T2 Neoproterozoic palaeobiology and geobiology

T2-1

EARLY ANIMAL EVOLUTION AND PALAEOECOLOGY: ACROSS THE GREAT DIVIDE

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The Ediacaran through Cambrian interval of early animal evolution, including the Cambrian explosion, has been the subject of intense study. A major hypothesis for the Cambrian explosion is that the genetic toolkit to accomplish this had already evolved and that the diversity of form represented in the explosion was due to exploitation of increasing ecological opportunities. A detailed understanding of the ecology of the Ediacaran-Cambrian is needed to explore the ramifications of this hypothesis. Heretofore palaeoecological study of this crucial interval has typically tended to focus on particular categories of available data, segregated by time (Ediacaran vs. Cambrian) and fossil type. A complication in analyses has been that the animal fossil record of this interval is unusually complex when compared to other times in Earth history. Perhaps trace fossils and related bioturbation structures are the simplest component of this record, but they are still difficult to understand due to widespread non-actualistic occurrence of microbial structures combined with the evolutionary advent of vertical bioturbation. Much of what we know about the body fossil record is driven by the distribution of disparate types of lagerstätten, from Doushantuo to Ediacara to Chengjiang to Burgess. This is also the time of appearance of the mineralised fossil record, with the first advent of skeletons and then the rapid increase in skeleton morphology, as represented by the Cambrian explosion. Another factor affecting our understanding of this time is the possibility that a mass extinction occurred at the Precambrian-Cambrian boundary. Although much of what we know about this crucial time interval may be strongly influenced by differential preservation among the various lagerstätten, overlain by the advent of biomineralisation, a variety of ecological patterns have begun to emerge. These include trends in tiering and macro-predation, as well as changes due to the agronomic and Cambrian substrate revolutions. As we continue to integrate palaeoenvironmental and phylogenetic studies with new approaches to understanding palaeoecology of the Ediacaran-Cambrian, we continue to discover that these non-actualistic ecosystems were more complex than was previously thought.

Keywords: Ediacaran; Cambrian; palaeoecology; evolution.

T2-2

SEQUENCING THE EDIACARAN PERIOD VIA THE APPLICATION OF HIGH-PRECISION GEOCHRONOLOGY

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A growing database of high-precision U-Pb zircon dates provides calibration of terminal Neoproterozoic time. The base of the Ediacaran Period is defined at the base of the Nucaleena (Marinoan) cap-carbonate as exposed in Enorama Creek, Flinders Ranges, South Australia. High-precision U-Pb (zircon) ages from Namibia (within the glacial Ghaub Formation) and Southern China (within the cap carbonate to the Nantuo tillite) indicate synchronous termination of the Marinoan glaciation at 635 Ma. Age constraints from Australia that pertain to the age of the base of the Ediacaran Period remain equivocal. The top of the Ediacaran Period/Base Cambrian Period is not dated at its type locality, however data from Oman and Namibia constrain it to be 542 Ma. During the Ediacaran Period the short-lived (<2 Myr) Gaskiers glaciation occurred at ca. 582 Ma. When all well-dated sequences containing Ediacaran fossils are considered in the context of global chemostratigraphic correlation schemes, a number of major conclusions can be drawn. The oldest known Ediacaran fossils (Rangeomorphs) first appear in Newfoundland within ca. 5 Myr of the termination of the Gaskiers glaciation and are present in various successions worldwide until close to the end of the Ediacaran Period. During this interval (ca. 570-551 Ma) the global carbon cycle underwent a major reorganisation consistent with progressive oxidation and remineralisation of the organic reservoir. At broadly the same time, and suggestive of a link, the first complex trace fossils as well as the stem group mollusc *Kimberella* (ca. 555 Ma) are found in White Sea sections as well as the first macroscopic algae of the Miaohe Biota of Doushantuo Formation (>551 Ma). Weakly calcified metazoans, such as *Cloudina* and *Namacalathus* appear ca. 548 and continue to the Ediacaran/Cambrian boundary where they appear to go extinct. The past decade has seen better agreement between molecular clock and fossil record estimates for timing of animal evolution, the relationship between macroscopic fossils and the termination of the last glaciation, and the timing of the rise and fall of Ediacarans. Future work will centre on further constraining outstanding events (such as the age of the Doushantuo embryos and base/nadir of the Shuram/Wonoka $\delta^{13}C$ excursion) and utilising the highly calibrated record to understand developmental and environmental controls on evolution that paved the way for the Cambrian explosion.

T2-3

ENVIRONMENTAL AND MINERALOGICAL CONTROLS OF NON-MINERALISED FOSSIL PRESERVATION IN THE NEOPROTEROZOIC DOUSHANTUO FORMATION

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Determination of environmental conditions at the time of deposition of the Neoproterozoic Doushantuo Formation is needed to answer questions about the temporal and spatial distribution

of fossils. Macroscopic fossils are restricted to the upper part of the Doushantuo Formation and consist of distinct assemblages with distinct modes of preservation. These observations may reflect 1) spatial variations in abundance of certain species on the Yangtze Platform or 2) taphonomic bias introduced by preservation pathways. Our study of redox indicators, including degree of pyritisation and concentrations of molybdenum, indicate that anoxic, sulfidic conditions prevailed at the time of upper shale deposition in the Yangtze Gorges area. Studies from time equivalent strata in other parts of the palaeoplatform (e.g. Weng'an date) indicate oxic conditions. This implies lateral gradients in oxygen concentrations across the platform. Our data does not support interpretations of in-situ preservation of aerobic algae in the Miaohe section, but suggest transport of species to a stagnant euxinic basin before preservation. A strong relationship between mineral surface area and total organic carbon content of the upper shales supports previous research highlighting the role of clay minerals in the preservation of non-mineralised carbonaceous fossils.

Keywords: Doushantuo Formation, redox, Miaohe biota, clay-organic interactions.

T2-4

NEOPROTEROZOIC SEQUENCES IN CENTRAL BRAZIL

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In Central Brazil, sedimentary sequences related to Cryogenian and Ediacaran intervals have been recognized on the Amazon and São Francisco cratons, and along the Paraguay and Brasília fold belts, which border them. In the Paraguay Belt (Alvarenga et al.2000) on the southern border of the Amazon Craton, the Neoproterozoic carbonate sequence of the Araras Group is overlying the Puga Formation, which represents a glacial diamictite related to Marinoan glacial event (~635 Ma). Carbon and strontium isotopic data of the Araras Group can be correlated to others Marinoan cap carbonates (Alvarenga et al.2004). In the south of Paraguay Belt, the Tamengo Formation at the top of the Corumbá Group, which is equivalent to the Araras Group, shows fossils as *Corumbella werneri*, *Cloudina lucianoi* and *Eoholynia corumbensis* sp., which suggest an Ediacaran age for this formation. A second diamictite level, 50 m thick, has been found, overlying the carbonates of the Araras Group. This diamictite is associated with shales and limestones of the Serra Azul Formation and has been correlated to the Gaskiers glaciation (~ 580 Ma). All these data suggest an Ediacaran interval for the sedimentation of the Araras and Corumbá groups. Below the Palaeozoic sediments of the Parecis Basin, two distinct carbonate units have been observed in deep holes and are interpreted as cap dolomites related to Marinoan and Gaskiers glaciations respectively. The Brasília Fold Belt on the western border of the São Francisco Craton (Dardenne, 2000) shows Neoproterozoic sedimentary sequences related to the Bambuí and Vazante/Paranoá groups, which seem older than those found in the Paraguay Fold Belt in function of isotopic data, absence of fossils and stromatolite assemblages. In the Bambuí Group, the cap dolomites at the base of the Sete Lagoas Formation, which overlays the Jequitaí glacial diamictite, have been dated by Pb/Pb isochron on carbonates at ca 740 Ma. These data, associated with results of C, O and Sr isotopes, indicate a probable Sturtian age for the Jequitaí

glaciation and a Cryogenian interval for the Bambuí sedimentation. The Vazante and Paranoá groups, which underlay the Bambuí Group and the Jequitaí Formation, consist essentially of quartzites, siltites, shales and stromatolitic dolostones, overlying the Rio Bonito glacial diamictite of unknown age: Kaigas or older? The presence of Conophytonides, as *Conophyton cylindricus* Malov and *Conophyton metula* Kirichenko, allows us to distinguish the carbonate sequences of the Vazante and Paranoá groups from those of the Bambuí Group (Dardenne, 2000). The C, O and Sr isotopic data obtained from dolomitic rocks of these groups are fairly distinct from the data observed in the Bambuí Group and are more consistent with a Mesoproterozoic age.

Keywords: Amazon, São Francisco, Glaciations, Neoproterozoic.

References

Alvarenga, C.J.S., Moura, C.A.V.,Gorayeb, P.S.S., Abreu, F.A.M. 2000. Paraguay and Araguaia Belts. In: Cordani,U.G., Milani E.J., Thomas Filho, A., Campos, D.A., eds., Tectonic Evolution of South America, Rio de Janeiro, International Geological Congress, 31, p.183-193.

Alvarenga, C.J.S., Santos,R.V., Dantas, E.L.2004. C-O-Sr isotopic stratigraphy of cap carbonates overlying Marinoan-age glacial diamictites in the Paraguay Belt, Brazil. Precambrian Research 131:1-21.

Dardenne, M.A.2000. The Brasília Fold Belt In: Cordani,U.G., Milani E.J., Thomas Filho, A., Campos, D.A., eds., Tectonic Evolution of South America, Rio de Janeiro, International Geological Congress, 31, p.231-263.

T2-5

MORPHOLOGICAL DISPARITY OF EDIACARA FOSSILS

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Ediacara fossils have been known from late Neoproterozoic successions on almost all major continents. Previous work on Ediacara fossils largely focused on the morphological, ecological, and phylogenetic interpretation of individual taxa, but little attention has been paid to the overall morphological disparity of Ediacara assemblages. In this research, we use morphometric methods to characterise the morphological disparity of Ediacara assemblages through space and time. This quantitative method minimizes taxonomic subjectivity involved in taxic counting methods and focuses on basic body constructions of Ediacara fossils. We collected morphological data of nearly 200 Ediacara taxa from more than 10 assemblages that were described in 20 monographs. We coded 47 morphological characters ranging from overall body shape, symmetry, segmentation, and many other features believed to be biological rather than taphonomic. Our preliminary analysis of these data using dissimilarity analysis and multidimensional scaling method suggests that morphological disparity of the older Ediacara assemblages, including the Charnwood Forest Biota in England and the Newfoundland Biota in Canada, is comparable to younger Ediacara assemblages in Australia and Baltica. It also appears that there is significant overlapping between the realised morphospace of the older and younger Ediacara assemblages. These results, in combination with the increasing Ediacara biodiversity (as measured by the numbers of species and

genera) from the older to younger assemblages, indicate that Ediacara morphospace was nearly maximally occupied during early Ediacara history and later saturated with lower level taxa. This pattern is remarkably similar to morphological histories of many other eukaryotic groups, including acritarchs and several metazoan clades.

T2-6

EDIACARAN (VENDIAN) RADIATION OF MARINE BIOTA: PALAEOECOLOGICAL AND STRATIGRAPHIC IMPLICATIONS

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Over three decades of collecting abundant fossils from the Ediacaran (Vendian) shallow-water siliciclastic deposits in the White Sea region reveal the most complete record of the eukaryotic radiation prior the Cambrian Period. The fossil record includes soft-bodied invertebrates, bioturbations, megascopic tissue-grade algae, organic-walled microfossils, bacterial mats and mound-shape biosedimentary structures. Rich taphonomic spectra and comprehensive biodiversity open the possibility for palaeoecological reconstructions and wide stratigraphic correlations. Faunal elements known separately from the Ediacaran (Vendian) of the Urals, Arctic Siberia, Ukraine, Newfoundland, Great Britain, Namibia, South Australia, and other regions are discovered in the White Sea region along with some endemic invertebrates. Distribution pattern of the metazoan fossil shows: diversity increase at the species and higher taxonomic levels up the stratigraphic succession, step-wise mode of the biodiversity growth, variety of the species' time ranges, distinct faunal communities preserved in situ, change in the palaeofaunistic connections of the palaeobasin, increasing cephalization in the bilaterians, growing intensity of bioturbation, disappearance of the metazoan body and trace fossils in the brackish sedimentary facies. These facts indicate the major metazoan diversification in the marine habitats well before the Cambrian. This diversification concerned both the stem groups (such as Phylum Proarticulata) and the crown groups (such as diploblastic Phylum Trilobozoa, and triploblastic phyla Molluska and Arthropoda). Wide geographic occurrence of many taxa suggests an absence of significant palaeogeographic or palaeoclimatic factors of isolation in the Ediacaran (Vendian) ocean as well as an existence of effective modes of reproduction and distribution (most probably via planktonic larva). A uranium-led zircon age 555.3 Ma can be considered at present as the oldest calibration point for the triploblastic invertebrates (Bilateria) on the molecular phylogenetic tree of the metazoans. Biodiversity dynamics through the radiometrically dated part of the Vendian succession does not demonstrate any correlation with the carbon isotope excursions obtained in the carbonate basins. Locomotion and feeding trace fossil that are preserved jointly with the producers' body fossils (*Kimberella, Yorgia, Dickinsonia, Epibaion* etc.) prove that during the Ediacaran (Vendian) a vast group of the triploblastic invertebrates actively exploited the epibenthic food resources. Though the diet of the particular species remains uncertain, the selective grazing or predation can be supposed in some cases. Postulated grazing of the Vendian giant metazoans (such as *Yorgia* or *Dickinsonia*) over the bacterial mats cannot be proved and might not be the case because of the

same ecological reasons as for the recent cyanobacterial mats. Vendian metazoan communities were trophically structured like the recent ones and included predators, herbivores, detritovores and tiered suspension feeders. Primary producers making the base of the food pyramid in the Ediacaran (Vendian) ocean are represented by cyanobacteria and diverse eukaryotic phytoplankton and macroscopic algae. Radiation of the photosynthesizing eukaryotes went in concert with the metazoan radiation during the Ediacaran (Vendian). Band-like, cord-like and plate-like thalii are dominating among algae. The highest complexity achieved in algae is documented for genus *Archyfasma*. Its thallus is composed of two types of tissue: the cortex with small parenchymatous cells and with large distinctive verrucose structures on the cortex surface, and the longitudinal-fibrous medulla. Such a complicated anatomical organisation resembles the recent advanced red and brown algae. There is no evidence of any feeding marks on the thalii of the macroscopic algae. Abundant phytoplankton, algae and the metazoan fossils provide a solid basis for the biostratigraphy of the Ediacaran (Vendian) as well as for the paleobiogeographic reconstructions.

