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CHEMICAL AND MINERALOGICAL DETERIORATION OF BASEMENT SCHISTS IN PARTS OF OBUDU PLATEAU, SOUTHEASTERN NIGERIA

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ABSTRACT

Obudu plateau is a basement complex area predominantly made up of migmatites, gneisses and schists. An augered drill hole was made in new Ikwette, a location in the Schist domain of the basement. This study reports the chemical, textural and mineralogical alteration from the fresh mica schist up through the saprolite to the lateritic zone near the surface resulting from weathering.

The evolutionary pathway from mica schist to the lateritic product reveals that the most profound changes have taken place between samples OB5 and OB7. The extensive depletion of silica is matched by the equally extensive enrichment in Alumina, Iron oxide and LOI –water.

Keywords: Horst, Basement complex, Mica schist, Depletion, Alumina.

INTRODUCTION

The primary laterite forming factors include climate (precipitation, leaching, capillary rise and temperature), topography (drainage), vegetation, parent rock and time. A combination of the laterite - forming factors and the soil forming process of weathering produces the distinctive morphological properties and particular chemical and mineralogical composition of laterites.

Lateritization is the process whereby rocks are converted to laterite by the enrichment of Iron oxide and the depletion of silica. Lateritization is favoured by low relief, a warm climate with alternating wet and dry seasons, and a fluctuating water table near the surface, which enables insoluble ferric oxides to be precipitated in the zone of aeration.

The percolation of very high amount of rainfall through the soil causes desilication. Soluble salts such as bases of calcium, sodium and potassium are completely removed from the tropical soil during lateritization, leaving behind highly stable oxides and hydroxides of iron and aluminium. Excessive accumulation of hydroxides of iron and aluminium lead to the formation of indurated rock-like layer beneath the surface called laterite. Laterites are rapidly developed upon iron rich parent materials such as basalts, but thick laterites are common in basement areas where they form on iron-deficient gneisses and schists.

Minor amounts of metal contained in unweathered rock may be concentrated into economic deposits during weathering. Enrichment takes place where the oxidized metallic products are stable and other constituents are selectively leached away. Therefore depending on the materials, environment and products involved, weathering processes may:

a) destroy an existing ore deposit
b) produce one from previously barren or sub-economic rock, or
c) change the mineralogy of a deposit.

In tropical climates where leaching is especially effective, only the most insoluble oxides remain at the surface. Iron and aluminium from such stable compounds are so abundant that they are commonly left as residual concentrates. These iron or aluminium rich soils are known as “laterites; the Latin word for “brick earth”.

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Laterite is reddish to brown in colour and may be vesicular, concretionary, cellular, vermicular, slag-like pisolitic, concrete-like or gravely (conglomeratic) in texture. It is composed chiefly of ferric oxides with minor amount of alumina, manganese oxides, and variable quantities of quartz grains and rock fragments. Laterite also contains significant proportion of clay minerals. The composition of laterite varies according to the nature of the underlying rock and the amount of chemical decay that has occurred.

LOCATION AND GEOLOGY

The study area (figure 1) is part of Obudu Plateau in Cross River State of Nigeria. It lies within the reactivated Precambrian Basement of Nigeria, which forms a portion of the pan-African Tectonothermal belt located between the West African Craton, to the west and the Gabon-Congo Craton, to the east.
It is bounded by longitudes 9^0 15'E to 10^0 00'E and latitudes 6^0 30'N to 6^0 45' N covering an area of about $75km^2$. It is a part of the Obudu Plateau and represents a terminal portion of the western Bamenda Massif of the Cameroons that wedges into eastern Nigeria (Orajaka, 1964; Umeji, 1988, Ekwueme, 1991).

