstone and trappæan rocks. These beds also dip to the south-east, and pass upwards into quartz rock. In fact, we have in this last phænomenon, though in the valley and in miniature, exactly what we had found to be the succession upon a large scale in the Taganai. Having traversed the marshy valley of the streamlet Jesma, the micaceous and quartzose rocks reappear in little hummocks (Tismünski), the depressions in which are filled with ores of iron. On the banks of a little stream called Tchornaya (Blackwater), coarse-grained granite with occasional beryl appears. Near this point, where the ascent of the Ural-tau commences, a thin-bedded sandy limestone occurs, dipping slightly to the west. This rock, from its structure evidently of palæozoic age, presents a singular lithological aspect, in having its laminæ transfused with hornblende. Micaceous schist, with great bands of quartz rock, rises out from the flank of this limestone, and constitutes the crest or watershed called the Ural-tau. If the traveller does not quit the road, which naturally passes in one of the depressions, little exceeding 900 feet above the lake of Miask, he can scarcely form any conception of the true nature of the ridge, but guided by General Anòsoff and Major Lissenko, we ascended the jagged peaks in the forest (600 to 700 feet higher), which lie a short distance to the north of the road. The very form of these rocks, as represented in the drawing, facing the title-page of this work, might lead to the belief, that they are simply vertical or highly inclined strata in a very metamorphic condition, and on examining them such proved to be the case. Immense heaps of debris of jointed quartz rock, necessarily presenting sharp angles and edges, form a long, rugged talus. In these the original structure of sandstone, grit, and even *conglomerate*, is clearly discernible, though the whole mass has been transformed from its original condition into crystalline quartz rock, of whitish and pink colours, occasionally, indeed, with flakes of mica, and passing into the rock called avanturine[1]. In other masses the forms, and even colours of the pebbles and coarser grains of sand are quite visible, as well as the planes and joints of the beds. Some fine serrated masses of this rock, which have resisted atmospheric degradation, are still *in situ*, and constitute the peak (Uralskaya sopka) represented in the drawing which forms the frontispiece[2]. The openings between these masses frequently indicate the faces of the beds, which here, as in the Taganai, are very highly inclined (70° to 80°), and produce a broken and serrated outline.

In descending from the Ural-tau to the drainage of the Miass, bosses of red-coloured granite are soon seen protruding, occasionally in veins, through the adjacent mica schist, and extending to the village of Syrostan. The highly altered condition of the rocks which form the Ural-tau is therefore well explained; for they are, in truth, encased like a wedge between two zones of plutonic eruption, and the very peaks of the watershed are seen to be merely metamorphosed grit and conglomerate. At the village of Syrostan an intrusive junction is observed between the granite and mica schist, where the latter rock, usually finely laminated, is more massive and compact as it approaches the point of contact. The mica schist is succeeded by limestone, which followed on its strike a little to the north of this spot, is, as before said, a highly saccharoid and white marble, containing Encrinites, and thus we get another independent proof of the sedimentary origin of all these stratified masses. From this point to Miask, the tract may be termed the metalliferous or auriferous zone. It is made up, as will be seen by reference to the coloured section, of much serpentine with hornblende slates and

[1] The Siberian variety of avanturine had never been seen in England in a great polished mass, until His Imperial Majesty presented a magnificent vase of it to Mr. Murchison. That beautiful ornament, and the porphyry column on which it stands, were extracted from the hills of Bieloretsk and Korgon, a dependence of the Altai Mountains. They were polished at the Siberian works of Kolyvan, in the distant Government of Tomsk.

[2] When the Grand Duke Alexander, the heir to the crown of all the Russias, visited this part of the Ural, His Imperial Highness attained the summit of these peaks, about 2500 feet above the sea, the last 500 or 600 feet being very difficult of access. We followed his example, and with one foot dangling in Asia and the other in Europe, sang the national anthem, of "Long live the Emperor" (see Lithograph opposite Title-page, and the inscription on the summit, which records the Imperial visit).

chloritic quartzose schists. At the spot called Listvenaya-gora, or the Larch Hill, limestone occurs in a brecciated condition, associated with chlorite schist, and pierced by points of greenstone, the upland depressions being filled with local detritus from which gold has been extracted. Then follow argillaceous schists, in which are auriferous quartzose veins[1]. The remainder of the section to Miask exhibits a highly broken series ; a mass of thin-bedded limestone being thrown up at one point by a fault against mica schist; at another place, a peculiar garnet rock enveloped in serpentine, has been termed by M. Rose "Dichter or Derben granat," or compact garnet. M. G. Rose has given a woodcut representing this rock as being inclosed between walls of serpentine[2]. The serpentine of this spot, which, according to that author, contains diallage, appeared to us to act the part of an eruptive rock, and to have caught up a mass of grauwacke, which is highly mineralized ; in short, the compact garnet rock of Rose, which he has so accurately analysed, appeared to us to be nothing more than a crystallized sedimentary mass. Among the less altered strata which follow are conglomerate and grauwacke schist, with an imperfect slaty cleavage, dipping sharp to the east, and these are succeeded by greenstone and serpentine, the latter inclosing a mass of that peculiar rock the Listvanite of Rose, which, with its flakes of talc and disseminated iron, may be considered a sort of dolomite.

Flanked on the west by a valley of argillaceous schist with quartz veins, in which the river Miass flows, the tract immediately to the east of the Zavod of Miask is chiefly remarkable, in exposing the granitiform ridges constituting the little and great Ilmen hills, which inclose a small lake. By the ordinary observer, the chief rock on the western flank of these hills would be pronounced gneissose or flaglike granite, resembling varieties of which we have previously spoken. In the upper and southern suburbs of the Zavod, the rock appeared to us to dip at a moderate angle from the side of the hill, and to be affected by regular joints, similar, in short, to that which we have mentioned at Kanevsk and Ekaterinburg. Baron Humboldt has very clearly pointed out the distinctions between stratified granites (of Siberia and South America) and gneiss ; for though the former, often sloping down declivities, are regularly stratified, in beds of equable thickness, just like those of any sedimentary deposit, the great traveller has convinced himself that

[1] These veins of gold "*in situ*" were formerly worked, but have been abandoned ; all the gold now produced in the environs of Miask being extracted from superficial detritus (see next Chapter).

[2] Reise, vol. ii. p. 99.

the phænomenon is due to the manner in which the igneous matter flowed, cooled and became solidified[1]. Whatever, therefore, may be the mineral distinctions in the granitiform rocks which compose the western slopes of the Ilmen Hills near Miask, and however much they may have a stratified character, we believe that they are all of igneous origin. But why should we not meet with granite as regularly stratified as the greenstone and basalt of former epochs, or as the lava of modern times, all of which are common phænomena? In illustrating the borders of England and Wales, or the region of Siluria, we have, indeed, ourselves described several tracts (Llandrindod in Radnorshire, and Shelve in Shropshire, &c.) where thin-bedded crystalline rocks, having a true igneous matrix, not only alternate conformably with ordinary sedimentary strata, but have even enveloped the marine remains of the period[2]. The largest portion of North Wales, as Professor Sedgwick has so well shown[3], is, indeed, made up of such alternations, on a very grand scale, of Lower Silurian strata with porphyries. Beds similar to the "schaalstein" of the Lahn in Nassau, which prevail in several places along the eastern flank of the Ural, are, in fact, but one of the terms in a series of igneously-formed strata, which are linked on to sedimentary deposits, whilst their opposite extreme is developed in the flaglike granites and syenites of which we are here speaking. These rocks are succeeded on the east by great masses of granite, which have usurped so large a portion of the surface in the adjacent parts of Siberia, and of whose extension to the south we shall speak hereafter.

We do not profess to enter upon a description of the many beautiful and curious minerals, now well-known to collectors, which have been obtained from these hills of Miask, but referring to the work of M. G. Rose, we will merely announce, that all the finest of these (zircon, black mica in large plates, green felspar in enormous crystals, albite, elaolite, sodalite, cancrinite, apatite, ilmenite, titanium of iron, pyrochlore, hornblende, beryl, topaz, garnet, &c.) are found either in beds, veins, or nests of the granitic ridge of the Ilmen. Masses of the rock with which some of the above minerals were associated, and which dip south-west from the sides of the greater Ilmen, and which appeared to us nothing more than flaglike

[1] See Humboldt's description of these granites, Asie Centrale, vol. i. p. 295 *et seq.*, and Rélat. Historique, t. xi. pp. 58, 84, 99 and 405; t. iii. p. 250. Dr. M'Culloch has also described certain granites of Aberdeenshire as apparently stratified, though he viewed them only as "examples of laminar disposition." (Syst. of Geol., vol. ii. p. 94.)

[2] Silurian System, pp. 269, 325 *et seq.*

[3] Proc. Geol. Soc., vol. iii.

stratified granite, forming the external coating of the hill, have, under the critical examination of M. Rose, been distinguished by the new name of "miascite,"—a rock in which, in addition to white felspar and black mica, the place of the quartz is taken by "elaolite[1]," a mineral having a strong resemblance to quartz. All these rocks, which show passages from granite to syenite, and the "weisstein" of the Germans, are, we repeat, to be considered of plutonic origin; and of this, indeed, M. Rose has afforded an independent proof, by showing that a mass of highly altered, granular limestone is singularly caught up and enveloped by them, on the summit of the Ilmen ridge, and is impregnated with apatite and other simple minerals[2].

Eastern Flanks of the Ural between Miask and Verch-Uralsk.—Included between the granitic and eruptive zone of the Ilmen Hills on the east, and the chief ridge or Ural-tau on the west, is included the prolongation of that metalliferous zone which has been just partially alluded to. This tract, watered by the river Miass, as it flows from south to north, is an undulating broad valley of rich pasture land, diversified on its western flank by the granitic hills of Tchaskofski, a southern embankment of the Ilmen Hills, and on the west by the eruptive greenstones, greenstone porphyries and serpentine which have burst through the schists and other stratified deposits. It is very metalliferous, particularly on its western and southern portions, which we shall afterwards describe, in reference to its alluvial and auriferous detritus. In the mean time we shall merely state, that at seven versts to the south of Miask we met with a hard Encrinite limestone, on the banks of the stream, in which it was difficult to discover a persistent strike, though the beds upon the whole, range from north to south. At this spot, the eruptive rocks being less protruded, the fossiliferous limestone occupies a broader oasis than usual in the South Ural; but in following the river towards its sources, the calcareous matter disappears, and the surface is for the most part re-occupied by various igneous rocks, which rise up in conical forms around the lake Aushkul. The opposite sketch is offered to convey an idea of the prevailing forms of the ground in the rich metalliferous tract around this lake. The rock in the foreground, on which we stood, is a compound of diallage and serpentine, and is to some extent magnetic; the most striking of the conical mounts on the hill of Aushkul (or holy mount of the Bashkirs), which rises to about 800 English feet above the lake[3], being composed, together with the lesser

[1] Rose, Reise nach dem Ural, pp. 17, 98.

[2] Rose, vol. ii. p. 69 *et seq.*

[3] Kupffer, Voyage dans l'Oural.

conical hills between it and the adjacent village, of similar eruptive serpentinous masses, with greenstone, porphyry, &c. The wooded ridge seen beyond the conical hills is called Narili, and the Ui-tash in the distance is a part of the Ural-tau, or watershed of the chain[1].

Referring to M. Rose for a copious detail of all the varieties of rocks and minerals of this neighbourhood, in which copper as well as gold mines abound, we merely dwell upon the facts, that here, as in all the other Uralian tracts on the eastern side of the mountain axis, serpentinous rocks abound and are associated with limestone, usually in a highly altered state, though occasionally containing *Encrinites*; that red and other coloured jaspers occur, in contact with the bands of greenstone porphyry, together with a sort of slaty calcareous conglomerate, penetrated by augite crystals; and that whilst such phænomena with veins and masses of copper ore and auriferous alluvia are abundant, the eastern granitic ridges extending from the Ilmen, also contain bands of limestone, associated with micaceous and chloritic schists, copper ores and numerous simple minerals.

From these facts we infer, that the whole of this part of the country originally consisted of a series of sedimentary schists, limestones, sandstones and conglomerates, which by the linear outburst of varied eruptive matter, have been left in their present highly mineralized condition[2].

Quitting for the present the beautiful valleys about the lake Aushkul, as rich in vegetable as in auriferous soil, the reader must now accompany us over verdant tracts, across the Kumatch and a few other trappæan ridges, which alternate with altered schists, to Kashaievo, on the outer flank of the chain, and thence traversing the great road from Miask to Verch-Uralsk, pass into another golden valley, or that of Cossatchi-datchi.

Cossatchi- or Kazatchi-datchi (the Cossack-ground).—At this spot we were already, as the name implies, on that frontier of Russia which is bounded by the wild Kirghis, against whom outposts or forts occupied by Cossacks were established,

[1] See detailed map of this tract, Rose, vol. ii. Tab. V.

[2] Among the mineral substances which occur, we must, however, say a word upon the chromate of iron, which, according to M. Rose and M. Kupffer, is sometimes found in serpentine associated with magnetic iron. We did not visit the mines of chromate of iron, but they are said to be so prolific, particularly at one spot dependent on the Polakofsk Zavod, and on the eastern slope of the Ural-tau, that not less than 20,000 poods, as we were informed, had been annually transported to Moscow. The use of this substance in manufactures is well known, and a manufacturer of Manchester has recently been induced to import the Uralian chromate, in consequence of a notice of its occurrence made by Mr. Murchison during the meeting of the British Association held at that town in 1842.

before the line was extended southwards and eastwards, as at the present day[1]. If, whilst in the heart of the metamorphic rocks of the Ural, we could recognise but feeble indications of animal forms in strata which once must have been charged with them, we rejoiced, on arriving in this little eastern tract, to find that it was one of the very richest of the palæozoic oases which had been spared from the devastation of ancient geological records, caused by the numerous outbursts of igneous matter in these regions. Even here, indeed, the little "preserve" we are about to describe, is absolutely surrounded by eruptive rocks. On the west rises a sharp ridge of greenstone, serpentine, &c., which may be considered a southern prolongation of the Kumatsh, which extends north-eastwards to Miask, whilst on the east are rounded trappæan hills of compact felspar rock. Near to the former is a lower hill called Serbaifsk, composed of schist with quartz veins, and below it, under the streamlet Schertim, are established works for gold washings, of which hereafter. For a few hundred paces to the east of this establishment is an alluvial plain in which the Schertim wanders, whence a mass of highly inclined stratified rock protrudes, which on its western face, or towards the point of disturbance, is of a schistose, chloritic character, much impregnated with hornblende, and towards the east becomes calcareous, and is then undistinguishable from a true schaalstein. In this rock we did not, in our hasty visit, succeed in discovering organic remains; but we consider it of Devonian age, because it is immediately flanked and overlaid by limestone, loaded with carboniferous fossils. This limestone occupies a plateau slightly raised above the adjacent brook, of perhaps about 100 acres in area, the surface of which, covered by a very scanty herbage, exhibits the limestone in a multitude of little hummocks, whose outline may be compared to that of a troubled sea, as represented in this woodcut.

60.

[1] Cossatchi-datchi is on the old line or frontier of the Kirghis, which passed thence along the Ural to Orsk. The new Cossack line is much advanced, and passes from Troitsk direct across the steppes to Orsk (see Map).

The geological observer, who casts his eye around and sees that the limestone is surrounded by eruptive rocks, would have little hesitation in supposing, that these included masses also owed their peculiar form to some plutonic influence; so completely do the calcareous protuberances resemble in outline the igneous "hornitos" of Jorullo in Mexico, described by Humboldt. Though all composed of limestone of a greyish-white colour, these calcareous hummocks, when examined, convince the geologist that they have been thrown into their present outline, by heat and gaseous vapours which formerly struggled for expansion; since not only are nearly all traces of bedding obliterated, but the rock is rendered highly fetid and sub-saccharoid, and breaks for the most part upon the slightest application of the hammer. We believe that, in this case, the metamorphic action has been exactly of that degree of intensity, which in rendering the limestone as pulverulent as sugar, has left the fossilized organic remains comparatively so uninjured, that they easily drop out from the ambient matter.

On referring to the Third Part of this work it will be seen, to how great an extent our palæozoic collection of the Ural has been enriched from this locality, which afforded us not only some new forms, but also many of the most characteristic species of the carboniferous limestone of the Valdai hills, Belgium, France and the British Isles. Among these we may specially enumerate—

> *Terebratula sacculus* (var. *hastata*) (Sow.), *T. pugnus* (Sow.), *T. pleurodon*, *T. rhomboidea* (Phill.), *T. fusiformis* (nob.), *Spirifer striatus* (Sow.), *S. glaber* (Sow.), *S. crassus* (De Kon.), *Orthis Michelini* (Ter. Lev.), *Productus Valdaicus* (nob.), or *P. striatus* (Fisch.), *P. Martini* (Sow.), *P. semireticulatus* (*antiquatus*), *P. Scoticus* (Sow.), *P. punctatus* (Sow.), *P. fimbriatus* (Sow.), *Cardium Uralicum* (nob.), *Arca arguta* (Phill.), *A. Lacordairiana* (De Kon.), *Cypricardia rhombea* (Phill.), *Edmondia Unioniformis* (*Isocardia*, Phill.), *Cardiomorpha sulcata* (De Kon.), *Pecten ellipticus* (Phill.), *Pleurotomaria striata* (Sow.), *P. Yvanii* (*Trochus*, Lev.), *Buccinum acutum* (Sow.), *Euomphalus æqualis* (*Planorbis*, Sow.), *E. tabulatus*, *Bellerophon hiulcus* (Mart.), *B. decussatus* (Flem.), *Nautilus bicarinatus* (De Kon.), *N. cyclostomus* (Phill.), *N. clitellarius* (Sow.), *N. Tcheffkini* (nob.), *Cyrtoceratites novem-angulatus* (nob.), *Orthoceratites calamus* (De Kon.), *Goniatites diadema* (Goldf.), *G. cyclolobus* (Phill.), *G. Barbottanus* (nob.), *G. Marianus* (nob.), *Asaphus gemmiliferus* (Phill.).

Even in this convulsed region, we fancied we could distinguish the portion of these limestones which was the oldest, from that which succeeded it; for near the junction with the bedded schaalstein, evidently of high antiquity, we found at the point marked *p* in the preceding woodcut, the large form of *Productus Valdaicus* or *P. striatus* (Fisch.), which, as before shown, characterizes the lowest band of the formation in Russia; whilst at the point *q* we collected many Goniatites and other species which pertain to higher members.

Those alone who have the same respect for a true characteristic fossil as ourselves, can imagine the feelings of delight with which we here found congregated in one natural Siberian storehouse, so great a number of shells, some of which we could not distinguish from well-known forms of the mountain limestone of Yorkshire, Westmoreland and Derbyshire, nor others from species which are abundant in the same formation in Belgium and France!—a striking proof, surely, of the wide range of similar influences and conditions under which the creatures of the palæozoic æra were brought into existence.

The fossils of Cossatchi-datchi must, therefore, be considered as geological medals of high price, in a country throughout which their traces are so much effaced[1]. Without this discovery, we could scarcely have ventured to affirm, that many other adjacent masses of crystalline limestone, immersed among the granites and trappæan rocks of these mountains, belonged to similar or conterminous deposits. We shall presently see, that strata of like age are prolonged far to the south in the steppes of the Kirghis, where they are still more enveloped by granitic and other igneous rocks.

Eastern Region between the Ural and Troitsk.—In receding further from the Ural chain to the south of Miask, and in the parallel of Cossatchi-datchi, the traveller who quits the trappæan hills which surround the last-mentione dcalcareous tract, finds himself in a low undulating country composed of granite, which partially covered by black earth, rises to the surface in numerous knolls, and is well-exposed on the banks of the Ui, near the small town of Uvelsk. This granite, which is large-grained and of a reddish tint, constitutes, in truth, a granitic steppe perfectly destitute of wood, over which we travelled towards Troitsk. The lithological character of the subsoil of this steppe, for a considerable breadth, is only diversified by patches of white granular marble or limestone, which, though much altered, still exhibits a flaglike structure, and a strike from north-north-west to south-south-east, to which, indeed, the contiguous ridges of granite also conform. This direction, though divergent from that of the chief adjacent chain, is only to be considered as one of those local aberrations from the meridian strike which occur at intervals on both flanks of the Ural. At two or three versts to the south-east of a village called Kossobrodskaya, a low narrow ridge of regularly bedded, sandy

[1] We owe great obligations to M. Barbot de Marni, the Director of the gold works at Cossatchi-datchi, who supplied us with many of our best fossils, and entertained us with the real kindness of all the Uralian settlers. The *Goniatites Barbottanus* (supra) is named after him.

schists, having in parts a "schaalstein" aspect, strikes nearly north and south, the beds of which are either vertical or plunge 75° and 80° to the east. These schists are, in parts, almost a hornstone, occasionally contain small, flattened quartzose concretions, and are again flanked by an intrusive rock which we noted on the spot as being hornblendic granite or syenite[1].

At Ossipovskaya, where we joined the high road from Verch-Uralsk to Troitsk, the banks of the Ui are composed of a greenstone, which cuts irregularly through schistose grauwacke, having nearly a north and south strike. Nearly destitute of all vegetation, except the Artemisia or wormwood (the roots and leaves of which during the hot summer of 1841 were covered with locusts), the tract extending to Troitsk offers very little interest either to the geologist or botanist, the bare and wild steppes on the opposite bank of the Ui being alone varied by a few Kirghis huts. Masses of limestone do, however, occur to the west and east of Troitsk, in which we sought in vain for traces of organic remains, though in the limestone near the town, Colonel Helmersen collected fossils which are considered to be of palæozoic age. By reference to the eastern end of the long transverse section, Pl. IV., the reader may at once comprehend the general nature of all this thinly-peopled, sterile and parched-up region, from which we gladly escaped to revisit the green and gay Ural[2].

[1] In reference to what appears in the text in this and the following page, as well as previously (p. 395), concerning granite and syenite, we may observe, that the late Dr. MacCulloch was the first English author who drew a *geological* distinction between granitic and syenitic rocks. Granite (inclnding, however, a species of syenite) was, he contended, associated with the most ancient crystalline rocks, whilst syenite was subsequent to and often incumbent on what he termed secondary rocks (Geol. Trans. Old Ser. vol. iii. p. 337). More recent observations have, however, shown, that true granite has in various countries cut through palæozoic and even secondary or mesozoic deposits, and thns no geological distinction, marking epochs of eruption, can be established between that rock and syenite. They are, in truth, mineral varieties of intrusive masses which geologists must recognise as intimately connected in their operations.

[2] Standing out as the advanced post of Russia in this parallel, Troitsk, though having a population of 5000 only, is a town of considerable importance, through the barter and commerce which is there carried on between Russia and the Asiatic countries of the Kirghis, Bokhara, &c. The large Menovoi-dwor, or Exchange, stands on the southern or Kirghis side of the river Ui and opposite the town. Four to five hundred Bokharians, a few Persians, and not less than 20,000 Kirghis are said to frequent it annually with their varions goods. The Bokharians exchange their strong silk-cotton goods for copper, iron, hardware and money, whilst the Kirghis bny cotton, cloth, &c. Russian goods to the value of three millions of rubles are here sold to people who traverse deserts, and it was noted as a remarkable feature in their commerce, that this was the first year (1841) in which no caravan had been attacked or pillaged in its passage through the steppes.

Regaining the same parallels of granitic and schistose rocks, with limestone, which we had before traversed, we thence passed over granitic zones on our route to Verch-Uralsk (see Map, Pl. VII. and Section, Pl. IV.). One of these, lying to the east of Stepnaya, rises into several cheese-shaped knolls, not unlike the Cornish tors, and on examination this rock proved also to have a laminated structure, somewhat resembling other granites before described. This rock is succeeded on the west by micaceous schists, having a north and south strike. To the west of Stepnaya points of greenstone appear; and near the station of Kidysh, slaty, grey limestones, evidently palæozoic, and probably either of Devonian or carboniferous age (for they are quite on the strike of Cossatchi-datchi), having also a north and south direction, are included between the greenstone on the east, and a second ridge of granite on the west. Schistose and talcose strata, with courses of "schaalstein" and bands of white quartz follow, and the whole of this stratified series is flanked on the west by a still more important ridge of intrusive rocks, which having a syenitic character in one part becomes a true granite on the west, as seen at the station of Karagaisk.

This lateral excursion into Siberia, like that of the Issetz (p. 361), was made in order to ascertain, if these lower eastern regions differed materially from the Ural Mountains. We came back convinced, that to whatever extent the intruding rocks may be lithologically distinguished from those in the crest of the chain, the original fundamental rocks of this part of Siberia are members of the same palæozoic series as those of the Ural; the essential difference consisting in the more profuse development of granite in the lower than in the higher region. In a word, each of the narrow granitoid or trappæan ridges of the Siberian or Kirghis steppes, is but a miniature representation of the Ural, to which range they nearly all preserve a parallelism, accommodating their direction to each variation of its line of bearing. Though deprived of organic evidences for wide distances (and how are they to be found in a rapid journey?), their occurrence at Troitsk on the one hand, and at Cossatchi-datchi on the other, in strata which at both places are associated on to similar metamorphic and intrusive rocks, affords a clear demonstration, that however we are incapable of dividing it into systems, the original subsoil of all these regions belongs to the palæozoic æra.

This view is corroborated by the sketch which is given by Colonel Helmersen and his associate Captain Tchaikovsky, of the structure of the region to the south of that which has been just alluded to. Beyond Stepnaya, the granite, which may be considered an extension of that of the Ilmen Hills, is prolonged into the low chain, which under the names of Djabyk Karagai and Kara-Edir-tau, runs parallel to the Ural, and constitutes a well-marked watershed between the affluents of the river Tobol and those of the Ural. It is the same embranchment which, still further to the south, is confluent with the southern extremities of the axis of the Ural Mountains. In this eastern parallel, rocks similar to those in the adjacent and higher Ural (chlorite and talc schist, quartz rock, clay-slate and *limestone*, with hornstone, jasper, dolomite, &c.) succeed on either flank of the chief axis of eruption. Again, as in the Ural, *encrinites* have been traced in the intercalated limestone, which Colonel Helmersen is even disposed to consider of the *carboniferous* age. We have attempted to lay down the features of these wild tracts of the Kirghis in a general manner upon our Map, and will now merely say, that according to Captain Tchaikovsky, the granite, as at Ekaterinburg, is the youngest of all the eruptive rocks, dykes of it having been found to traverse greenstone, which, together with greenstone porphyry, serpentine, &c., are repeated over and over amidst countless bands, which we can only consider as metamorphosed palæozoic strata[1].

Eastern Flank of the South Ural between Verch-Uralsk on the north and Orsk upon the south.—Before we describe the other transverse sections across the South Ural, we beg to offer a very brief description of the geological features of its eastern flank between Verch-Uralsk and Orsk, i.e. along the course of the river Ural, or what is called the Old Line of the Cossacks. Of Verch-Uralsk, as the point which connects the Uralian and Siberian regions (see Pl. IV.), we shall have again to speak, when detailing the great transverse section from thence to Sterlitamak. Covered with black earth and morass, no rock is visible near Verch-Uralsk, and it is only on advancing from thence to Spaskaya, that round-backed stony hills set in. In one of these, grey subcrystalline limestone appears, which is penetrated by greenstone and porphyry, and near the upper part of that village, a thick-bedded limestone dips 18° to the south-west[2].

The dominant eruptive rock in this tract is a red felspathic porphyry, the

[1] Reise nach dem Ural, und dem Kirgisen Steppe, p. 217 *et seq.* The road along the new Russian frontier, or the new line of the Cossacks, which passes direct from Orsk to Troitsk, embraces nearly all this steppe region, and traverses the watershed in question a few stations to the north-east of Orsk (see Map, Pl. VI., in which we have inserted the chief features noticed by Colonel Helmersen).

[2] We found a chambered shell in this rock very much resembling an Ammonite, but unfortunately it has been lost. Whatever this shell may have been, we could not when on the spot dissociate the rock which contained it from the encrinite limestone.

prevalent variety of which is of a reddish colour, with large white crystals of felspar, and a little quartz. Another variety, occasionally columnar, like some of the porphyries of the Isle of Arran, has a dark grey compact base, with crystals of light colour; and a third has a light grey base, with crystals of pink felspar. As in many other parts of the world, where such bosses and ribs of porphyry are flanked by schists, the latter at the points of contact are in a jaspideous condition. A little to the north-east of the station of Magnitnaya, and on the opposite bank of the river Ural, the chain is subtended by a parallel ridge containing magnetic iron ore, and called the Ula Utasse-tau, which is also associated with porphyry[1]. This is the last hill of magnetic iron which accompanies the chain in its southward extension, and by reference to the Map it will be seen, that this rock, at least in mountain masses, is invariably peculiar to the Asiatic side of the axis, and is, wherever it exists, associated with porphyritic eruptions. At Yangelskaya, porphyry appears in the streets of the village, and we met with no rocks of palæozoic age, till we were half-way between the station of Syrtinskaya and the fortress of Kizilsk.

The carboniferous limestone of greyish colour is there considerably expanded, and seems to fold over subjacent masses of porphyry. In it we found *Productus Valdaicus*, and two other smaller species, with Pectens, corals and Encrinites. This limestone is exposed on both banks of the Ural at Kizilsk, where it has a well-determined strike from north-north-west to south-south-east, and dips 40° to the west-south-west. Some of the underlying beds had a hard magnesian character, and a cone of porphyry protrudes on the left bank of the stream.

A few versts to the south of Kizilsk the eruptive rocks have somewhat of a basaltic character, but M. Rose has shown that they are in truth augitic porphyry, accompanied by amygdaloid, with chalcedony and calc spar. Again, at Gruznushinsk, and thence to Berezofsk, the whole country is usurped by porphyry or greenstone porphyry, which occupies cliffs from sixty to eighty feet on the banks of the river. This is a tract of very fine herbage, and much resembles in aspect the richest grassy countries of the Scottish border, like which it is well-watered and pastoral. To the south of Urtazimsk the carboniferous limestone recurs in

[1] For a detailed account of the crystalline rocks along this old line of the Cossack forts, the reader must consult the work of MM. Hofmann and Helmersen (Geog. Untersuchung des Sud Ural Geb. 1831). On the west side of the line, or nearer to the Ural chain, the schists are converted into jasper, numerous bands of which we traversed in two other sections. See Pl. III. fig. 5. and Pl. IV. (Verch-Uralsk.)

strong ledges, which containing Encrinites and Cidaris, and having the same north-north-west strike, dip still more sharply *towards* the chain or west-south-west. Hereabouts, and at Orlofskaya[1], the porphyries are occasionally black and slaty, with acicular crystals of felspar; the red porphyry has a coarsely granular base, and greenstone porphyry is not uncommon. Towards Orsk, the country gradually lowering into a steppe, the limestone is no longer visible, but wherever the porphyritic or other igneous rocks do not prevail, the intermediate spaces are occupied by dark grey coarse grits and conglomerates which have the same strike and high inclination as the limestone, and, together with the interjacent ridges of porphyry, proceed excentrically from the Ural chain, striking from north-north-west to south-south-east (see Map). We believe that these grits, sandstones and conglomerates form the upper member of the carboniferous group, an inference which is sustained by the section from Orsk to Orenburg. In approaching the axis (as between Burmaya and Orsk), these grits have more of the true meridian strike than when examined further from the chain.

Transverse Section of the South Ural from Orsk towards Orenburg (Pl. III. fig. 3).—Orsk has doubtless been fixed upon as the Russian advanced post towards the steppes of the Kirghis, on account of the insulated hill called Preobrajenski-gora, which rises up in the low country on the right bank of the Or, at its confluence with the river Ural. This hill, on which the church stands, is chiefly composed of an eruptive rock, which M. Rose describes as greenstone porphyry.

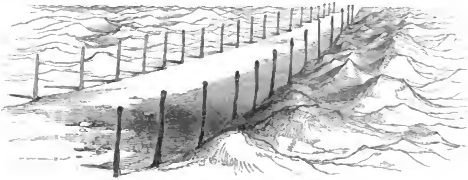
Hofmann, Helmersen and Rose have described various quarries of ribboned and other jaspers, both to the north of the citadel, and also eastwards of it in the river Or, and in all cases they are directly in contact with greenstone porphyry. In the Preobrajenski-gora, the schists through which the intrusive rock rises, are highly altered and jaspidified at and near the contact, but at a certain distance from it they are nothing more than hardened grauwacke. We are entirely of the same opinion as M. Rose, that the jaspers are simply altered schists: we further believe that they are of the carboniferous, or certainly not older than the uppermost Devonian age, because they are succeeded on both flanks by carboniferous limestone, shale and conglomerate. All the jaspideous bands near Orsk have, in

[1] Once for all it may be stated, that certain places in Russia are occasionally cited by us in the text with the termination *aya*, some of which on reference to the Map are inserted without it. This termination ought not, rigidly speaking, to be employed in a foreign language, for it is only employed by the Russians in an adjective sense to signify the post, station, forge, &c. of the place in question.

fact, precisely the same strike (north-north-west to south-south-east) as the adjacent carboniferous deposits which we have described along the north and south course of the river Ural, whilst to the west they are separated from other carboniferous rocks by a great central band of eruption which occupies the Guberlinski Hills[1].

Guberlinski Hills (Pl. III. fig. 3).—Escorted by mounted Bashkirs, armed with bows and arrows[2] (for we were now on the extreme frontier of the wild Kirghis), we quitted the low and arid tract around Orsk, and passed among some hillocks of a conglomerate, partly calcareous. As these masses are horizontally bedded, we conceive that they can have no connection with the highly inclined carboniferous conglomerates and jaspidified schists. Reaching the station of Khabarnoi, we ascended the Guberlinski Hills, composed essentially of plutonic rocks, having chiefly the character of greenstone, serpentine, &c.; these hills, which from their low altitude are only considered a plateau by Helmersen[3], are of the highest interest to the geologist in determining the true meridian direction of the mineral axis of the Ural. When viewed upon their summit over which the road passes, they are seen to be made up of a series of rapid, bare and stony undulations, resembling an agitated sea, scarcely any one wave of which rises higher than another, as represented in this woodcut.

61.



[1] M. Rose gives a valuable detailed account of one of the broken prolongations of the Irendyk, which here terminating near the river Ural, is separated by a valley from the Guberlinski Hills. Greenstone and hypersthene rock abound in it, and he offers a diagram, showing how the latter rock has overflowed the schists, which in contact with it are jaspers, and a little removed from it contain Kiesel-schiefer. (Reise nach dem Ural, 2 Th. p. 192.)

[2] See a sketch of one of our escort, opposite p. 444, where the Bashkir soldier is contrasted with a Russian peasant.

[3] 965 English feet above Orenburg.

Looking from these hills due southwards, across the broad transversal valley, in which the river Ural here flows to the west, the geologist accustomed to mountain outlines, at once recognises, that the very same low conical forms are continuous into the distant Kirghis elevations of Katen Edir-tau and Urkatch, which ranging southwards to the Mugodjar Hills and Mount Airuk, constitute the true mineral axis of the Ural. Again, if the same line be prolonged by hills of similar constitution to the south of Mount Airuk, which near the country of the Great Bursuk are in like manner flanked by altered rocks, limestones and grits as in the Russian Ural, and if this line be further prolonged along the major axis of the Aral Sea, we find another ridge of similar character to the north-east of Khivah, which thus seems to mark the extension of the enormously long meridian fissure in the earth's surface, of which the Ural is the dominant feature. We have before indicated that the eastern flanking ridge of the Kara Edir-tau of the steppes of the Kirghis, which we agree with Baron Humboldt and Colonel Helmersen in considering a prolongation of the Ilmen Hills, bends inwards in its course southwards, and unites with the Mugodjar and Airuk ridge. Judging from their low altitude, pure geographers may look upon both the Kara Edir-tau and hills of Guberlinsk as mere plateaux, whilst the geologist must view both these elevated lines as embranchments of the same great fissure of eruption which unite in their prolongation to the south.

But without entering further into general considerations, let us now adhere to the description of the Guberlinski Hills.

On their summit, and not far from a guard-house, the undulating cones of greenstone are diversified by the occurrence of large masses of pure white magnesite[1], which arranged both in laminated and concretionary forms, is associated with an earthy trap rock. In other parts the rocks having a serpentinous aspect, contain asbestos, and further on they change their character from greenstones to black diallage rocks. In advancing to their western slopes, the Guberlinski Hills become more ravined, and offer some wild and barren scenes, from whence the traveller looks down into the picturesque valley in which the village of Guberlinski is placed, the arid, brown rocks above forming a fine contrast to the grassy slopes beneath. The accompanying vignette, taken from the gateway of the post-house in the vil-

[1] Our companion Lieutenant Koksharof, whose correct eye for mineral distinctions we have often had occasion to remark, considered this magnesian substance to be "Gurhofian."

lage below, and looking upwards to the mountain, will convey a tolerably good idea of the scene.

From this spot, the road leading through the alluvial gravel of the valley in which the Ural flows, and only skirting the hilly tracts, we had no opportunity of examining the rocks for some little space; but to the west of the station of Podgornoi, the road again leads over one of the southern spurs of the chain. This ridge partly consists of igneous rocks, which throw off patches of limestone and iron ore. These are followed by hills having a more rounded outline, and consisting for the most part of strong ledges of grit and conglomerate, which highly inclined to the west, dip away, therefore, from the great axis of eruption, and overlie the shreds of dismembered limestone which fringe the trappæan hills. The Podgornoi hills strike from nearly north-north-west to south-south-east, and the beds dip 65° west-south-west, thus showing that the Guberlinski Hills form the true axis of the chain, throwing off similar limestones, grits and conglomerates, both to the east and west. That these highly inclined conglomerates are truly carboniferous we had no doubt, for they contain plants of that age, as well as fragments of pre-existing limestones; and we believe that, like the conglomerates of which we have before spoken, and which succeed to the carboniferous limestone on the other flank of the axis north-east of Orsk, they are all of the same epoch. To the west of Podgornoi the conglomerates and grits are repeated in masses of enormous thickness, and are associated with calcareous grit, and flaglike, grey granular limestone. The strike of these last-mentioned beds is north-north-west, and they dip to the east-north-east, forming a trough with those to the east of Podgornoi. In comparing them with other deposits in the Ural, we can scarcely doubt that these last-mentioned strata belong to the group of calcareous psammites and conglomerates which we term the grits of Artinsk, and which have been shown to constitute the uppermost member of the Carboniferous system in these regions.

Other calcareous grits and flagstones which appear at Illienskaya and a few places in the low country, but which we did not see *in situ*, the surface being much covered up with gravel and clay, belong in all probability to the Permian system, and are, we doubt not, confluent with the great masses of that deposit, which, occupying all the low region around the city of Orenburg, are extended upon the flanks of the Mugodjar Hills, and ramify westwards for a considerable distance in the great depression watered by the Ural, along which we travelled.

In one parallel, the carboniferous limestone is thrown out in a great advanced spur, which advances to the river Ural, and is called from its shape Verbluya-gora or Camel Hill. This ridgy elevation (about 1000 feet above the sea) is, however, a mere southern counterfort of the carboniferous limestone which constitutes the Gurmaya (Bashkir) Hills, an extension, indeed, of the remarkable calcareous zone which will be mentioned in the next page (see Map).

At Verchni Ozernaia, and in all the tract extending from thence to the Gurmaya Hills, the substrata of gypsum, limestone and sandstone, grit, &c., are all unquestionably Permian; but whether similar rocks occupy the whole of the broad depression in which the Ural flows, and extend continuously eastwards to Orsk, can only be decided by an accurate and detailed survey. One fact which seems established by this traverse across the south end of the Ural is, that no palæozoic rocks of higher antiquity than the carboniferous are exposed in this parallel, or in the transverse valley of the Ural (see Map).

We shall now appeal to sections further to the north, which explain the full development of the South Ural where it rises into mountainous masses.

Oblique Section from the hills north-east of Orenburg across the plateau of Preobrajensk, and thence over the Irendyk ridge (Pl. III. figs. 4 and 5).—Although we have already described the red Permian strata in the low region adjacent to the hilly country under review (p. 147), we take this opportunity of endeavouring to convey to others the impression produced upon ourselves, when on quitting the edges of the mountains, we journeyed along the flat and boundless steppe towards Orenburg. By looking at the opposite sketch the reader may picture to himself our sensations in an intensely sultry day, when, driving across the plain, the distant spires of the city first broke upon our sight. Emerging, on the contrary, from this parched-up flat expanse, how refreshing was the sight of the verdant limestone hills, in the midst of which we passed some delightful days at the Katchufka, or summer residence of our distinguished friend General Perowski, then Governor-General of this province! The second lithograph represents the view of the Gurmaya Hills before alluded to, and which form, in fact, the southern termination of the calcareous chain in this parallel.

Proceeding from the hospitable retreat of the Katchufka, the dense shade of whose evergreen oaks was doubly agreeable to us, after having been scorched in the saliferous plains of Illetzkaya Zastchita (p. 184 *et seq.*), we now beg our readers to accompany us over the South Ural in two transverse sections across a little frequented portion of the chain, which we were enabled to make through the kindness

and good arrangements of General Perowski. The whole of the south-western portion of the Ural Mountains, from whence we took our departure, is composed of an infinite number of sharp ridges of carboniferous limestone of about 900 to 1000 feet in height, which expanding in rapid undulations trend towards the south into the Gurmaya and Camel Hills.

To the north of the Katchufka the ridges diminish in number, and the whole calcareous zone is reduced to the width of less than twenty versts, between the Permian rocks on the west and older palæozoic rocks on the east. Richly ornamented at intervals with fine trees and herbage, this limestone district appeared to us to be one of the most favoured tracts inhabited by the poor Bashkirs, through whose lands we travelled for so long a distance[1].

In the outer or western portion of these calcareous hills we observed Fusulinæ in a gritty limestone, fossils, as has been before shown, characteristic of the upper division of the formation in many parts of Russia; whilst in the inner portion were thick beds of pure limestone with large Producti, including the *P. Valdaicus*, which is equally characteristic of its lower members. These organic remains, accompanied as they were by a prevalent dip to the west, already taught us that, notwithstanding many breaks and contortions, we were advancing to older strata. In a tract covered with fine vegetation and in which no quarries had ever been opened, it was difficult, even with very steep slopes and deep glades, to define the geological character of the succeeding beds, but from occasional glimpses they seemed to consist of black schists with thin courses of impure limestone containing Encrinites

[1] Though the great mass of the South Ural is still possessed by the Bashkirs, the Russians are daily purchasing their lands, wherever ores or fine soil occur, and the original inhabitants (like the Red Indians of America) are thus gradually compressed into limits incompatible with the existence of a nomadic race, destitute of any agricultural art, and living exclusively on the produce of their herds of horses. In the most mountainous tracts, however, Bashkirs alone are still to be found, among whom we could not have been forwarded without the special orders of General Perowski, who furnished us indeed with provisions and a carriage suitable to the rugged country, directing Bashkir officers (who do the duty of Cossacks) to accompany us. We can never forget either the pleasant hours we passed at the Katchufka of General Perowski or the services he rendered us in this tour, still less the admirable MS. map of the whole region with which he furnished us. It was on this occasion that we induced M. J. Khanikoff, attached to the staff of the Governor-General, to describe the geographical features of all the surrounding countries, and to furnish a memoir, which Mr. Murchison has since inserted in the 14th volume of the Transactions of the Royal Geographical Society of London. The name of Perowski has been printed in the preceding pages, 131 *et seq.* as it is pronounced, "*Perofski* or *Perovski.*"

and thin, grass-like fossil plants[1]. Where the road (Starai-tract) ascends from these pastoral valleys, the external features entirely change. Instead of the copious vegetation which usually accompanies well-watered calcareous soils, we had now reached a monotonous plateau void of all limestone, with a poor and stunted herbage, through which we could occasionally detect the ends of the strata only. These are composed of a greenish, earthy, thinly foliated psammite, which alternated repeatedly in highly inclined positions, with siliceous flagstone and thinly laminated schists, no fossils being discoverable in the strata, save a few wretched casts of what might be either the terrestrial plants (grasses?) or marine fucoids. To the east of the station of Berdek these schists are exposed in a ravine, but still they told no tale, except that, being highly inclined, they were traversed by an oblique and nearly horizontal rude cleavage.

At the Zavod of Preobrajensk the river Urmanzelair, a tributary of the Sakmara, runs in a gorge of contorted, green, psammitic grauwacke with schist, in which no calcareous matter and no fossils were observed[2]. To what age then can we refer the great mass of rocks between the Bashkir village of Tchematzine and Preobrajensk? Though in the absence of fossils we cannot satisfactorily reply, we know that all these schistose strata underlie the carboniferous limestone; and here, therefore, as in many parts of the continent of Europe where limestones and fossils are wanting, we can do no more than consider them all as lower Palæozoic. Good reasons, indeed, exist for supposing, that the oldest of these grauwacke beds must be of Silurian age, for in a subsequent section it will appear, that in following these same masses to the north, they become calcareous and contain characteristic fossils.

From Preobrajensk to the point where we crossed the Sakmara river, scarcely any feature worth recording presented itself, for we were, in fact, travelling upon the strike of the same schistose strata. On the river Silayefskaya, and ranging thence to Zuluck, quartzose and micaceous schists strike north-north-east and south-south-west, dipping 40° to the west; and at the spot where we traversed the Sakmara, chlorite schist appears in contact with a boss of serpentine. So far

[1] The chief Bashkir village in this tract of black calcareous schist is called Tchematzine, and is surrounded by magnificent trees, including Birches of extraordinary size.

[2] This Zavod is established here on account of the water-power, the copper which is smelted at it being brought from the rich mines in the Permian rocks of the government of Orenburg, on the west.

then we could discern, that low as this plateau is, in reference to the Irendyk ridge which we were approaching, it might be considered the mineral axis, if really composed, as we believe it to be, of the oldest rocks in this part of the chain.

The Irendyk (continuation of Pl. III. fig. 5.).—From the dull and spiritless plateau of Preobrajensk, composed of its grauwacke schists and grits, some of which, however, where not metamorphosed, have a good deal the aspect of the Silurian sandstone of England, we ascended steep and verdant slopes to the peaks of the Irendyk, which, in this parallel, constitutes the geographical axis of the South Ural, and separates the waters which flow eastwards into the river Ural, from those which run westwards into the Sakmara and Bielaya. This ridge is essentially eruptive, and its external forms are highly picturesque. It is made up of felspathic rocks which pass into greenstone, slaty porphyry and porphyritic breccia, and rise to above 3000[1] feet above the sea. We spent a night amid these peaks in the tents of the Bashkir chief Mohammed John[2], who was encamped here for the summer pastures of his herds of mares and flocks of sheep, and offer a sketch of the scene which presented itself at day-break in this wild and richly-wooded mountain recess. On ascending to the summits, the chief of which at this point is called Katlantchik, we found them to consist of stratified compact felspar rock or eurite, which is in parts porphyritic, the whole having an appearance of bedding, the strata being either vertical or dipping 70° to east-south-east. A little lower on the eastern slope, the rocks are either granular felspathic trap, or greenstone porphyritic greenstone and grey porphyry, with pink felspar crystals; in a word, the same group of eruptive rocks which we had met with in the adjacent valley of the Ural river, distant from the Irendyk about fifty versts.

The most remarkable feature on this slope of the mountain ridge, is the infinite number of alternations or parallel bands of igneous rocks (porphyries) with jaspers and flinty schists, the former most frequently occupying low parallel ridges, the latter the interjacent depressions. During the brief moments at our disposal, we looked in vain for organic remains in these highly altered masses; still, when fol-

[1] Helmersen makes the culminating crest of this ridge 2942 French or 3135 English feet.

[2] Our host, Mohammed John, who appears in the foreground of the opposite sketch, was a fine specimen of a lusty Bashkir, with a capacious stomach well filled with Kumiss, or mares' milk. In his tent (where we slept upon fresh-chopped fir-leaves) we were refreshed with excellent tea, whilst surrounded by numerous black skins filled with Kumiss, and ornamented chests, from which one of his wives unpacked his best crockery. In the annexed sketch of this camp, one Russian peasant is introduced as a contrast. The portly officer is a Russianized Bashkir.

lowed on their strike, these are the very same strata which rise out from beneath and are associated with the carboniferous limestone in the valley of the Ural river. Some of these schists which have been converted into jaspers are therefore clearly of carboniferous, and others may be of Devonian age; for the Silurian formations are all, we apprehend, represented by the rocks on the west side or near the axis of the Irendyk. The section which we have thus briefly described, traversing the river Kizilsk, terminates on the east at Yangelskaya on the river Ural; and having thus brought back our readers to a valley to which we had previously introduced them, we will now explain to them our last traverse of the chain.

Transverse Section of the central and most expanded region of the South Ural, from Verch-Uralsk to Sterlitamak (Coloured Section, Pl. IV.).—This section is most important in re-assuring us, that large masses of rock in the very heart of the Ural chain are really palæozoic,—a point which the preceding traverse does little to establish. It is also of high interest, from passing directly over the numerous south-western embranchments into which the chain ramifies in this parallel, which may thus be contrasted with its south-eastern limbs which we have been considering. In a word, our coloured section is so laid down as to carry the reader from Troitsk in the steppes of the Kirghis on the east, by Verch-Uralsk to Sterlitamak, and thence into the great flanking plateaux of Permian rock upon the west. The country on both flanks of the chain, properly so called, i. e. between Troitsk and Verch-Uralsk on the east, and in the region beyond Sterlitamak on the west, having already been described, pp. 438 *et seq.* and 150 *et seq.*, the section of the mountainous or central portion only will be now developed.

Although porphyries and carboniferous limestone are seen to the south and granitic rocks to the north-east of Verch-Uralsk, the substrata immediately around the town are obscured by black earth and alluvia, which extend for some miles to the low elevations on the flank of the chain, a few beds of fractured schist appearing only at intervals. The first counterforts consist of bare, low bosses of porphyry and trap-breccia, which throw off and include between them, red jaspideous schists, dipping sharply to the east. A valley occupied by black earth succeeds, from which rises a second ridge, called the Beresoiva-gora or Birch-tree Hill, with jaspers or altered strata on its flanks. This mass consists, in the centre, of a greenish augite porphyry, with amygdaloids on its sides, which to the west are flanked by a wall of saccharoid limestone, having a strike of north and south (10° to 15° east of north). A third and lesser ridge, called the Cherry Hill, is made up of porphyritic greenstone and felspar rock on its eastern side, and of slaty stratified porphyry on its highest points, dipping sharply to the east.

Though here of much less altitude than in the Irendyk, it is thus evident, that these low hills, which are on the direct continuation of that ridge, are composed of precisely similar intrusive rocks and of stratified masses, having on the whole the same inclination and strike (see Map, Pl. VII.). A narrow valley is then passed, which covered by black earth on the surface, is occupied beneath by a coarse and slightly auriferous ancient alluvia, which is watered by the small river Mindak, whence the ascent of the chief central ridge commences[1]. The eastern spur of this ridge, called Muchty, exposes serpentine, followed by schists with quartzose veins, doubtless those from whence the gold alluvia in the adjacent valley have been derived; and after passing several bosses of felspathic and trappæan rocks with talcose schists having sahlbands of serpentine, the summit is found to be composed of talcose, quartzose and micaceous schists, with veins of quartz, &c. In an adjacent depression, called Bursuk, the schists are black, with large masses of quartz, both in veins and concretions, the schist itself containing carburet of iron. These talcose and schistose rocks, rolling over in great flexures in which the easterly dip is most prevalent, rise up into the chief mountain (Gara-tash[2]), composed in great part of glossy fractured quartz rock, around the base of which the road meanders. These quartzose masses, in parts chloritic, in parts micaceous, and having on the whole a greenish tint, have so much the aspect of primary rocks that some portions of them have been described by Colonel Helmersen as gneiss. They roll over (though the dip is mostly to the east) and also occupy the western slopes of the mountain which descend by Uzuk-tash towards the Zavod of Bielo-rietz.

To the east of this Zavod, and also on the banks of the river near the works,

[1] The northern prolongation of the Irendyk is here separated by this depression of the Mindak or Mindiak from the heights of Gara-tash, which are the direct southern extension of the ridge, to which in the central and northern mountains of the chain the name of Ural-tau is confined. Seeing that this latter ridge (Gara-tash, &c.) subsides gradually in its range to the south and is lost in the elevated plateau of the Sakmara, we consider that from this parallel of latitude the Irendyk being the watershed, must be viewed as the true southern limb of the Ural-tau. Notwithstanding, therefore, the separation of the ridges by the narrow valley of the Mindak, they are here so nearly confluent, that the Muchty Hill which we are describing may be looked upon as a connecting link between them, if the geographer wishes to follow the most continuous line of heights which separates the waters flowing to the east and west.

[2] The summit of Gara-tash is 2370 French feet, or upwards of 2500 English feet above the sea.

strong bands of limestone, for the most part saccharoidal and of white colours, appear, and these also have a decided eastern dip (10° north of east) at angles of 45°, as if they passed beneath the whole mass of the chloritic and quartzose rocks. Towards the mountain this limestone is white, crystalline and slaty: at the Zavod, somewhat removed from it, the rock is bluish-grey; and a little to the west, or still further from the axis, a similar limestone is found fairly encased between schists which are highly micaceous, though less crystalline than in the mountains on the east. These beds, having the dominant strike of this portion of the chain, or from south and by west to north and by east, pass into thick masses of slaty grey limestone, which, far removed from any intrusive rock, exhibit a sufficient quantity of organic remains to leave little doubt as to their being of true Silurian age. Among the corals were *Favosites Gothlandica* and *Stromatopora concentrica*, whilst the chief mollusks were two small Terebratulæ, one of which we cannot well distinguish from the *T. plicatella* of Gothland, and the other approaches near to a form which occurs with the Pentameri at Bogoslofsk and on the Is (see pp. 394, 396).

Judging from their inclination, it would seem that all these limestones, the whole of which have an easterly dip, must pass under the metamorphic crystalline rocks of Gara-tash. We have, however, repeatedly shown in the preceding pages, that in similar highly dislocated and altered masses of other parts of the chain, it is futile to endeavour to read off the order of the strata by superposition; for to the west of Zlataùst and elsewhere, as well as in this tract, the masses are often unquestionably *inverted*, the younger beds dipping under the more ancient. Seeing, however, that in the parallel of Verch-Uralsk, and wherever the igneous rocks are less rife, the carboniferous limestone on the eastern flank of the chain prevails, and that as soon as we recede westwards from the great centre of disturbance and metamorphism we meet with Silurian remains, we think that, by fair analogy, the included masses may be considered to have been originally grauwacke schists, grits, &c., which, like those on the banks of the Serebrianka and other localities, are interpolated between the Silurian rocks properly so called, and the carboniferous limestones. In advancing to the west across the Nura, Yanick, and other rivers, which descending from the slopes of the Yamantau, Bakty and the prolongations of the lofty Iremel[1] fall into the Bielaya, we passed over several low elevations

[1] The want of time prevented our deviating from the route to ascend the Iremel, or even its southern spurs Bakty and Yamantau. We felt, however, the less reluctance to continue our route, because these mountains had been described by Colonel Helmersen, and M. Khanikoff had recently explained to us, that

of limestone, calcareous grit and flagstone, in which we detected a few corals. Further west and in the parallel of the Kraka Hills, which lay to the south of our route, the limestone, black and slaty on fracture and associated with black schists, was found, at a little hamlet called Katchu-kova, to contain various characteristic Silurian types, such as *Pentamerus Vogulicus*, probably the same variety which occurs at Crasnoi Glasnova (p. 364), *Murchisonia*, apparently the same species as on the Is and at Nijny Tagilsk, with ill-preserved Terebratulæ, Turbo, Encrinites, &c.

Again, if any misgivings had arisen concerning our inferences derived from previous sections, that the whole or nearly the whole of this chain had once been formed of palæozoic strata which had subsequently been altered by metamorphism and eruption, they were at once dispelled by the evidences which here presented themselves. To the west of the black Pentamerus limestone and schist, we met with stony masses of quartz rock (altered sandstone), in which we detected casts of Bellerophons and Encrinites, which gave to the strata very much the appearance of the shelly Caradoc sandstone of the British Isles; whilst in a very short distance, this same purple and grey quartz rock passed into chloritic, talcose and micaceous slates, having the primary aspect of some of the masses of the Gara-tash mountain (see Pl. IV.). In a country devoid of quarries and with few abrupt ravines, we could not pretend to put these various strata into geometrical order. It was enough for our purpose to find, that standing as we here did *in the very centre* of the South Ural, we were surrounded by Silurian fossils, and that the strata in which they were imbedded graduated on either side into crystalline and metamorphic overlying masses. The rocks in which we had found these remains are, in fact, the less elevated and less altered portions only of deposits, which in their extension to the north or north-north-east rise into the culminating peaks of Yamantau, Bakty, Iremel, and Taganai, &c. Nor could we cast our eyes to the south, over the rugged and lofty Kraka Hills extending to the south and by west, and consider how when prolonged they terminate in the plateau of Kanikolsk and Preobrajensk which we had previously traversed, without being impressed with

the Iremel itself was composed of shattered quartz rock, in short another Taganai. In the Appendix is given a list of the heights of the South Ural and adjacent lands as prepared by M. J. Khanikoff, whose admeasurements of the south-western embranchments of the chain assign to several points a very considerable altitude: thus Jamantau or Yamantau is placed at 5400 English feet (or 325 feet higher than the Iremel! which has hitherto been ranked as the highest point of the South Ural), Yurma 3116, Zilmerdak 3137, Tutcha 3651, Kalù 2753, &c.

the belief, that the masses, which here afforded us true evidences of their age, were probably the mere northern prolongations of those monotonous and subcrystalline rocks of the great plateau of the Sakmara, amid which we had detected no vestiges of them.

These Silurian quartz rocks proceeding from the range of the Iremel seemed to fold over and form a sort of axis, and to the west they are followed by slates having the most marked slaty cleavage which we had seen in the Ural chain[1]. The system of schists and black limestone is thence continued in undulations, one peak of quartz rock only, the Yuluch-gora, appearing on the banks of the Bielaya, just where that river turns to the south, and flows to the Zavod of Uziansk[2],—a grand and picturesque position, with high calcareous banks.

Again, schists, quartzose bands and limestone are thrown about in undulations producing a lovely and rich country, extending from the Uziansk to the Zavod of Avziansk, but as in this space the road following the river Bielaya to the south, runs chiefly in the direction of the chain, we could not look for much variation. In approaching Avziansk, however, we again traversed to the west by a rocky defile, which clearly explains, how much the country is made up of repetitions of a great series of sedimentary rocks. On the eastern bank of the stream a large mass of thick-bedded limestone dips sharply to the east, whilst on the other, slaty limestones with calcareous schists, &c. plunge still more rapidly (70°) to the west. The limestones are overlaid by calcareous grits and schists, and the latter by flagstones, and grey, purple and whitish grits, with a basis of felspar; in parts almost a quartz rock. These strata occupy a distinct basin of about a mile or more in breadth, from the western side of which limestones, containing concretions of silex, rise up with a rapid inclination to the east. Though we employed our hammers for some time, and traversed the sides and summits of this little basin on foot, we were to our great mortification unable to detect in it any fossils, yet, doubtless, such may be found by persons who have time at their command. Whilst they were unquestionably, from their mineral character, members of the palæozoic series (for they had not a feature of crystalline or primarized rocks), we were unable, in the

[1] These slates, the laminæ of which marked by different colours are crossed by cleavage planes, occur about four versts east of the floating bridge of Perevosnia.

[2] This Zavod of Uziansk belongs to M. J. Demidoff, in the deep-coloured limestones of which we found the *Favosites polymorpha* and large Cyathophyllum, very nearly allied to the *C. dianthus*. These rocks may, therefore, be either Devonian or Silurian.

absence of fossils, to assign to these limestones of Avziansk[1] an exact place in our classification. Seeing, however, that they are succeeded on the west by schists, red earth and quartzose sandstone which rise out from beneath them, we cannot consider them very low in the series, and they most probably pertain either to the Lower Devonian or Upper Silurian formations (see Coloured Section, Pl. IV.).

For some distance to the west of Avziansk, the road leads over highly undulating hills, all of them being composed of quartzose grauwacke, schists and psammite, which as they dip easterly, under the trough just described, fold over to the west at Bretag, and Priutch Uisse, into the valley of the Nugush. When contrasted with the rich valley of the Bielaya, these mountains have a woodland and sterile aspect, and their highest summit, the Yurma-tau, is, according to M. J. Khanikoff, 3116 English feet above the sea. This, in fact, is the most westerly of the four dominant ridges of these western embranchments of the Central Ural, being succeeded on the west, first by the Kalù, 2755 feet, afterwards by the Ala-tau, about 2000 feet high, and lastly by the Akri-tau, a somewhat lower ridge, which forms the western flank of the whole chain[2]. On the whole, indeed, these ridges, constituting anticlinal domes, may be described as hard quartzose sandstones, having troughs of impure limestone between them, which latter rock in the depression watered by the Nugush, is of grey and blue colours, with numerous white veins, and not unlike the Devonian limestone of the North Ural. At the Bashkir station of Kulghina, which is on the western slope of Kalù, we observed very regularly stratified and wholly unaltered limestone, both red and grey, with shale, &c. dipping first slightly to the west, and afterwards rising to occupy a trough in a valley of some breadth: but here also we were unable to obtain fossils. On its western flank this basin is succeeded by calcareous flags, passing downwards into quartzose sandstone of yellow

[1] We were most hospitably entertained at this Zavod of Petrof-Avziansk, between which and the western edge of the mountain of Akri-tau, the country is very wild and entirely inhabited by Bashkirs.

[2] We were benighted in passing along the slopes of the Kalù, and cannot therefore speak of its structure, though we believe it to be composed of quartzose grauwacke. The small horses of the Bashkirs are unequal to heavy labour, and eight of them (sometimes nine), with four riders, were deemed essential to conduct our tarantass along this "*Commerzi-tract*!" Our "attelage" measured forty-five feet from the leading horse to the carriage;—with such long cords do these wild people fasten on one little pair of horses before the other! The relays of horses, boys and men, were usually stationed in the glade at some ferry or natural boundary upon our route. We recur with delight to this very picturesque region, which it would give us the greatest pleasure to revisit and work out in detail. Our survey of it was necessarily hurried; for we were then pressing on, in order to reach the carboniferous steppes of the Donetz before the close of the summer.

and purple colours with schists and conglomerate, which latter rise up with an easterly dip and form the Ala-tau. From this ridge we descended into a broad depression on the west, occupied by shale, and covered with dense foliage, on the other side of which rises boldly the Akri-tau. Knowing that this was the last western ridge of the mountains, our anxiety increased as we approached it, to discover some organic remains, by which a key might be had to explain the age of the numerous undulations over which we had passed, from the Silurian axis of the chain. The shale of the valley to the west of the Ala-tau, forming a broad anticlinal, bends over to the west and passes beneath the Akri-tau, thus exhibiting a valley of elevation. Near the little hamlet of Deriklè, towards the eastern end of this depression, we found the *Favosites polymorpha*, thus indicating that these calcareous shales were either of the Upper Silurian or Devonian age. The lowest beds of Akri-tau on the west side of the valley, are grey psammites, inclined westwards at 32°, and the overlying mass of the mountain is made up of very striking ledges of dingy green and yellowish-brown, slightly micaceous sandstone, much resembling the Ludlow rocks of England, where they contain little calcareous matter, as on the banks of the Wye. This external resemblance is carried so far, that the surfaces of the rocks are often covered with the same purple film of iron ore so common near Ludlow. Towards the western slope of the Akri-tau these beds are surmounted by red, gritty, fine conglomerate, reddish hard quartzose, green spotted sandstone, with hard purple and grey rocks, the whole of which are really undistinguishable from many examples of the Scottish Old Red Sandstone. Having before us such analogies in mineral succession, from Upper Silurian through Old Red Sandstone, little more was now wanting to complete the belief, that the rocks were really such, than to find them surmounted by the carboniferous limestone, and in this we were not disappointed.

The strata which succeeded, and in perfect conformity, to the red sandstones, were dark-coloured limestones, with *Productus striatus* (Fisch.), *P. Valdaicus*, *P. antiquatus* (Sow.), *Lithostrotion floriforme*, &c. These are followed by carbonaceous grits, which are partially dislocated, and after a fault, the section terminates towards the plains of the Permian system, exposing a great thickness of white-veined limestones, of light and dark-grey colours, with courses of black flint, the whole charged with numerous true carboniferous fossils, including the well-known *Spirifer Mosquensis* (Fisch.), *Terebratula lamellosa* (*Spir. id.* Lév.), and corals, &c. The fortunate discovery of these fossils, in the uppermost band of these mountains, assured us, that the rocks immediately below them were truly of Devonian age, particularly when coupled with the fact, that in the central ridges of the chain we had found true Silurian types. Other geologists who follow us, and who may have more time at their disposal, will, we feel confident, fill up the lacunæ in the proofs of succession, by collecting fossils in the interjacent calcareous zones, where, for want of time, we could not detect them.

The strike of the beds in the Akri-tau and adjacent ridges being from 10° east of north to 10° west of south, this geological direction is in perfect harmony with the geographical alinement of these sedimentary masses, which constitute the expanded flanks of the South-western Ural, and which are made up of a number of folds slightly divergent from the main ridge of eruptive matter, from which the further they recede, the more are they found to assume their ordinary sedimentary characters.

The remainder of this important transverse section to the west, as expressed in Pl. IV., shows, first, a trough of gypseous Permian rocks; then the striking carboniferous outlier of Tcheke-tau, close to the town of Sterlitamak, replete with carboniferous fossils (see p. 130); and, lastly, an ascending order into the full development of the Permian strata, as exposed in the environs of Bielebei, where they have been previously described, p. 151[1].

Conclusion.—After the details in this and the preceding chapters, we now ask our readers to consider with us, for a moment, what have probably been the movements and mutations—what the original structure of these mountains.

No geologist can have traversed the chain in the south-western parallel, which has just been described, and seen the ridges gradually open out with wider sweeps and broader valleys as they recede from the axis, without being led to think, that

[1] We had made ourselves thoroughly acquainted with all the details of the mountain limestone on the eastern flanks of the Ural near Sterlitamak, inclnding the outlier of Tchke-tau, before we visited our hospitable friend Major Wangenheim von Qualen at the Zavod of Troitsk, near Bielebei. As we were thus the first to establish along this frontier a clear base-line for the Permian deposits, and thus to unravel their real age, at a time when others were wholly unacquainted with it, we were rather surprised to find that a year after we quitted the country, Major Wangenheim published a geological sketch (Verhandl. der Kais. Russ. Mineralog. Gesells. zu St. Petersburg, 1843, p. 1), in which he announced this emergence of the carboniferous rocks as a discovery of his own. Our work has, indeed, been a long time in preparation, but the chapter which describes the Tcheke-tau, p. 130, as well as memoirs read to the Geological Society, were printed long before Major Wangenheim's paper. He was, indeed, entirely ignorant of the relations in question when we visited him, and begged us to explain the succession of the strata.

an intense movement having been communicated to the central ridge, certain wave-like undulations to which the whole has been subjected, were necessarily most rapid towards that disturbing centre, and gradually died away as they receded from it. In short, the views which American geologists have so admirably worked out in the Apalachian chain[1] may, we think, be considered equally striking in the South-western Ural. Thus, in the tract between Verch-Uralsk and Bieloretzk, highly metamorphosed strata, with many intrusive rocks, are thrown about in rapid undulations, forming high mountains, steep slopes and deep valleys (see coloured section, Pl. IV.). Next we meet with Silurian strata rolling over in numerous folds, which expand into the wider troughs of Uziansk and Petrofsk. These undulations becoming wider, and the ridges decreasing in altitude as they recede from the axis, the whole series terminates on the west, in the broad trough between the Akri-tau and Tcheke-tau. Again, with this expansion and retrocession from the chief axis, and with the diminution in altitude, the crystalline characters of the chain gradually disappear. The limestones part with their saccharoid and slaty aspect, the mica schists pass into micaceous flagstones, the quartz rocks into conglomerates and psammites, and thus the observer is regularly conducted, with few if any discordant or unconformable junctions, from a crystalline nucleus into ordinary sedimentary masses. Though partaking more of a general description than we could wish, such we feel confident is the true picture of this portion of the Ural.

Interstratified as these palæozoic sediments have been, in other parallels, with large bands of igneous matter, which we believe to have been coeval with their accumulation, and afterwards cut through in many places by intrusive rocks which have altered their original character, and often highly mineralized them, it is impracticable to draw a well-defined base-line for this greatly contorted, broken and often inverted series. In one spot only, have we detected true Lower Silurian shells: even the upper members of that system are, for the most part, mere detached masses of limestone, which, along the eastern flank of the chain, being pierced on all sides, and surrounded by eruptive rocks with much serpentine, constitute one of the chief auriferous zones, to which we shall presently advert. In several sections on both flanks of the chain, we have, indeed, shown a succession through a large Devonian series to carboniferous limestones; whilst in other places, as in the eastern steppes, the lower of these two formations is either covered up by eruptive

[1] "On the Physical Structure of the Apalachian Chain," by Professors W. B. and H. D. Rogers. (Trans. Assoc. Amer. Geol., 1840–42, p. 474.)

matter, or is so metamorphosed that the earliest traces of life which can be observed occur in the carboniferous strata. Accurately and rigidly to determine the boundaries and passages of such highly mineralized products, must be the result of long and minute geological labour. We have chiefly restricted our efforts to the development of the original constitution of the chain, and the enormous amount of metamorphism and disturbance which large portions of it have undergone.

One of the facts most worthy of the attention of geologists which have been obtained by researches in the Ural Mountains, is the very frequently *inverted* dip of the strata where they approach the axis; the formations, which we know to be of younger age, being, as it were, succeeded in ascending order by those which were deposited before them. This phænomenon, far from being peculiar, is, however, of frequent occurrence along the sides of other ridges, where masses of eruptive matter have been ejected in the contiguity of sedimentary deposits. We have before adverted to a similar phænomenon upon the northern flank of the Eastern Alps[1], where the cretaceous and Jurassic deposits along a line of great extent, are so inverted, as to dip under the crystalline and more ancient rocks, and a like order is well known to those who have examined the Alps of Savoy. In a former publication we accounted for the inversion of the Silurian strata on the western flank of the Malvern Hills, in the manner suggested many years ago by Mr. Leonard Horner, by supposing that those strata were not only raised into a vertical position by the outburst of the contiguous syenite, but were also thereby thrown further over or backwards[2]. Such an explanation may, doubtless, suffice in cases analogous to the example of the Malvern Hills, where the same strata can be followed from inverted to vertical, and therefrom to normal positions. In the much grander examples, however, of the Alps and the Ural Mountains, where long linear masses occur in such positions *on several parallels and at considerable distances from the great axis of eruption*, it would seem that an easier, if not more rational solution of the problem is offered by supposing, that the emission of as much molten matter from the interior of the earth as would form the chief and central ridges of the mountains, may have left cavities occupied for a time only by gaseous vapours, into which the ends of the strata, fractured on lines parallel to the line of disturbance, may have fallen, thus producing their inverted position by a simple movement of lateral depression towards the cavity left by the outburst of the erupted masses. In other

[1] Geol. Trans. vol. iii. p. 303. [2] Geol. Trans. Old Ser. vol. i. p. 281; and Silur. Syst. p. 423.

words, as the moving agent was fluid plutonic matter, we may naturally imagine that it was connected with deeply-seated lateral sheets of similarly molten materials, which flowing towards the central line to fill up the space previously occupied by the elevated axis, may have caused the cavities in question. In suggesting this hypothesis for consideration, we shall further illustrate it in the Appendix.

If some persons be disposed to think, that certain of the Uralian crystalline rocks, particularly those which appear on various parallels on the Asiatic side of the axis, may, like the azoic rocks of Sweden (Chap. I.), have been formed during a period anterior to that to which the term palæozoic ought to be applied, we are at once at issue with them. The cases are, in truth, wholly dissimilar. In Scandinavia, as has been shown, there exist, at intervals, true *Lower* Silurian rocks, containing a copious list of the organic remains belonging to the earliest ascertained æra of animal creation, which are there seen to repose *un*conformably upon crystalline stratified rocks of an entirely distinct character, and with completely discrepant lines of bearing—anterior, therefore, to the lowest known palæozoic sediments. In the Ural, on the contrary, though Carboniferous, Devonian and Upper Silurian strata, either succeed each other regularly, as on the western side, or appear in oases on the eastern, where they have been torn into fragments by bands of eruptive matter, it is at one or two spots only, that any traces of Lower Silurian beds can be detected. That such have existed, however, is proved by these very exceptions, and we, therefore, believe that along the central crest, where igneous outbursts have been most intense, and where, therefore, the lowest sediments have been most upheaved, inverted and altered, limestones, sandstones and schists, which at one period may have resembled those of the Lower Silurian of Sweden and of the government of St. Petersburgh, have been converted into crystalline limestone, chloritic and micaceous schists and quartz rocks. We draw this inference, not only because the quartz rock and the chlorite schist are seen to graduate into and inclose subordinate calcareous masses, which still present traces of organic remains, but also because throughout the chain, the whole series of rocks, from the most unaltered carboniferous deposits on the western flank, to the most highly altered Silurians, as well as the crystalline metamorphic rocks of the axis, are all parallel to each other,—all so graduate into each other, and are, in short, so interlinked, that we can nowhere, as in Sweden, obtain a definite base-line which exhibits the lowest stages of animal life as completely separated from an anterior state of things. On the contrary, in the Ural Mountains, when we try to reach Lower Silurian vestiges, the record is usually defaced, though the walls are still standing, on which, according to the sequence in other countries, we ought to be able to decipher it.

But let us not be misunderstood. Looking to the British Isles, we well know, that there are large tracts in them, where schistose deposits of considerable thickness, void of fossils, and also much associated with rocks of igneous origin, underlie strata in which Lower Silurian remains have been detected, and which yet preserve, like those of the Ural, a general parallelism to the fossiliferous rocks above them. We would not, therefore, dogmatically contend, that in the convulsed and crystalline centre of the Ural, there may not have existed some such sedimentary masses which also were accumulated before the creation of the animals of the Lower Silurian type. Recurring, however, to the facts, that all the sedimentary and metamorphic masses of these mountains preserve one to the other a perfect parallelism of direction ; that the altered rocks are seen to graduate into the unaltered ; that the most altered occasionally envelope parallel bands of limestone with organic remains ; and, lastly, that though a patch or two of true Lower Silurian strata are still recognizable, the regular place where, according to the established law of succession, such protozoic beds ought to appear, is commonly taken by rocks which have undergone metamorphism and mineralization, through the evolution of igneous matter along a great meridian fissure, we think we are fairly sustained, both by direct evidence and fair analogy, in maintaining, that the original deposits out of which, in conjunction with eruptive matter, the Ural Mountains have been formed, belonged chiefly to one great palæozoic æra, made up of the Silurian, Devonian and Carboniferous systems.

From our own researches and those of others to the east of the chain, we are disposed to draw exactly the same conclusions in respect to the adjacent rocks of Siberia ; for although the characters of the last intrusive rocks are different, and though in some places granites (rocks very rarely seen in the Central Ural) usurp wide spaces in the lower ridges or Asiatic plateaux, we are unacquainted with a single phænomenon which can shake our belief, that all these granitoid rocks (whether at Verkhoturie, Ekaterinburg, Miask, or in the steppes of Troitsk) were emitted after the completion of the Carboniferous system, and for the most part were posterior to the greenstones and other eruptive rocks of the Ural. Trending parallel to the Ural chain, and therefore, in a broad sense, forming one of its appendages, these granitic, syenitic and associated rocks are essentially to be distinguished from the old crystalline rocks of Scandinavia, and must be viewed as of the same age as those of Christiania in Norway, which have there also burst through palæozoic deposits.