Keywords: algae, bioturbations, metazoans, Neoproterozoic
This study is supported by the Russian Fund for Basic Research and RAS Program 18.

T2-7

FOSSIL ASSOCIATIONS OF THE EDIACARA BIOTA: PALAEOENVIRONMENTAL AND BIOSTRATIGRAPHIC INTERPRETATIONS

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Megafossils of the Ediacara biota group into four clusters: the Avalon Association comprising assemblages of the Avalon zone of eastern Newfoundland and Leicester in England; the White Sea Association of assemblages from the East European platform, Siberia, NW Canada and South Australia; the Nama Association of Namibia, western USA and SW Canada; and the Yangtze Association of South China. These associations have been variously interpreted as reflecting palaeobiogeography, a biostratigraphic succession, preservational styles, and palaeoenvironmental differences. Uranium-lead dates on zircons from volcanic ash beds, in Newfoundland, Northern Russia, South China and Namibia suggest a temporal sequence for these associations. Grouping of Russian and Australian assemblages (the White Sea Association) in a single palaeobiogeographic province is difficult to reconcile with the palaeogeographical separation of Russian and Australian assemblages in most Ediacaran continental reconstructions. Preservational styles must, in part, be related to palaeoenvironmental settings. The recent discovery of core taxa from the Avalon, Yangtze and Nama associations, in the Ediacara Member of the Rawnsley Quartzite in South

Australia, gives some support to the argument that these associations may be palaeoenvironmental rather than biostratigraphic. An array of forms, not previously observed in shallower marine benthic assemblages of the Ediacara biota in South Australia, occur within delta-front channel sand deposits. Preservation of certain taxa in situ, and also in transported assemblages, has resulted in taphonomic variants that should not be given taxonomic status unless palaeoenvironmental setting is first considered. Furthermore, the recognition of carbonaceous megafossils in the Miaohe biota in South China, that resemble sandstone moulds and casts of tubular, blade-like, and disc-shaped taxa in the Ediacara biota, demonstrates that cosmopolitan taxa may appear in different palaeoenvironmental settings with a different taphonomic history. There are still some general biostratigraphic trends in the mid to late Ediacaran. Rangeomorphs, frondose Ediacara taxa that share fractal construction, are characteristic of the middle Ediacaran (575 to ~560 Ma), but were gradually replaced by the simpler, serially constructed Pteridiniomorphs in the late Ediacaran (~560 to 542 Ma). The transition form the Avalon Association (575 to ~560 Ma) is best defined by the appearance of trace fossils and bilaterian body fossils that characterise the White Sea and Nama associations (~560 to 542 Ma).
Keywords: Ediacara, Ediacaran, biostratigraphy, taphonomy.

T2-8

IS THE BASAL EDIACARAN CAP DOLOSTONE DIACHRONOUS?

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The base of the cap dolostone (CD) atop Marinoan glacial deposits at Enorama Creek in South Australia defines the beginning of the Ediacaran Period. There is broad consensus that the CD records post-glacial flooding of continental platforms, shelves and inland seas by waters that were highly oversaturated with respect to carbonate. Climate models suggest that the time-scale for ice-sheet meltdown and consequent sea-level rise was in the order of 2,000 years, but multiple reversals of palaeomagnetic polarity recorded in CDs in different areas suggests a time-scale >100 times longer assuming a reversal frequency comparable to the Phanerozoic.

We studied across-strike variability in litho- and chemostratigraphy of the younger (635 Ma) CD in the Otavi Group of Namibia, which is exposed for 150 km shoreward and 15 km seaward of a well-defined platform-slope break. We estimate the palaeodepths of slope sections (with respect to the top of the platform) by comparison with the characteristic profile of the prograded western slope of the modern Great Bahama Bank. Distinct platform and slope lithofacies are observed at all stratigraphic levels except for the CD, where wave-generated structures (e.g., low-angle cross-lamination and giant wave ripples) extend to palaeodepths of ~600 m below the top of the platform. The structures could only have formed in water depths much less than 600 m, implying that sea level stood well below the top of the platform while the CD was deposited on the slope. The CD on the slope must therefore be older than its correlative on the platform.

We tested the inferred diachroneity of the CD by comparing high-resolution carbon isotope profiles at various distances shoreward and seaward of the platform-slope break. The CD ranges in thickness from ~75 m at the seaward edge of the platform to ~15 m in the most shoreward sections. Irrespective of thickness, all platformal sections share the same range in $\delta^{13}C$, evolving smoothly with minimal scatter from -3.0‰ (VPDB) at the base to -4.5‰ at the top. The consistency between multiple sections suggests that the isotopic changes are primary and do not result from diagenetic alteration during dolomitization. On the slope, the CD tapers in thickness from ~70 m near the top to ~4 m in the most distal sections. Like platform sections, slope sections become more depleted in ^{13}C with time, but they are more enriched overall to varying degrees. The most enriched section, also one of the thinnest, varies smoothly with little scatter from -0.2‰ at the base to -2.4‰ at the top. Given the negative slope of virtually all sections, the overall enrichment of slope sections relative to the platform, and of distal compared with proximal sections on the slope, supports the diachronous interpretation.

A secular change in $\delta^{13}C$ of -4.3‰ is not easily explained on a time-scale of ~2,000 years, which is ~100X less than the residence time of carbon in the ocean. Large increases in temperature (0-30ºC) and salinity are required, potentially combined with kinetic isotope effects associated with rapid carbonate precipitation. Alternatively, conventional interpretation of the palaeomagnetic reversals gives a time scale that could accommodate significant secular change in surface seawater $\delta^{13}C$. However, the existence of CDs in areas of terrigenous sedimentation is difficult to reconcile with a depositional time scale of 10^5-10^6 years. Their distinctive sedimentary structures are more consistent with a deposition rate of 1.0 cm/yr than 0.01 cm/yr. Strong positive feedbacks involved in the meltdown of large ice sheets at low latitudes ensure rapid deglaciation. Therefore, if CDs represent transgressions of 10^5-10^6-years duration, they cannot be glacioeustatic in origin. The anomalous thickness of many cap-carbonate sequences would not be attributable to subsidence during the glacial period. We speculate that the magnetic reversal frequency at 635 Ma was higher than the Phanerozoic average, possibly due to a small or absent inner core. Irrespective of the time-scale, the regional-scale diachroneity implied by our study has implications for observed inter-regional variability in the basal Ediacaran CD.

T2-9

NEW FIND OF CAMBRIAN TYPE ARTHROPODA FROM THE EDIACARAN OF THE WHITE SEA, RUSSIA

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New imprints of soft bodied organisms resembling arthropods of the order Nectaspidida were discovered on the White Sea fossil locality in 2005. They belong to Zimnii Gori formation of the Upper Vendian Epoch of the Ediacaran. The same bedding planes contain some characteristic Ediacaran (Vendian) species: *Tribrachidium heraldicum, Dickinsonia costata, Kimberella*

quadrata, Parvancorina minchami and others. These strata have been dated as 553.3 +/- 0.3 Ma (Martin et al., 2000). New organisms are preserved as typical Ediacara fossils, namely, as negative imprints on the sole of fine-grained sandstone layer. The oval imprints are external mould of exoskeletons divided into short head and long tail parts with axial ridge. The suture between the parts looks like a clear furrow; the lateral border is even. Two long simple antennas of the biggest specimen lie under and ahead the exoskeleton. Pleuras of the tail part are crosshatched which could be interpreted as segmentation or appendages lying under the collapsed exoskeleton. The new organism might be compared with Naraoiidae, namely *Misszhouia longicaudata* Zhang et Hou, 1985 from the Lower Cambrian of Chengjiang, but is not well preserved. Nectaspidida with non-mineralized exoskeleton were described from the Lower Palaeozoic up Cambrian to Silurian. Most of them are known from Cambrian (Burgess Shale (Walcott, 1912), Chengjiang (Hou, Bergstrom, 1997) and others). If the interpretation is correct the new organism might be the first Precambrian representative of very common Palaeozoic Arthropoda genera.

Keywords: Vend-Ediacaran biota, Arthropoda, Naraoiidae.

References

Hou X. & Bergstrom J., 1997. Arthropods of the Lower Cambrian Chengjiang fauna southwest China. Fossils and Strata, No. 45, pp. 1-116. Oslo.

Martin, M.W., Grazhdankin D.V., Bowring S.A., Evans D.A.D., Fedonkin, M.A., Kirshvink, J.L., 2000. Age of Neoproterozoic bilaterian body and trace fossils, White Sea, Russia: Implications for metazoan evolution. Science, 288 (5467), 841 - 845.

Walcott C.D., 1912. Middle Cambrian Branchiopoda, Malacostraca, Trilobita, and Merostomata. Smiths. Miscell. Coll., V. 57, No. 6, pp. 145-228.

T2-10

BIOLOGICAL RESPONSE TO THE DEPOSITIONAL ENVIRONMENTS CHANGE DURING THE NEOPROTEROZOIC JIULIQIAO STAGE

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The Neoproterozoic Jiuliqiao Formation, consisted of sandy, silty and dolomitic limestone, deposited mainly in shallow ramp environment in Huainan region, Anhui Province. According to event deposits, outcrop sequence stratigraphy, paleontology, stromatolite reefs, three parts of the Formation could be subdivided. The lower sandy and silty limestone is 13—18m thick; molar-tooth carbonate veins and slump structure in this part indicated the violent earthquakes events had happened during the early depositing period; few organisms were found in this part. The mid stromatolite limestone part is 19—62m thick; eight stromatolite reefs cycles and five storm deposition cycles in this part indicated that secular ocean storms events and reef-building activity during this period, besides the stromatolite-made cyanobacteria, some acritarchs and macroscopic algae were found in this part. The upper sandy limestone part is 7—10m thick; abundant macroscopic algae, acritarchs and the enigmatic macroscopic worm-like organisms in

this part indicated the flourishing period of organisms. The acritarchs, which were obtained from the mid and upper part of Jiuliqiao Formation, comprised seventeen form genus, fifteen species and thirteen species indeterminate of Acanthomorphitae, Herkomorphitae, Pteromorphitae, Nematomorphitae, Sphaeromorphitae and many multicellular algal fragments. Compare with the acritarchs from the lower Liulaobei Formation in this area, many multicellular algal fragments and some new species (e.g. *Bailikania diligena* and ?*Lomentunella vaginata*) were found in Jiuliqiao Formation, and almost all acritarchs from the Jiuliqiao Formation had bigger size. Such characters maybe indicated that a new developing stage of the microplankton had come forth during the Jiuliqiao Stage. Almost all Macroscopic fossils in the Jiuliqiao Formation were preserved in the upper silty limestone, though they had been researched for more than two decades, by now, the organic attribute of the worm-like fossils have not been settled. The stromatolites *Baicalia, Inzeria, Minjaria* of the Jiuliqiao Formation had built up different reefs: small scale lenticular and mounded in the lower part, large scale mounds in the mid part, and small scale lenticular in the upper part. Eight reef-building cycles were divided, which indicated the stromatolite-made cyanobacteria's adapting process to different depositional environments. Three stromatolite reef types were divided as the storm environment reef, the transgression reef and the regression reef according to the characters of different reefs and their relationship with the depositional environments. Storm events had baffled the reef-building process at first but accelerated the process later, the transgression accelerated the reef-building process, while the abrupt deepening of the water could terminate the reef-building process, and the regression process had negative influence on the reef-building process. The distribution of macroscopic fossils, acritarchs and stromatolite reefs in the Jiuliqiao Formation indicated that, a complicated biocommunity had been formed during this period. The struggles for existence between different organisms became obvious, and might have resulted in the interbedded outcropping characters of the macroscopic fossils and acritarchs. Different events, during the Jiuliqiao Stage had different influences on organisms. The violent earthquakes made few organisms survive during the early period; The developing process from puissant to recessionary of the storm events could be correlated with such process: the stromatolite reefs becoming bigger, the micro and macro fossil become manifolding. the phenomena indicate that frequent storm events had negative influence on the organisms in Huainan region, while the stromatolite-made cyanobacteria had better adaptability than others during the Jiuliqiao Time.