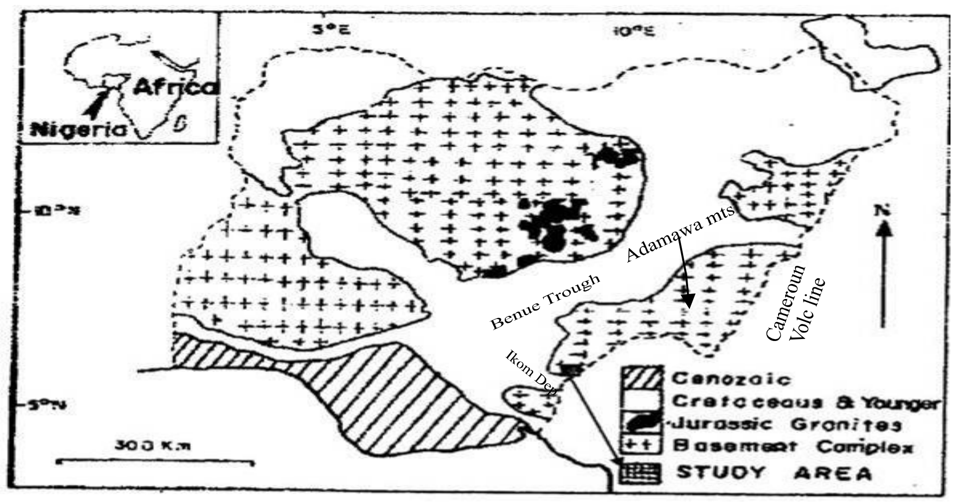

Fig. 1: Geological map of Nigeria showing location of study area

Generally, the geology of Obudu Plateau can be classified into four units:
(a) Migmatite - gneiss complex
(b) Schists
(c) Granitic, charnockitic and peridotitic intrusives
(d) Unmetamorphosed dolerite dykes and dioritic intrusives.

The dominant rock unit in the Plateau is the migmatite-gneiss complex, while dioritic and peridotitic rocks are minor occurrences [1], [2] and [3].

Porphyroblastic paragneisses constitute a large part of the basement rocks of Obudu Plateau. The paragneisses in the eastern part of the Plateau are more quartzose than the western paragneisses, which are more aluminous [3]. Prominent north-trending gneisses are abundant in Obanliku, Sankwala, Oloibi and Ishikpeche hills.

Ekwueme [6] further subdivided the gneisses of the Obudu Plateau into garnet-sillimanite gneisses, garnet-hornblende gneisses and pyroxene - bearing gneisses. He noted that the gneisses are coarse - grained and form prominent hills, which have been eroded in parts to expose dolerite dykes. The gneisses and the schists are frequently migmatitic.

Ekwueme [5] relying on the stable co-existence of garnet, kyanite and sillimanite in the garnet sillimanite gneiss inferred that metamorphism in Obudu Plateau attained at least intermediate pressures and reached the highest grade of the amphibolite facies of the Barrovian type.

The Schists most of which are migmatized, are fairly distributed in Obudu Plateau. Amphibolites occur as lenses in the gneisses, and they are products of deformation and metamorphism.

Highly deformed high-grade migmatitic schists are frequently found in association with high-grade migmatitic gneisses, and both together form the basement units into which granites and pegmatite dykes intrude. Most of the schists contain garnets, except those that are sillimanite - bearing. Ekwueme [5] suggested that the sillimanite-bearing schists are products of the alteration of initial garnet-bearing schists.

Pegmatites are common in Obudu Plateau, but are more frequent in the schists than in the gneisses. Muscovite-bearing pegmatites are also common; others are the biotite bearing and muscovite-biotite-bearing varieties.

Charnockites are also abundant. They range from medium to coarse-grained to granulite textures [5]. They crop out at River Metu, Busi, Bogene and Bebi [5]. The structural disposition of the charnockites along fracture zones suggests emplacement due to faulting. They are associated with granite, pegmatites and granulites. The foliated variety trend N - S or NE - SW.

Dolerite dykes are common in Obudu Plateau. Some of the dolerites are finegrained, while others are medium-grained. The fine-grained dolertites are quantitatively minor compared to the medium to coarse-grained variety.