Reverting to the probable original structure of this chain; let not geologists be appalled, when we call upon them to regard the chief crystalline axis of the Ural, as an equivalent (for the most part) of the Silurian strata. We can assure them, that so far from being a mass of too great dimensions fairly to represent such deposits, all the lower Uralian rocks united, are but feeble in thickness, when compared with the grand Silurian series of Britain; which, as is now well understood, occupies the whole principality of Wales and several of the adjacent English counties. Instead of being compelled to call for the presence of the many thousand feet of Silurian sediment which there exist, in order to construct the narrow central ridge of the Ural, the latter mountains expose at intervals, within themselves alone, abundant sedimentary materials out of which all their crystalline schists and quartz rocks may have been formed. In a word, by comparing different portions of this chain, and by following its masses upon their strike, we are assured, that the same zone which in one tract has a mechanical aspect and is fossiliferous, graduates, in another parallel of latitude, into a metamorphosed crystalline condition, whereby not only the organic remains, but even the original impress of sedimentary origin are to a great degree obliterated. In this respect, therefore, the Ural may be compared with many other regions, and notably with the Cumbrian or lake region of the British Isles, where, as before said[1], the equivalent of the great mass of the Lower Silurian rocks is composed of crystalline slaty masses, alternating with much igneous matter; all those records of the most ancient beings in the palæozoic succession, which are so clearly exhibited in Wales and Siluria, being no longer traceable.

We may now conclude this long chapter with a few words upon the direction of the chief Uralian rocks. The geologist who inspects our Map, or who has followed our descriptions, can scarcely have failed to perceive, that although these mountains have, upon the whole, what must be called a meridian direction, different portions of them are subject to considerable aberrations from that line. Thus from the Arctic Ural, in latitude 64° to latitude 55½°, the dominant ridge ranges from north and by west to south and by east; occasionally the strata on either flank of the axis having a strike of 25°, 30°, and even 35° west of north. In

[1] See Introductory matter, Chapter I.

the South Ural, on the contrary, the great radiating western branches trend from north-north-east to south-south-west; and whilst the chief axis in the Irendyk, with numerous masses on the west of the Sakmara and in the line of the Ural river, holds its course to the south, many of the rocks which flank it on the east, resume the prevalent strike of the strata in the North Ural, and trend from north-north-west to south-south-east. Seeing that the interstratified and contemporaneous igneous rocks which appear at the Katchkanar and other places along the crest of the chain, have the same direction as the adjacent sedimentary masses, we believe that the meridian alinement of the ridge began to be impressed upon it at the very earliest period when the original sediments were formed; in other words, that from the most primæval traceable period, there has been a fissure more or less devious from the meridian, by which igneous matter has been extravasated at different periods. If our own observations were not adequate to establish this point, our readers may draw the same conclusions from the writings of Baron Humboldt, as well as from the details of Mr. G. Rose, in his description of certain stratified masses which lie between Nijny Tagilsk and the crest of the chain[1]. Humboldt, Rose, Helmersen and Le Play, all, indeed, concur in showing the prevalence of the latter rock along this crest of the Ural, and even upon its western side, where it is succeeded by black dolomites, occasionally fossiliferous, associated with chlorite and talc schists.

There were, then, we conceive, plutonic evolutions of slaty hornblende rock during the earlier portion of the Silurian period all along this great fissure, and these, after periods of repose, were followed by outbursts of greenstone, porphyry and other eruptive rocks. The effects produced during one of these periods of disturbance, are partially seen in a few conglomerates of the Old Red Sandstone or Devonian age, as well as in the fragmentary and altered condition of the Upper Silurian limestones along the eastern flank of the chain. Again, an agitation of this chain is distinctly marked by the coarse conglomerates at the close of the carboniferous age, which from the very nature of their materials, must at one time have been deposited in shallow water and positions more or less horizontal. In such positions, indeed, they are still found, when remote from the eruptive axis; but on approaching that line of igneous disturbance, these very beds (in one portion of the mountains) are thrown upon their edges, in the manner which we have

[1] M. Rose has there described two long linear masses, the one of limestone in a highly granular state, the other of conformably interstratified hornblende slate.

pointed out in the Guberlinski Hills of the South Ural, where they have precisely the strike and direction of the more ancient and adjacent masses of the chain.

That the Silurian, Devonian and Carboniferous rocks have all been disturbed and affected in parallel lines, has been shown in repeated sections, though the directions of the very same strata in distant parts of the chain differ from each other in their bearing to the extent of 35° or even 40°. Still, however, throughout the North Ural, the beds of all the formations, when examined *in the same tract*, are usually parallel to each other from the centre of the chain to its extreme flanks.

The point, however, to which we would now specially point attention is, that not only these older palæozoic, but even the younger Permian deposits, which in many parts lie in horizontal strata against the edges of the upturned older palæozoic rocks, out of whose debris they have been formed, have for considerable distances been affected upon lines of elevation parallel to those of more ancient date. In the South Ural we have shown, that similar deposits on the opposite flanks of the chain have assumed fan-like directions over considerable spaces, and that whilst on the European side of the axis, the Silurian, Devonian and Carboniferous rocks trend to the west of south, on the east side, or along the valley of the Ural, the carboniferous formations strike to the east of south. This is observed, however, where the mountains spread out into a considerable width, and such aberrations are not persistent; for when viewed on a great scale, the meridian direction is resumed near the extreme flanks of the South Ural, and is maintained both in the line of eruption of the Kara Edir-tau and the Mugodjar Hills on the east, and in the Guberlinski and Urkatch Hills on the west, which uniting in Mount Airuk are thus seen to constitute one great zone of meridian eruption, as indicated by Humboldt (see Map, Pl. VI.).

Another feature to which we may now advert is, that on the south-western flank of the Russian Ural, or in all the country extending north and south across the rivers Sakmara and Ik, and along the north and south fissure of the Bielaya, the Permian conglomerates and sandstones range parallel to the bands of carboniferous limestone, and have been thrown into positions more or less conformable to them. The highly inclined outliers of carboniferous limestone which appear along that line, are sharply elevated axes or domes, which in their movements have also raised up the Permian deposits, in directions parallel to the outer edge of the Ural chain. Thus, whilst the gypseous Permian beds lie in horizontal and undisturbed masses against the chief mass of the carboniferous limestone, which really forms the outer wall of the Ural chain, the very same limestone is thrown up through the Permian deposits, which are also dislocated, in the remarkable outliers of Tcheketau, &c. near Sterlitamak. The whole of the hilly tract of Permian strata bounded on the east by the river Ik, and on the west by the Ushatirka, and ranging southwards across the Sakmara to the Ural river; in short, all the south-western counterforts of the Ural chain are made up of sandstones, conglomerates and limestones of the Permian age, which have been affected, though in a less degree, upon lines parallel to the carboniferous limestone. In a hill upon the right bank of the Ik, a tributary of the Sakmara, near Spaskoi, the sandstones are upwards of 1300 English feet[1] above the sea; and in Mount Girialsk, between the Sakmara and Ural rivers, where they are 1085 English feet high, these conglomerates strike north-north-west, south-south-east, and are inclined to the west at angles of 35°. In a word, they are there conformable, not only to the carboniferous limestone (see p. 146), but have exactly the same strike as the chief masses of older rocks which constitute the Southern Ural in that parallel of latitude. In directing attention, however, to these relations, we are quite aware of the necessity of drawing a marked distinction between the earlier dislocations and alterations which affected the Uralian chain, properly so called, and those which have occurred subsequently on its flanks, and on lines parallel to it. The latter pertain to geological casualties of a minor order of intensity; for although these flanking Permian strata and the carboniferous limestones which pierce them, have been thrown up on outlying parallels, the older or carboniferous deposit, in such positions, never exhibits the same altered or dislocated condition as in the Ural Mountains, in no portion of which have the Permian deposits ever been detected.

From all these facts, then, we have come to the same conclusions as those at which we arrived after an examination of the Silurian region of the British Isles; —that whatever may have been the direction of an ancient fissure in the crust of the earth (we here include all partial deviations and embranchments dependent thereon), other parallel outbursts and upheavals have naturally taken place *along the same line* at subsequent epochs. That repetitions of such a phænomenon ought in all probability to have occurred along the same lines—those of least resistance—through which molten matter had been habituated to find its way to the surface, is what any one who reasons from existing analogies might be led to expect; and that it has been so along the chief direction of the palæozoic deposits of Wales and En-

[1] These heights, like most of those given, are taken from Colonel Helmersen's observations.

gland from the earliest Silurian period to the Carboniferous æra included,—in one instance, indeed, to the close of the New Red Sandstone[1], and in the Ural Mountains from the Silurian, till after the Permian period,—are facts which it is important to record.

Lastly, if throughout the whole chain of the Ural we can, from the direction of the deposits alone, make no distinction as to epochs of dislocation, still less can we attempt to do so when we turn to the Timan range, which, though trending for 500 miles from north-east to south-west, consists, as we have shown, of palæozoic rocks of the same age as those of the Ural; the only distinction being, that along no portion of that low ridge are the Permian deposits affected, as along the south-western flank of those mountains.

P.S. In alluding to the inverted position of strata, we ought not to forget the remarkable case cited in North Wales, where along a considerable space in Montgomeryshire and Radnorshire, the Upper Silurian rocks either dip under or abut against what are now known to be Lower Silurian, but which, from want of sufficient examination, were formerly supposed to be distinct, and were then called Cambrian. (See Silurian System, p. 309, and Chap. I. of this work.)

[1] See Silurian System, p. 294 *et seq.*

CHAPTER XIX.

ANCIENT SURFACE OF THE URAL MOUNTAINS AND THE ADJACENT COUNTRIES.—GOLD AND MAMMOTH ALLUVIA.

Introductory View, showing the Mineral conditions of the Ural Chain when the Palæozoic Conglomerates were formed.—No trace of Gold or Platinum in the ancient Cupriferous detritus on the West, nor in the Tertiary Grits on the East Flank of the Chain.—The present Watershed and the Gold Ore both formed during a comparatively modern period.—Auriferous Alluvia at the Mines of Berezovsk.—The Detritus of Gold veins and Mammoths' bones therein.—Mines of Chrestovodsvisgensk with Gold and Diamonds.—Mines of Peshanka near Bogoslofsk with Gold, Mammoths' bones, &c.—Ores of Platinum as well as of Gold occasionally formed by diffusion through the Rocks.—Auriferous and Mammoth detritus along the East Flank of the Chain to Soimanofski Zavod.—Great richness of similar accumulations south of Miask.—No traces of action of the sea on the East Flank of the Chain from after the Palæozoic period to the present day.—The Gold Shingle of the Ural and its overlying Clay formed in the Lakes of an ancient Siberian Continent, where the Mammoths and other extinct Animals lived.—The fossil Mammalian Remains carried for ages into Lakes and Rivers, and thence into Estuaries and the Northern Sea.—Their final destruction probably caused by the last elevations of the Ural.—The Remains of fossil Animals in the Drift of European Russia considered.—The supposed preservation of the Bos Urus to the present day explained.—Relative changes of Sea and Land considered.

THE reader will already have seen, that just as surely as one sediment has succeeded to another in the Ural Mountains, so have certain igneous evolutions and changes taken place at different periods, by which conglomerates were successively formed upon their shores. Thus, for example, we have already shown, that the formation of magnetic iron was coincident with the outburst of one sort of trappæan rock (greenstone porphyry), which however posterior to stratified and other igneous rocks, was in itself succeeded by copper ore and serpentine, whilst the latter has been subsequently cut through by syenites and granites.

Amid the results of these various disturbances, we will now endeavour to indicate the period, at which the rocks of the Ural were impregnated with gold, and when the auriferous alluvia were formed. Looking at the Ural as a great meridian chain, we have already shown, that the palæozoic and sedimentary deposits of which its central ridge and eastern parallels essentially consisted have, to a great extent, parted with their original characters, and have usually assumed a crystalline aspect. Issuing from the summit and eastern edge of this metamorphic mass, eruptive rocks form the culminating points of the chain, to the east of which and extending into the low countries of Siberia, other parallel lines of eruption, ranging more or less from north to south, and also traversing palæozoic rocks, constitute an undulating zone, composed of hills of slight elevations, parallel to the chief ridge. These lower eastern ridges, all either composed of eruptive igneous rocks, or the original strata through which they have burst forth, are the chief seats of the mineral and metalliferous productions of the chain. For though auriferous detritus occurs, in one instance, on the western side of the watershed, that exceptional case is accompanied by the same phænomena as are uniformly apparent in the eastern gold zones, viz. the contiguity of parallel ridges of eruptive rocks.

The general feature of the great mass of auriferous materials being invariably found on the eastern flank of the chain, coupled with their almost total absence on its western slopes, has been already dwelt upon by Humboldt, who has shown, that in relation to the other geological phænomena the formation of gold veins is of comparatively recent date, and little, if at all, anterior to the destruction of the mammoths. Having ourselves arrived at the same conclusion, we must explain the evidences which have led us to adopt this view, because in one material geological point they are independent of the reasons which influenced our great precursor. This point consists, in developing the geographical changes which the region has undergone in former geological epochs, and by deducing from their results, that the auriferous phænomenon *must* have been posterior to all such early conditions.

In the first part of this work we have endeavoured to establish, that the widely-spread cupriferous deposits of Permia, which occupy all the low country to the west of these mountains, have been derived from pre-existing eastern lands, upon which the plants and vegetables inclosed in the Permian conglomerates must have grown. Judging from its composition,—it is entirely made up of fragments of ancient Uralian rocks,—the great Permian deposit must have been accumulated, not only after the completion of the Silurian, Devonian and Carboniferous systems, but after their consolidation, and either after or during their mineralization with copper ores. This is a clear and undeniable conclusion, at which the field geologist who has examined this region arrives; for in whatever parallel of latitude he may trace this ancient detritus, he invariably finds it to be more coarse and metalliferous as it approaches the mountains from which its materials have been derived, whilst in receding from them, such mineral matter (always in the form of deposit and never in the condition of veins) as regularly dies away and is lost in marine marls, sands and limestone. But if the Ural Mountains were, as we contend they must have been, the source whence all these cupriferous sediments, as well as detritus and fossil vegetables were supplied, very different, indeed, must have been their former outline from that which now prevails; for on the *western* slope of the axis down which the waters now flow into Permia, there are no great veinstones and original sources from which such debris could have been derived. All the spots where the largest veins, masses and original centres of copper ore occur, whether at Bogoslofsk, Nijny Tagilsk, Gumeshefsk and Polofsk, south of Miask or other and intermediate places, are on *the eastern side of the chief ridge*. Supposing that these mines were in the process of forming, or having been formed, were undergoing destruction, during an æra in which the land had assumed its present outline, almost every cupriferous particle and drop of water impregnated with or transporting such mineral matter, must have descended into the adjacent low country of Siberia. By no natural agency could any considerable quantity of such coarse materials be now carried to the low countries[1] on the west, between which and all the great copper sources which are known, lies the ridge of the Ural. Now, as all the cupriferous detritus has been carried to the

[1] The case of Gumeshefsk is, indeed, not so demonstrative as those of Bogoslofsk, Nijny Tagilsk, Polofsk, &c.; for the small river near the former place winds through the chain to the west. *The line of heights*, however, is to the west of Gumeshefsk, and equally separates that tract from the low country on the west. We are now alluding, it will be recollected, to very ancient residuary detritus, which must have been derived from that which is now the east side of the line of greatest altitude, and we show, that as with the present configuration little or no such cupriferous detritus could be poured down to the west on account of a high *intervening* ridge, so we feel sure that such ridge (the present crest of the Ural) has been thrown or raised up after the accumulation of the Permian deposits.

western flank of the mountains, and not a particle of it into the low country of Siberia, it follows, that by far the greatest variation in physical outline which the region has undergone,—one by which a lofty wall was thrown up between Permia and the original copper sites of the Ural,—*took place at a period posterior to the formation of the Permian deposits.*

To illustrate this view, we refer to our proofs, that all the region of Permia was submerged during the gathering together of its copper-bearing sediment (charged with remains of *marine* animals, mingled with the branches and leaves of trees), whilst the opposite low country of Siberia is entirely void of all such marine-formed strata. The original subsoil of Siberia exhibits, as we have shown, ancient or palæozoic rocks only, similar to those of which the chain of the Ural was originally composed, covered in part by recent tertiary accumulations, but without a remnant of former marine detritus, whether of the carboniferous or Permian æras, such as that which overlaps and covers the edges of rocks of the same age on the west. It follows, then, as a necessary induction, that when the cupriferous gravel and conglomerate were washed into the sea-shores and bottoms west of this chain, the tract extending eastwards from it was excluded from such waters, and therefore above them. In other words, what we now call the Ural Mountains, then formed the rocky shore of a very ancient and probably low continent, from which powerful streams descended into a western sea. But did this old continent contain gold and platinum as well as iron and copper? Certainly not; for had it been so, some trace, however slight, of gold or platinum must have been found in the Permian debris; and yet long and patiently as the detrital copper-mines on the European side of the chain have been worked, no one has ever heard of such an occurrence.

Nor if we recede further into antiquity and look to some of the earlier "reliquiæ" of this chain, those, for example, which under the form of carboniferous conglomerates are most clearly indicative of one of its great upheavals, can we detect in them any traces of gold ores; though those conglomerates are compounded of all sorts of rocks which pre-existed in the Ural. Searching, indeed, throughout the whole series of detritus, whether carboniferous, Permian, or that of much younger age, the tertiary beds of Kaltchedansk and Verkhoturie, in none of these regenerated deposits has a vestige of gold ore been found.

To render this inference still more conclusive, it may be stated, that not only the absence of auriferous fragments, but the very materials of which the carboniferous and Permian conglomerates are composed, similarly bespeak a like change of outline since the period of their deposit; for if the present watershed of the Ural had then been in existence, scarcely any fragments or pebbles of porphyry, greenstone, or Lydian stone, could have found their way into the region of Permia,—all, or nearly all such, would naturally be transported to the depressions on the Siberian flank of the chain where these rocks abound *in situ*. But the contrary has been the case: the Permian deposits on the west contain the detritus of such igneous and metamorphic rocks, whilst nothing like it is to be seen in Siberia.

Whether, therefore, we judge from the total absence of all auriferous matter in the ancient conglomerates on the west, and in the tertiary grits upon the east, or from the absolute materials in the whole series of regenerated deposits, we conclude that the chain became auriferous during the most recent disturbances by which it was affected, and that this took place when its highest peaks were thrown up, when the present watershed was established, and when the syenitic granites and other comparatively recent igneous rocks were erupted along its eastern slopes.

The only detritus in which grains and portions of gold and platinum have been found is, in truth, that in which remains of mammoths and rhinoceroses have also been detected; and coupling this last fact with the omission of all auriferous veins in the more ancient alluvia of the chain, there can be no doubt, that in this region, gold was one of the most recent mineral productions anterior to the historic æra. The very nature and form of the ground in which the auriferous debris have been heaped up, shows that, unlike the ancient or Permian detritus, this took up its position when the present configuration had been to a great extent brought about, and when valleys existed, in which large quadrupeds, closely allied to those which now live among us, were entombed. We believe, then, that before the surface assumed its present outline, the tract we now call the Ural Mountains was a low ridge, extending from north to south, and forming the western shore of a continent on which such animals lived and died during long ages.

In proceeding to describe a few of the auriferous spots which came under our notice, we at once disavow any pretension to explain their statistical and mining details. Our time was too much limited for such inquiries, concerning which we must again refer to the works of Humboldt, Rose, Helmersen, and of many officers of the Imperial School of Mines who have written upon their respective stations. Our sole object is to bring before the mind of the reader, the mode and period in which the auriferous detritus was accumulated.

Whoever may take in his hand the detailed geological map of any auriferous tract of the Ural or Siberia, and observe that the affluents of the rivers are chiefly the sites which the gold detritus occupies, might naturally be led to infer, that it was nothing but the residue of rivers or streamlets. This, however, would be a gross misapprehension. The gold alluvia of the Ural (sand it can very rarely be called) is a gravel seldom less coarse than that around London and the east of England, and for the most part a shingle, composed chiefly of moderately-sized and small subangular fragments of the adjacent rocks. It is, in short, that portion of the detritus of this chain, which has been derived from such rocks as have been impregnated with gold, or which contained gold-bearing veins. With the exception of the presence of very minute portions of gold, platinum or magnetic iron disseminated in it, and which are very rarely perceptible to the eye, it is nothing but the debris of certain mineralized masses which have been formerly shed off from the flanks of these mountains, and have partially filled up the depressions adjacent to them.

Unlike the Scandinavian and other chains, which burthened with much detritus have cast off portions of it to great distances from their flanks, the sides of the Ural are void of all such far-transported or rounded blocks; every loose fragment having been derived from an adjacent elevation, and having been usually washed down, in strict relation to the chief existing features of the land[1]. In fact, the term *drift* is not correctly applicable to these Uralian masses, which are purely *local*, and in which there are none of those boulders, that in other countries have been transported across hills and valleys, far from the place of their origin. Neither do the sides of the mountains exhibit striæ of denudation nor polished surfaces; and all the superficial detritus, without exception (parts of which only are auriferous), is strictly local. Let us now consider the nature and relations of the gold accumulations, at a few of the principal sites where they are worked.

Gold Mines of Berezovsk near Ekaterinburg.—These mines, situated about twenty-five versts to the north-north-east of Ekaterinburg, have long been most productive, and are interesting to the geologist and mineralogist in offering the only subterranean shafts in all this region by which gold is still extracted from the parent rock[2].

[1] The same distinction was formerly pointed out between the *local drift* of Siluria and the foreign or northern drift of England. See Silurian System, p. 509 *et seq.*

[2] From the year 1745, to the time of our visit, 1841, these mines had afforded 52,000,000 of poods of ore-stuff which had yielded 679 poods of gold. The proportion of gold to the vein-stone or detritus necessarily varies exceedingly in different localities, and from time to time, even at the same place. At

The chief fundamental rocks are talcose, chloritic schists and clay slates, like those which prevail around Ekaterinburg, and these have been cut through by parallel bands of a felspathic rock called "beresite," which M. Rose considers to be a decomposed granite,—a continuation, in fact, of the granites of the Shartash lake and Ekaterinburg (see Map). The band of "beresite," which bears, in truth, the aspect of a metalliferous lode, trends from north to south, and contains within it many veins of quartz, in which the gold occurs, and from which it is extracted both by vertical shafts and lateral galleries which have been made in the masses of the "beresite." On each flank of the lode, the talc schist in contact with the beresite is a reddish decomposing altered rock, called "crassick" by the workmen. In some parts of the works the quartz veins so multiply as almost to exclude the beresite, whilst some other or poorer veins traverse the mass diagonally and even from west to east. In contact with the quartz veins, the beresite is usually compact and hard, but at a little distance from them, that substance is usually in a form which would convey to the ordinary observer merely the idea of kaolin or decomposed felspar rock. No shaft has been sunk lower than twenty-eight fathoms, and no perceptible change was observed in the nature of the mineral substances at that depth; but owing to the influx of water and the want of steam-engines, the works, at the period of our visit, were only carried on at a level of sixteen fathoms.

Referring to the valuable details of M. Rose, both as respects the nature of the matrix and its imbedded minerals[1], we thus briefly allude to the rock *in situ*, in order to explain how the alluvia which cover it, and which partake of the *local* character of all the Uralian detritus, should also be auriferous. The gold alluvium at this locality occupies a narrow depression in which a tiny stream called the Berezof meanders. The detritus reposing upon an irregular surface of the schistose

Berezovsk 100 poods of gravel formerly gave from five to eight zolotniks; but now the same quantity does not afford more than from one quarter to one-half of a zolotnik. The Magdalenski mine near Bogoslofsk has been known to afford, in one year, as much as half a pound of gold in 100 poods, though in general the same quantity only produces one zolotnik!

There are 96 zolotniks in a Russian pound, which is equal to 14 *oz.* 7 *dr. English avoirdupois. The Russian pood, or* 40 *lbs. of that country, is consequently equal to* 36 *lbs.* 2 *oz. English avoirdupois.* [See Travaux de la Commission pour fixer les mesures et les poids de l'Empire de Russie, rédigés par A. Th. Kupffer.]

[1] Besides the quartz, M. Rose enumerates tourmaline, talc crystals, pyrophyllite, bitter spar, iron pyrites, brown iron ore, needle ore (bismuth), grey copper, copper pyrites, sulphate of copper, carbonate of lead, vanadiate of lead, gold, &c.; but of all these minerals quartz is much the most abundant.

rocks or granite which has penetrated them is composed of their various debris, chiefly angular, and in thickness from eighteen to twenty feet. It is, in fact, local drift, and is spread over the whole of the adjacent depression with little reference to the streamlet which now flows in it, and which is made to follow the works; for by its water alone is the ore washed out of the detritus. We shall not describe these works, though we may state that they are more productive in those spots where the broken materials and coarse sands are most ferruginous, and that during the washing process, the black, glancing grains of magnetic iron ore, form a good indication of the presence of gold. Our chief aim is to show the position in which the bones of mammoths were found in this coarse debris, covered by clay, bog-earth and soil.

62.

a. Auriferous rocks "in situ." b. Auriferous detritus.
c. Overlying clay covered by humus and bog. ——→ Position of mammoth bones.

The above diagram at once explains these relations; for, as we have before said, the drift in which the gold occurs, fills up all the original inequalities of the surface of the rocks; and in one of the lowest of these depressions, from eighteen to twenty feet below the surface and at least 200 feet distant from the little river, very well-preserved tusks and other bones of a mammoth were discovered by M. Koksharof, sen.[1], formerly director of these works. Now the coarse gold, gravel and sand is covered by a thick mass of clay, which is wholly unstratified, and this again by a poor imperfect grassy peat, and, lastly, by the sterile humus or soil of the country. With the exception of the gold in the gravel, these relations may be paralleled in many other tracts of Europe. For example, just in similar coarse gravel and sand, have often been found the bones of mammoths and other extinct animals in the ancient valleys of the Rhine and Danube, and many other places. There, as in the Ural, the coarse detritus is usually covered with the finer materials of sediment, either in the form of clay or of sand and löss. In the upper clay of this place, as in the löss of the Rhine, similar remains have also been found; and all that we now point out is, that by the distribution of the materials in which such remains occur they could not have been placed there by the puny Berezof

[1] M. Koksharof presented these bones to Mr. Murchison, and they are now in London.

stream, which in itself is wholly incompetent even to wear out its own course in these masses of ancient and pre-existing debris.

We did not visit a twentieth part of the gold workings of the Ural, some of which occur much higher up towards the axis of the chain, others further removed from it than those of Berezovsk, and we must point to the map for many of these positions, in all of which the alluvial phænomena are more or less the same as those above mentioned, the detritus being invariably derived either from the rocks *in situ* or from the *adjacent* higher hills. We shall, in the sequel, describe other examples of exactly similar sepulture of the bones of the mammoth in the South Ural, and in the mean time we may say a very few words on the extension of the auriferous zone to the north.

Gold-bearing alluvia have been found at various spots nearly all along the eastern flank of the chain, both in the lateral, or north and south, and in the transverse, or east and west valleys, formed amid the rocks which we have formerly described. These auriferous alluvia, notably rich along the zone where greenstones, porphyries and serpentines have traversed ancient limestones, have been followed by the Russian miners to the north of Petropavlosk, between which place and Berezovsk the excavations and works have been numerous. Around the Zavods of Nijny Tagilsk and Blagodat, and even extending to the western talus of the watershed, these gold alluvia have been considerably worked in those parallels, and in some instances, the ore of platinum is formed in the very same masses. In reference to the works depending on Nijny Tagilsk it may be stated, that the zone which ranges close along the western side of the crest of the chain is poor in gold, the particles of which are associated with chromate of iron and platinum, and are supposed to have been derived from the hornblende and metamorphic rocks which there rise up to form the axis. The richest band is that which runs from north to south, a little to the east of Laisk, whilst two other but poorer zones occur in the mineralized low ridges, still further east, or at forty and sixty versts from Nijny Tagilsk. In this parallel of latitude, therefore, the gold-bearing detritus is found, at intervals, and in zones, extending from north to south over a country near 100 versts in width, and is everywhere made up of fragments of the metamorphic and eruptive rocks of the region, and most frequently in portions of quartz veins. Varying in thickness and importance, according to the original depression or cavities in which they have been deposited, these materials lie at all levels, the little modern streams having had no sort of influence in accumulating them.

Gold Mines of Chrestovodsvisgensk.—This is the only gold-work of any magnitude which fairly lies at the *western foot* of the Ural chain; for those which depend upon the Zavod of Nijny Tagilsk are, as has already been stated, close to the eruptive axis. But even here the relations are on the whole similar to those more productive deposits which occur along the eastern side of the axis; for the alluvia are accumulated to the eastern side of the black dolomitic limestone before described,—a rock, as before shown, which is seen to pass into the talcose and quartzose schists which constitute the chief mass of the axis of the Ural. Nay, more, this gold alluvium also lies between the great metamorphic axis of the Ural and the eruptive ridge of Bissersk (see Map); so that, in truth, the mines of Chrestovodsvisgensk cannot be said to offer an exception to the general conditions, under which all the gold alluvia on the Siberian side of the chain have been formed. Filling the narrow valleys which radiate from the ridge, all watered by various small streamlets which fall into the Koiva, the gold shingle is here piled up in thick accumulations, which, as you ascend the Adolfski brook to the chief mines, are found to increase to a thickness of about forty or fifty feet, covered by masses of clay. At these upper works, the overlying detritus is so considerable, that in order to avoid the expense of removing it, horizontal galleries are driven near the level of the rivulet, and the most auriferous portions of the gravel are thus extracted. This detritus, which is nearly all angular and chiefly made up of chloritic, talcose and quartzose rocks with some fragments of eruptive rocks, is apparently void of limestone or dolomite, thereby showing, that it has been really derived from the breaking up of the higher adjacent Uralian slopes upon the east, which are essentially composed of such rocks. Thence it has been spread out in great mounds, which diminish in importance as they descend into the lower grounds, where the alluvium overlaps the edges of the black dolomite or Devonian limestone before described. No remains of great pachydermatous quadrupeds have been found in this coarse shingle, though the bones of Elks have been detected in the overlying clay.

The gold alluvia of this tract have been rendered conspicuous by having afforded specimens of diamonds; and as some doubt was at first thrown upon the reality of the discovery, we think it right to state, that from every inquiry we made upon the spot, no sort of suspicion can attach to the evidence. In referring the reader to the description of these diamonds in the works of Baron Humboldt and M. Rose, it is only necessary to state, that upwards of forty specimens (all of which we saw in the cabinet of Prince Butera) were detected in the detritus upon the banks of the Adolfski rivulet, at the time when the alluvium was there worked for gold. The operations being no longer carried on in that spot,—the quantity of gold being too small to repay the cost,—no more diamonds can have been detected.

Judging from the mineral character of the Uralian rocks, Baron Humboldt had even before his visit to Siberia foretold, that diamonds would be found in the Ural as in other countries which contain platinum and palladium; and whilst he was engaged in his journey to the Altai, the discovery at Chrestovodsvisgensk was made. Since that period Colonel Helmersen has shown, that diamonds have been found (though in a rare specimen or two) at three other points along the Ural chain[1].

As the existence, therefore, of diamonds in the Ural cannot be disputed, it is gratifying to know, that quartzose micaceous schist, identical with the diamond-bearing *Itacolumite* of the Brazils, really occurs in the portion of the Ural adjacent to those mines, and in a tract from whence the drainage of the Koiva and Poludaska streamlets descend. We are indebted to Colonel Helmersen for this discovery, from which, as well as from his finding the same itacolumite in various parts of the Ural, he infers that it has been the real site of the diamonds[2]. With the precise geological age of the itacolumite of the Brazils we are unacquainted, though, like that of the Ural, it is evidently a metamorphic rock. In the former country it has been described by Eschwege as the chief seat of the diamonds, and all the rivulets in which they most abound flow from mountains composed of it. In M. Claussen's description of a portion of the province of Mina's Geraes (Mountain of Grammagoa), we are assured, that powerful and slightly inclined bands of soft micaceous sandstone, having occasionally the aspect of itacolumite, repose directly on transition rocks, and contain diamonds between the flakes of mica, just as garnets occur in mica schist[3]. Whether this sandstone or psammite, as M. Claussen supposes[4], has been metamorphosed into the crystalline micaceous schist called itacolumite (by no means improbable), it is not for us to determine; but as diamonds have been found, in exactly similar sandstones and grits, in Hindostan[5], there

[1] Ekaterinburg, Kushvinsk and Verch-Uralsk. Baron Humboldt and M. Rose were prevented from visiting Chrestovodsvisgensk.

[2] Reise nach dem Ural, 2 Abth. p. 202.

[3] Bulletin de l'Acad. de Bruxelles, 1841, tom. viii. p. 330. A Brazilian specimen of itacolumite in the Imperial Museum of the School of Mines contains two diamonds.

[4] Geogn. Gemälde von Brasilien, p. 38; and Pluto Brasiliensis, p. 424.

[5] See also Mineral. Report on the districts of Nellore, Cuddapah and Guntoor, by Lieut. Ouchterlony;

can be little doubt that these precious stones were originally formed in different parts of the world in sedimentary deposits not more ancient than those which constitute the flanks of the Ural chain. We may add, that as carbonaceous grits of the Devonian and Carboniferous periods exist, it is very easy to conceive, how these masses, like other sediments to which we have previously alluded, have been transmuted into the quartzose micaceous schists which occur in this chain, and how the diamonds have been derived from them and deposited in the auriferous gravel[1].

Peshanka Gold Mine near Bogoslofsk.—After this short digression, we now return to the east flank of the chain. The gold alluvia of the rich mine of Peshanka, like those of Berezovsk, occur on both sides of a small rivulet, which meanders through a depression between the copper mines of Turyinsk and the river Kakva. The chief underlying rock is greenstone, and the gold sands situated immediately upon it are the richest. As no fragments of quartzose veinstones have ever been found here, the gold grains being simply collected by washing the finer sandy gravel, it has been supposed, that the gold is diffused throughout the subjacent rock, which, according to M. Karpinski, who then directed the mine, was in part a syenite. We were even told, that upon analysis this last-mentioned rock had been found to contain gold. As far as we could judge from appearances, the surface was covered by large blocks of syenite lying in the sand and gravel, which as in other places was covered with clay, in which the bones of mammoth, rhinoceros, &c. had been found, chiefly near the mouth of this little valley. Most of the gold has been extracted near the centre of the detrital mass, whose maximum thickness is about seven feet, and which is clearly divisible, as elsewhere, into two parts, viz. overlying clay and shingle, and auriferous sand beneath. On the whole, the inspection of this locality led us to believe, that the gold had been diffused through the subjacent rock, and that the auriferous epoch, or the close of it, was marked by the scouring and denudation of the surfaces of the rock so impreg-

Madras, 1841. Some of these tracts appear to resemble very much in composition the axis of the Ural. See also Lieut. Newbold's papers on the gold and diamonds in various parts of India, Journ. Royal Asiatic Soc. 1843, pp. 203—226.

[1] We cannot, for the reasons before assigned, participate in the idea partially alluded to by M. Rose, and cited in the Appendix to Baron Humboldt's work, that the diamonds of Chrestovodsvisgensk may have had their origin in the black dolomite of that place; for although that rock has been shown to contain carbon, the alluvia in which the diamonds were found, though overlying the dolomite, exhibit no portions of it. We agree with Colonel Helmersen, that the diamonds, like the gold shingle and the major part of the accompanying detritus, have been drifted from the adjacent flank of the higher mountains, in which micaceous quartz rocks exist, fragments of them (itacolumite) being also found in the alluvium.

nated[1]. All the coarse detritus had evidently been forced hither by the same waters which entombed the mammoths; for the present stream can scarcely remove a pebble the size of an inch. In following this rivulet and the river Kakva, into which it falls, to the lower grounds of Siberia, the remains of mammoth, rhinoceros and *Bos Urus* multiply, and in the old alluvium on the banks of the rivers Pellim and Tavda, both tributaries of the Tobol, are very abundant.

Origin of the Ore of Platinum, and probable diffusion of that Metal as well as Gold through certain rocks.—We have just spoken of the diffusion of gold ore through certain rocks of the North Ural. Even at the moment when we made the memoranda on the Peshanka, and saw how completely the auriferous sand at that spot seemed to be simply the disintegrated surface of the subjacent rock (a sort of syenite or "granite pourrie"), we could not doubt of the likelihood of such a phænomenon. Since that time Professor Hoffman has ascertained, that in a considerable region of eastern Siberia, the gold *is really disseminated*, not only through granitic and other igneous rocks, but also through large bodies of clay slate[2]. In this respect, indeed, there is nothing in the dissemination of the gold, which is in any respect dissimilar to what is known of the diffusion of magnetic iron, pyrites and various other minerals, through the substance of rocks, both igneous and sedimentary. The fact is, then, that though gold has frequently been, and is for the most part, formed in quartzose and other veins which have either penetrated or been separated from the mass of the formation (and of these the Ural affords countless examples), it has also been diffused in some tracts throughout the whole body of the rock, whether of igneous or aqueous origin.

Though ores of platinum are found in the alluvia of the Ural chain in various parallels of latitude, it is only within the territories of the Demidoff family that they are still worked. After an examination of the greater number of the platinum works belonging to Nijny Tagilsk, all of which lie on the western slope of the Ural-tau in that parallel, M. G. Rose had shown, that in one only of the numerous masses of alluvia was any gold mixed with it, and that in no instance could he detect any veinstones of quartz or other fragments of rocks, nor of magnetic iron

[1] Since the year 1829, when it was discovered, this mine of Peshanka had yielded, to 1840, or in eleven years, 250 poods or 10,000 Russian lbs. of gold.

[2] For an account of the enormous increase of gold derived from the eastern governments of Siberia in the last two years, with speculations thereon, see Mr. Murchison's Address to the Royal Geographical Society (Journal Royal Geog. Soc. Lond. vol. xiv. part i. p. lxvi.). An extract will be given in the Appendix.

ore, so abundant in the gold alluvia. The platinum had formerly, it appears, been found, for the most part, in fragments from the weight of a zolotnik to near one pound, though rarer examples had occurred of pieces weighing from three to upwards of eight pounds. According to Rose, the major part of the detritus associated with the platinum consists of serpentine, with very rare appearances of hypersthene or other minerals, the ground over which it has been washed being either chlorite schist or quartzose talc schist, the latter containing diffused epidote. The platiniferous alluvia on the west slope of the Ural ridge, like the gold alluvia on the east, has in truth been drifted down into adjacent depressions from the culminating peaks of hornblende slate, serpentine and greenstone, and is occasionally from ten to twelve feet thick. It differs only from the gold alluvia in being usually arranged in narrower masses, the breadth of one mass being eighteen to twenty four feet, and of another thirty to forty, and their lengths from 300 to 400 feet; whilst there are many gold accumulations more than treble such length and breadth. In our own examination, indeed, of a heap of detritus north of Kushvinsk, from which platinum ore had been extracted, we could detect no sensible geological distinction between it and the auriferous detritus in the neighbouring valleys, since we found them both to be composed of various sub-angular veinstones and rocks of the adjacent ridges (see p. 381). By this observation, however, we by no means wish to imply, that the formation of platinum ore may not, in other instances, have been accomplished by a natural process separate from that which in most instances elaborated the gold; but we believe, that with the present amount of evidence it would be unsafe to attribute the origin, of either platinum or gold, exclusively to one mode of formation.

We are led to make this remark from a recent publication of M. Le Play, whilst these sheets are passing through the press[1]. Availing himself of the light thrown upon this subject by the scientific researches of M. Schwetzof and the mineral agents of M. Demidoff, this able mineral surveyor, who, as before said, visited a part of the Ural Mountains since we quitted them, has come to the conclusion, that the platinum of Nijny Tagilsk was not formed in veins, but disseminated throughout the whole mass of certain crystalline rocks (*gisement primitif*). He founds this belief on having followed twenty or more courses of platiniferous alluvia up to a common centre, the mountain La Martiane, from which they have all been derived, and of whose detritus they are all composed. No quartzose veinstones occur, and

[1] Comptes Rendus à l'Institut de France, Novembre 1844.

all the platinum is finely and equally diffused in the proportion of 1 in 200 of a mass which is made up of fragments of greenstone and serpentine, but chiefly of the latter. Moreover, the fragments of serpentine associated with the platinum are positively saturated with its predominant associate chromate of iron, and though as yet no platinum has been recognized in the rock, M. Le Play contends, that it must be imperceptibly diffused through a mass whose disintegration yields this ore.

Such data, including those afforded by Humboldt[1] and Rose, certainly afford fair grounds for presuming, that the platinum in these localities (the most remarkable in Russia) must have been diffused through the rock, just as we now know that in large tracts of Siberia gold is also diffused. Still, all these facts cannot induce us to change our opinions respecting a heterogeneous mass of platiniferous alluvia which we have ourselves seen on the eastern slopes of the Ural, between Kushvinsk and Turinsk, where fragments of greenstone, porphyry, jasper, &c. are mixed with fossiliferous limestone, and grains of quartz and magnetic iron ore. The phænomena, therefore, at the Demidoff works of platinum ore, can by no means be assumed as applying generally to the origin of that metal. Colonel Helmersen has, indeed, distinctly stated, that grains of platinum have been extracted from quartzose veins in the "Beresite," which are loaded with gold, and he properly insists upon that as a known source of platinum[2]. We are therefore disposed to think, that the ore of platinum has been formed in the rocks pretty much in the same manner and at the same period as gold, sometimes in veins, though perhaps even more commonly by diffusion through the mass. Being a much rarer mineral than gold, it is of course to be expected that a greater difficulty should prevail in accurately defining the origin of platinum; the more so, when its cost of production, and the few uses to which it can be beneficially applied, have led to the abandonment of nearly all the Uralian works, except those kept in activity by the Demidoff family.

Other Gold Alluvia on the Eastern Flank of the Chain.—For an account of many of the numerous sites of gold worked along the east flank of the Ural, besides that

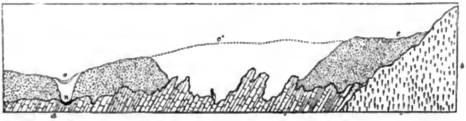
[1] See Humboldt, Asie Centrale, tom. i. p. 517, where Baron Humboldt suggested this idea. "L'absence totale," says he, "du quartz dans les lavages qui renferment le platine seul à Nijni Tagilsk, est un fait tellement important, que l'on se demande si le peu de platine qui est mêlé à toutes les alluvions aurifères appartient exclusivement à la même source, *à une dissémination primitive* dans la serpentine avec fer chromaté, ou si l'on doit admettre que dans les lavages très pauvres en platine le métal a été originairement réuni à l'or dans les filons de quartz même, qui ont traversé les schistes talqueux et chloritiques."

[2] Reise nach dem Ural, 2 Abth. p. 212.

of Berezovsk, to which we have briefly adverted, we must again refer our readers to the many excellent and minute details in the work of M. Rose. Whether in the zone, which is most eminently productive of gold (that which ranges by the eastern side of Nijny Tagilsk, and is probably the continuation of that of Berezovsk), or in the less productive zone nearer to the Ural crest, which extends southwards from the west side of Nijny Tagilsk to the west of Neviansk, and includes the works of Rudiansk and Verchneivinsk; or again in the auriferous zone much further to the east,—in all these tracts the phænomena are essentially the same. The alluvium is everywhere a coarse local detritus, varying in thickness from two to ten and twelve feet, and usually covered by much stiff clay. The component stony fragments in each work necessarily vary, according to the nature of the adjacent rocks; but in almost every case quartz is abundant, generally accompanied by pieces of highly crystalline chlorite schist, talc schist or clay slate. In one quarry or set of works, fragments of beresite or decomposed granite prevail, in another greenstone porphyry, in a third serpentine, in a fourth augite porphyry. Iron pyrites appear in one and not in another, but garnets, zircons, magnetic iron ore, chromate of iron, specular iron and other iron ores, are, with rare exceptions, common to all these accumulations. One of the most remarkable of all these loose deposits between Nijny Tagilsk and Ekaterinburg, as illustrating our own views of the nature of the waters which must have been employed in accumulating such shingle, is cited by Colonel Helmersen on the left bank of the Neiva and Zavod lake of Neviansk. There the detritus of very great thickness occupies ground higher *than any in the immediate neighbourhood*, and is spread out in a direction almost at right angles to the little river Neiva, which flows at its foot. It is just such a massive pile of detritus as one of those which we have described on the west flank of the chain at Chrestovodsvisgensk. The upper layer consists of yellowish red clay, with a few rollers only and a little gold, from seven to ten feet thick; the next, of a dark red earthy mass in the upper end of the excavations, seven to ten feet; and in the lower eight to nineteen feet, and spreading out over a breadth of 320 feet, the whole being auriferous. This mass, observes Colonel Helmersen, is so rich in pebbles of white quartz, that in some places it resembles a quartz conglomerate, whilst in other parts are many fragments of red quartz, clay slate, brown iron ore, serpentine, talc schiefer and white dolomite. That the quartz pebbles are the chief auriferous fragments, is placed beyond a doubt, for one quartz block was found to contain upwards of four pounds of gold.

Gold Alluvia at Soimanofsk in the South Ural.—Let us now cast a glance over the gold mines to the north and south of Miask, on which some of the features which bear upon our views are still better developed than in the North Ural. One of the most northern of these spots, called Soimanofsk, is highly interesting, as being situated upon a great line of igneous eruption and metamorphism, to which allusion has already been made. It lies, in fact, at the opening of a small transverse valley, close to the foot of the chain, in which masses of quartzose and schistose rocks, with a very copious development of limestone enveloped in serpentinous and other eruptive rocks, are covered with a very great thickness of auriferous alluvia. A large portion of the auriferous gravel having been removed, the limestone has been exposed throughout a considerable area, as represented in this woodcut, and it is curious to observe to what powerful action its surface had been subjected before this detritus was lodged in it.

63.



a. Beds of inclined limestone. *b*. Eruptive and serpentine rocks. *c*. Gold shingle or gravel.
*c**. Excavation of the gold shingle. *o*. Bed of the rivulet before the works were commenced. *n*. The present bed of the rivulet.

The tops of the highly inclined beds are, in fact, rounded off, and the interstices between them worn into holes and cavities, as if by the action of water. Now here, as at Berezovsk, mammoth remains have also been found, and they were lodged in the very lowest part of the excavation, at the spot to which the figure of a man is pointing in the above woodcut, and at about *fifty feet* beneath the surface of overlying gravel, before it was removed (see upper dotted line *c**). The evidence at this spot seems therefore decisive of the fact, that the entombment of the mammoths was here accompanied by powerful local debacles, which filled up the depressions with the debris of the adjacent ridge[1]. To this consideration, however, we shall return in the sequel.

[1] That streams like those which now flow could never have accumulated the immense mass of detritus here exposed, is seen by referring to the present small rivulet *o*, the bed of which has been lowered by the miners to the level *n*.

Gold Mines South of Miask.—Amid the many auriferous tracts along the eastern flanks of the Ural, there is no one which has afforded greater wealth, none certainly in which such large lumps of gold ore have been found, as in the tract which extends from the parallel of Miask to the south of the lake Aushkul, and is inclosed between the Ural-tau on the west, and the Ilmen ridge, or its prolongations on the east. It is probable that a great portion of this gold ore has been derived from the breaking up of quartzose veinstones, which intersected the clay slate and chlorite schist of this region; such veins having, in fact, been partially worked to the west of Miask (see Coloured Section, Pl. III. fig. 1). The tract to which we now particularly invite attention, lies, however, to the south of Miask, and comprehends the very productive mines on the left bank of the river Miass, or in the depressions watered by the streamlets Kutaranganka, Iremel, &c. Ascending the river Miass along a rich verdant valley, we were much surprised in having a site of gold ore pointed out in the very heart of a calcareous basin which occupies this portion of the valley, and between eruptive rocks both on the east and west. In some parts the cliffs forming the banks of the little stream are seen to be composed of hard and altered, but regularly bedded and jointed limestone, in which *encrinites* are occasionally discernible, and in one of the denudations in this rock the gold workings called Verchne-Miask have been established. The detritus here may be termed a heavy argillaceous breccia from six to twenty feet thick, in which blocks or fragments of limestone, varying from four inches to seven inches, and even to occasional slabs from four feet by two, are associated with smaller fragments of quartz, greenstone, chlorite, schist, &c.; the whole resting on the disturbed edges of the limestone. Now the points to which we wish to call attention in reference to this detritus, are, first, that the smaller fragments are those which have travelled over the little valley on the west, whilst the larger are those of the limestone *in situ*, many of which have merely been re-aggregated on the spot; and, secondly, that gold ore also occurring in the harder and other materials, is also said to be disseminated through this limestone[1].

The most productive of the gold workings of this tract occur in the undulating grounds on the western side of this valley[2], where the depressions around several

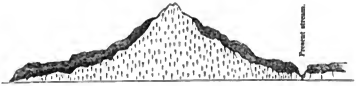
[1] This fact of gold being diffused through limestone, we mention on the authority of General Anosoff and Major Lissenko, who were there with us.

[2] M. G. Rose has given a very minute description of the nature of the detritus and subjacent rocks at many of these gold works. (See his Special Map of this tract, vol. ii.)

little conical hills, composed of serpentine, diallage and other trappæan rocks with slaty schists, rise up and form low counterforts on the eastern edge of the Ural-tau. Little streamlets called Tashkuturgan and Kushkinovka, across either of which a man can jump, are employed for the grinding and washing of this detritus.

In order to satisfy the reader that the gold alluvia have been formed in an ancient alluvial period, when the relations of land and water differed from those of the present day, we first annex a little diagram taken from a spot adjacent to the works of Zarevo Nikolayefsk.

64.



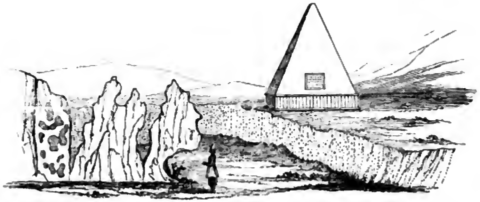
This drawing represents a conical hill upwards of 100 feet in height, chiefly composed of a slaty greenstone, from the sides and summit of which gold detritus, consisting of fragments of quartz veins, chlorite schist and greenstone have been taken in greater abundance in and towards the depressions on the sides, though in smaller quantities *all over the hill and even to its summit.* This fact, like that near Neviansk, proves, that although the detritus is more or less local, it has been accumulated by an agency which carried it down in broad sheets, and distributed it over all the inequalities of the surface, lodging it on acclivities as well as in hollows. In the depressions, as might indeed be looked for, the greatest masses of detritus have been accumulated, and there only are they covered with a thick spread of clay. In these latter hollows, particularly around the Zavod of Zarevo-Alexandrofsk, the very heavy " pepites " or lumps of solid gold have been found (evidently portions of very rich veinstones or nests of ore) which have rendered this locality so celebrated[1]. At the period of our visit,t he heaviest of these " pepites " (others of thirteen and sixteen pounds having preceded it) weighed twenty-four pounds sixty-eight zolotniks; but since we left Russia a lump of native gold was found in these works in 1843, which is now deposited with the others in the Museum of the Imperial School of Mines, and which weighs about

[1] These workings vary much in their value; formerly they gave from 9 to 10 zolotniks of gold per pood of gravel, now they afford $1\frac{1}{2}$ zolotnik only. For the equivalent of Russian weights, see p. 477.

seventy-eight English pounds[1]! This may fairly be called the largest gold boulder which was ever washed away from a rock! Large lumps of gold are, however, to be considered as exceptions in the Ural, and most of those which are of any magnitude have been found in this one small tract watered by the Tashkuturgan rivulet, and collected at the adjacent works of Zarevo-Alexandrofsk and Nikolayefsk.

It forms, as before said, no part of our design to enter either into the mineralogical or statistical details connected with these gold mines[2]. Referring the reader to the mining map of this district, published by M. Rose, we simply beg to call attention to our rude drawing of a portion of the works a very little to the north of a monument erected to commemorate the visit of the Emperor Alexander in 1824.

65.



In clearing away the auriferous detritus, here from ten to twelve feet in thickness, portions of the fundamental rock were laid open, the surfaces of which are so hollowed out into cavities, as to leave no doubt that, like the previous example (p. 487), they must have been subjected to very considerable erosion by water, though, for reasons which we shall presently assign, we believe that this effect was produced at an ancient period, and not when they were buried under the coarse

[1] The first mentioned of these specimens was found on the occasion of the visit of the Emperor Alexander to these mines, when the little monument represented in the above woodcut was erected. The large pepite was found at some depth in the alluvia on which one of the old buildings had been placed. See Major Oserkys' description of this and other Russian "pepites"; Kais. Russ. Min. Gesell. Jahr 1844, p. 70, with figures of the two chief lumps of gold.

[2] M. Rose states that upwards of 100 localities in the Miask district are auriferous.

gold shingle and drift which surround them. The chief of these projecting bosses of rock consisted of greenstone passing into a large concretionary felspar rock, and in contact with these trappæan masses are veinstones of quartz and calc spar in talc schist, &c. These, in short, as well as various others along the eastern edge of the Ural-tau, are the rocks out of which the auriferous detritus has been derived; and in the great mass of local drift we see quite enough to convince us that it must have been got together during long periods of attrition and atmospheric action. To this coarse and ancient detritus, the existing water-courses have simply this relation,—that they have partially hollowed out channels in it, just as the rivers of England and France have worn their way through the ancient gravel, which is there spread over low and broad expanses, whether former estuaries or rivers of those countries. This observation applies, indeed, to every heap of auriferous detritus on the Siberian flank of the Ural.

If it were our object we might describe other auriferous localities which we visited, such as that of Cossatchi-datchi, where the gold detritus is lodged against the foot of the carboniferous limestone, whose fossils and condition have been described, and of the Mindiak river between Verch-Uralsk and the Ural-tau on the west; but we have already said more than enough for the objects of our general reasoning[1].

In the South Ural, then, as in the North, the remains of mammoths, *Bos Urus*, and *Rhinoceros tichorhinus*[2] are found in all the coarse detritus; but as that only which is auriferous is cut into, the bones are seldom detected out of the line of the gold works. The Bashkirs, indeed, attach a superstitious feeling of respect to these bones, and have been known to say to the Russian miners who first settled among them, "Take from us our gold if you will, but for God's sake leave us the bones of our ancestors[3]."

[1] In the southern Bashkir districts the upper drift of the country is often composed of black earth, that substance covering the coarse shingle, just as the yellow or grey clay surmounts it in the north. Such examples are clearly displayed in the valley of the little river Mindiak, between Verch-Uralsk and the Ural-tau. In short, no one can have cast his eye over the adjacent regions of Siberia, without seeing that this black earth or "tchornozem" is there the most recent of the alluvial accumulations, as it is never surmounted by but always overlaps the coarser alluvia which we have been considering (see the last Chapter).

[2] From a description of Pallas it is believed, that remains of mastodon have also been found in the Ural Mountains. They have certainly been found in Southern Russia (see p. 503).

[3] The Samoyedes (as Count Keyserling learnt in his tour to the Petchora) have a most singular belief respecting the mammoth, which would lead us to suppose, that many entire forms of the animal may from

Habitation and Destruction of the Mammoths.—Though mammoths occur in certain quantities on the flanks of the Ural, thus leading us to believe, that when alive they inhabited the tract where their skeletons are entombed, it must be recollected, that as by other proofs we have already endeavoured to show the comparatively recent elevation of the Ural crest, this region cannot be looked upon as having been rendered highly mountainous until the very period when great numbers of these animals were destroyed—a destruction which we believe to have been mainly accomplished when the present watersheds between Europe and Asia were determined.

Let us suppose, then, that the mammoths and their associates ranged over these hills, when they formed the elevated edge of an eastern continent. Further, let it be assumed (and this, indeed, is quite in accordance with the physical features of this region), that the greater number of the broad depressions which are now filled with auriferous and mammoth detritus were *then occupied by lakes*, in the grounds around which these extinct quadrupeds had long lived, and into whose shores or bottoms *their bones had been washed for ages*, and we shall then have before us the conditions which will best explain the Uralian phænomenon. No one can observe what the Russian miner has accomplished, by damming up the existing rivers, and thus forming artificial lakes in every sinuous tract in which ores are worked, without being naturally led to the idea which we suggest, that larger and deeper lakes were formerly in existence,—lakes, in fact, which in still more primæval times fed the great rivers that washed the Permian detritus to the sea then existing upon the west. Granting these premises, all the relations of the Uralian mammoth alluvia may, it appears to us, be rationally explained; for in some of the most violent movements of elevation which gave rise to the present central watershed, we may readily conceive how, their barriers being broken down, these lacustrine waters were poured off, and how their shingly bottoms and shores, already containing bones of mammoths, were desiccated and raised up into the irregular mounds which now constitute the auriferous alluvia. The very nature of the auriferous shingle, with its subangular fragments, so completely resembles the detritus of lakes, and is so unlike the gravel formed on the shore of seas, that

time to time have been known to them or their predecessors. The mammoth of their legend is a great subterranean monster delighting in ice caverns, and to whom they attach a superstitious reverence, believing that the man who exposes the creature to day, thereby kills it and brings misfortune on his family. This serves to explain, why it is so difficult to obtain, through the natives, the disinterment of an entire animal.

independent of the *entire absence of any marine remains whatever of tertiary or recent age*, all along the immediate eastern flank of the Ural mountains, we have no hesitation in believing, that the gold detritus was accumulated during a terrestrial and lacustrine condition of the surface. One fact only which we have mentioned seems, at first sight, to militate against this view, viz. the deeply eroded surfaces of some of the palæozoic rocks. But however these appearances may have been produced, it is manifest they could not have resulted from the denuding action of the same water, in which the shingly and slightly rounded angular detritus was formed. Such abraded surfaces may, to a great extent, have been produced, at periods long anterior to that of which we are now treating, and when the edges of the palæozoic strata, first emerging from beneath the sea, left their irregular and water-worn surfaces to be filled with terrestrial and lacustrine deposits of after-days.

In some cases, however, the denuding and abrading power of waters, produced both by the bursting of lakes and the change in the direction of the currents, must have been very considerable, for such alone would account for several of the appearances we have spoken of, and the transport of large blocks and enormous pepites of gold into broad lateral depressions.

In proposing a lacustrine entombment for the Uralian mammals, we are borne out by the constant position of thick masses of silt and clay overlying the coarser shingle. If the deposits had been submarine—even if no traces of shells were visible, there might have been some indications of the action of the waves—some appearance of a coast-line: but nowhere can the geologist imagine such a former state, whilst the superposition of the clay to the shingle is best explained, on the hypothesis of formation under lacustrine or broad fluviatile conditions, which eventually assumed a tranquil character. Such, in fact, are precisely the cases of the great valleys of the Rhine and the Danube; and just as we have imagined that the mammoth lived in those Uralian tracts, when the adjacent parts of Siberia were occupied by lakes, so do we suppose that the like animals, whose bones are found, both in the coarse shingle of the Rhine and in the overlying löss near Baden-Baden, once lived upon the grounds which now constitute the Black Forest and adjacent Alpine tracts whence the detritus has been derived. With evidences of internal lakes and ancient rivers, in which the bones of some of its ancient quadrupeds were lodged, Great Britain, though evidently also the abode of mammoths, is distinguished from the Ural and Siberia, in exhibiting around its coasts, and even far into the interior, the proofs of the abode of the sea or marine estuaries during long periods.

But we now return to the Ural. A former terrestrial surface on which the great quadrupeds lived for long ages, and the rupture and desiccation of adjacent lakes, coincident with some of the last elevations of the chain, will, we are convinced, best explain the condition in which the remains of the mammoths are left buried on the edges of the uplifted ridges of the Ural, as well as in the low lands and great estuaries furthest removed from them. In the depressions at the very foot of the chain, the mammoth skeletons are broken up, and their bones, together with those of *Rhinoceros tichorhinus* and *Bos Urus*, are rudely commingled in the coarse shingle, derived from the mountains or in the clay above it. In proportion, however, as we advance into the plains of Siberia or descend into the valley of the Tobol and the Obe or their affluents, these bones increase in quantity, and are at the same time in much better conservation. Even in the flat country of Siberia, about thirty versts eastward of our excursion on the Issetz (see p. 366), Pallas mentions the occurrence of teeth, vertebræ and bones of mammoth and remains of fossil ox, as having been found abundantly by the peasants at several localities near Tamakulsk and the source and banks of the little streams Atish and Suvarish, both tributaries of the Issetz. He also gives (from the information he received) a detailed account of the order in which various beds of sand and clay there succeed to each other, and in which sharks' teeth and palates of fishes also occur. Hence he concludes, that the beds in which the bones were found formed the bottom of an argillaceous sea, and that certain sandy, micaceous materials in superior beds were washed down from the mountains. Now we cannot for a moment suppose that the great naturalist could have been mistaken in the marine character of the fish remains; but as he did not visit the spot himself[1], there may still be some doubt that the mammoths' bones occur in the very same beds with the fossil wood, sharks' teeth, &c.; for these, we apprehend, must certainly belong to the tertiary deposits of clay, sand, lignite and millstone grit of which we took leave at Kaltchedansk, and which appear to extend widely into Siberia. That deposit is, we must think, of higher antiquity than the detrital accumulations which inclose the mammoths. However this may be, the further the Siberian rivers are followed towards their mouths, the more,

[1] Pallas derived his information respecting the order of the beds and the position of the remains at and near Tamakulsk from Colonel Bibikoff, Director of the Forge of Kamensk (see vol. ii. p. 392, French Ed., 1793).

we repeat, do the mammalian remains increase[1], until at length whole skeletons have been found entire, some with all the flesh and hair adherent. Unwilling, as we always were, to adopt the idea of Cuvier and other eminent geologists, that entire mammoths with their skin were killed and preserved by a sudden change of climate, we now distinctly advocate the views of Lyell and Humboldt, that these creatures were the denizens of countries near to which their bones are found[2].

The single fact of the very wide diffusion of mammoth bones over the surface of such enormous regions of the earth, would in itself lead us to believe, that those creatures had really been long inhabitants of such countries, living and dying there for ages, whilst their final destruction may have resulted from aqueous debacles dependent on oscillations of the land, the elevation of ridges, and the formation of much local detritus. In the case of the extinct species of Carnivora, it has been happily and successfully shown by Dr. Buckland, that for long ages they inhabited the caves of the British Islands. Again, in low tracts of Yorkshire, where tranquil lacustrine deposits have occurred, their bones (even those of the lion) have been found so perfectly unbroken and unworn in the fine gravel in which they are heaped up (as at Market Weighton)[3], that few persons would be disposed to deny, that such feline and other animals once roamed over the British Isles as well as

[1] Sujeff, the associate of Pallas, found these mammalian remains in great abundance on the banks of the Obe, near the mouth of the Pittiarski and 150 versts south of Berezof. (Pallas, vol. iv. p. 50.)

[2] For some time the frozen mammoth found by Adams and deposited in the Imperial Museum at St. Petersburg was an unique specimen. Since then two other examples have been reported, and one of these is, we are informed by Mr. Frears, on the point of arriving at the museum of Moscow. The conservation of the skin is, indeed, not peculiar to the mammoth, but also applies to the *Rhinoceros tichorhinus*, portions of whose skin and hair are still adherent to the bones of a fine specimen of that animal preserved in the Museum of Natural History at St. Petersburg, and deposited there by Pallas. On referring personally to Baron Humboldt since the publication of his work on Central Asia, he expressed his opinion, that the perfect conservation of the skin, mustachios and whole body of Prince Menzikoff, buried 100 years ago in Siberia and accidentally disinterred, ought to satisfy us respecting the conservation of the mammoth by simple reference to the climate of that country.

[3] The researches of the Rev. W. V. Harcourt and of Mr. H. E. Strickland are most important in showing (the former at Market Weighton, the latter at Cropthorne on the Avon) the co-existence of the mammoth, *Bos Urus*, rhinoceros, hippopotamus, lion, bear, tiger, hyæna, deer, &c. (all of species distinct from those in existence), with land and freshwater shells, nearly all of which are identical with species now living in Britain; thus proving, that no very great change of climate has taken place since these animals were contemporaneous (see Proceedings of the Geol. Soc., 1834, Silurian System, p. 554, and Phil. Mag., Sept. 1829 and Jan. 1830).

other European countries. Why then is it improbable, that large elephants, with a peculiarly thick integument, a close coating of wool and much long shaggy hair, should have also been the occupants of wide tracts of Northern Europe and Asia[1]? At one time it was deemed expedient to imagine a sudden fall of temperature in order to account for the peculiar conservation of these creatures, by which they were supposed to have been at once frozen up in the mud into which they had been washed, or the morasses into which they had sunk.

The discovery, indeed, of a *Rhinoceros tichorhinus* by Pallas, with its skin and flesh adherent, upon the banks of the Viljni, a tributary of the Lena (a portion of this rhinoceros, with the skin and hair adherent to the sides of the head, are now to be seen in the Museum of Natural History at St. Petersburg), and still more the subsequent acquisition of the entire carcass of a mammoth, on the banks of the Lena in lat. 70° N., by Mr. Adams, the details relating to which have been so fully given by geologists of all countries, naturally, indeed, led to such ideas. Convinced, by their perfect preservation, that these animals must have lived in or near the countries where their bones are found, Cuvier declared it to be his opinion, that they must have disappeared by a revolution which at once destroyed all the individuals, accompanied by a sudden change of climate.

In England this view was very ably sustained by Dr. Buckland, and particularly in his memoir on the fossil remains which occur in Eschscholtz Bay, and other places on the east side of Behring's Straits[2], where vast quantities of mammoths' bones occur in mud cliffs, apparently similar to those of the mouths of the Lena and other great rivers in Northern Siberia. So long as geologists were compelled to argue upon the nature and habits of the mammoth, as if it were similar to an Asiatic elephant, the opinions of such great masters were necessarily dominant. Mr. Lyell had, however, the courage to lead the way in taking a new and highly philosophic view of the subject by suggesting, that the peculiar covering of these great mammals rendered them fit inhabitants of a northern climate, and that no greater catastrophes were required to account for their destruction, than the gradual elevation of large masses of Siberia, which laying dry the low shores and estuaries

[1] This coating, Dr. Fleming has well remarked, was probably as impenetrable to rain and cold as that of the musk ox of the polar circle, Edinb. New Phil. Journ., No. 12, p. 285.

[2] See Beechey's Voyage to the Pacific, vol. ii. Appendix, p. 593. Besides the abundant remains of mammoths, Dr. Buckland describes those of *Bos Urus*, deer and horse. They occur in cliffs of mud and sand about 90 feet high, which are usually much congealed and frozen.

into which their bones had been washed, would necessarily render the climate much more intensely cold[1].

But even if it be admitted that the climate must have been more mild when mammoths lived than at the present day, there still occurred the obvious difficulty, that without some entire change in the nature of its vegetation, of which the surface of Siberia offers no indications, by no possibility could a great phyllophagous, or branch-eating animal like the true elephants (which require rich Asiatic jungles for their sustenance), have lived in a region of fir-trees, birch, willows and moss. Comparative anatomy and physiology have here, however, fortunately come to the assistance of the geologist, and in this, as in many other of his darkest paths, have been his surest beacons. Examining and comparing the composite structure of the very numerous teeth of the mammoth, Professor Owen has ascertained that they possess a peculiarity in the greater proportion of the dense enamel, which essentially distinguishes them from the teeth of the Asiatic or African elephant, and which specially provided the mammoth with the means of subsisting upon the coarser ligneous tissues of trees and shrubs. In short, this great zoological authority, combining the consideration of the peculiar structure of their teeth with the nature of their epidermis and coverings, has come to the conclusion, that the mammoth was, by its very organization, a meet companion for the rein-deer and other inhabitants of the north[2]!

Applying the views of Humboldt, we might well admit, that the rise of the Ural and Altai mountains, and with them of enormous masses of the continent of Asia, must have so refrigerated Siberia, that its forests, which in the halcyon days of mammoths may have extended in certain promontories to near the Icy Sea, had necessarily shrunk back to their present limits, and left these coasts entirely to the rein-deer and its mosses. But to require our belief that the mammoth ever *lived* in the *northernmost* tracts of Siberia is uncalled for, since geologists well know that the wide and low tracts of Northern Siberia, in which its remains are most abundant, were *then* evidently beneath the sea, and the bones must have been

[1] There is no portion of Mr. Lyell's speculations upon ancient physical geography which has impressed us with greater respect for his talents, than his view of the adaptation of the mammoths to a residence in the former Siberia; and we rejoice that the geological evidences we have brought to bear upon the question essentially sustain his inferences. See Lyell, Principles of Geology, 4th Ed. vol. i. pp. 141, 150 *et seq.*, where the whole question is discussed with references to Dr. Fleming and other zoologists.

[2] See Owen's History of British Fossil Mammalia and Birds, 1844, p. 261 *et seq.*

drifted thither, and possibly for some distance[1]. Yet if we suppose, that these animals lived on certain lands, as in the Ural and the north-trending chains, up to 60° and 65° N. lat. (which facts and physical conditions warrant), we are still indebted to Professor Owen for having removed the greatest of all the difficulties which previouslye nvironed the problem; since there is no longer any objection to the mammoth being an inhabitant even of the Arctic Circle, provided (and there are still such examples in Europe) fir-trees and shrub-like vegetables could exist in such latitudes.

From the physical structure of the region we are indeed entitled to suppose, that not only the Ural and Altai mountains, but also their advanced northern ridges and plateaux (a half or two-thirds of Siberia), formerly constituted a region covered with forests, like those of the Ural, in some parts, and with brushwood steppes in others, from which whole herds of mammoths, as suggested by Mr. Lyell, would naturally migrate in the summers (even now intensely hot) to the embouchures of the great streams and edges of the then Arctic Sea. Such might have been, we may add, the position and condition of some of these creatures at the periods when, as we have imagined, the highest ridges of the Ural were thrown up, followed by the rupture of many lakes, and the consequent inundation of large tracts of the flat country, previously frequented by these great herbivorous animals. During their long occupancy of these lands, myriads of their carcases must doubtless have been washed down by the rivers and buried in local mud and alluvium,—in such positions, in fact, as they are found along the banks of the Sosva and the tributaries of the Obe, before alluded to. Others reaching the mouths of the streams, may easily have been transported into the estuaries, and even, by the power of such volumes of water as are poured forth into the glacial ocean by the Obe, the Yenisei and the Lena, borne out far to sea and there lodged on former mud banks, which now constitute the shores of New Siberia, where thousands of bones of these mammals are interred[2]. If the power of drifting the bodies of animals to

[1] Marine remains were found by Pallas, associated with mammoths' bones, in numerous places in and about 70° N. lat.

[2] See Admiral Wrangel's Voyage for a description of the sands and mud of the "Tundra" (evidently all ancient marine sediment) in which the mammoth bones are found on the continent, including his companion Anjou's account of their enormous quantity in the isles of New Siberia (English edition, translated by Mrs. Sabine).

great distances be assigned to any rivers (and mariners have seen floating carcases in the ocean very far removed from the lands from whence they came), in no part of the world is it more probable, that such operations may have been carried on upon a gigantic scale, than from the northern shores of Siberia, where such enormous rivers must have continuously extended their influence to several degrees of latitude beyond their mouths, and where the nature of the climate is singularly favourable to the conservation of animal substances.

And here let us say a word more on the ancient physical geography of this region. Such as are the present north-flowing courses of the great Siberian rivers, such we affirm they must have been from the very earliest periods,—from the time, in short, when the *palæozoic* rocks constituting the Altai and Ural Mountains and their dependencies were raised into dry lands, never more to be depressed beneath the waters of the ocean. Infinitely the loftiest and the grandest of these chains, the Altai with its snowy peaks (yet void of glaciers) ranging from west to east, is the great southern watershed from whence the Siberian rivers must, we say, have flowed from south to north during long ages, whilst the peculiarity of all the great counterforts or advanced ridges of that mighty chain, consists in their being composed of palæozoic, metamorphic and igneous rocks, which equally extend from south to north in a number of long, low meridian, parallel ridges. These north and south ridges, of which the Ural is the westernmost, thus encase each river, and preventing its flexure to the east and west, have necessarily determined its course to the glacial ocean, from epochs long anterior to the creation of a mammoth.

Looking to their low altitude above the sea, their muddy and sandy composition, and also to the discovery by Pallas of *marine remains* in many of them, we must believe that all the low promontories between the Obe, the Yenisei[1] and the Lena, which lie northwards of the ancient ridges and plateaux, were under the waters and estuaries at the periods when the mammoths ranged over the Ural, the Altai and the adjacent regions of Siberia, then above the sea[2]. Such of these

[1] We write Yenisei, like all other Russian words, as it is pronounced. The German J, as used by Pallas and the early German explorers of distant parts of Russia, has unluckily found its way into all English maps. Pallas states, that the fossil bones which fall from the high cliffs of the Yenisei, opposite Krasnoyarsk, are so numerous, that on decomposing they form a substance which he calls "Osteocolle." (Vol. iv. p. 443. Fr. Ed. See also Appendix to Beechey's Voyage.)

[2] The definition of the outlines of the land and sea during the mammoth period, or the extent to which marine estuaries entered into the continent of Siberia, including possibly even a separation of the Ural from the Altai, can alone be determined by the united labours of many observers. If the data of Pallas

creatures as were entombed in masses of tenacious clay at the mouths of these estuaries would necessarily be preserved almost intact, whilst the desiccation and elevation of such mud-banks, accompanied by an increase of cold, due to the raising up of a large terrestrial surface like Siberia, would thoroughly well account for the occasional conservation of their thick hides and much of their animal matter.

Whether, then, we argue from the evidences presented to us in the Ural chain and its flanks, from the ancient geography of Siberia, or from the natural history of the mammoths, and their adaptation to existence in the same parallels of latitude as those in and near which they are now found, we can, it appears to us, arrive at no other conclusions than those which we have endeavoured to sustain, and which, in fact, do not imply even as great an oscillation of land within this comparatively modern period, as would be required to explain the surface phænomena of most other parts of Europe with which we are acquainted. In truth, the uprising of Siberia "en masse" to the height of one or two hundred feet above its general level when mammoths lived, will amply suffice to explain both the desiccation of its northern shores, into the mud of which the fossil terrestrial remains had been washed, and the increased cold over that vast mass of continental land.

In the meantime we may repeat, that whether discovered in the gravelly detritus or clay on either flank of the Ural, in the high banks of the great streams which respectively flow into Asia and Europe, or in still greater quantities on the sides of the estuaries of the great Siberian rivers upon the glacial ocean, in all cases we find the mammoths entombed in materials which, whether coarse lacustrine shingle near the mountains, or mud and sand at a distance from them, all announce in the most emphatic manner, that these great creatures lived in lands adjacent to lakes and estuaries, in which during long ages their bones were interred, and were sometimes carried out to sea and commingled with oceanic remains.

Though we now take leave of the Ural chain, we will terminate the subject which occupies us, by giving a very brief sketch of the manner in which the great extinct mammals are distributed over European Russia.