Keywords: organisms event deposits, depositional environment, Neoproterozoic.

T2-11

MICROBIAL MATS FROM NEOPROTEROZOIC SILICICLASTIC FACIES OF NORTHEAST CHINA

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Microbial mats are complex ecosystems and that have flourished in the marine biosphere. They have been actively involved in shaping the environment of our planet since they made their debut

well back in the Early Archean. Microbial mats are known to be more commonly recorded in rocks of early geological time than the subsequent geological periods because of the relatively later advent of the bioturbation by metazoans. The fossilised microbial structures are crucial for our understanding of the evolution of the early biosphere. Mats are widely thought to form the accreting surface of most stromatolites and other large-scale benthic microbial carbonates in the Precambrian. However, in contrast, very limited information has been available for microbial activities in coeval marine siliciclastic-dominated facies. The fossilised microbial mats described here are recovered from thin-bedded sandstones at the base of Nanguanling Formation, South Liaoning, northeast China. In association with the mats are numerous *Aspidella*-like structures. But its age is constrained to Cryogenian on the basis of the isotopic data of 87Sr/86Sr and the global correlation of molar-tooth carbonates by the IGCP 447working group. These sedimentary structures may be closely related with microbial mats. There are many pits (ranging from about 1 mm to 50 mm in diameter) on the top surface. Very large pits (larger than 40 mm across) are quite rare. A few pits have sculptures shaped as concentric circles, strikingly similar to the outline of the Ediacaran *Aspidella*. Moreover, there are "Domal Structures" and little wrinkle structures in some samples. The wrinkle structures are accreted with the pits in some specimens. The wrinkles neither go through nor go across the pits, exclusively surrounding the pits. It seems that the intercrest distance and the surface pattern of the wrinkles are, to some extent, influenced by the pits. The surface pattern is polygonal-like surrounding the pits. The intercrest distance is about 5mm or above and the crest height is less than 0.5 mm. The crest shape is pointed at the top. The morphological characteristics of the surface structures suggest that they may be closely related with microbial mats. SEM and thin section studies have been planed to further confirm the microbial involvement in building these surface structures.

T2-12

TERMINAL PROTEROZOIC (EDIACARAN) LYAMTSA ALGOFLORA, WHITE SEA, RUSSIA

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Proterozoic carbonaceous macrofossils in the Terminal Proterozoic (Ediacaran) are known worldwide. The nature of the carbonaceous macrofossils is a subject of discussion, and some forms are presumably referred to different groups of modern algae (Xiao et al., 1998, Gnilovskaya, 2003). The morphology of their thalli and the level of their complexity is a base for formal classification of these fossils (Gnilovskaya et al., 1988, Hofmann, 1994). Many forms of carbonaceous macrofossils were described from the Terminal Proterozoic Vendian complex of the Russian Platform. Three consecutive complexes of such compressions (vendotaenids) were established. First, a lowermost complex named Eoholynian flora. It is characteristic of the upper part of the Redkino Regional Stage deposits and includes Chuareacean, Moraniacean, and Eoholyniacean algae (Gnilovskaya et al., 1988). Vendotaenids from the White Sea area were represented by some unique examples (Ragozina, 2001; Gnilovskaya, 2003, Leonov, 2003). Detailed field work at the Lyamtsa locality (Onega Peninsula, White Sea, Arkhangelsk Province,

Russia) has produced a collection of vendotaenids from the lowermost part of Ust'Pinega formation – Lyamtsa and Arkhangelsk beds. The age of this flora is insufficiently older than the published earlier age of the upper part of Ust'Pinega Formation - 555.3 Ma (Martin et al., 2000). The fossil complex includes seven taxa: planktonic Chuareacean forms - *Beltanelloides sorichevae*, benthic crust-like algae of family Moraniaceae - *Favosiphycus wuki*, bush-shaped talli - *Eoholynia* cf. *mosquensis*, *Eoholinia fruticulosa*, fragments of relatively big ribbon-shaped algae with parenchymatous thalli - *Archyfasma dimera, A. lamellata, Gandvikia caudata*. The complex is characterised by the presence of relatively big and mechanically resistant multilayered thalli of Archaefasmalean algae that resemble recent brown algae. Some forms were known from the uppermost deposits like *Beltanelloides* and *Eoholynia*. Anatomical details of some Lyamtsa forms are very close to organic films from the Lower Redkino Mogilev Formation of Podolia (Ukraine) (Asseeva, 1988). The specific Lower Redkino algoflora was established. It is stratigrafically contemporaneous with the Doushantuo Flora (according to Knoll and Xiao (1999) data), and antedates the Upper Redkino Eoholynian algoflora (Gnilovskaya et al., 1988).

Keywords: Vendotaenids, algae, Terminal

A research was supported by a Russian Fund for Basic Research (RFBR N 05-05-64825) and a Grant of the President (NSH – 2899.2006.5).

References

Gnilovskaya M. B. (ed.), Istchenko A. A. et al., 1988. Vendotaenids from Eastern European platform, Leningrad. 143 p. [in Russian] Gnilovskaya M.B., 2003. Paleontological Journal. N 2. p. 98 – 104. [in Russian]

Hofmann H., 1994. Early Life on Earth. Nobel Symposium № 84. Columbia University Press, New York, p. 342-357. Knoll A.H., Xiao S., 1999. Acta Paleontologica Sinica, N 16. p. 225-236.

Leonov M. V., 2003. Bacterial Paleontology. Proceedings of SPIE. vol.4939. p. 47-52.

Martin, M.W., Grazhdankin, D.V., Bowring, S.A., Evans, D.A.D., Fedonkin, M.A., and Kirschvink, J. L., 2000. Science. vol. 288. p. 841-845. Xiao Sh., Knoll A., Yuan X., 1998. J. Paleont. 72(6). p. 1072-1086.

T2-13

A LATE NEOPROTEROZOIC GLACIATION IN THE CADOMIAN BASEMENT OF CENTRAL AND WESTERN EUROPE (BOHEMIAN AND ARMORICAN MASSIFS): CONSTRAINTS BY LASER ABLATION-ICP-MS U/PB DATING OF DETRITAL ZIRCON GRAINS AND BASIN DEVELOPMENT

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The Precambrian basement of Central and Western Europe consists mainly of Late Neoproterozic volcanoclastic sediments deposited in marginal basins in an active margin setting of the Avalonian-Cadomian Orogenic Belt at the Gondwanan margin. In places glaciomarine tillites in combination with passive margin sequences occur in the sedimentary succession. Neoproterozoic to Early Palaeozoic marginal basins, island arc remnants, and postkinematic plutons are referred to as the Cadomian basement of the Avalonian-Cadomian Orogen. Remnants of the Cadomian basement are involved in the peri-Gondwanan microplates of Avalonia and Cadomia. The Cadomian basement is cropping out in the Bohemian and Armorican Massifs in places in spectacular sections. Most Precambrian rocks in these massifs are metamorphosed and deformed by the Variscan Orogeny. Less affected Neoproterozoic rock units of the Bohemian Massif are cropping out in the Saxo-Thuringian Zone and in the Tepla-Barrandian Unit and occupy around 25 % of the pre-Permian surface of the massif. In the Armorican Massif Neoproterozoic rocks, characterised by a weak Variscan metamorphic overprint, are concentrated in the tectonostratigraphic terranes north of the North Armorican Shear Zone. We have used U/Pb LA-ICPMS data of detrital zircon grains from different Neoproterozoic (Ediacaran) sandstones of the Saxo-Thuringian Zone and the northern Armorican Massif to characterise the provenance of the detrital material and the maximum ages of deposition. In general the maximum sedimentation age of the units is 570-580 Ma, thus contemporaneous to the activity of the Cadomian active margin. Neoproterozoic sediments including glaciomarine tillites are deposited after c. 570-580 Ma, as inferred from the youngest detrital zircon grains. A minimum age of sedimentation is given by igneous complexes intruding the sediments at around 540 Ma. Thus a glacial event in the Cadomian Orogenic Belt can be bracketed between 540-580 Ma. Currently, there is much debate about the palaeogeography of the Avalonian-Cadomian Orogen. Potential source areas are Amazonia, the West African Craton and the Sub-Sahara Metacraton. Parts of these cratons became recycled during the Cadomian orogeny at the Gondwana margin. The three cratons differ in their mean age and the presence or absence of certain zircon age populations. The zircon age pattern of the Precambrian rocks of the Saxo-Thuringian Zone and the Armorican Massif suggests a provenance from the West African Craton. The possibilities of a linkage to the Snowball Earth, palaeogeographic constraints and the implications for the spatial distribution of the Ediacaran organisms will be presented.

Keywords: Neoproterozoic, Ediacaran, glaciation, geochronology

T2-14

QUESTIONABLE NEOPROTEROZOIC ANIMALS

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Ediacaran sediments were commonly bound in microbial mats. These mats create unusual conditions (laminated sediments that easily part horizontally but are very resistant to vertical penetration due to the cohesiveness of the microbes). These conditions enhance the construction

by inorganic processes of pseudofossils resembling certain kinds of biological signatures — circles, spheres or domes, thick trails either single or in radiating groups, radiating arrays of thin, broken linear features, and various scratch marks. Other presumed animals are more likely to be fossils of other organisms that lived passively on the firm mat surfaces. The fossils can be sorted into several general categories: circular impressions, fronds, body fossils, trace fossils, and unknowns. In each category, some of the fossils are best interpreted as pseudofossils, as they represent either inorganic processes that produce structures resembling animals, or they are organisms best placed in non-animal groups. Discoid impressions, made by another object touching the substrate as it swings through arcs, forming the well-known scratch circles, are common in Neoproterozoic deposits. A second category of pseudofossils are those circular fossils that resemble medusoids; they have a small circular central area surrounded by a few to many thick tentacle-like impressions extending away from the central area. These fossils include *Hiemalora, Eoporpita*, and similar forms. They are likely formed by the escape of water or gas from layers below or within a stratified microbial mat. The structures form as the fluid reaches an impenetrable layer where it first makes a convexity and then channels out from that. Thus, they resemble thick tentacled medusoids in general aspect. Other fluid escape structures resemble closely certain trace fossils while other structures formed by trapped gas or water are domes. Fluid exhaust structures may include radiating lines engraved in the sediments by particles being blasted along bedding planes in the subsurface mat lamina as the fluid explosively expands from a central source. Among those fossils that may represent other non-animal fossils are *Nemiana* and *Beltanoides*. These circular fossils show concentric folds near their peripheries in all well-preserved cases. Such folds can be made by the compression of spherical objects. The living green alga *Ventricaria* makes spherical reproductive structures of the approximate size as these fossils; when compressed they form circular impressions with marginal folds. A careful reanalysis of curvilinear, radiating, and engraved linear impressions, and circular or domal structures, and possibly some other unusual specimens is required in order to properly interpret the diversity, structure and function of these Neoproterozoic biotas.

T2-15

THE POSSIBLE HUGE CYANOBACTERIA FOSSILS FROM EDIACARIAN DOUSHANTUO FORMATION AT WENG'AN, GUIZHOU, SOUTHWEST CHINA

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The phosphatised microtubular fossils are one of the important fossils in Weng'an biota of the Ediacarian (Sinian) Doushantuo Formation. Based on the branching mode, the inner of the tube with cross-walls (curved and sometimes incomplete), and chamber, Xiao et al. (2000) considered that these fossils are basal or stem-group cnidarian, similar to extinct tabulates and different from algal and other metazoan. The authors also reported some cnidarian microtubular fossils with multi-branches in 2006.

Recently, a few of tubular fossils are found from the samples in the Ediacarian (Sinian) Doushantuo Formation, they are columned, slightly curved, and 100～250μm in diameter. The outline of the fossils is similar with the cnidarian microtubular fossils, whereas the structures of them are different. In contrast, except the diameter of the fossils is bigger, the fossils show an imaginable affinity with filaceous cyanobacteria. The multilayered gelatinous sheaths, cell divisions and hormogon can be seen in the thin sections (Fig. 1). Some micro-folds and other flexibility distortion developed in multilayered gelatinous sheaths, which indicate that the sheaths are originally formed. In addition, most specimens only preserved the multilayered gelatinous sheaths because the trichomes have a lower decay-resistance than sheaths.

The possible discovery of a huge filaceous cyanobacteria shows that the tubular fossils in the Weng'an biota have multiple origins, which is very important for realising the real affinities of Weng'an biota.