Physiography, climate and vegetation

The study area has a rugged topography comprising north-easterly trending ridges separated by lowlands, which form valleys and passes. Generally, the Obudu Plateau constitutes the highest elevated part of south-eastern Nigeria, with a maximum height of 1576m above sea level at the Obudu Cattle Ranch [4].

Most rivers are seasonal, over flowing their banks in the rainy seasons and reducing in water volume or even completely drying out in the dry seasons. The drainage is structurally controlled as almost all the rivers rise from the Northeastern part and flow toward the south west in line with the Pan African trends.
The present day climate is characterized by a high annual rainfall between 1000mm and 2500mm. The rainfall regime includes a long wet season of heavy rainfall (March-October) and a relatively short dry season.

The vegetation cover in the study area is influenced by the climatic type, soil cover and human activities. The vegetation types include Guinea savanna and Montane vegetation [4].
The Guinea Savanna is characterized by very tall grasses interspersed with trees. Tall trees of the rainforest type abound around the river valleys. The common trees of the Guinea savanna are acacias, baobab and shea-butter.

The Obudu-Cattle Ranch road is the only major road that traverses the study area, running roughly East-West. Secondary roads include Sankwala-Bayasung road, running N-S in the western part of the Obudu area.

Accessibility is highly limited by the preponderance of very high peaks. Thus, the roads and footpaths are largely restricted to the plains or foot of hills or in few cases, along the Obudu-Cattle Ranch road.

METHOD OF STUDY

As a result of the stable landscape of most of the study area, Gulley sites and extensive road-cuts are almost absent. To get to appreciable depth in this study, a shaft was drilled from which samples were recovered. The shaft was made by the use of a 10m x 0.015m post-hole diameter steel anger.

Although unweathered parent rock was inaccessible on this site, field observations and subsequent laboratory analysis of the saprolite revealed that the parent rock is mica schist. The drill-hole profile was logged in the field for lithological characterisation and samples were taken from different horizons for subsequent laboratory analyses. As the fresh parent rock could not be reached due to the limitation of the borring auger, only the weathered profile consisting of saprolite and the superjacent laterite was sampled. The most representative samples, designated OB1 through OB7, taken at approximately 0.7m intervals were chemically analysed in this study.

Powdered samples were analysed for Mineralogical composition using a siemens Diffrac 11 X-Ray Diffractometer with Cuk-α radiation. Loss-on-ignition was determined by fusing for 15 minutes at 1200°C, while major and trace element composition was determined by X-Ray Fluorescence spectrophotometer after palletising by fusion with lithiumtetraborate.

Altogether, 11 major oxides and 24 trace elements were so determined.

RESULTS AND DISCUSSIONS

The data obtained from the chemical and mineralogical analysis of the schists samples are presented in tables and graphs for interpretations

Tables 1 and 2 respectively show major oxides and trace element concentration in the profile over schist in New Ikwete, while figures 1 and 2 indicate lithological and mineralogical evolution from the base upward.

Table 1: Major oxides distribution in lateritic profile in New Ikwete (wt%)

Major Oxides	OB 1 (wt%)	OB 2 (wt%)	OB 3 (wt%)	OB 4 (wt%)	OB 5 (wt%)	OB 6 (wt%)	OB 7 (wt%)
SiO_2	62.02	62.03	60.62	58.40	54.2	34.08	25.00
Al_2O_3	16.5	18.4	19.44	20.17	18.72	25.51	25.3
Fe_2O_3	8.7	8.2	8.05	11.03	13.55	27.05	32.1
TiO_2	2.44	2.9	0.87	0.68	0.92	1.95	0.75
MnO	0.02	0.13	0.04	0.14	0.15	0.15	0.18
MgO	0.02	0.1	0.18	0.06	0.08	0.11	0.07
CaO	0.01	0.02	0.12	0.01	0.02	0.01	0.01
Na_2O	0.15	0.11	0.14	0.04	0.14	0.15	0.11
K_2O	0.12	0.07	0.37	0.17	0.19	0.17	0.09
P_2O_5	0.07	0.17	0.08	0.07	0.08	0.07	0.11
SO_3	0.08	0.1	0.16	0.12	0.16	0.17	0.18
LOI	9.15	7.34	9.54	9.21	11.09	10.61	15.26
Total	**99.28**	**99.57**	**99.61**	**100.1**	**99.3**	**100.03**	**99.16**

Lithological Development

The lithological development of the profile is summarised in Fig. 2

The drilled section, including the topsoil cover, measures some 5 metres and comprises from the unreached bedrock upwards of the following lithologies. All lithologies grade one into another almost imperceptibly.