Fossil Quadrupeds of Russia in Europe.—Far from being peculiar to the Ural

respecting the grounds on the lower region of the Issetz river (p. 490) be sustained, then, indeed, we see no reason why a very considerable tract to the south of that river, which is covered with black earth, may not also have been under an arm of the sea at that period. At the same time we think that the granitic hills between Miask and Troitsk and the chain of Kara-Edir-tau, both of which are destitute of any traces of marine sediment, must have then been above the waters.

Mountains and Siberia, the remains of mammoths and other lost quadrupeds have been found over very considerable regions of Russia in Europe. Pallas had long ago mentioned several localities where such mammalian remains have been observed. Though we ourselves are acquainted with situations in which they have been found in the governments of Moscow, Vladimir, Perm, &c., we best know them through the collections formed in the Imperial Museum of Natural History of Moscow, where, under the auspices and direction of our venerable friend Dr. Fischer, they have obtained a just celebrity.

In Russia, as in every other great region which has been examined, the races of lost mammals present some types which connect her former lands with those of other countries, associated with forms which are peculiar to her. Thus, whilst in common with America, Russia contains the mammoth and mastodon, and, in common with Britain, the *Elephas primigenius*, *Rhinoceros tichorhinus*, *Trogontherium*, beaver, bear, elk, &c., she once possessed generic forms, as *Merycotherium* and *Elasmotherium*, which have not, hitherto, been found elsewhere. Russia is, indeed, as peculiar in her possession of the latter extraordinary pachyderm as South America is for the *Mylodon* and *Glyptodon*[1].

The lost races of mammals which have been detected in Russia in Europe, are found, we have said, in exactly the same sort of detritus as that in which they occur in the flat northern tracts of Siberia, or near the mouths of its great rivers. In all the central and southern parts of European Russia, there are no high ridges of elevation, and consequently no coarse local detritus, like that on the flanks of the Ural, so that the mammoth alluvium assumes the same aspect as in the distant plains of Siberia, where it is equally removed from disturbing causes. Here, however, it is equally evident, that such alluvium has been the result of currents of water, for it is piled up, and often tumultuously, in great thicknesses, and constitutes the chief banks of most of the streams, as well as the covering of numerous plateaux. Occasionally, indeed, the coarser clay drift passes upwards into finely levigated silt, which in certain tracts may be represented by the rich

[1] The geological position of *Lophiodon Sibericum*, which is stated to have been found in a *calcareous formation* in the government of Orenburg, is doubtful; if it be miocene or eocene, it accords with the beds containing *Lophiodon* in Continental Europe and England. *Elasmotherium* may be said to be as peculiar to Russia as *Mylodon*, &c. to South America; but we are informed by Professor Owen, that there are no existing analogues in Siberia to illustrate the *Elasmotherium*, like the Sloths and Armadillos of South America, which explain the affinities of the Megatherian animals. See Professor Owen's most remarkable work on the Mylodon (4to. London, 1842).

black earth or tchornozem, of which we shall treat at some length in the last chapter. In illustrating the ordinary character of the mammoth alluvia of European Russia, we cannot, perhaps, do better than cite the example of Taganrog, because, exceedingly remote from the regions we have been considering, and, indeed, from any mountains, it there forms the summit of abrupt cliffs on the Sea of Azof, its relations to the underlying strata being well-exposed. The annexed view of Taganrog from the west, is given to show that the underlying tertiary limestone of the newer Miocene age (see description and woodcut, p. 296) there forms the

66.

base of the cliffs (*c*), the rocks of which, rising to about twenty feet above the sea, are covered by finely laminated sands, as represented by the whitish band (*b*) in the cliff, which are charged with fluviatile shells, little differing, if at all, from those now inhabiting the adjacent river Don. Above this, and occupying a thickness of about fifty feet, is the clay drift (*a*), as indicated by the sloping bank, in which the mammoth bones are interred, some very fine and well-preserved specimens of them having been found exactly at the period of our visit. This mammoth drift is just as completely separated from any deposit resulting from existing agency, as the auriferous detritus and coarse clay on the sides of the Ural hills, or as the high mud-banks forming the cliffs of the great Siberian rivers and estuaries, for it covers the whole of the coast plateau, the present adjacent river Krinka and the Sea of Azof being 100 feet beneath it. In truth, like similar drift over wide spaces of Central and Southern Russia, it is distributed at various levels, and most clearly indicates considerable submergence at the period when these animals were destroyed. Such facts as to the nature and distribution of the entombing materials, which occupy cliffs high above the valleys, compel us to believe, that the greater part of this low continent, *unlike* the Ural and the higher portions of Siberia, was not dry land during the existence of the mammoths, or in the period immediately antecedent to our own; but was then rather in the same subaqueous condition as the low lands of northern Siberia, when the mammoths' bones were there transported into estuaries. Hence, we think, that many of the mammalian remains to which we now allude, may have been transported into adjacent lakes and estuaries by rivers, and in some instances carried out great distances to sea from the surrounding lands,—the Ural (including a large tract of Permia) and Siberia on the east, the Crimæa[1] and Caucasus on the south, or the Carpathian Mountains on the west.

But besides these former encompassing lands, there are certain tracts within Russia, which though now of no great altitude, are so exempt from debris and drift, that it is natural to infer they may have formed low islets in the ancient waters which covered the great mass of the present lands. This view we would support by an illustration drawn from natural history and the nature of the ground.

Of all the remarkable quadrupeds which ranged over the former continents, one species only now remains alive (and this point even is doubtful[2]) to connect the

[1] See Demidoff, Voyage dans la Russie Méridionale, vol. ii. The reader will there find an account of the remains of bones of mammoth, bos, *Ursus spelæus*, horse, &c., as interred in a reddish-coloured argillaceous drift near Odessa (*Terrain Clysmien*), which covers the surface and enters into the clefts of the subjacent tertiary or steppe limestone. M. Huot, the author of that description, refers this deposit to lacustrine waters. He also found the *Mastodon angustidens* associated with the mammoth at Kamisch Burun, near Kertch. These animals lived, of course, in the adjacent high grounds of the Caucasus and Crimæa (see our remarks thereon, p. 304).

[2] Notwithstanding the deep interest attached to the *Bos Aurochs*, which may, we suppose, prove to be the only existing remnant of the great quadrupeds of former days, there does not exist a single skeleton or stuffed specimen of the species either in France or the British Isles. As far as England is concerned, this reproach is about to be removed through the munificence of the Emperor Nicholas, who, at the request of Mr. Murchison (graciously supported by His Imperial Highness the Grand Duke Michael), has directed that a fine animal, selected from the unique herd now living in the forest called Bialavieja, should be killed, and his skin and skeleton sent to the Museum of the Royal College of Surgeons. It may not be known, that without a stringent ukase to prohibit its annihilation, the peasantry of Lithuania would long ago have exterminated this noble species. Though we have been led to believe in the specific identity of this Lithuanian Aurochs with the extinct Urus (*Urus priscus* of Bojanus and V. Meyer), that opinion is not generally admitted. But we may hope that the question will be set at rest, as soon as Professor Owen has the means of testing it. If the living Aurochs be the real descendant of the great fossil animal, it might, judging from the usual difference of size, be considered to have degenerated; though in the Museum at Warsaw, where we have seen three specimens which are there preserved, one of them is nearly double the size of the other two. We ourselves procured a very remarkable front and horns of the *Bos Aurochs*, found in the gravel west of Perm with mammoths' teeth, and M. Hommaire de Hell also found a fine head of the same in the steppes between the Sea of Azof and the Caspian.

historic æra, or the present outline of the land with that which preceded it. This is the *Bos Urus* (*Aurochs*), or primæval ox, whose bones are so frequently associated with those of the mammoth in different parts of Russia and many parts of Europe. But if the species be the same, how has this exception been made, and how have herds of these oxen been preserved in a living state? Looking at the forest of Bialavieja[1] in Lithuania as the only locality in which this species now exists, and seeing that it is not far from the edge of the southern granitic steppe, we cannot avoid theorizing on a contingency by which some of these creatures may possibly have been preserved. That granitic steppe, the rocks of which we know to be of the highest antiquity, since they have even afforded materials for the construction of some adjacent Silurian strata, is in many parts so completely devoid of all superficial covering, and so entirely differs in that respect from the thickly-overspread tracts upon its north and south, as to justify the inference, that it was never depressed beneath the waters since the beginning of the palæozoic æra, but escaped the submersions which affected all the surrounding regions of Russia in Europe. Some individuals of the *Bos Urus* may therefore, we conceive, have been dwellers in this granitic ridge until the retirement of the surrounding waters enabled them or their descendants to repeople the new jungles and forests of the fresh-formed ground, and thus we could explain, by reasoning from geological appearances, how it happens that they are now found living in the forests of Lithuania. Attaching, however, no great value to this speculation, which may prove useless, if the living species is found to be different from the extinct, we leave it to naturalists to say, whether, under circumstances of great and probably sudden

[1] Count V. Krasinski, the author of the 'History of the Reformation in Poland,' prepared, at the request of our friend Colonel Jackson, a very interesting account of this forest and its inhabitants, from which we extract the following data. The forest of Bialawieza (Bialavieja) is in the government o Grodno on the river Narevka, and lying between the towns of Orla, Shereshef and Prujany, occupies a space of about 29 German, or 145 English square miles (see Map, Pl. VI.). Having been an ancient hunting-ground of the kings of Poland, it has been preserved in its wildest pristine state. The Aurochs (*Zubr* in the Polish language) *was always peculiar to Lithuania, if not to this very forest*. According to the earliest records, it was clearly distinguished from the native wild ox or *Tur* (an animal possibly similar to the wild oxen of Chillingham in Northumberland), which appears to have been much more common, even in the 16th century, than the Zubr or Aurochs. An ancient picture, in the possession of the last king of Poland, represents King Ladislaus Jajellem presenting a live *Zubr* to the fathers of the Council of Constance! thus proving that it was very rare in the beginning of the 15th century. (See also Mém. Déscrip. sur la Forêt de Bialawieza par le Baron de Brinnen; published at Warsaw in 1828, at which time it was believed that 875 head of *Zubrs* were still living in the forest.)

change of land and water[1], and other difficulties dependent on a limited subsistence, the Aurochs or *Zubr* of Lithuania was not, from his activity and hardy habits, more likely to have survived such oscillations, than his unwieldy associates, the mammoth, mastodon and rhinoceros.

In terminating the subject of the entombment and dispersion of the great races of Mammalia, we may remind our readers, that in our endeavours to point out the ancient physical geographical features of the Ural Mountains, and the adjacent tracts of Siberia, geological proofs have been adduced to show, that a vast portion of that region having been entirely exempt from all oceanic influence during ancient periods of long duration, was thereby eminently qualified to be the residence of such animals during the whole of their existence. It has further been proved, that the production of gold veins, and the elevations of the Ural, which have given to these mountains their present height and relief, are phænomena of a comparatively recent date,—phænomena which, in lowering the temperature of the great region so affected, were, we have little doubt, the chief causes of the final destruction of the mammoths, which, with all their adaptation to existence in northern latitudes, could scarcely be supposed to have been capable of long enduring the want of sustenance incident to Siberian winters of the present period.

When we turn from the great Siberian continent, which anterior to its elevation was their chief abode, and look to other parts of Europe where their remains also occur, how remarkable is it, that we find the number of these creatures to be justly proportionate to the magnitude of the ancient masses of land which the labours of geologists have defined! Take the British Isles, for example, and let all their low recently elevated districts be submerged; let, in short, England be viewed as the comparatively small island she was, when the ancient estuary of the Thames, including the plains of Hyde Park, Chelsea, Hounslow and Uxbridge were under the waters,—when the Severn extended far into the heart of the kingdom, and large eastern tracts of the island were submerged, and there will then remain but moderate-sized feeding grounds for the great quadrupeds whose bones are found in the gravel of the adjacent rivers and estuaries. This limited area of subsistence could necessarily only keep up a small stock of such animals; and just as we might expect, the remains of British mammoths occur in very small numbers indeed, when compared with those of the great charnel-houses in Siberia,

[1] In the next chapter reasons will be assigned to induce the belief that the surface of Russia in Europe was depressed at that period.

into which their bones had been carried down during countless ages, from the largest mass of surface which geological inquiries have yet shown to have been *dry land* during that epoch.

In treating this subject, we have been gradually led on to speculate on features which connect the former with the present surface of a large portion of the earth, and have little other reference to submarine conditions, than the elevation into land of the bottoms of estuaries and sea-shores on the edge of that continent. In the next chapter, however, we must entirely change the scene, by returning to the consideration of Russia in Europe, nearly the whole of whose superficies presents phænomena of a very different class, which we shall endeavour to show, can alone have been produced by very powerful currents and long-continued submersion under the waters of the sea,—phænomena which, we think, prevailed during the period when the great mammalia were the inhabitants of Siberia and certain southern tracts to which we have alluded.

P.S.—It may seem remarkable, that in a region like Russia, so extensively tenanted by *bears*, when first reclaimed by man, we should scarcely have alluded to their occurrence during a former condition of the surface. Their bones, however, have been found, as well as those of horses, elks and many other animals, on whose remains we have not thought it necessary to expatiate, as they are mere repetitions of a phænomenon common to other parts of Europe. Judging from the analogy of other countries, where the bones of the *Ursus spelæus* have usually been found in rocky caverns, it is evident, that from the nature of her surface, Russia in Europe offers very few spots where the geologist might hope to find them. We have, however, alluded to caverns in the Ural Mountains and Siberia (the caves of Yermac on the Tchussovaya and others on the Issetz, pp. 365 and 368), which being in positions far above the highest floods and on precipitous faces of palæozoic limestone, would, if explored by some Russian Buckland, afford, we have little doubt, the remains of extinct animals.

CHAPTER XX.

SCANDINAVIAN DRIFT AND ERRATIC BLOCKS IN RUSSIA.

General spread of a Drift from the North over the Low Countries of Russia and Germany.—Theories proposed to account for Foreign Drift.—The Russian Drift and Erratic Blocks described along the northern frontier of Russia.—Shown to have been distributed in trainées under the sea.—Chiefly arrested on Hills and Elevations, and less abundant in Depressions.—Large Blocks most frequent on Clay, and broad low sandy spaces often free from them.—Character of the Drift changes in its advance southwards, according to the nature of the subsoil which it traverses.—Distinctions between the Local Materials in Russia and those of Poland and Germany.—The transport of the Drift from lower to higher lands shown to be impossible under terrestrial conditions; and the Glacier Theory, as applied to these Regions, rejected.—The far Southern and South-eastern advance of the Drift into certain Depressions explained by reference to Bays and Promontories of a former Continent.—Erratic Blocks shown to have proceeded excentrically from Scandinavia and Lapland.—The largest and furthest-borne supposed to have been transported in Icebergs detached from ancient Glaciers.—The low northern Crystalline Tracts could not have determined the advance of Glaciers over a higher Continent.—Scratched surfaces coincident with the direction of the Drift over many Low Countries of Europe.—Theory of the Authors of this work explained, viz. that moistened masses of Drift have, under powerful causes of translation, operated like the Moraines of Glaciers.—Former Submarine condition of Russia.

FROM the German Ocean and Hamburg on the west to the White Sea on the east, a vast zone of country, having a length of near 2000 miles and a width varying from 400 to 800 miles, is more or less covered with loose detritus, including erratic, crystalline blocks of colossal size, the whole of which have been derived from the Scandinavian chain[1]. When we consider, that throughout this vast space, these blocks have all been transported from the same range of mountains and often carried to enormous distances, it will readily be admitted, that whilst it is entirely different from the regions we have just been considering, no portion of Europe affords so fine a field for the discussion of the difficult problem, of how such heavy masses were so far transported? In the earlier days of geological science, this great spread of northern detritus was merged with the coarse debris of other parts of Europe under the term "diluvium," meaning thereby that it was the wreck of a general deluge which had passed over our continents. With increased observation, however, it was found, that whilst certain tracts of country (like our great Siberian case) were entirely exempt from them, each region which contained such foreign materials had derived them from contiguous chains and from various points of the compass; and hence it was concluded (at least by many geologists), that they were drifted to their relative existing positions by various currents of water, set in movement in different directions by elevations and depressions of separate masses of land.

Latterly this subject has attracted more than ordinary attention, through the labours of several observers in the Alps, and new theories have arisen. Whilst Sefström and his followers in the north had been contending, that all the detritus of which we are now about to treat resulted from a great northern deluge, Agassiz and his predecessors Venetz and Charpentier, showing the transporting force of glaciers, endeavoured to demonstrate, that many of the heaps of detritus around the flanks of the Alps are nothing more than "moraines," the residue of ancient and more extensive glaciers.

Arguing from the phænomena of the Alps, M. Agassiz further attempted to establish a general glacial theory, by which he supposed, that all the northern hemisphere was, during a long period, covered with ice and snow; that glaciers, advancing *by expansion* from certain centres, and carrying with them, on their lower surfaces, the blocks and pebbles which were entangled in them when they first moved from the mountain side, scratched and polished the surfaces of the continents over which they passed, precisely in the same manner as rocks are now affected on a small scale by the existing glaciers of the Alps; and lastly, that upon the melting and breaking up of these great former glaciers many of the large blocks

[1] See the Map on which the southern limit of these blocks is marked.

which they contained were floated away in débâcles of icebergs and deposited at great distances from the source of their origin. Still more recently, Professor James Forbes, extending the views of De Saussure by an assiduous personal survey of the Alpine glaciers, has demonstrated by exact experiments on the nature of their ice and its movements, that glaciers never can advance except by their own gravitation and upon inclined surfaces.

But apart from the Alpine theories and observations, Mr. Lyell and others had previously shown how, under former relations of sea and land, icebergs wafted by prevailing currents may have carried foreign blocks to great distances, and one of us had applied this view to explain the transport of the great foreign boulders which are distributed in the central counties of England[1]. Our own view had, we think, this advantage, in reference to tracts like this under consideration, that in showing the presence of sea-shells of modern characters in mounds of far-borne detritus, it completely established, that the surface of such tracts was *beneath the sea* when the blocks were distributed. Hence we subsequently inferred, that the glacial Alpine theory, which is constructed upon the belief that such surface was sub-aërial, was in such cases entirely inapplicable; subaqueous action being alone admissible.

After this slight introduction, and referring our readers to the ingenious and able works of the writers alluded to, we now proceed to throw together our own observations upon the transported matter of the great northern regions.

The superficial detritus of Russia, Poland and Prussia, like that of other regions which we have examined, is referable to the great mountain-chain in its vicinity. The chief, if not the only, distinction between it and all other far-borne drift, consists in the great breadth and length of the dispersed detritus, in reference to the low mountains from whence it has been derived; for whilst in other parts of Europe various local centres of elevation have shed their detritus in different directions (England, France and the Alps offer sufficient examples), the vast regions

[1] Silurian System, pp. 522 to 547. By consulting these two chapters of a former work by Mr. Murchison, the reader will find a full development of his views respecting the transport of some drift by water, and of great foreign erratics by icebergs. These chapters were written (1838 and 1839) before the appearance of the works of MM. Agassiz and Charpentier on the agency of *glaciers* in transporting erratic blocks, a question which Mr. Murchison subsequently considered at some length in an Anniversary Discourse addressed to the Geological Society of London, 1842, in which will be found some of the same ideas developed in this chapter. (Proceedings of Geol. Soc. vol. iii. p. 671.)

under consideration have been uniformly covered with crystalline materials which have proceeded from Scandinavia and Lapland only.

Confining ourselves, in the first instance, to the Russian detritus, we now proceed to give a succinct account of its nature and distribution between the mouth of the Niemen on the south-west, and that of the Dwina of Archangel on the north-east,—such, in fact, as it appeared to us when we travelled along the southern edge of the crystalline rocks, from whence all the debris has been sent forth. By this means we shall make a transverse section, as it were, of all the drift on a line little distant from the source of its origin, and then follow it to distant parts of the interior of Russia.

Geological travellers who, like ourselves, have crossed over Northern Russia from its western frontier on the Niemen to Archangel on the White Sea, cannot avoid being struck with the general sameness of this distribution, and also with the fact, that the detritus has been borne southwards in long zones, often separated from each other by depressions, occasionally of great width, in which few or no blocks are discernible.

Thus the broad depression of the Niemen, and even the low argillaceous hillocks on its eastern slopes, are almost, if not entirely, exempt from blocks, the *chaussée* for the first two Russian stations through the forests being mended with small gravel brought from distances of fifteen and twenty versts. In approaching the third station, however, blocks appear on the surface of the clay drift. Again, the summits and slopes of hills (200 or 300 feet high) on both sides of the station of Bublia,—particularly the plateau to the north-east of it,—are covered with blocks of granite, porphyry and other Swedish rocks, both rounded and subangular, and occasionally of large size, together with corallines and shells of Silurian rocks, whilst the intervening valley, in which the Wendau Canal has been cut, is exclusively occupied by fine yellow sands. Having passed the plateau between Lithuania and Courland, where mud and northern blocks still prevail and are widely spread over the latter province (around Mittau), we again remarked the comparative absence in the estuary of the Düna, particularly on the low grounds and hillocks forming the eastern banks of that river, which are almost exclusively occupied by loose sands, immediately surmounting the Devonian strata with their ichthyolites.

Passing to the east of the station of Walk, no sooner do argillaceous hillocks (about sixty or eighty feet above the plain) appear, than again they are covered with erratics of gneiss, granite gneiss and other northern blocks of various sizes. The cliffs forming the eastern or right bank of the river Embach are loaded on their surface with similar detritus. Thence to Kaigatz the drift is also argillaceous and blocks abound, extending all along the plateaux to Dörpat, where the larger granitic blocks repose on an argillaceous and sandy alluvium, which separates them from the subjacent Devonian sands and marls.

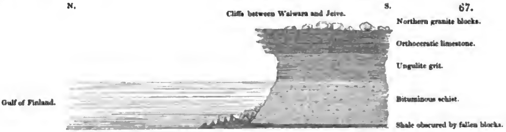
In ascending from Dörpat and the lake Peipus to the calcareous plateau[1]

[1] In this plateau, extending by Shavli, &c., some Silurian limestone, which we have described in the 3rd Chapter, exists *in situ*, but the greater portion of the calcareous debris we met with had evidently been drifted from the north—probably from Oesel; for the corals which are so abundant in the detritus do not occur in the cliffs of the mainland, but are Upper Silurian species which abound *in situ* at that island.

which occupies the coast, the detritus consists of rolled and rounded fragments chiefly of Silurian limestone, here and there capped by a great granitic block,—a tract most joyfully reached by those who, travelling as we did in the early spring, just after the melting of the snow, had with such difficulty ploughed through the muddy, marly and sandy detritus of the western district. We shall afterwards enlarge on a feature which here struck us forcibly, viz. that the principal mass of the detritus of each district is of local origin, and very clearly bespeaks the nature of the subjacent formation; whilst the great northern drift is perfectly independent of such subsoil, and has been distributed in zones, or "trainées," which traverse the Silurian, Devonian, and Carboniferous regions.

On reaching the cliffs of Lower Silurian limestone, which stand out against the sea of the Gulf of Finland, we found their surface completely denuded of all local drift (their calcareous debris having been swept to the south). Without any accompaniments of smaller gravel, or rounded stones or clay, the hard limestone flags are there at once covered with blocks large and small, nearly all angular or subangular, which are spread about in little groups or single masses, as represented in this woodcut.

67.



Here then are blocks, every one of which may be paralleled with the granitic, porphyritic, or gneiss rocks of Finland, and which have clearly been transported without rubbing or friction; for they are not rounded or worn down by any attrition, and are unaccompanied by the rounded boulders, clay, or sand, which indicate a drift by water alone. They must therefore have been lodged or deposited on these cliffs (150 feet or more above the adjacent Baltic) by some cause independent of pure aqueous action. To the consideration of this point we shall hereafter return.

Let us now continue to make the general transverse section of all the northern detritus which occurs along the southern frontier of the crystalline rocks of Finland and Russian Lapland.

3 U 2

Standing as it does on the very northern edge of the Silurian band and in the lowest stratum of that formation, St. Petersburg and its environs is a favourable tract for studying the distribution of the northern drift.

In travelling to the north of that metropolis, hills chiefly composed of sand, derived from the wearing down and washing of the adjacent granitic region, are soon found to contain many blocks of northern origin, and these increase in quantity and magnitude, forming ridges and undulating hills, from which you pass to the edge of the crystalline nucleus of Finland. To the south of the capital the Lower Silurian clay has been to a great extent denuded, or covered merely with more recent alluvial deposits. On this flat, granitic and northern blocks are comparatively rare, though an occasional specimen of very great size has been detected in the marshes; but no sooner is the plateau land on the south ascended (the framework of which consists of the Lower Silurian limestone), than vast quantities of these blocks, some rounded and others not much so, occur both in isolated patches and in "trainées." They are seen on all the elevations on both sides, and particularly to the south of the observatory of Pulkova, and on the tops and slopes of the ravines (into which they are occasionally rolled), whether on the sides of the brook Pulkovka or all along the low eminences which slope away to Peterhoff. The calcareous plateau to the south of Czarskoe-Celo and the sandy valley of Pavlosk, are for the most part void of them, the latter being absolutely filled with the sand derived from the breaking up of the ungulite sandstone; but a vast and copious trainée is seen upon the southern slope of one of the hills, near the sources of the little river Slavenka.

We particularly remarked that in this group of the Slavenka, the greater number of the blocks were by no means rounded; many, indeed, are still quite angular and some subangular. Being accompanied to this spot by Dr. Wörth, to whom, in former pages, we have so warmly expressed our obligations, that zealous mineralogist distinctly assured us, that there was not among these blocks (whether gneiss, granite, or greenstone, &c.) a single example which could not be paralleled with its parent rock in Finland. Here again, as in the Dörpat and Lithuanian tracts, we had a convincing proof, that the direction of the drift had been from north to south, quite independently of the Finnish blocks; for the true Devonian rocks, which are here charged with ichthyolites, are surmounted by flag-like fragments of the Lower Silurian limestone, occasionally very large, which have been drifted from the adjacent plateau on the north[1].

[1] We cannot give this passing account of the detritus near St. Petersburg, without adverting to the more detailed description of it by Mr. Strangways (Trans. Geol. Soc., Old Series, vol. v. p. 392). Showing that the drift is often from thirty to forty feet thick, and sometimes occupies entire hills, he states that it is made up both of crystalline rocks that have been transported from Finland on the north (referring many of them to their native quarries) and of the debris of the strata *in situ*. In regard to the latter, he mentions how the wide spread of sands in some tracts, particularly to the north of the Neva and the environs of Peterhoff and Pavlovsk, has been occasioned by the breaking up of what he calls the "intermediate sandstone" (our Ungulite sandstone), and how the limestone, or "pleta," is usually covered with light brown earth. We were also struck, as well as Mr. Strangways, with the appearance of thick masses of very finely laminated clay on the road from St. Petersburg to Strelna, and in which there occur

In the low country east of St. Petersburg, watered by the river Volkof and its tributaries, the northern crystalline erratic blocks are very scarce, the subjacent Silurian rocks being for the most part covered with a thick alluvium of clay containing very few boulders. The tract, indeed, where the Volkof empties itself into the Lake Ladoga, is entirely void of them, the surface being exclusively occupied by sands which often assume the character of dunes, like those at the estuary of the Düna. In travelling from Nova Ladoga to Ladenoie Pole, we were much struck with the almost total absence of the erratic phænomenon; during the whole width, in fact, of the southern shore of the great Lake Ladoga.

To the north we had a vast inland lake near 200 versts long, whose northern shores are exclusively composed of granitic and greenstone rocks, with some metamorphosed Silurian strata, and whose east and west shores are covered with their spoil,—and yet not a fragment of them is visible at its southern termination! Are we to presume that in this parallel such erratics are all buried in the bottom of this sheet of water? Some doubtless may have been so disposed of, but this explanation is quite inadequate; since the northern blocks have been transported, as we shall afterwards show, many hundred versts to the south of the lake, and in this very parallel of longitude. The fact is, that unlike the southern shores of the Gulf of Finland west of Narva (p. 512), the south shore of the Lake Ladoga is a dead

fine layers of small pebbles. These beds, like the finely laminated sands in many parts of Russia, clearly indicate, that there were periods of repose as well as of powerful current, during the accumulation of the materials which we are now merging under the head of "drift." It is perhaps unnecessary to state, that for these and many other reasons, we cannot agree with Mr. Strangways in the theoretical view (prevalent at the period when he wrote), that all these deposits were the residue of a great flood which passed over the land *before* the lateral valleys were formed,—the latter having been fashioned out by the *retiring* wave. The very fact which he cites, of large lumps of the intermediate or Ungulite sandstone having been transported from a lower level on the north to high plateaux on the south, is subversive, we think, of the then prevailing theory. We would also observe, that he does not draw sufficient distinction between the prevalence of large northern blocks on the plateaux and their rarity in the low plains. The immediate vicinity of the metropolis it must, however, be admitted, has offered some exceptions to the non-occurrence of erratics in the low grounds; for though they have fast disappeared, several peculiar northern *rolled* fragments are cited by Strangways from the south of the Moscow gate. He further mentions, that the block on which the statue of Peter the Great stands (reduced two-thirds in size and chiselled into its present grotesque form by the artist!) was found in a bog between St. Petersburg and Cesterbeck. Still we are firm in our belief, that *these are exceptions*; a fact, indeed, of which any one may convince himself by merely passing along the railroad from the capital to Czarskoe-Celo, where the argillaceous surface for many miles (including the race-course at the northern foot of the escarpment of the low limestone hills) is entirely free from northern blocks, though they occur in vast abundance on the plateaux further south.

flat, with no eminences to *catch* the drift, which however transported, has passed on southwards till arrested by other heights[1].

Very different is the surface of the Carelian country to the north of Olonetz, and which lies between the lakes Onega and Ladoga. Here again we found ourselves in precisely the same sort of tract as that on the edges of Finland north of St. Petersburg. Undulating hillocks, or rather ridges, 200 or 300 feet in height, trending for the most part from north to south, or north-north-west to south-south-east, succeed each other in rapid succession, and are from top to bottom composed of granitic and northern detritus, often separated from each other by small lakes. We were, in fact, on the ancient shore of the great Scandinavian chain, and amidst bands of its granitic detritus, much resembling that to which we shall afterwards allude as covering many parts of Sweden[2].

The point we most wished to ascertain was, if the crystalline and hard rocks which rise to the surface immediately to the north of Petrozavodsk, and over which the vast mounds and ridges of detritus to the south of it had passed, exhibited the phænomenon of polished and scratched surfaces, and if these scratches were in the chief direction of the drift.

On this point we soon satisfied ourselves, by boating up the Lake Onega to the northern extremity of the little bay or strait of Salomi, where we found the hard eruptive greenstone and associated breccia (Salomenski-kamen, see p. 18) perfectly rounded off and grooved on the northern face of a small promontory opposite to the church, with innumerable small striæ having the direction of magnetic north and south. As the water of the lake which washes round this small headland was very transparent, we could observe the striæ down the northern slope of the rock

[1] Being tired with the continuous expanse of sands which here cover the lowest Silurian clay, we became very impatient to discover some rock *in situ*, and determined to ascend the banks of the river Oyat for that purpose. As soon, however, as the peasants had prepared our equipage, it was quite evident that our search would be fruitless, for not one of the horses *was shod*; an economy very generally practised in Russia, where no hard ground or rock is at the surface. We had, in fact, been led to this excursion by our constant inquiry after *stones*; and the Russian peasants, who are invariably well acquainted with every natural feature in their neighbourhood, dragged us through sandy forests for many miles, until they truly pointed out a few northern blocks, the only stones, in fact, of the whole tract.

[2] At Petrozavodsk there seemed to be some means of separating this coarse and ancient drift, which contains boulders and is covered by them, from certain overlying sands, which having filled depressions in the drift clay, have since been excavated; but we had not time satisfactorily to work out this question. Other peculiar phænomena, caused by the melting and bursting of the ice of the lake Onega near Petrozavodsk, will be described in the next chapter.

to eight or ten feet below the liquid surface, whilst on tracing them up on the rock exposed to the atmosphere we found them persistent to near the summit of the little hill, particularly wherever the thin coating of turf and soil, on which a few stunted fir-trees grew, was uncovered. To the south side of the hill, on the contrary, no such traces of wearing, friction or striation could be seen, and thus we had before us, on the edges of Russian Lapland, the very phænomenon so extensively observed by Sefström over Sweden, and on the consideration of which we shall subsequently dwell, viz. a rounded, worn and striated surface of the northern sides of promontories, whose southern faces are natural and unaffected by any mechanical agency.

Whilst great heaps or ridges of rounded granite blocks and gravel occupy the tract before alluded to south of Petrozavodsk (masses of the same being doubtless buried in the lake), large and subangular blocks have travelled further to the south, as we proved by detecting several of them on the very summits of the greenstone and syenitic promontories, which in heights of 400 to 600 feet above the lake, constitute its south-western coast, and extend to the north bank of the river Svir.

Arrived at the southernmost of these hard promontories, just where the igneous rocks subside towards a vast plain, and are no longer to be found across the whole regions of Russia,—on a slope, where emerging from umbrageous thickets, we enjoyed a magnificent prospect, having the Lake Onega on the left, the deep and pellucid river Svir in front, and the undulating regions of Muscovy beyond it, a very remarkable trainée of blocks of granite, gneiss, greenstone, &c., mingled with a few quartzose boulders derived from the region over which we had travelled, was spread out at our feet. This fact is in perfect accordance with that observed on the southern side of the plateau of Czarskoe-Celo, and also with the common Swedish phænomena of which we shall hereafter treat.

This trainée, of vast width, extends for some versts to the south of the river Svir, where its numerous boulders, many of them much rounded, constitute a water-worn, pebbly surface, not unlike that of the " crau " in the south of France. After passing over the indurated and quartzose rocks which exist in it, this drift also overlaps the same formation, where it becomes the unaltered Old Red Sandstone (Devonian), and in which, on the banks of the Mgra in this neighbourhood, we found characteristic ichthyolites (see p. 47).

The south end of the Lake Onega, equally flat with that of Lake Ladoga, presents, indeed, a striking contrast to the latter, in its surface being covered with a coarse northern drift of a few feet in thickness, beneath which the upper beds of the Old Red Sandstone or the lower beds of the carboniferous limestone are occasionally detected. This distinction may be explained by the great difference of physical outline of the east and west banks of these two lakes; for whilst those of Ladoga,—at least for some distance from its southern end,—are flat and low, without the trace of a hard subjacent rock, those of Onega, consisting, as we have shown, of trappæan and quartz rocks on the west, and of hills of Old Red Sandstone with its ichthyolites on the east (p. 47), form striking promontories, *under the lee of which* all this drift has been accumulated. It was also curious to observe, how exactly the line which this drift had taken, from north and by west to south and by east, was indicated by a change in the nature of its materials, as we traversed its direction and approached the city of Vitegra; the granitic rocks common to all the region in the north still prevailing, whilst the boulders of quartz rock and trap disappeared. Their absence, again, is strictly coincident with the fact, that the eastern side of the lake to which we had advanced, contains no such rocks *in situ* at its northern end, but simply Old Red Sandstone in its unaltered state. In ascending, however, the eastern sides of the lake we found fragments of Lydian stone and altered limestone, derived from masses which lie to the north of that parallel. In extending our researches eastwards to the plateaux on the banks of the Andoma and its tributaries, to examine the Old Red or Devonian rocks with their caps of mountain limestone (p. 74), we were much struck with the comparative absence of drift. This contrast was, therefore, a proof, in addition to the many examples we have already cited, that the agency by which the distribution of the rounded and highly-worn drift had been accomplished, acted in north and south zones of greater or lesser width. Still, on these high grounds, an erratic northern block may here and there be detected, and on advancing to the southern or south-south-east slope of the carboniferous limestone, we again met with a profuse spread of northern granitic boulders and blocks, but without a trace of quartz rock.

For a considerable distance to the east of Vitegra, the country is singularly exempt from all northern and foreign detritus, the Old Red Sandstone being either seen *in situ*, or the surface detritus being, as it were, entirely made up of that subjacent rock; but on reaching the plateau which separates the waters flowing into the Dwina and White Sea from those which flow into the Baltic, the carboniferous limestone is occasionally seen to be covered with a drift, composed of northern boulders, mixed up with the limestone of the tract,—one of the largest of the granitic blocks near Perkina, resting upon the local detritus, was from twelve to fifteen feet in diameter. Again, all northern detritus either disappears or becomes exceedingly scarce, and the road to Cargopol for several stages is either formed upon the denuded carboniferous limestone or on its spoil, with very little other superficial covering. Though a few northern blocks appear near the station of Braneva, the ordinary character of the superficial detritus of a considerable part of the country between Cargopol and the Dwina, is of a very tranquilly-formed character. Thus on the Onega river and its feeder, the Tchutchetza, the banks are composed of fine sandy loam of a considerable thickness, not unlike the löss of the Danube, and this becoming more sandy, continues to Archangelskoi; near to which, indeed, the carboniferous limestone is solely covered by a few inches of fine dark mould. Again, sands, occasionally loamy, and rarely passing into a state of "löss," for the most part nothing but sea-sands, encumber the surface of the carboniferous limestone, which only peeps out, at intervals; and through several stages we could only discover a solitary northern block in the course of many miles, a few of them being visible at the little post-house of Kodysez. Between that place and Süskaya on the Dwina, are picturesque small lakes, surrounded by rapidly undulating sandy hills, occasionally somewhat argillaceous and finely laminated, and then passing into löss; *but far and wide must the traveller roam to find an erratic block.*

This is perhaps the most extensive boulderless tract which we traversed in Northern Russia. On approaching, however, the higher grounds which form the left of the Dwina, the soil becomes argillaceous, and granitic northern blocks again occur upon the surface[1].

Near the estuary of the Dwina, or for a certain distance to the south of Archangel, the right bank of the river, which is high and opposite to the plains and meadows of Kholmogor or Kolmogorri, is composed of irregular accumulations of reddish argillaceous sand and marl, apparently void of stratification; nothing more than regenerated piles of the subjacent Old Red Sandstone, which formation then succeeds to the carboniferous, and therefore makes up the mass of the drift. The surface of this tract, rarely sandy, and for the most part argillaceous and boggy, very seldom exhibits anything like a large granitic boulder.

Traversing the Dwina to its west bank, and coasting the low promontories which fringe the White Sea, we there also travelled three stations in dunes of sand and stunted woods, before we met with a northern travelled rock. No sooner, however, did we arrive in the same parallel of longitude as the isles of rocky gneiss and granite in the bay, than we began to find a few erratics derived from them[2].

[1] In the next chapter we shall show how some of these boulders have been moved in modern times.

[2] The monastery of St. Nicholas stands on one of these isles. The sandy shores of the White Sea, along which we were then forcing our way (accompanied by our kind friend Mr. Whitehead, Her Britannic Majesty's Consul at Archangel), were covered at intervals with numerous plants, which formed a rich foreground to the magnificent marine prospect of the glassy sea with its islets and white monasteries. The plants we observed were chiefly those of the flora of North Britain, and, exclusive of some remarkable roses, we collected *Linnæa borealis*, *Pyrula uniflora*, *Rubus Chamæmorus*, *Rubus* (species unknown), *Impatiens Noli-me-tangere*, *Cornus Suecica*, *Trientalis Europæa*, *Thymus Serpyllum*, *Circæa Alpina*, *Vaccinium Oxycoccus*, &c. We were also much struck with the large size and good shape of the cows in these boreal tracts. They are, in fact, quite as large and fine-coated as those of the English Suffolk breed, and not unlike them. This feature of civilization is due to that remarkable sovereign Peter the Great, who imported Dutch cattle, suitable to the rich and deep pastures on the left bank of the Dwina, near the ancient town of Kholmogor, from whence the breed has spread over a considerable tract. Kholmogor was the chief town of these parts (long before the foundation of Archangel), when the intrepid

Whether the salt-pits which occur to the west of Ninokotski are proofs of the comparative recent sojourn of the sea in these parts, or depend on springs which issue from subjacent Old Red or Devonian strata, seems doubtful. Some of them may, for all that we know, be formed like salt-pans from the present sea, as on parts of the British shores; but at the station of Unskoi a salt spring unquestionably issues from a subjacent stratum, which we believe to be Devonian. Between this place and the western side of the promontory which constitutes the east coast of the bay of Onega, undulating hills, often argillaceous, are capped with northern blocks and sand, and a few slabs of hard red sandstone, as we particularly observed in the heights upon the left bank of the river Kianda. In fact, the whole of the great promontory which stands out northwards towards the White Sea, the southern side only of which we examined, is covered with blocks and erratic matter, and thus we were again in a detrital zone, which presented a striking contrast to the sandy and loamy surface between it and the Dwina. In certain ravines on the east coast of the bay of Onega we met with such great masses of subangular blocks of gneiss and granite, that we were almost disposed to think these rocks must be *in situ*; the more so as we knew, that the little islets in the bay were composed of such. When the structure of these isles, or the chief of them, Ki-ostrof, was described (p. 17), we had not visited the coasts of Norway and Sweden; and we must therefore now state, that, whether in structure or in outline, Ki-ostrof and its associated islets exactly resemble the "skärs[1]" of these countries, of which hereafter.

This islet forms the southernmost of a group of granitic isles which extend northwards; and on the largest of them, at the mouth of the bay, is built the Solavetski monastery. Ki-ostrof, as well as its adjacent islets, is an elongated narrow "skär," the shape of which conforms to that of the bay of Onega; its northernmost face being very much worn down and polished[2], whilst its southern

English navigator, Chancellor (anno 1551), *discovered* Muscovy *viâ* the White Sea, and there waited until he received an invitation from the Czar Ivan Vassilievitch to visit Moscow.

[1] This Swedish word is pronounced like the English word *share*.

[2] Though we did not visit the Isle of Dago, which lies between the Finnish and Swedish shores whence the granite blocks have been derived, and the low plateau of Courland on which they are lodged, we know from Professor Eichwald, who gave us specimens from the spot, that in some parts the surface of the Upper Silurian limestone in that island has been scratched, as if weighty, harrowing bodies had passed over it from north to south. It is, of course, impossible that any such permanent scratches can have been impressed on the incoherent rocks of Russia.

end is higher, with small indented bays into which heaps of rounded boulders have been lodged under the side of the cliffs. The explanation of this peculiarity of outline will be entered upon in the sequel, in treating of the much better examples of similarly-shaped and eroded isles and promontories in Scandinavia. We will now only observe by the way, that in the large wood trade which is carried on between Onega and England, the rafts of timber now find their resting-place from the tidal influence, in the southern bay of the little Ki-ostrof, just as the boulders of old did; that side being now as well protected from the roll of the northern surge, as it was of old, from the violent current of the northern drift.

We have thus endeavoured to explain the nature of the northern drift, as well as the manner in which it has been deposited, along the northern frontier of the sedimentary deposits of Russia, and the reader will, we hope, have perceived, that in general such detritus is most accumulated on plateaux and high grounds, and particularly on their southern slopes. We have also shown, that it occurs in north and south zones of greater and lesser width and length. It has further been stated, that in a broad space of country between Vitegra and Archangel, of small elevation and at no great distance from the source of their origin, erratic blocks are very rarely to be detected, whilst in approaching their sources, or the crystalline nucleus of the White Sea, they increase.

Let us now follow these *trainées* to the interior. To the south of the government of St. Petersburg, the Valdai Hills, like other high grounds to which we have adverted, have arrested vast quantities of blocks (granite, gneiss, greenstone and porphyry of Finland), which in many parallels of longitude are profusely spread over the southern talus of these hills, and have been transported to Moscow, and to great distances south of that city. Taking the direction of the great mass of drift which has passed to the south and south-south-east, we may, indeed, confidently refer to the same origin the blocks which are traceable at intervals as far southwards as Voroneje (see Map), a distance of about 700 or 800 miles from the nearest edge of their parent country. Following the drift in the longitudinal parallel of the lake of Onega, which we have indicated as a powerful zone, we found the regions around Tcherepovetz, Mologa, Yaroslavl and Vladimir, even as far southwards as Jelatma, or Yelatma, not only encumbered with large erratic blocks, but with such vast masses of gravel, clay and sand, that it is quite impossible to detect a trace of the subjacent rocks over very wide tracts, even in the beds of the Volga and the deepest cutting rivers. The body or matrix of the drift in this region is made up of the ruins of the Devonian and Carboniferous rocks, over which the current has swept. The former being, for the most part, a slightly coherent red sandstone with marls, has contributed to give the dominant colour to the mass, whilst fragments of the chert and flint which abound in the latter are so profusely distributed, that a geologist unacquainted with the structure of the carboniferous limestone of Russia, might at first sight really take them to be the relics of a chalk formation. In these respects, indeed, the detritus resembles that of Moscow and many other tracts.

Near Jurievetz upon the Volga, we found erratic blocks of quartz rock associated with others of that trap breccia, which we have remarked as peculiar to the north-western side of the lake of Onega near Petrozavodsk. Having become well-acquainted with that rock *in situ*, and having assured ourselves that it does not exist, either to the west or east of the particular zone in question, we had in this instance just as clear evidence of the direction in which these fragments had been transported for 500 miles from north-west to south-east, as the mineralogists of St. Petersburg possess of a shorter southern transport, in the Finnish rocks to the south of that city. The blocks of quartz rock and Solamenski-kamen, as seen for a stage or two to the south of Jurievetz, Mednikovo, &c., lie upon the higher undulating grounds which form the right bank of the Volga, and the general mass of the superficial materials on which the blocks repose, are finely laminated yellowish sands and loams which for the most part obscure the red marls, forming the subsoil of the country (see p. 179 *et seq.*). At Garbàtof on the Oka, which lies to the west of the tract in question, and at several localities along the banks of that stream, we found materials of northern drift in the overlying detritus, often of considerable thickness, but in none of these instances could we discover a trace of the peculiar rocks which constitute the promontories of Petrozavodsk on the right bank of the Lake Onega, the northern erratics being chiefly granites or gneiss, such as occur *in situ* to the north of the Lake Ladoga (see Map, Pl. VI.).

We have said that the blocks to the south-east of Jurievetz occupy undulating grounds rather higher than the adjacent depressions, and in such positions we also observed them towards Nikolsk, and also on high cliffs overhanging the Suchona river, between Totma and Ustiug. To the south and to the north of the last-mentioned town, northern granitic blocks are also seen[1]; and we were struck with

[1] The shrine of St. Procopius in the cathedral church of Ustiug is in high reputation with the natives, because about 300 years ago that holy man is said to have saved Ustiug from being destroyed by a shower

their comparative abundance on the higher undulating grounds between it and Krasnoborsk, whilst the lower country in which the Dwina flows towards Archangel is almost, if not entirely, exempt from them. That tract forms, indeed, a portion of the broad sand-covered tracts between Cargopol and the Dwina which have been already described, as being free from every sort of northern drift.

These facts, including what we have said of the position of the blocks to the south of Jurievetz, where they lie on the highest portions of a tract composed of finely laminated, loamy sands, appear to us to favour strongly the view on which we shall afterwards dwell, that the great erratics (so far detached from the sources of their origin and often separated therefrom by wide regions in which no trace of such detritus is found) were probably floated to their present habitats in former icebergs, when the sands in question formed the bottom of a sea, which extended from the shores of Scandinavia, and in which the icebergs sailed southwards with the current, until arrested by the higher grounds in question. But what was the condition at that time of these higher grounds? By inspecting the Map the reader will perceive, that the country around Ust-Sisolsk, and thence to the edge of the Timan range,—in short, the upper grounds in which the feeders of the Vitchegda spring, form the extreme limit in that direction of every Scandinavian erratic. Still further to the north-east, the Timan range constitutes their eastern girdle, for no trace of them has we believe been detected beyond it, in the basin of the Petchora. The ancient elevation of that range explains this feature of the phænomenon.

In our last chapter on the Ural Mountains, it has been shown, that a large portion of Siberia and the whole of the Ural chain must have been above the waters during long periods antecedent to our æra; and we would now observe, that such elevations as those, which affected the central ridge of these mountains, could scarcely have taken place without occasioning a corresponding rise over a considerable area on the west. May we not, therefore, suppose, that the same elevations which last raised the Ural Mountains and Siberia, and rendered those tracts the residence of mammoths and other wild animals, had also raised the large area of the governments of Perm, Viatka and Orenburg, which lies between the eastern limit of the Scandinavian blocks and the edge of the Ural Mountains?

of *aërolites* which fell from heaven. Our mineralogical curiosity was roused, and, unseen, we contrived to chip off a small fragment from the block, which from its blackened and polished external aspect (due to long adoration and the smoke of incense) might really have passed for an aërolite—when it proved to be a true granitic northern boulder. So much for the legend and St. Procopius.

The nature of the superficial detritus which occupies the surface of that area is much in favour of this view. For a considerable space to the west of the Ural, there is not a vestige of any superficial deposit which can be referred to the influence of the sea; no far-transported blocks—no finely levigated sands and dunes—no great diluvial hillocks of clay and drift; but, on the contrary, all the detritus, like that of the Ural and Siberia, is local and small. We believe, therefore, that the region so characterized was really above the waters and inhabited by mammoths, when the erratic blocks were transported over the adjacent north-western sea, and that the then coast of the Siberian and Uralian lands advanced near to the line marked on the Map as the extreme boundary of the granitic erratics, which were, we believe, stranded on or near the shelving shore of these ancient lands.

In speaking of Russia, we have already endeavoured to show, that the drift has been diversified and added to, as it passed southwards, by deriving new materials from each zone of rocks which it traversed. The Silurian and Devonian deposits, which contain few hard beds, have not, as might be expected, furnished many boulders, their debris consisting chiefly of grey and red mud and sand; but the carboniferous limestone, containing bands of *flint and chert*, fragments of these have been most largely distributed, and being readily known by their included organic remains, are valuable "*drift marks*," if we may use the expression. In proof of the uniform direction of the drift, we may state, that there is no instance of one of these flints having been found to the north of the carboniferous zone, from whence alone they can have been derived, whilst they are profusely scattered over its surface and extend for vast distances beyond its southern limits. This phænomenon is in perfect accordance with what we have observed in the country of Siluria and other tracts of Western Europe, where the direction of drift in any particular line may be tested by the addition of fresh materials of the subsoil over which it passed.

In treating, however, of the great block region of all the northern states, it must be said, that these indicia of the character of the subsoil in each of the successive geological tracts, proceeding from north to south, are confined to Russia; for in Northern Prussia and Poland no rocks whatever have been detected even in the deepest denudations. The northern materials, with the occasional detritus of Swedish Silurian strata, are there alone mixed up with sands and clay of uniform colour, chiefly the spoil of the tertiary deposits of those countries. In Mecklenburg and Prussia the blocks occur, for the most part, as in Russia, on the slopes or sides of the hills, and occasionally in thick groups: the tracts between Schwerin and Lubeck on the east, and again around Seelaw on the right bank of the Oder, being fine examples. In the rapidly undulating country between the Oder and Posen, particularly at the village of Kähorl, the largest boulders (all much-rounded) are found on the north side of a little hill. In some districts they occur at intervals, and seem more equably scattered about. In many others, particularly in Pomerania, they occupy irregular lines or *traineés* ranging from north to south. Thus also, in the sandy plains east of Posen, not a block is to be seen for several miles from east to west; but the moment you reach the small elevations, somewhat more argillaceous, which rise towards the Polish frontier, they are again numerous. In that frontier sandy plain, the blocks are usually small, but in the hills between Konin and Kolàa, the subsoil of which is composed of tertiary claystone as white as chalk, loads of large blocks are buried in and mixed with gravel and sand, at heights of 300 or 400 feet above the sea. In passing from west to east, the traveller is here struck, as in Russia, with the great change in the character of the blocks in each new degree of longitude, showing that they have been derived from different districts of Scandinavia and have been distributed in *trainées*; for whilst to the west of Posen they are nearly all granitic, to the east they are chiefly of quartz rock or altered sandstone. In the richly cultivated, argillaceous and loamy plains between Kolàa and Warsaw, the detritus is more equably spread about at rarer intervals, and not in groups. At Warsaw the excavations made for brick-earth, expose a subsoil of incoherent white sand inosculating with some clay, and occasionally containing small pebbles of quartz rock and Lydian stone; the whole representing the tertiary beds of the region. These are covered by the drift clay and loam, with erratic northern blocks upon the surface.

The drift of Russia and Germany, in common with that of England, exhibits, for the most part, a diminution in the quantity and size of the blocks, the further they have ranged from the source of their origin. Hence, in the parallel of Moscow, to which place and far beyond it they extend, the fragments of granite and greenstone seldom exceed two or three feet in diameter[1]; whilst near St. Petersburg their diameter is often as many yards. In passing from the White Sea to

[1] The larger blocks are rapidly disappearing, being broken up for the chaussées and for building purposes. The observation in the text, that the blocks diminish in size as they are traced to the south, is, it must be understood, liable to exceptions, there being examples of large blocks at great distances from their origin, which can, we believe, only have travelled thither in floating icebergs.

Nijni Novogorod, the same facts present themselves. To the south of Ustiug the granitic and greenstone blocks begin to be scarce, though, as before said, we met with a fine example several feet in diameter, even as far south as Garbàtof, on the Oka.

The traveller who does not court the long and devious routes by which we journeyed, may verify some of the prominent points of observation without quitting the sides of the splendid chaussée from St. Petersburg to Moscow, which is entirely made of northern, granitic and greenstone blocks; but to obtain a due conception of the vast area over which the detritus is spread out, as well as to understand the very irregular dispersion of the blocks,—sometimes placed at wide distances from each other, at other times in heaps, here quite upon the surface, there entangled in mud,—he must traverse not only the northern tracts, but also the great central region of Vologda and its contiguous governments. In doing this, he may, for a while, be led to speculate upon the former existence of basins of sand in one tract and of clay in another; but the more he extends his survey, the more will he find, that all these accumulations and their associated blocks are parts of one great system of operations, and that they have all been formed in one long period of time. He will also be convinced, that the widely-spread and finely laminated sands cannot have been accumulated except under water; and when he sees that these sands and gravel, as on the Vaga, overlie strata replete with pleistocene or modern marine shells before described (p. 328), he will conclude with us, that this great northern drift (by whatever power transported) was deposited *on the bottom of a sea.* This, in our view, is a condition which must be present to the mind, before we can draw just conclusions respecting the method by which the blocks were transported. As the Valdai Hills, the highest grounds in European Russia (from 800 to 1100 feet above the sea), are covered with them, there is no doubt in our minds, that the whole of that portion of the continent was beneath the waters, at the period of the distribution of the blocks. Even in such tracts, however, there are phænomena which lead us to infer, that the present form of the land prevailed to a considerable extent even when submerged, and that such outline had a great influence upon the manner in which the blocks were lodged.

By reference to the Map, it will be seen that the southern limit of these erratics is by no means uniform, as represented by previous writers, but on the contrary very devious. The detritus does not, in fact, occupy an equably shelving, southern talus, but, though often on plateaux, it has in many instances followed, even to great distances, the course of the existing north and south valleys at its southern extremity. As if, however, to mark how entirely dissimilar the transport has been to anything which we can imagine under terrestrial conditions, this ancient detritus has usually been propelled in an opposite direction to the present course of the waters and consequently *up-hill*, with reference to the present surface. For example, all the rivers of Russia, Poland and Prussia which have their exit into the White Sea or Baltic, as well as the Oka and other southern tributaries of the Volga, flow from the south, yet all the detritus has been propelled from the north.

There is, indeed, no feature more curious in the distribution of the drift along its southern frontier, than its far advance to the south along certain great valleys, and its omission in such localities upon the interjacent higher grounds. Such, for example, are the heaps of detritus, syenite, granite and greenstone which advance into the valley of the Don near Voroneje, and on the west by another north and south parallel to the neighbourhood of Putievil[1] on the Sem, a tributary of the Desna, leaving (as shown upon our Map) the central dome of Orel almost if not entirely free from such transported matter.

These are truly remarkable facts ; and we feel confident that there are no other parts of Europe in which foreign materials have been transported so far as from Russian Lapland and Finland to Voroneje and Putievil, points from 700 to 800 English miles, in straight lines, from the nearest crystalline rocks whence such fragments can have proceeded.

We are not personally acquainted with the marshes of Pinsk, which indicate we apprehend the southern limit of erratics in that parallel ; but we are certain that the southern granitic steppe to which we have before alluded, was a dividing barrier before the period of their distribution, as no portion of it offers evidence of subaqueous transport. In Poland, however, and in the adjacent part of Russia, we found, that in the great valleys of the Vistula and the Oder, the blocks were distributed precisely as in the valleys of the Don and the Desna. Along the Vistula they range in rare and isolated specimens up to the environs of Crakow (500 miles from the nearest shores of Sweden), where the northern granites are easily distinguished by their character from those of the adjacent Carpathian chain, the fragments of which, like those of many other mountains, never advance more than a few miles beyond its flanks. In the valley of the Oder also, the same northern materials, quite distinct from those of the flanking Silesian mountains, are found

[1] This spot is in the government of Kursk.

in great abundance at Gleinitz[1], where they are extended from the chief boulder country north of Breslau, in a long *trainée* between the chain of Siles iancrystalline rocks on the west and the hilly districts of Poland on the east . On inspecting the Map, the reader will perceive, that a considerable portion of southern Poland, particularly all that tract of palæozoic rocks of which Kielce is the centre, is thus peninsulated, like the dome of Orel in Russia, between two advanced lines of boulders, none of which have been distributed in the intervening higher space[2].

Now, if, as we believe, it is impossible to imagine, that the detritus in question should have been carried across the Baltic Sea, and from the level of that sea several hundred miles up these streams, under any conceivable terrestrial conditions, it follows from this consideration alone, that all theories to account for the movement of such bodies over the dry surface of the earth are inadmissible. The hypothesis of glaciers advancing up-hill for the distance of 700 or 800 miles involve in fact a physical absurdity.

But if the spread of the northern detritus have no reference to terrestrial conditions, how is it, an opponent may say, that the valleys of the Don, the Vistula and the Oder are strewed over with it,whilst interjacent eminences are excluded? We reply, that a submerged condition of Russia, Poland and Prussia at the period of the distribution of the northern blocks being granted, there is no difficulty in supposing, that the configuration of the bottom of the waters was to a great extent the same as that of the present continent. In fact, we can scarcely doubt that it must have been so, because we have numberless proofs that the substrata were heaved up without any great ruptures, and must have been raised "en masse." We therefore conceive, that when submerged, the valleys of the Oder, the Vistula and the Don were marine bays or fiords, into which currents flowed from the north, and that the higher grounds, devoid of blocks, were then low promontories, extending from the main land on the south, or isles adjacent to it. If, indeed, the larger blocks were for the most part transported upon floating icebergs, we can

[1] At Gleinitz, and between that town and Oppeln, the rounded boulders are not so abundant in the low parts of the valley of the Oder as on hillocks of sand and gravel. The red porphyries of Sweden are there intermixed with northern granite, gneiss and greenstone.

[2] In a report to the Academy of Sciences of Paris (January 1842) on a memoir of M. Durocher, M. Elie de Beaumont has noticed certain relations between the distribution of the erratic blocks, and the forms of the countries which they have invaded. We take this opportunity of specially recommending to the notice of our readers that report, in which M. Elie de Beaumont has thrown together, with great ability, a number of facts relating to the erratic phænomena of northern Europe.

readily explain why, when melted, the contents of such masses should have been carried much further southward by currents into north and south bays, and why the interjacent banks should be void of similar sea-borne spoil.

We were, indeed, peculiarly interested in tracing this northern detritus up such ancient bays, to the very edge of the Carpathians and Riesen-Gebirge, which mountains must, from their constitution and elevation, have formed the northern masses of a southern continent, when the ancient sea covered the low regions of Prussia, Poland and Germany.

We have spoken of this detritus as *northern*, because the blocks to which we previously referred, have, in a general sense, been transported from the Scandinavian mountains to the south. A more extended examination of the whole phænomenon compels us to view it in a broader and different light. On the east shores of England, particularly on that of Yorkshire, Norwegian detritus is by no means uncommon, and it is there mingled with some of the rocky masses which have been shed off from local centres of eruption in the British Isles upon the west. In Denmark the blocks have been derived from north and by east. In most parts of Prussia they can be traced to due northerly sources. We no sooner, however, arrive opposite the coasts of Finnish Lapland, where the granitic and crystalline boundary sweeps round to north-east, than we find the direction of the blocks changing accordingly. The very peculiar rocks of Solamenski-kamen, for example, near Nijni Novogorod, have been shown to proceed from north-west to south-east, whilst at Ust-Sisolsk in the government of Vologda, the Scandinavian boulders have had, as nearly as possible, an eastern course.

In no instance do the Scandinavian blocks advance near to the Ural chain, a fact which we have endeavoured to account for by supposing, that large adjacent tracts upon the west, as well as the mountains themselves, were above the waters during the erratic period. We have, indeed, fully explained, that those mountains and both their flanks are void of all boulders and far-borne detritus. Though exhibiting proofs of intense dislocation, the Ural is, therefore, a perfect contrast in this respect to the Scandinavian chain. According to our hypothesis of floating icebergs, the derivation of the blocks in the one case, and their total absence in the other, are perfectly in accordance with natural history conditions. For as in Norway and Sweden glaciers now exist, so may they formerly have existed. On the other hand, as there is no glacier in the Ural, even up to 70° N. lat., so according to the rules of the glacialist there never can have been one, since there are no moraines, nor any striated and polished rocks in the whole region—effects, as they would say, necessarily absent where no glaciers have passed, or as we should say, where neither boulders nor gravel have been carried over the surface, by water or in floating icebergs. All the north-eastern region of Russia in Europe included between the Timan range and the Ural is also, as before said, void of the erratics from Scandinavia, but as you approach that crystalline centre the blocks are again found, having been extended from it to the east.

Lastly, the young and adventurous M. Böhtlingk completed, in his short life, the proofs on this point, by satisfactorily establishing, that the erratic Scandinavian blocks had also been shed off from the coast of Kemi into the bay of Onega, and from Russian Lapland into the Icy Sea, both in northerly, north-westerly and north-easterly directions; and thus nearly the whole periphery of their origin having been surveyed, we know, that by whatever cause determined, the Scandinavian blocks were on the whole, transported to their present positions by great excentric movements. What, then, was the nature of these movements? If, for the reasons already assigned and others on which we shall hereafter dwell, terrestrial glaciers be considered agents which can never explain such phænomena, there are, it appears to us, only two methods of accounting for such far-borne detritus. One of these is the action of drift, by which fragments of mountain chains, dissevered from their parent masses at periods of disturbance and oscillation, have been transported to great distances by powerful currents of water; the other, the floating away of ice islands from the edges of chains, formerly encompassed by sea-advancing glaciers, which isles, after sailing in certain directions, have dropped their loads on the bottom of the sea; that sea bottom on which the blocks are distributed having been since raised into the dry land. Let us consider these two operations in reference to the facts with which we are acquainted, and see how far each can be made to explain the several conditions under which we find the far-transported detritus.

And first as to icebergs. The examination of the boulders of the north has led us to adhere to the belief, which we have long entertained, that there, as in central England, the largest blocks were transported to their present positions in ice-floes which broke loose from former glaciers. We, therefore, think, that ice and snow may, at one time, have covered large parts of Scandinavia and Lapland; that glaciers advanced from thence to the edges of the sea of the post-pliocene or block period, and that finally upon an alteration of climate, probably occasioned by sudden successive changes in the relations of land and water, these glaciers were broken up, and fragments of them, constituting isles with included blocks, were transported during long periods to the south. As it is demonstrable, that the whole region has undergone great variation of relative level subsequent to this dispersion of the blocks, by the conversion of the ancient bed of the sea into a continent, so are we disposed to think, that this change was caused by general expansive forces from beneath, which, unable to obtain a vent through any fissures, in the uniform crust of sediment which is spread over this undisturbed region, raised up *en masse* the strata by which they were repressed.

Under the belief that the sea covered all these flat regions when the detritus was dispersed, it is not difficult to explain, why the larger blocks are more frequently found associated with clay than sand. Icebergs such as now float in the Antarctic and Pacific Seas, and to which we have elsewhere referred[1], must we conceive have offered rough, jagged and unequal bottoms, which impinging on submarine undulations of mud or clay, would naturally be thereby arrested and often held in oscillation until the glacial masses dissolved and deposited their loads; but the loose and incoherent sands, often arranged over widely-extended flat surfaces, would oppose comparatively no such obstacles, and the hard, icy mass easily forcing onwards would proceed until its bottom impinged upon a bank. We shall presently advert to Swedish examples which, illustrating this process, serve to explain, why the greater number of the large boulders are found in groups on the summits and slopes of hills. In the meantime, if such were the ancient conditions under which the boulders were deposited over the plains of Russia and Northern Germany, it is clear that we cannot deny the application of this aqueous portion of the glacial theory to those tracts. We will not here recapitulate our general reasoning for the adoption of such views, which we formerly applied to Scotland; not from any study of Alpine phænomena, but from the facts then before us, and the perusal of the persuasive writings of Mr. C. Darwin. We then thought, that under certain changes of sea and land, as pointed out by him, ice might have been formed on the shores of former islands which now appear as the mountains of Scotland and Cumberland. Though we now see reasons to limit and modify this view in reference to those

[1] See Silurian System, p. 541, *et ante*, in which some of the icebergs of the Pacific are described as being 300 feet above the sea, and as having a depth of near 2000 feet below its surface. The practical application of this phænomenon in illustrating the condition of certain Swedish phænomena will be given towards the close of this chapter.

countries (of which hereafter), we think that its application to Scandinavia, Lapland and the northernmost limits of Russia proper, will to a great extent solve our problem. Before this chapter is concluded we will go a step further, and looking back to the region itself, which may be supposed to have been glacial, because it is the seat of the origin of the transported blocks, we shall see how far the phænomena which it presents accord with our views.

In Russia our time only permitted us to examine personally the southern edges of the rocky or northern region from whence all the detritus has travelled; but we there actually saw in the government of Olonetz examples of the polished surfaces of hard rocks accompanied by many parallel scratches, all of which, as we before said, proceeded from north-north-west to south-south-east. These polished and scratched surfaces are exactly like those with which we have been long familiar in parts of Scotland, and are, as it will be shown, common to all regions of hard rock over which drift and blocks have moved.

The direction of the scratches on the rocks in the environs of Petrozavodsk is precisely coincident with the major axis of the Great Lake (almost a freshwater sea), and of all the minor parallel lakes of this region. No one can inspect a map of this tract without being forcibly struck by the parallelisms of these numerous long and narrow lakes, the longer axes of which, like those of Finland, are all directed from north-north-east to south-south-west, or in the same line as the drift. Seeing that these lakes, in the region to which we now allude, are flanked by long parallel ridges of plutonic rocks, we are disposed to think, that the cavities now occupied by water may have resulted from ancient cracks or fissures. During six months of the year they are still covered with ice, to some of the operations of which we shall advert in the next chapter.

And here we beg to be excused, for again showing the utter inapplicability of the subaërial glacial theory to the Russian phænomena. An essential condition in that theory, as modified by Professor James Forbes, is the existence of high mountains from the edges of which glaciers may have gravitated into contiguous lower grounds; *for no modern glacier has been formed without such conditions.* Even at Spitzbergen and in the highest latitudes, the French naturalist M. Martens has observed, that the formation of a glacier is invariably dependent on the inclination and form of the ground, the valleys of great width and with open sides being necessarily void of them; for in such situations the accumulated snow never consolidates into a glacier. Now in the region near the lake Onega there are no mountains either contiguous or distant! Elevations of 400 and 500 feet in height above the adjacent lakes, are indeed as prevalent to the south and east as they are to the north-west of the spots so scratched, and hence we are unable to imagine any process by which glaciers could have advanced, and always *precisely* in the same direction as all the great fissures of the country, and the far-transported blocks[1].

The same objections to the scratches and polishing by the action of glaciers, as those which have been mentioned in the case of the Lake Onega, may be urged in relation to very large countries in Scandinavia (also striated and polished); viz. the absence of mountains whence glaciers can have moved forward. In no district, perhaps, is this objection more apparent than on the eastern shores of the Bothnian Gulf, where the scratches and drift both proceed in a *south-easterly* direction. If these marks were caused by the movement of glaciers, advancing from the north-west, they must have proceeded from the opposite coast of Sweden, where there are no high grounds. Again, the great arm of the Baltic Sea (the Bothnian Gulf) *intervenes*[2], and hence if a *subaërial* condition of things be imagined, this sea must then have been one permanent mass of ice, or a valley filled with glacial detritus through which the glaciers advanced from Sweden, before they imprinted their first scratches on the opposite shores of Finland. Such an inference would be, it is true, in one respect analogous to that part of the Alpine glacial theory by which M. Agassiz supposes, that not only the lake of Geneva but all the deep chasms between the Alps and the Jura (a depth of many thousand feet) were formerly filled up with solid ice. But even if we admit the much greater increment of ice, magnify the lake of Geneva into the Baltic, and abandon ourselves, for argument sake, to the Alpine hypothesis, how are we to explain the passage of the blocks, not over the Baltic, but up into the hilly tracts of Finland, with anything like the present levels? Then, again, how imagine the advance of

[1] M. Böhtlingk did not merely show, that the blocks are transported excentrically from Scandinavia and Lapland, but also that the rocks are invariably worn down and striated on the side from whence the drift has passed. See the arrows in the Map. Pl. VI., which rudely indicate such directions and phænomena around the nucleus of those northern countries.

[2] Where we examined them, in the environs of Åbo, as well as in the Isles of Åland, the rocks are all worn down on their north-north-western faces, and the striæ proceed from north-north-west to south-south-east. We therefore believe that the chief masses of granite in Courland have been derived from the Åland Isles. But even if this be so, the argument is just the same: indeed the case is more difficult, if we are to imagine that glaciers advanced over the frozen Baltic from the Åland Isles to Mitau, the distance being much greater!

glaciers having *fronts of such vast dimensions?* How, again, could they have produced throughout their course, *over undulating countries, the same persistent scratches?* How, in a word, could they have *moved up-hill throughout such vast spaces?* Does not the direction of every modern glacier, even those which advance to the sea, differ with the form of the background and of the ridges which encase it? And if so, how is it conceivable that the striæ in this part of the world should have been made by glaciers properly so called? So much therefore for the glacial terrestrial theory as inapplicable to the low regions of hard Scandinavian rocks.

To the hypothesis, which supposes, that all these phænomena may have been produced by water, it is objected, that nowhere in existing nature has a "vera causa" been found to support it. The advance of ice, say they who oppose the action of water, must have produced such scratches and polishings, because we see that modern glaciers produce like effects, whilst water, they add, never could with any materials which it hurled down, have left such parallel and decisive marks of its passage in one direction. In support of this view they appeal to the beds of mountain torrents and rivers which have been recently acted on by water and pebbles, and not finding any parallel scratchings under such conditions, they reject the use of water as a power which could have produced such results. Now before we can arrive at just and rational general conclusions, a greater number of data must be got together, than those which have yet been collected. It is idle to interrogate beds of torrents and rivers, where succeeding droughts and frosts destroy the ephemeral marks made by the water of the previous season. There can be scarcely any analogy between such cases and the effects which we imagine to have been produced by drift, which streaming down from the opposite sides of chains in the process of elevation, is supposed so to have ground down and furrowed with deep scratches the subjacent rocks. Have we yet experimented in any way on hard surfaces under such conditions? and if not, ought we to reject all the inferences which they involve? If it be impossible that human beings should ever be placed in situations to observe such debâcles as we think must have occurred, when the bottoms of seas were raised into dry lands, let us, at all events, institute experiments upon a small scale, which if well-conducted, may enable us in some degree to form correct opinions. But may we not considerably extend our belief in the transporting power of water, now that the ingenious experiments of Mr. Scott Russell on waves of *translation*, and the mathematical application of them by Mr. Hopkins to geological phænomena, have shown that elevations of continental masses of only fifty feet each, from beneath an ocean having a depth of 300 or 400 feet, would cause the most powerful divergent waves, which could transport large boulders to great distances[1]?

Granting, however, that water has exercised all the influence attributed to it by these philosophers, the existence of intervening deep valleys, transverse to the direction which the erratic drift has taken, and the subangular state of many of the far-borne blocks, must prevent our adoption of this agency only, as explaining all the conditions of the problem. Strengthened by having ourselves found marine shells associated with erratic blocks, we have previously expressed our agreement with Mr. Lyell, that the bottoms of icebergs grating upon submarine rocks may *occasionally* have furrowed, scratched, and polished their surfaces, precisely in the

[1] "In describing the motion of such masses of water, Mr. Hopkins invokes the aid of those waves of *translation* whose properties have been reduced to laws by the ingenious and valuable researches of Mr. Scott Russell, and who, giving us measures of their relative velocity and power, has brought forward exact proofs of the transference by them of solid bodies immersed in water. Such waves have in fact been generated by the experiments of Mr. Scott Russell, exactly in the same way as Mr. Hopkins supposes waves to have originated on the great geological scale. These experiments prove, that a sudden elevation of a solid mass from beneath the water, causes a corresponding elevation of the surface of the fluid, which infallibly produces a wave of translation of the first order. Now this wave is termed one of *translation*, because it is found not to rise and fall like common waves, but wholly to rise and maintain itself above the level of the water. Arguing that this wave is propagated with a velocity which varies with the square root of the depth of the ocean, Mr. Russell determines the velocity of wave transmission; but what is of most importance to the geologist is, that the old idea of the agitation and power of waves extending a little way down only in the sea, is found to be not true as touching waves of translation; for Mr. Scott Russell has ascertained that when they are in action, the motion of the particles of the water is *nearly as great at the bottom as at the top*. He further shows, that the body moved at the bottom, is not rolled backwards and forwards as by a common surface-wave, but has a continuous forward motion during the whole transit of the wave's length. A complete transposition does therefore result from the wave transit; and the wave of translation, says Mr. Scott Russell, may be regarded as a mechanical agent for the transmission of power as complete and perfect as the lever or the inclined plane.

"Arguing from these remarkable data, and applying them to our geological phænomena, Mr. Hopkins states, that currents of twenty-five and thirty miles an hour may be easily accounted for, if repetitions of elevations of from 160 to 200 feet be granted; and with motive powers producing a repetition of such waves, this author has no difficulty in transporting to great distances, masses of rock of larger dimensions than any boulders in the North of England." See Mr. Murchison's Anniversary Address to the Geological Society (anno 1843), Proc. Geol. Soc. vol. iv. p. 9. Mr. Scott Russell's views were first explained to the Meeting of the British Association for the Advancement of Science in 1843, and are now preparing for publication.

same way as glaciers act on the solid rocks over which they are propelled[1]. But such a cause, however it may have acted partially, is totally inadequate to explain the *general* striation of the Scandinavian continent. Again, though great waves of translation, moving in determinate directions dependent on oscillations of the land, may account for the transport of rolled debris to given points, they cannot be alone appealed to, as having produced the symmetrical and parallel striæ on the surface of the rocks. An examination, however, of the former condition of the accumulations which have been so transported, or in other words, of the nature of the bodies which have scratched the rocks, may serve to clear away the obscurity which still veils this subject.