Keywords: Ediacarian(Sinian), Doushantuo Formation, tubular fossils, cyanobacteria

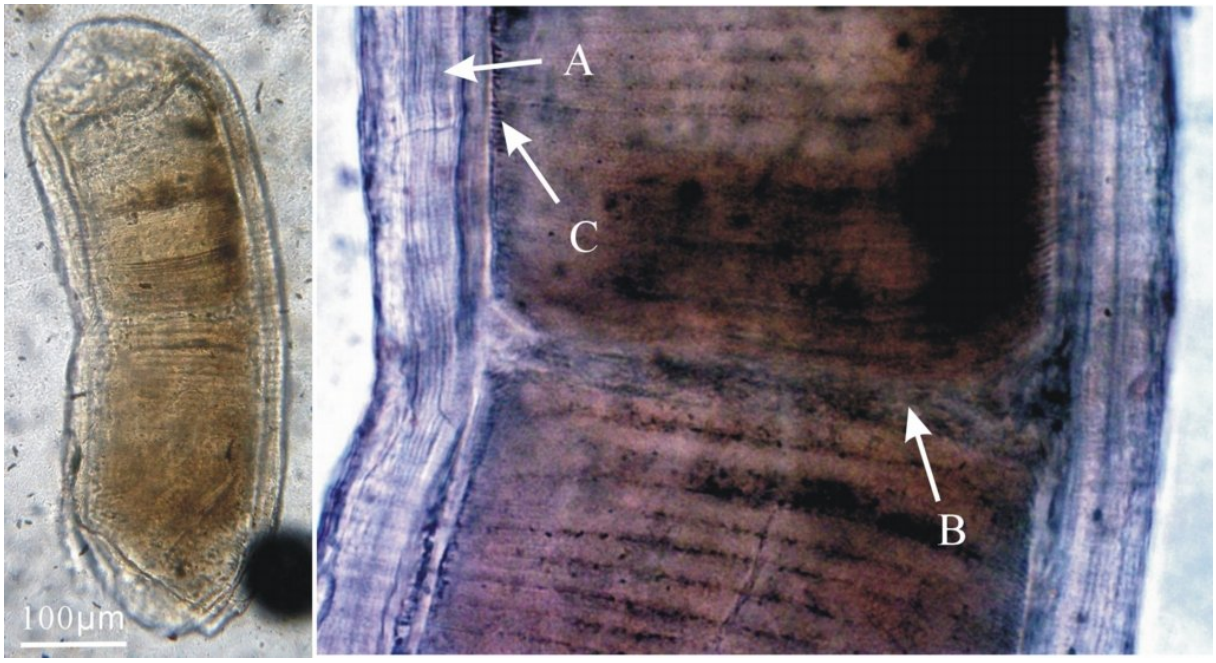

Fig. 1 the possible huge cyanobacteria

A. the multilayered gelatinous sheaths, B. the hormogon, C. the cell division

T2-16

A THICK EDIACARAN CARBONATE SUCCESSION IN ARCTIC ALASKA

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The Katakturuk Dolomite is a 2.1 km-thick succession of Neoproterozoic shallow-water carbonates

exposed along north-vergent Palaeogene thrust sheets in the NE Brooks Range of Arctic Alaska. Age of deposition is constrained above by the Cambrian Nanook Limestone and below by 936±3 Ma detrital zircons from the Neruokpuk Formation (McClelland 1997). Pre-Cretaceous reconstructions place Arctic Alaska offshore of Banks Island (Toro et al. 2004); however, there are no pre-Mesozoic palaeomagnetic constraints.

Lithofacies diagnostic of a basal Ediacaran cap carbonate (Allen & Hoffman 2004; Halverson et al. 2005) (herein referred to as the Nularuik cap) occur ~500 m from the base of the Katakturuk. Although no glacial diamictites have been identified, the Nularuik cap contains finely-laminated, reverse-graded peloids, tubestone stromatolite bioherms, giant wave ripples, and decametres of pseudomorphosed aragonite crystal fans precipitated as sea-floor cement. These structures and their stratigraphic order suggest an Ediacaran age for the upper ~1550 m (members K2 and K3) of the Katakturuk Dolomite.

Carbon isotope profiles of the Nularuik cap dolostone have a positive slope with a nadir at -2‰ and high variability within each section. Normalised to the thickness of the cap dolostone (and excluding isotopic values of cements), this pattern is similar to the basal Doushantuo cap carbonate in South China (Jiang et al. 2003), which has been dated at 635.2±0.6 Ma (Condon et al. 2005). In northern Namibia, where underlying glacial deposits have been dated at 635±0.5 Ma (Hoffmann et al. 2004), shelf sections are 3-4‰ lighter than foreslope sections (deposited earlier in the transgressive sequence); yet, both display a smooth, negative slope. Moreover, carbon isotopic values at the dolostone-limestone transition are ~4-7‰ lighter in Namibia than in Alaska and China (Halverson et al. 2005). Assuming the carbon residence time is much greater than the mixing time of the ocean, these large inter- and intra-basinal isotopic differences in basal Ediacaran cap carbonates are very difficult to understand. An explanation may require modelling that incorporates isotopic fractionations (particularly temperature dependent (Li et al. 1995)), kinetic effects, salinity, a strong biological pump, and the preservation of an isotopic gradient through extremely fast sedimentation rates and diachronous deposition during the post-glacial transgression.

Higher in the Katakturuk (at the base of K3) is another negative carbon isotope excursion associated with relatively small-scale crystal fans and a karstic surface. This interval is potentially correlative with the Rainstorm Member of the Johnnie Formation in the southwestern US, and in turn other intra-Ediacaran negative carbon isotope excursions in Australia, Oman, and South China (see Halverson et al. 2005 and Condon et al. 2005 for different possible Ediacaran composite carbon isotope curves). The upper ~1km of the Katakturuk (K3) appears to represent a period of relative carbon isotope stability culminating with the Precambrian-Cambrian boundary negative excursion.

In overall lithologic and isotopic character, the Katakturuk Dolomite is most similar to the Ediacaran succession of the South China platform (Doushantuo and Denying Fms.). It has been proposed that South China had a Neoproterozoic palaeogeographic position adjacent to NW Laurentia (Li et al. 1995). Further isotopic, stratigraphic, and palaeomagnetic studies may help test this model.

References

Allen P. & Hoffman P., 2005. *Nature* **433**, 123-127.

Condon D., Zhu M., Bowring S., Wang W., Yang A., & Jin, Y., 2005. *Science* **308**, 95-98.
Halverson G., Hoffman P., Schrag D., Maloof A. & Rice A., 2005. *GSA Bulletin* **117,** 1181-1207.
Higgins J. & Schrag D., 2003. *Geophysics, Geochemistry, Geosystems* **4**.
Hoffmann K., Condon D., Bowring S. & Crowley J., 2004. *Geology* **32**, 817-820.
Jiang G., Kennedy M. & Christie-Blick N., 2003. *Nature* **426**, 822-826.
Li Z., Zhang L. & Powell C., 1995. *Geology* **23**, 407-410.
McClelland W., 1997. *GSA, Cordilleran Section, Abstracts with Programs* **29**, 28.
Toro J., Toro F., Bird K. & Harrison C., 2004. *GSA* **36** (5), 22.

T2-17

HIGH RESOLUTION LITHOSTRATIGRAPHY AND FACIES ANALYSIS OF THE EDIACARAN DOUSHANTUO FORMATION, SOUTH CHINA: IMPLICATIONS FOR PALEOCLIMATE, SEA LEVEL CHANGE, AND BIOLOGICAL EVOLUTION

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The Ediacaran Period is characterized by prominent stable isotopic excursions and multiple biological events including the proliferation of acanthomorphic acritarchs, Ediacara biota, and eumetazoans. Although the detailed relationship between the sedimentological, geochemical, and fossil record remains highly debated, it has been proposed that termination of the Cryogenian glaciations and the Ediacaran Acraman impact event may have played significant roles. A high-resolution litho-, bio-, and chemostratigraphic study is key to test these competing hypotheses. The 635-551 Ma Doushantuo Formation in South China represents one of the most complete and fossiliferous successions, and has the greatest potential to clarify the temporal relationship of the biological and paleoceanographic events that may help derive a global picture of Neoproterozoic geobiological events. We report here high-resolution lithostratigraphic data from two sections in the Yangtze Gorges area, South China. These results are integrated with a preliminary bio- and chemostratigraphic framework from the same sections as well as from the Doushantuo Formation at Weng'an, South China. In the Yangtze Gorges area, the lower Doushantuo Formation consists of a 5-m-thick cap carbonate followed by ~90-m-thick cherty shale and dolomicrosparite beds. Lack of wave- or tidal-generated sedimentary structures and occurrence of abundant parallel laminations and casual graded bedding suggest deposition below fair-weather wave base, likely created by rapid transgression after termination of the Nantuo glaciation. The middle Doushantuo Formation consists of thinly bedded limestone and silty dolomite. Intraclastic packestone layers, low angle crossbedding, small-scale erosional bases, and microbial laminae suggest deposition from shallow subtidal environments. The uppermost Doushantuo Formation is characterized by ~9-m-thick black shales that produce strongly negative carbon isotope values. It has been suggested that the ~580 Ma Gaskiers glaciation in Avalonia may be coeval with the base of this shale unit, although no glacial deposit is preserved at this horizon. Although sharp lithofacies change is indeed present at the base of the upper shale, there is no

evidence for an erosional unconformity. Therefore, the Doushantuo Formation in the Yangtze Gorges area appears to represent a continuous and very condensed Ediacaran succession. It is enigmatic how the basin maintained extremely slow sedimentation rates (<3 μm/year) for 84 Myr. Regardless, the two shale units of the Doushantuo probably resulted from rapid drowning due to sea level rise related to deglaciation, reflecting second order sea level fluctuations indicative of intermediate greenhouse climate conditions and periods of enhanced anoxia, productivity, and chemical stratification. Although lithostratigraphic and facies data presented here aide in regional correlation of the Doushantuo Formation, the application of sequence stratigraphy remains problematic: no sequence boundaries can be confidently traced from the Yangtze Gorges area to Weng'an. Further, although carbon isotope chemostratigraphy can offer a first-order correlation scheme, internal heterogeneity and diagenetic influences pose a hindrance at high resolution. Future efforts need to focus on reliable geochronological dating as well as high resolution biostratigraphy, in order to further test the reliability of global chemostratigraphic correlation.

Keywords: Ediacaran, South China, Doushantuo Formation, Paleoenvironmental analysis

T2-18

CALIBRATING SEAWATER SR-ISOTOPE COMPOSITION DURING THE EDIACARAN:INSIGHT FROM CENTRAL SIBERIA

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In 1993, carbonate formations, deeply depleted in ^{13}C and not-related to glaciations have been reported from Australia (Pell et al., 1993), Oman (Burns and Matter, 1993) and Siberia (Pokrovsky and Gertsev, 1993). In all regions, these formations are 500-1100 m thick and exposed over distances of hundreds of kilometres. The assumption that these formations may represent a synchronous event, occurring between 600 and 540 Ma (Melezhik et al., 2005), has recently been corroborated by new geochronological (Condon et al., 2005; Zhang et al., 2005) and carbon-isotope data (Halverson et al., 2005). This event was termed the Wonoka Event after the formational name of ^{13}C-low carbonates in Australia. Although the precise duration of the event remains unknown, it has been arbitrarily proposed that it could have extended over c. 50 Ma (Le Guerroué et al., 2006a). Recent detailed sedimentological studies performed in many regions have demonstrated that ^{13}C-low carbonates were precipitated from seawater in an open marine environment. However, the existence of these carbonates and the nature of $\delta^{13}C$, ranging between -13 and -8‰, have remained unexplained since the early 1900s and represent a challenging problem (Melezhik et al., 2005; Le Guerroué et al., 2006b; Pokrovsky et al., 2006). While the nature of the inorganic carbon pool of the Wonoka Ocean remains enigmatic, data on the Sr-isotope composition of seawater are incomplete and controversial. Recent compilations suggest that in post-Marinoan time (635 Ma) $^{87}Sr/^{86}Sr$ ratios sharply increased from 0.7072 to 0.7087 with the latter being roughly coeval with the nadir in $\delta^{13}C$ values in the Wonoka Event (Halverson et al., 2006). Results obtained from Siberia show a different pattern.

In Siberia, the Zhuya Grope probably representing the Wonoka Event can be traced discontinuously within an area of c. 40,000 km^2, forming the world's largest exposures of sedimentary carbonates extremely depleted in ^{13}C ever reported in the literature. Four sections, each c. 1000 m thick, were measured along a 500 km-long, NW-SE-trending transect across Central Siberia. Main lithologies include (a) interbedded shale and limestone, (b) interbedded sandstone and limestone, (c) stromatolitic limestone, (d) oolitic grainstone, and (e) oncoid/interclastic grainstone. These rocks comprise five facies associations: (1) deep subtidal, (2) shallow subtidal, (3) calcareous sand shoal, (4) peritidal carbonate complex, and (5) peritidal siliciclastic-carbonate. These facies associations were deposited on a carbonate platform evolving from (i) carbonate-siliciclastic and (ii) carbonate ramps to (iii) a peritidal rimmed shelf and (iv) open shelf. Finally, the shelf rim and peritidal complexes were flooded and could not be re-established due to the increased siliciclastic input.