1. Coarse-grained pisolitic laterite - dark red, semi-consolidated but friable, gravel sized pisolitic material.
2. Medium-grained pisolitic laterite - transitional and similar to the underlying material except in grain size
3. Fine-grained pisolitic laterite-dark, reddish-brown, soft unconsolidated sand-sized material. Here no structural features from bedrock or saprolite are discernable.
4. Saprolite - reddish brown, weathered rock, but with details of macro and microstructural characteristics (lineations and foliations) still intact.

Mineralogical Development

Highlights of the mineralogical development as documented from the x-ray patterns (Fig. 3) are the appearance of gibbsite and its growth at the expense of kaolinite and quartz, and a notable increase in the content of goethite and hematite. Kaolinite (although it may not be present in the parent rock in any appreciable amounts), is an important constituent of the saprolite which represents the deepest part of the logged profile. From the base to the top of the profile, gibbsite content has increased. The mineralogical development and composition of the profile from the saprolite through to the laterite at the top is shown in fig 2.

Saprolite (OB 1)

In Hand specimen, the schistose texture is still evident. Quartz bands are still relatively fresh and coherent but at the boundaries between these and the mica bands, infiltrations of ochre-coloured goethite have penetrated into the intercrystalline boundaries of the polyquartz crystals and have begun to undermine their coherence.

Biotite is already highly degraded into goethite and kaolinite. The Kaolinite occurs in clots. Although the goethite is pervasive and ubiquitous within these mica bands, relics and ghost textures of the phyllosilicates are still largely preserved. These changes progressively intensify until all primary schistose textures are completely obliterated in the laterite.

Laterite (OB6-7)

The overall texture is concretionary. The pisolites which are granule-to gravel-sized and dark red to black in colour are held in a matrix of ochre-coloured goethite. The quartz bands have completely disappeared. In their place, minor silt-sized quartz grains occur indiscreetly within the concentration as well as in the matrix of black haematite.

The chemical data are listed in tables 1 and 2. *A* ternary plot of SiO_2, $A1_20_3$, and Fe_20_3 presented in Fig 3 summarises the bulk chemical composition of the section and its evolution from saprolite (OB 1) to laterite (OB 7).

However, because the fresh rock could not be reached in this site, many of the most mobile elements represented by several earth and alkaline- earths, were already completely lost or nearly so with values of 0ppm to 66ppm. Values for the major oxides; $Si0_2$, Al_20_3 and Fe_20_3 shown in a ternary plot indicate that, while SiO_2 has decreased considerably on the one hand, Al_20_3, Fe_20_3 and LOI-, the last parameter being an index of degree of bauxitisation [8] have increased by higher proportions on the other. The trace elements which show significant to strong changes are Ce, Cr, V, Zr and Pb. The remaining ones show moderate to insignificant changes. These are La, Ni, Y, Sc, Gu, Pb, Th, Co, Ba, As, B, Mo, Nb, Ta, Sn and Zn.