We have already shown, that parallel scratches on the surface of polished rocks exist in low tracts at vast distances from mountains, and at the same time have stated, that the presence of high mountains behind a glacier is indispensable both to the former presence of such a body, and according to experiment and demonstration, to the possibility of its movement. Geologists must, therefore, satisfy themselves if there be no other mode of accounting for such polishing and scratching, besides the incumbent pressure of moving masses of ice. We in no way contend against the value of the explanation of the action of glaciers in Alpine regions; nay, we perfectly subscribe to it, and thank its able expounders for having afforded us so good an analogy. We would even make use of the theory to enable us better to comprehend, how certain masses which still cover the earth and are present to our eyes, in regions where glaciers *never can have existed*, may have yet produced the same results. Let us explain our meaning. In very numerous countries, whether in low situations, or in those parallels of latitude where no permanent ice has been known within the historic period, scratched and polished rocks have been observed. Now in all, or nearly all such tracts, we are also aware of the prevalence of greater or smaller quantities of drifted detritus. If the tract be rocky and broken up by dislocations, this drift has passed over the shoulders of the hills and through the gorges, frequently lodging itself in part upon them, but generally having been carried into the adjacent depressions. Captivated by the glacial theory, which shows that moraines are the residue of glaciers, some geolo-

[1] Principles of Geology, vol. i. p. 265, fourth edition. See also Mr. Murchison's Anniversary Addresses to the Geological Society of London, Proc. Geol. Soc. vol. iii. p. 686 *et seq.* and vol. iv. p. 90, in which a great many points in the theories of drift and glaciers are discussed, and where it is shown that Mr. P. Dobson, of the United States, was the first person who suggested this idea.

gists hastily concluded, that all accumulations of like external form, in the neighbourhood of which, scored and polished surfaces of hard rocks appear, are true glacial moraines. We utterly deny this inference, which would even compel us to believe in the former existence of glaciers in a greater number of low than lofty positions. We think, that with no other agents than those which are still exhibited as *geological* signs, many of the appearances which have been recently referred to glacial action may be satisfactorily accounted for.

In regard to the theory which explains the advance of glaciers, it may be said, that all the authors who have written on that subject, refer the scratching and polishing process to the same cause—the great incumbent weight of a mass, which moving in a given and determinate direction, and passing over all minor obstacles, has produced that result by the moist sand and gravel at its base. Now, in our opinion, the great heaps of drift (whether derived from distant or adjacent hills) must at one period of their movement have produced similar impressions upon the subjacent rocks. For what was the condition of the drift at the particular periods of translation to which we refer, *i. e.* when rocks covered with gravel, sand and shingle, were raised up from beneath the sea? In its essential properties of weight, solidity, ductility, and materials for polishing and scoring at its base, a mass of moistened drift, one or two hundred feet in height, and a mile or two in length, must have embodied nearly all the properties of a glacier, the nature of the movement and the actual state of such mass of detritus being properly understood.

Polished and scored surfaces of rock were, indeed, well known before the glacial theory came into fashion. They were long ago pointed out by Sir James Hall, Dr. Buckland and other observers, who then supposed that the striæ were due to the rush of torrents in given directions, hurling with them stones and gravel. The objection to this explanation is, as before said, that the ordinary torrential action of water is too irregular to have produced a general parallelism of striæ. But in bringing to the mind's eye, as we here attempt to do, the manner in which masses of moist and pliant detritus were shouldered off the sides of mountains and hills or forced through gorges, we must recollect that, in the cases to which we appeal, we have to treat of materials which, previously *under the sea*, were subsequently and often violently thrown off into depressions upon the elevation of the bottom of that sea or the lowering of an adjacent tract. The first effect of such a process would be to pour off large waves of translation with many loose materials, but the greater heaps of broken matter beneath such waves being comparatively drained by the first rush of the waters, would be in the condition of moist pliable masses of great weight, which, in every situation that offered sufficient declivity, would be forced either by the influence of the superincumbent wave or by their own momentum into the adjacent depressions, and like the glaciers of the Alps, would follow the inclined planes or main courses of the newly-formed valleys.

Who that has studied the detritus of mountain chains will not admit, that in cubic measure and in weight the masses which now encumber certain narrow valleys, wherever their extension into the plains has been checked by local obstacles, are not as massive and as thick as the highest moraine ever left by a glacier?

And if so, will any one deny, that such moving masses of gravel, sand and blocks, so piled up as to have the full weight of the largest glacier, may not have produced the same mechanical results upon their under surface? If the geologist asserts his belief, that such was the condition of things, and also shows that such heaps have very frequently fine sand and gravel at their lower extremities, will not the mechanic support him in his opinion, that not only the subjacent rocks over which these heavy plastic masses of detritus travelled, but also the sides of the valleys against which when confined they pressed, may have been grooved and scored by them as well as by a glacier? The glacier, it is true, travels slowly, whilst under our hypothesis, the moistened drift must have moved more rapidly. But might not the same effects follow? Will not a heavy incumbent mass scratch and polish by rapid as well as by slow action?

Let this view be objected to: still it is clear that no geologist can venture to appeal to subaërial phænomena in reference to any of those numerous tracts, the coarse detrital accumulations of which were formed under the sea and are often associated with marine shells. If we, then, collate the whole of the elements of the problem of superficial detritus, including the scoring and polishing of rocks and the transport to distant places of huge blocks, and find that in a great multitude of cases, a prior submarine condition of things and subsequent elevations of mountains, or depressions of adjacent basins are essential postulates, we at once confine the application of glaciers to limited centres of action. Freeing ourselves from hasty generalizations drawn from a few isolated data, we appeal also to other "veræ causæ" which are still before our eyes, and which were set in movement when the surface of the planet underwent great mutations, and when the desiccation of vast oceanic regions was accomplished by elevation from beneath.

Whilst, however, we think that large portions of superficial drift have so acted as to produce precisely the same effects as glaciers, both upon the subjacent and laterally adjacent rocks over which they travelled, we would carefully avoid falling into the error of some persons, who, advocating the general icy theory, have endeavoured to bring all the detrital phænomena into one category. We think, that wherever from the latitude of the mountains and their altitude, glaciers may naturally have existed, the glacialists are there fully entitled to apply those doctrines which they have been taught by a study of the Alps. Thus in reference to the coldest and highest regions of Scandinavia and Lapland, we can see no sort of objection to their once having been the seat of glaciers, whose feet extended to the lower surrounding regions, then covered by the sea. It is, therefore, quite consistent with modern observations, that masses of ice detached from time to time in the form of floating icebergs, should have carried their loads, in the manner observed by many navigators, to great distances before they dropped them. In a word, the blocks of the plains of Prussia and Russia with reference to Scandinavia are, we contend, precisely analogous to the coarse detrital matter observed by Capt. Sir James Ross, and which floating northwards in icebergs from the Antarctic pole, has actually been strewed over the bottom of those seas at the distance of hundreds of miles from the source of its origin. An elevation of the bottom of that ocean would, in truth, offer to us an Antarctic Russia and Poland. The direction in which the Scandinavian boulders have been transported, is to us a distinct proof, that their propulsion was due to the upheaval of a chain which in its elevation must have forced off excentric currents that carried with them or drifted the broken materials on its flanks, often lodging them in the form of long "osars," or by impelling forwards ice-floes containing other blocks in such currents. In this operation there must necessarily have been a combination of the agencies of ice with powerful currents of water and half-frozen detritus, and we can very readily believe, how such masses grating over the slopes of the northern crystalline rocks, then forming the bottom of the sea adjacent to the elevated chain, may have occasionally produced marks of abrasion, scoring and polish like those to which we have alluded. By such operations we may figure to ourselves how some of the low and hard rocks on the southern shores of Finland, Sweden and Russian Lapland, were scored and abraded—always, however, in the dominant direction of the great current; and whilst the very distantly transported blocks were carried to their present habitats by floats of ice, we can also suppose, how a large proportion of the mud, sand and gravel was the residue of great streams diverging from the elevated chain and distributing these materials in the trainées which have been described. The next process which followed in Russia and Prussia was the desiccation of the submarine low tracts by their final elevation from beneath the sea. Now if this upheaval had been violent, like that of the strata in many parts of the British Isles and in other parts of Europe, where beds containing marine shells occur at very different altitudes[1] within very limited distances, and the subjacent strata are dislocated, contorted and sometimes reversed, similar results would have followed, and the drift would have been thrown off on the flanks of each protruded band of rocks and deposited on its sides or in hollows, in the manner we have alluded to. Such, however, was not the mode in which those vast low countries of the north-east were raised from beneath the sea. Their ascent was accomplished, on the contrary, without any violent fractures or dismemberments of the subjacent rocks, and simply by an equable elevation "en masse"; and hence the detrital matter, as well as the surface of the subsoil on which it rests, are necessarily, we believe, presented to us with very much the same aspect as when they lay beneath the sea. But even if considerable violence had been used in this operation (and we can conceive no phænomenon of such an extent without great degradation), still from its very nature, the subsoil of Russia, void as it is of all crystalline character, and for the most part incoherent and soft, can never have been in a condition to exhibit on its surface any of those striated appearances which in lofty and alpine regions have been produced by the friction of glaciers, and which in the low and gnarled promontories of the south of Ireland and Sweden, as well as in many parts of France, Scotland and England, to some of which we shall presently advert, have, as we think, unquestionably resulted from the friction of *incumbent masses of local and moistened drift*.

We must here meet an objection which may be made to our views of a submarine condition of the surface of Russia at the period of transport. It may be said, that marine remains have not been found in the Russian detritus. We not only, however, appeal to England, where such sea-shells and distant blocks are found together, but also to Denmark, where the drift, full of large northern boulders, is, in fact, a portion of the great transported masses in question, and has been shown by Prof. Forchhammer, Dr. Beck and Mr. Lyell to contain quasi-modern sea-shells; and we have ourselves shown, that similar shells exist beneath the drift in the north-eastern extremity of Russia. Knowing how long a period

[1] See Silurian System, p. 534.

elapsed before such shelly marine remains were discovered in the central counties of England, and reminding our readers that Russia has, as yet, been very little examined, we have no doubt that additional similar proofs will be hereafter obtained in it. But even should such be more extensively discovered, they may, after all, prove exceptions to the general rule, and we found this opinion upon the very nature of the prominent masses of the detritus and our idea of its origin. Those portions of it which were formed by powerful currents dependent on upheavals and depressions cannot be expected to contain sea shells. Still less could the glaciers which we have supposed to exist formerly in Scandinavia have contained marine exuviæ, for, as in the Alps and similar centres, they must have been chiefly charged with blocks, gravel, mud and sand. The portions of masses thus originally constituted being floated to southern tracts and melted, would cover over the bottoms of seas with thin, irregularly heaped-up materials, and thus can we explain why such deposits, though becoming truly submarine, should rarely, if ever appear in conjunction with sea shells,—ice, if we may so express ourselves, having been the chief agent by which a *subaërial* impress has been given to large portions of the *bottom of the ocean.*

CHAPTER XXI.

DRIFT AND ERRATIC BLOCKS OF SCANDINAVIA (*continued*).—ABRASION AND STRIATION OF ROCKS.

Detritus of Denmark shows the long continuance of submarine conditions, and the dispersion of Boulders at various periods.—Striation, and its excentric direction in Norway as well as in North-eastern Lapland, prove the Northern Scandinavian Mountains to have been the Centre whence all the Detritus radiated.—Powerful denudation of Sweden.—Its southern Promontories and the Islands in the Bothnian Gulf worn down and striated on their Northern Faces, and unaffected on their Southern Sides.—These results referred to the passage of the Osar Drift.—Illustration of the distinction between the Osars, as formed by Aqueous Action only, and the great Angular Blocks as transported by Ice-floes.—The Drift in Great Britain and Ireland shown to have equally produced the Striation and Polish of Rocks as in Sweden.—Reference to the Striated Rocks of Greece; and supposed Elevation of adjacent Sea-bottoms applied to the argument derived from the presence of Shells of Arctic Characters.—Limits of the ancient terrestrial Icy Tract of the North.—Large Eastern and Southern Lands above the Sea and inhabited by Mammoths, whilst the Countries covered by foreign Drift were beneath it.

OUR chief observations on the Russian and German detritus, such as they were when we last returned from those countries, as well as our theoretical views of its production being stated, we now proceed to offer the result of a more recent survey of Sweden and Norway, which strongly corroborates the conclusions at which we had previously arrived. Let us first, however, say a few words on the zone of drift which has been lodged upon Denmark.

The enormous quantities of broken, loose materials which have been poured off into the German Ocean may be imagined, from the relics of the detrital masses which have been transported to the cliffs of Norfolk and Yorkshire in England.

In Denmark, indeed, whether in Holstein, Seeland or Jutland, the fundamental rock of the country, or chalk, is so covered with foreign materials, that in his valuable geological map of that region, our friend Professor Forchhammer has chiefly had to indicate their varied nature. In his description of these detrital masses he has shown, that though formed at different periods they are all charged with northern boulders. The earliest of these are beds, which he considers as closing the cretaceous epoch; the included northern fragments (not, however, of great size) being in this instance associated with corallines. The next, in which boulders of considerable size occur, contains shells of the sub-apennine or miocene age—shells which bespeak a Mediterranean climate. The strata of these periods are here and there much dislocated, a phænomenon which will not appear strange to those who have observed the highly inclined beds, also of miocene age, and charged with large boulders, which constitute the high peaks of the Superga near Turin. No one has ever contended that such boulder beds of the north of Italy, associated as they are with shells of a former Mediterranean sea, were connected with glacial operations; and as little can it be argued, that their analogues in the north should have been so formed; any sort of glacial action under conditions of so warm a temperature being quite inadmissible. The succeeding superficial deposit in Denmark, where it forms whole cliffs, is that which is, properly speaking, our Russian and German drift, or "the boulder clay" of Forchhammer. In this western region, which is not far from the source of their origin, the blocks are often of gigantic size, and are associated with sands and sandy clay, containing fragments of modern shells, like those of the adjacent open northern sea, viz. *Balanus*, *Corbula nucleus* and *Cyprina Islandica*. According to Professor Forchhammer, this coarse drift has recently so undergone regeneration, as to form long ridges of sand and gravel which have been thrown up in reefs or shingle banks within the historic æra.

Besides these boulders and their associates, there are other superficial deposits in Denmark which indicate successive elevations and changes. The blocks, for example, often occur in lines along great fractures or parallel to them, and are then associated with *Mytilus edulis*, *Cardium edule*, *Buccinum reticulatum*, all indicating raised beaches. Again, wherever blue clay prevails, the *Mya* or *Hiatella Arctica* occurs, which being a deep sea shell, indicates that it has been thrown up and mixed with littoral shells. It is unnecessary that we should here attempt to describe all the successive changes which have occurred in Denmark between the time of the transport of the coarse boulders and the present day. All which it concerns us to point out, is the manner in which the coarser block detritus has been piled up, and to endeavour to explain the manner in which we conceive it has been swept from the north.

Completely agreeing with Prof. Forchhammer, that the northern detritus in Denmark must have been accumulated under water, we can nevertheless scarcely venture to adopt the whole of his belief, that it can all have been aggregated by ordinary submarine currents, brought into play by moderate and gradual oscillations of the land. A much more powerful cause than any now in action is, we think, required to explain the surface phænomenon of Scandinavia.

Whether we examine the hard and crystalline rocks on the sides of the Norwegian fiords, or traverse the promontories towards the interior of that country, some of which, in the southern region, are upwards of 2000 feet, and others in the north about twice that height above the sea, we find the surface powerfully eroded, frequently much worn down and polished, and their surface marked in numerous places by parallel furrows and innumerable fine mechanical striæ. Either at the head of the Gulf of Christiania, or in the high grounds of Ringerigge, all the striæ and markings which fell under our observation are directed from north-north-west to south-south-east, and this is the normal direction assigned to the greater number of the Norwegian scratches by Professor Keilhau. That author has observed such striæ upon the surface of opposite and high plateaux, where the detrital materials which produced such striation must have passed athwart valleys of great depth, and whose base is now occupied by lakes. In such cases he imagines that the amount of detritus must have been so mighty, as to fill up all the intervening cavities, though in other valleys the direction of the striæ is found to deviate from the normal line, and to sweep, as by an eddy, round the flanks of the mountain. In Norway, at least in the southern parts, with which we are alone acquainted, the northern faces of the promontories are much worn down, abraded, polished and scratched, whilst their southern faces, generally more abrupt, are in a rough and natural condition[1]. Such, in fact, are many of the rocky isles, or "skårs[2]," which the traveller sails by, as he ascends by Gottenburg to the bay

[1] Professor Keilhau pointed out to us a phænomenon in the upland valley above Christiania, more than two miles from the sea, and certainly 200 or 300 feet above it, which is of high interest in showing that all the scratches of the rock must have been brought about by submarine agency. *The Silurian rocks on the sides of the valley are there perforated by Pholades apparently of existing species.*

[2] "Skår," Swedish for a sea-rock. "Os," Swedish for a pile of gravel, is "osar" in the plural.

of Christiania. We defer, however, considering the origin of this form of outline until we treat of Sweden, where these appearances are still more frequent.

If the axis of Norway and Lapland was the great centre, from whence the chief masses of the detritus which cover Sweden have been derived, the latter country is highly interesting, in showing us the manner in which such detritus is piled up, and the manner in which it is associated with the phænomenon of the striation and polish of the rocks. Professor Sefström, to whose opinions we have before alluded, is the author most entitled to praise for having excited attention to the phænomenon of southern Sweden. He has endeavoured to show, that the osars, or boulder ridges of that country, are peculiar to it; a point on which we can scarcely coincide with him, since we are acquainted with many diluvial ridges in Scotland, Ireland, and other countries which so resemble the Swedish osars in length, height and arrangement of materials, that they must have had the same origin[1]. If such "osars" were situated near an alpine range, the advocates for the glacial theory would at once call them "moraines." But whatever they be named, it is quite manifest that they have been formed by water, since the boulders which occur throughout them are uniformly rounded as if by much powerful attrition. These osars, each seldom more than a mile in length, though often forming a prolonged series, are common over nearly all the *flat* regions of Sweden; and as there are no mountains of any altitude whatever from the southern edges of Lapland to the parallel of Torneo, it is quite impossible, independent of other reasons, that such ridges should be the residue of glaciers; for nowhere, as before said, are there elevated centres from which glaciers can have advanced. The whole of the superficial phænomena of the country are indeed at variance with this hypothesis; for still more clearly than in Norway are all the hard and crystalline rocks affected by furrows and striæ, the normal direction of which is from north-north-west to south-south-east, and still more are the north sides of each promontory worn down, polished and striated, whilst the south sides are abrupt, rough, and void of all such appearances. It was the generality of this phænomenon in all those parts of Sweden known to him, that impressed Sefström with the conviction, that nothing short of a violent flood from the north, which had hurled loads of coarse detritus with great vehemence

[1] Mr. Murchison was singularly indebted to Baron Berzelius, who warmly advocates the chief features of Sefström's view, for having pointed out in detail the structure of the great os of Stockholm, and some remarkably beautiful examples of the polish and striation of the rocks, which are quite analogous to those around Edinburgh and in many other parts of the British Isles.

against the northern sides of the hills, could have produced such grinding, polishing and abrading results. The position and form of the osars he explained by supposing, that the force of the deluge being exhausted upon each of these promontories whose northern sides it wore down, "stoss seite," the waters had simply power to pile up the rude and rounded materials in lower lineal ridges, which being under the shelter, or "lee side" of the hill, would thus be protected from the powerful efforts of the general current.

We could not examine the materials of the great os close to Stockholm, nor of those adjacent to Upsala and other parts of Sweden without being convinced, that they never could have been accumulated by currents of like force and energy to those which now prevail in any part of the world. They all bespeak, that an enormous power has piled up such colossal heaps and completely rounded the blocks contained in them. By whatever force transported from north-north-west to south-south-east, or from north and by west to south and by east (for such are the linear directions of the principal *Swedish* osars), these masses, whose materials show that they have travelled over the low promontories of this country, could not, at all events, have been moved over that surface without producing extraordinary denudation of the subjacent rocks. And what does Sweden exhibit? A crystalline nucleus of ancient gneiss, or granite worn down, ground and polished, in the very direction in which the drift *has* moved; nay, more, from the outliers of Silurian strata, often horizontal, which remain as islets of denudation, perched upon this broad crystalline expanse, we know that beds, so similar in composition, contents and position at distant and intermediate places, must once have had a very wide continuance over the low lands of Sweden. But such has been the force of erosion and the power of drift, that $\frac{99}{100}$ths of these deposits have been borne away and lodged either in the depression of the Baltic Sea or carried into the plains of Germany; innumerable fragments of them with many Silurian fossils having been transported to the low grounds of Brunswick[1] and Prussia, &c. So much Silurian spoil has been spread over these tracts, that if swept back to Sweden it would indeed, to a great extent, fill up the interstices between the detached masses of the denuded strata of that country.

This grinding down, as it were, to the earliest-formed solid rocks, is in itself a

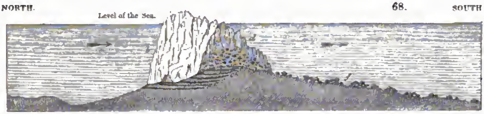
[1] See Klöden's work on the fossils of the March of Brandenburg and northern German plains. All these fossils have been transported from Sweden. (Versteinerungen der Mark Brandenburg. Berlin, 1834.)

proof of the stupendous denuding power of that great operation; and when we look to the surface of those crystalline rocks themselves, still more are we astonished at the influence which must have been exerted. We now specially allude to the "stoss seite," or worn side of all the rocks exposed to the north, as contrasted with their natural or lee side. Without a personal visit to Sweden and without crossing the Gulf of Bothnia, from Stockholm to Åbo, we could, indeed, have formed no conception of the grandeur and uniformity of this phænomenon. We there threaded our way through hundreds of small isles, none of them rising to more than 60 or 100 feet above the Baltic Sea, and found that the north side of every one exposed a face, worn down, rounded, polished and striated, as if by a stupendous macerating weight, whilst every south face was abrupt and rough. On the one side, in short, all is mechanical, as if the surface had been planed down by art; on the other all is rugged and natural. No one, we say, who has ever glanced at such marvellous and uniform appearances, would any longer contend, that they can have been produced by ordinary tides and currents. Nothing, in a word, short of the passage of an infinite number of heavy glaciers and their moraines, *or* of the coarse drift or osar current, which swept with it the great mass of the transition rocks into the plains of Germany, could have accomplished such mighty ends. The onward march of glaciers over these flat regions and seas being inadmissible, elevations of the Scandinavian continent are of course required to account for the waves of translation and powerful currents required for such a purpose; for no gradual swellings of the land, such as those which are now going on in parts of that country, could possibly have produced such results. These can, indeed, alone have been accomplished by successive sudden upcasts, which threw off great devastating and erosive waves, and determined the currents in an uniform direction. But looking to the low altitude of Sweden, the vast erosion of its surface and the piles of loose materials by which it is encumbered, we can scarcely refrain from believing, that a great corresponding depression also took place, by which the regions of Russia in Europe, Poland and Germany, over which we have traced the northern drift, were so lowered as to cause long-continued currents to set in to the south from the Scandinavian chain. Such conditions, then, and those we have before suggested, may, we think, explain the boulder ridges, the wearing away and striation of the northern sides of the rocks in question and the passage of the rounded blocks, even though they occupy flat regions.

In Sweden, however, it is essential to draw the distinction (as Sefström and Berzelius have done) between the osars, or coarse drift of rounded blocks, gravel, and the great subangular blocks which cover them. Now in examining the tracts round Upsala, we had no difficulty in fully admitting a fact, first pointed out by Mr. Lyell, that blue marine clay abounding with shells (including the *Tellina Baltica*) is distinctly overlaid by osars, which are there chiefly composed of sand and gravel; thus proving satisfactorily that these masses were of aqueous origin. On this point we entirely agree with Mr. Lyell, though we differ from him as to the intensity of the agency employed in forming these osars; which must, we believe, have been infinitely greater than that which could have ever have resulted from rivers, in *a flat country* like this, pouring their contents into estuaries and bays.

In looking to the three osars, which extend in succession from north and by west to south and by east, between Old and New Upsala, we may now add, that we perceived what we consider to be striking evidences of the manner in which the subangular blocks upon their surface were accumulated. The most northern of these, called Tun-os, the summit of which is about 100 feet above the adjoining flat country, is composed of sands, clays and gravel, and is about half a mile long. On its northern face this os is distinguished by several ledges of coarse shingle, which rise up over each other in converging terraces, which gradually diminish in area as you proceed southwards to the summit of the hill. No very large blocks are associated with these shingle ridges until you reach the uppermost or smallest ellipse, whence a shower, as it were, of large angular and half-rounded blocks slope down the southern talus of the os. Seeing that blocks of the same aspect (granite, gneiss, greenstone, &c.) were similarly lodged on the summit and southern slopes of the next lower os, as well as on the third, or Stor-stens-kulle (where one of the blocks, still quite angular, is *twenty feet high* and upwards of *seventy feet* round its base), we naturally concluded, that these great angular fragments were dropped upon these promontories by floating icebergs. The terrace-within-terrace shingle on the north face of the chief os strongly corroborated this view; for supposing an iceberg floating from the north, to have been arrested by impinging against this hill of gravel and sand whilst a strong current was flowing from that point, the first summer's sun would naturally diminish its volume, whilst the force of the current would move the icy mass onwards. By the union of these causes the shrinkage and advance of the iceberg would proceed each season, and thus, by the steady action of a northern current, the ledges of shingle having been washed up round the northern base of the iceberg, would be left as memorials of each successive reduction of that body. At length, when reduced to the minimum size at which it could be held together, it would, in dissolving, necessarily shed its load upon the sloping talus of the os, the blocks being assisted by the same current in their southward progress down the slope of the submarine hill. This case appears to us to be so illustrative and confirmatory of our views, that we annex two small diagrams giving a plan of the ground and a profile view of the same.

NORTH. 68. SOUTH



a. Ancient submarine hill composed of sea sand and clay, with *Tellina Baltica*, and now forming the land called Tun-os

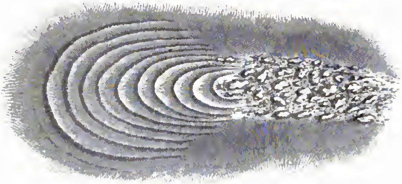
b. Iceberg in its largest state when arrested by the submarine hill.

c c c c c. Terraces of gravel formed successively as the iceberg was forced southwards.

d. Iceberg in its last state, when diminished and advanced to the south, exposing blocks and gravel within it.

e. Talus covered by blocks derived from the melted iceberg. ——► direction of the current.

69.



In this enlarged plan, the converging terraces (*c c*) of the section are represented to the left, the line of blocks (*f*) to the right.

These phænomena at Old Upsala seem to us fully to indicate the difference between the sub-aqueous and highly-rolled, tumultuous drift, which like the " till " of Scotland, resulted from some of the earlier oscillations in these latitudes, and the operation of the currents upon icebergs which were stranded and dissolved; for had the same power of water been there in play, as that which formed the Bronkeberg Os near Stockholm and many others like it in Sweden, the blocks in question, although they, for the most part, lie to the lee, or sheltered side of the hills, would have been rounded and polished, whereas nearly all of them (and the great block of Stor-stens-kulle stands out upon the very summit of a hill) have their angles as fresh, as if never affected by other than ordinary atmospheric agency.

The prevalence of the rounded or worn blocks *in* the mass of detritus or osar *trainées*, whilst the angular blocks are chiefly on their surface, are features well-explained, if we suppose that the more violent current by which the one class of boulders was hurled on, was succeeded by other south-flowing streams, in which ice-floes were transported.

Whilst we have stated that the normal and general direction of the striæ in Sweden is either from north to south, or from north-north-west to south-south-east, we know that there are many exceptions. Such, for example, are certain marks near Gottenburg and Uddevalla observed by M. Forchhammer, which proceed from east to west. There again, we should say, that such striæ are merely in the direction which certain local masses of drift have taken, and which have been carried from the east into the fiords, or mouths of lateral valleys, on the west. And here it must be recollected, that numerous inlets around these estuaries, such as Uddevalla and Gottenburg, and that above Christiania, before adverted to (p. 329), indicate by the presence of marine shells, often at considerable heights, that the sea occupied these lands till a very recent period.

But such aberrations from the normal direction perfectly concur with the excentric shedding off of the debris indicated in Lapland by M. Böhtlinghk. For, as we have before shown, this great drift *is northern in reference to Russia and Germany only*. To the Icy Sea it is a southern[1], to the Yorkshire coast an eastern, and to the Timan ridge a western drift. Northern Scandinavia was, therefore, a vast, crystalline nucleus, which owing, as we believe, to its sudden elevations, accompanied by great environing depressions, poured off its detritus at one time vehemently, at another more tranquilly, and thus accomplished those residual phænomena which it has been so difficult to explain. We are further induced to suppose, that the highest portions of this chain, extending from the Dovre-feld in Norway to the axis of Russian Lapland, constituted a region of glaciers which, broken up by some of the oscillations alluded to, sent forth numerous icebergs, which were often floated away to great distances before they melted, and deposited the erratic blocks described in the preceding chapter.

[1] M. Siljeström has already shown, that the translation of the detritus from the Sneehatten and highest points of the Norwegian axis has taken place from south to north and from south-south-east to north-north-west, thus completing the proofs of an excentric Scandinavian movement. (See the arrows upon the Map, Pl. VI., and the Postscript to this Chapter.)

If for a moment we turn our attention to the British Isles, analogous phænomena are found all around their shores: sea-beaches and bottoms fringe the rocks at various altitudes: coarse and thick heaps of detritus encumber the slopes of the hills; and in numerous situations, whether on inland mountains or low rocks upon the level of the sea, as well as far removed from any great elevations, striated, worn and polished surfaces are frequent.

To begin with one example out of many of the latter class—one to which no geologist has yet adverted,—we are acquainted with no finer case of striation and polish of the solid rocks than at the bay of Derrynane in the south of Ireland. There, the mass of detritus has naturally found its exit to the western sea, by an east and west depression, the low, undulating hummocks of hard and highly-contorted, slaty rocks (Devonian) having been worn down, highly polished and scratched in *the direction of the major axis of the valley*. The sides of this valley, opening to a fine marine bay, are formed of picturesque rocks, which by their outline necessarily confined the drift in a direction from east to west. Again, on the south side of Macgillicuddy's Reeks, the chief central mountain in the south of Ireland, great piles of drift are lodged at intervals in a deep gorge which leads eastwards from the gap of Dunlooe to the upper lakes of Killarney: and alongside, as it were, of such masses of detritus, the rocky cliffs are polished, grooved and striated, both on their upper surfaces and on their steep sides. In this way we may also infer, how the loose materials have been shed off excentrically from elevated centres, and spread out in the "escars" of the lower Irish tracts.

In the south of Scotland, as in the Highlands, great terraces or linear ridges of coarse gravel and rounded blocks have been deposited on the slopes of the hills and in ancient bays or estuaries. Sir James Hall[1] was the first geologist who applied the diluvial views of De Saussure and Pallas to explain the striation of the Scottish rocks, and looking to the direction of such marks on the sides of the hills near Edinburgh, and connecting them with the form of the rock ridges, the "crag and tail" of Scottish observers, that philosopher naturally concluded, that the same great aqueous debacle which had poured off the detritus into the low grounds had scored and grooved the rocks over which it had passed. One of the most

[1] See Transactions of the Royal Society of Edinburgh, vol. vii., in which, pp. 169 *et seq.*, the reader will find how, in the year 1812, Sir James Hall applied and modified the action of the great supposed diluvian wave. We specially commend to the attention of the reader the excellent observations of Mr. Charles Maclaren in his work, 'Geology of Fife and the Lothians,' on the groovings and dressings on the surface of rocks, p. 214. Edinburgh, 1839.

remarkable examples in that country with which we are personally acquainted, is, where the hard siliceous sandstone of Braambury, near Brora[1], has been cut into by fine markings, *irregularly* parallel, which are visible on the south-western face of that hill, wherever the turf and earth is removed from the subjacent rock. In that case, as near Edinburgh, hills of moderate height only are to be seen in the direction whence the chief local current has proceeded; and a deep gorge leading up to Loch Brora indicates the channel by which the drift was poured off against Braambury hill, prior to its distribution or submergence along the shore. In a word, all the great banks of drift and sand which diversify the tracts on the south side of the Moray Firth are but "osars," which proceed from the ends of the promontories of the central Scottish mountains, whilst on their opposite or western side, the shores and estuaries of various lochs on the coast between the mainland and the Hebrides exhibit similar masses of detritus. Whenever they can be detected, and we have seen them even on the flanks of Schehallion, towards the centre of the Scottish chain, the striæ are invariably in the same direction as that which the main mass of adjacent gravel and detritus (however transported) has taken in its passage over the land. In the case of Schehallion, the loose matter has been formed in the adjacent valley of Kenmore into terraces, which are finely displayed in the beautiful park of the Marquis of Breadalbane.

According to Dr. Buckland, who has sought to apply the views of Professor Agassiz to various parts of the British Isles, these terraces are but the evidences of ancient moraines, the remains of former glaciers, which passing from the shoulders of Schehallion and the adjacent hills, found their resting-place in the valley of Kenmore. Arguing that nothing but a glacier can have produced the parallel grooves, striæ and "roches moutonnées," Dr. Buckland has further been induced to carry out the application of the same views to other hills in Scotland, to certain centres of Cumberland, and to the slopes around the Welsh group of Snowdon. In stating our objections to the views of that eminent geologist, let us take the case of Snowdon[2]. Whether we examine its northern, north-eastern or western flanks, many such boulders occur, at intervals, as must, we contend, have been accumulated under water. Around more than one-half of the periphery of the mountain, the highest point of which is only 3571 feet above the sea, there can, indeed, be no ambiguity; for sea shells of existing or pleistocene species are commingled with the detritus upon its flanks, and we can perceive no distinction between such de-

[1] Geol. Trans., 2nd Series, vol. ii. p. 357. [2] See *Obs.* end of Chap., p. 556.

posits, whether on the summit of Moel Tryfane at heights of 1700 feet above the sea, or in the lower country of Shropshire at heights of 300 and 400 feet. In all other cases around Snowdon as well as on Schehallion, therefore, we, for our parts, can see nothing more than may be completely explained by the transmission of massive bodies of detritus, which derived from the higher parts of those mountains at the periods of their elevation, would necessarily, we contend, have produced exactly the same appearances as if a heavy incumbent glacier had traversed them[1]. The coarse drift of the British geologist, or the osar of the Swede, are no imaginary creations. They are enormous banks and ridges of stones which have usually undergone great friction, are associated with clays and sands, sometimes finely disposed, at other times tumultuously arranged, as if by water, and among them, whether in Sweden, Denmark, England, Scotland or Ireland, are occasionally found sea shells. Why then are glaciers, although doubtless they are and have been "veræ causæ" of striation, in countries where very high mountains are in evidence, —why, we ask, are they to be forced upon us as the sole means of solving this problem, in regions where no such features exist? and why in such low situations are we not to infer, that the drift has done the same work as the glacier has performed in the lofty Alps?

But some of the very marine shells on which we have been insisting as proofs of the aqueous formation of this boulder drift, are said to be Arctic species, and have therefore been quoted as indicating the prevalence of a colder climate in our latitudes in those days than at present[2]. Hence glaciers, it is supposed, may have been adjacent to such arctic animals. But what are the species of shells associated with the great boulder drift in Denmark? why in many tracts the very same which now

[1] This explanation applies equally to Killarney and all the other cases cited.

[2] We were, at one time, disposed to think, that the presence of sub-fossil shells of Arctic character naturally indicated the former presence of a much colder climate in those latitudes where they have been found (see Proceedings of Geol. Soc., vol. iii. p. 680). But independent of discoveries in submarine life, we now hold that it is unnecessary to have recourse to such an argument, in relation to any phænomena in the British Isles or similar latitudes; for we can easily imagine, that when very different physical features prevailed, and when lands now above the sea were beneath it, cold currents may have extended very far southwards of the arctic circle, and have been inhabited by species now restricted (through geographical changes) to a less horizontal range. Again, we then believed, that no great erratic blocks had ever been seen in equatorial or intertropical tracts, but we learn from the last researches of Sir Robert Schomburgk in British Guiana, that enormous boulders of far-transported crystalline rocks are there found on the surface of the sedimentary deposits of the plains and slopes,—a region in which no ice or glaciers can ever have existed (see memoir read before the Royal Geographical Society of London, which will appear in the 15th volume of the Journal of that body).

live *in the adjacent seas*. And though several of the latter are Arctic species, no glaciers occur within several hundred miles of the seas in which they live. Again, the researches of Prof. E. Forbes in the Ægean, and of Prof. Löven in the North Sea have taught us, that the more or less Arctic character of shells essentially depends upon the depth of the submarine zone at which the animals lived. Who then will assert, in opposition to such facts and the opinion of such authorities, that many of the so-called raised beaches in Sweden, Norway and England, are not, in truth, *sea-bottoms*, which, under whatever difference of latitude they may have been accumulated, necessarily bear more or less an Arctic character? Suppose, for example, a mutation in the present configuration of the Mediterranean, not so great as many which have affected our continents, and that its deepest soundings were raised up into hills, leaving banks of shells which, from the depths at which they lived, would necessarily have an Arctic character; and further imagine that this raised sea-bottom was absolutely contiguous to certain rocks of Greece[1], which have lately been described as having the same polish and striæ as our northern examples, might it not be argued, that because certain shells were present, glaciers and an Arctic climate once prevailed there? Wild as such reasoning would now appear, it might really have been maintained, had not the discoveries of Professor E. Forbes thrown a new light upon the subject and entirely prevented its application. At present, therefore, we presume that no one, on account of the parallel striation and polish of her crystalline limestone, is prepared to allow that the flanks of Parnassus have been subjected to the action of glaciers. Even there, indeed, we have the substitute for the glacier and its reliquiæ in mounds of gravel, debris and boulders (resembling in form both longitudinal and transverse moraines), which have been shed off from the mountain side.

The abettors of the general application of the glacier theory to every region where the "roches moutonnées" of De Saussure, or striæ similar to those of the Alps, are visible, failing necessarily in their efforts to show how these phænomena can have been produced by ice, in countries where the first elements in that theory are wanting, must, we contend, limit their inductions to centres of great elevation, and consequently of great cold. To support this view we need not travel to exceptional cases in Greece: even the flat regions of Belgium and northern France frequently expose polished and striated surfaces of the palæozoic limestones, where

[1] See Mr. Trevelyan's account of the scratched and polished surfaces of Mount Parnassus in Greece. Proc. Geol. Soc. of London, vol. iv. p. 203.

superjacent masses of drift have been removed from them. Such we have ourselves remarked on the surface of the low hills of carboniferous limestone on the right bank of the Rhine near Düsseldorf, where, when the superincumbent gravel is cleared away, the edges of the highly inclined beds are seen to have been truncated and smoothed down, as if they had been subjected to the passage of a heavy incumbent mass, the sand at the base of which had served as a polishing powder. These facts are, we repeat, nothing more than what have been detected under similar conditions of overlying drift throughout large, low portions of the British Isles; and to bring back their application to our own immediate subject, all these detrital heaps are simply the equivalents of the "Osars" in Sweden, the great block clay and sand of Denmark, and the piles of stones, sand, clay and gravel which are spread out in such enormous masses over the low countries of Russia, Poland and Germany. A vast portion—by far the greater part—of this drift has therefore, we think, been transported by aqueous action, consequent on powerful waves of translation and currents occasioned by relative and often paroxysmal changes of the level of sea and land. Now that we are sustained by the reasoning of mathematicians, who show us, that with sudden vertical elevations, each not exceeding fifty feet in the case of an ocean of 300 or 400 feet in depth[1] (and might not corresponding depressions produce the same?), bodies of water have the power of hurling on enormous blocks, sand and gravel to vast distances and over considerable inequalities, we are relieved from one of the great difficulties opposed to the rational explanation of the position of a very large proportion of this drifted matter. Whatever may have been the period of their action, such aqueous debacles have probably formed many of the conglomerates of previous ages, and with the help of ice floes, much of that foreign drift, of which we have already treated.

Seeing that there are no mountains whatever from which a glacier can ever have been propelled in southern Sweden, Finland, or north-eastern Russia, and yet that these regions are powerfully abraded, scored and polished, we have naturally come to the conclusion, that effects so extensively developed over such flat countries, must have resulted from the enormous masses of debris and rolled stones, which, always found in adjacent positions, *have invariably taken the same direction as the*

[1] For a mathematical application of the powers of the waves of translation, described by Mr. Scott Russell (Trans. of the Brit. Assoc. for the Advancement of Science for 1844), to geological dynamics, see the very able memoir of Mr. Hopkins "On the elevation and denudation of the lake district of Cumberland and Westmoreland" (Proc. Geol. Soc. Lond., vol. iii. p. 763).

grooves and striæ on the polished rocks. These vast mounds of drift (derived from the breaking up of the rocks) are our lithological substitutes for glaciers, and whether their weight, the nature of their materials, or the plasticity of their mass (when in a moist state) be considered, no one can deny that they may have produced effects precisely similar to those of the true glacial "moraine."

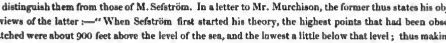
But whilst we reject the application of the terrestrial glacier theory to Sweden, Finland, north-eastern Russia and the whole of northern Germany,—in short, to all the low countries of Europe,—we believe, as before stated, that in the axis of northern Scandinavia and Lapland (the highest point of which is upwards of 8000 feet above the sea) arctic glaciers did formerly exist. These glaciers, probably more extensive than those which there now prevail, formed, we may imagine, the shores of the sea that then covered all the low lands of Sweden, Finland and Russia, and bathed the edges of such glaciers, just as those of the icy sea now advance to the ice-bound cliffs of Spitzbergen. The icebergs floating therefrom explain the far transport of the large and often subangular blocks, which chiefly occupy the *surface* of these drifted accumulations, and have often been carried to enormous distances from their native beds without losing their original outline; a condition perfectly irreconcileable to their transport by water, even were currents capable of hurling such huge fragments for hundreds of miles up inclined planes and over hills and valleys.

In bidding adieu to this subject, we are, therefore, far from denying to glaciers that which we consider their legitimate agency; nay, we require the aid of icy masses, detached from them into open seas, to account for certain superficial phænomena, which without them would, we apprehend, remain perfectly inexplicable by any natural operation: but we confidently maintain, that aqueous detrital conditions will best account for the great diffusion of drift over the surface of the globe, and at the same time explain the very general striation and abrasion of the rocks, at low as well as high levels, in numerous parallels of latitude.

In conclusion, we would remind our readers, that exempted as she has been (in all her higher lands at least) from any submarine influences, Siberia is entirely free from erratic blocks, though environed on three sides by high mountains. From this great negative fact, combined with all the positive evidence adduced in this chapter, we infer, that without having been beneath the sea, no country can have had its surface strewed over with *foreign* drift or boulders, like European Russia. All lands, therefore, in the northern hemisphere which are as void of such drift as large portions of Siberia on the one hand, and Siluria on the other, may have been, like them, for ages the habitation of the great extinct quadrupeds. Such countries must, in all probability, have been as long above the sea as the low and drift-covered tracts of Europe were beneath it.

P.S.—The allusion to Professor Forchhammer in the text (p. 541) does not do justice to his opinions, or sufficiently distinguish them from those of M. Sefström. In a letter to Mr. Murchison, the former thus states his objections to the views of the latter :—"When Sefström first started his theory, the highest points that had been observed to be scratched were about 900 feet above the level of the sea, and the lowest a little below that level; thus making about 1000 feet of difference between the highest and lowest markings. That difference has now augmented by additional observations to more than 4000 feet. Hence Sefström is obliged to imagine the motion of his flood to have been very quick, or otherwise the boulders could not have been suspended in the muddy mass. I had sufficient difficulty to imagine a stream 1000 feet deep; but a current of 4000, moving with such a velocity that the boulders could not subside, is utterly beyond my power of conception. Again, when Sefström first brought forth his views, all the worn sides which had been observed faced the north, and the supposition of a violent current from the Polar regions had some probability in it. But Böhtlingk having shown, that such worn sides in the northernmost part of Scandinavia face to the south, whilst Siljeström has observed the same phænomenon to the north of the Dovrefjeld, we must now look for the origin of the current in the range of high lands or axis of the peninsula[1]. Now, whatever masses of ice (glaciers) imagination may heap up on the top and flanks of the Dovre and its prolongation, they certainly would not be sufficient on melting to move such a stream. Further, the distance from that chain to the south of Sweden (about 7° of latitude, the height of Sneehätten, the loftiest mountain, being upwards of 8000 feet) affords a mean declivity that seems to be quite inadequate to give velocity to a current such as is required to move boulders. Sefström must also have supposed, that the numerous striated rocks which have a worn or weather side, and a lee or protected side, must originally have had the form of fig. *a* (see diagram overleaf), which by the action of the flood was changed to fig. *b*; the part under the dotted line being washed away, which, considering the hardness of the Scandinavian granite, is an enormous demand. Besides, the first form seldom or ever occurs in (Scandinavian?) rocks. Their original outline is most frequently a flattened ellipse, as represented in fig. *c*; and their present shape (fig. *d*) would best be explained by the action of water on their steep or lee side, which, assisted by degradation arising from the jointed structure of the rocks, has removed the portion under the dotted line."

NORTH. 70. SOUTH.



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[1] These decisive observations of M. Böhtlingk and M. Siljeström respecting the form of the skärs and the course which the detritus has absolutely taken to the north as well as to the south, are subversive of the theory of M. Durocher, expressed in a memoir before alluded to, that the drift passed *over* Scandinavia from the Polar regions. We must not omit to state, that as early as the year 1828 (Ann. des Sci. Nat. vol. xiv. p. 6), our distinguished friend, M. Brongniart, when travelling with Baron Berzelius, observed the chief phænomenon of the striæ on the rocks proceeding from north-east to south-west, and the parallelism of the Osars to that direction. To do justice, however, to all the authors who have written on this subject, we must refer our readers to a lucid summary of their works by Baron Berzelius, "Jahres Bericht ueber die Fortschritte der Phys. Wiss." 1844, p. 386. They will there find, that although Swedenborg, as far back as 1719, made some observations, Lasteyrie (Travels in Sweden and Norway, 1799 and 1800) gave the earliest clear ideas of the weather and lee side of the rocks. Sefström first published in 1836. Nordenskiold has in the last year added some data from Russian Lapland to those collected by Böhtlingk, whose observations respecting the excentric shedding off of the blocks he has completely confirmed.

To those who have read our descriptions and reasoning in this and the preceding chapter, it is needless to say, that the hypothesis of the melting of snows in the high lands of Scandinavia, as applied to the rejection of Sefström's theory, is a terrestrial agent, which can have no sort of application to the subaqueous conditions whereon we have insisted. We have expressed our belief, that the boulder drift resulted from sudden elevations (perhaps many) of the axis of Scandinavia, accompanied by environing lateral depressions of great depth;—such, for example, as placed all northern Germany and the Valdai Hills far beneath the surface of the waters;—whilst the waves of transport generated by each great oscillation, hurled on separate masses of subjacent drift in *excentric* or radiating directions from the main ridge or chief nucleus of disturbance. Touching the remarks of Professor Forchhammer on the form of the Swedish rocks, we cannot see how the rugged and vertical sides (fig. *d*) should have been produced by the action of the sea, since he admits, in another part of his letter, that "the materials of the osars are certainly the agents which scratched the surface." Now, the striated sides are those which have been opposed to the line of drift, which has invariably polished and worn them, whilst the opposite or rugged sides never exhibit any appearances of marine or detrital action. Nor can we admit that the rocky "skärs" so affected, have invariably the same mathematical form; for, according to our observation in Sweden, the curve of their surface on the worn side is various, whilst the rugged face is sometimes a very sloping natural broken talus, as in the drawing below, at other times a vertical cliff, as he has drawn it above, particularly in certain islets near Gottenburg, which are now washed by the sea. We still, therefore, retain our opinions as expressed in the text, that the abrasion and striation of the surface were caused by the *passage of masses of drift, moved in excentric directions with reference to the whole area affected*. Thus we explain any local deviations from what may be considered the normal or grand lines of drift, and even (as must be the case whenever powerful currents have been set in motion by various oscillations of the land) how several systems of striæ may occasionally be found to cross each other, as has, indeed, been found to be the case at Alten by Siljeström and at Faxoe by Forchhammer (see Vetens. Handling., Stockholm, 1843, and Proc. Roy. Soc. of Copenhagen, 1843).

By another letter received from Professor Forchhammer, since our preceding sheets were printed, we find that we had misinterpreted one of his views (p. 542), and that, like ourselves, when accounting for the production of the northern detritus, he believes that periods of violent upheaval and depression have alternated with tranquil epochs (see his memoir, Poggendorf's Ann., 1843). He has further communicated to us some curious facts illustrating the present action of icebergs and the transport of blocks, which will be cited in the Appendix. In the meantime we may say that our theory differs from his and that of any author who has written upon Scandinavia, in referring such phænomena to waves of *translation*, on whose powers of transporting subjacent heavy masses of loose materials we base our chief conclusions respecting the rounded Scandinavian drift, the wearing away and striation of the rocks; whilst the large subangular erratics were, we think, carried by floating icebergs, which in grating along the sea-bottom, *may have also scratched the rocky surface.*

71.

Obs.—Whilst these pages are passing through the press, a memoir has been read by Mr. A. F. Macintosh (before the Geol. Soc. of London), "On the supposed evidence of glaciers in North Wales," in which he combats the hypothesis of Dr. Boekland (see p. 550), and showing, like ourselves, that the detritus had been accumulated under water, endeavours to prove (extending an idea of Mr. Bowman), that nearly all these groovings and striæ around Snowdon, which had been referred to the action of glaciers, are due to *lines of structure* in the rocks and atmospheric agency. We may again allude to this point in the Appendix, now simply stating that the greater number of the deviously parallel scratches on the worn surface of the hard crystalline rocks of the north, are, in our opinion, clearly *mechanical*, and cannot be connected with structural conditions.

CHAPTER XXII.

The Black Earth or Tchornozem of Central and Southern Russia shown to be a Subaqueous Formation.—Modern Terrestrial Changes.—Peculiar state of the surface of Russia during the Spring Debacles.—Action on Ice of Rivers and Lakes in throwing up Ridges of Stone.—Great Annual Denudation of the Subsoil.—Enormous Deltas and new-formed Lands.—Changes operated by Man, compared with Geological Phænomena.—Resumé of the chief Objects attained in this Work, and Conclusion.

NOTWITHSTANDING the long descriptions already given of the subaqueous accumulations which encumber the surface of Russia in Europe, we have still to speak of a widely-spread superficial deposit, which must be referred to a similar origin. This is the "Tchornozem" or black earth, which, for the extent of its uniformity in colour and composition, is without parallel in Europe. Having had the opportunity of tracing the relations of this peculiar earth over wider tracts than most modern observers, we have thrown together a few remarks which may serve to explain the range and extent of the deposit, its relations to the physical features of the land, its chemical composition, and the theory of its origin.

The "tchornozem" has its northernmost limit defined by a waving line, which, passing from near Kief and Tchernigof, a little to the south of Lichvin, appears in the 54° of north latitude in that tract, then advances in its course eastward to the 57°, and occupies the left bank of the Volga west of Tcheboksar, between Nijny Novogorod and Kazan. In approaching the Ural chain, we saw no black earth to the north of Kazan, but it was plentiful on the Kama and around Ufa. Again, on the Asiatic or Siberian side of the Ural mountains, we travelled through one large mass of it near Kamensk, south of the Issetz river in latitude 56° north, and, as before observed, through another, between Miask and Troitsk. Of its limits in the great Siberian plains we cannot speak from personal observation, but we were given to understand, that it spreads over considerable spaces in the eastern, central and southern parts of that region. Although we met with it occasionally in the low gorges of the chain, and in the Bashkir country on both flanks of the *southern* Ural (in plateaux more than 1000 feet above the sea), and also in the steppes of the Kirghis, we did not see it in the plains near Orenburg, nor to the south of that city. We know, indeed, that it does not exist in the flat southern steppes extending to beyond Illetzkaya Zastchita and between that place and the mouth of the Volga; for there the surface is strewed with fine submarine detritus containing numerous shells of the same species as those which now inhabit the adjacent Caspian. In short, we apprehend, that the true black earth occupies small tracts only of the area once overspread by the great Caspian of former epochs (see p. 299). Nor did we meet with any black earth to the south of Tzaritzin on the Volga, in the steppes of the Kalmucks between that place and the mouth of the Don; nor indeed, except in very limited patches, along the Sea of Azof, or in other words, on the southern face of that elevation between the Dnieper and the Don, which constitutes what is commonly called the granitic steppe. It occurs, however, in great thickness on the plateaux on the northern side of that axis, where, as it really surmounts the carboniferous limestone with many seams of coal, a geologist who had not observed it in other places might, at first sight, be led to suppose, that the black matter was due to the decomposition of the subjacent carbonaceous strata[1]. It lies, however, upon rocks of all ages, and the greatest masses are included in the territories thus roughly defined. Geologically considered, therefore, the tchornozem occupies the centre of a trough, large as an European empire, having the detritus of the crystalline and older rocks for its northern, and the low granitic steppes and Caspian deposits for its southern limits.

It is found at all levels in European Russia, sometimes on plateaux, as on the right bank of the Volga, high above the adjacent plains, in various parallels, from $56\frac{1}{2}°$ north latitude to the high grounds extending to Saratof, and at heights of not less than 400 feet above the valleys; in other places on undulations, and often in broad valleys, where the rivers, having cut through the deposit, expose its thickness on their banks. In the country where the southern limits of the northern subaqueous drift are traceable, it is interesting to observe, that the no thern materials, reduced to small size and mixed with local debris, are succeeded if not overlapped by the black earth. In one spot, however, near Voroneje, we observed northern

[1] For description of these coal-fields see p. 92 *et seq.*, and Pl. I.

erratics superimposed on the black earth, a fact which agrees with our views of the subaqueous origin of both.

The black soil does not, however, occupy all the vast country alluded to. It occurs, indeed, in separate areas, sometimes covering several large districts, and varies from a few feet to 15 or 20 feet in thickness. In travelling over these black tracts in a dry summer, we were often, during a whole day, more or less surrounded by a cloud of black dust, arising from the dried-up tchornozem, which is of so subtile a nature as to rise up through the sod, in rich grass countries, under the stamp of the horse's feet, and forms so dense a cloud, that the traveller is often begrimed like a working collier.

The tchornozem is unquestionably the finest soil in Russia, whether for the production of wheat or grass. It is so fertile as arable land, that the farmers never apply manure; and after taking many crops in succession, leave it fallow for a year or two, and then resume their scourging treatment[1].

On fracturing a hardened lump of this earth which we extracted from beneath 10 to 12 feet of similar earth, all jet-black when moist, and which we had kneaded together to bring away, it offered in its dry state a slightly ferruginous brown tint; and we further perceived, that besides the black matrix, grains of lighter-coloured sand were interspersed. Having submitted a portion of the mass to Mr. R. Phillips, he has obligingly furnished us with this analysis:—

Silica	69·8
Alumina	13·5
Lime	1·6
Oxide of iron	7
Organic matter	6·4
Traces of humic acid, sulphuric acid, chlorine, &c.	1·7
	100

Dr. Daubeny, who has also interested himself in the examination of this black earth, and has detected about the same proportion of organic matter as that noticed by Mr. Phillips, thus expresses himself:—"The possession of a deep soil, easily penetrated by the roots of plants, and containing so large a per-centage of mild humus, would alone impart great fertility."

[1] On this head we can now say no more, and must refer our readers to vol. iii. p. 1. of the Transactions of the Royal Agricultural Society of England, where we have enlarged upon the productive qualities of this soil.

The French agricultural chemist, M. Payen, who analysed a portion of the black earth at our request, says :—" The composition of this earth is *remarkable for the proportion of azotized matter which it contains*. The connexion between this earth and the organic substance, when the latter is so rich in nitrogen, appears to me to be essentially one of the surest indications of the fertility of soil, other conditions of chemical properties and mineral composition being favourable. In this respect, and according to my compared analyses, the earth in question approaches very near to two of the most fertile soils of France, that of the Limagne d'Auvergne (valley of the Upper Loire) and that of the neighbourhood of St. Denis, near Paris, notably in the farms of Marville and Stains."

The analyses of these able chemists afford us nearly the same results as to the proportions of the earthy constituents, whilst we learn from M. Payen[1], that the unusually large quantity of nitrogen in the carbonaceous portion of the black earth may be the principal cause of its fertility. It would seem, however, that without a close attention also to the mechanical aggregation as well as the composition of soils, it must be very difficult to estimate their fertilizing powers. Thus some of the poorest lands, as dissimilar in colour as in produce from the tchornozem, have almost to minute quantities, the same proportions of sand, clay, iron and vegetable matter. It is therefore, we believe, the extremely fine levigation of the silica, enabling that substance so to combine with the alumina as to form a

[1] We here subjoin one of the original documents of M. Payen, with the substantial results of the analysis of a specimen of tchornozem sent to him by Colonel de Gourieff.

Analyse.

100 terre = 6·95 mat. organique combustible, 93·05 cendres		6·95
Solubles dans l'ac. chlorhyd. bouillant = 13·79	Alumine . =	5·04
	Ox. de fer . =	5·62
	Chaux . . =	0·82
	Magnésie . =	0·98
	Chls. alcals. . =	1·21
Insolubles dans l'ac. chlorhyd. bouillant = 79·30	Silice . . . =	71·56
	Alumine . . =	6·36
	Chaux (traces).	
	Magnésie . =	0·24
		98·78

Azote pour 1000 :—de matière normale = 1·66 ; de matière sèche = 1·74 ; de matière organique = 24·99.

The analysis of M. Payen indicates the presence in 100 parts of the original earth of

Combustible organic matter . . . . 6·95, *containing* 2·45 *nitrogen !*

or in other words, 4·140 grammes of the earth yield 9·498 *cubic centimetres of nitrogen or azotic gas.*

peculiar, loamy permeable clay, which, with the aid of its combined nitrogen, renders this soil so eminently productive.

When we speculate on the probable origin of the tchornozem, the first impression might be (what is indeed the prevalent opinion in Russia),—that it is the humus arising from decayed forests or vegetables during the present period. But we entirely dissent from this opinion; judging from the uniform nature of the soil, its distribution at all levels, and also that in no part of the empire does it ever contain a trace of trees, roots, or vegetable fibre. It is in vain to say, that such terrestrial vegetables may have been entirely decomposed; for in the denudations which expose 15 to 20 feet of this matter, some remains of the plants would surely be found in the lowest parts of the solid earth, just as we find roots and branches of oak, pine, birch, and hazel in our peat bogs. We would also add, that if the black earth had been produced by the decay of trees, traces of it would certainly be found in northern Russia, where forests have so long existed. But in no part of northern Russia (large portions of which have been cleared and converted into arable land) is there a vestige of black earth, whilst it specially abounds to the south of a certain line, or exactly in those extensive and steppe-like undulations, which have been void of trees throughout all known time.

Recognizing the great extent and uniformity of the tchornozem at various elevations, Mr. Strangways indicates its existence at intervals from the Volga to the tracts near the mouth of the Danube, and even to Podolia and East Gallicia[1]. He further remarks, that in Podolia it yields a large quantity of *nitre*, and that though more sparingly distributed in the lower steppes of the Caucasus than in the higher plateaux, this mould is found to the east of the Sea of Azof, *i. e.* between that sea and the Caspian, and chiefly near the mouths of the rivers Kuban and Terek and around the *salt marshes*, near the edges of which the tchornozem is covered with a saline efflorescence having a disagreeable odour.

Now if, from these facts, it be impossible to adopt the hypothesis of simple terrestrial origin, and that we consider it a subaqueous deposit, with what known accumulation shall we compare the black earth? Is it to be placed in parallel with the finely levigated silt which the Germans call löss, or with the upper diluvial

[1] MS. read before the Geol. Soc. of London, anno 1824. In his valuable observations, Mr. Strangways, whose botanical knowledge is well known, also repudiates the prevalent idea, that this black mould can have been derived from the decomposition of forests. "The character of the black mould being everywhere the same, it is difficult (he says) to imagine that the same plants ever grew in so many situations with such opposite aspects, on such different soils and over so vast a surface."

mud which in Belgium, France and Germany is said to bound the northern drift? Though this comparison is made by M. A. Erman, and has been alluded to by M. E. de Beaumont[1], we conceive that it still requires some modification and explanation. With the ordinary diluvial or drift clay the black earth has, indeed, little in common; for it does not contain a single transported pebble. Besides, it is never mixed with that drift which occupies such large tracts of northern Russia. Again, the composition of the tchornozem is most distinct from the löss of Germany, which light-coloured, sandy, calcareous mass, is abundantly filled with terrestrial and lacustrine shells in perfect preservation, clearly indicating that it was accumulated on the sides of ancient, wide, lacustrine rivers, which were barred up so as to form lakes in the way described by Mr. Lyell, just before the present configuration of the land was completed. The fact, also, that the löss has not yet been seen on high plateaux, but occupies the sides and bottoms of great valleys, is in itself sufficient to prove, that although it may have been accumulated at nearly the same epoch, it cannot be considered the exact equivalent of the tchornozem, which, containing no terrestrial and fluviatile remains, is found at all levels without any relation to the existing form of the land.

Debarred, by the absence of any portions of plants in its composition, from referring it to the decay of vegetation, and unable, from its mineral peculiarity and the absence of organic remains, to compare it with any known deposit, let us see whether the subaqueous condition of Russia at a comparatively recent period, of which we have just spoken, may not help us to solve the problem.

In no part of the great region occupied by the coarse northern drift is there a trace, as before stated, of the tchornozem, though yellow and white sands and stiff clays abound, the latter constantly charged with some transported pebbles. Extending then as far southwards, as currents or icebergs, to which we have formerly referred, would transport them, it is very natural to suppose that, where the northern boulders ceased to advance, the bottom of the then sea, remote from any disturbing force, would become covered with fine silt or mud, such as we know, from the soundings of hydrographers, is often found beneath mediterranean waters, far removed from the action of strong running water.

If its origin be thus marine, we think it highly probable, that this fine silt may, to some extent, have been derived from the destruction of the black Jurassic shale,

[1] See Comptes Rendus, 1841, p. 1223, including observations upon a notice of the tchornozem by our friend the Baron A. de Meyendorf.

so uniform in its colour over all northern and central Russia. By reference to the Map it will appear, that this shale, which formerly must have had a vast extension, has been most widely denuded. Nor could it have been otherwise, when exposed to those powerful currents (which as the superior stratum it must have been) that carried southwards the northern materials. Such currents may then, we believe, have moved on this fine sediment in solution to the very extremity of their influence, and thus transported it southward of the limit of the northern boulders. There is another reason for supposing that the Jurassic shale has furnished a portion of the materials for the tchornozem, in the absence of that earth to the south of certain tracts where we have reason to think that the former has never existed. In truth, it is in this respect exactly like the northern drift of Russia, which invariably contains many materials of the formation immediately north of it. Now, as there neither is nor has been much Jurassic shale north of Moscow, but abundance in the environs of that city, so it is only on passing the plateaux to the south of that parallel, that we find the first great spread of this singular black material.

But even if this explanation of the chief derivation of the black earth be accepted in regard to European Russia, there are, we admit, difficulties respecting great masses of it in southern Siberia, over which no northern current transporting blocks has certainly ever swept. Granting, however, that the Siberian black earth had equally a marine origin, may not its materials have been carried northwards round the south end of the Ural chain? Or may not a large portion of the low grounds of Siberia have been then under the waters of large lakes, whose bottoms would necessarily be muddy, as the whole region is void of coarse detritus?

Forbearing to speculate with our present knowledge upon the probable extension of bays of the ancient sea into those parts of Siberia, we cannot avoid alluding to a striking analogy between the deposition of the rich cotton soil of Hindostan and our Russian tchornozem. We learn from Captain Newbold, who described the "Regur" or Indian cotton soil some years ago[1], that it is a dark-coloured silt which occupies the summits of plateaux at various elevations, and is spread out in separate broad masses, from the northern part of central India to the south of Trichinopoly, but is unknown on the coasts. This Indian earth bears, indeed, a remarkable geological affinity to that of Russia in being never found to the north, or along the low country under the Himalaya Mountains, the great source of all the gravelly detritus of that peninsula. In Hindostan therefore, we believe, that this

[1] See Records of the Royal Society. The memoir was not printed.

earth was originally marine silt, which, like the tchornozem of Russia, had been transported beyond the reach of coarser detrital influences[1].

The absence of any marine shells in this fine Russian sediment is, it is true, a negative fact, which, if unaccompanied by explanation, might indispose some persons to admit our hypothesis. We must, however, bear in mind that, after their emersion, the low central parts of this empire, if but slowly elevated, may have long continued in an intermediate state of mire with little egress for water; so that the remains of delicate testacea and sea-weeds (if they formerly existed) may have been entirely decomposed by the alternations of aqueous and atmospheric agency. However this may have been, we cannot look at the very great uniformity of its composition over such vast tracts, and its independence of existing drainage, without rejecting any theory which would explain the production of the tchornozem by subaërial and existing causes only, and we therefore refer its origin to aqueous deposit, and the subsequent modifications which the surface underwent, when passing into a terrestrial condition, long anterior to its occupation by the human race[2].

[1] In aspect, however, as well as in composition, the specimens of "Regur" which *we have seen*, differ essentially from the tchornozem in not being, by any means, so black, in containing much coarser grains of sand (even pebbles), and also calcareous (tufaceous) concretions, which are attributed by Captain Newbold to springs rising from the subjacent rocks.

[2] We are not prepared to say to what extent the productive thick humus of the southern steppes and of Wallachia and Moldavia may be referred to the same period of accumulation as the tchornozem, but in a calculation of the productiveness of the South Russian soil, M. Ritter evidently groups all these tracts with the black earth. If the rich southern soil be analogous to the black earth, we of course entirely dissent from M. Huot, who states that its formation commenced at the epoch when the first human societies were established, and has been continually increasing, and further, that it contains intact vegetable matter. This description will in no respect answer to that of the tchornozem, in which neither Pallas, nor Strangways, nor ourselves have been able to trace any vegetable fibre, and which, for all the reasons above adduced, could not have been formed in the present period. (See Demidoff's Voyage dans la Russie Mér., vol. ii. p. 460 *et seq.*)

Nor can we agree with M. Huot, that the total absence of trees in southern Russia and the steppes is due to any political causes, or to the wood-destroying habits of the nomadic tribes, who have for so many ages occupied those regions. The absence of trees over certain flat and steppe-like regions of Asia is universal, whilst similar tracts in northern climes are specially covered with forests. This distribution results from general conditions of climate; and the want of dew, to which the inhabitants of South Russia attribute the want of wood, seems to us to be a much better reason than that of M. Huot. At all events we utterly disbelieve in the former existence of forests which have been destroyed (for Herodotus tells us that large tracts of the Scythians were entirely bare of wood), and we are firmly persuaded, that by no efforts could any government produce forests in those districts, except in certain rocky and moist spots.

But whether the tchornozem was originally the residue of a sea, or of great internal lakes, we specially dwell upon the probability, that during the elevation of the tracts occupied by it, the mire from which it has been derived, being then in a putrescent state, acquired its nitrogen and possibly in part its colour, from the decomposition of aqueous plants and microscopic animals, the remains of which may yet be looked for. Although, therefore, we would not be held to maintain, that the sea necessarily covered all the tracts now occupied by black earth, or that this substance was necessarily derived from the black Jurassic shale, we distinctly assert, that, from its composition and distribution, it must have been formed under water.

Modern Changes in the surface of Russia in Europe.—The former sea-bottoms of European Russia having been, as we believe, desiccated, and converted by elevation into a continent, we proceed to consider the changes which have since taken place, and are still occurring on the surface of this great mass of land. We have already stated, that the scratches on the rocks, the great fissures now occupied by the northern lakes, and the course of the remotely-drifted materials (as far as the flat regions of Russia in Europe are concerned), have nearly all common and *undeviating* directions. During the modern epoch, however, a new order of operations has arisen. The detritus is now carried down in every direction by the existing water-courses, wherever the inclination of the country favours such transport. In truth, some materials which were formerly transported from *north to south*, are annually carried back a part of their journey to the north, and others which had equally travelled from the north, are borne both to the *east and west*. The banks of most of the rivers in northern and central Russia consist, in fact, of the foreign drift which has been described; and hence it is evident, that on mouldering away, these accumulations must fall into the water, the northern erratics thus often becoming imbedded in the winter's ice. In the spring, when the ice is broken up, many of these blocks are occasionally borne in small floes, which, when they get into the central current, will follow the stream for a certain distance, until stranding on its bottoms or sides, they melt and deposit their stony loads. The protrusion of an irregularity or rock in the bed of a stream, having once given rise to the accumulation of such materials, the impediments to navigation are periodically increased by the accession of fresh loads of boulders. In this manner, blocks which had been transported by the old erratic drift to the edge of the Valdai Hills, are brought back northwards by the currents of the Volkof and the Msta. The great

Dwina of the East also offers examples of such action of transport from south to north, whilst the Volga, particularly in its course from Mologa to Yaroslaf, performs the same operation in another direction, when flowing from north-east to south-west. These river beds also offer an analogy, assisting us to explain why the large boulders of the northern drift are usually found associated with mud or clay. In many places we observed them to be accumulated in groups, sticking in the mud, just at the high-water mark, and where they would naturally be left at the breaking up of the frost, when the swollen streams flowing at high levels, the sharp edges of the ice would become fastened into the muddy banks until they dissolved; whilst the same masses would shoal away from slopes of incoherent sand. The granitic boulders so found in fluvial detritus, and often high on the sides of the banks, are frequently more rounded and worn than those mementos of the ancient northern drift which lie simply on the surface of the lands, a fact well-explained by the river blocks having undergone subsequent rolling on the river-sides.

"*Elevated Fluviatile Ridges of Angular Blocks.*"—Another effect of fluvio-glacial action must now be explained. Towards the mouth of the Dwina, and about 110 versts above Archangel, the white carboniferous limestone before described occupies the banks in horizontal layers, the edges of which are partially covered with mud and sand. The limestone is best seen when the water is low, as at the period of our visit. About thirty feet above the summer level of the stream, the terrace on the river-side is covered for two or three versts by a band of irregularly piled, loose and large angular blocks of the same limestone, arranged in a long uniform ledge, the surface of which slopes both to the river and to the roadway, so that the view of the stream is shut out from the traveller by this ledge. In other words, these materials (all purely local) constitute a broken ridge of stones between the road and high-water mark. A woodcut will best explain these appearances,

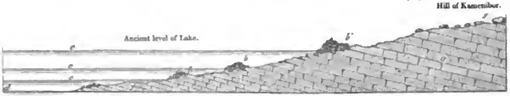
72.

showing (*a*) the ancient hillocks of sand above the road-terrace, which is partially covered with water at high inundations, (*b*) the ridge of broken limestone, (*c*) the sloping river-bank, and (*d*) the summer level of the stream. The occurrence of these supra-riparial ridges of angular blocks "*in situ*" is thus explained. When the Dwina is at its maximum height (*e*), the water which then covers the edges of the thin beds of horizontal limestone (*f*) penetrates into its chinks, and when frozen and expanded, causes considerable disruptions of the rock, and the consequent entanglement of stony fragments in the ice. In the spring, the fresh-swollen stream inundates its banks (here very shelving), and upon occasions of remarkable floods so expands, that in bursting it throws up its icy fragments to fifteen or twenty feet above the highest level of the stream. The waters subsiding, these lateral ice-heaps melt away, and leave upon the bank the rifted and angular blocks (*b*), as evidences of the highest ice-mark[1]. In Lapland, M. Böhtlingk has adduced some extraordinary examples of this sort of glacio-fluviatile action; for he assures us that he there found large granitic boulders, weighing several tons, actually entangled and suspended like birds'-nests in the branches of pine-trees at heights of thirty or forty feet above the summer level of the streams.

Elevated Block Ridges on the Banks of Lakes.—Until we observed the angular and elevated block ridges on the banks of the Dwina, and assured ourselves that ice is a "*vera causa*" in elevating large stony masses, we had great difficulty in explaining the origin of certain ledges, which stand at higher levels on the western side of the lake of Onega. The chief of these, which was pointed out to us by Colonel Armstrong of Petrozavodsk, occurs on the slopes of the hill Kamenibor, and is composed of the hard quartzose sandstone or altered old red sandstone, described in the fourth chapter. Lying, as nearly as we could guess by the eye, at about 200 feet above the lake, this ledge (*b'*), as represented in the subjoined section,

[1] Though we were only present in the summer season, and therefore could not witness such phænomena, we have before us a description of an extraordinary breaking-up of the Dwina at Archangel by our kind friend Mr. Whitehead, Her Britannic Majesty's Consul at that port, to whom we had written on the subject, which satisfies us, that if the edge of the river there consisted of jointed thin-bedded limestone, like that to which we allude, instead of the fine mud and sand, which alone constitute its banks, the same results must have ensued lower down the stream. Mr. Whitehead's account is as follows:—"I wish you could witness such a breaking-up of our river as we had in the spring of 1835. In the course of five or six hours the water rose fourteen or fifteen feet, with the ice one compact mass upon it. Calculate the enormous pressure of such a body of water with the impetus of such a current, and you may, perhaps, form some idea of the crash when the ice did give way. It was grand in the extreme, and if we could calculate upon such a breaking up this spring, I should say you would be richly repaid by coming to see it. I could compare it to nothing but the roaring of artillery. Blocks of ice remained for a long time high and dry upon the banks."

73.



is about twelve or fifteen feet wide in its central part, from which its surface gradually slopes away on each side, so as to leave a width of about thirty paces for its base. It is composed of angular blocks (some not less than ten and twelve feet in their greatest diameter) which consist exclusively of the same quartzose sandstone as that which constitutes the subsoil on which they lie. The sloping surface of the Kamenibor, still higher above the ledge, presents, it is true, some scattered granitic boulders (*f*), but we could not detect one of them in this ridge of angular blocks of siliceous grit. To consider it as an ancient edge of the lake which had been drained off to its present level, appeared, at first sight, to be impossible; for the gigantic, angular and unworn blocks, only slightly covered by lichens, and piled up like the broken rocks in a foreground of Salvator Rosa, were totally unlike any ancient lake-banks we had ever seen. They were, indeed, wholly dissimilar to the parallel roads of shingle at Glen Roy in Scotland, which several geologists have attributed to lacustrine deposit[1]. We therefore began to speculate on the possibility of these coarse angular masses, *in situ*, being the results of ancient rents caused by earthquakes, which fissuring the strata *in lines parallel to the lakes*, had left these shattered piles in their present linear form. This hypothesis seemed, however, to be untenable, both from the very condition of the blocks, and still more by our observing two lower terraces (*b b*) formed of similar materials, and lying at other levels between the higher ledge and the shore of the lake. We then began to think, that although unlike anything

[1] No subject has afforded a more fertile theme for discussion than the shingle terraces or parallel roads of Glen Roy. Dr. Macculloch, Sir G. Mackenzie, Sir J. Dick Lauder, and Mr. C. Darwin, have written largely upon them, the first three referring them (under different modifications) to lacustrine deposit, the latter to submarine influence, when these tracts were fiords or ancient estuaries. In this last opinion we entirely concur, as might be inferred from what we have said in the previous chapter on Scottish drift and gravel. It ought further to be stated, that when Professor Agassiz visited Glen Roy (anno 1840), he considered the parallel roads to have been formed by ancient glacial action, suggesting that a lofty wall or mountain of ice had barred up former lakes, which were drained off by its disruptions. Without now entering into these theories, we have only to say, that our cases of Petrozavodsk and the Dwina are very different, indeed, from the phænomena of Glen Roy.

we had ever seen on lake or river-banks in the British Isles and Western Europe, the three ridges must be connected with ancient lacustrine conditions, and that however produced, they would be found to indicate, that in former periods of our own æra (long subsequent to the deposit of the northern blocks, none of which, as we have said, are found in this local detritus) the Lake Onega occupied a much wider space, and stood at much higher levels (*c c c*), from which it had been successively let off to its present state. The modern glacial action of the Dwina subsequently seen, explained to us, indeed, very perfectly, how during more extended glacial action on its banks, the vast Lake Onega might have produced the more striking ledges of Petrozavodsk; and thus we were led to believe, that the fresh-water lakes of the interior of Russia had been drained off *at intervals* by successive elevations of the land, and that the present lakes are but the remnants of former and much more extensive waters, which stood at higher levels. A traveller from the Alps, well-versed in the phænomena of glaciers, but unacquainted with the peculiar glacial action of Russia, especially of that which we detected on the Dwina, might perhaps, on seeing these ledges near Petrozavodsk, have identified them with Swiss "moraines," and, honestly imbued with his own theory, might have so written as to lead others to adopt his views. Now, we refer these ledges to a natural operation common to the extreme climate of Northern Russia, which in the expansion of water and the rupture of ice, frequently dislodges whole layers of stone, and piles them up in a broken talus above the ordinary edge of the lake or river, and even, as proved by M. Böhtlingk, in the case we have cited, leaves large blocks suspended in the lower forks of the trees. In furtherance of this view it may be stated, that, for a long time, all European Russia must have been much more extensively covered with water than at present. A mere inspection of the great detailed map of the North of Russia, in which so many lakes, some of them already half-dried up, are laid down, would lead the geographer to the same conclusion. In short, geological phænomena, ancient tradition and modern history all combine to establish the fact, that as a great portion of the flat and central regions of Russia in Europe were beneath the sea at a very recent period, so the depressions in the higher and rocky lands which lie to the north, must afterwards have been occupied by lakes, the waters of which were successively let off; the shallower of such depressions having been in many instances first converted into marshes, then into forests, tenanted by bears, elks and other wild animals, and, lastly, into plains or valleys occupied by man.