All measured sections exhibit facies-independent, upward, linear increases of $\delta^{13}C$ from -13 to -8‰. The carbonate ramp-facies carbonates have elevated contents of silica and aluminium and a high Sr concentration (up to 1%), whereas the reefal stromatolite and peritidal-rimmed shelf carbonates are pure though depleted in Sr content (300 ppm on average). The striking difference in the Sr concentration suggests contrasting styles/rates of diagenetic stabilisation of an aragonite precursor in different depositional settings. Strontium isotope ratios ranging between 0.70786 and 0.70874 and show a strong positive co-variation with Mn concentrations and a significant negative correlation with the Sr content, thus indicating a variable degree of post-depositional resetting. When all altered samples are excluded, the least altered show a linear stratigraphic increase from 0.70799 to 0.70825 within the 550 m-thick upper part of the sequence. The least altered ratios of the Zhuinskaya Group, combined with the published data for underlying ^{13}C-rich (+4 to +8‰) carbonates of the Dal'niaya Tayga Group (0.70727 - 0.70769, Vinogradov, et al., 1996; Pokrovsky et al., 2006), are far less radiogenic with respect to those published for supposedly correlative stratigraphic intervals. The obvious inconsistency calls for a revision of the strontium isotope reference curve for the Ediacaran.

Keywords: Ediacaran, Wonoka, strontium isotopes, carbon isotopes, carbonate platform

T2-19

EMERGING BIOTA OF THE CRYOGENIAN : EXAMPLES FROM INDIA

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Ninety percent of the history of the Earth is represented by the Precambrian time-span (4.570 Ga to 0.542 Ga) during which time there was a gradual increase in atmospheric oxygen, a necessary component in the biosphere's evolution. While evaluating the evolutionary tempo and trends in the biosphere, it is becoming convincingly clear that one of the giant leaps of evolution remains the emergence of the eukaryotes. Eukaryotes being a complex configuration of organic molecules, modified easily under changing physical and chemical conditions. Their process of mutation gave

them the advantage to generate new forms of life. Some of the key evolutionary phenomenons associated with eukaryotic biosphere are well documented in the Ediacaran Period. However, the preceding Cryogenian Period (850 to 630 Ma) conceals the physio-chemical global events which triggered a massive change in the eukaryotic biosphere. Notionally, a time span of about 220 Ma (equivalent to entire Palaeozoic) is a long duration for "Cryogenian" and therefore tracing biological events in such deep time has never been simple. Although a broad framework of early evolution is better understood today than it was about a decade ago, in the evolutionary scheme of things, records of various bio-events on a chronological scale makes them very relevant as it provides the much required time lines for tagging them with other physical, chemical and geological events associated with evolution of the earth as a whole. Lately, the blurred evolutionary scheme of the "Ediacaran" has been fine tuned with a well constrained geochronometric scheme; however, the "Cryogenian" biological events are presently vague with faint geochronometric constraints. Globally, some key biotic components such as Stromatolites (*Conophyton, Jacutophyton, Baicalia, Stratifera, Inzeria, Boxonia, Gymnosolen, Jurusania, Parmites, Minjaria, Acaciella, Tungussia*, thrombolites and calcimicrobes etc.), Acritarchs (*Kildinella, Trachysphaeridium, Nucellosphaeridium, Trachyhystrichosphaeridium* etc.), Carbonaceous mega-fossils (*Chuaria, Tawuia, Longfengshania, Morania, Beltina, Daltaenia, Tyrasotaenia* etc.) and earliest Ediacaran disks with a host of microbial components are known to be dotted throughout the "Cryogenian" time interval. A biostratigraphic scheme is yet to emerge on a chronometric scale. The 'Sturtian' and 'Marinoan' glacials with the possible inclusion of 'Kaigas' might have stressed the biosphere temporarily, but the de-glaciation events would have provided new niches for "evolutionary bursts" due to the availability of up-welled nutrients, turbulent marine circulation and better availability of large shallow marine realms. The tectonic movements would have also affected the rates of evolution. Unfortunately, present knowledge of these phenomenon are in a state of confusion and there is a need for it to be sorted out in order to generate an orderly picture in which global geological events could be put side by side with biotic events of emergence and diversification. In India, some key "Cryogenian" successions are located in the "Peninsular" part as well as in the "Himalayas". In peninsular India, the upper Vindhyan succession (the Kaimur, Rewa and Bhander Groups) is well known for its biota, specially the stromatolites, carbonaceous mega remains and microbial fossils, including acritarchs. The succession is developed in both terrigenous clastic and calcareous facies. Many of the aforementioned Neoproterozoic biotic elements are well documented from various horizons of the upper Vindhyan successions. Chronostratigraphically, the upper Vindhyans range broadly within a 850 to 650 Ma time interval. The other successions with promising "Cryogenian" biotic records are in the Chattisgarh and Bhima basins with exceptionally well developed Stromatolites and carbonaceous mega-fossils. *Sabellidites* and *Sinosabellidites* have been recorded from the Bhima basin. In the Himalyan region, samples from the Cryogenian Period are well documented in the Inner Sedimentary Belt of the Lesser Himalaya. A host of stromatolites, acritarchs and other microbial components are known from the shale-facies and silicified horizons of the Deoban and associated groups. Recently, a caché of carbonaceous fossils with abundant *Chuaria, Tawuia, Beltina* and many other forms have been discovered. Glaciogenic and cap carbonate horizon of possible Sturtian time span underlies the succession at several places. The above data from several basins of India suggests that the Indian successions contain a wealth of biotic data along with marker geological events in their "Cryogenian" successions which can be correlated with other

parts of the world. This would facilitate the gerenation of a well constrained evolutionary scheme for the biosphere's development during this crucial phase of the earth past when major eukaryotic systems evolved and diversified.

T2-20

TAPHONOMY OF DOUSHANTUO ANIMAL EMBRYOS AS DETERMINED BY CONFOCAL RAMAN IMAGING

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Exquisitely preserved animal embryos from Neoproterozoic Doushantuo phosphorites in Weng'an, Guizhou Province, South China contain folded micron-scale organic carbon membranes. Animal embryos examined in thin section using confocal Raman imaging exhibit heterogeneous organic carbon distribution, often associated with morphological features of diagenetic and biological origins. Disordered and graphitic carbon peaks in Raman spectra are complex and varied in a manner that is indicative of simple macromolecular material with a very mild thermal alteration history. The matrix contains comparatively little organic carbon and is composed of phosphorite, carbonate, silica and even clay minerals, which may have been deposited in or forced into the microfossils during diagenesis. Parallel membrane-like structures composed of phosphate and carbon approximately 1μm in thickness sometimes form invaginated layers at microfossil boundaries and, more rarely, occur at the edges of blastomeres within a single embryo. Other microfossils exhibit zoning of phosphate and carbonate at their outer boundaries, possibly due to chemical alteration after early diagenesis. These compositional features shed light on the taphonomic processes responsible for the unusual preservation of Doushantuo microfossils as well as new biological features with possible taxonomic implications.
Keywords: fertilization envelope, membranes, organic carbon, biogenicity

T2-21

DEVELOPMENT OF SEGMENTS IN VENDOBIONTS VERSUS METAZOANS

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Modular quilting is the key feature of large and foliate Ediacaran organisms (Vendobionta). Combined with axial polarity, it may result in body shapes reminiscent of metameric animals such as trilobites. Yet, the underlying developmental pathways are fundamentally different: 1) the proximal segment may differentiate into either a head-like structure (*Yorgia*; *Spriggina*; *Parvancorina*) or a discoidal holdfast (*Charniodiscus*), 2) the distal-most segment is not

determined by an anus, but always represents the latest module, a 3) there is no dorsoventral polarity - the two surfaces are identical, even in flat-prostrate and mobile forms (*Dickinsonia*; *Yorgia*), as they are in flat Foraminifera (*Frondicularia*), 4) axial polarity could be reversed in response to extrinsic events (*Pteridinium*), 5) a median septum may separate alternating quilts that fuse into two (*Phyllozoon* spindles), three (*Pteridinium*), or four (*Swartpuntia*) free vanes, and 6) Spindle-shaped forms lack not only dorsoventral, but also axial polarity. In order to understand this early evolutionary experiment, it is probably more adequate to compare vendobionts not with metazoans, but with coeval giant protozoans (Xenophyophoria), which also survive on modern deep-sea bottoms. Their chambers also contain a fecal fill skeleton (stercomare) and may show serial or alternating patterns; but their organic walls are agglutinated and unable to expand. The naked vendobiontan quilts, in contrast, expanded regularly without molting, which allowed some forms (Rangeomorpha) to switch from serial to fractal compartmentation during ontogeny. The challenge is to interpret these extinct organisms in terms of molecular genetics.

Keywords: Segmentation, Ediacaran, Development, Evolution

T2-22

NEW SPICULE-BEARING ORGANISM OF SPONGE GRADE FROM THE EDIACARAN (VENDIAN) OF THE WHITE SEA, RUSSIA

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The fossil locality on the Solza River is one of the rich in the region; the fossil concentration reaches here a few tens of specimens per the square meter. The fossiliferous deposits belong to Ust-Pinega Formation of the upper Ediacaran (Vendian. In addition to the new fossils and rare cyclic forms the same bedding planes contain some characteristic Ediacara species: *Dickinsonia costata*, *Kimberella quadrata*, *Tribrachidium heraldicum Armilifera parva*, *Cyanorus singularis*, *Vendia rachiata*, *Solza margarita* [4] .*Kimberella*- fusiform trace fossils that are the most abundant fossils cover all the surface of the bed. New organisms are preserved as negative imprints on the slightly pyritized sole of fine-grained cross-bedded sandstone layer. That sandy layer was probably formed as a result of single rapid sedimentation event over a large area of the Ediacaran (Vendian sea floor with its habitants. In spite of the evident hydrodynamic activity of this event, all the traces have the finest integrity [3]. It is probably that they are left on the non-preserved substance, microbial film, rather than on the clayey surface of the bottom. The development of such substrate membranes has been proposed for other Ediacaran basins [2]. Dense accumulations of overlapping oval, to elongated imprints of a new organism are common on the fossil site. The surfaces of the majority of imprints bear a system of narrow star-shaped structures; other specimens are absolutely flat or folded. Three mentioned preservational morphs caused by post-mortem changes reflect different stages of decay. All specimens, at least those composing groups, were preserved *in situ*. Characters that define the new taxon are the star-shaped concave structures of 2-5 mm diameter. Some specimens bear single star-shaped structure and others have a great number of those in the form of networks. The star-shaped structures can be interpreted as

spicules. Judging from the state of deformation, the spicules were rather flexible than rigid. Spicules were not always preserved being situated under the cover. The general morphological pattern of the organism can be reconstructed as sac-shaped body attached by its basal part to the substrate. New fossil might be compared with Eiffelia Walcott [5] from the Middle Cambrian of British Columbia and Vaveliksia Fedonkin [1] from the Ediacaran (Vendian of Podolia, Ukraine. Thus, new organism from the Ediacaran (Vendian of South-eastern White Sea Region on the Solza River are interpreted as organism with organic spicules of Sponge grade.

Keywords: Vend-Ediacaran biota, Sponges.

This work was supported in part by the Russian Foundation of Basic Research, project no. 05-05-64825 and the Scientific School of Academicians B.S. Sokolov and M.A Fedonkin, project NSH-2899.2006.5.

References

1. Fedonkin M.A., 1985. Systematic description of the Vendian Metazoa. In: Vendian System: Historical Geological and Palaeontological Substantiation. V. 1 (eds B.S. Sokolov and A.B Iwanowski), pp. 70-112, Moscow: Nauka [in Russian].

2. Gehling, J. G., 1999. Microbial Mats in Terminal Proterozoic Siliciclastics: Ediacaran Death Masks. Palaios, V. 14, pp. 40-57.

3. Ivantsov A. Yu., Fedonkin M.A., 2001. Locomotion Trails of the Vendian Invertebrates preserved with the Producer's body Fossils, White Sea, Russia. North American Paleontological Convention, .rogram & Abstracts, PaleoBios, V. 21, p. 72. Berkeley.

4. Ivantsov A.Yu., 2004. New Proarticulata from the Vendian of the Arkhangel'sk Region. Paleontological Journal, Vol. 38, No. 3, pp. 247-253. Transl. from Paleontologicheskii Zhurnal, No. 3, pp. 21-26.

5. Walcott C.D., 1920. Middle Cambrian Spongia. Smiths. Miscell. Coll., V. 67, No. 6, pp.261-364.

T2-23

EDIACARA FOSSILS FROM THE DENGYING FORMATION SOUTH CHINA: A NEW TAPHONOMIC WINDOW FOR THE EDIACARA BIOLOGY

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Ediacara fossils are among the oldest, most diverse, complex macroscopic life forms in the Earth's history. Although they have been systematically studied for nearly 60 years, their bodyplan, taphonomy, ecology and affinity are quite controversial. They were variably interpreted as sponges, cnidarians or cnidarian-grade organisms, bilateral animals, fungi or fungus-like organisms, lichens, xenophyophoran protists or vendobionts, macroscopic organisms with quilted bodyplan, and organisms of uncertain affinities. The controversial nature of these interpretations is partly due to

the narrow taphonomic window in which these fossils are preserved. Classical Ediacara fossils are typically preserved as casts and molds in siliciclastic rocks. Although this siliciclastic taphonomic window offers some incredible taphonomic resolution when the sediments are fine-grained, the internal anatomy is rarely preserved in traditional Ediacara fossils. We explore an alternative taphonomic window in bituminous limestone of the 551-542 Ma Dengying Formation in the Yangtze Gorges area, South China. Several Ediacara forms from the Dengying Formation have been studied using serial thin section technique. They are decimetre-scale in horizontal, but millimetre-scale in vertical dimension. One of the forms shows a fractal branching patterns, with biserially arranged tubular units along a central axis. Each tubular unit is composed of two vertical side walls, a roof, a floor, and a distal open end. The Dengying limestone opens up a new taphonomic window for the Ediacaran biology. We hypothesise that the three-dimensional preservation of Ediacara fossils in the Dengying Formation was made possible by early diagenetic calcite cementation.