Table 2: Trace element concentration in the lateritic profile in New Ikwete (PPM)

Major Oxides	OB 1 (PPM)	OB 2 (PPM)	OB 3 (PPM)	OB 4 (PPM)	OB 5 (PPM)	OB 6 (PPM)	OB 7 (PPM)
Ba	500	523	445	443	342	307	319
Ce	19	42	100	208	285	323	68
Co	21	20	22	22	21	22	22
Cr	313	308	271	343	400	500	640
La	22	40	50	58	65	77	30
Sc	13	13	12	19	24	25	27
V	143	149	153	198	296	425	567
As	6	8	7	8	7	8	13
Bi	7	8	7	8	7	8	13
Cu	49	43	30	37	44	44	48
Mo	3	4	5	6	6	8	12
Nb	20	18	19	21	21	21	19
Ni	18	28	40	41	39	39	32
Pb	15	38	60	90	110	140	42
Rb	4	10	17	16	16	12	7
Sn	22	22	22	22	21	20	21
Sr	5	11	16	15	18	14	10
Ta	6	5	6	5	6	5	6
Th	17	17	23	24	33	47	37
U	15	11	10	10	10	16	20
W	7	6	5	6	7	5	5
Y	19	40	58	58	59	58	23
Zn	13	19	29	28	30	40	21
Zr	408	567	616	622	601	706	269

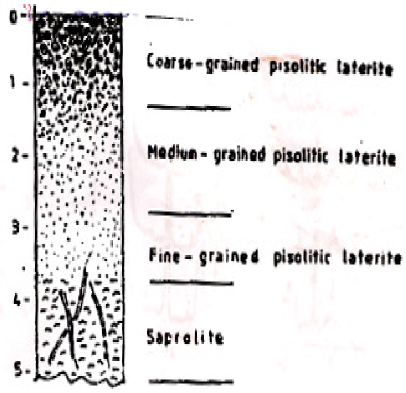

Fig.2 Lithological log of the Lateritic profile over schist in New Ikwete

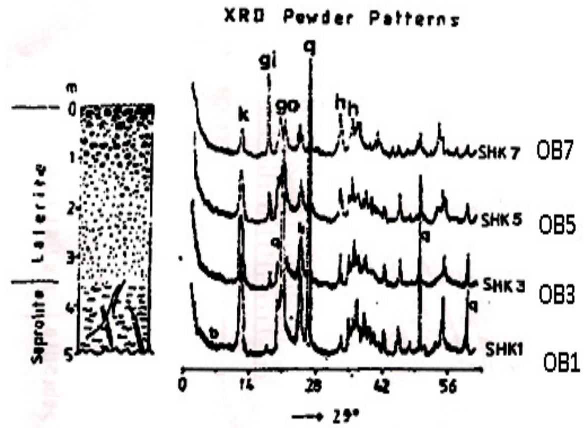

Fig 3: Mineralogical log of the lateritic profile over schist showing powder patterns in new Ikwete (K=kaolinite; b=biotite; gi = gibbsite: q= quartz. Go = goethite and h= hematite)

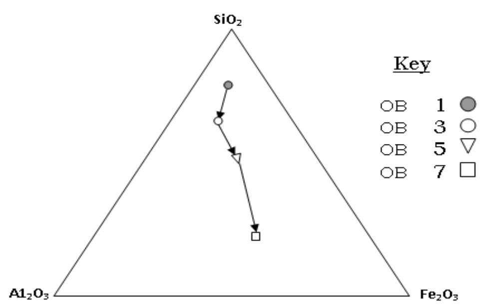

Figure 4: SiO_2-Al_2O_3-Fe_2O_3 ternary plot of laterite over schist at new Ikwete (Obudu) showing chemical evolution from silica-rich, alumina and iron oxide-poor to silica-poor, alumina and iron oxide rich composition.

CONCLUSION

Along the weathering profile provided by the drill hole, there are both mineralogical decomposition and marked chemical variation from the fresh basement rock to the surface. The important major oxides SiO_2, Fe_2O_3, Al_2O_3 are concentrated at about 2m of the profiles.

The chemical evolution depicts a development trend from a silica-rich parent rock to a silica depleted, Iron and Alumina rich end products. The Al_2O_3-Fe_2O_3-SiO_2 ternary as seen in the large deviation in the composition of the parent rock and the weathered profile. The evolutionary pathway from mica-schist to Alumma rich laterite reveals that the most profound changes have taken place between samples OB5 and OB7. The extensive depletion of silica is matched by the equally extensive enrichment in Alumina, Iron oxide and LOI-water [10].

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