Modern Estuary Phænomenon explanatory of the former origin of Coal.—Besides these proofs of successive desiccation and change of outline, the North of Russia affords examples of modern accumulations, some of which throw light upon the probable origin, in more ancient epochs, of certain beds of coal. The embouchure of the Dwina, from ten or twelve miles broad at Archangel, is studded by not less than 250 small wooded islets, the sides of which and of the low country on the left bank of the stream, rise only to the height of a few feet above the high water-mark, and exhibit numerous alternations of fine silt. On disembarking at that bank near the post station opposite to the city, we found the cliff to be composed of the following materials in descending order:—1st, vegetable soil and boggy woodland, into which the roots of living trees penetrated; 2nd, clay and sand, alternating in fine laminæ, with fragments of decayed wood, and indicating the deposit by the river; 3rd, bog and peat, the remains of a former decayed vegetation, with blackened and rotted roots, &c.; 4th, river sand repeated; 5th, stiff blue clay, reaching down to the water's edge. Now this arrangement seemed to us very distinctly to indicate the alternation of river freshes or inundations with periods of dry land, on which vegetables grew, whilst the blue clay or base of the section might represent the ancient bottom of the estuary, contemporaneous with that in which, higher up the Dwina, we had found the post-pliocene shells. At all events, whatever the lower blue clay might be, the overlying beds offer all the analogy which we require, in order to account for the phænomena prevalent in some of our coal-fields, of the alternation of certain beds of coal and shale, wherein all the vegetables present the appearance of having been entombed *in situ* with other large layers, indicating the action of drift. For if this low left bank were submerged, and its materials consolidated by long-continued pressure, we might, doubtless, anticipate that there would be produced two distinct carbonaceous masses, one, in fact, formed out of vegetation in place, whilst the other, composed of estuary silt, and converted into carbonaceous sandstones and shale, would contain, here and there, fossil stems of trees which had been drifted by the stream, and placed irregularly, either athwart the strata, or laid along them in flattened masses.

Modern Ravines or "Avrachs."—There are no superficial features in Russia more worthy of the notice of geologists, than the striking fissures which are from year to year laid open in the earth, and often proceed to great depths downwards, not only into the drift and ancient alluvia, but also into the true subsoil. Some of these fissures have been described by Mr. Strangways, and the region in which he notices them near Jurievetz on the Volga, and Nijni Novogorod, is that where they appeared to us also most remarkable. These "avrachs" or "baltas" of the Russians are common to every part of the country, where high plateaux, essentially composed of soft materials, are flanked by valleys at some depth below them. The rapidity with which they are widened after the ground has once begun to yawn, is quite surprising to those who have been accustomed only to survey the trodden tracts of Europe, and other parts of the world.

Central Russia, indeed, has been shown to consist, to a very great extent, of a series of undulations, composed of *incoherent* materials. In other words, it is a country so devoid of a hard framework, that the vast increment of clay, sand, or mud, which occupies her surface, is easily denuded, when an adequate cause is brought into play. The opening or fissuring of these masses, then, is first due to an *extreme climate*, which subjects the surface to intense and long droughts, alternating with heavy debacles, arising from the melting of thick coverings of snow and ice. During the hot and parching summers the argillaceous grounds necessarily split into rents, and wherever these occur, they are necessarily filled in winter with great accumulations of snow and ice. The thaw of the succeeding spring melting these bodies, the smallest crack of the previous year is enlarged into a gulley, which, widening as it approaches the steep sides of the hill, becomes, in a few seasons, a broad and deep ravine, through which the melted snow, mud, sand and clay, with occasional boulders and blocks, are transported into the adjacent river. It is the conjunction, therefore, of the very incoherent nature of the upper deposits of Russia with the extremes of her climate, that explains the formation and rapid extension of her innumerable ravines. It would, indeed, be a curious problem to ascertain, to what extent these ravines encroach annually upon the best arable and pasture grounds of the empire (even in the suburbs of important towns), and in what progression this waste takes place. This might be approximately ascertained, by measuring the rapidly increasing delta in the Caspian near Astrakhan, at the mouth of the Volga, and the very perceptible silting up of the Sea of Azof by the contents of the river Don. In no instance have we seen any means adopted to check this continual wear and tear, by which millions of tons of the richest soils are annually destroyed, and carried away by the great rivers, though by levelling their sides and filling up the chasms in their early state, much of the evil might be averted. We may here also mention, that it is owing to the fissured nature of the sides of the hills, and the wide mouths of these gulleys, that the great roads of Russia pass almost invariably over the very highest parts of the table-lands, where the "avrachs" are, comparatively speaking, small or rare. Instead of travelling along the banks of the great water-courses, as would be the case in western Europe, it has been found impossible to maintain roads along these lower levels,—first, from their being inundated during the spring season; and, secondly, by the innumerable mouths of the ravines, which defy all the efforts of bridge-makers, and are for ever changing their courses and dimensions.

In the mean time, though by unchecked natural processes, the finest plateaux of Russia should, in the lapse of ages, be levelled with the plains, yet has the geologist to thank these "avrachs" for most of his best sections; since it is generally near their mouths, where the denudation has been deepest, that the parent-rock or true subsoil is laid bare.

State of the Surface of Russia during the Spring Floods.—Increase of Deltas and Formation of new Lands.—Mud Volcanoes.—Elevations of Land, &c.—The great amount of change which Russia has experienced, and is undergoing by the degradation of her perishable subsoil, is, as we have said, mainly due to an excessive climate. The enormous volume of water, by which large portions of her surface are still covered at every annual melting of the snows, can scarcely be imagined, except by those who have traversed (we may say sailed over) some of the central and southern countries in the spring season, when to the eye of the geologist the lands seem to be emerging, like isles and promontories, on all sides from beneath the waters. It is then that each broad valley is, for six weeks or more, in a condition similar to that which we can imagine to have been the state of England, France and other countries, when their streams, instead of occupying their present beds, were lake-rivers or estuaries of great width, wherein many of the old gravel and sand-banks of geologists were accumulated, and in which the bones of extinct mammals are found.

The height of the waters during this annual inundation can, indeed, be exactly read off, wherever any great stream has rocky banks. In gorges we have occasionally noted the spring high-water mark as having been forty feet above the dry summer level; and when it is considered, that such enormous volumes of water have, for ages, flowed off to the sea through deposits, for the most part incoherent, we can well account for the vast increase of the deltas, within the historic period, at the mouths of all the chief or south-flowing rivers.

So great, indeed, must have been the increment of matter in the Caspian, the Black Sea and the Sea of Azof, that we must not be surprised to find very essential distinctions between the features of the present lands near the mouths of such rivers, and those which prevailed during the earlier days of their occupancy by man. Thus freshwater shells common in the Volga have been found at about 300 feet below the city of Astrakhan, which is thus built upon the mud of that river. By its daily increasing delta, the Caspian Sea is, indeed, constantly encroached upon and diminished in area, the shallow water already extending to forty and fifty miles south of the present embouchure[1]. Thus also, near the mouth of the Don, the formation of new land has proceeded very rapidly; and even since the commercial port of Taganrog was founded by the Empress Catharine, the waters of the Sea of Azof have been so silted up, that large ships cannot now approach within eleven versts of their former anchoring-ground.

Again, in regard to the Dnieper, if we may rely upon Herodotus, who personally examined the coasts of the Black Sea between that river and the Danube, a still greater change must have taken place in its relations to the land. The father of history speaks, for example, of the Borysthenes (Dnieper) having two distinct navigable mouths; and of these features he seems to have been an eye-witness. The easternmost branch, he adds, dividing from the main stream a long way up, fell into the sea to the east of the race-course of Achilles (the Kosa Tendra and Kosa Djarilgatch of our maps); whilst he further speaks of two intermediate, inland, but navigable streams, one of which united with the present river, the other with the lost branch. Whether the desiccation and stoppage of the lost branch of the Dnieper has been occasioned by the formation of fresh land at its mouth, which occupying a portion of the low sandy tract between the mainland and the Crimæa, eventually forced back the waters, and threw them into the present stream; or whether the operation was aided by a rise of the land connected with, or parallel to the great lines of ancient disturbance in the Crimæa and the Caucasus, are points

[1] These new lands at the mouths of the great south-flowing Russian streams are marked upon our Map, Pl. VI., in a peculiar tint. The Sea of Azof, near Taganrog, is ten to twelve feet deep only, and in no part of it do the soundings exceed forty-five feet. The new port of Berdiansk, established by that enlightened administrator of the governments of New Russia and the Crimæa, Count M. Woronzow, is one of the best havens in the Sea of Azof. In the Caspian, which has no outlet, observations are wanting to prove, whether its volume of water is *really diminishing* by an evaporation which exceeds the annual supply of the Volga.

which it would require an assiduous personal examination to determine[1]. For, however the produce of the rivers may have so largely encroached upon the limited internal seas which subtend Russia in Europe, both on the north as well as on the south (St. Petersburgh being, doubtless, in great part built upon river silt of modern date), we must also look to elevation as a cause, which has actually

[1] We are indebted to the researches of Professor Henry Malden, of University College, London and his friendly communication of them, for our acquaintance with this curious point, which bears so directly on modern geological or ancient historical changes. Referring us to Herodotus (B. iv. cc. 16, 24, 54, 55, 56 and 76), wherein that author gives a minute account of Scythia and the Scythians, partly from his own observations, partly from inquiries instituted in the country itself, the learned Professor, in a letter addressed to Mr. Murchison, enters at some length into an analysis of the interpretation which can be put upon the words of the historian, who during his travels had certainly been at the Greek colony of Olbia on the Bug. Though there is internal evidence in his work, that Herodotus travelled over the country between that river (Hypaxis) and the Dnieper, there is no indication of his having crossed the latter, nor of his having sailed along the coast, eastward of its mouth, since he speaks of the race-course of Achilles in such a manner, as to show that he had not seen it, whilst he does not seem to have been aware of the peninsulated form of the Crimæa, nor to have had any accurate knowledge of the isthmus of Perecop. He appears, indeed, to have had an exaggerated notion of the extent to which the Dnieper was navigable (to Gerhi 140 days' sail, the place of sepulture of the Scythian kings), unless we suppose that since his day the waters of that stream have been greatly lessened, and its cataracts formed by elevation of the land. Herodotus speaks positively of the river Gerrhus being *parted off* from the Borysthenes at that part of the country up to which the latter river was known; whence flowing into the Hypacyris, it formed the boundary between the pastoral and agricultural Scythians. Without following Professor Malden through his elaborate inquiry, in which he endeavours to reconcile certain apparent inconsistencies in the account of the great historian, we agree with him, that it is by no means improbable, that in a former period, the Borysthenes may have had a larger delta, and two mouths, though now confined to one,—an opinion also entertained by that sound geographer, Major Rennell. Professor Malden further speculates upon the eastern stream of such a delta having been the Gerrhus; whilst the rivers Panticapes and Hypacyris, cited by Herodotus as flowing out of lakes between the Borysthenes and the Gerrhus, accord well (he says) with the notion of a great former delta. As, however, it appears that the brief descriptions of Strabo are not inconsistent with the present state of the country, the Gerrhus of Herodotus may, after all, be the same river alluded to by Ptolemy under that name, and which some persons have supposed to be the present Molotchina, which falls into the Sea of Azof. Regretting that, with our slight personal knowledge of this tract, we cannot offer to our learned friend any fresh physical knowledge to enable him to decide on the relative merits of certain passages in history, we may say, that apparently no geographical feature exists which can have prevented the Dnieper from having formerly had two mouths, the easternmost of which proceeding from the spot named Kakofka may have flowed due south either by Katlantchak into the Gulf of Perecop, or into what is now the Putrid Sea, whilst the other branch passed, as at present, by Kherson to the west. However difficult it may be to reconcile all the statements of Herodotus, his general assertion, that streams east of the Bug were navigable to ships for some distance from their mouths, where no rivers are now to be seen which are even accessible in boats, ought to induce us to suppose, that since his time desiccation may have taken place to a considerable amount.

produced still more decided changes,—changes whereby the grounds which are known to have been formerly submerged, have been placed at some height above the waters.

In this manner, we necessarily distinguish the changes which occurred in the tract between the Palus Mæotis and the Black Sea, before the times of the Greeks and Romans, from those which can have been since produced by the mere increment of fluviatile deltas or blown sands at the river mouths. The origin of the peninsula of Kertch and the Isles of the Kuban, must, we agree with M. Dubois de Montpéreux, be referred to such elevation of the land[1].

Changes produced by Mud Volcanoes, &c.—That similar elevations have been in progress from still remoter antiquity in all these southern regions, we have already attempted to show, and particularly in regard to the bottom of a former great Caspian Sea which we have proved to have been upheaved and desiccated at successive periods. Now the very coasts of the Chersonesus where marked changes have occurred in the historic æra, are in the vicinity, or, it may even be said, in the ancient line of elevation of the Caucasus and the Crimæa, along and parallel to which, mud volcanoes have been erupted, that have continued in action to the present day, and have raised up land above the waters which did not exist in the time of the ancient historians.

[1] For a complete illustration of this branch of our subject, we gladly refer to a most instructive plate in the work of our distinguished contemporary, M. Dubois de Montpéreux. That plate contains five small maps, each representing the condition of the tract between Circassia and the Caucasus on the one hand, and the Crimæa on the other, during successive periods. In the first the Chersonesus Tauricus appears as a cretaceous promontory, separated by a wide strait from another advanced cretaceous spur of the Caucasus (Circassia),—in short, after the elevation of the chalk, and when the tertiary deposits were nearly completed, a few of their coral islands only appearing above the waters to the north of the strait. The next map exhibits the tract after the elevation of the tertiary formations, by which movement the peninsula of Kertch was united with the Crimæa very much in its present form, yet when a few isles only and the Cimmerian Bosphorus had been formed. The third gives the apparition of Taman and several adjacent isles of the Kuban through the eruption of mud volcanoes. The fourth, which is the historical portrait of the outlines, as restored from the writings of Strabo, exhibits the chief islets of the Kuban already united with the main land, yet leaving free maritime passages for the Greek sailors of those days, to the east and south of the Cimmerian Isle, with the river Hypanis flowing to the north-west into the embayed waters between the Cimmerian Isle and the Sindic promontory. The fifth and last plan, as taken from an accurate map of 1834, shows how the Hypanis (the present Kuban) has changed its course, and now flows to the south and west below the former Sindic promontory, which was thus converted into the isle or peninsula of Taman, whilst the larger islets are almost united, and some of the smaller absolutely joined to the main land (the old sea-passages being blocked up) by the great increment of deltic matter.

That some of these elevations occurred within the historic æra, may be inferred from the fact, that in the walls of the fortress of Sudac, near Theodosia in the Crimæa, we ourselves saw stones procured from coast-cliffs, which contained shells of the *Cardium edule* and *Mytilus edulis*, now living in the adjacent Black Sea, and which we are disposed to think must have been thrown up on the line of eruption of the mud volcanoes, and parallel to the axis of the Caucasus (see Map, Pl. VI.). The opinion we formed upon the spot, that these mud volcanoes have a deep seat, and are as directly connected with internal igneous agency as any other geological phænomenon of eruption, is, we think, sustained not only by their extension over a tract 200 versts in length (that line of direction being coincident with the fires of Bakù and other mud eruptions in the Caspian), but, above all, by the occurrence of fragments of limestone and shale (unlike any portions of the surrounding strata), which they have ejected with their mud and scoriæ[1]. These mud volcanoes are, therefore, in our estimation, the last remnants of ancient and more intense igneous action, by which enormous masses of sedimentary matter have been hurled up, in former epochs, to constitute the lofty Caucasus.

In alluding to these southern tracts of Russia which have been so recently illustrated by M. Dubois de Montpéreux, by the French savans employed by M. Demidoff and by M. Hommaire de Hell, whose work is not even completed whilst we write, we must again render justice to Mr. Strangways, to whose manuscript, read 21 years ago before the Geological Society, we have previously alluded[2]. Speculating upon the probable former connection of now detached masses of water which might then have formed an eastern Mediterranean, and citing Strabo, and his commentator Gosselin, for various descriptions of ancient geographical features, including the probable voyage of the Argonauts beyond the Crimæa, which must then have been an island, he concludes with the following striking passage:—

"By whatever cause it may have been drained, the low steppe exhibits no diluvian phænomena, no system of valleys, no sign of a debacle or sudden and violent

[1] See M. de Verneuil, Mem. Soc. Géol. de Fr., vol. iii. p. 6–10. Strangways also mentions the presence of fragments of limestone and shale in the black bituminous mud and red scoriæ as an indication that the seat of the eruptions is deep. (MS., read before the Geological Society of London, anno 1824.)

[2] Mr. Strangways further makes a suggestion respecting the desirableness of the very operation which has been recently carried out by M. Hommaire de Hell. "It is much to be regretted (he says in allusion to the operations of MM. Parrot and Engelhardt) that they did not make their observations along the course of the Manych instead of across the high steppes. The greatest elevation of the low steppe above the Sea of Azof is still undetermined."

retreat of the water. Its present state must therefore be attributed, I think, to *a gradual drying up of the sea which covered it, till in process of time it became broken into a series of lakes*, the level of which is determined by the proportion which the water poured into them by rivers or falling from the clouds, bears to that taken from them by evaporation." In support of this view, Mr. Strangways, quoting Pliny, further shows that such was the opinion of the ancients. "Sed in Carcinite Tauricâ incipit, *quondam mari circumfusâ et ipsâ*." Plin. iv. 12. "Ad hos confugerat Mithridates Claudio principe, narravitque Thulos iis esse confines, qui ab oriente Caspii maris fauces attingerent: *siccari eas æstu recedente*." Plin. vi. 5.

Though opposed to our own view, which has been already to a great extent expressed (p. 314), viz. that elevations to various levels will alone adequately explain the phænomena of the steppe limestones and sandy steppes (both the bottoms of a former Caspian), we specially cite these passages to prove, that the opinions which have been recently sustained, particularly by French authors, respecting the desiccation of the Caspian and other inland sheets of water by *evaporation only*, was anticipated by the earliest of our contemporaries who wrote upon the geological structure of Russia, and who, unacquainted with many of the facts elicited by subsequent researches, endeavoured to explain existing phænomena by evidences of ancient tradition, which had escaped the notice of his precursors.

Changes operated by Man.—But besides such great natural alterations of outline and the diurnal wear of the surface, there can be no doubt, that man himself has produced considerable changes. Thus for a long time most geographers viewed as little better than a fable, the tradition or opinion derived both from the features of the country, the details of the historians of Alexander the Great, or the recital of the old English traveller Jenkinson, that the main stream of the Oxus once flowed into the Caspian Sea.

Humboldt has the merit of bringing out in all its force the high probability of such having anciently been the case, and a very modern discovery of M. N. Khanikoff has, we think, strengthened his inference. It has been recently ascertained that the river Tanghi-Daria (the Orontes of the ancients), which formerly flowed into the sea of Aral in a line considerably south of the Jaxartes, was deflected into that stream a few years ago by the mere manual operation of the natives (the Khokans), who fearful that their well-watered tract might fall a prey to their warlike and predatory neighbours of Khivah, constructed a dam and turned their river northwards to the Jaxartes, thus sterilizing a wide and rich tract towards the southern end of the sea of Aral, and contiguous to the Khivan frontier[1].

A similar operation therefore, and possibly of no greater magnitude, effected by the Khivans, may have deflected the principal ancient stream of the Oxus from its course through the low steppe of the Turkomans and by the south of the plateau of Ust-Urt to the Caspian Sea, and have caused the waters of that mighty stream to flow into its present Aralian estuary, thus verifying the words of old Jenkinson, " The water that serveth all that countrey (Khivah) is drawn by ditches out of the river Oxus unto the great destruction of that river, for which cause it falleth not into the Caspian Sea, *as it has done in times past*; and in short time all that land is like to be destroyed, and become a wilderness for want of water, when the river Oxus shall faile[2]."

The hands of man have also produced and are still effecting considerable changes in large tracts of Russia, by the destruction of her forests and the conversion of her northern marshes into arable lands. A few centuries only have elapsed since northern Russia was a dense virgin forest, with vast intervening marshes and lakes, but now her gigantic pine trees are felled, lakes and marshes are drained, and the culture of corn is extended to the latitude of the White Sea. The natural recipients of so much moisture having been destroyed, we may (exclusive of the great spring debacle which in an extreme climate may have been always nearly the same) in great measure account for the sensible diminution of late years in the waters of the Volga and other great streams, whose affluents rise in those very countries where large tracts are now drained.

M. Baer and M. Köppen[3], observers of great authority, have, indeed, supposed, that in truth much the same volume still passes through the Volga as in former

[1] See letter of M. N. Khanikoff to Mr. Murchison, Journal of the Royal Geogr. Soc., vol. xiv. p. 333, where it is shown, that even in the year 1810! the Tanghi-Daria was a copious stream.

[2] See Hakluyt, vol. i. p. 367, ed. 1809.

[3] See a Report of a Commission by M. Köppen, with a preface by M. Baer, " Ueber den Wald und Wasser vorrath im Gebiete der obern und mittlern Wolga. Beiträge zur Kentniss des Russischen Reiches, vol. iv. St. Petersburg, 1841." In this memoir, a distinction is drawn between the moisture proceeding from the Atlantic with its westerly gales, and that of the White Sea with its north-easterly winds. The main fact however is, that the sources of the Volga (and this applies to many other Russian rivers) were spongy marshes, which are now so much drained, as to occasion a diminution in the volume of the stream at certain seasons.

periods of Russian history, but that owing to drainage of the marshy woodlands which fed that stream, it is not held back for a length of time, as of old, in the upper natural reservoirs, but flows off quickly into the low countries, and being carried in a short season to the sea, leaves the river too low for navigation in the height of the summer season. Whether this opinion be adopted or that of a sensible annual diminution of moisture, caused by the destruction of dense forests which formerly obstructed evaporation, the result is the same as concerning the effects upon the surface and the internal tracts of the country. For our own part, we can scarcely refrain from thinking, that the axe of the miner (for wood is the chief fuel of the Russian mines) has been a prime cause of this increasing drought; an opinion which we formed in the Ural Mountains, from whence the Kama and greatest feeders of the Volga proceed, and where the inhabitants, complaining of the annual decrease of water, invariably refer this effect to the clearing away of their forests.

Conclusion.—In terminating our view of the physical structure and mutations of so vast a portion of the earth's surface as Russia in Europe and the Ural Mountains, we will not attempt to recapitulate, in any lengthened detail, the various results of our labours, nor revert to our inferences respecting coal and other mineral productions and their intimate dependence upon geological conditions[1]. Those readers who may have had the patience to peruse this volume, will, we trust, have found no want of illustrations of our views on every geological subject, from the formation of the earliest deposits to the comparatively recent changes which have just been alluded to.

Our first effort was to impart to the reader a correct view of the succession of the various sedimentary strata which constitute the framework of these regions, by laying before him a series of evidences of the order in which the different forms of ancient life succeed to each other. In all that portion of the work, there are, we may be allowed to say, no theoretical views whatever. We have there simply unfolded the leaves of fossil records that attest the former presence of many generations of animals, which having respectively lived their day, were succeeded by others. In so doing, we have endeavoured to act as fair and impartial historians, and we are bound to say, that the examination of the subsoil of Russia has very much extended and improved our general knowledge of the events, which have

[1] See Preface, and pp. 77, 89 to 123, &c.

taken place upon the surface of the globe, whether as respects the most ancient or more modern accumulations.

In the first place, we have indicated the existence over large tracts in Scandinavia, the Baltic provinces and northern Russia, of those Lower Silurian strata, which by extensive examination of various countries, have been found to contain the earliest vestiges of animal life. This point has, indeed, been rendered singularly clear in Sweden, where Lower Silurian rocks, perfectly identified with those of their typical regions in the British Isles, rest at once on crystalline or azoic rocks of antecedent date, in which the remains of all organized beings, if such there ever were, have been entirely obliterated. Representing as elsewhere the lowest recognizable stage charged with organic matter, the Lower Silurian rocks of Sweden and Russia teach us, that among the earliest animals known to us were crustaceans, with eyes[1] suited to the recesses of the seas in which they lived, and that these, with certain Mollusca, Zoophytes and Crinoidea, which have long since passed away, were associated with marine fucoids, the latter being, as far as we know, the only vegetables of which there is a trace in this protozoic group.

The next or Upper Silurian stage of Russia and the Baltic Isles is remarkable for the close analogy of all, and the identity of a great number of its mollusks and corals with those of the same period in the British Isles. In it, however, no traces of fishes have been found; a negative fact which induces us to remark, that whilst the Lower Silurian formations have nowhere offered the fragment of a vertebrated animal, and that a very few small fishes of peculiar form have only been found at some localities of the Upper Silurian deposits in England (chiefly in their highest beds), the system must, on the whole, be viewed as one almost void of this great class of organic beings.

The Silurian system of the northern countries of Europe is indeed closely analogous to that of Great Britain; and its examination has taught us, that wherever the sediments of the same age in the two regions resemble each other in lithological texture, such similarity is accompanied by a close approximation and frequent identity in the associated organic remains.

The survey of Russia has next strikingly confirmed the fact, that the Devonian or Old Red system of English geologists is the second great natural group of deposits in the ascending order; and there, as in the British Isles, it is the great fossil "*piscina*," in which the mass of the earliest fishes has been preserved. The

[1] See Dr. Buckland's masterly description of the structure of the eyes of Trilobites, "Sixth Bridgewater Treatise," vol. i. p. 396.

development of the Russian strata of this age has further dispelled all doubt concerning the identity between the Old Red Sandstone of Scotland with its ichthyolites, and the slaty, calcareous rocks of Devonshire and the Rhenish provinces with their shells and corals, since it exhibits innumerable proofs, that the fishes and mollusks, which in most parts of western Europe appear to have been severally peculiar to smaller detached basins, were in this region living in the same sea, and entombed in the same beds. Here also, as in the Silurian rocks, we perceive a marked connection between the mineral character of this deposit (which occupies so vast an area in Russia) and its imbedded fossils; for in certain great sandy tracts of that empire, as in the Scottish Old Red Sandstone, its organic remains are exclusively those of fishes; whilst in districts, where calcareous and diversified strata occur, similar species of fishes are associated with mollusks and other organic bodies.

Ascending to the third system, it has been shown, that a very large portion of Russia is occupied by limestones and associated shales and sands, which, from their fossils, are completely assimilated to the carboniferous or mountain limestone of other well-known countries. Trilobites, extremely abundant in the Silurian and rare in the Devonian strata, become very scarce in this deposit; and though ichthyolites, including some of peculiar sauroid forms, are abundant in this formation in England, Belgium and France, they seldom occur in Russia; a scarcity which may have depended on the absence of favouring submarine conditions. Brachiopods entirely different from those of the subjacent formations, constitute, in truth, the great and general terms of distinction; many of the species being absolutely the same as those of the like age in the British Isles, even when the deposit is followed into the low countries of Siberia. In the regions under review, as elsewhere, these carboniferous rocks are the lowest receptacles in which numerous land plants have been found, and these vegetables also are often undistinguishable from those which occur in similar beds of western Europe. These and other examples observed at Melville Island, the north coast of America, in Spitzbergen and Nova Zemlia, as well as in the more southern latitudes of Europe, have led us to believe, that in all those ancient periods, when the same species of shells lived in seas distant from each other upwards of 4000 miles, and when the first tree-bearing lands, whether Arctic or equatorial, produced the same great monocotyledonous plants (the source of all great coal-fields), there must have been a lower and more uniform outline of the surface, and consequently a climate infinitely more equable and universal, if not more warm, than at the present day[1].

When thoroughly examined, the rocks of each new country are found to fill up lacunæ or present new zoological evidences; and thus in Russia we have first learnt, that the minute foraminifera occur in strata of such high antiquity as the carboniferous.

The exploration of the enormous basin of red sands, marls, limestones and cupriferous deposits covering a vast region, of which the ancient Permia is the centre, and a comparison of the same with synchronous deposits in Germany and England, have led us to propose a common name for a group, which we have shown is naturally and indissolubly connected with the three underlying or palæozoic systems, and entirely distinct in all its contents, whether animal or vegetable, from the overlying secondary formations. This point is, we consider, of great importance in geological classification, particularly with reference to other countries where such deposits have been generally, though erroneously, connected with the New Red Sandstone, whilst, in truth, they are intimately related to the coal strata beneath them. In this deposit the earliest-formed Saurians appear,—animals, however, very distinct in generic character and structure from those of the subsequent epoch.

On the doubtful and partial occurrence of the trias of continental geologists we have little to say, as it is nowhere clearly apparent in Russia proper; though we have expressed our belief that the fossils of Mount Bogdo, in the steppe of Astrakhan, seem to be of the age of the Muschelkalk.

In the Oolitic or Jurassic series, which is so fully developed in England, France and Germany, the lias and lower oolites of those countries are entirely wanting. The Oxford clay and its associated rocks, including the calcareous grit and coral rag, alone appear on the surface, and contain, besides analogous groups of shells, the same species of Saurians as in England; another decisive proof, derived from a comparatively high order of animals, of the continuation of much more widely

[1] The presence of the true carboniferous limestone in Spitzbergen is well known, both as recently observed by Professor Löven, and also through fossils brought to England by the polar voyagers and to Paris by the naturalists of the French "Expédition du Nord." (See Bullet. Soc. Géol. de France, vol. xiii. p. 24.) Indeed, both there and in Nova Zemlia, as proved by M. Baer, coal exists in considerable quantities, though the fossil vegetation, of tropical character, from which it is formed, is for the most part now buried under eternal snows.

extended conditions of climate in those days than in our own. With some subdivisionary distinctions of mineral character, the chalk of Russia is in a remarkable degree analogous, both in mineral and zoological contents, to that of England, whilst some of the lower tertiary beds which overlie it are perfectly similar in their fossils to strata of the same age in the London and other basins. The miocene, or middle tertiary deposits, are, in truth, nothing more than continuations of those of Austria and the Danube, known to be identical with the shelly beds of the north of Italy.

In treating this portion of our subject, we have specially dwelt upon a great physical feature regarding the former geography of the terrestrial surface, to which little or no attention has been previously paid. The steppe limestones of the south of Russia and those surrounding the Caspian, Azof and Aral seas, are shown to have been relics of an enormous inland sheet of water, fully as large as the present Mediterranean, and probably having had scarcely any communication with the ocean. This opinion is strictly derived from the evidences of the organic remains, which, whether imbedded in limestone cliffs at 200 or 300 feet above the sea, or lying loose in the sands of the lower steppes, are all species perfectly distinct from those of the ocean of this or any former date, but identical with or analogous to forms now living in the present Caspian and Aral seas.

In the north of Russia marine deposits with existing oceanic shells occur, also indicating periods approaching to our own; and it has further been shown, that vast accumulations of foreign drift, which encumber the surface, have been accumulated under the waters of the sea. Finally, we have attempted to point out the manner in which certain subaqueous deposits were desiccated, and how after passing into lands they have been since modified.

This long register, from the earliest traces of organic existence, has been read off, notwithstanding the prevalent absence of those facilities which are offered to the observer in other countries. In western Europe, the various strata are often so inclined, that the succession of several formations is frequently seen in escarpments occupying the breadth of a few miles only. The case, however, is not so in Russia, where the whole series of deposits, over an area nearly as large as all that part of Europe to which geologists have hitherto attended, may, with very slight exceptions, be termed a great horizontal mass, the undulations and denudations in which alone enable us to decipher its details of succession, by travelling over the enormous spaces which any one of its members occupies. But however monotonous and fatiguing to the fossilist or lover of varied scenery, this great Russian basin, void of all traces of eruptive rock, is, it must be admitted, unrivalled as a theatre for the study of the sedimentary formations in their pristine state. The contemplation of it teaches us, that wherever eruptive agency is absent, the antiquity of the formations which constitute the crust of the globe, can in no wise be judged of from their mineral or lithological aspect; for the very oldest deposits (Lower Silurian), charged with fossils common to the crystalline slaty rocks of other regions, there occur as greensands and half-consolidated, mudlike limestones, which, together with many portions of the Devonian, Carboniferous and Permian systems, are sometimes not to be distinguished in lithological aspect from the younger secondary or even tertiary deposits of western Europe!

We also learn, that notwithstanding the absence of violent dislocations, the various Russian formations, though horizontal, or so nearly so, that they may be all considered conformable to each other, are as distinctly separable by their included remains, as in those typical and dislocated tracts where geologists first worked out their order. The theoretical doctrine, derived from an examination of a small portion of the globe, which supposes that the termination of groups of former organic beings was entirely dependent upon contiguous eruptions, which ravaging the earth at given periods and dismembering the former beds of the ocean, destroyed its existing inhabitants, must therefore bend before such copious evidences. These evidences most clearly announce, that over spaces as large as other European kingdoms, the sediment of one palæozoic period was accumulated around the relics of a peculiar set of animals and then tranquilly succeeded by another large formation, when different groups of creatures were brought into being, without any sudden revolutions or fractures of those portions of the crust of the planet.

Let us not, however, be misunderstood. Although we have ascertained that the framework of the earth has here undergone scarcely any violent ruptures, we have already adverted to grand and broad movements of elevation and depression to which the whole country must have been subjected, and without which it would be difficult to explain the omissions in the series of deposits whereof we have spoken. Thus it has been shown, that in one of the very earliest periods, the lowest Silurian rocks along the Finnish and Lappish frontier have been highly disturbed and metamorphosed, and that in the Russian Baltic governments, as in Sweden, they have been raised and placed beyond the influence of the waters under which the Upper Silurian deposits of the Baltic were accumulated. The lower and upheaved deposits must, however, have been soon after depressed, for the Devonian strata with their ichthyolites are found resting on them. Again, we believe that the great central dome of the Devonian rocks of Orel was elevated not long after its formation, and, acting as a bar or line of separation in the waters, thus produced a distribution of sedimentary matter on its southern side very different from that upon its northern, and separated the great cretaceous and tertiary country on the one side from the palæozoic rocks on the other.

Looking to the differences, however partial, between the fossil floras of the carboniferous and Permian rocks, we cannot but infer, that these plants were in existence upon adjacent lands during each of these periods; nor can we view the existence of the Jurassic series with its Ammonites and Belemnites, nor mark the great hiatus which exists between the base of this group and the Permian rocks beneath it, without believing, that broad and decided oscillations of sea and land took place both in and around these regions, which placed certain masses above the influence of the waters, during the very long interval of time which necessarily elapsed.

Yet, after all, Russia in Europe constitutes but one huge depositary basin, surrounded on nearly all sides by plutonic, metamorphic and crystalline rocks. We readily therefore admit, that the various changes which took place in Scandinavia and Lapland on the north, in the Ural Mountains and Siberia on the east, in the Caucasus and granitic steppes on the south, and in the Carpathian and Silesian mountains on the south-west, may have considerably affected the conditions and influenced the relations of all the sedimentary accumulations of the low territories of Muscovy. Still, notwithstanding this admission, we dwell upon the fact, that such enormously wide horizontal deposits of different ages are nearly all conformable in superposition, and yet all clearly separable from each other by mineral characters and organic remains;—thus decisively showing, that old races of animals have disappeared and have been succeeded by others over vast regions, in which there never has been the smallest eruption of plutonic or volcanic matter.

However we may explain its elevation to various levels, the ancient bottom of one great inland internal sea of brackish water, large as the present Mediterranean, which occupying, as we have stated, a vast depression in the earth's surface between the Caucasian chain and Russia, extended over enormous tracts of Asia, must be considered as having originated in great physical changes. In the present condition of nature, we compare that vast internal brackish sea with the present Caspians within its area, and thus from fossil reliquiæ, some at considerable altitudes, and others very little above the present waters, we can safely affirm, that this ancient Mediterranean was for a long lapse of ages almost if not entirely shut out from the ocean, its bottom having subsequently undergone successive elevations *en masse*, like those of the central Russian deposits.

If these are among the results of our investigations of the tranquilly-formed deposits of Russia, and if light has been thus thrown upon the land-marks of geological science; the explorations of the Ural Mountains have, we trust, proved not less interesting, by exhibiting a picture of intense disturbance and mineralization in regions which teem with metalliferous wealth. And what a contrast to European Russia! In vain do we there search for a single foot of subsoil of the palæozoic age which has not undergone agitation, change or fracture caused by repeated emission of masses of eruptive matter commencing from very remote periods.

By these operations the palæozoic rocks of the Ural have been metamorphosed, in great part changed in their external characters, and were also thrown up to form land (probably at first of no great altitude), whence peculiar plants of a very ancient date were washed towards the west into the sea of that epoch, under which the cupriferous Permian deposits and their marine remains were accumulated. The dark-coloured, hard, veined and crystallized condition of the older palæozoic strata in the Ural, where eruptive agency has been in activity from the remotest æra, when contrasted with the white, soft, muddy limestones and incoherent sandstones which were originally formed at the *same time* in the tranquil basin of European Russia, must, indeed, be received as a convincing proof, that such a rocky crystalline character has been caused by the action of internal heat, which in the Ural and Siberia made its way to the surface in the form of varied plutonic eruptions.

In explaining the different elevations by which the present outline of the Ural chain was elaborated, we consider the principal movement—that which twisted the strata and often inverted them—to have taken place after the formation of the carboniferous limestone. We have further shown, that, after the Permian strata had been deposited in horizontal positions on the edges of the older rocks, they were affected by newer lines of upheaval of much less intensity and extent, but perfectly parallel to the chief meridian chain. Lastly, we have proved, that since then, and at an epoch comparatively recent, the central axis of these mountains, or at least its watershed, has been so modified, that all the rich and original masses of copper ore from which the arenaceous deposits on the west must have derived their cupriferous materials, are now shut out from all physical communication with them, and lie on the eastern flank of the Ural ridge.

But although it has been thus demonstrated, that in a general sense (subject to great local deviations) these lines of disturbance, produced at different periods, have all, more or less, a meridian direction, such facts do not impugn the value of one of the leading speculations of M. Elie de Beaumont,—that relative directions of great mountain chains are indicative of the age in which they were thrown up. No one can look at our general map without seeing, that it exhibits three grand natural features which support this portion of the theory of our eminent contemporary. Thus, the Scandinavian mountains, along which the older palæozoic rocks only have been elevated, range from south-west to north-east. In the Ural, where the chief disturbances have taken place *after* the carboniferous and Permian deposits (neither of which formations exist in Scandinavia), the direction is north and south. And thirdly, in the Caucasus, in which no vestige of palæozoic life has been detected, and where the mightiest upheavals have occurred posterior to the oolite and the chalk, the range is distinctly from west-north-west to east-south-east. These data, therefore, as established by geological labours, compel us to believe, *that there is a connection* between certain great lines of elevation of the earth's surface and the periods at which they were produced.

From the absence of all marine deposits of tertiary or recent age, either in their valleys or on their immediate eastern flank, we feel confident, that the Ural Mountains and the adjacent regions of Siberia had been long above the waters and were the habitations of the mammoths and other great quadrupeds, before the gold alluvia were formed and the present watershed or Ural-tau was established. And whilst these portions of the earth were already terrestrial surfaces, it has been shown, that the whole of northern Germany and Russia must have been beneath the sea, under which the erratic blocks and gravel were transported from Scandinavia and Lapland.

If from these mighty oscillations in the north, we turn to the consideration of the southern and south-eastern limits of this great empire, how are we to account for the grand and equable elevations of large regions and the violent disturbance of all the sedimentary deposits in the Caucasian chain, without explaining them in the same way as those of Russia and the Ural? Yet, however analogous, the phænomena of the Caucasian chain, as just expressed, are very different in age from those of the north or the Ural Mountains. And as the eruptions, by which enormous masses of sedimentary and plutonic matter were heaved up to great heights, took place after the consolidation of the chalk; might not, we ask, the raising up of so much solid matter have led to a great corresponding depression in an adjacent portion of the earth's surface? May not, in short, some of the first upheavals of the mighty Caucasus have been the means of separating a wide tract from the ancient ocean, and of occasioning at the same time that vast depression in which the Aralo-Caspian beds were accumulated?

But if we thus hypothetically attempt to shadow out the cause of one of the many great changes which have taken place, it should be remembered, that, with the exception of such passing allusions (including our speculations upon the transport of erratic superficial materials and the accumulation of the black earth), nothing involving the true history and classification of the successive formations of the earth's crust,—nothing, in short, affecting the great truths of inductive geology,—has been advanced, which is not substantiated by ample proofs.

In Russia and Scandinavia, the first pages of true geological history are, we have said, more clearly, legibly and largely defined than in any other region with which we are acquainted[1]; and, in conclusion, we now refer our readers to our second volume, which consisting of a detailed description of the fossil remains in each rock system, constitutes the chief justification of those leading inductions, by the accuracy of which we are desirous of being judged.

It would, indeed, be presumptuous did we pretend, that this work could be regarded as a full and accurate monograph of the structural relations of the vast empire of Russia. But although years must elapse before such a consummation be attained, we offer this outline to the public, in the hope that those who from their knowledge of the subject will be best aware of its imperfections, may approve of the efforts we have made, to lay down and render permanent some additional foundation-stones of geological science.

Finally, may we not say, that every effort made by man to read new lessons in the ancient book of nature has augmented his admiration of the works of the

[1] In North America they are equally well defined. (See Introduction, Chapter I.)

Creator? and when it is seen, that the true history of the changes which He has successively ordained in our planet, from the earliest days of animated nature to the present period, has been evolved by the comparatively recent labours of a few men of science, we may be permitted to rejoice in having formed a part of the zealous band whose researches after truth have developed so many new sources of natural knowledge,—sources, which at every onward step proclaim, in the language of the sublime Italian poet,

> "La gloria di Colui che tutto muove
> Per l'universo penetra e risplende."

APPENDIX.

A.

Description of some characteristic Palæozoic Corals of Russia. By W. LONSDALE, F.G.S.

Syringopora parallela, Fischer.

TUBES slender, nearly parallel, closely fasciculated, rarely branched; outer surface rugose, inner furrowed longitudinally; furrows exceeding twelve; connecting processes very short, unequally disposed; internal, funnel-shaped plates very irregular; medial pipe variable in position and form; terminal cup deep; sides furrowed; intermediate ridges tubercled; edge smooth, sharp.

Harmodites parallelus, Fischer de Waldheim, Oryctographie du Gouvernement de Moscou, p. 161. pl. 37. fig. 6. (Carboniferous limestone, Miatchkova near Moscow.)

The specimen assigned to this species agreed with M. Fischer's excellent figure, and with his description in all respects, except that the enlargement of the tubes at the insertion of the connecting processes was not a constant character. It agreed likewise very nearly with Goldfuss's figure of *Syring. reticulata* (Petref. pl. 25. fig. 8. p. 76), an Olne fossil, which is stated by M. Fischer to occur also in the neighbourhood of Moscow; and is considered by him to differ from *Syring. parallela* only in wanting the enlargements of the tubes (Oryc., p. 161). The author of these Notes not having been able to compare the Russian specimen, under consideration, with one from Olne, or with the fossils from other localities assigned to *Syring. reticulata* by numerous authorities, it has been deemed advisable not to give that specific name as a synonym.

The fine specimen of *Syring. parallela* which was examined, was about three inches in height and width, and one and a half in thickness. The tubes in their vertical range probably equalled that of the mass of the coral, though their diameter seldom exceeded a line. They diverged slightly from the base upwards, but were individually so nearly straight, that the adjacent tubes might be regarded as parallel. The interspaces were very small. The outer wall was seldom well-exhibited, but it possessed considerable relative thickness; and the portions best preserved displayed clearly a very minutely porous structure, somewhat similar to that of *Tubipora musica*. The longitudinal furrows, first noticed in a published account of the genus, it is believed, by M. de Blainville (Man. d'Actinol. p. 354), were, as in other species, not often to be detected. Their exact number was not ascertained, but it exceeded twelve, a determination nevertheless of interest, in an attempt to assign a systematic position to the genus, and sufficient, it is conceived, to remove Syringopora from the families Tubiporina or Halcyonina. Where best displayed, the furrows were rather less in breadth than the dividing ridges; and the latter were so prominently tubercled, as to give to perfect casts of the former a similar aspect. The funnel-shaped plates had generally an oblique upper edge, and were extremely irregular in position as well as curvature, and apparently seldom ranged singly around the tube at their superior extremity. The medial pipe, when it could be detected, was commonly excentric, and its range was occasionally marked by an earthy ferruginous stain. Nothing was noticed respecting the transverse processes, except that the pipe by which they were permeated resembled the one in the tubes, and was connected with it. Only the half of a terminal cup was observed, but its sharp edge and furrowed as well as tubercled ribs were excellently shown; the bottom was formed of a portion of a curved plate, moulded against the ribbed side.

No changes incident upon age were observed, the walls at the upper extremity of the tubes varying as much in thickness as at the lower; and there was not the least sign of external additions, by means of a mantle, the parallel tubes though occasionally almost in contact, for some distance, being yet unconnected by any layer of animal origin.

In its general characters Syringopora presents so many affinities to Tubipora, that the earlier describers of the fossils belonging to it, were justified in placing them in that genus. This agreement has been more recently dwelt upon by Fischer, and alluded to by Prof. Goldfuss in making his separation, as well as by M. de Blainville and Dr. Milne Edwards (Lamarck, 2nd edit. vol. ii. p. 327); but it is inferred, from the characters already noticed, that Syringopora should be assigned to that division of Ehrenberg's Zoocorallia which includes genera having more than eight tentacules or lamellæ, and provided with an internal stony structure; and in which that authority has placed the true Turbinoliæ.

Localities and Formations.—Perimishel, south of Kaluga; Vitegra, Ilinsk on the Tchussovaya: Carboniferous limestone. Odoyef near Lichvin: Upper Devonian?

The latter specimen, two and a half inches in breadth, two in width, and one in height, consisted of closely aggregated tubes, which presented no perceptible differences from those of the carboniferous fossil; but they diverged much more rapidly, and though parallel in some portions of the specimen, they exhibited great irregularities of growth, due apparently to external disturbing causes.

Syringopora distans.

Tubes not closely fasciculated, slightly bent; branches few; connecting processes distant; funnel-shaped plates irregular; medial pipe generally excentric.

Harmodites distans, Fischer de Waldheim, Oryct. de Moscou, p. 161. pl. 37. figs. 1, 2. (Arkhangelsky, ten versts from Moscow in alluvial marly sand.)

M. Fischer considers the Russian coral to be identical with Goldfuss's *Syring. ramulosa* from Olne (Petref. pl. 25. fig. 7. p. 76), but as the author of these Notes did not possess, in this case also, the means of comparing specimens from the different localities, it was considered advisable only to allude to M. Fischer's identification.

The small fragment of *Syring. distans* which was examined, agreed generally with the slight though graphic figures in the 'Oryctographie'; but it bore evident marks of friction, and afforded few facilities for ascertaining satisfactorily the structural details. The tubes differed from those of *Syring. parallela* in their greater relative dimensions, the average diameter being one and a half line, and in the strength of the outer walls, both of the tubes and the connecting processes. The walls, so far as the characters could be ascertained, were externally smooth or very slightly traversed by lines of growth: the substance of which they were composed exhibited faintly a microscopic, reticulated structure, similar to that noticed in the memoranda on *Syring. parallela*; and the cast of the interior indicated, in a few cases, the former existence of slight furrows. The disposition of the internal funnel-shaped plates was extremely irregular, as well as the range of the medial tube, where it could be traced; presenting in each case marked differences from the uniformity delineated in figure 7 *b* of *Syring. ramulosa.* (Petref. pl. 25.) The broken commencements of the connecting processes gave the tubes a very knotty aspect. Their cavities, at the points of issue, were more or less occupied by curved plates, diverging extensions of those in the main stems; but the chief part of the process appeared to be traversed, in the best-exposed case, by a simple pipe of considerable dimensions.

Locality and Formation.—Shidrova, River Vaga. Drift from the Carboniferous limestone.

Syringopora.—In the cabinet of M. de Verneuil is a specimen of Syringopora, resembling in its manner of growth and dimensions the preceding species, but with stronger indications of internal furrows. On account of the silicified mode of mineralization, its characters could not be satisfactorily ascertained.

Locality and Formation.—Ilinsk, on the river Tchussovaya, west of the Ural Mountains. Carboniferous limestone.

Catenipora labyrinthica, Goldfuss.

Goldfuss, Petrefacta, p 75. pl. 25. fig. 5.

Halysites labyrinthica, Fischer de Waldheim, Oryc. Gouvern. Moscou, p. 164, pl. 38. figs. 1, 2, 4. M. Fischer's specimens were obtained from detritus in the neighbourhood of Moscow.

In conformity with the suggestion of Dr. Milne Edwards, this genus is removed from the systematic positions usually assigned to it; but the number of furrows or incipient lamellæ being clearly 12, it cannot be regarded as an "Alcyonien" (Lamarck, 2nd edit. ii. p. 322), and is therefore placed in these memoranda next to Syringopora, and in the 3rd family of Ehrenberg's Zoocorallia.

Localities and Formation.—Isle of Dago. Upper Silurian. Top of Lower Silurian, at Naissi, in Lithuania.

Chætetes, Fischer.

So greatly do the corals referrible to this genus resemble Favosites (Calamopora), that all the authorities, except M. Fischer, by whom palæozoic species have been described, have considered them as belonging to it. M. Fischer, in his summary of characters, observes, that Chætetes is distinguished from Favosites (Calamopora) by the absence in the tubes of "diaphragms," or transverse laminæ. This statement probably originated from an examination of specimens of *Chæt. radians*, in which species the diaphragms are often very widely separated, and not unfrequently have been almost altogether removed by decomposition. In this respect, therefore, Chætetes does not differ from Favosites; but it differs in the absence of connecting foramina, as well as in other essential structural characters. (Oryctographie, &c., p. 159.)

When a specimen of Favosites, retaining in part the substance of the original coral, is vertically fractured, the walls of the adjacent columns separate readily, and the exposed surfaces are clearly shown to present the outer side by exhibiting the irregular lines of growth, and by the total absence of any attached fractured edges of diaphragms. At the re-entering angles formed by the meeting of the planes of two adjacent columns, there may likewise be generally traced an undisturbed line of separation. In those cases in which mineral matter has wholly replaced the original substance of the coral, and has also been moulded on its structural markings, the same tendency to divide along the outer side of the walls is retained, the exposed surfaces equally exhibiting the irregular lines of growth and the absence of fractured diaphragms. Care, however, must be taken in those species which, like *Favosites alveolaris*, have the connecting foramina on the angles, to detect the line of separation along that junction, as the structural inequalities are there often great, and the dividing seams in consequence concealed. In some cases also, an apparently perfect blending is produced by a projecting foramen being received within a corresponding opposite cavity. In all these instances, nevertheless, the exterior sides of the broad planes of the columns are easily parted, and their true nature may be clearly recognised.

On the contrary, in Chætetes the walls of adjacent columns seem to be inseparable, or formed of intimately united laminæ. In extensive sections of *Chæt. radians*, having the interior of the tubes but slightly coated with infiltered matter, not a single instance was discovered of the outer side of a wall. Many flat, vertical planes were noticed, as well as re-entering angles formed by the junction of two walls, situated obliquely to the general surface of the specimen; but in every case the flat plane or the re-entering angle could be traced upwards or downwards till it passed within the area of a tube, and therefore ascertained to be an inner portion of the same tube exposed by fracture; or if this could not be effected, a careful examination of the edges of the planes never failed to prove that they were rough, and that the unevenness was due to the remains of walls which had projected from them, and had constituted inner sides of destroyed columns. In other specimens of the same species, retaining the original substance of the coral but having the tubes filled with calcareous spar, not a vestige of the outer surface of a wall could be discovered; and in others, again, in which the animal structure had been replaced by infiltered matter, characters analogous to those of Favosites could in nowise be perceived.

These differences are believed to be necessary results of the distinct mode by which additional columns were developed in each genus.

In Favosites the additional tubes dependent on the growth of the polypes originated, so far as the author is acquainted with the genus, either in gemmules deposited in interspaces or developed on the extreme margin of the parent polype. In either instance a perfect individuality immediately took place, and the young animal, which rapidly attained considerable lateral dimensions, constructed its tube without the area of the parent column, building up the walls unassisted by its neighbours. In almost every example the sides of the surrounding tubes are impressed by those of the interposed tube, indicating that the whole grew contemporaneously, and that the struggles for space of the vigorous, rapidly expanding young polype interfered with the outline of the walls of the full-grown animal, which necessarily possessed, on account of its lateral enlargement having ceased, no power to resist such encroachments. From the mode of development having been thus wholly interstitial, it is inferred, that the exterior surfaces of adjacent walls must naturally and easily separate. It is further inferred, that the polypes at the superior boundary of the coral mass had no common connexion, but were perfectly circumscribed and separated.

The essential manner of developing additional tubes in Chætetes was, however, by a subdivision within the area of the parent. On examining transverse sections (pl. A., fig. 9 *a*), particularly those in which the coral is but slightly coated with infiltered matter, a plate will be frequently seen projecting from one or more sides: and by extending the research, similar laminæ will be found to range quite across, effecting either a simple subdivision into two areas, or a complex one into three or even four. These intersected spaces are easily distinguished by the plates springing from sides and not angles. Again, in a vertical section of such specimens, thin, interrupted laminæ will be readily detected, ranging perpendicularly within many of the tubes. They are not usually continuous for any distance, but they perfectly agree in their nature with the plates just noticed; and the want of persistence may be rightly assigned to the perishable tendency of the coral. Cases, however, were observed of plates which extended without interruption, and probably from their first development, for more than an inch. In such examples the walls of the original tube ranged regularly upwards, but with a slight divergence, and the introduced lamina, at first not quite medial, gradually assumed that position. From this plan of producing additional tubes, it is presumed that there could be no natural tendency in the component structure of the walls to divide into two plates, as in Favosites; and, further, that the polypes by which a mass of tubes was formed had a community of existence, and were united at the outer boundary of the coral in one animal layer.

Based on these imperfectly explained structures, the following provisional generic characters are proposed:—

A polymorphous polypidom formed of tubes closely aggregated and traversed by diaphragms; walls inseparable; additional tubes produced by subdivisions within the area of the parent tube, or by extensions of the polype along the margin of the coral mass.

To suggest grounds for specific distinctions in fossil corals of so simple a composition is extremely difficult, especially when characters dependent upon the limits of growth have not been ascertained. So far, however, as the describer's observations have extended, the distinctions in the arrangement of the diaphragms afford apparently one means for inferring differential structures; those variations implying, it is presumed, peculiarities in the form of the polypes. In the remarks upon *Chæt. radians* it is shown, that the diaphragms are distributed in concentric or parallel bands, and often at considerable distances, the bands being composed of a single series of plates, or of a variable number of closely-situated laminæ, whilst in the account of *Chæt. Petropolitanus* it is explained, that the diaphragms are irregularly distributed over the whole area of a vertical section. In other fossils belonging to the genus, but not included in this notice, distinct peculiarities were observed. It is further suggested, that the characters exhibited by well-preserved terminal edges of the tubes might afford some aid in specific determinations; a protected surface of *Chæt. radians*, which presented probably a periodical renewal of growth, having the edges surmounted by a series of very prominent tubercles.

The above remarks are not offered with the idea, that the characters alluded to could constitute alone specific distinctions; but they are advanced with the hope, that they may assist in discovering essential structures.

Figure 9 *a* in the Plate A., illustrative of the corals, exhibits the sub-divisional laminæ mentioned in the remarks on the mode of producing additional tubes within the area of pre-existing.

Chætetes radians, Fischer.

Mass elliptical or semi-globose; tubes divergent, polygonal; diaphragms in parallel bands variously composed; superior edges of tubes generally even, sometimes tuberculated. (Plate A., fig. 9.)

Chætetes radians, Fischer, Oryc. de Moscou, p. 160. pl. 36. f. 6. (Miatchkova); Milne Edwards, 2nd edit. Lamarck, Anim. sans Vert., ii. p. 459.

This fine and apparently abundant coral is believed to differ from the carboniferous limestone fossils of England, referrible to the same genus. One of the specimens examined in preparing these memoranda, was a portion of an irregularly elliptical mass, those measurements which might be termed the semi-axis major, or greatest altitude, and the semi-axis minor being respectively four and two and a half inches (fig. 9.). The tubes diverged rapidly in the direction of the latter line, but the curvature gradually decreased as they assumed an upward range, disappearing in the greater axis. The exterior of the specimen presented considerable evenness of surface, but a variable amount of curvature. The diameter of the tubes was about one-third of a line, but the length in some cases appeared to be equal to the altitude of the specimen.

Perfect terminations to the tubes, or such as might be assumed to be perfect, were not noticed, the edges being either fractured and worn or in a state of development, presenting boldly-serrated or tuberculated margins. The mouths were more or less occupied by calcareous spar, according to the amount of infiltered matter; in some cases they were also partially or wholly crossed by the transverse laminæ.

The bands of diaphragms ranged nearly parallel to each other and to the surface of the specimens. The distance between them was generally from one and a half to two lines, and in some cases no distinct band could be detected in an interval of four lines, but near the surface the distance did not exceed one line. In all cases, however, whether the bands were composed of a single series of plates forming a continuous arched line, or of many plates more or less closely disposed, and attaining, it is believed, in some rare instances nearly half an inch in thickness, there were well-defined, relatively broad intervals, in which it was rare to detect even a single isolated plate. The broadest bands which were noticed, were situated at the base of one specimen and near the circumference of another.

The mode of developing tubes within the area of others was exhibited in every transverse and vertical section (fig. 9 *a*), but no satisfactory information was obtained, whereby their commencement could be connected with the production of the diaphragms, or separated from it. The polygonal form in these additional tubes was apparently produced by the gradual deposition of matter at the angles formed by the divisional plates with the walls from which they issued. In some few instances, a round pore, varying in diameter in different cases, was noticed in a thickened interval; and it was considered to present a rudimentary state of an interspacetial tube, developed by an extension of the membrane connecting the polype mass.

Localities and Formation.—Kaluga, and Vitegra, Borovitchi near Valdai. Carboniferous limestone.

Chætetes dilatatus, Fischer.

Incrusting; tubes polygonal, small, short, vertical or inclined; diaphragms not numerous; superior termination of tubes even, or tuberculated at the angles, and granulated on the edges.

Chætetes dilatatus, Fischer de Waldheim, Orye. de Moscou, p. 160. tab. 36. fig. 2. (Miatchkova).

The coral believed to belong to this species, agreeing perfectly with M. Fischer's description, encrusted a specimen of *Chæt. radians*. It occupied a surface about two inches in width and one in breadth; but its greatest altitude did not exceed a quarter of an inch. It was distinguished from the species on which it rested, by the relative fineness of the tubes, the diameter being about one-fourth of a line; and by their generally unconformable position, particularly in the lower portion. The diaphragms, so far as they could be ascertained, were irregularly distributed in this specimen; but in another fossil, from Miatchkova, considered to belong to the species, they were very numerous; and the membrane, mentioned by M. Fischer as surrounding the mouth, appeared to be an imperfect development of diaphragms. In a sheltered position, a few preserved terminations exhibited a bold tubercle at the angles, and a series of finer points along the edges; but no weight, as a specific distinction, is placed upon this character. Divisional plates connected with the production of additional tubes were noticed.

Localities and Formation.—Borovitchi; Miatchkova. Carboniferous limestone.

Chætetes Petropolitanus.

Globular, hemispherical or inversely conical; tubes polygonal, irregularly arranged; diaphragms not in bands but unequally distributed throughout the tubes. (Plate A., fig. 10.)

Favosites Petropolitana, Pander, Beiträge zur Geognosie des Russischen Reiches, p. 100–105. tab. 1. figs. 6, 7, 8, 9, 10 *a*, 10 *b*, 11. 1830.

Calamopora fibrosa, Eichwald, Système Silurien de l'Esthonie, p. 209. 1840.

A careful examination of specimens agreeing with M. Pander's figures and general remarks, led to the inference, that they possessed all the essential generic characters of Chætetes.

M. Pander considers the globular, hemispherical and conical specimens described by him, as varieties of one species; and, it is believed, that the differences which may be noticed internally, depend on the conditions under which the polypidom was developed. In a well-preserved hemispherical specimen, two inches in diameter and nine lines in the thickest part, the tubes did not radiate suddenly from the centre, but the lateral increase had been produced by the successive addition of marginal tubes, which sprung from the base, and slightly inclined outwards. The concave under-surface of the same specimen exhibited, besides concentric irregularities, the oblique lower terminations of the tubes arranged in a manner which resembled radiating lines. In a conical specimen one and a quarter inch in height, and an inch in diameter at the upper (broad) extremity, the increase in width had also resulted from a similar mode of production; but all the tubes necessarily ranged vertically, and the conical surface exhibited also circular irregularities, as well as terminations of the tubes, though less distinctly in that specimen than in another of the same form. A mass of a nearly globular shape, two and a half inches in one diameter, and three in the other, had the surface almost wholly weathered, and therefore exhibited no clear characters; but internally, the arrangement of the tubes agreed with that of the hemispherical specimen.

The original walls of the coral were, apparently, almost membranous, and liable under some conditions to irregular contractions, as well as considerable deviations in the line of growth; but in the large, globular mass, such inequalities were far less conspicuous.

The diaphragms, exposed in vertical sections, of all the varieties of form, were distributed over the whole surface, and without the least indication of grouping in bands. In the hemispherical (pl. A., fig. 10) and conical specimens, which exhibited considerable irregularities in growth, the disposition of the diaphragms was very unequal; while in the large globular mass, a portion of which is represented by fig. 10 *a*, the plates, without observing any definite order, were uniformly distributed. In some portions, however, of the other varieties the number of plates corresponded; and the differences displayed, may, it is believed, be rightly assigned to circumstances which affected the mode of growth or production of the polypes, and consequently modified the distribution of the diaphragms.

With respect to the development of additional tubes within the area of those which pre-existed, it may be stated, that divisional laminæ were noticed in transparent, vertical slices of the hemispherical and globose varieties, though less distinctly in the latter than the former: and that while, in a similar section of the conical specimen, they were not satisfactorily detected, a transverse slice exhibited clearly divisional laminæ, ranging from opposite planes. The whole of these specimens, moreover, proved clearly the powers which the polype mass possessed of extending laterally and producing marginal tubes.

Chætetes Petropolitanus having been considered identical with *Favosites* (*Chætetes*) *fibrosa, var. globosa*, of the Eifel, it is necessary to observe, that in vertical sections of a specimen of the latter fossil, which belonged to M. de Verneuil's cabinet, perpendicular, divisional laminæ within the tubes were noticed, also fragments of the original coral, exhibiting only interior surface-walls, similar to those of *Chæt. radians*; and it was therefore inferred that the fossil ought to be removed from the genus Favosites. As regards the species, it may be stated, that the diaphragms were uniformly rare, without any signs of disturbed growth. The height of the specimen was seven lines.

Chæt. Petropolitanus is believed to be identical with a globose tubular coral which occurs in the Lower Silurian beds of Christiania Bay, Norway.

Localities and Formation.—Nikolsk to Petropavlosk, on the river Volkof; banks of the Siass river; ravines of Pulkovka and Popovka, south of St. Petersburgh; plateau of Czarskoe-eelo; sea cliffs from Narva to Reval. Lower Silurian.

Lithodendron.

The Lithodendra of English fossil zoologists differ materially in structure from the corals typical of the subdivisions of the genus, as originally proposed by Schweigger (Beobachtungen, Syst. tab. VI.). As however those corals have been referred by approved authorities to other established genera, leaving Schweigger's Lithodendron without a representative, and as the continental systematic zoologists who have adopted the genus, more or less in conformity with the original proposer's views, have also included in it corals of great diversity of characters, it has been deemed correct in retaining the generic name, long applied by British geologists to peculiar mountain limestone polyparia, to adopt Prof. J. Phillips's characters, though they differ completely from those of Schweigger.

Mr. Phillips's generic characters are, "cells concave with a prominent central umbo or axis; lamellæ generally twisted or extinct near the centre." Geol. Yorshire, part ii. p. 202. 1836.

To this summary may be added the notice, that the coral is branched, the branches springing from germs developed on the side of the parent stem and never resulting from a subdivision of the polype; that each stem and branch is traversed through its whole length by a single lamelliferous tube; that the exterior of the coral was not thickened by a permanently investing mantle, adjacent surfaces only being partially united by the extension of a limited mantle; and that the lamellæ are simple, but bi-plated and numerous.

By these characters and the internal structure, Lithodendron may be easily distinguished from (1) Oculina, (2) Dendrophyllia, (3) Caryophyllia and (4) Cladocora. From the first by the continuous, central, lamelliferous tube; from the first and second by the absence of external thickenings arising from a permanently investing mantle; from Caryophyllia, as restricted by Ehrenberg, in the branches not resulting from a subdivision of the polypes; and from all the four genera by the peculiar central diaphragms, inclined upwards against the axis, as noticed by Prof. Phillips in his description of species, and represented in his illustrations of the genus. (Geol. Yorks., part ii. pl. 2. figs. 17, 18.)

Lithodendron costatum, sp. n.

Stems closely clustered, cylindrical, strongly ribbed; lamellæ simple, variable; interspaces crossed by arched and inclined plates; central diaphragms sloped upwards, not arched; axis spindle-shaped; terminal cup deep, lamellæ not very prominent, unequal; height of central boss less than depth of cup.

a

b

Fig. a. represents the mode of branching, and of the occasional union of branches or stems.
Fig. b. Vertical section magnified, to exhibit the general characters of the interior.

This species is chiefly distinguished by the neat longitudinal ribs. The specimen examined was about two and a half inches in width and one and a half in breadth, and contained parts of twenty-five closely aggregated stems. The height of the largest portion did not exceed three quarters of an inch, and its greatest diameter was three lines. Only two lateral shoots were noticed, and neither of them was in a position to permit the mode of connexion with the parent stem to be fully ascertained. The more favourably exposed case exhibited transverse sections of the main stem and of the lower extremity of the attached branch. At the junction there was no clear demarcation between the two, but a white, rather excentric line and an imperfect blending of lamellæ. The other branch (fig. *a*), which was fully exposed, as respected position and mode of growth, exhibited from its divergence, a diameter equal to that of the main stem. A perfect transverse section of the connecting animal secretion, presented a repetition of the structure within the tube, or an outer extension, from each surface, of the lamellæ, with intermediate plates, and at the junction there was a strong white line.

An internal vertical section (fig. *b*) not quite through the centre displayed at the opposite edges an irregular band of inclined, curved, or vesicular plates, bounded on each side by an unequal, but more solid layer. Within these bands, intersections of vertical lamellæ were partially exhibited, but the greater portion of the area was traversed by the edges of up-turned plates or diaphragms, sometimes single, more frequently intermingled with subordinate though similar laminæ. A strong white line ranging not quite through the centre, and against which the up-turned plates abutted, marked the position of the axis. In the description of *Lithodendron concameratum*, some further details respecting the internal structure of the genus will be found.

Transverse sections of the stems gave very variable characters. At the circumference there were generally between the lamellæ, one or more series of arched laminæ intersections of the plates, mentioned in the remarks on the vertical structure. The lamellæ, alternately broad and narrow, varied considerably in their extension; and the central area was likewise very unequal in dimensions, as well as in the number and in the curvature of the intersected diaphragms. The spindle-shaped axis was also not uniformly bold.

Locality and Formation.—Perimishel, south of Kaluga. Carboniferous limestone.

Lithodendron annulatum, sp. n.

Stems clustered, cylindrical, faintly ribbed, strongly but irregularly annulated, with subordinate, fine, waved lines; central diaphragms waved, upward inclination not great; axis oval. (Plate A., fig. 5.)

Lithodendron annulatum attained probably considerable dimensions, though the largest specimen examined had an altitude of only three inches, the diameter of the tubes being almost uniformly five lines. It is distinguished from other species, known to the describer, by its bold, rounded, but unequal annular ridges, with subordinate fine lines, and by the waved contour of the central plates (fig. 5 *a*). The only additional point of structural interest observed in this species was the proof, that the cementing layer between adjacent stems was secreted during the growth of the coral—the bold annular ridges being in some cases almost confluent, and the fine lines of growth being distinctly traceable from the surface of one stem across the connecting layer to the surface of the next.

Localities and Formation.—River Issetz, east of Ekaterinburg; Ilinsk, on the Tchussovaya. Carboniferous limestone.

Lithodendron concameratum, sp. n.

Stems aggregated, cylindrical, slender, faintly ribbed, very rarely branched, occasionally united; lamellæ simple, equal in breadth; interstitial plates arched; central diaphragms dome-shaped, more or less crossed by vertical laminæ; axis compressed, not persistent, formed of union of lamellæ; walls without an internal vesicular layer.

This curious coral differs in some respects from the ordinary forms of Lithodendron, yet it possesses all the essential elements of the genus. It is distinguished specifically by the dome-shaped diaphragms. The specimen examined, was three inches in height and one and a half in breadth and depth: it consisted of closely aggregated stems which had a nearly uniform diameter of two lines, and ranged upwards almost perpendicularly. The lateral connexions, so far as they could be ascertained, were few and of limited extent. Only one very imperfect fragment of a branch or side-shoot was observed.

The outer wall, as exposed in vertical and transverse sections, was thin and without a trace of vesicular lining. The external ribs in a few protected stems were distinct and round. The lamellæ, about twenty in number, sprung directly from the inner surface of the wall, and were simple in structure and uniform in breadth in any single transverse section, but their characters varied according to the nature of the section and the state of preservation. The perfect diaphragm formed a complete dome with a slight spindle-shaped opening or impression in the centre. A well-preserved under surface was surrounded by a circle of narrow lamellæ apparently perfect, as the edges presented an almost uniform, arched outline; between these lamellæ were the interstitial commencements of the diaphragms, and from their edges grooves ranged upwards for some distance towards the centre of the dome, but there was not the slightest trace of even an attenuated extension of the lamellæ in the grooves. The centre of the dome was a uniform smooth surface, with only an impression of the apex of the axis.

The superior surface of the diaphragms had, under all conditions, near its circumference, a series of radii of variable dimensions. In one case, which exhibited what was probably a portion of the upper side of an inner layer of the diaphragm, slightly raised lines were visible, agreeing in position with the furrows on the under surface of the dome, and the centre was smooth to a similar extent. The other half of the same diaphragm had a distinct coating independent of an incrustation, and was traversed by sharp ridges which ranged to the very centre. In other cases these ridges were developed into prominent lamellæ, which converged boldly from the inner side of the wall and terminating centrally, formed a projecting boss or the axis. Some transverse sections exhibited an inner circle, in consequence of the removal of the middle of a diaphragm and the exposing of subjacent lamellæ.

Whether the intervals between two successive diaphragms were fully intersected by lamellæ-plates was not satisfactorily ascertained, as in the majority of vertical sections, which exposed the interior of the stems, the structure had been very partially preserved. In one instance, however, a series of successive intervals so far retained their original characters as to lead to the inference, that the lamellæ-plates wholly intersected those chambers with the exception of a relatively large aperture near the apex. This inference would apparently accord with the previously noticed smooth or unfurrowed surface of the central portion of the under side of the diaphragm.

The axis exhibited very variable characters, but these differences were also chiefly due to the degree of preservation either of it or of the surrounding laminæ. Being essentially composed of a union of the latter (developed upwards to the under surface of the diaphragm), its distinctness or prominence, in a transverse section, depended on the fracture or the amount to which it had been separated by weathering from the environing plates. In some cases it displayed a conical boss, in others it was apparently wanting. In vertical sections it exhibited, where preserved, a compressed body ranging between the successive diaphragms and surrounded by fractured edges of lamellæ, sometimes almost inconspicuous, but sometimes extending outwards like the ornamental sculpturing of a pinnacle. It is inferred that the axis never penetrated the diaphragm, on account of the mode of production and the perfect dome-plate, before noticed, being only indented in the centre.

Locality and Formation.—River Oceter, Government of Tula. Carboniferous limestone.

Lithodendron fasciculatum, J. Phillips.

Stems cylindrical, nearly smooth, often united laterally; lamellæ simple, alternately broad and narrow; central diaphragms highly inclined, curved; axis spindle-shaped; walls with an internal vesicular layer.

Lithodendron fasciculatum, Phillips, Geol. Yorkshire, part ii. p. 202. plate 2. figs. 16, 17.

Madrepora, Parkinson, Organic Remains, ii. p. 51. plate 6. fig. 8.

It was deemed advisable not to quote the other authorities who have noticed this species, more than one coral being probably described under the same name.

The Russian fossil assigned to *Lithod. fasciculatum* differed not essentially in any of its details from specimens obtained at Bristol, and identical with Parkinson's figure quoted by Prof. Phillips.

Locality and Formation.—River Tchussovaya, west flank of Ural Mountains. Carboniferous limestone.

Cladocora? sarmentosa, sp. n.

Stems cylindrical, slender, fasciculated; lamellæ simple, alternately broad and very narrow; interstitial plates very irregular; centre no axis, but blending of lamellæ; external wall thin, fine transverse ridges.

This coral resembled externally and in mode of growth the Lithodendra of the carboniferous limestone, but it had no axis or upturned central diaphragms, nor were the adjacent stems in any way united. In the simplicity of the internal structure, which admitted of no subdivisions into areas, there was an agreement with the Cladocora of Ehrenberg (e. g. *Clad. lævigata*, *Madrepora flexuosa*, Solander and Ellis, plate 31. figs. 5, 6), also in the total absence of external thickenings as well as lateral junctions; there were, moreover, no signs of regular bifurcations of the stems; but as the true mode of production of the lateral branches was not ascertained, it was considered correct to mark the generic determination as doubtful.