T2-24

THE CRYOGENIAN PERIOD: DEFINITIONS AND GLOBAL CORRELATION

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The mixed geochronometric/conceptual scheme of Precambrian time-units (Plumb, 1991) has generally not been accepted by the international geological community and is set to be abandoned. The Cryogenian Period, currently defined as the interval in Earth history beginning at 850 Ma and ending around 650 Ma illustrates the problem. Although period boundaries were intentionally "chosen so as to delimit or enclose, rather than designate" geological events, application of the conceptually vivid label, the *Cryogenian* Period, to sediments now known to have been deposited over 100 million years before the onset of Neoproterozoic glaciation but not to those associated with the ~635 Ma "Snowball Earth" episode of global glaciation has become confusing and fails to achieve the original aim of "conveying as much information in as few words as possible" (Plumb & James, 1986). Older periods, for which geochronological ages and global stratigraphic correlation schemes may be more poorly constrained, face potentially greater mismatches between original concept and age, which has led recently to the move towards establishing a natural, rock-based Precambrian time-scale analogous to that of the Phanerozoic Eon but with less emphasis on biostratigraphy (Bleeker, 2004). The first period to be redefined in this way was the Ediacaran Period that begins during global deglaciation at approximately 632 Ma and ends close to the first signs of macroscopic shelly organisms and complex trace fossils around 542 Ma. Its onset is currently defined not on the basis of biostratigraphy but at a significant chemo-oceanographic event – the globally correlative cap dolostone horizon (Knoll et al., 2004).

It is impossible at present to determine which glacial deposits in the world are the oldest using the limited resolution of current stratigraphic calibration schemes. This limitation, together with the observation that most glaciogenic units sit on erosive surfaces, means that evidence for glaciation in the sedimentary record cannot be used as a lithological marker defining the beginning of the Cryogenian Period. Instead, a globally correlative level must be sought that is stratigraphically below the first appearance of glacial climate in the Neoproterozoic. The purpose of this presentation is to assess what the new Cryogenian Period might encompass in terms of chemo-oceanographic events, isotopic excursions, sedimentological trends and biostratigraphy. By virtue of the extreme events that shaped the Cryogenian Period, the assigning of strata to this characteristic interval of Earth history has the potential to convey much information to the expert and the lay-person alike. Its definition is therefore of profound importance to how Earth science is taught to generations of future students and science teachers.

Geochronology

Age constraints for Neoproterozoic glaciations have improved considerably over the past decade. There is increasing evidence for widespread glaciation around 635 Ma, in glaciogenic diamictite deposits that underlie cap dolostones marking the onset of the Ediacaran Period on all continents except Antarctica. Age constraints on earlier pulses of glaciation are generally maxima that restrict the Cryogenian System in Scotland to <810 Ma, in Australia to <785 Ma, in Oman to <~780 Ma, in Namibia to <780 Ma (Kaigas), in Zambia to <770 Ma, < 770 Ma in N. China, in Canada to <760 Ma, <760 Ma in S. China and <750 Ma in Namibia (Chuos). Other age constraints confirm glaciation between 715 Ma and 680 Ma in the USA and Oman, consistent with constraints elsewhere; anomalously, glaciogenic deposits of the Kaigas Formation of Namibia seem to be older than 735 Ma, but younger than 770 Ma. At present, no glaciogenic units have been reported recently to be older than 750 Ma, while deposits between 750 Ma and 635 Ma appear to be of too diverse age to represent the popular but overly simplistic scenario of two distinct Neoproterozoic climate events: Sturtian and Marinoan glaciations. At present, best age estimates for the Neoproterozoic glaciations that might fall into any future Cryogenian Period are ~750 Ma – 632 Ma.

Isotopic record

Oxygen isotopes – The mid-late Neoproterozoic appears on current data to have been a period of unusually elevated $\delta^{18}O$ values in marine carbonate rocks. High $\delta^{18}O$ values in dolomitic units overlying lower diamictite levels are apparent in both Australia (Areyonga Formation $\delta^{18}O$ up to +0.4‰) and Namibia (Gobabis Formation $\delta^{18}O$ up to -0.8‰ and Rasthof Formation $\delta^{18}O$ up to 2.1‰). Although such values are significantly elevated over Precambrian norms, and in particular basal Ediacaran cap dolostones (Shields, 2005), they are restricted to dolomite in the study by Kennedy et al. (1998). Other studies do reveal similarly elevated $\delta^{18}O$ in primary limestones (Fairchild et al., 2000; Shields et al., 2002) of pre-glacial strata of the late Neoproterozoic. By comparison with the Palaeozoic record of marine carbonate $\delta^{18}O$, for example associated with the late Ordovician, such values are typical of glaciation and global cooling. The pervasive effects of diagenetic alteration on carbonate $\delta^{18}O$ make it difficult to interpret the Neoproterozoic marine $\delta^{18}O$ record any more robustly at present. Intriguingly, Zheng et al. (2004) trace the formation of anomalously ^{18}O-depleted magmas in the South China Block to 758 ± 15 Ma that they consider

formed from mixing with huge volumes of snowmelt. If this interpretation is correct, then the approximately contemporaneous Chang'an Formation of South China may relate to an early episode of Neoproterozoic glaciation.

Sulfur isotopes – There is a distinctive global sulfur isotope anomaly in interglacial shales and siltstones of post Sturtian-glacial age (Gorjan et al., 2000, 2003). Bacteria produced sulfides in Australia, Canada, China, and Namibia extremely enriched in ^{34}S, with a $\delta^{34}S_{sulfide}$ mean of +30‰ and maximum values up to +62‰. These values correspond to $\delta^{34}S_{sulfate}$ values between +10 and +50‰ (Gorjan et al., 2000, 2003; Hurtgen et al., 2005). The late Cryogenian was therefore a unique interval in Neoproterozoic Earth history, where bacteria metabolising seawater sulfate in low concentrations (Hurtgen et al., 2005) under euxinic conditions produced sulfides with $\delta^{34}S$ values approaching and surpassing seawater sulfate $\delta^{34}S$. Older Cryogenian rocks exhibit more Phanerozoic-like characteristics: $\delta^{34}S_{sulfide}$ values between -10 and +10‰ and $\delta^{34}S_{sulfate}$ values averaging about +25‰. It may prove possible therefore to correlate late and early Cryogenian sedimentary successions based on these sulfur isotope characteristics.

Carbon isotopes – There is now a large database of carbon isotope data for Cryogenian successions in Australia (Hill & Walter, 2000; Walter et al., 2000), NW Canada (Asmerom et al., 1991; Kaufman & Knoll, 1995), Greenland–Svalbard (Halverson et al., 2005 and references therein), Mongolia (Shields et al., 2002), Namibia (Haverson et al., 2005 and references therein), N Norway (Halverson et al., 2005), Scotland (Brasier & Shields, 2000), and the USA (Death Valley, Corsetti & Kaufman, 2003; Grand Canyon, Dehler et al., 2005). There are $\delta^{13}C$ swings comparable to those in the Ediacaran (up to 15‰) and several points of correlation can be made. In particular, there is a good correlation between Australia, Svalbard–Greenland, and Namibia between about 800 and 662 Ma (Hill & Walter, 2000; Walter et al., 2000; Halverson et al., 2005), but connections could also be made with NW Canada, Mongolia, and the USA. There are also two features that distinguish the Cryogenian from the Ediacaran: 1) not all the large negative $\delta^{13}C$ swings in the Cryogenian correlate with glacial deposits, and; 2) Cryogenian $\Delta\delta^{13}C_{carb\text{-}org}$ values typically range between 28 and 30‰, whereas Ediacaran $\Delta\delta^{13}C_{carb\text{-}org}$ values are >32‰ (Hayes et al., 1999; Calver, 2000; Hill & Walter, 2000; Walter et al., 2000; Dehler et al., 2005. However, data from Mongolia (Shields et al., 2002) seem to contradict this pattern and here, too, there may be a distinction between early and late Cryogenian systematics.

Strontium isotopes - The Neoproterozoic eon saw seawater $^{87}Sr/^{86}Sr$ rising from a Mesoproterozoic plateau of 0.704-5 to 0.7084 by the Precambrian-Cambrian boundary. It is unclear exactly when this rise began; however, early-mid- Neoproterozoic, but apparently pre-glacial marine carbonates commonly exhibit $^{87}Sr/^{86}Sr$ ratios <0.706: Atar Group, Mauritania (0.7059); Gillen Member, Bitter Springs Formation, Australia (0.7057); Shaler Group, Canada (0.7058); Little Dal Group (0.7055); Wanlong Formation, China (0.7055); Karatau Group, S. Urals (0.7052); Neryuen Formation, Uchur-Maya (0.7052). Pre-glacial marine carbonate units of the Neoproterozoic show that seawater $^{87}Sr/^{86}Sr$ had increased modestly by ~750 Ma: Loves Creek Member, Bitter Springs Formation, Australia (0.7063); Coates Lake Group, Canada (0.7064-66); Xinmincun Formation, China (0.7063); E. Greenland/NE Svalbard (0.7064-0.7071); while post-glacial units of lower Cryogenian successions are only slightly higher, ranging from

0.7067-0.7074, values that are apparently characteristic of the entire Cryogenian interval. Because of the clear trend towards higher seawater $^{87}Sr/^{86}Sr$ before and after the Cryogenian Period, Sr isotope ratios may provide important constraints on the global stratigraphic definition and correlation of the Cryogenian.

Biostratigraphy

A biostratigraphic framework for correlating and subdividing the Cryogenian, while evidently not as strong as in the Ediacaran, is possible. In Australia, biostratigraphic correlations can be established from both stromatolite biostratigraphy and palynology, and are consistent with results obtained from $\delta^{13}C$ stratigraphy (Hill et al., 2000). The use of stromatolite morphology for correlative purposes is not universally accepted but there are consistencies within Australian basins, and tentatively between Australia and the Chuar Group. At about 800 Ma (Bitter Springs age), the *Acaciella australica* stromatolite assemblage occurs across Australia at a time when $\delta^{13}C$ values are between -4 and 0‰. At about 760 Ma, the *Baicalia burra* stromatolite assemblage is present across Australia with $\delta^{13}C$ values between +4 and +8‰. *Baicalia* is also recorded in the upper Chuar Group (~760–740 Ma) with similar $\delta^{13}C$ values. Also at ~760 Ma, the distinctive acritarch, *Cerebrosphaera buickii*, first appears in three Australian basins, and correlates with the Svanbergfjellet and Draken Conglomerate Formations (Lower Akademikerbreen Group, Svlabard) where it was first described by Butterfield et al. (1994). The fossiliferous Chuar Group also contains *Chuaria circularis* (Walcott, 1989), abundant vase-shaped microfossils (Porter et al., 2003), and acritarchs (Vidal and Ford, 1985), which if discovered in other global successions will greatly enhance the potential of biostratigraphic markers for Cryogenian correlation. Current biostratigraphic schemes rely heavily on international correlation schemes that are far from being universally accepted, which means that it is unclear to which extent the Cryogenian Period may have its own distinctive fossil signature.

Carbonate sedimentology

Importantly, almost all marine carbonate successions of the pre-glacial Neoproterozoic contain molar-tooth structure, which is a type of early diagenetic, microsparry calcite cavity fill. Beside the stratigraphic argument that all these occurrences occur below units showing evidence for glaciation (e.g. Fairchild et al., 2000), even where glaciogenic strata are absent molar-tooth calcite and associated limestones consistently yield least-altered $^{87}Sr/^{86}Sr$ ratios that are 0.7067 or lower. Therefore, molar-tooth structure and other forms of microsparry calcite cavity fill are restricted to pre-Cryogenian periods of the Precambrian (Shields, 2002).

Other carbonate sedimentary features mark the transition from the early Neoproterozoic to the Cryogenian Period, namely the introduction of new textures in marine carbonate successions, such as thrombolites or clotted textures in limestones, Girvanella-like tubular threads, and Renalcis-like clots. The appearance of such calcimicrobial textures implies the calcification of cyanobacterial sheaths, which have been reported from pre-Cryogenian strata in Russia (Burovaya Formation), Canada (Little Dal Formation) and in Svalbard. Intriguingly, all these units also contain the last molar-tooth structures of the Precambrian in their particular regions.