Several fragments of this coral were examined, but they appeared to be, for the greater part, portions of one mass. The height and width of the principal specimen were about two inches. The stems, which were separated by slight intervals, were nearly cylindrical, slightly flexuose, and had an almost uniform diameter of two lines.

The outer wall was exceedingly thin, and apparently had no decided vesicular lining. Externally it was traversed by close, fine, annular ridges and stronger irregularities of growth, and partially decomposed surfaces exhibited faint indications of vertical ribs. The lamellæ, which sprung directly from the inner surface of the wall, were about thirty in number, and were alternately broad and very narrow, the former ranging with slight flexures to the centre. They appeared to have been simple in structure, but liable to fracture and decomposition, presenting in many cases considerable irregularities and occasionally indistinctness of outline. The interstitial plates displayed, in the best transverse sections, a series of fine arched lines, parallel to the wall and at a short distance from it; other similar curves, but not forming a regular series, also appeared nearer the centre. In vertical sections the plates exhibited fine straight lines, though without any great uniformity of arrangement: they had evidently been very liable likewise to fracture and decomposition.

The centre had no distinct axis, consisting merely of a union of the broader lamellæ with occasionally an additional plate, as if a lamella had divided.

Only one very unsatisfactory instance of the base of a lateral stem was noticed.

Locality and Formation.—Kamensk, east of Ekaterinburg. Carboniferous limestone.

Columnaria sulcata, Goldfuss.

Tubes 5–6 sided; sides generally unequal; lamellæ alternately broad and narrow, sometimes straight and simple, sometimes irregularly curved and fasciculated, united in pairs at the periphery by curvatures; interspaces, numerous connecting plates; centre, union of broader lamellæ, no axis; outer wall unweathered, flat; weathered, crenulated; terminal cup very deep; young tubes interpolated laterally. (Plate A., fig. 1.)

Goldfuss, Petrefacta, p. 72. tab. 24. fig. 9. (Bensberg); De Blainville, Man. d'Act., p. 351; Milne Edwards, 2nd edit., Lamarck, Anim. sans Vert., tom. ii. p. 343.

So far as the Russian specimen could be compared with Goldfuss's figures and description, no essential differences were noticed, and the only observed variation consisted in the occasionally irregular range and uniting of the lamellæ. With respect to Goldfuss's additional remarks on the species (Petref. Zusätze, p. 245), and his identifying it with *Cyathophyllum quadrigeminum*, it will perhaps be sufficient to state, that, independent of internal structure, the reproductive process of Columnaria is distinct from that of Cyathophyllum, and if any of the corals figured under the name of *Cyathop. quadrigeminum* (pl. 19 fig. 1 *a* ?) exhibit that process, they should be separated from both the species and the genus.

The grounds for considering *Lithostrotion* to be distinct from Columnaria, with which it has been united by M. de Blainville (Man. d'Actinol., p. 350), will be found in the concluding paragraph of the general remarks on that genus.

The Russian specimen which was examined, formed apparently part of a hemispherical mass. It was about three inches square on the upper surface, and one and a half in thickness at the outer edge, the lower surface being very uneven. The columns in general diverged slightly. Their form was very irregular, the relative dimensions in the sides of even the fully-developed being often extremely unequal. The diameter of the more regular, which had attained this state, averaged two and a half lines.

In an endeavour to trace the mode of production of the young columns and their progress towards maturity, it is necessary to premise, that no instance was observed in the series of exposed transverse sections of a line indicating a fissiparous process, or of such an irregularity among the lamellæ as would arise from the development of germs. The earliest signs of young columns existed in the occurrence of small intervals, irregular in form, but surrounded by facets of adjacent columns as perfect in their boundary structure as were the facets of the other sides adjacent to which no intervals appeared (fig. 1, 1 *a*). The outline of these spaces was generally more or less curved, producing convexities in the planes of the adjacent columns, and where it was three-sided it resembled a spherical triangle. This character is conceived to be of importance; for if the curvature had existed uniformly only on the facet of one of the older columns, it might have indicated a fissiparous separation from that column. It is believed, however, that the curves may be considered to have resulted from the struggles of the young polype on all sides for room; and that it was therefore called into existence while the older polypes were constructing their tubes, and had not given them a sufficient solidity to resist the outer pressure.

In the next state the intervals (which apparently arose from a decay of feebly-constructed solid parts) were occupied by lamelliferous tubes (fig. 1, 1 *a*), agreeing perfectly in character with the mature columns, except that the number of lamellæ was much smaller, and that the sides were considerably curved. Between this state and the fully-developed no other changes necessarily appeared than an increase in the number of the lamellæ and a tendency to produce, for the greater part, straight walls.

A perfect vertical exterior of the columns was not exposed, but in transverse sections a nearly even line traversed the middle of the comparatively thick opake layer, which intervened between the adjacent stellated lamellæ (fig. 1 *a*); proving clearly, that the walls were separable, and resulted from the labours of individual polypes. The outer characters so excellently given in Prof. Goldfuss's figures, 9 *a* to 9 *c*, plate 24. (Petref.), were also well exhibited in weathered or decayed portions, and clearly shown to be due to the removal of the exterior and the preservation of the arched union of pairs of the lamellæ.

The only perfect terminal cups which were preserved, were seated below the surface and within the specimen, having belonged to polypes prematurely killed, and overarched by the lateral extension of other columns. They were deep and elliptical in outline (figs. 1 *b*, 1 *c*), and totally unlike those of the coral represented in plate 19, fig. 1 *a* of the 'Petrefacta Musei Bonnensis.' They were lined by regularly curved, slightly projecting lamellæ, the alternate narrower plates descending also nearly to the bottom. No central boss was exhibited.

Locality and Formation.—Habsal, near Reval. Lower Silurian.

Lithostrotion, Lhwyd.

This name was originally proposed by Lhwyd (Ichnographia, 1699) for a coral figured in the 23rd plate of his work, and designated "Lithostrotion sive Basaltes minimus striatus et stellatus." It was apparently first adopted as a systematic generic appellation by Dr. Fleming, in his 'History of British Animals' (p. 508, 1828); and it has been subsequently retained by other authorities, but without any great precision, respecting essential characters. In a notice on a genus for which the designation of Stylastræa is suggested, will be found reasons for concluding, that Lhwyd's fossil (*Lithost. striatum?* Brit. Anim. p. 508) possesses characters so perfectly different from those of Dr. Fleming's *Lithost. floriforme*, as to render the establishment of a distinct genus necessary. At first it appeared advisable to retain Lhwyd's name for his own coral, and to apply the new one to *Lithost. floriforme*; but as the former fossil is little known, and has probably been mistaken, in some cases, for other fossils of similar general aspect, yet very different structure, and as *Lithost. floriforme* is a well-known, strongly marked coral and excellently figured by Martin in his 'Petrificata Derbiensia' (pl. 43, 1809), though without an available name, it was subsequently deemed correct to apply the new term to the obscure fossil, and the old term to the one which was well known, and by which geologists have been accustomed to designate it.

The characters by which it is proposed to distinguish Lithostrotion from other lamelliferous Anthozoa are the following.

A coral composed of stems generally coadunated; interior of stems separable into three differently constructed areas; 1, a central axis; 2, an inner zone composed of vertical lamellæ; 3, an outer zone formed partly of lamellæ but chiefly of variously arched or vesicular plates: the mode of reproduction was by germs developed within the area of the parent stem, or without it by an occasional extension of the polype.

The specific characters depend upon the difference in the structural details of the three areas.

By the above descriptive notice, Lithostrotion, it is presumed, will be readily distinguished from the uni-areal and non-proliferous Columnaria, to which it has been united by some authors; from the bi-areal though proliferous Cyathophyllum; and from the uni-areal, subdividing polype, Astrea, with both of which it has been also identified.

Lithostrotion emarciatum.

Columns irregularly polygonal, outer surface rarely exposed, inner broadly ribbed; axis elliptical, detachable; inner zone bounded outwardly by arched plates, lamellæ generally of equal breadth; outer zone very vesicular, plates broad slightly convex, not highly inclined, very partially traversed by extensions of lamellæ; terminal cup not deep; boss slightly prominent surrounded by a depressed area; inner zone nearly flat, lamellæ distinct, simple; band of outer area highly inclined towards the exterior circumference, vesicular plates broad, slightly convex.

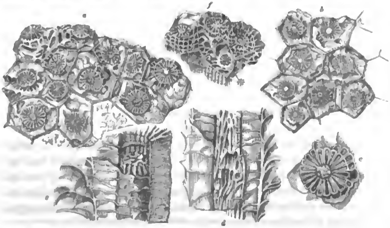


Fig. *a*. Transverse section, upper surface.

Fig. *b*. Transverse section, under surface.

Fig. *c*. Magnified portion of under surface to exhibit the characters of the lamellæ.

Fig. *d*. Vertical section, magnified, to show the internal structure of the axis, and the connexion with the inner zone.

Fig. *e*. Vertical section, magnified, to exhibit the perpendicular external and transverse internal characters of the axis, and the nature of the interstitial plates between the lamellæ, also the connexion of the inner with the vesicular or outer zone.

Fig. *f*. An immature column at * within the area of the parent column: the continuous boundary of the latter may be easily traced.

Astrea emarciata, Fischer. Oryc. Gouvern. de Moscou, pl. 31. fig. 5. p. 154. (Limestone of Tessovo.)

One of the specimens from which the preceding characters were obtained, had on a label, affixed to it in Russia, "*Astrea emarciata*," and it is therefore presumed that the determination must be correct, though the agreement with M. Fischer's figure was not perfect. It is necessary however to state, that the Russian carboniferous coral cannot be considered identical with the original *Astrea emarciata* from the tertiary strata of Grignon, although Lamarck's descriptive notice is reprinted in the 'Oryctographie.' (Anim. sans Vert. 2nd edit. ii. p. 417. No. 29. Oryc. p. 154.) As the specific name appears to be well-known in Russia, it is nevertheless deemed correct to retain it, and the generic being altered, it is trusted no confusion will arise.

Between *Lithost. emarciatum* and the English carboniferous fossil *Lithost. floriforme*, the following differences may be observed. In transverse sections of the Russian coral, parallel to the upper surface (fig. *a*), the principal vertical lamellæ have uniformly a very limited range in the outer zone; whereas, in similar sections of the British species, they extend almost constantly to the polygonal periphery; in *Lithost. emarciatum*, again, secondary or intermediate lamellæ are nearly wanting, or rudimentary, but in *Lithost. floriforme* they are well-developed, alternating in the outer zone, for the greater part, regularly with the primary lamellæ, even to the very walls of the columns. Other distinctions consist in the greater width of the vesicular plates in the Russian coral, consequent on the small range of the lamellæ; and in the number of truncated edges being much less, on account of the plates being less inclined.

The specimens of *Lithost. emarciatum* which were examined, consisted of slightly radiating columns of variable dimensions, and apparently not separable mechanically. The width of the largest mass was four and a half inches, and the altitude three inches. Another specimen presented continuous columns three and a half inches in height, with a nearly uniform width of six lines. The greatest observed diameter was about nine lines. Vertical sections of many contiguous columns, exhibited, on account of the interstices between the laminæ of the original coral not having been filled with mineral matter, very irregular surfaces, formed for the greater part of congeries of curved plates, belonging to the outer zone, variously united and inclined upwards; here and there was likewise a flat, vertical surface, ribbed and crossed by edges of fractured vesicular plates, presenting the inner surface of a wall; and occasionally, but more rarely, there was a reticulated semi-cylindrical indentation, flanked on each side by narrow flat perpendicular planes, which were traversed by nearly horizontal lines, the whole representing different, vertical sections of the inner zone; in some cases again the indentation was replaced by a convex body variously traversed by lines, and exhibited an axis half separated from the surrounding structures. A transverse section parallel to the upper surface is shown in figure *a*, and to the under surface in figure *b*, the triple composition of the column being perfectly displayed in both.

A few remarks must be offered on structural details.

(1.) Transverse sections of the axis presented very variable characters, but the composition of this central area consisted of vertical, waved plates (fig. *d*), which converged, more or less regularly, towards a medial line (fig. *e*), and were united by highly inclined laminæ; the whole being encompassed by a thin wall, and forming a persistent elliptical body. No very satisfactory proofs were obtained of any connexion between the vertical plates and the lamellæ of the surrounding zone; but some of the attenuated edges of the latter abutted against the wall, as well as nearly all the inner extremities of the interstitial, horizontal plates (fig. *e*). The general characters of the interior of the axis, and the mode of union with the lamelliferous zone, are given in figure (*d*); and the reader is requested to compare the persistent structure with the cone-in-cone, or non-persistent composition of the axis of *Lithost. mammillare* (fig. *b*, p. 606), as affording a valuable example of the assistance which this portion of the coral may yield in specific determinations. A further illustration is noticed in the description of *Lithost. astroides* (fig. *b*, p. 607).

(2.) The lamellæ of the inner zone had, apparently, a continuous, vertical range throughout the column. For a short distance from the axis, each consisted of a single plate (figs. *b*, *c*), and then swelling out more or less abruptly divided into two layers, the outer pairs of which were united at the circumference of the zone by curved extensions. In some few instances, very narrow, secondary or intermediate lamellæ occurred, formed also of two layers, similarly connected to the proximate broad plates. Without the regular limits of this inner zone, fractured surfaces often exhibited curved edges between partial lamellæ, both being intersections of the component parts of the exterior area (figs. *a*, *c*). The interstitial laminæ of the inner zone (figs. *d*, *e*), though in general more or less waved, were, for the greater part, horizontally arranged, but they were sometimes highly inclined, and the variations in their position produced a great irregularity of character in transverse fractures.

(3.) The arched or vaulted plates, which composed the outer area, sprung from the lamelliferous zone in a somewhat similar manner to the acanthus leaves of a Corinthian capital; but they were variously united and reticulated in their range towards the periphery. On the under surface (fig. *b*) they were more or less distinctly traversed by faint grooves and intermediate slightly convex bands; the former being prolonged indications of the fine divisional spaces between the two plates of the lamellæ; and the latter, of the arches by which the opposite plates were united. The upper surface (figs. *a*, *f*) of these bladder-like or vesicular laminæ was almost invariably so concealed by a coating of crystallized carbonate of lime, that minor structural details were not ascertainable. The vertically discontinuous lamellæ, by which they were more or less traversed, were curved on the upper or free edge, resembling segments of circles; and their range towards the periphery of the column was generally very limited, though in some few instances equal to the whole breadth of the area. They sprung, apparently with rare exceptions, from the narrow interval between the subdivided plates of the primary lamellæ; and were probably connected with them, vertical sections of the inner zone exhibiting only outer sides of the plates, crossed by fractured edges of the interstitial laminæ.

The single terminal cup which was examined, was seated within the body of the largest specimen, and completely over-arched by the growth of other columns. It required no particular observation.

The whole of the lamellæ and plates forming the internal structure of the coral, as well as the walls, were apparently imperforated.

Cases of young columns springing within the area of those fully developed, were sufficiently numerous to prove the essential mode of reproduction, and an illustrative example is given in fig. *f*, at the part marked with an asterisk. English specimens of *Lithost. floriforme*, which permitted polished sections to be made, exhibited every stage of development from the germ with an imperfect boundary, and scarcely a trace of lamellæ, through all the intermediate gradations to the perfect, fully constructed column with distinct solid walls. The germs always appeared among the vesicular plates near the inner margin of the parent column, but not in immediate connexion with the wall, and the rudimentary lamellæ, converging from an imperfect periphery, could not be referred, even in part, to the lamellæ of the old column. This statement is necessary to prevent the suspicion that the young columns of Lithostrotion were produced by a subdivision of the parent polype, as in the true Astreæ of Ehrenberg.

In the specimens of *Lithost. emarciatum*, examined by the describer, no cases were observed of interpolated columns, produced by an extension of the germ-bearing portion of the polype, over an interval arising from accident or irregular growth in the coral.

Locality and Formation.—Borovitchi, near Valdai. Carboniferous limestone.

Lithostrotion mammillare.

Columns irregularly aggregated; axis cylindrical, formed of twisted, conical, separable plates; inner zone narrow; outer zone broad, arched plates highly inclined, wholly traversed on the upper surface by vertically discontinuous lamellæ; inner surface of walls strongly ribbed; terminal star, boss prominent, spirally twisted; surrounding, depressed area deep, lined by the lamellæ of the inner zone; upper band or outer zone broad, more or less inclined, crossed by numerous lamellæ; boundary between the stars projecting, sharp, crenulated.

a b

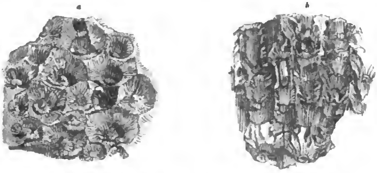


Fig. a. Terminal perfect surface, natural size.
Fig. b. Vertical section exhibiting the peculiar characters of the axis, natural size.

Astrea mammillaris, Fischer de Waldheim, Oryc. Gouvern. de Moscou, p. 154. pl. 31. figs. 2, 3. (Limestone of Tessovo; siliceous nodules near Moscow.)

This species is distinguished from the other three, described in these memoranda, by the peculiar characters of the cone-in-cone plates of the axis; from *Lithost. emarciatum*, it differs in addition to that marked structure in the vaulted plates of the outer zone being almost wholly traversed by lamelliferous laminæ; and from *Lithost. astroides*, by the great amount, in that species, of complicated reticulations and blendings of the three areas, whereby great care is required in detecting the existence of each.

The only specimen examined was a siliceous cast, three and a half inches wide, three broad, and one and a half thick; and it apparently formed part of a circular mass, the columns radiating rapidly from the thickest side. The upper surface consisted wholly of terminal stars, well-preserved, but irregularly grouped, and it indicated considerable inequalities of growth (fig. *a*). The siliceous mode of preservation did not permit the structural details to be fully ascertained.

(1.) The axis (fig. *b*) sometimes presented in fractured surfaces, a persistent cylindrical body, similar to that of *Lithost. emarciatum*, but there was constantly at the lower extremity a conical indentation, as well as a total absence of all traces of a reticulated structure. These hollows were exhibited on the under surface of every transversely fractured column, and presented casts of conically-twisted plates, which appeared to be easily separated, and altogether unconnected vertically by intermediate laminæ.

(2.) The narrow, inner zone was not so preserved, that its characters could be well ascertained; and there were indications of a much greater intermingling of its component parts with those of the outer area, than in *Lithost. emarciatum*. That it formed in the original condition of the coral a distinct structural division, was nevertheless evident from smooth semicylindrical casts on the inner side of the external zone (fig. *b*), and from the occurrence, in one case, of a perfect cylindrical cavity surrounding the axis. The lamellæ were apparently thin, and of uniform breadth; and the interstices presented casts of curved transverse or connecting plates.

(3.) The vaulted laminæ of the outer area generally sprang upwards for a short distance almost vertically, and then curved more or less rapidly towards the external wall (fig. *b*). They appeared to be, in some cases at least, prolonged expansions of the interstitial curved plates belonging to the inner zone. On the under surface they exhibited no distinctive characters except numerous subdivisions near the base, due to the above-noticed structural connexions, and the consequent appearance of intersecting edges of lamellæ. On the upper surface they were, in all observed cases, traversed by slightly projecting lamellæ-like ridges of unequal strength.

The characters of the terminal cups are excellently given in M. Fischer's figure 3, plate 31. (Oryet.)

No decided cases of gemmuliferous reproductions within the area of mature columns were noticed; but there were several instances of small columns projecting irregularly above the general surface, and in positions which rendered it difficult to imagine, that in a still smaller or younger state, they could have been included within the area of the adjacent mature columns. Similar developments are very common in English specimens of *Lithost. floriforme*, and in the remarks on the Russian coral (p. 610) believed to belong to that species, a notice will be found of an irregular cluster of small columns united by a layer representing a membranous expansion of the polypes.

Locality and Formation.—Priksha (Valdai), Government of Novogorod. Carboniferous limestone.

Lithostrotion astroides, sp. n.

Columns irregularly aggregated; axis not separable, no boundary wall, formed of plates conically united; inner zone narrow; lamellæ alternately broad and rudimentary, united at the periphery by arched extensions; interstitial plates numerous, horizontal, connected with laminæ composing the axis; outer zone arched, vesicular plates intersected throughout by attenuated lamellæ; walls broadly ribbed; terminal star, boss prominent, spirally twisted, connected at base with interstitial plates; surrounding depression traversed by lamellæ of inner zone; upper band or outer area more or less inclined, wholly crossed by lamelliferous plates with numerous small convex laminæ.

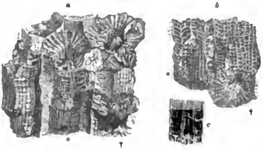


Fig. *a* represents a weathered portion of the coral, natural size.
Fig. *b* exhibits part of the interior free from matrix, natural size.
Fig. *c*. Magnified portion of inner zone from near the asterisk in fig. *b*.

Though clearly shown in weathered portions (* † fig. *a*) to be composed of an axis surrounded by an inner, circular zone, and of an outer area of diverging, feather-like plates, yet a recently exposed section, including many adjacent columns, presented such a perfect structural blending, that without the assistance of the former it would have been almost impossible to have detected the generic characters, or to have avoided considering the fossil as an Astrea. The upper surface of the specimen (fig. *a*), which exhibited several perfect stars, resembled greatly that of *Lithost. mammillare*, and the composition of the axis agreed to a certain extent with that of the axis of the same species; but in all the details of differential structure *Lithost. astroides* was well distinguished from the three other Russian corals belonging to the genus.

The only specimen examined was a silicified, irregular mass, three and a half inches in height and three in breadth and depth. It consisted wholly of somewhat confusedly aggregated columns, averaging, in terminal stars, seven lines in diameter; and though it was so completely charged with silex for half an inch from the surface that no characters could be clearly traced, yet the interior was so free from infiltered mineral matter, that all the solid framework of the original coral was fully exposed (fig. *b*).

(1.) The axis (fig. *b*) was completely united structurally with the inner zone, not merely by being essentially composed of expansions of interstitial plates, but by vertical extensions also of the lamellæ, which connected perpendicularly the successive, conical, twisted laminæ. It therefore could not be exhibited naturally or in a fracture as a distinct body, in the same way as in *Lithost. emarciatum*, *L. mammillare*, or *L. floriforme*; nor could the conical laminæ be clearly detached from each other as in the second of those species. The characters exhibited by the axis varied with different periods of development. In one state it presented only a medial plate with slightly twisted, spiral extensions of lamellæ, but in another of a broad semi-conical lamina on each side the medial line, forming a perfect cap and concealing all other component parts.

(2.) The inner zone with the axis united as one body was well shown in a weathered surface († fig. *a*), presenting a long cylinder, flanked by a diverging, feather-like structure. No such separation was clearly exhibited in the fractured interior of the specimen which retained perfectly the characters of the original coral, but the commencement of the transverse perpendicular laminæ († fig. *b*) marked the boundaries of the two areas. The cylinder consisted of a conically-twisted centre, the axis, with radiating lamellæ which were united within the zone horizontally and obliquely by the interstitial plates, and at the periphery by vertically connecting arched laminæ.

(3.) The outer zone differed in characters from that of the other species included in these notices by being traversed completely by perpendicularly persistent, thin lamellæ; and in the arched, highly inclined, diverging plates being not merely very narrow, on account of their thorough intersection, but individually of very limited range, resembling the small vesicular laminæ in the outer area of Cyathophyllum and other genera (* fig. *b*).

One instance of a young column considerably advanced towards maturity was observed within the area of an old column.

Localities and Formation.—Pinega (sixty versts west); Carboniferous limestone. Tchussovaya banks, above Ust-Koiva; Carboniferous limestone. The latter specimen was a very imperfect siliceous cast, which did not permit its characters to be clearly ascertained, but it was believed to belong to this species.

Lithostrotion floriforme, Fleming.

Columns irregularly aggregated; axis cylindrical, spirally twisted, detachable; inner zone, breadth small, lamellæ alternately broad and narrow; interstitial plates horizontal or inclined; outer zone, vesicular laminæ broad, highly inclined, traversed on the upper surface only by lamelliferous plates extending to the periphery; outer wall in general broadly ribbed, sometimes broadly furrowed; terminal cup deep; boss prominent, spirally twisted; surrounding depression lined by lamellæ of inner zone; band of outer area more or less inclined; vesicular plates broad, crossed wholly by sharp, vertical, unequally projecting laminæ; boundary ridges prominent, crenulated.

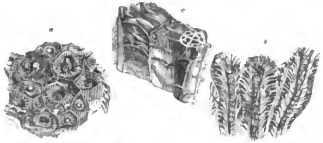


Fig. *a*. General character of the upper surface, natural size.
Fig. *b*. Vertical section, natural size, to show the characters of the axis, and inner and outer zones, as well as the mode of union.
Fig. *c*. Portion of the same magnified.

Erismatolithus madreporites (floriformis), Martin, Petrificata Derbiensia, pl. 43. figs. 3, 4; pl. 44. fig. 5. 1809.

Lithostrotion floriforme, Fleming, British Animals, p. 508, 1828; Morris, Catalogue of British Fossils, p. 40, 1843.

Columnaria floriformis, De Blainville, Manuel d'Actinologie, p. 350, 1834; Milne Edwards, 2nd edit. Lamarck, Animaux sans Vertèbres, ii. p. 343, 1836.

Cyathophyllum floriforme, J. Phillips, Geology of Yorkshire, part ii. p. 202, 1836.

The coral under consideration resembled *Lithost. emarciatum* in the structure of the axis, but it differed from that species in the lamellæ of the inner zone being in all mature columns alternately broad and narrow, and in the vesicular plates of the outer zone being uniformly much more inclined, and traversed, not partially by lamelliferous laminæ resembling segments of circles, but wholly by fine layers produced to the outer walls of the columns. Between the Russian fossil and the English *Lithost. floriforme* no essential differences were detected, though two specimens of the former were compared with a tolerably good series of the latter.

The height of the larger Russian specimen was three inches and three quarters, the breadth two, and the depth one and three quarters. The columns were small, the diameter of the greatest being five lines, but in some English specimens the average dimensions were about the same. The upward line of growth was very irregular, and not unfrequently twisted (fig. *b*); and at the superior termination there were occasionally between the lamelliferous columns small, depressed intervals, not bladder-like, but lined by a thin rugose layer, which had been deposited apparently by a membranous extension of the adjacent polypes. Similar irregularities in growth and in upper terminal surfaces occur in British specimens of *Lithost. floriforme*.

(1.) The axis was sometimes partially displayed to the extent of nine and ten lines. It presented (fig. *b*) a twisted, narrow cylinder, not indented or cupped at the lower end as in *Lithost. mammillare*, but traversed by an even or nearly flat surface, composed of variously reticulated plates, as in *Lithost. emarciatum*. In this and all other characters, the axis of *Lithost. floriforme* agreed with that of *Lithost. emarciatum*.

(2.) The characteristic distinction in a transverse section of the inner zone was the interpolation, near the periphery, of narrow lamellæ, with more or less numerous, connecting straight or arched plates, giving to the transverse section an amount of complicated structure, not possessed by the three species believed to be at present peculiar to Russia. In this respect, again, there is a perfect agreement with English specimens of *Lithost. floriforme*.

(3.) The laminæ composing the outer area sprang directly, in broad plates, from the side of the inner zone (fig. *c*), without, apparently, any of the intersections or subdivisions at the base mentioned in the description of *Lithost. mammillare*. The plates sometimes extended to the wall of the column in a single curve, but more often there was an intermingling of minor arches. The under surface exhibited no regular furrows or flattened ribs. The laminæ, which traversed the upper surface, were prolongations of the lamellæ of the inner zone. In some cases they filled up, in a vertical section, the whole area of the bladder-like spaces, but more frequently their dimensions were limited to a series of fine crests or lamellæ edges. Similar structures occur in British *Lithost. floriforme*.

The terminal stars not rarely exhibited a pseudo-proliferous character, in consequence of the uppermost series of arched plates having been in part accidentally removed or not fully developed (fig. *a*). This character was also sometimes strengthened by the irregular depressions or interspaces between the columns before alluded to.

Cases of what were believed to be young columns, which had arisen from germs developed within the area of others, were noticed; but the great irregularities in the grouping of the former lead to the inference, that they frequently originated in an extension of the polypes over intervals due to unequal growth or accident. An instance was observed of three small columns, and part of a side of an old one, united in the middle by a thin triangular layer, which, on account of the arrangement of the rugose lines of deposition, had clearly resulted from the labours of three of the polypes. With respect to this assigned mode of production, it is necessary to state, that in the many English specimens of *Lithost. floriforme* examined by the describer, not an instance occurred of a mature column totally studded over by young columns, and consequently of a parent smothered by its own progeny, though such appears to have been the case in some species of Cyathophyllum. On the contrary, the incipient columns always appeared near the inner margin, and thus left ample space for the upward growth of the old polype. Examples may possibly be discovered of terminal stars entirely occupied by the bases of small columns, but it is presumed that the extremities of the latter will be found to rest on the component structures of the old star, and not to spring from within them; and, consequently, that the superimposed columns originated in partial extensions over a prematurely destroyed polype.

Locality and Formation.—Borovitchi, near Valdai. Carboniferous limestone.

Favosites alveolaris, Goldfuss.

Calamopora alveolaris, Goldf. Petref. p. 77. pl. 26. fig. 1. Favosites, Corrigenda, p. 245. 1826–1833.

Favosites alveolaris, De Blainville, Man. d'Actinologie, p. 402. 1830–1834. Silurian System, part ii. p. 681; pl. 15 *bis*. figs. 1, 2. 1839.

In Mr. Murchison's Isle of Dago collection, was a cylindrical specimen of this coral, eighteen inches in length and five in its greatest diameter. It differed in none of its structural details from M. Goldfuss's excellent figures, except that the average width of the tubes at the outer surface of the specimen was rather less than a line, or about one-half of that of the unmagnified figure (1 *a*) in the Petrefacta (pl. 26), but the dimensions agreed very nearly with those of the fossil given in Mr. Murchison's 'Silurian System' (pl. 15 *bis*. fig. 2). There was, however, a difference, in an apparent total absence of the papillæ on the inner walls of the columns, represented by Professor Goldfuss.

Localities and Formation.—Isle of Dago, Petropavlosk and Volshanka River (North Ural). Upper Silurian.

Favosites polymorpha, Goldfuss.

Cal. polymorpha, Goldf., pl. 27 and 28, pp. 79, 245; Silurian System, part ii. p. 684. pl. 15. fig. 2. 1839.

In the notice on this species in Mr. Murchison's work, all the Favosites consisting of cylindrical branches, and wanting the peculiar vertical ridge within the tube, characteristic of the fossil figured under the name of *Calamopora (Favosites) spongites* by Goldfuss (Petref. pl. 28. fig. 1), were referred to *Favosites (Calamopora) polymorpha*, though some of them were included by that authority in the species spongites. The alteration, nevertheless, appeared to be justified by M. Goldfuss's own remark, that the corals are perhaps only varieties.

The fossil from Katchukof, assigned in this instance to *Fav. polymorpha*, and probably the one from the Ural Chain east of Alatau, agreed closely with the Silurian specimen figured in pl. 15. of Mr. Murchison's work; but the coral from the lake of Petropavlofsk resembled, in the greater thickness of its walls, more nearly the Devonshire (Devonian) variety.

Localities and Formations.—Katchukof, on the Upper Belaia and Uziansk Zavod, in the South Ural Chain; Silurian. East of Alatau, South Ural; Devonian[1]? Banks of the lake of Petropavlofsk sixty versts north-west from the Works of Bogoslofsk, North Ural; Upper Silurian?

Michelinia concinna, sp. n.

Columns irregularly polygonal, more or less rounded internally; central plates numerous, transverse, broad, slightly convex or concave; walls variously constructed, perforated; terminal cells lined with vesicular plates. (Pl. A. fig. 3.)

Of this coral, two specimens, both from a locality five versts east of Ust-Koiva, were examined. One of them, a thin layer, about two inches in width and one and a quarter in breadth, exhibited transverse sections of the interior of the columns; and the central plates, when viewed on the upper surface, resembled those of *Michelinia tenuisepta*, as delineated by M. de Koninck in his work on the 'Palæozoic Fossils of Belgium[2],' pl. C. fig. 3 b.; but in the vertical section the Russian coral differed essentially from that species, according to the structure represented by M. Michelin in pl. 16, fig. 3 b. of his 'Iconographie Zoophytologique[3],' the transverse plates having a great uniformity of position, with, in general, a slightly convex or concave outline, and not a total want of regularity of situation and curvature. A similar distinction was observed between the Russian fossil and a specimen from the Mendip Hills (England), of the coral to which the name of *Michel. tenuisepta* is now applied. This fossil was originally noticed and figured by Parkinson (Org. Rem. vol. ii. pp. 39, 40. pl. 5. fig. 9); and was first introduced into a systematic arrangement of Polyparia, it is believed, by Dr. Fleming, under the name of *Porites cellulosa* (British Animals, p. 511 (1828), where Parkinson's figure is quoted); but it was subsequently assigned by Mr. Phillips, though with a doubt, to Calamopora, and distinguished by the specific name of tenuisepta (Illust. Geol. Yorkshire, part ii. (1836), pl. 2. fig. 30. pp. 201 and 246, for the generic doubt; Mr. Phillips refers to Parkinson's figure and locality); and, lastly, M. de Koninck gives Mr. Phillips's *Calamopora tenuisepta* as a synonym in describing *Michelinia tenuisepta*.

An examination of the Mendip Hill specimen also, not only proved Mr. Phillips to be correct in stating that "the walls are perforated towards the margins" (*opus cit.* p. 201), but that the perforations, irregular in form, size and position, extended throughout the whole length of the tubes, wherever the inner surface of the walls was laid open or stript of a lining of highly inclined plates. It is therefore probable that M. de Koninck's specimens, as in the one figured in plate C. of his work, were so provided with a layer of lateral plates, that the perforations were concealed (see Descript. Anim. Foss. p. 32).

The finest specimen of *Michelinia concinna* might be considered as the fourth of an elliptical mass (Pl. A. fig. 3), and the dimensions on the lines of the major and minor axis, were respectively, two inches and one

[1] Bord de l' étang de Petropawlofsk 60 versts de la fabrique de Bohoslow sur le N. E.

[2] Déscription des Anim. Foss. dans le Terr. Houllier et dans le Syst. Supér. du Terr. Anthraxifère de la Belgique. 4to, 1842.

[3] Icon. Zooph. des Polypiers Fossiles de France et Pays Environnants. 4to, 1842.

inch: the thickness, so far as it was preserved, was one inch. The columns possessed a nearly uniform diameter of two lines. The central plates were separated by small intervals, and they very generally ranged across the area of the tubes, but they were occasionally of more limited extent; in all cases, however, there was a great tendency to a uniformity of arrangement and to a slight convex or concave curvature. Near some of the superior terminations of the columns, as well as in other parts, were slight local irregularities. These central plates occasionally abutted against a well-defined band of small, arched or vesicular laminæ, but they more frequently blended with the complex structure of the sides of the tubes.

Divisional walls, formed of a distinct compact layer, were noticed to a very limited extent, and even then not satisfactorily; nor are any represented by MM. de Koninck and Michelin, in the species figured by them; but in the Mendip Hill fossil, a solid partition was noticed in some portions. The boundary or exterior of adjacent columns in *Michelinia concinna*, was formed, apparently, or so far as it could be ascertained, of a blending of upturned margins of central plates, with occasionally an inner vesicular lining. The wall, believed to be thus composed, was not often exhibited, and to the extent to which it was examined, no vertical furrows were noticed; but it was clearly perforated by foramina (fig. 3 *a*), less regular in character than those of Favosites, but with smooth edges, and plainly not referrible to accidental fractures. Their lineal arrangement in two instances gave the walls the semblance of being furrowed. These boundaries exhibited no tendency to separate in a vertical fracture, and the upper surface presented instances of a vesicular filling-up between some of the columns. That the polypes, which formed the mass of columns, did not enjoy a perfect blending of animal existence, is, however, evident from the not unfrequent occurrence in specimens of Michelinia, of considerable intervals, as noticed by M. de Koninck (*opus cit.* p. 30), and even of extremely narrow spaces; and it is therefore probable that the intermediate matter above mentioned was deposited by occasional extensions of the polype. These characters are considered of importance in leading to a correct separation from Favosites of many corals which otherwise might be referred to that genus.

The terminal cups were not well-exhibited; but in the best cases the polygonal boundary was sharp, and the hollow so lined by laminæ as to be perfectly circular.

With respect to the mode of producing additional columns, the principal specimen of *Michel. concinna* afforded abundant proofs of increase along the marginal boundary; and it is believed that instances of interpolated young columns were noticed.

Locality and Formation.—East of Ust-Koiva, on the Tchussovaya. Carboniferous limestone.

Cyathophyllum turbinatum, Goldf.

Petrefacta, &c., p. 56. pl. 16. fig. 8. (1826.)

Silurian System, part ii. p. 690. pl. 16. fig. 11. (1839.)

A group of three stems, agreeing perfectly in their bi-areal structure with the fossil figured in Mr. Murchison's work.

Locality and Formation.—Petropavlofsk, N. Ural. Upper Silurian.

The above species and *Cyathophyllum dianthus*, as represented in the 'Silurian System' (pl. 16. fig. 12), and exhibited in a specimen of the Gothland coral, described by Fougt (Amœn. Acad. vol. i. Corallia Baltica, fig. 10), as well as referred to by M. Goldfuss in his account of the species, being believed to represent the typical structures of the genus Cyathophyllum, the present inquiry has suggested the necessity of grouping certain analogous corals, which agree in the bi-areal composition, and probably in the mode of reproduction with *Cyath. turbinatum* and *Cyath. dianthus*, but which exhibit peculiarities not so limited to one modification as to enable their being assigned to single species.

The distinctive characters of one of these proposed groups or sub-genera were originally noticed in Russian specimens from the river Kakva and Petropavlofsk, and more recently under a differential form in a fine Gothland coral, contained in Mr. Murchison's cabinet, and believed to be the *Cyathophyllum articulatum* of M. Hisinger (Lethæa Suecica, p. 102. tab. 29. fig. 4). The peculiarities consist,—first, in the lamellæ of the outer area being pierced, from the inner surface of the wall, through their whole breadth by well-defined, relatively large foramina, terminating on the inner edge in a distinct row of short tubuli; and, secondly, in the total absence of interstitial vesicular laminæ at every period of growth.

For this sub-genus the name of Tryplasma is provisionally suggested, founded on the foraminated lamellæ (*τρύπα, foramen*; *ἐλασμὸς, lamina*).

The Russian specimens were all imperfect fragments, but that from the river Kakva was considered in a state to be so far compared with the Gothland coral, as to permit differential characters to be satisfactorily ascertained. A mere comparison of the figures accompanying the following notice (Pl. A. fig. 7), with that given by M. Hisinger, might alone lead to the inference of the two fossils being specifically distinct[1]; but, independent of the great relative size and isolated nature of the one, and the slender form as well as dense grouping of the other, variations exist in the shape and arrangement of the foramina, and the characters of the lamellæ. The gemmuliferous mode of reproduction carefully given in M. Hisinger's figure, was also fully shown in the Gothland specimen, the offsets springing chiefly from the side of the parent stem, but, possibly, in some instances from within the area of a once terminal cup. The nature of the Russian fragments prevented the detection of any analogous process.

Cyathophyllum Sub-genus Tryplasma.

Cyath. Tryplasma æquabilis, sp. n.

Cylindrical; central area, transverse diaphragms broad, prolonged partly between the lamellæ; outer area narrow, lamellæ numerous, alternately broad and very narrow, foramina round; outer wall thin. (Pl. A. fig. 7.)

This notice of specific characters, as well as the following memoranda, must be regarded as only indicative of the leading peculiarities of the fossil.

The extent and dimension of the specimen from the river Kakva are given in figures 7, 7 *a*, Plate A; and though the fragment was so weathered as to exhibit perfectly no one surface, yet the oblique direction of the sections greatly facilitated the examination of the foramina. The diaphragms in their transverse range exhibited no distinctive characters, but beyond the central area, they were simply continued between and, possibly, through the lamellæ, to the outer wall; and therefore presented at the boundary of the lamelliferous zone, a marked difference from the complicated blendings in *Cyathophyllum turbinatum*. The lamellæ issued boldly from the wall (fig. 7 *a*) exhibiting their full thickness in contact with it, but the extension of even the broader was limited. In the oblique vertical section (fig. 7), their range was indicated near the bottom by parallel rows of circles, alternately larger and smaller, the internal areas being more or less distinct, according, apparently, to the degree of blending between the decomposed coral and the infiltered lime. The rows were divided by bands of fine, slightly waved lines. Close to the left of the section the foramina were again shown, either in an analogous condition, or as distinct dark pores in a white crust. To the right of these rows, as well as lower down, and near the opposite boundary, were other series of circles with relatively broad, vertical intervals. Where the successive circles were not connected by any white or pale brown substance, they were believed to represent the tubular extensions on

[1] See also the figures of *Tryp.* (*Cyathophyllum*) *articulata*, Pl. A. fig. 8, and the description of the Plate.

the edge of the lamellæ; and where such uniting matter occurred, that the lamellæ also were more or less represented. In the vertical intervals above noticed could be detected, here and there, an indistinct circle or a white speck; and they were conceived to mark the range of the narrow lamellæ. The obliquely transverse section (fig. 7 *a*) gave, more or less fully in both the broad and narrow lamellæ, all the changes from the circle imbedded in the substance of the lamellæ, to the tubular or isolated ring. In this section the range of the foramina to the very external boundary of the coral was shown in a few cases, but it is believed that the outer envelope was never pierced.

The specimens from Petropavlofsk were of much less dimensions, and possibly belonged to a distinct species, but the whole of the original coral had disappeared, and the surfaces were much weathered. All the sub-generic characters were, however, exhibited, and the extension of the diaphragms, through the lamellæ, was implied by intersecting parallel lines, which could be connected with the central structure. The former existence of broad lamellæ was also proved by grooves or casts with circular markings; and of narrow, by similar but smaller impressions on the intervening ridges.

Localities and Formations.—The river Kakva; East side of the North Ural Mountains; Silurian. Petropavlofsk, northernmost Russo-Uralian mines. Silurian or Devonian?.

Strombodes ————.

Cylindrical (?); lamellæ unequally distant, sometimes laterally in contact, more or less contortedly united at the centre; lamellæ-plates easily separated, inner surfaces rough, striated obliquely and vertically; interstitial laminæ variously inclined, occasionally very vesicular towards the periphery; outer surface transversely rugose. (Pl. A. fig. 13.)

The specimen from which the above notice was obtained, consisted of an aggregate of crushed fragments in a matrix of Fusulina limestone, but it possessed considerable interest, as it was believed to afford a generic representative in Russia of one of the most abundant of British carboniferous corals. The English fossil, the "Sun-stones" of dealers, and one of the lamelliferous polypidoms to which the names of *Fungites, Turbinolia fungites* and *Cyathophyllum fungites* have been applied by some authorities, consists essentially of numerous, vertical, bi-plated lamellæ, more or less contorted in the centre, but in general nearly straight in their range to the circumference, where they sometimes become indistinct. The interstices are almost invariably narrow, and are closely beset with variously-inclined or arched laminæ. In some specimens a distinct boundary wall encompasses the coral in part or wholly, but more frequently, the margin is irregular in outline and exhibits no definite or peculiar structure. Lastly, the diameter of a specimen often varies greatly, contracting to two-thirds or one-half (from three inches to two, or two to one), whereby it acquires the appearance of a young column springing from the centre of an old one; and in transverse, rough fractures, indications have been detected of a free separation of horizontal layers. These characters clearly justify the removal of the "Sun-stones" from true Turbinoliæ and Cyathophylla, and are conceived sufficient to warrant the placing them in the genus Strombodes, as originally proposed by Schweigger (Beobachtungen, Systematic Table VI.). The Russian fossil under consideration was far too imperfectly exhibited to ascertain its full characters, but so far as the structures were preserved there was a close agreement with some of the smaller "Sun-stones." The fragments of stems, about half an inch in diameter, but rarely persistent for even a quarter of an inch in height, displayed no expansions or contractions, but sometimes an unequal development on opposite sides. The lamellæ, strongly bi-plated, were contortedly united at the centre, but nearly straight in their range to the circumference, preserving a uniform thickness where the outer, prominent, vesicular plates did not exist, but becoming attenuated where they formed a marked band. Occasionally the lamellæ were in contact in one portion of a section, but relatively distant in the remainder. The interstitial plates were much less vesicular near the centre than in the English fossil, though in the latter, in areas of equally limited extent, the equivalent laminæ varied in character.

It has been deemed correct to give this very defective notice, in the hope that it may call attention to what is considered an interesting additional connexion between the palæozoic faunæ of Eastern and Western Europe. It has been considered right not to suggest a specific name, as there were no means of determining how far the fragments examined may be referable to the *Turbinolia arietina* of M. Fischer (Oryctographie, pl. 30. fig. 4).

Locality and Formation.—Ussa River, junction with the Volga near Samara. Upper Carbon. limestone.

Cystiphyllum impunctum, sp. n.

Stems cylindrical, grouped, traversed externally by longitudinal obsolete striæ and transverse irregular lines of growth; beneath the outer wall, broad, shallow furrows, strongly punctured; vesicular laminæ variable in size; no radiating lines or lamellæ.

This coral differed materially from any described species known to the author, but it agreed in the punctured furrows and the absence of radiating lines with the characters of a very imperfect specimen of Cystiphyllum from the Devonian limestones of Newton Bushel (England).

Two groups of *Cyst. impunctum* were examined. The larger consisted of parts of six stems closely aggregated, but without the cylindrical contour being affected, and fractured portions exhibited no clear proofs of the adjacent sides having been united. The finest stem, imperfect at each extremity, was three inches and a half in height, and had throughout the greater portion of its range a uniform diameter of ten lines. The outer walls were imperfectly displayed, but they were apparently thin and nearly solid. The subjacent impunctured furrows, or casts of tuberculated, compressed ribs, were well-exhibited in some parts; and they were equally strong at both extremities of the stems, ranging longitudinally; they were also traversed by the edges of the vesicular laminæ. The whole of the interior was occupied by the bladder-like plates, which were very irregular in size, curvature and disposition. No signs of the mode of producing additional stems were observed.

Locality and Formation.—Margin of the lake of Petropavlofsk, sixty versts north-west from the works of Bogoslofsk. Silurian.

CANINIA, Michelin.

Corals belonging to this genus have unfortunately been described under the double appellations of Caninia and Siphonophyllia. The former designation was proposed by M. Michelin at the Scientific Congress of Turin in 1840, and a description of the generic characters was published in 1841 in the Supplement to the Dictionnaire des Sciences Naturelles, tome i. 2ième partie, p. 485. In one of the earlier numbers of the Iconographie Zoophytologique de France (1841 ?), M. Michelin also published a detailed explanation with illustrative figures of *Can. gigantea* (p. 81. pl. 16. fig. 1). The first account of the Siphonophyllia of Dr. Scouler, laid before the public, is believed to be that given by Mr. M'Coy in p. 187 of the "Synopsis of the Carboniferous Limestone Fossils of Ireland," prepared under the directions of Mr. Griffith (1844). The generic name, Caninia, appearing therefore to have been first published with descriptive characters, the retaining it has been deemed correct.

The notices, however, which have been thus communicated do not express fully the structures by which the corals described in them may be separated from previously established genera[1]; and in conse-

[1] Dr. Scouler's account of the genus (Siphonophyllia) not having been yet published, the above remark cannot apply to his views respecting its structure.

quence apparently of the difficulty, under some circumstances, of detecting the siphon-like contortion of the plates, and possibly also from other internal structures not having been fully considered at all periods of development or under irregularities of growth, doubts have been expressed respecting the necessity of retaining Caninia as distinct from Cyathophyllum[1]. It is believed, nevertheless, from an examination of M. Michelin's figures of *Caninia gigantea* (Iconog. Zool. pl. 16. fig. 1), of Mr. Hutching's excellent delineation of *Siphonophyllia (Caninia) cylindrica* in Mr. Griffith's volume (pl. 27. fig. 5), and of specimens of that fossil presented to the Geological Society of London by the Earl of Enniskillen, that M. Michelin's genus is perfectly distinct from Cyathophyllum; and it would possibly not have been considered by Professor Goldfuss as belonging to it, had the coral been brought under his consideration. The true Cyathophylla of that authority, taking *Cyathophyllum turbinatum* as exhibited in Gothland as well as British and Russian specimens, and *Cyath. ceratites*, and *Cyath. flexuosum* (Petref. pl. 17. figs. 2 *h*, 3 *b*), as characteristic of the genus, have internally only *two* areas, an inner composed of transverse plates or diaphragms, and an outer of vertical lamellæ connected by inclined or variously arched interstitial laminæ. Caninia, on the contrary, is composed internally of *three* well-marked structural divisions:—1st, a central area composed of transverse diaphragms having more or less distinct, siphon-like folds, which penetrate obliquely downwards; 2ndly, a middle area or zone composed of vertical, persistent bi-plated lamellæ, with intermediate connecting laminæ or interstitial extensions of the diaphragm, arranged horizontally or variously inclined, sometimes obliquely downwards; and 3rdly, an outer area composed essentially of vesicular or arched plates inclined upwards at considerable angles, and more or less intersected by attenuated extensions or ramifications of the lamellæ. These three structures are excellently represented in Mr. Hutching's figure already quoted, and though, as there represented, they pass into each, yet each area has its peculiar characters, and may easily be defined in either a vertical or a transverse section. The three divisions are also truthfully and clearly exhibited in M. Michelin's figure 1 *a*, plate 16 of his work.

It can form no part of these notices to describe the complicated details of the Irish coral (*Siphon.* (*Can.*) *cylindrica*), and they will doubtlessly be fully and far more satisfactorily explained when the original observations of the authority by whom the coral was first generically distinguished in Ireland shall be laid before the public; but in preparing the following notice of a Russian Caninia of very similar aspect, it was found necessary to refer to the characters exhibited in the Irish specimens belonging to the Geological Society of London, as the fossil under consideration was too imperfect to allow the characters to be separately investigated. The specimen was believed to be distinct from *Can. gigantea* or *Can.* (*Siphon.*) *cylindrica*; but as the structure of no one of the areas was perfectly shown, and could be only alluded to, the describer did not feel authorised to propose a specific name.

Caninia ———.

Cylindrical; central area, siphon-like folds indistinct; middle area, lamellæ numerous, interstitial laminæ horizontal; outer area, vesicular laminæ highly inclined, very complicated, intersected by extensions of the lamellæ.

The fragment from which the above proofs of generic structure were obtained, was about two inches in diameter, but the exterior was in no part preserved, and therefore the actual width was not ascertainable; the greatest height, measuring from the extremities of the fractured sides, was only two inches and a half; the outline was cylindrical, but slightly bent.

1. The central area was apparently about ten lines in diameter, but it was so imperfectly exhibited, that its extent could not be clearly defined. In specimens of *Can.* (*Siphonophyllia*) *cylindrica*, the size of which

[1] See M. de Koninck's remarks on Cyathophyllum, Desc. Anim. Foss. Terr. Houill. &c. de la Belgique, p. 21.

agreed with that of the Russian coral, the diameter of the central area was also about ten lines. The diaphragms were very thin, and undulated so far as they were exposed; on one side were also indications of a siphon-like fold or sudden depression; but this character was so indistinct, that if it had not been exhibited in other fossils, and described by the authorities alluded to in the remarks upon the genus, the fold or depression would not have claimed special attention. The margin of the upper or under surface of the diaphragms was likewise so defectively shown, that the inner terminations of the lamellæ could not be detected, though in the Irish fossil they constitute a marked feature, forming a circle of bold sharp crenulations or narrow plates around the boundary of the area on the upper side of the diaphragm, and a series of grooves on the under side.

2. The middle area or zone varied in width from four to three lines in different portions of the same transverse section, and in *Can.* (*Siphon.*) *cylindrica* similar inequalities were noticed; but in the Irish specimen, and possibly in the Russian, there was no constant connexion between the greater or less breadth, and the position of the folds in the diaphragms. The lamellæ were formed of two plates, distinctly separable, but the inner surfaces were exposed to a very limited extent. In vertical sections of the Irish coral this character is, in general, finely shown, the facility with which the two plates separate giving specimens of considerable length a great tendency to split. The persistence thus displayed in the vertical range of the lamellæ, as well as the unbroken regularity of the highly inclined lines on their surface, exposed in one specimen from Ireland for more than two inches and a half, satisfactorily demonstrated that the same polype constructed the whole of that portion, though intersected by full fifty diaphragms; and it is believed that each specimen, even when twelve or fourteen or more inches in height, was the production of one animal. At the part, in the Russian fossil, where the siphon-like depression occurred, there was also irregularity in the arrangement of the lamellæ. The union of the lamellæ with the diaphragms could not be satisfactorily studied. The interstitial extensions of the latter plates between the lamellæ, had, to the extent exposed, a nearly horizontal range, and they were slightly concave.

3. The greatest width of the perfect outer area could not be ascertained, but it exceeded five lines: in *Can.* (*Siphon.*) *cylindrica* it varied in the same transverse section from four to seven lines. The inner boundary, as in that fossil, was well-defined by the abrupt commencement of the highly inclined, arched or vesicular laminæ of which the area was essentially composed. These laminæ varied in form, position and extent, and they were occasionally furrowed and deeply indented, but no decided foramina were noticed, though they occur in the Irish coral. The attenuated extensions of the lamellæ traversed the whole area so far as it was preserved, but not always in one uniformly persistent plate, instances occurring of splitting into subordinate ramifications, and their sides were always more or less feathered by the vesicular laminæ. The structure of this area was also very imperfectly displayed.

Locality and Formation.—East of Usolie, on the Volga above Samara. Carboniferous limestone.

Caninia ibicina?

Conical, curved; central area, diaphragms connected marginally by bold extensions of lamellæ, siphon-fold small; middle area, inner surface of lamellæ-plates not readily separable, interstitial laminæ horizontal, waved; outer area, vesicular plates numerous. (Pl. A. fig. 6.)

Turbinolia ibicina?, Fischer de Waldheim, Oryctographie du Gouvernement de Moscou, p. 153. pl. 30. fig. 5; Miatchkova.

Between the younger state, described in the next page, of this Caninia and M. Fischer de Waldheim's *Turb. ibicina*, there is a considerable resemblance so far as the characters of the latter are delineated, both apparently consisting of a central area with transverse diaphragms, and an outer of vertical lamellæ; but it is difficult to imagine that the figure given in the 'Oryctographie' can represent a young specimen, and therefore it may be doubted, if there be a generic agreement; nevertheless, as it is possible for a Caninia to be so reduced externally by weathering that it might present the aspect of the figure above quoted; and as the mature fossil under consideration would, if similarly reduced, afford analogous appearances, it has been considered better to adopt doubtfully M. Fischer's name than to propose decisively a new one.

Three fragments imbedded in the Fusulina limestone of Velikovo were referred to this species, the differences which were noticed in the component structures being considered due to variable conditions dependent upon age and mode of growth. The largest specimen (Pl. A. fig. 6), about one inch and a half in length and one in breadth at the upper extremity, was so greatly bent, that the lamellæ and diaphragms were completely distorted, and no siphon-folds could be detected. This specimen, nevertheless, was highly interesting, as it exhibited an important structural change due to different states of development. In the upper part the three areas were fully shown, they appeared also further down, but with the vesicular much diminished, and in the lowest exposed portion only two were visible, or the central with the diaphragms, and the intermediate with the vertical lamellæ crossed by transversely waved plates. In this bi-areal state, however, Caniniæ may be easily distinguished from Cyathophylla by the absence in the lamelliferous zone of all vesicular laminæ.

In the second fragment (figs. 6 *a*, 6 *b*), which was merely a bi-areal segment five lines in length and breadth, the characters, to the extent preserved, were better exposed than in the larger specimen, the curvature being slight. The bi-plated lamellæ were thick and simple in character, with ample interspaces, and their inner margins projected prominently between the diaphragms. The siphon-folds were also well-exhibited, penetrating obliquely into the lamelliferous zone.

The third fragment (fig. 6 *c*), imbedded in the same matrix as the second, and possibly a portion of it, afforded an additional important change dependent upon growth. It was a baseal termination, conical, and slightly bent; about one inch in length, and half an inch in its greatest diameter. At the upper part the exterior was not fully preserved, but about the centre of the fractured termination was a small perforation, or pipe (fig. 6 *d*), which descended obliquely and was surrounded by several concentric laminæ, occupying apparently the whole of the area. The outer zone immediately surrounding this structure (fig. 6 *c*) was composed of thick lamellæ obscurely bi-plated, but slightly grooved externally; and, though almost in close contact, their sides were faintly marked by waved interstitial laminæ. A little lower, and thence to the base, the central area was contracted to an ill-defined interval, more or less occupied by the irregular edges of the lamellæ; but the outer zone preserved the characters of the upper part. The inferior terminations of the lamellæ were peculiar, and, if rightly understood, of great interest in an attempt to investigate the characters of the genus. They were clearly rounded and smooth (fig. 6 *c*), but not from abrasion, and they exhibited not the least trace of having been attached, leading, therefore, to the inference that at one period at least the coral was free.

M. de Koninck, in his remarks on the genus, details a series of changes in the characters of the siphon analogous to those noticed in the second and third specimens; and he states still further, that he has not rarely met with two modifications, a central cone, and a species of lateral siphon, "sur la même cloison *."

Locality and Formation.—Velikovo, between Vladimir and Kovrof. Upper Carboniferous limestone.

In another specimen of limestone from the same locality was also a fragment of the bi-areal and baseal portions of a Caninia, but deserving of notice on account of the additional evidence it afforded of curious irregularities of development. It was one inch and a half in length, nine lines in diameter at the upper extremity, and four at the lower. The central area presented a depressed cone, composed of diaphragms so highly contorted and intermingled with lamellæ, that the component structures could not be separated

* *Op. cit.* on the structure of Cyathophyllum, p. 21.

without attention, and it resembled more the aspect of the equivalent section of a Strombodes than the normal condition of a Caninia. The true characters of the latter genus, including a small siphon, were however all recognizable. The lower end was obliquely fractured, but exhibited near the centre a minute convex (concave in the section which gave the under surface) plate, and two irregular openings near it, the whole being surronnded by a dense zone of lamellæ.

Stylastræa.

In the remarks on Lithostrotion (p. 602), it is stated, that the coral for which Lhwyd originally proposed the name (Lithophylacii Britanniei Ichnographia, Epistol. v. p. 122 and pl. 23, 1699) differs essentially in structure and in the mode of producing additional columns from the *Lithost. floriforme* of Dr. Fleming[1]; and it is shown that the internal structure of that fossil and of other Russian species of Lithostrotion admits of a triple subdivision, or into,—1, a central area occupied by a variously constituted axis; 2, a middle area composed essentially of persistent vertical lamellæ; and 3, an outer area formed of arched laminæ, more or less intersected by vertical plates or extensions of the lamellæ: it is also shown that the additional columns are chiefly developed within the area of the parent column, though occasionally without it; and further, that there is no prevailing natural tendency for the walls of the adjacent columns to separate when a specimen is fractured vertically. It is now proposed to explain what is believed to be the characters of the fossil to which Lhwyd first applied the name of Lithostrotion, and to point out the difference between them and those of Dr. Fleming's *Lithost. floriforme*.

Lhwyd's figure (Ichnographia, tab. 23) expresses admirably, though rudely, the brief descriptive characters engraved on the plate, "Lithostrotion sive Basaltes minimus striatus et stellatus," the vertical surface exhibiting a series of polygonal or basaltic-like columns longitudinally striated, and the transverse a congeries of variously sized, polygonal stars. Lhwyd unfortunately gives no additional information in the letter where the fossil is mentioned (Epistol. v. p. 122); but Parkinson, in his description of a coral assigned by him apparently with great correctness to Lhwyd's "Lithostrotion sive Basaltes" (Org. Rem., vol. ii. p. 43—45, pl. 5. figs. 6 and 3), says, that it "breaks with a moderate force laterally applied into angular ledges," that "one or more of the columns may be detached by a moderate stroke," and that "a close examination, especially of its polished surface, will show that the stone is composed of a congeries of polygonal columns exactly adapted and closely concreted together in a parallel direction." The first and last of these statements are strictly applicable to Lhwyd's figure, the vertical surface bearing evidence of facility of fracture, and the whole three to a coral found in the mountain limestone near Bristol. Parkinson further states, that "the longitudinal section exhibits a striated plumose appearance, and that numerous exceedingly slender, longitudinal lamellæ, corresponding with the external striæ, are disposed perpendicularly from the circumference to the centre in a stellated form, intersected vertically and horizontally by proportionally numerous and equally delicate lamellæ" (p. 44). These characters are likewise prominently exhibited by the Bristol coral before mentioned; and believing that Parkinson was perfectly correct in referring his specimen to Lhwyd's 'Lithostrotion,' and that consequently the Bristol fossil is also generically if not specifically identical with the latter, it is proposed to explain briefly the leading characters by which Lhwyd's polypidom may be known from Dr. Fleming's Lithostrotion.

The Bristol coral consists of columns closely aggregated, and so moulded as to fit perfectly and fill all irregularities; but they are easily separated on every side, the adjacent walls of each column having been developed by the inhabiting polype, without apparently any superior, superficial community of existence

[1] *Lithostrotion striatum* of the same authority, though referred to Lhwyd's figure, may, it is believed, be applied more accurately to a carboniferous fossil resembling it, but possessing truly the generic character of *Lithost. floriforme*. Brit. Anim. 508.

with the occupants of surrounding columns. In *Lithostrotion floriforme*, on the contrary, as already stated, there is no tendency to divide naturally on all sides, the walls being essentially "coadunated," a character alluded to by Martin in his account of the fossil; and though he says that "they are in most specimens separable," yet such natural divisions have been found to be only occasional and confined to a limited part of the exterior of the columns, the other portions being firmly united. These separations are believed to occur only where two groups of columns have been irregularly brought in contact. (Petri. Derb. description of pl. 43 and 44, referred to by Dr. Fleming, Brit. Anim. p. 508.) Internally Lhwyd's or the Bristol coral is divisible in the mature state into two areas, not three:—1st, a centre more or less extensive, occupied by lamellæ variously blended or by contorted laminæ, but not traversed by a distinct, persistent axis; and 2ndly, an outer area intersected by vertical persistent lamellæ, the interstices being variously crossed by inclined or arched vesicular plates. The additional columns were produced by a subdivision parallel to one of the facets of the pre-existing column, and not by the development of a circular germ. Externally, the partition was rendered visible by a line commencing in outer walls on opposite sides of a column, and ranging upwards, it almost immediately marked a clear boundary between two distinct columns. The polypes which inhabited these structures formed, as before stated, independent, adjacent walls, and had, it is inferred, no connexion at the upper extremities. To this mode of production, the facility with which the columns are detached is necessarily ascribed. In *Lithost. floriforme* the germ produced within the area of the parent was circular, its periphery having no parallelism with the sides of the previous column, and it did not develope a separate wall, the boundary between the young and the old columns having been a conjoint labour. It may be also stated, that the aptitude of the polypes to fill every inequality due to growth, precluded the possibility of the introduction of interstitial columns.

The internal characters dependent upon this manner of reproduction were better exhibited in a Russian coral, described in the next page, than in the Bristol fossil, but they are briefly noticed here to complete, as far as possible, the generic memoranda. In a section, purposely made, about half a line below the point, where a subdivision was visible, the transverse under surface exhibited not the least sign of any irregularity in the lamellæ or in the interstitial plates. The young or offset column, which commenced immediately above the section (Pl. A. fig. 2 *b*), nearly subdivided the facets from which it sprung, but its area was much less than half that of the pre-existing column. The exposed surface was inclined obliquely forward, and therefore did not display everywhere an equal state of development. The structure exhibited in this uneven plane was much less regular than that in the section beneath, though not very different from the arrangement of the component laminæ near the sides of other columns in which no subdivisions existed: traces also of extension upwards of the lamellæ of the undivided column were likewise detectable, indicating that the polype of the young column possessed, to a certain extent at least, the secreting membranes of the old. It must also be stated, that though irregularities in the exterior of the columns attended in some cases the production of the offset, yet that in others there was no disconnection upwards between the ribs of that portion of the undivided wall which was subjacent to the young column, and those on the surface of the latter. In every instance in the Russian specimen as well as in the English the divisional line of the offset was parallel to one of the facets, and the youngest condition of the severed portion was an irregular polygon. In Lithostrotion, the lamellæ of the offspring could not be referred even in part to a continuation with pre-existing structures.

In all respects, therefore, it is believed that the Bristol, and consequently Lhwyd's coral, is generically distinct from Dr. Fleming's *Lithostrotion floriforme*.

In the inferred mode of producing additional columns, there is a resemblance to the fossiliferous operation characteristic of the Astrea and Favia of Ehrenberg as well as of the restricted Caryophyllia of the same authority. In the two former however the polypes belonging to one specimen possess a perfect community of existence, and as the walls of the adjacent stems are also inseparable, there are marked generic distinctions from Lhwyd's coral. With Ehrenberg's Caryophyllia, including the Lobophyllia of De Blainville, there is a greater agreement, each polype having at the superior termination a perfectly distinct boundary, and in general considerable intervals between it and those next adjacent; but internally the structure of the Bristol coral and others allied to it, is so very distinct from that of Caryophyllia, particularly in the bi-plated nature of the lamellæ and in the vesicular character of the interstitial plates, as to warrant, independent of the mode of grouping and the decided continuation on the outer side of the divided stems, of the lamellæ of the undivided, a generic separation.

It is proposed, therefore, to apply to Lhwyd's coral the generic designation of Stylastræa (*στύλος, columna*; *ἄστρον, astrum*), recommended to the describer by Mr. Murchison on account of its columnar aspect; and if Parkinson be correct in considering it as identical with a fossil described by Volkmann, it is further suggested that it should be distinguished from other species by the designation of *Stylastræa vorticalis*. (Parkinson, Org. Rem., vol. ii. p. 45.)

The following may be given as a summary of the generic characters, so far as the nature of the coral is known to the describer:—

A columnar, lamelliferous, stony polypidom; lamellæ exceeding twelve, bi-plated; columns closely aggregated, easily separated; internal structure twofold,—1st, a central area occupied by variously blended lamellæ or contorted laminæ, without a distinct, persistent axis; 2nd, an outer zone, traversed by vertical, continuous, bi-plated lamellæ, not fasciculated; interstices occupied by numerous, arched or vesicular laminæ; additional columns produced by subdivisions of the parent column; polypes perfectly circumscribed at the superior termination; no connecting mantle.

Stylastræa inconferta, sp. n.

Columns 4—6-sided, irregular in the breadth of the planes and the range upwards; outer surface unequally ribbed; central area, variously contorted laminæ; outer zone, lamellæ about thirty-four, alternately broad and very narrow; interstitial plates numerous; terminal cup not observed; additional columns bi-partite (only?). (Pl. A. fig. 2.)

This fossil differs from Lhwyd's species in the greater dimensions of the columns, in the more open structure of the interior, and in the centre being much less occupied by prolongations of the lamellæ.

The specimen of *Styl. inconferta* which was examined, was a fragment detached from the interior of a mass, and it measured about four inches and a half in altitude, two and a quarter in width, and one and a half in extreme thickness. The columns exhibited not the slightest indications of divergence, but they were more or less irregular in form and range, and so perfectly moulded to each other as to indicate a complete aptitude in the polypes to fill every interspace (fig. 2). They had in some places been fractured, and occasionally dislocated, apparently during the life of the animal; and at the upper extremity the whole mass of the specimen, to the depth of half an inch, had so far undergone decomposition, that it presented only a confused aggregate of broken plates with slight traces of polygonal boundaries. The average diameter of the more regular columns was four lines.

1. The central area, which was circular and rarely exceeded one line in diameter, had no definite boundary, and was composed of irregular laminæ variously inclined and intermingled, but sometimes, though rarely, extended transversely across the area, giving such limited vertical sections very much the aspect of the interior of a Cyathophyllum: the general structure, however, agreed more nearly with that of a Lithodendron without an axis. Rough transverse sections, moreover, never gave a centre composed of a smooth, flat disc similar to that of Cyathophyllum; and such surfaces, when polished, always exhibited faint curved lines, without any symmetrical structure, indicative of the axis of Lithostrotion or Lithodendron.

2. The lamellæ of the outer area sprang very generally from the boundary wall, the narrow being almost rudimentary, but the broad ranging with slight flexures across the zone, and sometimes into the central structure. Though conjointly exceedingly thin, the two plates could readily be detected in polished, transverse sections; and in longitudinal fractures (fig. 2, 2 *a* mag.), the separated feathered surfaces were as clearly displayed in these comparatively minute columns as in the gigantic Caninia of Ireland. There was, however, this difference; in Stylastræa the inner surface of the plates extended to the wall of the column, while in Caninia it was confined to a limited intermediate zone. The surface was traversed by strong, waved lines, inclined upwards and outwards. The interstitial plates, prolongations, in part at least, of the central laminæ, were, as exposed in vertical sections, highly inclined, vesicular and numerous, but not so close or small as in Lhwyd's coral; and in transverse sections they exhibited variously combined, curved or arched lines, also less numerous or closely disposed than in that fossil, on account apparently of the rudimentary character of the alternate or narrow lamellæ.

The exterior of the columns (fig. 2) was very irregular in outline, conforming, as before stated, to all inequalities of upward development; and not unfrequently one column overlapped, in part, an adjacent facet. The sides were crossed by fine, waved lines and prominent ridges, indicative of renewed or disturbed growth; and they were traversed vertically by broad ribs of variable strength and persistence.

With respect to the mode of producing additional columns, the remarks already given (p. 620 and fig. 2 *b*) contain all the information acquired from the examination of this specimen, except that stages of gradual completion of internal structure in the divided columns were noticed (fig. 2 *c*), and that the reproductive developments took place very irregularly, and in general at considerable intervals. No signs of a triple or quadruple partition were detected.

Locality and Formation.—Kossatchi-Datchi, south of Miask, eastern side of the Ural Chain. Carboniferous limestone. (*Stylastræa inconferta* thus affords an additional interesting link between the carboniferous *fauna* of Western Europe and that of the borders of Asia.)

Diphyphyllum.

This generic designation is proposed for certain corals which exhibit an aggregate of characters believed to be sufficiently peculiar to warrant the fossils possessing them being considered the type of a new genus. The peculiarities were first observed in a specimen from the carboniferous limestone of the neighbourhood of Kamensk, on the Siberian side of the Ural Mountains, and more recently in a fossil of not rare occurrence in the equivalent formation near Bristol. The genera with which these corals are most nearly allied, as respects either structural details or mode of reproduction, are Lithodendron, Cyathophyllum, Stylastræa and Caryophyllia of Ehrenberg. In the following notice, allusion is constantly made to the English specimens also, as they exhibited prominently, in some instances, characters which were but slightly indicated in those from Kamensk; and the reader is requested while perusing it to consult the figures of the latter fossil given in Plate A. (figs. 4 to 4 *c*).

The points of resemblance between the corals under consideration and well-known species of Lithodendron, are, in some states, so considerable, that the Bristol fossil may have been occasionally referred to one of them. In the mode of growth, both Lithodendron and the proposed genus agree by having developed ramified masses, with the stems more or less distant from each other, but occasionally united when the interval was small. Internally both genera exhibit, in the zone surrounding the central area, a great uniformity of structure, allowance being made for specific diversities, and the variations which occur in different portions of the same specimen. The lamellæ in both are also bi-plated. As regards the central area, it was composed in the Kamensk specimens of convex or flat diaphragms; but in neither longitudinal or transverse sections obtained by fracture, and subsequently polished, were any signs detected of an axis; nor did they occur in a specimen, so worn down by the describer that the centre could not be passed, and an axis exist, without being discovered. In some of the Bristol longitudinal sections, however, displaying in all other respects a perfect agreement with those of the Kamensk fossil, a central body was occasionally more or less developed, and when fully, it resembled so greatly the axis of true Lithodendra, that a generic identity might have been inferred. It is believed, nevertheless, that there are important essential differences between the apparent axis of the proposed genus and the real axis of the established one. In Lithodendron it forms a marked persistent body, variously constituted, but ranging continuously through the centre of the stem, and forming in the terminal cup a bold boss: there is also no connexion between it and the mode of ramification, the branches springing from the side, and being in no way influenced by it. In the proposed genus, on the contrary, the central body varies in characters, the variations depending, it is believed, on the manner in which the ramifying was effected. In longitudinal sections of both Kamensk and Bristol specimens, an acicular point, more or less prolonged, was not unfrequently noticed springing vertically or obliquely from the centre of one diaphragm, and occasionally ranging to the under surface of the next. In some sections from Bristol, not those which exhibited most strongly the apparent axis, similar acicular lines traversed two, or more, successive intervals, but without any regular connexion, the terminations on the upper and under sides of the diaphragms not coinciding in position. Between these intersected intervals, others occurred in which no central process was noticed. Again, in lieu of a single line, two occasionally appeared springing obliquely from a continuous base or diaphragm, and were united in an acute angle, either at the top of the interval, or after extending through more than one, and in such cases interrupting the range of the intermediate diaphragms. Occasionally also one of the transverse laminæ was bent upwards at an obtuse angle in the centre. In the most strongly characterized axes, the diaphragms were in general very irregular, and sharply inclined against the central acicular line; the whole agreeing, as before stated, almost perfectly in appearance with the axis of some true Lithodendra. All these structures were very unequally exhibited, and even the last was preceded and succeeded in the same section, which showed no distinct curvature, by regular diaphragms and intervals, without any indications of a central body. In nearly 300 transverse or oblique sections, displayed in polished Bristol slabs, no true axis was observed; and in the only terminal cup examined (a Kamensk specimen), no boss was discovered, during a careful removal of the sediment with which the depression had been filled.

It is proposed now to state briefly the conceived real nature of these various central structures, and to point out in what respects they are believed to differ from the axis of Lithodendra.

The branching in the corals under consideration, was effected by a perfect medial subdivision of the stem, and consequently in the exact range of the indications above noticed of irregularities in the inhabiting polype: moreover, those structural inequalities often immediately preceded the sub-divisional process, and could easily be referred as the first steps in that new order of growth which was speedily perfected in the divided branches. In figure 4 *b*, Plate A., an acicular line immediately precedes the bifurcation: and the reader is requested to compare the oblique, subdivided diaphragms at the commencement of the separated branches with the inclined plates mentioned above. It is therefore inferred, that all the irregularities or apparent axeal structures are but immature signs of the process which was effected at the fitting period; and further, that such a mode of branching precluded the existence of a persistent axis similar to that of Lithodendron: it has been already stated, there is no connexion in that genus, in position or otherwise, between the axis and the lateral offsets or branches developed from germs. According to Ehrenberg, this difference in the mode of ramification demands not only a generic separation, but tha tne coral should be placed in a distinct family from that to which Lithodendron belongs.

Respecting the other genera with which the Kamensk fossil has been stated to have certain resemblances, few remarks only are necessary.

Internally there is an almost perfect central agreement, except in the occasional irregularities, between the proposed genus and many of the corals usually assigned to Cyathophyllum; but there is, again, besides the distinction in the number of areas, the important difference, of one being perfectly bipartite and the other proliferous.

As regards Stylastræa, the structural details of the interior are also different as respects the areas, and the sub-divisional process, if rightly assigned to that genus, is much less perfect than in the Kamensk fossil; in Stylastræa also the adjacent columns are never laterally united.