Potential GSSPs

In the light of the fluidity of current correlation schemes, the future Cryogenian GSSP should

perhaps be placed at a level amenable to various means of stratigraphic correlation, such as a chemo-oceanographic event, recognisable on the basis of a number of isotopic proxies and by globally relevant changes in the geological record. Considering the absolute certainty of future advances in stratigraphic precision and geochronology, unimagineable today, there is little incentive to deliberate for decades on the definition of a GSSP that may become obsolete with time. However, the question of what we wish as geologists to convey by defining a new period of the geological timescale needs to be central to our thinking. In this regard, the criteria for inclusion or exclusion from the Cryogenian Period need to be as robust as possible and we suggest that a list be drawn up as soon as practicable for circulation.

Keywords: Cryogenian, stratigraphic correlation, isotope stratigraphy, biostratigraphy

References

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T2-25

NEOPROTEROZOIC MICROFLORA CHANGE RECORDED IN THE ANDRÉE LAND AND TILLITE GROUPS, NORTHEAST GREENLAND

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The Andrée Land Group and the Tillite Group of northeast Greenland comprise together a thick sedimentary succession composed of marine carbonate, mudstone, chert associated with Fe-rich phases and minor carbonate, conglomerate, diamictite and sandstone. The Andrée Group is a carbonate-bearing unit at the top of the predominantly marine succession of the Eleonore Bay Supergroup. The top of the Andrée Group is composed of fine-grained clastic sediments with chert horizons and minor carbonates. Some chert units are enriched by Fe, suggesting stagnant, anoxic depositional conditions. The overlying Tillite Group includes two diamictite-bearing units, which are referred to the Ulvesø and Storeelv formations. These units are considered to be glacigenic deposits that probably accumulated during the widespread Sturtian and the Marinoan glaciations respectively. The intermediate fine-grained sediments following the glaciations represent deposition in relatively warmer climatic conditions. $\delta^{13}C$ values for the succession show a pattern, which is comparable to the global pattern seen at other localities, i.e. a prominent decline from positive to negative values up towards the Ulvesø Formation (Sturtian).

Palynological preparation and analysis of samples from the Neoproterozoic succession has been carried out to establish the nature of the microfloral change in this part of the succession. The content of black organic matter is low in most samples. The organic content appears in the form of unstructured, angular to partly rounded grains. Abundant organic matter occurs in association with

black to dark-brown, sphaeromorphs in the most fine-grained part of the succession below the Ulvesø Formation and Sturtian glaciation. The black organic matter is strongly, thermally and diagenetically degraded but occasionally appears as the remains of organic sheets. The associated flora is dominated by abundant sphaeromorph acritarchs of 20–82 microns in diameter and with a discrete surface sculpture, possibly diagenetically induced. Variations in wall thickness do not follow variations in size and shape, so thin walls were probably also diagenetically induced. Concentric compression folds are common but no wall structures or apertures are visible. The palynomorphs are classified as *Leiosphaeridia* sp., a common Neoproterozoic taxon. The peak occurrence of *Leiosphaeridia* sp. is in one sample, 10 meters below the Ulvesø Formation but more restricted, similar floras are recorded both below and above. Few Leiosphaeres are recorded in fine-grained sediments within the Ulvesø Formation. Clusters of 14–20 microns small sphaeromorph acritarchs occur sporadically in the rich flora and degraded, thin-walled acanthomoph acritarchs occur rarely.

The presence and acme of acritarchs within this succession coincides with the large negative spike of $\delta^{13}C$, which characterises the Sturtian glaciation. The presence and acme of the acritarchs together with the strong negative signal of the carbon isotopes below the Ulvesø Formation is thus apparently not mutually consistent with the deep freeze conditions proposed by the Snowball Earth hypothesis.

Keywords: Neoproterozoic, arcritarchs, Sturtian, Greenland

T2-26

NEW DISCOVERIES OF LONGFENGSHANIACEAE FROM THE UPPERMOST EDIACARAN IN THE EASTERN YUNNAN, SOUTH CHINA

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A morphologically more diverse assemblage of Longfengshaniaceae has been found in the uppermost Ediacaran (Sinian) Jiucheng Member, Yuhucun Formation at Jinning and Jiangchuan County, eastern Yunnan, South China. A majority,of them are different from the *Longfengshania* in the Neoproterozoic Changlongshan Formation, Yanshan Mountain Area, North China and the Mesoproterozoic Little Dal Group, North America. They are mainly characterised by a more varied, often thallus-like appearance, such as shuttle-shaped, jujube nucleus-shaped, shovel-shaped, ribbon-shaped or balloon-shaped, and more sturdy stalk-like projection (stipe) with a smooth connection on the basal part of the thallus. In addition, they appear to have a remarkable attaching organ of lanceolate, shuttle-like or short stem-like structure at the base of the stipe. Six distinct morphological taxa are recognised, including one new genus, two new species and three conformis species. The characters of the family and the genus *Longfengshania* are further discussed and amended in this paper. The new discoveries of these carbonaceous macrofossils identified as Longfengshaniaceae algae on the basis of the diagnostic forms and

anastomosis patterns of their thalli and stipes, demonstrate that an important evolutionary radiation of metaphytes took place in the last Ediacaran stage. Moreover this flourishing of the benthonic thallophytes attached on the substrate from the eastern Yunnan, considered to be photosynthetic alga, probably provided continuous nutritional habitats for the explosion and diversification of the early Cambrian "Chengjiang Biota".

Keywords: the eastern Yunnan, Ediacaran, Jiucheng Member, Longfengshaniaceae.

T2-27

USING TEM TO ASSESS THE BIOLOGICAL AFFINITIES OF EDIACARAN ORGANIC-WALLED MICROFOSSILS

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The morphology and wall ultrastructure of well-preserved organic-walled microfossils, referred to as acritarchs, have been studied using different microscopic techniques. The fossils occur abundantly in Ediacaran deposits in the Officer Basin in Australia. The assemblages are taxonomically diverse, change over short stratigraphic intervals, and are largely facies independent across marine basins. Affinities of this informal group of fossils to the modern biota are, with the exception of only a few taxa, mostly unknown.

The present ultrastructural study of some Ediacaran age acritarchs extends our knowledge of the possible affinities of some taxa. The acanthomorphic (ornamented) acritarch *Gyalosphaeridium pulchrum* reveals a vesicle wall with four distinct layers. This, very rarely seen, multilayered structure is interpreted as being an undeniable eukaryotic feature. Some acritarchs possess a characteristic trilaminar sheath structure (TLS) that is similar to the TLS present in extant chlorophycean green algae. The absence of such TLS may suggest an affinity other than chlorophycean for *Gyalosphaeridium pulchrum*. Instead, the overall large size, complex ornamentation, and multilayered vesicle wall suggest that *Gyalosphaeridium pulchrum* may be more closely related to dinoflagellates than chlorophytes. The comparatively thick cell wall is evidence to suggest that the fossil is in the resting stage of its lifecycle. Comparison of the wall ultrastructure in some leiospheric (unornamented) acritarchs highlights the problems associated with this polyphyletic group of organic-walled microfossils.

Studies based on TEM are still in their infancy but hold promise for future research. Transmitted light microscopy (LM) has its limitations in magnification and resolution, factors that may be relevant when assessing the relationships of acritarchs to modern taxa. Scanning electron microscopy reveals details of surface morphology, microstructure and microelements, whereas TEM is a technique that can be used for high resolution images of the cell wall ultrastructure. Javaux *et al*. (2004) studied the wall ultrastructure of some morphologically simple acritarchs using TEM, and demonstrated either eukaryotic or prokaryotic affinities for some of the microfossils. These observations on wall ultrastructure reached conclusions that could not have

been drawn using LM alone. According to previous research using TEM, we can also verify that the division of acritarchs into leiospheres and acanthomorphs is entirely artificial and has no phylogenetic meaning.

Keywords: Wall ultrastructure, Ediacaran, acritarchs, biological affinities.

References

Javaux, E.J., Knoll, A.H. & Walter, M.R. 2004: TEM evidence for eukaryotic diversity in mid-Proterozoic oceans. *Geobiology* 2, 121-132.

T2-28

EDIACARAN BIOSTRATIGRAPHY OF SOUTH CHINA AND ITS ROLE IN GLOBAL CORRELATION OF THE EDIACARAN SYSTEM

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After overcoming numerous challenges, the IUGS Subcommission on the Terminal Proterozoic System has defined the initial GSSP (Global Stratotype Section and Point) of the Ediacaran Period at the base of the Nuccaleena cap carbonate that overlies the Marinoan Elatina diamictite along Enorama Creek in the Flinders Ranges, South Australia. The greater challenge in front of us, however, is to search for chronostratigraphic criteria that can be used to subdivide and correlate the Ediacaran System at a global scale. A variety of potential chronostratigraphic markers (e.g., Gaskiers diamictite, Acraman impact ejecta layer, stable isotope excursions, Doushantuo-Pertatataka acritarchs, *Cloudina*, *Palaeopascichnus*, and trace fossils) appear to have potential for regional and global correlation of the Ediacaran System.

Ediacaran successions in South China provide an opportunity to evaluate the chronostratigraphic values of these markers. Although the equivalents of the Gaskiers diamictite and Acraman impact ejecta layer have not been located in South China, the Ediacaran Doushantuo and Dengying formations yield a large volume of chemostratigraphic, biostratigraphic, and geochronological data. Analysis of these data shows that, in the Yangtze Gorges area, the Doushantuo-Pertatataka acritarchs first appear within the lower Doushantuo Formation (2nd Member), about 6 m above the Doushantuo cap carbonate (1st Member) or about 1.5 m above an ash dated at 632 Ma. The acritarch assemblage is initially dominated by a single species, *Tianzhushania spinosa*, followed by stepwise increase in diversity to >20 species in the upper part of the 2nd Member. Acanthomorphic acritarchs are still present in the 3rd Member, but their taxonomic diversity is somewhat decreased from that found in the 2nd Member. They finally disappear and are

succeeded by macroscopic algae and problematic macrofossils in the black shale of the 4th Member, which underlies an ash dated at 551 Ma. The overlying basal Dengying Formation (551-542 Ma) is unfossiliferous, although *Paracharnia*, *Palaeopascichnus*, *Cloudina*, *Sinotubulites*, *Vendotaenia*, various trace fossils, and a number of worm-like problematic macrofossils occur in the middle and upper Dengying Formation.

In sharp contrast to the Yangtze Gorges area, the Doushantuo-Pertatataka acritarchs appear in great diversity only in the upper Doushantuo Formation at Weng'an, suggesting paleoenvironmental and/or preservational controls. Beyond South China, they occur between the ~578 Ma Acraman impact ejecta layer and the ~565 Ma Ediacara Member in South Australia, between a major sequence boundary (glacioeustatic response to the Gaskiers glaciation?) and a pronounced negative C isotope excursion in northern India, and below the possibly 580-Ma Moelv diamictite in southern Norway. These inconsistent data indicate that the first and last appearances of Doushantuo-Pertatataka acritarchs, as well as their temporal relationship with the Acraman impact, Gaskiers glaciation, and C isotope events, remain poorly constrained at the global scale. However, the occurrence of *Cloudina* and *Palaeopascichnus* in the Dengying Formation (551-542 Ma) consistently points to potential chronostratigraphic value of these two genera. *Cloudina* has been previously reported from the Ara Group (~542 Ma) of Oman and the Nama Group (~549 Ma) of Namibia, whereas *Palaeopascichnus* has been known from the Ust-Pinega Formation (~555 Ma) of Russia, the Fermuse and Chapel Island formations (<565 Ma) of Newfoundland, and the Wonoka Formation of South Australia.

Key Words: Ediacaran, Biostratigraphy, South China, Biostratigraphy, South China

T2-29

THE AGE CONSTRAINT ON THE DOUSHANTUO FORMATION AND ITS BIOSTRATIGRAPHICAL CORRELATION BETWEEN THE YANGTZE GORGES AND WENG'AN AREA

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The Qingbaikou, Nanhuan and Sinian systems are used as a tripartite division of the Neoproterozoic in China. The redefined Sinian System in south China includes the Doushantuo and Dengying formations, and its upper boundary, i.e. the lower boundary of the Early Cambrian Meishucun Stage, is marked by the first appearance of the small shelly fossils from the *Anabarites trisulcatus - Protohertzina anabaric* assemblage. The lower boundary begins with a very well-developed cap carbonate at the base of the Doushantuo Formation. The 1.5 to 5 meters thick cap carbonate is characterised by unusual sedimentary structures, including sheet cracks filled with chalcedony and quartz, tepee-like structures, and barite fans. The cap carbonate is usually called the lower dolomite member (LD). Above is 100 to 120 m of shaly limestone, dolomitic limestone, black shale intercalated with chert nodules and bands, which is usually called the lower

shale member (LSh). Above that is about 70 m of a white dolomite sequence intercalated with chert beddings or lenticels, usually called the upper dolomite member (UD). The topmost 10 to 15 m is composed of black shale intercalated with concretions of carbonate (USh). According to the biostratigraphical investigations from nine sections of the Doushantuo formation in the Yangtze Gorges area, two silicified microfossil assemblages were found from LSh and UD. Chert nodules and bands in the shaly limestone and mudstones of LSh contain abundant and diverse (more than 20 species) acanthomorphic acritarchs, as well as multicellular algal thalli. These acanthomorphic acritarchs and multicellular algal thalli can be taxonomically compared with the Weng'an biota found in Guizhou. The black shale in this member also contains macroscopic carbonaceous compressions dominated by Chuarids (Tang et al. 2005). The other silicified assemblage was found in chert lenticels from UD, including abundant leiospheres, as well as acanthomorphic acritarchs, but lack *Tianzhushania*. The top Doushantuo black shale (USh) is characterised by extremely light organic carbon isotope values and contains macroscopic algal fossils (i.e. the Miaohe biota). An ash layer immediately above the cap carbonate in Jiuqunao section has been dated from 628.3±5.8 Ma by sensitive high-resolution ion microprobe (SHRIMP II) on zircons. Another ash layer immediately above the black shale unit (USh) gives a weighted mean 206Pb/238U age of 549.9±6.1 Ma (Yin et al. 2005a,b). These ages are both consistent with the ages obtained from the same horizon by Condon et al. (2005). The new ages suggest the lower boundary of the Sinian system should be 630 - 635 Ma, and the age of the Miaohe biota is older than 550 Ma. Together with other isotopic ages from the upper member of the Doushantuo Formation at Weng'an, Guizhou (Barford et al. 2002; Chen et al. 2004) and the biostratigraphical correlation between Yangtze Gorges and Weng'an area, the age of the Weng'an biota is more likely older than 580 Ma.