Lastly, while there is a strict accordance in the mode of branching, there is a complete dissimilarity internally between the coral which has been under consideration and Caryophyllia.

Believing, therefore, that the Siberian and English polypidoms are in their aggregated characters generically distinct, it is proposed to designate them by the appellation of Diphyphyllum, founded on the two-fold resemblance, first noticed in the Kamensk specimens, to Cyathophyllum centrically, and to Caryophyllia in the mode of branching (διφυὴς, *duas habens naturas*; φύλλον, *folium*).

The following generic characters are suggested:—

A stony, lamelliferous polypidom: lamellæ exceeding 12, *bi-plated; branched, branches dichotomous; internal structure, tri-areal:* 1, *central area, intersected by flat, convex or irregular diaphragms, no persistent axis;* 2, *intermediate area, traversed vertically by lamellæ; interspaces crossed obliquely or downwards by extensions of the diaphragms and subordinate plates;* 3, *outer area traversed by lateral extensions of lamellæ; interspaces crossed by arched or vesicular laminæ inclined upwards and outwards; stems not uniformly thickened by external secretions, but occasionally united when in juxtaposition.*

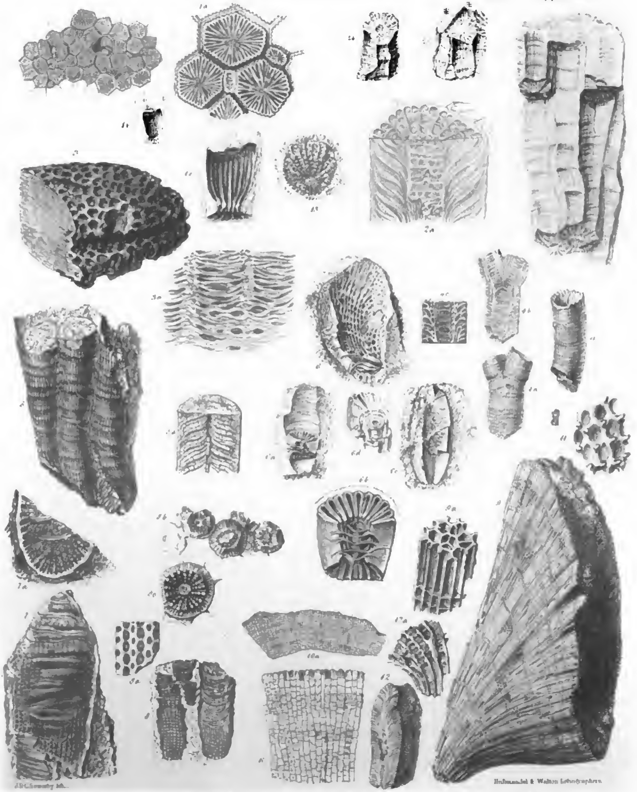
Diphyphyllum concinnum.

Stems cylindrical, nearly smooth; crossed externally by close, fine, waved lines, and stronger, unequal, distant bands; lamellæ numerous, variable; inner surface of plates furrowed strongly upwards and outwards; central area, diaphragms flat, convex or irregular; intermediate area, principal lamellæ exceeding 30, *more or less waved, intermediate very unequal; interstitial prolongations of diaphragms inclined sharply downwards, accessory plates nearly horizontal; outer area, lamellæ variable in strength and range, interstitial plates largely vesicular; terminal cup deep, lined by edges of the lamellæ, no central boss.* (Pl. A. fig. 4.)

The specimens of this coral which were examined, consisted of one subdivided stem (fig. 4 *a*, 4 *b*), and several portions of others (fig. 4); the larger having a nearly uniform diameter of four and a half lines, and the smaller of three and a half lines. The relative proportions of the areas were not quite constant, but in one specimen the width of the central was about two lines, and that of each of the others one line. The inner surfaces of the lamellæ plates agreed almost perfectly with those of Caninia and Stylastræa; and the lamellæ in their extension across the outer area, partook very much of the variable characters exhibited in the former genus; being sometimes alternately broad and narrow, the latter projecting partially into the intermediate zone, but sometimes so united to the vesicular laminæ as to form a complicated reticulation. The boundary wall was exceedingly thin throughout, and exhibited no indications of lateral junctions. The indications of an axis were very faint, being confined to the occasional appearance of a single line in the centre of the area, or to a few instances of conical irregularities in the diaphragms. The beautiful example of bifurcation represented in figures 4 *a*, 4 *b*, exhibits clearly the connexion between such irregularities and the sub-dividing process. The depth of the terminal cup was rather more than

Palæozoic Corals of Rufsia.

Plate A Appendix A



J. D. C. Sowerby lith.

Hullmandel & Walton Lithographers

1, 1a, 1c *Columnaria sulcata*
2, 2a–2c *Stylastrea inconferta*
3, 3a *Michelinia concinna*
4, 4a–4c *Diphyphyllum concinnum*
5, 5a *Lithodendron annulatum*
6, 6a–6d *Caninia Ibicina?*
7, 7a *Tryplasma aequabilis*
8, 8a–8c *Tryplasma articulata*
9, 9a *Chaetetes radians*
10, 10a *Chaetetes Petropolitanus*
11 *Stenopora spinigera*
12, 12a *Stenopora crinita* 13 *Strombodes*

half the diameter; the margin was sharp; the edges of the lamellæ projected slightly and the bottom was formed by the smooth surface of a diaphragm.

Locality and Formation.—Hill of Tchirief, Kamensk, on the river Issetz, eastern side of the Ural Chain. Carboniferous limestone.

Monticularia Sternbergii, Fischer.

Hydnophora Sternbergii, Fischer de Waldheim, Oryctographie du Gouvern. de Moscou, p. 157. pl. 34. fig. 5[1]. (Gregorievo, sixty versts south-west from Moscow.)

The specimen of this coral which was examined, consisted of soft, granular limestone, without a trace of animal secretion. The portions exhibiting the lamelliferous cones were of limited extent; but there was a perfect agreement in the number and character of rays, with M. Fischer's description and unmagnified figure. From the friable nature of the specimen, it was impossible to detect any extension inwards of the lamelliferous rays; but it was believed, on account of the agreement in the characters of the cones with those of a recent specimen of Monticularia, and from the difficulty of referring them to casts of an Astrea or any allied genus, that the fossil had been rightly studied by M. Fischer. Professor Goldfuss, in the additions to the first volume of the Petrefacta, has identified his *Astrea velamentosa*, a Maestricht fossil, with *Monticularia Sternbergii*, but most clearly on insufficient grounds (Petref. pp. 68, 245. pl. 23. fig. 4).

Locality and Formation.—Meshkovitza, Government of Kovno. Silurian[2].

Porites pyriformis, Ehrenberg.

Beiträge zur Kenntniss der Corallenthiere des Rothen Meeres, p. 120. 1831–1834. (Berlin Transactions, 1832.)

Heliopora interstincta, Eichwald, Système Silurien de l'Esthonie, p. 211. 1840.

In Mr. Murchison's works on the Silurian System, part ii. p. 686, a list of other synonyms and references is given.

It is believed, that the specific characters of the group of corals to which *Por. pyriformis* belongs, cannot be correctly determined, unless the specimens examined exhibit, not only the structure possessed during growth, but that also which the polype developed at the period when it apparently ceased to add to the stony fabric. So far, however, as a comparison of equally immature specimens would permit an opinion to be formed, the Russian fossil presented no essential structural differences from that found in the Silurian formations of England, of Gothland, or of Malmoe Isle in the Bay of Christiania. With respect to the Eifel coral described and figured by Prof. Goldfuss, under the name of *Astrea porosa*, (Petref. pl. 21. fig. 7), and identified by him, as well as by all other authorities, with the Gothland fossil, or *Porites pyriformis*, the same stage of development presents, it is believed, no structural difference, with the exception, perhaps, of a greater breadth of the lamellæ. This observation applies also to a coral common in the Devonian limestone of England, and assigned likewise to *Por. pyriformis*. In a notice, however, on one of the plates, illustrative of Professor Sedgwick and Mr. Murchison's Memoir on the Devonian System of England (Trans. Geol. Soc. London, 2nd ser. vol. v. pl. 58. 1840), some specimens

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[1] It has been considered necessary to retain the use of Lamarck's generic name, on account of its having been very generally adopted, though proposed subsequently to Hydnophora.

[2] The locality of Meshkovitza, north of Shavli, in the government of Kovno (Lithuania), where our fragment was collected, is unquestionably Silurian; whilst Fischer's locality is carboniferous. Believing the identification of Mr. Lonsdale to be correct, it does not appear to us absolutely necessary to suppose, that this species of coral is common to the two systems; for, after all, the Moscow specimen may have been derived from the northern drift, in which fragments of Silurian rocks are not uncommon.—R. I. M.

of that coral belonging to Mr. Austen are briefly shown to undergo a very remarkable change at a certain period of development, and inferred to be that which limited its growth. Whether the specific determination was correct, remains to be proved by the discovery of Silurian specimens, exhibiting fully the same state. The author of these notes is not aware of any observations having been made upon this important inquiry; and he is unwilling to propose, on imperfect evidence, specific separations; but a Gothland specimen in Mr. Murchison's cabinet afforded a few instances of the obliteration of tubes by the extension and union of the lamellæ. The characters, thus presented, differed however materially from those exhibited by the specimens from the Devonian limestones of England, being merely a junction of lamellæ without any of the fillings-up by transverse or convex laminæ so prominent in the other instances. It has, however, been deemed right to call attention to the subject, and it is hoped that it will receive from those possessed of the requisite facilities, a full share of consideration.

In the recent *Heliopora cærulea* of De Blainville (*Pocillopora cærulea*, Lamarck), a somewhat similar obliteration of the tubes occurs, but the agreement is not considered sufficient in the present state of the inquiry to justify the restoration of *Porites pyriformis* to that genus, other Anthozoa exhibiting also remarkable changes in the external characters at a certain, possibly final period of development.

Localities and Formations.—Isle of Dago; Petropavlofsk; Gothland; Malmoe Isle, in Christiania Bay; Upper Silurian.

Aulopora conglomerata?, Goldf.[1]

Petrefacta, p. 83. pl. 29. fig. 4.

The fossil assigned with a doubt to this coral, was attached to a mass of Favosites, and occupied a surface about an inch in diameter. It consisted of an aggregate of nearly horizontal or inclined tubes, forming what might be considered as the base, or commencement of a group similar to that figured by M. Goldfuss (*loc. cit. supra*).

Locality and Formation.—Isle of Dago. Upper Silurian.

Stromatopora concentrica, Goldfuss.

Petrefacta Musei Univer. Bonnensis, p. 22. tab. 8. fig. 5. 1826.

Mr. Murchison's Silurian System, part ii. p. 680. pl. 15. fig. 31. 1839.

No differences were observed between the Russian specimens of this coral, and those found in the Silurian formations of England. In Russia it occurs also in considerable masses, equalling many of the larger specimens obtained in the Wenlock limestone, one, from the Isle of Dago, measuring eight and a half inches in length, five in its greatest breadth, and three and a half in thickness; and another of an oval form from Petropavlofsk on the east flank of the Ural Chain, being about nine inches in one diameter, and five in the other.

It does not appear to be a common fossil in Gothland, not being mentioned by Fougt in his memoir on the Corals of the Baltic, or by Hisinger in the Lethæa Suecica; the author of these notes has also seen but one small fragment imbedded in a slab of encrinital limestone. It is believed to occur in one of the Silurian deposits of the bay of Christiania.

Localities and Formations.—Naissi in Lithuania; Gothland; Isle of Dago; North of Petrozavodsk; Petropavlofsk, and between N. and V. Turinsk, east flank of North Ural; Isles of Christiania Bay. Silurian.

FENESTELLA, Miller.

This genus was originally proposed by the late author of the work on Crinoidea, but it was first introduced into a published notice on fossil corals, in the Appendix to Mr. Murchison's 'Silurian System'

[1] A second species of Aulopora (*A. serpens?*) was found by Count Keyserling in the Devonian strata of Voroneje, but has not been submitted to Mr. Lonsdale.

(part ii. p. 677. 1839). Various polypidoms, however, similar in structure with the carboniferous limestone fossils to which the name was applied by Mr. Miller, having been recently referred to Gorgonia and Retepora, and the establishment of Fenestella objected to[1], it has been deemed necessary to point out briefly the characters by which the latter genus is distinguished from the two former.

From Gorgonia, whether limited according to Lamouroux, De Blainville and Ehrenberg, or considered more generally, as by Lamarck, Fenestella differs in its principal component structures. It has no contractile, separable, pulverulent crust, to which the cell of the polype is limited, nor has it any representative of an internal, horn-like axis, with or without a distinct central structure. The outer lamina, which in a state of decomposition may be said to resemble, to a certain extent, the crust of Gorgoniæ, consists, however, in a nearly perfect condition, of an apparently solid substance, more or less pierced by microscopic foramina, but bearing no trace of having been contractile, or largely composed of animal matter. On the side to which the cells are confined, it is very thin, except at the intervals where the cells bend suddenly outwards; while on the reverse side, it was not developed till the coral had attained a certain age, after which it was gradually thickened, and it often attained considerable dimensions in the lower part of the stem. In some old specimens, when this reverse lamina is partially abraded, and the internal layer of vertical tubuli is exposed, the resemblance to ordinary, recent Gorgoniæ is considerable; but a due examination of all the component parts will convince the observer that there is no generic identity. In the next place, as respects the cells, the differences are as great. In Gorgoniæ the whole contractile crust, including the sides of the polype-cavities, is but a great development of the outer tunic of the compound animal[2]; whereas in Fenestellæ, the laminæ composing the outer surface and the other walls of the cells, agree closely in characters with the equivalent portions of true calcareous cellular corals, and therefore had no intimate union or interblending with the membranes of the polype similar to that of Gorgoniæ. A careful consideration of these structures alone, will, it is believed, satisfy the palæontologist, that there is not merely a generic, but a much greater distinction. With regard to the interior of the coral, a perfect dissimilarity again prevails. Beneath the thick series of obliquely overlying cylindrical cells, limited to one side of the coral, there is no axis formed of concentric bands variously composed, yet distinct in character from the crust, but a parallel layer of vertical, capillary tubes, the walls of which differ not apparently from those of the cells. In the young states, this layer constitutes the outer surface of the non-cellular side,—a character not to be detected among Gorgoniæ, which develope, first, the perfectly surrounding crust, and then the fibrous or horn-like axis. The outer layer of the reverse side differs not, as before stated, essentially from the other solid portions, and was clearly formed by secretions from vessels connected with the polype by means of foramina or tubuli, in the same manner as in many cellular or tubular corals; and it cannot be regarded, like the crust in Gorgoniæ, as the product of an investing animal substance.

The characters thus imperfectly suggested for consideration, will, it is hoped, when better elucidated by accomplished palæontologists, lead to a right understanding of the corals assigned to Mr. Miller's genus, and remove every doubt respecting their not being "corticiferous polypidoms." Had that author lived and published the intended work, the nature of these fossils would not have been misunderstood by any observer.

Between Fenestella and Retepora the agreement is much greater than in the preceding case. In both genera the polype cells are limited to one side, and the reverse surface is formed as well as thickened by

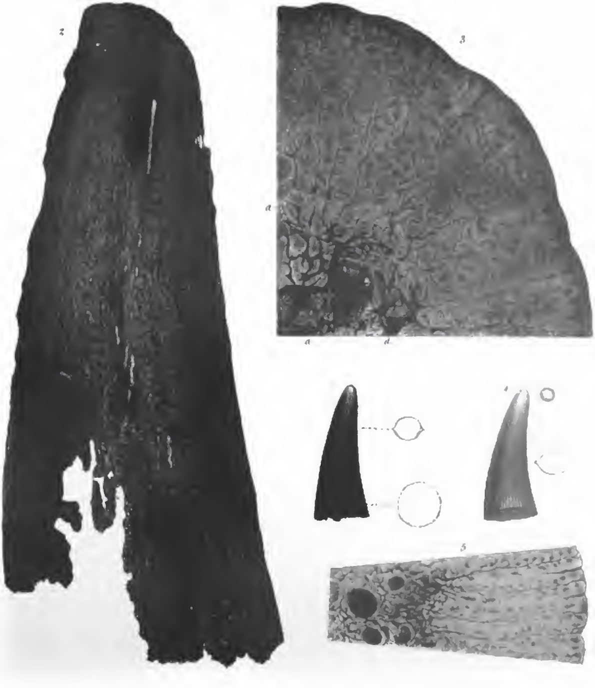
[1] Description Anim. Foss. Terr. Houiller, &c. de la Belgique, p. 3, 1842.

[2] See Dr. Milne Edwards' remarks on "Polypiers Corticifères." 2nd edit. Lamarck, Anim. sans Vert. ii. p. 464 *et seq.* 1836.

secretions from the animal through foramina in the first instance, and horizontal channels subsequently: but in true Reteporæ the intermediate layer of vertical capillary tubes is totally wanting, the corals possessing that structure, and formerly included in the genus, having been removed from it by Lamouroux and other authorities. Among the minor distinctions may be noticed, the oblique arrangement of the cells in Fenestella, whereby they in part overlie each other, and are more or less suddenly bent towards the oral termination; also the tendency to a cylindrical form and vertically lineal arrangement. If the meshes in Retepora generally can be regarded as the result only of oblique unions of branches, then the transverse processes in Fenestella, whether cellular or not, may likewise be considered as a generic distinction. A central dividing ridge, or the sculpturing exhibited on the cellular surface of some species of Fenestella cannot alone be regarded as an essential character, though no analogous structure appears to have been noticed in Reteporæ, the strength of the configurations depending generally upon the age of the specimen or of the part preserved, and the very existence being not unfrequently concealed by external thickenings. There are other details which the practised eye will detect and dwell upon, and render available in the aggregate; but it is hoped that sufficient have been indicated to prevent the most inexperienced palæontologist from assigning to Retepora such polypidoms as those under consideration, because they exhibit, at first sight, a certain amount of resemblance.

Between Fenestella and Hornera the agreement in some respects again is greater than in either of the preceding instances, but there are important essential differences. In Hornera there exists each of the three great structural characters already shown to belong to Fenestella, namely, a polypiferous surface, an intermediate layer of capillary tubes, and a reverse outer crust produced at a certain period of development, and thickened by secretions from the animal. In the cylindrical or slightly polygonal form of the polype cavity, as well as in the oblique overlying position, there are also certain but limited agreements, the cavity being of very limited extent in Fenestella. Hornera, however, has been shown by Dr. Milne Edwards to belong to the family of Tubuliporidæ (Recherches sur les Polypes, Mem. sur les Crisies, &c.), and it never exhibits the structures about to be noticed. In many published figures, a row of relatively large foramina are delineated ranging down the central ridge (where it exists); and they have been found to prevail in species possessing such divisional lines, whether one or more in number, but under different appearances, the foramina being sometimes near each other, sometimes at considerable distances, and generally in a straight row, though in one instance they were found to be arranged alternately or in zigzag. Occasionally they are entirely wanting. When the coral itself is not preserved, and the specimen exhibits only a cast of the surface, a conical indentation usually represents the foramen; and the difference is conjectured to arise from the outer covering of the opening having been destroyed where the coral is in part preserved, but impressed in a perfect condition where the cast only is exhibited. In the cast of a fine large coral which exhibited all the structural characters of Fenestellæ, but in which the polype-residences were disposed in quincunx without any divisional ridges, there were no lineally disposed foramina or indentations; but over or a little on one side of many of the oral apertures, were minute, semi-spherical convex casts, and in a few instances a corresponding concave impression. Respecting the true nature of these foramina or the chambers connected with them, no opinion is hazarded; but it is believed that they are strictly analogous to the rows of apertures in the Lunulites, which have the cells arranged in parallel lines, and that the semi-spherical cavities in the specimen last alluded to may be considered identical in nature with the shallow cavities of frequent occurrence over the mouths in those species of Lunulites which have the cells disposed in quincunx. Beyond this comparison, and the inference that Fenestella should be considered as belonging to the same family of polypidoms as Lunulites, and therefore not to the Tubuliporidæ, the author does not feel qualified at present to offer any remarks.

Plate B Appendix



1 . 2 . 3 *Dendrodus Murchisoni.* (Owen) 4 . 5 *Dend. biporcatus* (Owen)

How far a perfect examination of the numerous fossils which have been considered referable to Fenestella may suggest the necessity of forming subgenera, the describer cannot offer an opinion, many of the published species not having been accompanied by detailed illustrations; but he would suggest for the consideration of the palæontologists, who may pursue the inquiry, the following generic characters for Fenestella:—

A ramose, cellular, calcareous polypidom; cells variously distributed on one side of the branches, with or without dividing ridges: branches connected by transverse or oblique processes, cellular or not, forming generally expansions or funnel-shaped bodies; the latter with the cellular surface sometimes on the inner, sometimes on the outer side; cells cylindrical, obliquely arranged, overlying, mouths inclined outwards, more or less distant; interior of mature specimens, a layer of vertical capillary tubuli; reverse side of young specimens, the layer of tubuli—of mature specimens, a crust perforated by minute pores; in aged specimens both cellular and reverse surfaces greatly thickened, all external ribs or sculpturing obliterated, and oral apertures more or less contracted; a row of foramina or chambers between the parallely disposed cells, or a small shallow cavity over the mouth in species with cells in quincunx.

In the tabular list of Permian fossils given in page 255, eight species of Fenestella are included; but only *Fen. infundibuliformis* and *Fen. retiformis* claim particular attention, *Fen. antiqua* and *Fen.? dubia* being included in the list on the authority of Schlotheim, and the other four species, *Fen. anceps, Fen. flustracea, Fen. ramosa* and *Fen. virgulacea*, not having been discovered in Russia. For an opportunity of examining a fine series of English and continental specimens, the author is indebted to Mr. King, Curator of the Museum of the Natural History Society of Northumberland and Durham; and understanding that that gentleman purposes to publish a monograph of British magnesian limestone fossils, he feels it is totally unnecessary for him to offer any remarks on the English species, further than his belief that they possess all the essential structures of Fenestellæ. With respect to *Fen. anceps*, which exhibits a peculiar mode of growth, he conceives that, unless this character be accompanied by other more important differences, it should not be regarded as the grounds for a generic separation.

Fenestella infundibuliformis.

Irregularly bifurcated; branches compressed, broad; rows of cells exceeding two, alternate; capillary tubuli distinct; no external layer exhibited on the reverse side.

Gorgonia infundibuliformis, Goldfuss, Petrefacta, p. 98. pl. 36. fig. 2 *a* (Ural); De Blainville, Man. d'Actinol. p. 506.

The principal fragment of the coral assigned to this species scarcely exceeded three lines in height and width, but it agreed perfectly, so far as it could be compared, with the Ural fossil figured by Goldfuss. Under the same name that authority has also included the *Escharites retiformis* of Schlotheim from the Zechstein of Thuringia, and another polypidom from the older palæozoic rocks of Wüpperfurt. Confining, however, the attention to the Permian or zechstein corals, a comparison of figure 2 *a* in plate 36 of the 'Petrefacta,' and the Russian specimen collected by Mr. Murchison with figures 2 *b*, 2 *c*, proved a perfect want of agreement in the form and arrangement of the branches as well as of the cellular openings, especially as the Russian specimen was evidently not aged. It was therefore considered right to adopt M. de Blainville's limitation of the specific name *infundibuliformis* to the Russian fossil (*loc. cit.*), and to retain M. Schlotheim's *retiformis* for Fenestellæ, agreeing in character with the zechstein polypidom of Thuringia. The imperfect condition of the specimen did not permit any structural details to be ascertained, demanding special notice.

Locality and Formation.—Ilchegulova, in the Government of Orenburg. Permian.

4 M

Fenestella retiformis ?

Funnel-shaped or foliaceous; branches slender, approximate, bifurcated; cells small, bi-tri-serial, rows separated by narrow, irregularly tubercled ridges; transverse processes short, occasionally cellular; reverse side, outer surface smooth.

In the list of synonyms in the Table, p. 255, the references to Goldfuss are limited for the reasons stated in the notice on *Fen. infundibuliformis*, and of the identifications given by Geinitz in the 'Gæa von Sachsen,' p. 98, it is considered that *Retepora (Fen.) flustracea* should be omitted, the English fossil differing from *Fenestella retiformis*, as figured by Goldfuss (Petref. *Gorg. infundibuliformis*, pl. 36. fig. 2. *b, c*), in the extreme slenderness of the branches, and the absence of the persistent, closely-set row of cellular mouths, or possibly abraded vesicles, along the middle ridge. The reference to Ehrenberg, also given by Geinitz, should be equally omitted, as the fossil is not a corticiferous coral; but it must be observed that Ehrenberg himself expresses doubts respecting the true nature of Goldfuss's *Gorgonia infundibuliformis*. (Beiträge, &c., p. 140, 1834.)

The Russian specimen assigned doubtfully in this notice to *Fen. retiformis* had not been examined by the describer when the table of Permian fossils was prepared. It agreed with M. Goldfuss's figure 2 *b*, plate 36, in the foliaceous mode of growth, in the branches ranging parallelly and almost close together, in the angular form of the celluliferous surface, and in the prominence of the lateral rows of mouths. Along the cast of the dividing ridge there was also a row of indentations, answering to the middle series of openings in figure 2 *c* of Goldfuss; but they differed from the casts of the lateral rows of mouths in being conical pits and not annular impressions. No bifurcations are given in the figure last referred to, but in the Russian fossil they were numerous, and were preceded for a little distance by an interpolated row of cells, the three series being separated by two lines with conical impressions.

Locality and Formation.—Kniaspavlova, near Arzamas. Permian.

The two following species are from the Carboniferous system.

Fenestella Veneris ?

Foliaceous; branches slender, straight, distantly bifurcated; no increased width at the bifurcations; transverse processes slightly curved upwards; meshes elongated, narrow.

Retepora Veneris, Fischer de Waldheim ? Oryc. du Gouvern. de Moscou, p. 165. pl. 39. fig. 1.

The specimen from which the above defective characters were obtained agreed perfectly with M. Fischer's description and figures, but the siliceous mode of preservation, and the non-cellular surface only being exposed, nothing respecting the internal structure or the arrangement of the mouths could be ascertained. It was nevertheless considered correct to remove the fossil from the genus Retepora.

Locality and Formation.—Stretinsk, south-east of Kungur. Carboniferous limestone.

Fenestella Martis ?

Foliaceous; branches flat, very broad previous to bifurcation, in general unequally narrow immediately subsequent; meshes oval; cells 2–5 rows, alternate; transverse processes rarely cellular; vertical tubuli of intermediate layer relatively large; reverse side, outer crust thick, smooth, minutely foraminated.

Retepora Martis, Fischer de Waldheim ? *Op. cit.*, p. 165. pl. 39. fig. 2 (Serpukhof).

The specimen under consideration agreed, so far as it could be compared, with M. Fischer's coral, but as a complete structural identity could not be made, it was deemed advisable to regard the specific determination as doubtful.

The specimen was slightly curved, about one inch and a quarter in height and breadth, the branches diverging as from a centre, and not from a funnel-shaped base; and it was imbedded with the cellular side downwards in a hard crystalline matrix which did not admit of mechanical removal. The exposed surface consisted chiefly of the dorsal terminations of the cells, with patches of the tubular layer and a few fragments of the outer crust. The extremities of the cells occupied the whole width and length of the branches, and they varied slightly in size, but bore no resemblance to the terminations of true tubular polypidoms. The bifurcations were very irregular in position, being sometimes near together, but sometimes separated by considerable intervals; and the inequalities in the subdivided branches for a short distance were often very marked. The tubular layer was thin, but the outer crust had relatively a great thickness, modifying the form and size of the meshes. The perfect characters of the cellular surface could not be ascertained.

Locality and Formation.—Goradofka, in the coal-region of the Donetz. Upper carboniferous limestone with Fusulinæ and coal. See p. 97, and Pl. 1. f. 2.

Anthophyllum? incrustans.

Incrusting; tubes lamelliferous? short, more or less conical, not in contact, interspaces occupied by variously arranged laminæ.

Calamopora incrustans, Phillips? Illustrations, Geol. Yorkshire, part ii. p. 200. pl. 1. figs. 63, 64.

In the Table of Permian fossils (p. 255) the generic determination of this coral is given doubtfully, and it must be considered as quite provisional, the only specimen which the describer has seen being imperfectly preserved. He has, nevertheless, deemed himself warranted not to consider it a Favosites (Calamopora) on account of the laminated interspaces between the tubes; and it was this structure which induced him to assign the fossil to Anthophyllum as restricted by Ehrenberg.

The tubes were generally narrow at their lower extremity and widened very gradually. The greatest ascertained length was one line, and breadth at the upper end half a line. They were often much inclined for a third of their range, and were seldom wholly vertical. Traces of lamellæ were noticed, but they were very indistinct. Around the best-preserved mouths was a marginal swelling, indicative, probably, of the semi-globular protuberances represented in Mr. Phillips's magnified figure of *Cal. incrustans* (*Op. cit.*, pl. 1. fig 64). The intertubular structure, as exposed in a side section, consisted of transverse fine laminæ (see also fig. 64), and on the upper surface of similar plates, but arranged vertically, and more or less reticulated. No distinct rows of foramina were noticed on the sides of the tubes.

Locality and Formation.—Ust-Vaga, i. e. *débouchûre* of the Vaga into the Dwina. Permian.

Stenopora[1].

Under this generic name it has been proposed to include certain corals composed of elongated tubes, and which exhibit at one period of development the peculiarity of a perfectly closed mouth. It is believed that many palæozoic polypidoms which have been assigned to the genera Ceriopora and Millepora will be found to be referable to it.

In a recent notice on some Australian corals, the following generic characters were given:—

"*A ramose, spherical or amorphous tubular polypidom; tubes polygonal or cylindrical, radiated from a centre or an imaginary axis, contracted at irregular distances, but in planes parallel to the surface of the specimen; tubular mouths closed at final period of growth; ridges bounding the mouths, granulated or tuberculated; additional tubes interpolated*[2]."

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[1] In the Table, p. 255, the generic name Tubuliclidia appears, but it having been considered objectionable, Stenopora has been substituted for it.

[2] Physical Description of New South Wales, &c., by P. E. Strzelecki, p. 262, 1845.

Stenopora spinigera, sp. n.

Ramose; branches cylindrical, slender; tubes divergent, inclination variable, in close contact slightly polygonal or circular; mouths, when open, round or oval, with sharp boundary ridges; when partially or wholly closed, ridges thick; bold, spinous projections, irregularly situated. (Plate A. fig. 11.)

The finest specimen of this coral which was examined, consisted of a mass of fragments five inches in length, two and a half in breadth, and about one and a quarter in thickness. The diameter of the full-grown branches rarely exceeded a line, but they sometimes swelled suddenly and then contracted. The tubes in general diverged slightly, and the openings were in consequence for the greater part oblique to the surface and oval. No contractions previous to those connected with the final closing of the oral apertures were noticed.

Localities and Formation.—In addition to the Permian localities given in p. 255, may be mentioned Sakmarka, west flank of the South Ural. Permian limestone.

Stenopora crassa, sp. n.

Ramose; branches thick, divergent; tubes long, slightly inclined and polygonal in the axis of the branches; towards the periphery, suddenly bent outwards; contractions occasionally visible in the bent portions; outer surface imperfect. (Plate A. fig. 12.)

This species was distinguished from the preceding by the branches attaining in one portion of the specimen three quarters of an inch in diameter, and an altitude exceeding three inches. The tubes were slender, not exceeding the fourth of a line in diameter; but they were sometimes three lines in length before they inclined outwards, and two afterwards in the bent portion, or five lines in all. Proofs of contractions within the tubes were detected in many places near the circumference of the branch, but they were not so developed, on account, possibly, of the state of the specimen, as to exhibit the decided lineal range exhibited by some Australian species (*Op. cit.*, pl. 8). The outer surface was abraded, and the characters of the mouths or dividing ridges could not, consequently, be ascertained previously to the final narrowing of the oral aperture or after its completion.

Locality and Formation.—Ust-Vaga (junction of the river Vaga with the Dwina). Permian.

DESCRIPTION OF PLATE A.

PALÆOZOIC CORALS OF RUSSIA.

Fig. 1. *Columnaria sulcata.*—1, exhibits the general mode of grouping and interpolating additional columns, natural size; 1 *a*, portion magnified to show the straight divisional line between the columns; also the characters of young columns; 1 *b*, 1 *c*, a terminal cup, natural size and magnified. p. 601.

Fig. 2. *Stylastræa inconferta.*—2, represents the vertical mode of growth, and the tendency of the columns to separate along the outer surface of the walls; also a perpendicular internal section, natural size; 2 *a*, exhibits the bi-plated structure of the lamellæ, and the plumose markings on the inner surface of the plates; 2 *b*, gives the commencement or base of a young column springing from within the area of an old one, and at the point where the separation in the outer walls took place, natural size; 2 *c*, another instance of a young column by the side of an older (* *), the crest springing from the undivided wall, indicating the line of separation, natural size. (p. 621.)

Fig. 3. *Michelinia concinna.*—3, exhibits the general characters of the terminal upper surface and a lateral

polished section; 3 *a*, the side section magnified to show the arrangement of the transverse plates and the existence of foramina. (p. 611.)

Fig. 4. *Diphyphyllum concinnum.*—4, general characters of an undivided stem, natural size; 4 *a*, exterior of a divided stem, natural size; 4 *b*, interior of a divided stem to show the perfect bi-partition of the central structure and the uninterrupted continuation of the outer vesicular band or zone, natural size; 4 *c*, magnified portion of the interior to exhibit the analogy with the centre of Cyathophyllum. (p. 624.)

Fig. 5. *Lithodendron annulatum.*—5, group of stems to show the mode of occasional union, natural size; 5 *a*, vertical section to explain the nature of the central plates. (p. 599.)

Fig. 6. *Caninia Ibicina.*—6, illustrates the characters of the lower portion of a stem, natural size; to the left of the upper part the outer or vesicular zone is in contact with fragments of the lamelliferous zone; a little lower the vesicular zone is greatly diminished, and near the bottom the figure shows correctly that the structure of the coral was there limited to the lamelliferous zone, and the central area composed of transverse diaphragms; the siphon-folds were not noticed in this specimen; 6 *a*, 6 *b*, fragment of also a lower or bi-areal portion, but with the siphon folds preserved, natural size, and magnified; 6 *c*, a baseal termination, consisting of lamellæ in nearly close contact, with faint indications of a central structure, natural size; 6 *d*, portion of upper part of 6 c magnified to exhibit the siphon and concentric laminæ. (p. 617.)

Fig. 7. *Tryplasma æquabilis.*—7, gives, under various conditions, the vertical rows of foramina which perforated the lamellæ, natural size; 7 *a*, an obliqne transverse section, showing near the outer walls foramina in the substance of the lamellæ, and towards the centre rows of detached circles, indicating, it is believed, that the foramina terminated on the edge of the lamellæ in tubuli, natural size.

Fig. 8. *Tryplasma articulata.*—This coral, believed to be the *Cyathophyllum articulatum* of M. Hisinger, a Gothland fossil (Lethæa Suecica, pl. 29. fig. 4), is given to prove, that the peculiar characters exhibited by *Tryplasma æquabilis* occur in another coral with a sufficient amount of differential structure to warrant the establishing of a second species, and therefore the proposing of the sub-genus. Fig. 8 illustrates the general structure shown by a vertical section of the natural size, and 8 *a* gives a magnified view of the foramina; 8 *b*, 8 *c*, exhibit, in the natural size and magnified, superior terminations of the columns, with tubnlar projections along the edges of the lamellæ.

Fig. 9. *Chætetes radians.*—In fig. 9 the parallel, curved lines mark the position and range of the bands of diaphragms; 9 *a*, is given to illustrate the production of additional columns by vertical plates developed within the area of pre-existing columns; the figure exhibits accurately the characters of the plates in transverse and perpendicular sections; it shows also the nature of the diaphragms.

Fig. 10. *Chætetes Petropolitanus.*—Fig. 10 gives the general but irregular distribution of the diaphragms over the whole snrface, and not limited to bands as in *Chætetes radians*, magnified; 10 *a*, portion of a large globular specimen in which the diaphragms occurred throughout the vertical section in the manner exhibited, natural size.

Fig. 11. *Stenopora spinigera.*—Magnified figure, with mouths more or less closed.

Fig. 12. *Stenopora crassa.*—12, general characters of the coral; 12 *a*, contracted tubes magnified.

Fig. 13. *Strombodes.*—A transverse section for comparison with the English carboniferons species.

The Plate was lithographed by Mr. J. de Carle Sowerby with his habitual attention to truthfulness of character.

Tabular List of Corals included in the preceding Notes.

No.	Genera and Species.	Authors and References.	Palæozoic Systems in Russia. Sil.	Dev.	Carb.	Perm.	Localities in Russia.
	Stromatopora	Goldf.					
1	concentrica	Goldf. Petref. p.22. pl.8. f.5. *ante*, p.626.	•				Nassi, Isle of Dago, North of Petrosavodsk, Petropavlofsk and between N. and V. Turinsk in the north, Ural Mountains.
	Syringopora	Goldf.					
1	parallela	Harmodites id. Fisch. Oryc. p.161. pl.37. f.6. *ante*, p.591		?	•		Miatchkova, Perimishel, Vitegra, Ilinsk, Tchussovaya R., (C.), Odoyef (D.?)
2	distans	Harmodites id. Fisch. Oryc. p.161. pl.37. f.1, 2. *ante*, p.592.			•		Shidrova, R. Vaga (Drift of Carboniferous Limestone.)
	Catenipora	Lamk.					
1	labyrinthica	Goldf. Petref. p.75. pl.25. f.5. Halysites id. Fisch. Oryc. p.164. pl.36 f.1, 2. 4. *ante*, p.594	•				Isle of Dago, Nassu, and Shavli in Lithuania.
	Chaetetes	Fischer.					
1	radians	Fisch. Oryc. p.160. pl.36. f.6. *ante*, p.595. Pl. A.			•		Miatchkova, Borovitchi, Kaluga, Vitegra.
2	dilatatus	Fisch. Oryc. p.160. pl.36. f.2. *ante*, p.596.			•		Miatchkova, Borovitchi.
3	Petropolitanus	*ante*, p.596. Pl. A. f.10. Favosites id. Pander Beiträge, p.106. pl.1. f.6—11.	•				St. Petersburgh and Esthonia passim.
	Favosites	Lamk.					
1	alveolaris	Goldf. Petref. pp.77. 245. pl.26. f.1. *ante*, p.610	•				Dago, Petropavlofsk and Volshanka R. (Ural).
2	polymorpha	Goldf. Petref. pp.79. 245. pl.27. f.2. *ante*, p.610.	•	?			Katchukof on the Upper Bielaia, Usiansk Zavod and East of Ala-tau, South Ural, Petropavlofsk, North Ural.
	Michelinia	De Koninck					
1	concinna	Lons. *ante*, p.611. Pl. A. f.3.			•		Ust-Kova, West flank of Ural Mountains.
	Lithodendron	Schweigger, J. Phillips.					
1	costatum	Lons. *ante*, p.598. woodcut.			•		Perimishel, South of Kaluga.
2	annulatum	Lons. *ante*, p.599. Pl. A. f.5			•		River Issetz, E. of Ekaterinburg, Ilinsk, on the Tchussovaya, W. side of Ural Mountains.
3	concameratum	Lons. *ante*, p.599			•		River Oster, Government of Tula.
4	fasciculatum	J. Phillips, Geol. Yorks. ii. p.202. pl.2. f.16, 17. *ante*, p.599			•		River Tchussovaya, West side of Ural Mountains.
	Cladocora	Ehrenberg					
1	? sarmentosa	Lons. *ante*, p.600			•		Kamensk, E. of Ekaterinburg.
	Columnaria	Goldf.					
1	sulcata	Goldf. Petref. p.72. pl.24. f.9. *ante*, p.601. Pl. A. f.1	•				Habsal (Baltic Coast).
	Lithostrotion	Lhwyd, Fleming.					
1	emarciatum	Astrea id. Fisch. Oryc. p.154. pl.31. f.5. *ante*, p.603. woodcut			•		Borovitchi, near Valdai.
2	mammillare	Astrea id. Fisch. Oryc. p.154. pl.31. f.8, 9. *ante*, p.606. woodcut.			•		Prikaha, Valdai Hills.
3	astroides	Lons. *ante*, p.607. woodcut.			•		Pinega (60 versts west of Tchussovaya R.).
4	floriforme	Fleming, Brit. Anim. p.508. *ante*, p.602. woodcut.			•		Borovitchi, Valdai Hills.
	Strombodes	Schweigger					
1	species not named	*ante*, p.614. Pl. A. f.13			•		Usa River, junction with the Volga near Samara.
	Cyathophyllum	Goldf.					
1	turbinatum	Goldf. Petref. p.56. pl.16. f.8. *ante*, p.612.	•				Petropavlofsk, East side of N. Ural Mountains.
	Tryplasma	Lons.					
1	aequabilis	Lons. *ante*, p.613. Pl. A. f.7.	•	–			River Kakva, East side of Ural Mountains, Petropavlofsk (D.? or S.?).
	Cystiphyllum	Lons.					
1	impunctum	Lons. *ante*, p.615	•				Petropavlofsk, East side of N. Ural Mountains.
	Caninia	Michelin.					
1	species not named	*ante*, p.616			•		East of Usolie on the Volga, near Samara.
2	ibicina?	Turbinolia id. Fisch.? Oryc. p.151. pl.30. f.5. *ante*, p.617. Pl. A. f.6.			•		Velikovo, on the Klasma.
	Anthophyllum	Schweigger, Ehrenberg.					
1	? incrustans	Calamopora id. Phillips's Geol. Yorks. ii. p.200. pl.1. f.63, 64. *ante*, pp.255, 621				•	Ust-Vaga.
	Stylastraea						
1	inconferta	Lons. *ante*, p.621. Pl. A. f.8.			•		Kossatchi-Datchi, East side of the South Ural Mountains.
	Diphyphyllum	Lons.					
1	concinnum	Lons. *ante*, p.624. Pl. A. f.4.			•		Kamensk, East side of Ural Mountains.
	Monticularia	Lamk.					
1	Sternbergii	Hydnophora id. Fisch. Oryc. p.157. pl.34. f.5. *ante*, p.624.	•				Meshkovitsa, Lithuania.
	Porites	Lamk.					
1	pyriformis	Ehrenberg, Beiträge, p.120. Astrea porosa, Goldf. Petref. p.64. pl.21. f.7. *ante*, p.625.	•				Isle of Dago, Petropavlofsk, Ural Mountains.
	Aulopora	Goldf.					
1	conglomerata?	Goldf. Petref. p.83. pl.29. f.4. *ante*, p.626.	•				Isle of Dago.
	Stenopora	Lons.					
1	spinigera	Lons. *ante*, pp.255, 631. Pl. A. f.11.				•	Ust-Vaga.
2	crassa	Lons. *ante*, pp.255, 632. Pl. A. f.12.				•	Sakmarka, Ust-Vaga, &c. (see p.255).
	Fenestella	Miller.					
1	infundibuliformis	*ante*, p.629, see also p.255 for References				•	Ilchegulova, Orenburg, &c. (see p.255).
2	retiformis?	*ante*, p.629. also p.255.				•	Kniasporlova, near Arzamas (see also p.255).
3	Veneris?	*ante*, p.630. Retepora id. Fisch.? Oryc. p.163. pl.39. f.1			•		Strotinsk, south-east of Kungur.
4	Martis?	*ante*, p.630. Ret. id. Fisch.? Oryc. p.165. pl.39. f.2			•		Gerandofka in the Donets country.

B.

An Account of the Microscopic Structure of certain Fossil Teeth from the environs of Riga, by which they are determined to belong to the genus *Dendrodus* of Sauroid Fishes. By Professor Owen.

The teeth, of which the following is an account of the microscopic structure, were procured by Mr. Murchison from M. Pander, who collected them in the environs of Riga, and were submitted to me for examination with a view more especially to determine whether they appertained to the class of Reptiles or to that of Fishes.

By some of the palæontologists of Russia these fossil teeth had been referred to the Saurian order, and they bear, in fact, a close external resemblance to the teeth of crocodiles; but the absence of any definite proof of the existence of air-breathing Vertebrata anterior to the deposition of the magnesian limestone or dolomitic conglomerate rendered the question of the possible existence of Saurian reptiles in the Old Red Sandstone of Livonia one of far too high importance to be left in any degree questionable, through an opinion of the nature of a fossil tooth founded solely upon an inspection of its outward form.

The insufficiency of this kind of examination had, in fact, been made very manifest by the results of a microscopic investigation of the structure of some fossil teeth, transmitted to me a short time previously from Scotland by a friend who suspected them to belong to Saurians, but which were proved by their internal structure to be referable to the class of Fishes, and to be indicative of a new genus in the Sauroid family for which I proposed the name of *Dendrodus*. Those teeth were obtained from the central or cornstone division of the Old Red Sandstone of Scat-crag, near Elgin. They are described, and their microscopic structure illustrated, in the first number of the Microscopic Journal[1], and in my 'Odontography'[2].

I recognised in the fossil teeth from Riga a close external resemblance with those of the *Dendrodus* from Scat-crag, especially the *Dendr. biporcatus*. They presented the same conical, slightly compressed, subincurved form, the same subcircular base and obtuse summit, the same additional resemblance to the teeth of crocodiles in the two opposite ridges extending from near the base to the summit of the tooth; but the rest of the enamelled surface of the Russian teeth bore a greater resemblance to those of Saurians in having fine elevated longitudinal ridges, in addition to the linear impressions which were observable in the *Dendr. biporcatus*.

Fortunately, however, the difference between the internal structure of the teeth of true Saurians and of the teeth of Sauroid fishes is well-marked and easily recognisable. In the Crocodiles, recent and fossil, as well as in the Enaliosauria, the dentine or principal substance forming the body of the tooth consists of an uniform system of dentinal or calcigerous tubes, radiating from a slender central pulp-cavity to the periphery of the tooth, without any intermixture of vascular canals. In the *Dendrodus* there is a wide pulp-cavity, subdivided into irregular longitudinal canals or sinuses, from which a series of vascular canals radiate to the periphery of the tooth, sending off branches at right angles throughout their entire course, whilst the dentinal tubuli are continued from the slightly expanded terminations of these branches, and from the peripheral terminations of the radiating trunks. This high organization, arising out of the extensive distribution of the vascular system through the body of the tooth, does not exist in any Saurian reptile; the dental structure bearing the closest analogy to it, in the class of *Reptilia*, being that highly peculiar one which characterizes the teeth of the gigantic Labyrinthodont Batrachians. The difference,

[1] 8vo, 1841, p. 4. [2] Part ii. p. 171, plates 62 A, 62 B.

however, between this labyrinthic structure and that of the teeth of the *Dendrodus* is easily discerned, and I had the satisfaction to perceive in the microscopic sections of the Russian teeth all the characteristics of the teeth of the *Dendrodus*.

The longitudinal section in the opposite Plate, fig. 2, shows the entire body of the tooth, permeated by the vascular canals, ramifying with apparent irregularity, and anastomosing by their peripheral branches in fine loops. The characteristic disposition of the vascular canals or sinuses is shown in the magnified view of the quadrant of the circular transverse slice, at fig. 3.

The pulp-cavity, *a*, *a*, has been converted by a coarse kind of ossification into an irregular group of large medullary canals of a less cylindrical figure than in the *Dendrodus biporcatus*: these canals or processes of the pulp-cavity are connected together by a network less close and complex than in the *Dendr. biporcatus*. From the circumference of the central network finer medullary canals, or vertical sinuses, radiate at pretty regular intervals to the periphery of the tooth. Most of these canals divide once, and some twice in their course; the bifurcation taking place commonly near the periphery of the tooth, the branches slightly diverging. From each ray and its primary bifurcations short branches are given off at brief intervals, generally at right angles with the trunk, or slightly inclined towards the periphery of the tooth; these primary branches more seldom subdivide than in the *Dendr. biporcatus*, but terminate, as in the teeth of that species, by angular dilatations something like leaves, which resolve themselves into radiating fasciculi of calcigerous tubules. Each of these systems of radiating tubules constitutes a lobe of the dentine, which is separated from the adjoining lobes by an extremely delicate line, representing the cemental constituent of the tooth. The lobes of dentine continued from the terminal dilatations of the medullary rays are the largest and most regular in form. The extremely minute dentinal tubes terminate in a linear series of calcigerous cells; such lines being continued or reflected inwards from the periphery of the tooth, and doubtless form the remains of processes of the capsule of the tooth-matrix, which inclosed and, as it were, defined the lobes of dentine. The inflected line of minute cells may be traced to near the central reticulate system of large medullary canals. The external longitudinal fine grooves on the surface of the tooth indicate the entering lines or fissures filled by the fine cellular cement.

The close analogy, and at the same time the difference—at least specific—between the tooth of the Russian *Dendrodus Murchisoni* (mihi) and of that from the Scotch Old Red Sandstone will be at once seen by comparing figs. 3 and 5 in the opposite Plate.

Thus, the formerly supposed organic evidence of the supra-carboniferous nature of the sandstones of Livonia and Reval is completely negatived by the proof, that the problematical teeth are not those of reptiles or air-breathing Vertebrata; and, at the same time, positive proof has been obtained that they belong to the same peculiar genus of extinct sauroid fishes which has been hitherto only recognised as a fossil of the Old Red Sandstone.

The practical importance, independently of geological theory, of determining the relations of the red sandstone systems, in reference to the beds of coal which in many countries may be sought for with success under the Newer Red Sandstone and Zechstein (Permian), but can never be found beneath the Old Red or Devonian, places the value of the microscopic test of the nature of fossil teeth in a striking point of view; for if other proofs had not been obtained of the age of these deposits so extensively spread over Livonia and Northern Russia, this tooth alone would have decided the question.

R. Owen.

February 20, 1844.

C.

Professor Owen upon certain Saurians of the Permian Rocks.

In referring to Professor Owen some bones and fragments which he brought from Russia, Mr. Murchison was informed by that great authority in osteological subjects, that he considered one of them, the *Rhopalodon Mantellii* (Fischer), to be a genus very nearly allied to the thecodont Saurians of the dolomitic conglomerate of Bristol (*Thecodontosaurus* of Riley and Stutchbury), and quite distinct from the triassic genus *Cylindricodon* of Jäger, which he is disposed to consider as not very different from the *Hylæosaurus* of Mantell. The bones (humeri) brought from Russia (where they also occur in red grit and conglomerate near Menselinsk and at Kargala, near Bielebei in the government of Orenburg, see p. 155) have exactly the same structure as those found in the Bristol rock. In his last excursion to Russia (1844) Mr. Murchison obtained through the kind attention of M. Wörth a very illustrative cast of a considerable portion of the vertebral column of one of those Permian Saurians, which has been alluded to by Major Wangenheim von Qualen and Dr. Kutorga. (See Verh. der Min. Gesells. zu St. Petersburg. 1844.) Of this specimen Professor Owen thus speaks:—

"(1.) The coloured cast is a series of twelve costal and two sacral vertebræ of a reptile; belonging to the Crocodilian division of Sauria by the strong, short, rib-like processes from the sides of the two anchylosed sacral vertebræ,—a modification not present in Enaliosauria, but introduced in order to give a firm 'point d'appui' to the hinder extremities of those *higher Sauria which occasionally walk on dry land*. The articular ends of the dorsal vertebræ are concealed; though, from the appearance of their margins, I am led to think, that they were not co-adapted by ball-and-socket joints, as in the tertiary and existing Crocodiles, but were sub-biconcave, as in most of the secondary species. The vertebræ become shorter and broader as they approach the sacrum than in any modern and tertiary Crocodiles, or in any of the Wealden or Oolitic Crocodilia that I have seen; and the anterior vertebræ most resemble in their compressed bodies and very strong transverse processes the vertebra of the *Palæosaurus* figured in Messrs. Riley and Stutchbury's memoir on the Saurians of the Bristol magnesian conglomerates, Geol. Trans. vol. v. 2nd series, pl. 29. figs. 6 and 7. They are not identical; the Bristol specimen having a more concave inferior outline than the Russian specimen, so far as I can judge from the cast.

"(2.) The bone, in two pieces, marked H., is a Crocodilian humerus, most resembling, by the breadth and flattening of the proximal extremity, the thecodont type of that bone in the Crocodilian order: it is shorter in proportion to its length, and larger than that from the Bristol conglomerate, referred, in the memoir cited (p. 354. pl. 30. figs. 1 and 2), to the *Palæosaurus*.

"(3.) The bone marked F. is the distal end of a femur, which by the sub-tetrahedral figure of the shaft-portion, also manifests the thecodont modification of that bone, and pretty closely accords with the figures of the femur of the *Palæosaurus* (*loc. cit.* pl. 30. figs. 4 and 4 *a*), but, like the humerus from Russia, it is somewhat large.

"The materials which you have submitted to me are not quite enough for a satisfactory demonstration of the precise family of Crocodilian Sauria to which they belong, but they do not agree with the characters of the same parts in any Saurian that I am acquainted with, from the lias upwards, and they do agree sufficiently with the Bristol Thecodont Sauria, to render it highly probably that the teeth of the Permian Russian fossil, when determined, will exhibit the same thecodont characters."

College of Surgeons, March 5th, 1845.

D.

Account of the Forest of Bialavieja, the habitat of the wild Aurochs or Zubr. By Count DE KRASINSKI. (In a Letter to Colonel Jackson, Secretary of the Royal Geographical Society, see pp. 503, 504.)

The forest of Bialawieza (Bialavieja) is situated in the present government of Grodno in Lithuania, and extends between the towns of Orla, Shereshef and Prujany, over a surface of about twenty-nine square Polish or German miles (fifteen to a degree). It derives its name from the village of Bialavieja, which lies in the centre of the forest on the banks of the Narevka, and contains fifty-six peasants' cottages, a church and an inn. Close to this village, stands on a hill, a hunting-lodge, built by King Augustus III., and enlarged by his successor, King Stanislaus Poniatowski, but now falling into ruins. In another part of the forest are the ruins of a castle called Old Bialavieja. According to the local tradition, it was in olden time the hunting station of the sovereigns of the country, and derived its name, which signifies the White Tower, from its white-washed walls. Besides the above-mentioned village, there are, in the same forest, two hamlets called Teremiska and Pogorzelei: they lie at a short distance from each other, and contain, each of them, about twenty cottages.

There are, on the borders of the forest, twenty-four villages, which belong to the forest department (Board of Woods and Forests), and from whose inhabitants the keepers and guards of the forest of Bialavieja are selected. The principal of these villages is Hainovsk, formerly the residence of the *employés* of the forest.

The forest is divided into twelve districts, called *Strazi, i. e.* wards, namely, 1, the ward of Augustovsk, so called from Augustus, king of Poland, Elector of Saxony; 2, Narevsk; 3, Brovsk; 4, Hainovsk; 5, Krukovsk; 6, Okolnitzk; 7, Lessnänsk; 8, Starshinsk; 9, Stolpovisk; 10, Svietlitshansk; 11, Podbesk; 12, Dsädovlänsk.

A great number of streams issue from the forest; of these, the principal are the river Narev, into which the greater part of the other rivulets empty themselves, and the Lesna, a tributary of the Bug that formerly marked the limit between Poland and Lithuania.

The forest belonged to the demesnes of the royal household, and was exclusively reserved for the royal sports. It was on that account preserved from the clearings whereby so many forests were destroyed and converted into arable land. It remains therefore in the primitive state of an American forest. It contains a great quantity of different kinds of wild animals, such as bears, wild boars, wolves, foxes, lynx, elks, and roe-bucks, whilst many beavers are found on its rivers; but the most remarkable of its inhabitants is the aurochs, or bison, called in the Polish language *Zubr*. It appears from different records, in which the name of the Zubr is mentioned, that this animal was always peculiar to Lithuania, but it is impossible to ascertain whether it extended further than the forest of Bialavieja. The opinion that it was formerly found in other parts of the country, among others in the forests of Mazovia, seems to be erroneous, and to have arisen from a confusion of the *Tur* with the *Zubr*. The Tur, which is constantly mentioned in the old national songs of all the Slavonic countries, was, according to the description of contemporary writers, a wild ox, probably the same as that still preserved in England at Hamilton, Chillingham, and Alnwick, and entirely different from the Zubr.

A Latin poem, entitled "De Bisonte et ejus venatione," written by a certain Hussovianus for Pope Leo X., but dedicated after his death to Bona Sforza, Queen of Poland, and printed at Cracow, 1523, gives the following description of the *Zubr*:—

"Hæc fera Lithuanis longe sævissima sylvis
Nascitur, et fieri corpore tanta solet,

Ut, mirum! si quando caput vi victa reclinet,
Tres sedeant intra cornua bina viri.
Barba riget late, pendentibus horrida villis;
Lumina, terrorum plena, furore rubent.
Terribilesque jubae collo funduntur in armos,
Et genua, et frontem et pectoris ima tegunt.
Villosum toto prae se fert corpore caprum,
Quamvis effingunt omnia membra bovem."

Hussovianus de Bisonte et ejus venatione. Cracow, 1523.

This poem was published at a time when the Tur was still found in the forests of Mazovia, but it distinctly says that the Zubr is a native of Lithuania. The biographer of Cardinal Commendom, who accompanied this prelate in his journeys to Poland, the last of which was in 1572, says, in his description of Poland, that there are both Turs and Zubrs, that the Tur very much resembles an ox, and that its flesh has almost the same taste as beef. The Zubrs were already at that time more rare than the Turs, which are now entirely extinct.

The same author gives a curious description of the manner in which the Zubr was hunted. I had from Mr. Hallam a French copy of this work, from which I have largely drawn in the first chapter of the 2nd vol. of the 'History of the Reformation in Poland.' The title is, as well as I can remember, "Vie du Cardinal Commendom, par Gratiani, traduite en Français (from Latin, or Italian, I do not remember) par Flechier." There was in the collection of the last king of Poland, a volume of drawings representing different subjects relating to the Council of Constance; one of them contained the presentation to the assembled fathers of a live Zubr, sent by Ladislaus Jajellon king of Poland. This proves that it was regarded as a rare and curious animal, even at the beginning of the fifteenth century.

There are many stories related concerning the extraordinary strength of this animal. An ancient chronicle mentions that at a hunt given by King Alexander of Poland (who died in 1506), the Altan, whence his Queen Helena looked at the sport with her ladies, was overturned by the *Zubr's* running against it with great violence.

I may add that the work of Baron Brinken on the forest of Bialavieja is very important for its description of the flora as well as fauna of that tract, "*Mémoire Déscriptive sur la Forêt de Bialawieza,*" par le Bn. Brinken. Varsovie chez Glüksberg, 1828." According to his account, there were at that time 875 head of Zubrs living in the forest[1].

[1] After we were favoured with the above communication of Count de Krasinski, we observed that Professor Eichwald, in his work (Naturhistorische Skizze von Lithauen, Volhynien, und Podolien, Vilna, 1830), had given a very complete account of the forest of Bialavieja, and of its inhabitants the Auers or Aurochses. Among other peculiarities of these very wild animals, it is stated, that for spring and summer food they select *Ranunculus repens, Cirsium oleraceum, Hierochloe borealis,* and other acrid and bitter plants, and such shrubs as *Lonicera, Rhamnus,* &c., with lichens and tree mosses; and in winter the young trees of *Calluna vulgaris,* which they prefer to hay or any other food (birch and fir-trees being never touched by them). They roll and enjoy themselves in dry sand, seldom drink, and go whole days without water; that of the muddy rain-pools being adequate for them, though when pursued by wolves they swim well. The Aurochs lives to about forty, and breeds to thirty years of age, and offers no example of a cross with the domestic cow, to the smell of which he has a great antipathy. Owing to his great weight he is a slow mover, and when pressed is exhausted in a verst. In defence he can master three wolves, but falls a prey to a greater number. In the work of M. Eichwald it is further stated, that at a royal Polish chase of Augustus III. in 1752, forty-two of these animals were killed; and that in the year 1828 the total number was 696. A plan of the Forest is given, in which a river Biala is marked. (See *ante,* pp. 503, 504 and notes.)

E.

Alphabetical List of Simple Minerals found in the Ural Mountains or on their Flanks, arranged from a Catalogue prepared by Lieut. Koksharof of the Imperial Mining Corps.

Names of Minerals.	Localities.	Observations.
Aeschynite	Ilmen Hills near Miask	As fine prismatic crystals in granite.
Albite	Alabashka near Mursinsk, district of Ekaterinburg } Miask.	Occurs as indistinct crystals in granitic rocks.
	Mine of Pitalelersk near Bogoslofsk	As small crystals in greenstone porphyry.
Amber	At the village Kaltchedansk near the Zavod Kamensk.	Small pieces occur with lignite, gravel and sand.
Amethyst	Tushakalva near Mursinsk	Fine crystals of amethystine quartz in granite.
Amianthus	Near Ekaterinburg	In serpentine.
	(Elizabetsk, Uktusk and Pishminsk Zavods.)	
	In the Sholkovaya Mountain near Neviansk.	
Analcime	Mount Blagodat near Kushvinsk	In small compact masses and very small hexahedral crystals.
Anatas	Shabrovsk near Ekaterinburg	As small crystals in schist.
	Adolfsk near Bissersk	As grains and crystals in the detritus.
	Nijny-Tagilsk	Do. do.
Andalusite	Tushakalva near Mursinsk	Occurs in considerable masses, having a crystalline structure, and in granite.
Apatite	Takovaya	Fine prismatic crystals in mica schist.
	Ilmen Mountains near Miask	Crystals in "miascite."
	Akmatofsk near Zlataûst	In altered chloritic schist.
Augite, (green)	At the mine Zarevo-Nikolaevsk near Miask	In porphyry.
	Near the Zavod of Nijny-Tagilsk	Do.
	Mount Blagodat near Kushvinsk	In grains with magnetic iron.
Avanturine	Taganai and Uralskaya Sopka near Zlataûst.	This variety of quartz rock is finer in the mountains of Bieloretz in the Government of Tomsk and is polished at the works of Kolyvan. Splendid vases of the Siberian avanturine were presented to Baron Humboldt and Mr. Murchison by the Emperor of Russia.
Axinite	Berkutskaya Hill near Miask	Generally compact, occasionally in crystals in porphyritic greenstone.
Barytes (sulphate of)	Near the village of Medvedieva near Zlataûst.	In argillaceous schist.
	Mount Bertevaya near Nijny-Tagilsk, Bogoslofsk.	In copper mines.
Beryl.	Alabashka, Shaitansk, and Tushakova near Mursinsk	Fine crystals of yellow, blue and rose colour in granite. The transparent crystals sell for a high price. In the Museum of the Institute of the mines at St. Petersburgh, are to be seen crystals of Beryl nine inches and a half in length.
	Ilmen Mountains near Miask	
	In the mines of Aktimsk near Zlataûst	
	At Nazimskaya Gora near Zlataûst	In chlorite schist where pierced by greenstone.
Bitter spar	Near the Zavod of Beresovsk	As small rhomboidal crystals in the chloritic and talcose schist.
		When bitter spar is found in masses and mixed with chlorite and quartz, the rock thus composed is called "Listvenite."
	Klütchefsk near Miask	In serpentine.
	Neighbourhood of Neviansk	In chloritic schist.
Borsovite	Borsovsk near Kishtymsk	Found in blocks amid the auriferous detritus.
		This mineral contains crystals in grains of Corundum and Zeilanite.

Names of Minerals.	Localities.	Observations.
Brochantite	Near Gumeshevsk	As small crystals on the red copper ore.
Brucite	Near the Zavod of Pishminsk	As small white flakes in serpentine.
Bucklandite	Near Verkhoturia	As prismatic crystals in granite.
Cancrinite	Ilmensk near Miask	Small masses of a rose colour occur in the miascite of the Ilmen Hills. Its cleavage is parallel to the faces of a regular hexagonal prism.
Chlorite	In the mine of Akmatofsk and Nazimskaya Mountain near Zlataûst (see p. 428).	As small crystals exhibiting *dichroism*.
Chloritoid	Near the Zavod Mramorsk, Ekaterinburg.	In chloritic schist.
Chlorospinel	In the mountain Shishimskaya, west of Zlataûst.	Small octahedral crystals in talc schist.
Chrysoberyl	Near the village of Takovaya	As fine crystals of a deep green colour in micaceous schist. This mineral is found generally in triple, seldom in simple crystals, and exhibits *dichroism*.
Copper, native	Near Bogoslofsk and Nijny-Tagilsk	In small crystals remarkable for icositetrahedral forms?
Copper, sulphuret	Bogoslofsk.	
Copper, grey	Beresovsk, Kugush, Isk and Sanarsk near Miask.	
	Vassiliensky near Bogoslofsk.	
Copper, blue	Near Perm.	
Copper, pyrites	Bogoslofsk, near the Zavod of Beresovsk	In veins of quartz.
Copper, green	Mines of Turyinsk near Bogoslofsk.	
Copper, red	Ditto ditto.	
Copper, vanadiate of	Mine of Tvanusk, district of Perm	As hexagonal tablets in sandstone.
Corundum	Near the village of Kossoi Brod, neighbourhood of Ekaterinburg.	In small grains in chlorite schist.
	Ilmen Mountains near Miask Near Kishtymsk.	In felspar, some of the crystals are of a bright blue colour, and some, though very rarely, partly transparent.
Diallage	Near the Lake Aushkul, south of Miask	In serpentine.
Diamond	Near Ekaterinburg	Near the country house of M. Medjer, two diamonds have been found in the detritus, the largest weighing [illegible] carats.
	Verch-Uralsk (in auriferous sands)	One diamond only found here, weighing [illegible] carats.
	Near Kushvinsk	One diamond weighing [illegible] carats.
	Chrestovodavisgensk and Adolfsk near Bissersk.	Up to the year 1833 about forty diamonds had been found in the auriferous gravel. The largest weighed 2[illegible] carats, the smallest [illegible] carat (see p. 480).
Diaspore	Mramorsk in the neighbourhood of Ekaterinburg.	As crystalline masses in chloritic schist.
Diopside	Akmatofsk, Nazimskaya Mountain near Zlataûst.	Beautiful crystals in chloritic schist, where pierced by greenstone (see p. 428).
Elaolite	Ilmen Mountains near Miask	This mineral, with black mica and white felspar, forms the rock called miascite, subordinate to granite.
Emerald	Near the village of Takovaya	This locality is celebrated for its emeralds. The largest and most transparent crystals are cut and sent to the Imperial Winter Palace at St. Petersburgh.
Emery	Mramorsk	In chloritic schist.
Epidote	Reschety near Ekaterinburg, Agatsk do. Between the Zavod Kussinsk and the village Shumnaya near Zlataûst.	In veins of quartz. In porphyry.
	Near Kishtymsk	In small quantities in blocks of Borsovite.
Felspar	Alabashka near Mursinsk	In fine large crystals united in groups in granite.
	Voloshnaya Hill, east of Lake Ilmen, near Miask.	Fine green crystals (*Amazon Stone*). Groups of white and yellow crystals.

Names of Minerals.	Localities.	Observations.
Fluor spar	Near the village Bojevsk in the neighbourhood of the Zavod Kamensk.	
	Ilmen Hills near Miask	In miascite.
	Near the village of Syrostan, road from Miask to Zlataûst.	In granite.
	Takovaya	In crystalline masses in micaceous schist.
Garnet	At the copper-mines of Turyinsk near Bogoslofsk.	Crystals in metamorphic limestone and palæozoic rocks (see p. 398).
	Alabashka near Mursinsk.	
	Ilmen Mountain near Miask	In granite.
	Mount Shishimskaya, east of Zlataûst	Of a yellow colour in vein-stones.
	Taganai Mountain near Zlataûst	In metamorphic quartz rock.
Gold (native)	Mine of Zarevo-Alexandrofsk near Miask	This mine is famous for the largest "pepites" of gold that have been found at different periods (see pp. 489 *et seq.*).
	At the Zavod Beresovsk near Ekaterinburg.	The gold is here found in the veins of quartz, in small porous masses. The crystals present an octahedral form, with dodecahedral faces. Also in the auriferous sands in grains and crystals, and at numerous other localities not here cited (see pp. 476 *et seq.*).
Graphite	On the shore of the Lake Telanshuk near Miask.	In schist.
Hornblende	Near the Zavod of Keshevski, north of Ekaterinburg.	In albite and syenite.
	Near the Lake Kissagutch in the Ilmen Hills near Miask.	In the hornblende of this locality, are found octahedral crystals of zircon.
	Near the Lake Aushkul, south of Miask	In greenstone porphyry.
	Urenga Mountain near Zlataûst, and at numerous other localities.	In syenite.
Hypersthene	Mines of Kublevskay and Vissimo-shaitansk near Nijny-Tagilsk.	Isolated blocks in the detritus.
	Mine of Borsovsk near Kishtymsk	Do. do. in auriferous gravel.
Ilmenite	Ilmen Hills near Miask	In large rhomboidal crystals in the miascite.
Iridium (native)	Neviansk, Nijny-Tagilsk	Hexahedral crystals in the platiniferous sands.
Iron (magnetic)	Near the Zavod of Pishminsk	In octahedral crystals in serpentine.
	The Mount Beresovaya near Ekaterinburg and near the village Brussiansk.	Octahedral crystals in chloritic schist.
	Ilmen Hills.	
	Mine of Akmatofsk near Zlataûst	Do. do. do. do.
	Shishimskaya Mountain near Zlataûst.	
	Vissokaya Mountain near Nijny-Tagilsk	In large masses.
	The Katchkanar and Mount Blagodat	Do. do. (see pp. 370, 379, 392.)
Iron, hydrate of	Near the Zavod Bilimbaersk, Ekaterinburg.	In serpentine and in numerous isolated deposits.
	Near the Zavod of Kamensk	In carboniferous limestone.
	In the mountains of Neviansk.	
	Neighbourhood of Zlataûst	In limestone.
Iron, specular	The villages of Shabrovsk and Nagorsk near Ekaterinburg.	
	Near Bogoslofsk.	
	In the Berkulskaya Mountain near Miask	In large masses.
Iron, chromate of	Kishtymsk, near the Zavod of Syssersk.	
	In the mine of Malo-Mostorsk near Ekaterinburg.	
Iron, oxidulated	Ilmensk.	
Iron pyrites	Urenga Mountain, Zavod Lobvinsk near Zlataûst.	In hornblende schist. In greenstone porphyry.
Kyanite	Near the village Kolotkina, 40 versts south of Ekaterinburg.	In argillaceous schist.
	In the Mountain Taganai near Zlataûst.	In micaceous schist.
Laumonite	In Petropavlovsk Hill near Bogoslofsk	Decomposed crystals in greenstone porphyry.

Names of Minerals.	Localities.	Observations.
Lead, sulphuret of	Zavod of Beresovsk near Ekaterinburg...	In veins of quartz.
	The mine of Kugushefsk near Miask.	
	The mines of Pavlovsk and Anatolsk in the district of Nijny-Tagilsk.	
	Near Bogoslofsk and Ekaterinburg	In copper mines.
Lead, carbonate of	Zavod of Beresovsk..........................	Small crystals in veins of quartz.
Lead, phosphate of	Zavod of Beresovsk	Fine hexagonal prisms.
	In the Bertevaya Hill near Nijny-Tagilsk.	In quartz veins.
Lead, chromate of	The Bertevaya Hill near Nijny-Tagilsk..	In quartz veins.
	Zavod of Beresovsk near Ekaterinburg...	Fine prismatic crystals of a red colour.
Lead, vanadiate of	Zavod of Beresovsk	Fine prismatic crystals.
Lepidolite	The villages of Tushakava, Alabashka and Shaitansk near Mursinsk.	As fine transparent scales of a rose colour in granite.
Libethenite (phosphate of copper)	Nijny-Tagilsk	In small crystals with malachite.
Lime, carbonate of	Gumeshefsk Zavod..........................	In copper mines.
Lime (calc spar)	Ilmen Hills near Miask.	
	Bogoslofsk	Crystallized in copper mines.
Magnesite	Guberlinski Hills	In greenstone rocks.
Malachite..................	Nijny-Tagilsk.................................	In enormous stalagmitic masses.
	In the neighbourhood of Bogoslofsk......	In copper mines.
	Gumeshefsk Zavod..........................	In concretions and masses composed of very minute crystals in the copper ore.
Manganite	Near the village of Shabrova, neighbourhood of Ekaterinburg.	In grains in rhodomite.
Melanochroit	Beresovsk	Small indistinct crystals in quartz veins.
Mengite	East of the Ilmen Lake near Miask	Small prismatic crystals of a black colour in the granite.
Mica, mono-axial.........	Ilmen Hills near the village Kossoi-brod	In miascite.
	Near Zlataûst, near the Zavod Dolersk .	
Mica, di-axial	East of the Lake Ilmen	Fine crystals in the granite.
	Near the village Alabashka.	
Monazite	Ilmen Hills	Small crystals in the granite.
Needle ore	Zavod of Beresovsk near Ekaterinburg...	Indistinct prismatic crystals in quartz veins.
Oligoclas	Near the village of Schaitansk, neighbourhood of Mursinsk.	Occurs as compact masses in granite.
	Near the village Ajalsk, vicinity of Ekaterinburg.	In porphyry.
Osmium iridium	Sands in the vicinity of Neviansk	In hexagonal plates.
	Do. near Kishtymsk.	
Ouwarovite	Sarannvsk, north of Bissersk (see p. 390), and near Kishtymsk.	Abundant at the first of these localities, rare at the second.
		Occurs in fine green crystals in trap rocks, and often with chromate of iron. This mineral is considered to be a garnet containing chrome.
Perovskite	Mines of Akmatofsk, Nazimskaya Mountain near Zlataûst.	Fine hexahedral crystals in chlorite schist pierced by greenstone.
Phenakite..................	Near the village of Takovaya and Bolshoimeft.	In small crystals which are bright wine yellow, inclining to rose-coloured or white. At St. Petersburgh they are favourite ornaments of the ladies.
Pistacite	Near the Lake Tchornoya, Ilmen Hills near Miask.	In felspar.
	Mines of Akmatofsk near Zlataûst	Fine crystals in chlorite schist.
Platina, native	Vissimo, Shaitansk and other places in the vicinity of Nijny-Tagilsk.	In grains and sometimes hexahedral crystals. The largest pieces have been found in the Demidoff domains.
	Also in detritus between Kushvinsk and Turyinsk, and around the Katchkanar.	In detritus of trappæan and other rocks overlying Silurian limestone (see pp. 381 and 484).
Porcelain earth	In the mine Nikolaya Pavdinsk near Bogoslofsk.	In large masses.
	East of the Ilmen Hills.	

Names of Minerals.	Localities.	Observations.
Psilomelane	Aktensk mines near Zlataûst.	
Pyrites, copper	Near Bogoslofsk	In copper mines.
	Zavod of Beresovsk	Hexahedral crystals in quartz veins.
Pyrochlore	Ilmen Hills	Small crystals in granite.
Pyrolusite	Near Zlataûst and at the village Nagornoi near Ekaterinburg.	In auriferous sands.
Pyrophylite	Zavod of Beresovsk	Indistinct crystals in quartz veins.
Pyrrhite	Near the village Alabashka	Small yellow crystals in granite.
Quartz	Beresovsk near Ekaterinburg and in the Ilmen Hills.	Many transparent crystallized blocks (like "Cairgorm stones") are cut and polished.
Repidolite	Nazimskaya Mountain near Zlataûst	In chlorite schist pierced by greenstone (see p. 428).
Rhodochrom	Near Kishtymsk	Small compact masses on chromate of iron.
	At the village Saranovsk near Bissersk	In small masses .... do do.
Rhodonite	Near the village Shabrova, vicinity of Ekaterinburg.	In considerable masses.
Rhodozite	Near the village of Sarapulsk	Small crystals of dodecahedral form, with tetrahedral faces. The crystals are always found on red spheroidal tourmaline and are very rare.
	Near the village of Takovaya	Fine large crystals in micaceous schist.
Rutile	Mountains near the Zavod of Pishvinsk.	
Serpentine	Near the Lake Aushkul, south of Miask.	
Sodalite	Ilmen Mountains	Occurs as small masses of crystalline structure and fine blue colour in miascite. One single crystal of this mineral, now in the collection of the Mining Institute at St. Petersburgh, presents a dodecahedral form. The blue sodalite of the Ural was formerly termed Cancrinite.
Staurolite	Near the Zavod Polevsk, south of Ekaterinburg.	Large crystals in argillaceous schist.
	The Mount Taganai near Zlataûst	Large black crystals in mica schist.
	Near the Zavod of Nijny-Saldinsk	In mica schist.
Stilpnosiderite	Near Bogoslofsk	In copper mines.
Strahlstein	Near Verkneivinsk and Gornoshit, vicinity of Ekaterinburg.	
Strahlstein (actinolite)	In the Shishimskaya Mountain, east of Zlataûst.	In altered schist with greenstone.
	Near Zlataûst	In chloritic mica schist.
	Near Kishtymsk	Prismatic crystals in talc schist.
Sulphur, native	Beresovsk	As produced from the decomposition of pyrites in quartz veins.
Talc	Zavod of Beresovsk near Ekaterinburg	Small indistinct crystals in quartz veins.
	Near Brussiansk, vicinity of Ekaterinburg	Crystalline masses.
Tcheffkinite	The Ilmen Hills	In felspar.
Titanite	The mine of Akmatofsk near Zlataûst	Double crystals in chlorite schist.
	Near the Zavod Verch-Issetsk and the Lake of Schartosk near Ekaterinburg.	In small brown crystals in granite.
	Ilmen Mountains near Miask	In syenite or granite.
Topaz	Alabashka near Mursinsk	Magnificent crystals of the blue topaz are sometimes more than five inches long. They are found in granite, and when transparent, are sold on the spot for 500 or 1000 roubles each.
	The Ilmen Hills	Fine crystals of a white colour in the green felspar or amazon stone.
Tourmaline	The Ilmen Hills.	
Tourmaline (black)	Near the villages Alabashka and Shaitansk.	In granite.
Tourmaline (rose)	At the village Sarapulsk near Mursinsk.	This variety is very rare and sells for more than 100 roubles a crystal. The spheroidal groups of crystals sell for 500 or 1000 roubles each.

Names of Minerals.	Localities.	Observations.
Tourmaline (rose)	Near the Zavod of Beresovsk	Prismatic crystals.
	At Gorvoshit near Syssertsk, Verch-Neivinsk and the Lake Shartask, vicinity of Ekaterinburg.	In chlorite schist.
Uranotantal	The Ilmen Hills	In granitic rocks.
Uwarovite, see *Ouwarovite*.		
Vesuvian (Idocrase)	In the Beresovaya Hill, vicinity of Ekaterinburg.	Do.
	In the Shishimskaya Mountain near Zlataûst	In crystalline metamorphic rocks.
	Mine of Akmatofsk	In crystalline metamorphic rocks.
	Nazimskaya Mountain near Zlataûst	In crystalline metamorphic rocks.
Volbortite (vanadiate of copper)	Mines of Nijny-Tagilsk	Small crystals in copper mines.
Wavellite	Shishimskaya Mountain near Zlataûst	Hexagonal prisms in talc schist.
Xanthophyllite	Do. do. do.	In talc schist.
Zeylanite (pleonaste)	Mine of Borsovsk near Kishtymsk	In the auriferous sands.
Zinnober (sulphuret of mercury)	Mine of Oleno-Traviansk	Isolated fragments in the sands.
	Mines of Zarevo-Alexandrofsk and others near Miask.	In the auriferous sands.
Zinkblende	Near Bogoslofsk	In copper mines.
Zircon	Ilmen Hills	Fine crystals in miascite.
Zoisite	Village of Gomoshit near Ekaterinburg	In chlorite schist.

F.

Domanik Schist.

The reader will find that in the text, p. 413, we have considered the Domanik as the equivalent of the Wissenbach schists, and therefore, according to the reasoning formerly employed (see Geol. Trans. vol. vi. p. 253), belonging rather to the Uppermost Silurian than the Lowest Devonian. Since, however, the chapter on the Timan Range was written, the fossils of the Domanik having been carefully examined by Count Keyserling, he finds that its Goniatites are similar to those of Brilon in Westphalia, and Schubelhammer in Franconia. It must, therefore, be considered Lower Devonian, and we have placed it accordingly in the Table of Superposition attached to the Map, Pl. VI.

G.

Igneous Origin of Magnetic Iron Ore.

In the text, p. 413, we have dwelt at some length on this point, and it may further be curious for geologists to speculate on the possible application of the same view to many deep and unfathomed masses of iron in other countries. The broad and deep masses of red and often intensely crystalline hematite near Ulverstone in Cumberland, which fill chasms in the carboniferous limestone, are now usually looked upon as aqueous deposits. But may the striking vein of pure brown hematite charged with manganese, which at Lostwithiel in Cornwall seems to rise up through slaty rocks (Devonian) and *envelopes fragments of them in its matrix*, be considered an eruptive dyke like that to which we have alluded at Blagodat? In throwing out this query, we do not say that the English case ought not to be separately considered; for whilst it is possible that it may be explained in a somewhat similar manner to those of the Ural, it may, we admit, have resulted from a long-continued humid process—always, however, dependent on subterranean agency and internal heat and gas—through which the fluid was impregnated with metallic or other elements, that have either been crystallized or deposited in amorphous forms within the cavities of the rock. The hydrates of iron, which in many countries fill superficial cavities, belong clearly to another class of phænomena, and are to be generally considered as mere aqueous deposits, which are of comparatively recent age.

H.

Palæozoic Rocks of Scandinavia.

Some of the fossils from Hysbifiol in Sweden have very much the aspect of being derived from the uppermost beds of the Lower Silurian. In stating our belief, that the chief palæozoic strata of the continent of Sweden are Lower Silurian, as distinguished from those of Gothland, we allude simply to the zone which fell under our survey. We have grounds to think, that in some places patches of Upper Silurian group will also be found to occur, as in Norway. For example, our friend Prof. Forchhammer has informed us that he believes there are Upper Silurian fossils in the higher part of the Aalleberg in West Gothland, and at Klinte in Scania. At the latter place, indeed, the occurrence of the *Avicula retroflexa* and other Upper Silurian fossils quite unknown in the Lower Silurian beds, has already determined the point. In Scania also there is a red micaceous sandstone, connected with argillaceous beds and porphyry (as in Norway), in which forms like Avicula and Modiola have been discovered, and which Prof. Forchhammer thinks may be of the age of the Old Red Sandstone. Again, from what we saw of the specimens of rocks and fossils from Dalecarlia in the Museum of Stockholm, we have very little doubt that a country which has afforded the *Leptæna depressa*, *L. euglypha*, and a species of the peculiar genus *Brontes* (Goldfuss), must contain Upper as well as Lower Silurian rocks, while a portion of the sandstones which occupy that region may represent the Old Red Sandstone. These points we hope to be able to work out in the course of the ensuing summer (February, 1845).

I.

Inverted Strata on the Flanks of the Ural Mountains.

In reference to this phænomenon we have shown (p. 463 *et seq.*), how under the conditions exhibited along the flanks of the Ural, it is impracticable to explain the inversion on several parallels of longitude, by the mere uprising of the central ridge, and the consequent overthrowing or bending back of the strata upon themselves. We have, in fact, endeavoured to account for the inversions at considerable distances from the axis, by subsidences of the fractured ends of the rocks which approach towards the issue of eruption. But even admitting our hypothetical view, that the uprising of a large quantity of molten matter to swell the central ridge, might occasion cavities occupied by gases only, into which the ends of the fractured masses might sink; why, it will be asked, do the inward edges of such masses *dip towards* the chain? why have their external edges never been depressed? and why are they, on the contrary, *raised*? Now, the facts are, that the sedimentary rocks on the flanks of the Ural Mountains are fissured by a number of parallel north and south cracks, at some of which (as Nijny Serginsk and Bissersk on the west flank, and at numerous points on the east of the chain) molten matter has forced its way to the surface. If then we view the original condition of this eruptive matter when it was seeking to find a vent in its central or chief habitual fissure, we may liken it to a series of *great subterranean waves, moving from the eastern and western flanks*, where its issue was repressed (by the nature of the sediment and other causes), to that channel where it was liberated. In this way we may conceive, how the wave-like, upheaving lateral force, when applied from flanks to centre, raised up the outward ends of the fissured strata by a succession of heaves; and if this hypothesis be admissible, no great depression of their inward ends is called for. In speculating, however, on the possible modes of explaining this phænomenon, under such circumstances as those described in the text, we think that the highly contorted, inverted and basin-shaped strata, which are so common on the western Uralian slopes (notably in the gorge of the river Tchussovaya), are best explained by the lateral pressure of the sea and sedimentary matter in the low country on the west, and the great uprise of the central ridge on the east, by which operation the masses were squeezed up between two resisting bands, and were thrown back and partially inverted. The problems connected with this question are, in fact, various, and the inversions in each mountain chain are well worthy of analysis; though it must be admitted, that great light has already been thrown upon the subject by the labours of Professor Dumont in Belgium and those of Professors H. and W. Rogers in America.

K.

South Coast of the Black Sea.

The geological colours relating to the tracts south of the Black Sea, are assigned from a perusal of the writings of Mr. W. Hamilton and Mr. Ainsworth (see Researches in Asia Minor, Pontus, &c., vol. i. p. 158 *et seq.*, and Journal of the Roy. Geogr. Soc. vol. ix. p. 216 *et seq.*). It is, however, necessary to explain, that in all that region we do not pretend to define accurately the outline of the various rock masses, but simply to convey an idea of their general relations. Thus, whilst we know from the researches of Mr. W. Hamilton and Mr. H. Strickland, that true Silurian rocks exist at Constantinople, where they are overlaid by tertiary (miocene ?) deposits, it seems probable, that the crystalline and slaty rocks, perforated by much eruptive matter, which range from the eastern shores and gulfs of the Sea of Marmora (Mount Olympus, Ismid, &c.), are metamorphosed Silurian strata, similar to those of the Ural Mountains (c of Map, Pl. VI.). The great mass, however, of the sedimentary deposits of Bithynia, Paphlagonia and Pontus, consists of limestones, often semi-crystalline, with associated fucoid schists, sandstones, &c., which are, we apprehend, of the same age as the great outward spurs of the Caucasus (Circassia, &c.), and are, on the whole, of the Cretaceous age. We cannot gather from the writings of Hamilton or Ainsworth, that the Jura formation has any existence in these regions; all the secondary rocks of which appear to be referrible to the Scaglia, restricting the meaning of that term to strata of the age of the Cretaceous system, which have assumed the Mediterranean or crystalline type.

In the Caucasus, as in the Crimea, the labours of M. Dubois de Montpereux have satisfactorily shown the presence of both these great systems, and doubtless it is possible, that in a portion of the rocky, elevated and broken region to the south of the Black Sea, *some* Jurassic fragments may be eventually discovered.

The greatest interest, indeed, of this region, consists in its eastern range, or in the high plateaux of Khorasan, Kars and Anni, where tertiary deposits of the younger Miocene age have been heaved up by trachytic and other igneous rocks to heights of 5000 and 6000 feet above the sea, and where some tracts are so scoriaceous and volcanic, with large quantities of Obsidian, as to convey the idea of comparatively recent eruption. The observation of Mr. W. Hamilton, of peculiar tertiary strata at Sinope, is of great interest to us; for on examining the fossils he submitted to us therefrom, we have no hesitation in saying, that they belong to that former great internal Mediterranean (Aralo-Caspian) of brackish water, concerning which we have spoken so much [1]; and thus we learn that this grand ancient Caspian must have extended over a great portion of the Black Sea, as well as over the Seas of Azof, Caspian and Aral. In all these regions, this brackish water deposit succeeds to the oceanic miocene; a point of very great importance in developing the ancient geography of this large portion of the globe.

[1] See No. 10. Map, Pl. VI. and vol. i. pp. 297 *et seq.*

L.

Gold Produce of Siberia.

In reference to this subject, which excites so much interest, we reprint an extract from the Anniversary Discourse addressed by one of us to the Royal Geographical Society of London in 1844:—

"To this subject I wish to point the attention of statists and geographers, for it has already begun to occupy the thoughts of politicians, and may eventually have a very marked influence upon all civilized nations, in changing the relative value of gold as a standard.

"In Russia, as in the Brazils, the great mass of the metals is derived from local detritus or alluvia usually called gold sand, but for which (as far as Russia is concerned) the term of shingle would be much more appropriate. With very trifling exceptions, all such auriferous detritus in the Russian empire occur on the eastern or Siberian side of the Ural. Slightly known, and near Ekaterinburg only, in the days of Pallas, it was not until the reigns of Paul and Alexander, that these gold alluvia were found to extend in a certain zone to the north and south of that locality, throughout 5° or 6° of latitude, and that eventually gold was extracted from them to the annual value of about half a million sterling. Notwithstanding the increased exploration of late years, and many researches in the northern and southern portion of the chain, this quantity has been rarely exceeded, and latterly, the alluvia in some tracts being exhausted, it has begun to decrease. The reign of the Emperor Nicholas has, however, been distinguished by the important discovery, that portions of the great *eastern* regions of Siberia are highly auriferous, viz. in the governments of Tomsk and Yeniseik, where low ridges, similarly constructed to those on the eastern flank of the Ural, and like them trending from north to south, appear as offsets from the great east and west chain of the Altai which separates Siberia from China. And here it is curious to remark, that a very few years ago this distant region did not afford a third part of the gold which the Ural produced, but by recent researches, an augmentation so rapid and extraordinary has taken place, that in the last year the eastern Siberian tracts yielded considerably upwards of two millions and a quarter sterling, raising the total gold produce of the Russian empire to *near three millions sterling*!!

"Now if this great increment be sustained during a certain number of years, there can be no doubt, that it will, to some considerable extent, reduce the standard of value, and lead to considerable change in our social relations. The first question therefore is, to what extent is it likely to be sustained? Gold alluvia being but the detritus of veins which once existed in the adjacent rocks, it might be supposed that in piercing these rocks the miner would find more copious stores of the metal. Experience, however, has taught us that such is not the fact, and to whatever cause due, it is certain that the veins which rise from great depths in the crust of the earth are richly auriferous towards their *upper limit only*. Hence it is that nearly the whole of the ancient surface of rocks having undergone denudation and consequent destruction, the greater quantities of gold are found in the detritus on the flanks of the hills, or in the valleys between them. So long, therefore, as these alluvia are unexhausted, so long may the miner extract from them, by a cheap and easy method of macerating and washing, the ore which would be obtained at much greater cost from the solid rock. Now, those alluvia having well-defined bottoms, and being of measurable extent, may certainly be exhausted; and the disappearance of gold from all those civilized countries in whose early days it was abundantly found (even in our own isles), is a proof that such must sooner or later be the case. But how long is it before this period of exhaustion will arrive? When we reflect upon the length of time which the one region of Brazil has continued, I believe with undiminished quantity, to supply modern Europe with its great mass of gold, the opening out of a new El Dorado should teach us to be very cautious in attempting to limit the auriferous capacity of the vast and slightly explored regions of Siberia. The north and south counterforts of the great Altai may, in truth, prove to be but the indications of similar spurs, or detached meridian ridges, which may be discovered in many other tracts of a region equal in extent to the whole of Europe. From the researches of the Russian engineers, and from Humboldt and his associates, we learn that rocks similar to those which are so auriferous in the Ural, reappear in various parallels of longitude along the flanks of the Altai. By a recent letter, indeed, from my friend Colonel Helmersen, the distinguished and successful explorer of the Ural, Altai and Siberia, I learn that his former associate in these countries, Professor Hoffman, has, in his last visit of 1843, discovered a tract in Siberia, in which the very richest gold alluvia occur in a "terrain" exclusively composed of granite and metamorphic schists, the gold being in the latter. Now in the Ural, as in other parts of Siberia, greenstones, syenites and serpentines seem invariably to have been the agents by which the metamorphic rocks have been rendered auriferous; this discovery, therefore, widens the field of the gold-searchers, and opens out great probable, practical as well as theoretical, results. In truth, Siberia and its adjacent regions may be found to contain another Brazil, where granite also is the great eruptive agent of mineralization and metamorphism.

"Count Keyserling also assures me in one of his letters that the discovery of M. Hoffman *relates to an area larger than France*, every part of which seems to be more or less auriferous, and *all the subjacent rocks* (palæozoic schists and limestones?) when pounded up and analysed affording a certain per-centage of gold! If this diffusion of gold through the very matrix of rocks, which is, I may observe, a phænomenon hitherto almost unknown[1], be really found to hold good over so vast an area, it imparts a new and most important element to our reasoning, and renders it vastly more probable that no sort of limit can be set to the increase of the produce of Russian gold. We know also from our enterprising medallist, Adolph Erman, that palæozoic, eruptive and metamorphic rocks, similar to those of the Altai and the Ural, extend even to the Alden mountains[2], not far from the shores opposite Kamtschatka; and if so, why may they not contain the same minerals? Again, we are told by Helmersen and others, that some of the southern offsets from the Altai, which extend into China, are auriferous, and one of them, the Tar-Bagatai, the northern part of which is in the Russian territory, has already proved highly productive. The last fact is of very great importance; for the Celestial empire, which has only just now been partially opened out to European enterprise, may very probably (and I have strong reasons to think that the same classes of rocks extend through Chinese Tartary) prove to be another golden region like Siberia. Even in our own Hindostan, auriferous veins and deposits, as yet, it is true, of no great value, are known at various points from north to south, and have recently met with a good describer in Lieutenant Newbold, who strongly urges their further and more scientific exploration[3]; whilst we have yet to learn, whether, in the progress of civilization, the gold tracts of South Carolina may not afford considerable additions to the metallic wealth of the new world.

"But, reverting to Northern Asia, how are we to limit our anticipations of the augmentation of such produce, when it is a fact, that within the last few years only, a tenth portion of the earth's surface (Chinese Tartary and Siberia) has been, for the first time, made known to us as in many parts *auriferous*, and

[1] In our travels in the Ural we learned, indeed, from General Anosoff at Zlataûst, that by a searching analysis, gold had been discovered disseminated in the matrix of some of the *limestones* south of Miask.

[2] M. Adolph Erman has made the bold effort to colour geologically large portions of Siberia and the whole of Kamtschatka under the title of "Geognostische Skizze von Nord Asien." (Archiv für Russland. Berlin, vol. ii.) The more recent travels of M. Middendorff show the extension of the same eruptive and metamorphosed palæozoic rocks from Nertchinsk to the Stanovoi mountains, and to the Shantar Isles in the Sea of Okhotsk. (See Mr. Murchison's Anniversary Address to the Royal Geographical Society, May 1845.)

[3] Journal of the Royal Asiatic Society, 1843, p. 203.

when from one portion of it only, Europe is already supplied with so very large an amount of her chief circulating medium? Well, therefore, may political œconomists now beg for knowledge at the hands of the physical geographer and geologist, and learn from them the secret on which the public faith of empires may depend."

M.

Why the right bank of the Lower Volga is always higher than the left bank.

In the text and in the description of the Maps we have simply noted the fact, that the right bank of the Volga is almost invariably a high cliff, whilst the left bank is low. This remark requires to be modified before a rational attempt can be made to account for a phænomenon apparently so difficult of explanation. In the upper portion of its long and tortuous course, when the stream glides down from the Valdai Hills by Tver to Mologa and Yaroslavl, and again from the latter city by Kostroma to Yurievetz, no such feature is dominant; the left bank being frequently as high as the right. It is specially from the point where the Oka is confluent with the Volga at Nijny Novogorod, to the parallel where the mighty river quits the hilly grounds of Tzaritzin and Sarepta to debouche into the Caspian at Astrakhan, that the right bank is not only invariably the highest, but is in many places absolutely a cliff, standing out against the low countries on its left bank[1]. By a simple glance at our Map, the geological reader who has perused our description of the nature and extension of the former Caspian will at once see, that all the region occupying the right bank of the Volga from a little below Kazan, to the tract where the ground subsides into the low country of the Kalmucks, has the character of the edge of an ancient continent, whose eastern shore was washed by the great Aralo-Caspian Sea. Subsequent elevations of the whole continent which have desiccated to so great an extent the former bed of that enormous Mediterranean, in the manner we have explained, have simply left the Volga to find its way to the present Caspian, along the line of junction of the dried-up sea-beds and the ancient cliff; the respective relations of these masses being preserved. On further inspecting the Map, the reader will see, that the Caspian deposits are marked as extending northwards only to Spask; but here we must observe, that judging from the very low form of the grounds on the left bank of the Volga, both at Kazan and in ascending from thence by Tcheboksar to Nijny Novogorod, it is very probable that the Aralo-Caspian (the extension of which to Spask we should not have known without the researches of M. Jasikoff) may probably have ramified in a bay over the low expanses to the north of Tcheboksar and Nijny Novogorod. Those flat tracts, occupied by marshes, meadows and woodlands, are however so much overflowed by the Volga in the spring months, and have thereby been so overspread with modern alluvia, that it is not likely the traces of the residence of the ancient Caspian, if it ever extended there, can now be discovered, although the contour of the ground naturally leads us to speculate upon such having been the case. At all events we have no need to put forth any theory whatever to account for the phænomenon, from below the city of Kazan to the hills south of Sarepta, throughout which space, of about 600 English miles, the low country on the left bank of the Volga is shown by its shells to have been the bed of a former Mediterranean, of which the high grounds on its right bank constituted the western shore.

[1] In a memoir by our friend Major (now Lieutenant-Colonel) Blöde, the phænomenon of the right bank of other rivers in Russia being higher than the left is explained by a theoretical view of elevation and depression to which we cannot now render justice, having mislaid his work.

N.

Permian Rocks near Bachmuth (p. 114) and on the Suchona (p. 178).

As some geologists who follow our traces in Russia may be of opinion, that the red sandstones and yellow limestones near Bachmuth, which we have considered of Permian age, ought rather to be classed with the Carboniferous system, we will merely say, that a recent survey of the junction of the equivalents of the Permian rocks (lower red sandstone and magnesian limestone) with the subjacent coal measures in the West Riding of Yorkshire, has convinced us, that there, as in the environs of Bachmuth, the two deposits are naturally connected by mineral transition and conformable stratification. In both cases, that which comes under the head of Permian, is simply the continuation of the carboniferous group under a peculiar and modified type.

Not having detected fossils on the Strelna and Suchona in our first survey, the name of "calcaires muets" was then applied to the limestones subordinate to the red marls of that tract (p. 178); but the subsequent researches of Count Keyserling have rendered that *sobriquet* inapplicable, by the discovery of the *Terebratula Geinitziana* and *T. elongata* (see Permian Table, p. 222).

O.

Coal-fields of Poland and Silesia.

Having explained in the work, that throughout the Russian empire there is no productive coal-field *above* the carboniferous limestone, and that nearly all the Russian coal occurs *in* that formation, it is interesting to remark how, in receding from that peculiar eastern development and on entering into Poland and Silesia, the deposits of this age assume the prevalent type of Western Europe, and consist of coal with sandstone and shale in masses, which (like those of the Belgian and British coal-fields) distinctly overlie the carboniferous or mountain limestone. In traversing the carboniferous tracts of the kingdom of Poland west-north-west of Cracow (see Map), we found the mountain limestone at the surface to the north of Krzezowice, but that rock subsiding to the west, is succeeded at Sierza (the mines of Count A. Potocki) by true overlying coal-measures, which are worked by galleries on slightly inclined planes. Still further to the west these coal-measures greatly expand (also very slightly inclined) around the government mines of Dombrova, Bendzin, &c. (kingdom of Poland). The chief masses of coal, which are there worked in open quarries, exceed in magnitude any examples of the old or palæozoic coal with which we are acquainted. In the cuttings, for example, near Bendzin, the coal is at one spot actually nine *lachters* or near sixty feet thick, and therefore double the dimensions of the strongest British seam, that of the Dudley ten-yard coal. The overlying sand and shale are loaded with impressions of fossil plants, which are almost invariably found prostrate and much broken; and M. Pusch, now engaged in directing the works, informed us, that he never met with more than one instance of a vertical fossil tree-stem amid a very great profusion of ancient vegetation. In alluding to the vast thickness of this Polish coal, we may observe, that portions only of the *sixty feet* constitute fuel sufficiently good to forge the iron of the mines of the Imperial government.

The eastern limb of this coal-field passes into Prussia, and is worked at Königshütte, &c. in Lower Silesia, where, although the coal-seams are not so thick as on the Polish side of the frontier, the coal-seams are of good quality and are turned to the best profit. As this coal-field is evidently an upcast through surrounding secondary formations (Muschelkalk, Jura, &c., see Map, Pl. VI.), it may at some future day be advantageously won by deeper shafts over a considerable area.

The little coal-field of Upper Silesia occurs as a one-sided trough in the mountainous tract between

Breslau and Glätz, where a good many seams of coal of fair quality are exposed (usually at angles of high inclination), having been perforated by many eruptive rocks. On their eastern flank they repose on true carboniferous limestone with *Productus giganteus*, and on the west pass under red sandstone, shale, conglomerate and black limestone (Permian). See p. 199.

P.

Tertiary Deposits of Northern Germany and Poland.

Although we have ventured to colour a large region (chiefly, indeed, occupied by northern drift) as probably containing a substratum of Eocene age, we know that deposits of younger date also occur in it. Thus, Professor Göppert acquaints us, that some of the brown coal of Silesia (Taxus, &c.) contains plants comparatively modern, whilst that of Hessia is charged with extinct species, and is therefore of higher antiquity. The correct demarcation of these tertiary accumulations must be worked out by other geologists; our sole aim being, as we have explained (p. 281 *et seq.*), to show, that to the north of a certain zone there exist, at intervals, deposits containing older tertiary shells which essentially differ from those of the great masses of Miocene age that occupy South Poland, Volhynia, Podolia and Bessarabia.

Q.

Steppe Limestone (Aralo-Caspian).

In the introductory chapter (p. 8*), which was written after the great body of the work was printed, we have alluded to certain corrections made by the discoveries of M. Basinier and the comments thereon by Colonel Helmersen, of an inference we had drawn (p. 310), concerning the Ust-Urt, which we at one time supposed to be entirely occupied by the steppe limestone. In fact, the opinions there expressed (derived from the works of our precursors) are substantially corrected, p. 325, as well as in the introduction. The Map, Plate VI., has, indeed, been coloured according to our present views, as regulated by the subsequent perusal of the memoir of Colonel Helmersen, "Ueber die geognostische Beschaffenheit des Ust-Urt und in besondere dessen Östlichen Abfalles zum Aral See," Nov. 1844 (Classe Phys. Math. de l'Acad. Imp. de St. Pétersbourg, tom. iv. No. 73, 74). It is through the researches of M. Basinier, and the inductions of Helmersen, that not only the mass of the Ust-Urt, but also a wide tract to the north of it, have been placed in the parallel of the Oceanic Miocene deposits of Podolia, Volhynia and Bessarabia. But notwithstanding the existence of deposits of Miocene age in the Ust-Urt, it is still true, that the Aralo-Caspian or steppe limestone, such as we described it, forms the immediate cliffs of the Aral, as well as of the Caspian; whilst it is equally clear, that the two seas were formerly parts of the same great internal, brackish and freshwater Mediterranean, which spread over all the low country between them to the south of the Ust-Urt, and extended by Khivah far eastwards and southwards. Nor can it yet be positively assumed, that all the region of the Ust-Urt is formed of oceanic deposits; for until that vast plateau be traversed in various directions by competent geologists (M. Basinier having only passed along its eastern edge), it cannot be denied that portions of the steppe or Aralo-Caspian limestone which subtend it on three sides, may also have been elevated into some parts of it. In the meantime, our Map is coloured in consonance with the views of Colonel Helmersen, whose general opinion respecting the succession of the tertiary deposits in the eastern portion of the Aralo-Caspian region, is perfectly in accordance with that at which we arrived through our own observations, in respect to the western country around the Black Sea, the Crimæa and the Sea of Azof.

DESCRIPTION OF THE PLATES IN VOL. I.

I.—LITHOGRAPHIC SKETCHES.

1. *Frontispiece of Part I.*

This sketch represents the culminating points of the Ural Mountains between Zlataüst on the west and Miask. The rocks consist of quartz rock (probably metamorphic Silurian); and near their summit is engraved a memento of the visit of the Grand Duke Alexander, the heir apparent, when His Imperial Highness ascended to the highest pinnacle (see p. 434).

2. *Frontispiece of Part II.* (*Facing* p. 338.)

Gorge of the river Tchussovaya, on the western flank of the Ural Mountains, above Ust-Koiva, representing flexures of the Carboniferous and Devonian limestones, chiefly the former (see description, p. 388).

3. (*Facing* p. 362.)

This view represents the geologists descending the Siberian river Issetz, east of Ekaterinburg, in small canoes. The peasants are assembled at the village to witness and cheer the progress of the travellers, and the chief rural officer of the district is waiting to receive them at a river dam near one of the numerous corn-mills on that river. The rocks forming the river banks are porphyries.

4. (*Facing* p. 392.)

View from the summit of the Katchkanar in the North Ural Mountains. The lofty rocks in the foreground are of eruptive origin and highly magnetic, and the spectator is looking northwards over trackless, dense forests, the distant and loftier peaks being capped with snow.

5. (*Facing* p. 395.)

The Fortress and Monastery of Verkhoturiè or Verkoturiè, on the Siberian or east flank of the Ural Mountains, as seen from the west. This was one of the earliest strongholds of the Russians constructed after their occupation of Siberia. The rock is a granite.

6. (*Facing* p. 425.)

The peep into Siberia from Mount Sugomac near Kishtymsk is characteristic of the boundless flat tract occupied by numerous lakes which lies on the eastern flank of the Ural Mountains in that parallel. The Church and Zavod (forge) of Kishtymsk are seen below.

4 P

7. (*Facing* p. 428.)

The remarkable mountain of Taganai near Zlataûst, or "Tripod of the Moon" in the Bashkir language, is here viewed from the side of an adjacent mountain on the west. The peaks consist of quartz rock like those of the frontispiece, from which they are only separated by a valley. The tree in the foreground is intended to represent the *Pinus cembra,* so characteristic of the Ural Chain. Being sketched from a considerable height, the Taganai of this drawing scarcely conveys an idea of sufficient altitude.

8. (*Facing* p. 437.)

This view of the Lake Aushkul and the Holy Mount of the Bashkir inhabitants of the Southern Ural has been selected from many sketches, as giving a good general idea of one of the richest gold tracts on the eastern slopes of the chain, which is seen in the distance. The Russian officers are General Anosoff and Major Lissenko, who accompanied Mr. Murchison and Lieut. Koksharof from Zlataûst and Miask to this spot.

9. (*Facing* p. 448.)

View of the Guberlinski Hills (South Ural), as seen from the gate of the post-house in the village of that name. A Baskhir guard on horseback, with his bow and arrows and spear, who accompanied the travellers along this portion of the Kirghis frontier, is contrasted with a Russian peasant.

10, 11. (*Facing* p. 450.)

One of these sketches represents the travellers in their "tarantass" (a body of a britchka on long wooden poles), approaching Orenburg in the low steppes to the south of the Ural Chain; the other as they are coming back towards the ridges of Carboniferous limestone in the Gurmaya Hills of the South Ural. (See also p. 146.)

12. (*Facing* p. 453.)

A Bashkir summer camp in the high recesses of the Irendyk, or chief ridge of the South Ural. In the foreground is Mohammed John, the Bashkir proprietor of the camp, in conversation with a Russian settler and a mounted Bashkir. In the middle is a Russianized Bashkir officer and two common Bashkirs with a female; and in the distance are seen the mares from whose milk the "Kumiss" is being prepared over a fire. Black skins filled with Kumiss stand against the wicker-work of the tent, which is covered with a stout felt.

N.B. (For the two Plates A and B in the Appendix, the one illustrating the palæozoic corals the other teeth Devonian ichthyolites, see the accompanying descriptions.)

II.—COLOURED SECTIONS.

PLATE I.

This Plate refers exclusively to the Carboniferous region between the Don and the Dnieper, usually known as the coal-field of the Donetz. (See detailed account of, pp. 89 *et seq.*)

PLATES II. TO IV.

These three long coloured Plates represent a series of transverse sections of the North and South Ural Mountains on various parallels of latitude, as explained in the text from pp. 353 to 403, and pp. 420 to 461. As each coloured section has a separate title and is fully explained in the text and on the copper-plates, any repetition of description is here unnecessary. (At the heading of Chap. XVIII. p. 420, Plate III. has, through an omission, not been referred to.)

PLATE V.

Contains a section from the low tracts on the west, up to the axis of the Arctic Ural, and other sections across the Timan range and adjacent country. (See pp. 404 *et seq.*)

III.—MAPS.

PLATES VI. AND VII.

The General Map (Pl. VI.) was commenced in 1840, after our first journey to Russia, and in its earliest state (when exhibited at the British Association for the Advancement of Science in the autumn of that year) contained the chief demarcations of the older palæozoic formations only, as extending from south-west to north-east[1]. It was not, however, until after our much longer continued and more extensive explorations of 1841, that we were enabled to colour a general Map of Russia, a copy of which we laid before His Imperial Majesty in the autumn of that year, accompanied by a long section across the empire from south to north, of which the figure at the bottom of the Plate is a reduced copy. The existence of a great dome-shaped mass of Devonian rocks around Orel, which forms so prominent a feature in that section, was, indeed, observed by us on two parallels, in our journey from south to north during the autumn of that year, in which it was also

[1] In the Preface we have already spoken of a geological map of Russia compiled by Colonel Helmersen (St. Petersburgh, 1841), who in his account of its construction gives due merit to every contributor, from the early days of Strangways to the period of our first visit when we travelled to Archangel and across the province of Vologda (see Preface). Another map, also embracing our first year's results, was published by M. Adolph Erman in his Archiv für Russland (Berlin), 1841, a comparison of which with our present maps will show the progress made since that time.

observed by Colonel Helmersen quite independently of ourselves. (See p. 53 *et seq.*) In 1842 (our general classification having been pointed out in memoirs read before the Geological Society of London) the Map was engraved and coloured accordingly in the form which it now possesses, and with a table of organic remains to a great extent the same as that now appended to it. If the map had even then been published, all the main features of classification would have been sufficiently sustained for general objects; but we naturally withheld it until we had reviewed and more thoroughly examined our organic remains, and had so extended our researches as to produce the present work. Points of great importance have thus been added, the chief of which consist in the new features of the Southern Ural, the insertion of the correct physical geography of the Ural Chain, the geographical and geological outlines of Scandinavia, and of various ameliorations along the Polish and Carpathian frontiers; some of which we derived from our own explorations continued to 1844. Other changes and improvements have successively taken place, particularly in reference to great regions surrounding the area of our personal survey. For these we necessarily consulted the map of Von Dechen for the German frontier, and the new map of Zeuschner for the Carpathians. Turkey is chiefly coloured from Boué[1]; the Caucasus is entirely taken from Dubois de Montpereux; and the countries south of the Black Sea from the researches of Mr. W. J. Hamilton and Mr. W. Ainsworth; whilst the desert tracts between the Caspian and the Aral have undergone ameliorations through the critical inquiry of Colonel Helmersen into the observations of Basinier and other travellers. In regard to geographical features, the newest and most recent are those introduced from the Russian surveys of the South Ural and of all the wild regions extending therefrom to the Ust-Urt and the Caspian and Aral Seas. These are chiefly derived from maps scarcely yet published and prepared by the brothers Khani-

[1] We must here request geologists to understand, that as the portion of the Map representing South Hungary, Transylvania and Turkey is coloured to a small extent only from our personal knowledge, it is necessarily imperfect. Concerning a central portion of that region, we are, indeed, indebted for some corrections to our friend Mr. Warrington Smyth; but we beg unequivocally to state, that we are by no means certain whether portions of the crystalline rocks of these countries, which are coloured by us as metamorphic, may not be of azoic age; whilst some of the granites may also be of azoic age, and not as we have inserted them, of date posterior to the palæozoic deposits. At the same time, whether our method of parallelizing the Turkish crystalline masses be right or wrong, we are certain from personal inspection of the Carpathians, that the Tatra granitic rocks have been erupted long posterior to the palæozoic deposits, and are therefore wholly distinct in a geological sense from the azoic rocks of Scandinavia. They have indeed been evolved since the deposit of a sandstone which lies beneath the Liassic and Jurassic deposits, and have in some cases even protruded over these formations. Believing, in fact, that the Carpathians have been upheaved and mineralized in a manner very analogous to the Alps, we have (judging from their relations) assigned to all the granitic rocks between them and the shores of Greece, a like modern age; and on our general map we have not attempted to separate them from other eruptive rocks, even from those which are posterior to tertiary deposits.

koff, one of whom, M. James Khanikoff, is about to issue a Russian map of the South Ural, the other, M. N. Khanikoff, having obligingly sent us his compilation from various new surveys and his own, extending to the Aral and the Caspian[1].

Even in a purely geographical view, we are therefore enabled to lay before the European public a map charged with many outlines and positions unknown to geographers, especially to those of England. The most original portion, however, in which one of us (Count Keyserling with his associate Lieut. Krusenstern) has worked out, is the Timan Range and the basin of the Petchora, no correct features of which region were ever before published.

In an effort so arduous as the construction of a geological map of Russia in Europe and the Ural Mountains, and a tabular classification of all the sedimentary deposits, we bespeak the indulgence of critical geologists, and beg them not to look for errors of demarcation and detail, but fairly to regard the general intention and scope of the work. At the same time, we may be allowed to say, that we have laboured hard to render our Map as correct as possible up to the last moment, and have spared no expense in repeatedly altering the copper-plate as fresh knowledge was acquired. This process of improvement might doubtless have gone on for many years, but the period has arrived when we must launch our work. And here we must state, that although the Imperial Government possesses most elaborate and beautifully executed surveys of nearly all the frontier countries[2], no good physical maps have yet been published concerning the mass of Central Russia, nor are even the materials for their construction yet gathered together.

That vast undulating region consists of various round-backed and plateau-shaped masses of land, for the most part of small elevations from 200 to 600 feet above the sea, and rising at very rare intervals to altitudes exceeding 1000. To attempt the delineation of such monotonous hills without very accurate data, would merely have been to convey imperfect ideas; and we have, therefore, restricted ourselves to the representation of the chief mountain ranges by which Russia and Europe is subtended. In the interior we have alone lightly defined the chief watershed of the Valdai Hills, and a small though perceptible parallel ridge in Livonia, for which we are indebted to our friend M. Struve. We have also inserted the *remarkable feature of the high ground on the right bank of the Volga below Nijny Novogorod as contrasted with the low country on its left bank*[3]. When the great trigonometrical survey of that eminent astronomer and his associate General Tenner, to which we have alluded, shall be accomplished, then indeed the western frontier of Russia in Europe will be accurately laid down, and then may geologists proceed to eliminate details which are quite beside the objects of our present labours.

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[1] We have already adverted to the survey of Captain Romanoff between the South Ural and the Aral Sea, p. 341.

[2] See Mr. Murchison's account of these in his Anniversary Address read to the Royal Geographical Society, May 1845. (Journal of the Royal Geographical Society, vol. xv.)

[3] See explanation of this phænomenon, Appendix N. p. 650.

In defining the boundaries of the different formations beyond the sphere of our own explorations, we have necessarily consulted the observations of our predecessors. Of these the most useful to us in the first instance was a small general map compiled by Colonel Helmersen after our first visit to Russia. Any one, however, who will take the trouble of comparing our Map (Plate VI.) with all previous attempts, from the early map of Strangways to that of Helmersen, will see what improvements and additions have since been made. The outline, however, between the cretaceous and tertiary rocks of the South of Russia will, we apprehend, be found the most defective, that region having been traversed by us on a few parallels only, whilst the ages of the deposits have, as yet, been there but very obscurely tested over large tracts by any characteristic organic remains. The mineral characters of the surface (in the cretaceous and tertiary tracts) are, indeed, very often to a great extent the same, except where the white chalk appears.

In orthography we have usually endeavoured so to write the words upon our Maps, *that they may be correctly pronounced in the English language.* On this point we must observe, that we have everywhere endeavoured to avoid the use of that method of writing Russian names, which, through the authority of various German writers from the time of Pallas, has become too prevalent. The Russian *v*, for example, is exactly the English or French *v*; and the German *w* is, therefore, quite a misapplication in a joint English and French work. For the German *sch* we have simply employed *sh*, fearing that if the *c* had been interpolated, many English as well as French readers, would give a hard instead of a soft sound to the Russian words in which it appears. The vowels *a, e, i* are to be pronounced as is usual in foreign words, according to their Italian sound. The vowel *u* in every Russian word is pronounced like the French *ou* or the Italian *u*, and we therefore simply retain the *u*, attaching to it the Italian sound. In regard to the use of the *ch* before a vowel, we have not adhered to a practice introduced by some English writers, of applying it as pronounced in the words *choose* or *cheese*, but have prefixed a *T*, as in the words *Tchussovaya, Tchudova*, &c. Our reasons for preferring *Tch* are, that many Englishmen, in perusing foreign works, are apt to sound the *ch* hard (as the Germans), or like a guttural *k*, whilst again, if so written, it would necessarily be pronounced soft by Frenchmen (like our *sh*[1]); and thirdly, because when preceded by a *T*, no Frenchman, Englishman or German can pronounce the words incorrectly. In preparing the Map Mr. Arrowsmith has, indeed, occasionally used *ch*, but whenever we have detected it in time, a change has been made to *Tch*. Generally, where the letter *j* precedes a vowel, it is to be pronounced as *y*. In every such instance it was, indeed, our wish to use the *y*, as in the words *Yenisei, Yaroslavl*, &c., but in a very few examples (through the habit of writing names and places according to the German or French

[1] The strongest reason for not using *ch* as pronounced in the English word *choose* is, that in our own second or French volume such consonants are often soft before a vowel. Thus, the name of our young companion Lieut. Koksharoff is written Kokcharoff in French, the carboniferous locality *Priksha* of this volume is spelt *Prikcha* in the other, and *Shavli* in English is *Chavli* in French.

method) the *j* has erroneously crept into the text and Map, as in the mountain *Jurma*, and in the towns *Jurievetz* on the Volga and *Jelatma* on the Oka, which are distinctly pronounced *Yurma*, *Yurievetz* and *Yelatma*. And although there are examples in which the *J*, as pronounced by the English, conveys the proper sound, as in the Sclavonic words *Jevitze*, *Jeleznoe*, &c. (Gelesnai, Fr.), we ought perhaps invariably to have followed a method not unusual in writing Eastern names, and which we have occasionally adopted, as in the words *Djelebeck*, *Djabyk-karagai*, &c. There is a peculiarity in the Russian pronunciation of the *o*, which has rendered uniformity extremely difficult; custom or fashion having in many instances led the Russians to sound the *o* as a broad *a*, though the syllable be spelt with an *o*. In some of these cases we have written the word as it is pronounced, though in most we have simply followed the Russian spelling.

The geological classification adopted in the General Map is so apparent, that little or no explanation is here needed concerning the different sedimentary deposits which succeed to each other, from the oldest on the north to the youngest on the south, the divisions being essentially the same as those applied by one of us to England[1]. In defining the igneous rocks we have adhered to that principle which we believe we were the first to introduce, of representing all such rocks in tints of the same colour (red)[2]. In the General Map, details being impracticable on so small a scale, we have necessarily been limited to broad distinctions. Thereon, therefore, we simply represent the earliest formed sediments (anterior to all traces of organized beings) and which have been much affected by igneous agency in pale carmine (letter *a*). In darker carmine (*b*) we group all the eruptive rocks which have traversed the subsequent sedimentary deposits, one of the most recent of these masses being the granites on the eastern flank of the Ural Mountains. In those tracts, proofs have been obtained, not only that the granite has burst through all the sedimentary palæozoic rocks, but has also pierced other eruptive rocks;—such as greenstones, porphyries and serpentines. Whilst, therefore, we are unable to define such phænomena on the small scale of our General Map, we have attempted it in the special Geological Map of the Ural Mountains, wherein three classes of eruptive rocks are distinguished by different tints of red and by different signs.

As the Map, Plate VII., is the first effort made to give a geological representation of the Ural Mountains, so complex and diversified in mineral features, we trust that our labours will be viewed with indulgence by those who may hereafter have much greater opportunities than we possessed of grappling with such a task. Besides our own observations, however, we have endeavoured to compile the fragmentary descriptions of various parts of the chain, as given by Hermann, Erman, Humboldt, Rose, Helmersen, Hofmann, &c., and to

[1] See Geological Map of England by Mr. Murchison, published by the Society for the Diffusion of Useful Knowledge.

[2] See Maps of Brora and the Hebrides and of the Austrian Alps, Trans. Geol. Soc., vols. ii. and iii. new series, and Map of the Silurian Region in the work entitled the 'Silurian System.'

consult the local maps prepared by the different officers of the Imperial School of Mines alluded to in the text, in relation to the districts around different centres of mining operations. But, after all, the spaces being considerable, concerning which we have no information to be depended on, we have necessarily connected the broken materials in the best manner in our power. The great point we aim at in the Uralian Map, is to show a regular succession of the unaltered palæozoic deposits (3, 2 and 1) on the west flank of the chain, until they reach the great fissure of eruption along which they have been crystallized and metamorphosed (c, c^1, c^2, c^3); whilst on the east flank of the chain, though much dismembered and insulated amidst a vast spread of various igneous rocks, the same palæozoic masses are still recognisable, and occasionally become quite distinct when followed down into the low countries of Siberia (as on the river Issetz).

Humboldt, Rose, Helmersen, Hofmann, Erman, Tchihatcheff, Middendorff and other explorers of Siberia having, through the fossils brought back by them, satisfied us that the same rocks we define in the Ural, are largely developed in wild regions far to the east of these mountains, so we are led to hope, that the classification we have attempted may be of use in methodizing the arrangement and description of the chief Siberian rocks.

Another object is to show at a glance, that although originally composed of sedimentary formations essentially the same, and all affected on the same great meridian strike, the mountains of the North and South Ural offer some remarkable features of difference. In the former, the ancient deposits to the west of the axis contain but little quartz rock, whilst in the broad south-western expansion of the South Ural, such rocks (c^1) abound, and constitute some of the loftiest ridges, including the Iremel.

The gold alluvia, extending to the river Losva, and a little beyond the limits of the Uralian Map, (with the single exception of Chrestovodsvisgensk, near Bissersk, in parallel 58½°) are found on the eastern side of the great axis of mineralization. Taking Ekaterinburg as the centre of these auriferous deposits, they may be seen, as indicated by the bright gold colours dotted at intervals, to extend pretty nearly as far south as north of that city. They die away, however, in the parallel of Tanalysk; and to the south of the Lake Aushkul and Cossatchi-Datchi, few of the sites are worthy of much attention. This thinning out of the gold ore is accompanied by that remarkable change in the lithological features of the southernmost Ural, whereby schists of the carboniferous and other palæozoic rocks are interlaced with countless ridges and bands of porphyry, in contact with which they are converted into the far-famed Siberian jaspers (c^3). By traversing the Irendyk Ridge, which forms the chief axis of the South Ural in the parallels of Verkny Uralsk and Kizilsk, and also by crossing the end of the chain at Orsk, we had abundant opportunities of convincing ourselves, that the siliceous and flinty schists and jaspers are simply metamorphosed palæozoic strata (often carboniferous), which followed from north-north-west to south-south-east, terminate at Kizilsk, Urtazimsk and Tanalysk, in masses of carboniferous shale, the limestone associated with which is replete with Producti and Encrinites.

In venturing to colour, geologically, the wide tract between the Ural river and the forts of Constantinovsk and Michaelovsk in the Kirghis steppes on the east (to which our own researches did not extend), we simply desire to generalize the valuable facts obtained through the explorations of Colonel Helmersen and Captain Tchaikofsky. The first-named has, indeed, shown that the Djabyk Karagai, or northern end of the Kara-Edir Tau, is a continuation of the same granitic range which we traversed between Miask and Troitsk: also that the other eruptive rocks on either flank of the granite are greenstones, porphyries, serpentines, &c., which have altered and metamorphosed the palæozoic strata, as on the east flank of the Ural Range, producing in like manner chloritic schists, quartz rocks, granular limestones, &c.; whilst in some of the limestones, encrinites and other organic remains occur at intervals. This range of Djabyk Karagai or Kara-Edir Tau, is seen in the General Map to be confluent with the Mugodjar ridge, which is a southern prolongation of the Ural; and in perusing our pages the reader will find, that the granite of the Siberian and Kirghis steppes, which occupies such large surfaces from Miask, and extends at intervals by Ekaterinburg to Verkhoturie on the north, is, as already stated, the most recent eruptive rock of these regions.

Our extreme eastern limit of the palæozoic, eruptive and metamorphic rocks, which are dependencies of the Uralian chain, is necessarily to some extent arbitrary, particularly to the south of Troitsk; for, though at certain points, such as Verkhoturié and Kamensk, we have seen tertiary accumulations succeed, we can by no means assert that they are continuously extended to the south. The range of such tertiary deposits must, we know, be circumscribed, since we have, by the examination of fossils and rocks from various parts of Siberia, convinced ourselves, as before observed, that the same palæozoic, eruptive and altered rocks which are laid down on the Map, Plate VII., occur at numerous intervals throughout Siberia in all its breadth from west to east; an inference that has been extended to the shores of Kamtschkatka and the Isles of Shantar, in the Sea of Okhotsk, through the explorations of M. A. Erman and Professor Middendorff.

In colouring this Map, we have, as before said, adhered to our old principle, of representing all eruptive rocks under different tints of the same colour. Thus the greenstones, syenites and porphyries (*b*) are in the darkest tint of red; the serpentines (*b*) have waved vertical lines on a base of red; and the granites (b^2) are in a lighter red; all of them being made distinct from the pale red of the azoic rocks of Scandinavia, as represented in the other Map, Plate VI.

Of the Uralian Map, Plate VII., we need say no more, particularly as we have in the text and elsewhere acknowledged with gratitude our obligations to General Perovski and others (especially to M. J. Khanikoff), for materials which have given to the southern portion of the chain so fresh a geographical character. (See Journal of the Royal Geograph. Soc. vol. xiv.)

Nor can we, without becoming prolix, enter into much further explanation of the General Map. Three points in it, however, seem to require notice. The first is, that it indicates a clear distinction between those sedimentary (azoic) strata (*a*) which preceded all traces of animal life, and those palæozoic deposits (1, 2, 3, 4) which are charged with organic remains; each member of this vast group being specially distinguished.

The second point is, that whilst the Tertiary series is designated by three colours, which on the whole stand for the Eocene[1], Miocene and Pliocene periods, the latter is specially represented in South-eastern Russia and the adjacent Asiatic countries, by the remains of a vast internal brackish sea, as large as or larger than the present Mediterranean, which must have been almost entirely separated from the ocean. (See p. 652.)

In defining the outlines of the deposits of this vast former Mediterranean, we have been guided by what we know of it from personal observation in the steppes of the Kirghis, between Orenburg and Astrakhan, and in the tracts adjacent to the Sea of Azof, the Crimæa and the Black Sea. In those districts we clearly distinguished limestones which had been elevated to 150 or 200 feet above the sea, from sandy, low steppes, in which most of the same Caspian remains exist, and we have therefore endeavoured to carry out such division, by employing two tints of the same colour in reference to far and distant tracts of which we have no personal knowledge, but which from the description of various travellers mentioned in the work are believed to be of the same composition. The darkest of these tints (fig. 10) represents the bottoms of the earliest Caspian which have been elevated into rocky promontories, and the lighter tint (10′) the bottoms of the same sea subsequently desiccated, and of which the present Aral and Caspian are the greatly diminished existing types. (The northern raised sea-bottoms are similarly marked 10′.)

Thirdly, in reference to the very striking phænomenon of the distribution of the Scandinavian drift, we have indicated by arrows that it proceeded excentrically from a common central region, and have marked by an engraved devious line (coloured red) the extreme points to which the erratic blocks have been transported southwards and eastwards.

Lastly, notwithstanding the imperfections which must pertain to the first geological maps of such vast and slightly explored regions, we trust that our endeavours to extend the newest British classification into Asia, and thus to co-ordinate large portions of the globe, will be adequately appreciated by those who are aware of the difficulties we have had to encounter, and the importance of the objects in view. In truth, the region we have ventured (perhaps too boldly) to illustrate, is nearly twice as large as all those portions of Europe hitherto described by geologists; and this fact alone must be our apology for inevitable inaccuracies of detail, particularly in reference to the countries which surround the area of our personal explorations. In conclusion we would merely say, that if the *principle* of geological arrangement be found correct, our great object is accomplished.

[1] See Appendix, p. 651.

CORRIGENDA.

The first volume (with the exception of the first three chapters) having been printed before the organic remains had been definitively compared and named, certain changes in the names of species have taken place. In respect to the ichthyolites, some of the new names are announced at page 39, Chapter III. (See Vol. II.)

Page 24*, *for* Hoffman *read* Hofmann.
—— 42, for *Bellerophon armatus* read *Porcellia armata*, the name Porcellia of L'Eveillé being preserved for certain shells approaching to Bellerophon.
—— 43, for *Productus spinosus* read *P. spinulosus*.
—— 43, *for* reference to woodcuts, pp. 28 and 30 *read* pp. 29*, 30 and 30*.
—— 45, for *Leptæna productoides* read *Productus productoides*.
—— 45. The *Orthoceratites subfusiformis*, which we have only seen in fragments buried in the rock, may very probably be the same shell as the *O. subpyriformis*, which we collected in the Devonian strata of Voroneje.
—— 45 *et seq. for* Priutchka *read* Priksha.
—— 57, for *Orthis striatulus* read *O. striatula*.
—— 58, for *Terebratula plebeia* read *T. Puschiana*; since we now believe this form to be a new species.
—— 60, for *Leptæna arcuata* read *L.* (*Chonetes*) *armata* (Bouchard); we have since, however, seen reason to believe that this species is distinct, and have named it *Chonetes nana*.
—— 61, for *Leptæna caperata* read *Productus caperatus*.
—— 68 (note). The sketches of certain characteristic ichthyolites announced to be given by Prof. Agassiz in the Third Part or Second Volume of this work, have not been sent to the Authors: for the structure of three genera of Devonian ichthyolites, see Pl. II. Vol. II.
—— 69, line 9, *for* letter *c* upon the Map *read* No. 3 upon the Map.
—— 70, *for* Priutchka *read* Priksha.
—— 72 and 75, for *Cidarites Deucalionis* read *C. Rossicus* (V. Buch).
—— 72 and 76, for *Orthis arachnoides* read *O. arachnoidea*.
—— 73, for *Avicula Valdaica* read *Pecten Valdaicus*.
—— 79, line 26, *for* Catenipora *read* Syringopora.
—— 79 and 83, *for* Ocetre and Oceta *read* Ocetr river.
—— 80, line 5, *for* Anomia *read* Anomites.
—— 80, line 13 (below the woodcut), *for* tertiary *read* Jurassic.
—— 87 and 159, *for* Alveolinæ *read* Fusulinæ (see correction, p. 135).
—— 103, *for* valley of Kameuka *read* near Kamenka.
—— 111. *Orthis planissima*. This name having been employed in the collection of the Imperial Mining Corps, we used it, but have since identified the shell with *O. arachnoidea* (*supra*).
—— 115, for *Productus horridus* read *P. Leplayi*.
—— 115, 131, 133, for *Leptæna sarcinulata* read *Chonetes sarcinulata*; this species having been made by us the type of the genus Chonetes.
—— 125, line 3, for *Productus comoides* read *P. tenuistriatus* (nob.).
—— 131, line 9, for *Productus quadriradiatus* read *Spirifer quadriradiatus*.

Page 134, line 25, for *Nautilus Leplayi* (nob.) read *N. Leplayi* (Rousseau).
—— 135, line 11. The *Gorgonia retepora* is a misprint. The corals here alluded to belong to the genus Fenestella (see Description of Corals, Appendix).
—— 139 *et seq. for* rohte-todte *read* rothe-todte-liegende.
—— 143, *for* Rapoymaya *read* Rapolmaya.
—— 143, *for* Gorodok *in* read Gorodok *on* the Tchussovaya.
—— 167, *for* Retepora *read* Fenestella.
—— 174, for *Calamopora fibrosa* read *Stenopora crassa* (Lons.).
—— 175, for *Pentamerus superstes* read *Terebratula superstes*.
—— 209 and 224, *for* Malayoraslavetz *read* Mala Yaroslavetz.
—— 211 (note), *for* Timans *read* Timan.
—— 221, for *Tubuliclidia* read *Stenopora*.
—— 231, for *Belemnites Puzotianus* read *B. Puzosianus*.
—— 232, line 2, *for* Gryphæ *read* Gryphææ.
—— 234, for *Ammonites Fournetianus* read *A. coronatus* (Brug. *non* Schloth.), as re-determined by M. Alcide d'Orbigny.
—— 237, *for* Inoceramus grit *read* Avicula grit. M. von Buch has recently named the so-called Inoceramus, *Avicula Mosquensis*.
—— 245, for Goroditche *below* read Goroditche *above* Simbirsk.
—— 246, for *Orbicula mæstis* read *O. Mæotis*.
—— 246, *for* west-north-west of Simbirsk *read* north of Simbirsk.
—— 266, for *Inoceramus crista galli* read *Ostrea crista galli*.
—— 274, to the name *Ammonites Panderi* add (Eichw.).
—— 298, *for* Hindoo Kusk *read* Hindoo Kush.
—— 337, line 4, for *conquest* of Siberia read *colonization* of Siberia.
—— 341 (note), *for* M. Basiner *read* M. Basinler.
—— 342 and 398. Konshakofski or Kondjakofski is spelt (*Anglicè*) Konjakofski on the Map, Pl. VI.
—— 347, line 1, *for* at the head of this chapter, *read* the frontispiece to this work.
—— 396, line 1, *where there is an omission, read* north, *and for* R. Losva *read* Lobva.
—— 410, *for* Sophiusa river *read* Sopliusa.
—— 411, line 2 from bottom, *for* (see *ante*, p. 18), *read* p. 23.
—— 453, line 21, *for* greenstone, porphyritic greenstone, *read* porphyritic greenstone.
—— 523, *for* Kolaa *read* Kolo.
—— 526, *for* Gleinitz *read* Gleiwitz.
—— 564, *for* Wallachia *read* Walachia.
—— 566, woodcut 72, for *b* placed over the water, read *e*.
—— 568, over woodcut, *for* ancient level of lake *read* ancient levels of lake.

N.B. For orthography of Russian words employed in this volume and on the Maps, see p. 658,

POSTSCRIPT.

St. Petersburg, August 1845.

On revisiting this place after our volumes were printed, but before they were put into general circulation, we have availed ourselves of some of the most recent observations in Russia to improve our Map, Plate VI. Thus, through our friends M. Pander, who had just returned from a geological excursion, and Mr. Frears, a resident at Moscow, we learned that a thin band of ferrugino-argillaceous *pisolite* containing Belemnites, had been observed to form the base of the Jurassic deposit (Oxfordian) at several places around that metropolis (Gregorievo, Podolsk, Miatchkova, Bronnitzi, and on the little river Koloksha near Vladimir). In all these places the pisolite is, we are assured by M. Pander, precisely identical with that of Popilani in Courland; and in the government of Moscow it reposes directly upon the carboniferous limestone. The zealous researches of these Russian friends have, in fact, greatly extended our knowledge of the limits of the Jurassic deposits, particularly of the overlying sandstones, which seem to occupy considerable portions of the plateaux, leaving the carboniferous limestone exposed in the larger river valleys and gorges only. In a tract north of Medinsk the Jurassic shale is so bituminous, that it might be mistaken for a true carboniferous deposit, like certain beds of the same age described by us near Simbirsk (p. 245).

In respect to the region around Moscow we may also remark, that M. Pander has detected remains of Mammoth and Rhinoceros in reddish clay covered by erratic blocks eight versts to the south of Verchni Volotchok, and in one of these localities fractured flints of the carboniferous limestone are seen to alternate with bands of reddish clay. Bones of extinct quadrupeds had, indeed, been previously found in the vicinity of Moscow, but their true original position was unknown, as they had usually been picked out of the river beds into which they had fallen from the contiguous cliffs. The observations of M. Pander are, therefore, most important in convincing us, that such remains occur in an ancient drift: we may well believe that the animals of which these are the bones, were floated out to sea from the nearest lands of a former epoch, and their skeletons deposited (like those near Taganrog, p. 502) in gravel, sand and clay. In one spot 300 versts south of Petersburg, and twenty versts south of the river Kolomenka, M. Pander further found the horns of a stag in gravel or drift twenty-one feet below the surface, and covered by fine yellow sand, which is surmounted by clay and northern erratic blocks.

Our last visit has also been productive of some additional acquaintance with the limits of the Silurian and Devonian rocks south of St. Petersburg. Thus, whilst the country south of Gatchina, and for some versts to the south of that town, is composed of a yellowish magnesian limestone, containing Silurian Orthidæ and Trilobites (similar we believe to those species found by us in the strata on the Vloia, p. 30*), true Devonian rocks succeed near Sivoritzki at about twelve versts south of Gatchina, in greenish grey, micaceous sandstone and marly limestone, followed, at some versts further south, by red sands and sandstone, identical with those of Dörpat and of the river Mgra near Vitegra. Ichthyolites are found, at intervals, throughout this micaceous sandstone, which forms a striking escarpment in this country of broad undulations[1].

We have next to express our regret, that owing to some accident in its transmission, we did not receive a memoir by Major Ozersky[2], which gives a very clear and faithful description of the detailed succession of the strata that constitute the Silurian group of north-western Esthonia. After a very good account of the physical features of that tract, he describes a number of natural sections to the west of Reval, both on the coast and in the interior, as well as in the Isle of Dago[3], and he divides the Silurian rocks into three members. The Ungulite sandstone there forms (as, indeed, Eichwald and others have observed) the base of the cliffs, which in ascending order consist of inferior grit, bituminous schist and greenish sandstone. This lowest member is followed by chloritic limestone, capped by a band of sandstone and surmounted by a considerable thickness of limestone to which the author applies the term "Fliessen-kalkstein," dividing it into lower and upper beds. The third and uppermost division (also calcareous) is separated by him into a coarse-grained crystalline limestone beneath, and a compact though occasionally sandy limestone above, which constitutes the highest stratum he observed. Besides the Obolus or Ungulite, the lowest of these divisions contains the coral *Gorgonia flabelliformis* (Eichw.), and its upper beds the *Siphonotreta verrucosa* (nob.) (*Terebratula*, Eichw.). The middle group is (as described by us near St. Petersburg[4]) the great storehouse of organic remains, and in the districts which he illustrates Major Ozersky shows that it is more expanded than in any tract we have personally examined, whilst the fossils are those which we have enumerated and described. The upper group of this author is precisely that band which we have described near Shavli, Meshkovitza, Oberpahlen, &c., and which, as we have indicated, gradually disappears with the eastward range of the Silurian rocks; for it contains our *Pentamerus borealis* (*Gypidia*, Eichw.), and also several corals.

In expressing our obligations to Major Ozersky for his lucid memoir, in which he developes the lithological features of each substratum with a precision worthy of so good a mineralogist as himself, we are however at variance with his concluding comparisons, wherein he endeavours to find exact parallels for each of his lithological subdivisions in the English detailed order of the Silurian rocks, as seen in certain typical British tracts. His upper continental stratum is thus considered by him to be the representative of the Ludlow rocks; whereas in our estimate there is not a vestige of that formation in any portion of the mainland of the Russian Baltic provinces; though it has a distinct existence with many characteristic fossils in the Isle of Oesel as determined by M. Pander (p. 35). The superior portion of the uppermost group of Major Ozersky may, indeed, where loaded with such corals as the *Catenipora escharoides* and *Favosites Gothlandica*, be assimilated to the Wenlock limestone; but the lowest bed of this calcareous mass, which is charged with *Pentamerus borealis* (closely akin to *P. oblongus*), is clearly on the same level as the Horderley and Woolhope limestone of England, a point which we have indeed completely explained as respects Scandinavia, Russia and North America (pp. 5*, 12*, 34*). This Pentamerus bed forms so

[1] We made an excursion to this neighbourhood with M. Wörth and Professor Kutorga, who had previously observed the chief relations here alluded to.

[2] See the volume of the Imperial Mineralogical Society of St. Petersburg, 1844.

[3] At p. 35 we have considered Dago as Upper Silurian, and, in fact, the Wenlock or Dudley corals are there abundant in its uppermost stratum; but this isle contains the *Pentamerus borealis* and other fossils which pertain to the Lower Silurian strata, none of which are seen in Oesel.

[4] In addition to the proofs we have already adduced of the limestones of St. Petersburg being of Lower Silurian age, we beg to mention that our friend M. Volborth, who has so assiduously collected the fossils of this rock and described some of its Crinoidea, has detected in it the same *Agnostus* (Battus) which so distinguishes true Lower Silurian rocks at Kinnekulle and other places in Sweden and Norway.

clear a horizon in separating the Lower and Upper Silurian rocks over all parts of the globe where they exist, that so long as the original English classification be appealed to, no sort of doubt can be entertained, that every layer beneath it must be grouped with the Lower Silurian, as represented in our table attached to the Map, Pl. VI.; and it is therefore quite impossible to admit, that the chief limestones of Esthonia, which underlie that Pentamerus rock, can be compared with the Wenlock limestone. But in differing from Major Ozersky as to his comparisons of Russian deposits with those English formations with which we are necessarily well acquainted, we have specially to thank him for his excellent details of local succession, and for pointing out other phænomena of some importance. One of these is the presence of a coarse conglomerate of fragments of crystalline rocks (our Azoic) in the Ungulite sandstones, thereby proving, that even in Russia the Lower Silurian strata have been constructed out of rocks antecedently crystalline, just as we have proved to have been the case in Scandinavia. Another of these phænomena (confirming our anticipations and of great value in sustaining our views derived from other localities, see pp. 328, 524, 539) is the existence of raised sea beaches containing remains of species of shells still living in the adjacent Baltic; such as *Cardium edule*, *Mytilus edulis*, and *Tellina Baltica*; which fact, combined with the evidences afforded by banks of gravel, sand and blocks, clearly points to a comparatively recent elevation of Esthonia, and hence of all the flat regions of Russia. The author further offers proofs of the polish and striation of the denuded limestones—appearances referred by him to the action of floating ice. Being for a moment on a subject which we have handled at some length in the preceding pages, we may observe that during our present stay at St. Petersburg we have observed the phænomena on the surface of the yellow Silurian limestone south of Gatchina before alluded to, where it was first noticed by M. Wörth and Professor Kutorga. It is also worthy of a comment, that in the neighbourhood of Gatchina, where the striation and polish are seen, there are no accumulations of fine gravel or loose drift; huge, northern erratic blocks only occurring abundantly. In such instances, we willingly admit that the polish and striation may have been produced by the onward motion of ice-floes (carrying these blocks) which stranded in shallows and grated along the subjacent rocks. Such an action, however, we again maintain could never have been adequate to the uniform maceration, smoothing and grinding down (in the manner we have described) of all the northern faces of the crystalline rocks of Finland, Sweden, and of the myriads of isles of the Bothnian Gulf.

We have next to acquaint our readers, that the Map, Pl. VI., has received considerable improvement at its north-eastern extremity from the researches of the distinguished botanist Schrenk, who in the year 1836, and previous to his arduous tour in South-Eastern Siberia and along the Chinese frontier[1], gallantly faced the most inhospitable of all the Arabian tracts, and traversing the wilds of the Samoyedes to the Straits of Vaigatz, not only determined the physical geography and natural history of the region forming the end of the Arctic Ural, but also brought back collections sufficient to establish geological demarcations in a country which may not for a century be visited by any other man of science[2].

Whilst on the subject of new discoveries in the boreal tracts of Russia, we may mention, that the enterprising traveller Professor Middendorf of Kief has brought back with him from the shores of the Arctic Sea (between the rivers Obe and Lena), numerous fossil shells which on inspection we had no hesitation in identifying with those Oxfordian types with which we had become familiar in many parts of European Russia. Associated with numerous Belemnites and true Ammonites, we detected also those

[1] See last Anniversary Discourse of Mr. Murchison as President of the Royal Geographical Society. Journal of the Royal Geographical Society, vol. 15, p. ci.

[2] The chief geological data resulting from an examination of M. Schrenk's fossils, will be given in the forthcoming work of our friend and coadjutor, Count Keyserling, on the Timan, Petchora, etc., which, as we have previously said, forms a natural sequel to these volumes.

chambered shells with dentated lobes called Ceratites, one species of which, indeed, not having any of these indentations or serratures, might be referred to that division of Goniatites which are distinguished by rounded lobes. We thus learn how dangerous it is to generalize upon the age of a rock from the presence of any one fossil body; for had these Ceratites been alone or even in predominance, some geologists might have associated the Siberian beds with the Muschelkalk, or even with older formations; whereas a multitude of the most common of the Jurassic forms (including numerous Ammonites with their nacre) bespeak in the clearest manner the true age of these deposits.

Lastly, we are indebted to our friend Colonel Helmersen, for having made known to us a highly important and curious discovery of Professor Abich of Dörpat, on the northern flank of the Great Ararat, near the monastery of Korverab and in the valley of the Araxes; where he has detected numerous *Palæozoic fossils*, among which he cites the *Spirifer speciosus*, *S. ostiolatus*, *S. aperturatus*, with Orthidæ, Terebratulæ, Lingulæ, and the characteristic corals *Catenipora escharoides*, *Cyathophyllum flexuosum*, *Favosites*, &c.

This announcement is the more interesting to geologists, as no researches of other travellers have shown the existence of any formations of the palæozoic age in those eastern regions which form the south-eastern extremity of our Map, Pl. VI., the greater number of whose solid rocks have been referred to the cretaceous period. If, indeed, we might venture to throw out a surmise, we should be inclined to think, that the palæozoic band on the upper Araxes is the eastern continuation of rocks of Silurian age which show themselves on the southern slopes of the Balkan, and constituting portions of the Thracian Bosphorus, may, after some detailed researches, be found here and there in the intermediate space of Pontus, Bithynia and Paphlagonia.

Note. In this plate the scale of hei

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Fig 4

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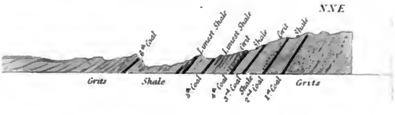
Fig 8

Coal beds East of the Village of Jeleznaya



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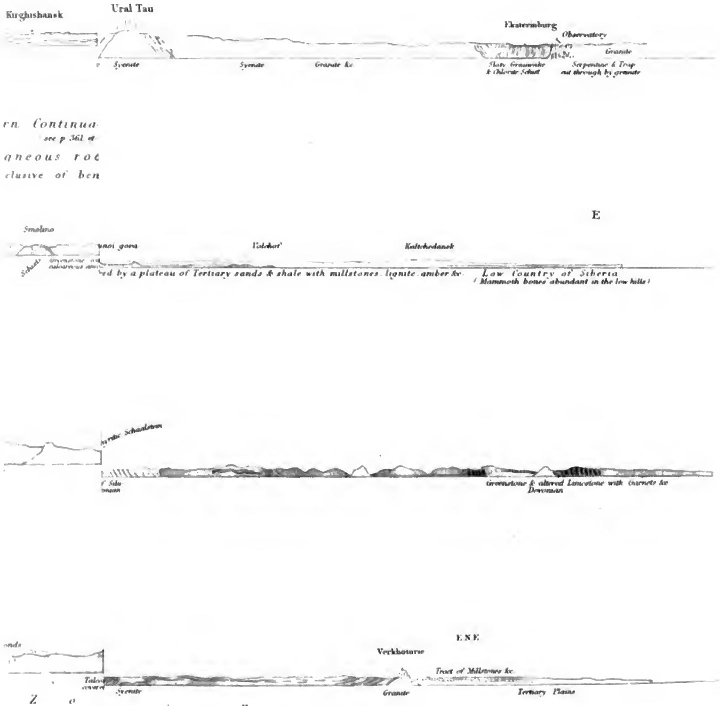

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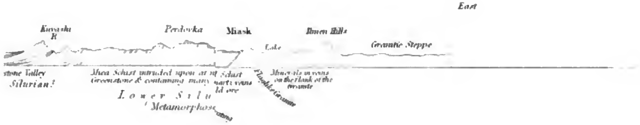
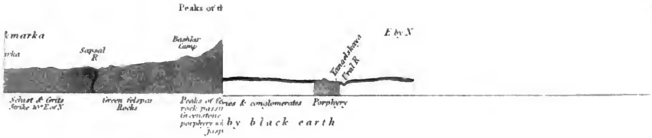
Plate 3.

Fig 1

Valley of the Kiga by Zlata





Plate

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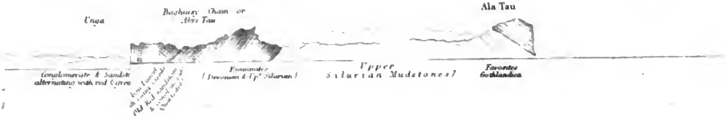

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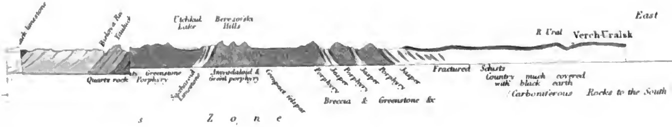

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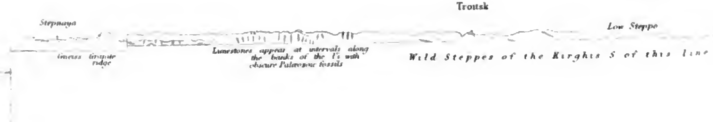

Fig 2.

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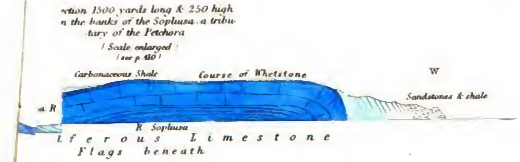

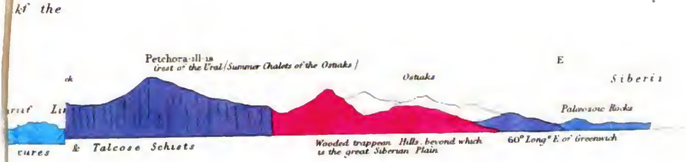

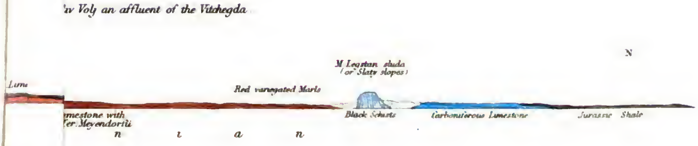

INDEX.

4 R

ERRATUM.

Page 18*, and Index, page 678, *for* Homberg *read* Hoburg.

THE END.

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