Supported by NNSFC (40272015) and CGS (200213000042).

References

Barfod, G. H., Albarède, F., Knoll A H,et al., 2002. New Lu–Hf and Pb–Pb age constraints on the earliest animal fossils. Earth and Planetary Science Letters, 201(1): 203–212.

Chen et al., 2004. Pb-Pb ages of Neoproterozoic Doushantuo phosphorites in South China: constraints on early metazoan evolution and glaciation events. Precam. Research, 132: 123-132.

Condon, D., Zhu, M., Bowring, S., Wang, W., Yang, A. and Jin, Y., 2005. U-Pb ages from the Neoproterozoic Doushantuo Formation, China. Science, 308: 95-98.

Tang Feng, Yin Chongyu, Liu Yongqing, Wang Ziqiang, Liu Pengju and Gao Linzhi, 2005 . New discovery of macroscopic carbonaceous compressions in Sinian Doushantuo Formation, eastern Yangtze Gorges Chinese Science Bulletin 50(23): 2632-2637.

Yin Chongyu, Tang Feng, Liu Yongqing, Gao Linzhi, Liu Pengju, Yang Zhiqing, Wan Yusheng and Wang Ziqiang, 2005a. U-Pb zircon age from the base of the Ediacaran Doushantuo Formation in the Yangtze Gorges, South China: constraint on the age of Marinoan glaciation. Episodes, 28(1): 48-49.

Yin Chongyu, Tang Feng, Liu Yongqing, Gao Linzhi, Yang Zhiqing, Wang Ziqiang, Liu Pengju,Xing Yuseng and Song Biao, 2005b. New U-Pb zircon ages from the Ediacaran (Sinian) System in the Yangtze Gorges: constraint on the age of Miaohe biota and Marinoan glaciation. Geological Bulletin of China, 24(5): 393-400.

T2-30

PALAEOLATITUDE CHANGE OF SOUTH CHINA BLOCK IN NEOPROTEROZOIC AND ITS IMPLICATIONS TO THE GLOBAL CLIMATE CHANGE

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A new palaeomagnetic investigation was carried out on red beds of the Xieshuihe formation, tillites of the Nantuo formation of the Nanhua system, and carbonates of the Doushantuo and Dengying formations of the Sinian system. Sampling sites were located at Sixi and Huajipo sections near Yichang, Hubei province, Xieshuihe and Zhongling section in Yangjiaping, Guzhang section, Huaihua section, and Qiancheng section in Hunan province. Over 600 samples were subjected to stepwise thermal and alternative demagnetisation. The magnetic remanence was measured using either a JR-6A spinner magnetometer or a 2G cryogenic magnetometer. Both clastic and carbonate samples were extensively remagnetised. A remagnetisation component directs to north with shallow inclinations was isolated from all sections. The most possible primary remanence was isolated from one quarter of the samples. This component is charaterised by eastward directions. It passes a fold test in Huaihua section (The fold was formed in Indosinian).

A large number of zircon U-Pb SHRIMP geochronology research has been carried out on igneous rocks of these strata. Combined with the previous results, absolute age of these strata are well known. They are: ~814±12 Ma, Changshuipu formation, Banxi group (Wang et al., 2003); ~809 Ma, Madiyi formation – Wuqiangxi formation (this study); 809±16 Ma, Laoshanya formation (Yin et al., 2003); ～663 Ma, Datangpo formation (Zhou et al., 2004); 650－635Ma, tillite of Nantuo formation (this study); and 635－550Ma, Doushantuo formation (Condon et al., 2005; Zhang et al., 2005). These data can provide the neccessary geochronology constraints on the palaeomagnetic explanation.

The palaeomagnetic study indicates that the Yangtze block has experienced movement across a long distance from high to low latitude, this is based on the characteristic components that indicate an easterly direction, with inclination from steep to shallow, and ages from old to new. The Yangtze block has experienced no obvious rotation during this period.

The change of palaeolatitude of the Yangtze block provides good constraints on the extreme changes in global climate during the Neoproterozoic. The Yangtze block is located at a high latitude of 65^{o}, ~800 Ma (Li et al., 2004). The red beds of the Banxi group indicate that they were deposited in an oxidising environment and torrid climate during this period. There was no evidence or clue of tillites or cold water deposition. Approximately 750Ma, the Yangtze block

moved to a mid-latitude of 37° (Zhang and Piper, 1997; Evans et al., 2000). The depositional environment of the Liantuo – Xieshuihe formations has long been debated. They may compare with either the tillites of the Chang'an formation or the interglacial of the Datangpo formation in the south of the Yangtze block, but both opinions lack concrete evidence. One of the significant results in this study is that the duration of deposition of the Nantuo formation was so short that the palaeolatitude of the cap carbonates can represent the palaeogeography of the Yangtze block when it was located near the equator during the Nantuo glacial and thawing period. The palaeomagnetic results from the middle to upper Doushantuo formation also indicates that the Yangtze block stayed at or near the equtor for a long time in the late Neoproterozoic (Macouin, et al, 2004).

The Yangtze block is one of the best preservational areas of the important Neoproterozoic global geological events. Our new study provides direct evidence of the equatorial and icy marine deposition environments during the Nantuo (Marinoan) glacial. The fact that there is no strata record of a cold environment, although the Yangtze block was located at or near a pole may indicate that it was very warm in the pre-Chang'an glacial. There may have been an extreme greenhouse climate in the mid Neoproterozoic (~800Ma), before the Snowball Earth.

T2-31

A NEW TYPE OF PRECAMBRIAN MEGASCOPIC FOSSILS: THE JINXIAN BIOTA FROM NORTHEASTERN CHINA

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Precambrian fossils are crucial for our understanding the evolution of early organisms. Megascopic body fossils are more important because they potentially represent macroorganisms. However, the Precambrian fossil record is sparse and dominated by microfossils and microbial structures. Here we show a new type of megascopic fossils recovered from the Xingmincun Formation (probably Neoproterozoic age), northeastern China. The specimens are flat, flexible (easily corrugated) and discoidal in outline. Concentric or spiral ridges are preserved on both sides. Petrographical thin section examination indicates that the specimen consists of a thin layer of microcrystalline quartz grains (about 20-30 m thick) wrapped by an outer sheath, composed primarily of chlorites. Field Emission Scanning Electron Microscopy (FE-SEM) coupled with an X-ray energy dispersive spectrometer system (EDX) analysis shows microstructures and relative element abundance of the fossils, but contributes little in solving their biological affinities. The fossils have previously been linked to discoidal impressions of the Ediacaran biota. Close examination on new materials indicates that they are radically different from either the Ediacaran impressions or any other Precambrian megascopic remains. Concentric or spiral ridges may result from rhythmic growth and the presence of twin specimens may suggest that the organisms undergo asexual reproduction or inhibition of growth in one direction. Referring them to any

known fossil or living group has proved to be difficult. We conclude that they represent a distinct group of Precambrian megascopic organisms regardless of their affinities remaining problematic.

Keywords Megascopic fossils, Precambrian, Ediacaran, Xingmincun Formation, Northeastern China, Liaoning

T2-32

EDIACARAN $\Delta^{13}C$ CHEMOSTRATIGRAPHY OF SOUTH CHINA

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Numerous studies on $\delta^{13}C$ chemostratigraphy of the Ediacaran System in South China indicate that pronounced carbon isotopic shifts may provide a useful and practical tool for intrabasinal stratigraphic correlations. Using litho- and biostratigraphic markers as independent calibrators, we combine new and previously published $\delta^{13}C$ data to construct a composite $\delta^{13}C$ profile for the Ediacaran System in South China. The composite curve shows, in chronostratigraphic order, 1) a negative $\delta^{13}C$ excursion (EN1) in the Doushantuo cap carbonate that overlies the Ghaub-age Nantuo diamictite; 2) a pronounced positive $\delta^{13}C$ excursion (EP1) in the lower Doushantuo Formation where Doushantuo-type acanthomorphic acritarchs first appear and then become abundant and diverse, and where micrometazoans and stem group florideophyte red algae emerge; 3) a mild negative $\delta^{13}C$ excursion (EN2) in the middle Doushantuo Formation; 4) a positive $\delta^{13}C$ excursion (EP2) in the upper Doushantuo Formation where Doushantuo-type acanthomorphic acritarchs, micrometazoans and red algae remain abundant and diverse; 5) a pronounced negative $\delta^{13}C$ excursion (EN3) at the top of the Doushantuo Formation; 6) a strongly positive $\delta^{13}C$ excursion (up to +6.3 ‰ PDB; EP3) in the lower Dengying Formation; 7) a stable $\delta^{13}C$ plateau (ca. +2.5 ‰ PDB; EI) in the middle and upper Dengying Formation where abundant vendotaenid algae, macroscopic Ediacara fossils, biomineralized animal tubes, and mostly horizontal animal traces occur; and 8) a –10‰ negative $\delta^{13}C$ excursion (EN4) immediately below the Ediacaran–Cambrian boundary. The general pattern of this composite $\delta^{13}C$ curve is robust, despite a considerable amount of variation among the $\delta^{13}C$ profiles of different sections. This composite $\delta^{13}C$ curve provides a first-order chemostratigraphic framework for the subdivision and correlation of the Ediacaran System in South China.

To construct a global $\delta^{13}C$ curve for the Ediacaran System would require independent chronostratigraphic controls to align $\delta^{13}C$ profiles from different sedimentary basins. At present, there are not sufficient biostratigraphic and geochronometric data to construct a robust global curve. However, the broadly consistent bio- and chemostratigraphic patterns among Ediacaran successions in South China, Mackenzie Mountains, Namibia, Siberia, Oman, and Australia are encouraging. Our data from South China also indicates that a global $\delta^{13}C$ curve for the Ediacaran

System, when eventually assembled, will be more complex than what was construed by pioneer Ediacaran chemostratigraphers more than a decade ago.

Keywords: Carbon isotopes, chemostratigraphy, Ediacaran, South China

T2-33

INTEGRATED EDIACARAN (SINIAN) CHRONOSTRATIGRAPHY OF SOUTH CHINA

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South China is an ideal key area for establishing global integrated Ediacaran chronostratigraphy, because the Ediacaran successions ranging in origin from shallow to deep marine facies are well developed and exposed throughout this area. In order to develop an integrated Ediacaran chronostratigraphy, 62 reference sections throughout the entire Yangtze Block from the shallow water to deep basin have been investigated during recent years. Based on analyses of sedimentary facies and sequence stratigraphy of more than 40 sections, four major sequences can be recognised in all Ediacaran successions from the shallow water facies on the Yangtze Platform. The three major sequence boundaries can be traced in the middle and upper part of the Doushantuo Formation, and the middle part of the Dengying Formation respectively. The well-established Ediacaran sequence stratigraphy can be used for high-resolution chronostratigraphic correlation of complex Ediacaran successions resulting from facies changes between subbasins on the Yangtze Platform. The Ediacaran subdivision and correlation based on the sequence stratigraphy is further supported by carbon isotope chemostratigraphy of 13 reference sections. Our carbon isotope chemostratigraphy indicate that there are three distinct and one minor negative carbon isotope excursions, and three positive carbon isotope excursions in the entire Ediacaran successions on the Yangtze Platform. A composite carbon isotope profile of the Ediacaran in South China based on the age constraints by recent new precise U-Pb dates for the volcanic ashes at the base (635Ma) and the top (551Ma) of the Doushantuo Formation demonstrate that it can be used for global chronostratigraphic subdivision and correlation of the Ediacaran successions.

Our correlation suggests that the sequence boundary in the middle part of the Doushantuo Formation reflects the eustatic sea-level change associated with the Gaskiers glaciation (580Ma), which is further supported by a small-scaled negative excursion of $\delta^{13}C$ data. The boundary meets the following events which can be globally correlated as well (1) end of the Neoproterozoic glaciations, and (2) first appearance of animals, and rapid increase in diversity of acanthomorph acritarchs. Consequently, these events can be used as global criteria to subdivide the Ediacaran System into two series.

Keywords: chronostratigraphy, Ediacaran, Sinian, South China