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Original Article

Geology and Possible Host for Bauxite Mineralization of Mambila Plateau, NE Nigeria

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Abstract *- Bauxites are normally formed from underlying aluminosilicate rocks as a result of tropical weathering. The most important mineral constituent of the bauxite ore is gibbsite, boehmite, or diaspore. The methods adopted for this study involved reconnaissance surveys, detailed geologic mapping, and petrographic studies. Two (2) major rock units were identified and collected for laboratory studies: basalt and trachyte. The basalt is black to dark green in hand specimen and generally displays columnar jointing structures. Its petrography showed plagioclase feldspar to be 55.33%, pyroxene 30.33%, and opaque mineral 14.33%. The trachyte, however, is generally light grey in hand specimen, massive, and displays a non-directional brecciation pattern. Its petrography showed sanidine to be 49.33%, augite 21.33%, oligoclase 11.00%, hornblende 9.00%, and opaque mineral 9.33%. The bauxites of the Mambilla Plateau are therefore found to be formed from residual chemical weathering of trachyte and occur as a blanket cover over saprolite.*

Keywords — *Mambilla Plateau, aluminosilicate, basalt, trachyte, gibbsite, hematite, kaolinite, quartz*

I. INTRODUCTION

Bauxite deposits are found worldwide, from Spain through southern France, Italy, Australia, Hungary, and Greece. Australia has huge reserves of bauxite and produces over 40% of the world's ore. Brazil, Guinea, and Jamaica are important producers. Africa produces over sixteen percent of the world's bauxite, with Guinea as the leading African country in bauxite production. Some major bauxite is found in the West African sub-region (Bardossy and Aleva, 1990) like Ghana (Kesse, 1984), Mali (Tardy, 1993), Cameroon, and Sierra Leone (USGS: Mineral Commodity Summary, 2011). Although excluded in the list of African bauxite producers, Nigeria has potential for its production in view of numerous crystalline rocks rich in aluminum oxide covering a substantial part of the country. Only minor occurrences with low concentrations of bauxite are known from some regions like Ekiti province and Jos plateau (Boulange and Eschenbrenner, 1971). Bauxite is typically classified according to its intended commercial application, such as abrasive, cement, chemical, metallurgical, and refractory. The demand for bauxite or aluminum is increasing day by day, and since bauxite deposit has been suspected at Mambilla Plateau, Taraba State, Nigeria, this research aimed to assess the detailed geology and possible host for the mineralization in the area. Mambilla Bauxite Deposits-Block I (Mayosumsum area) and Block II (Gurgu area) are located in Sardauna Local Government Area of Taraba State, Nigeria. The area is covered by topographic maps of Mambilla and Gashaka sheets 295 and 276, respectively, on the scale of 1:30,000. It is bounded by latitude 6° 56’N and 7° 1’ 30” N, longitude 11° 30’E, and 11° 6’ 30” E (Fig. 1) and covers approximately 770 square kilometers.Mambilla Plateau can be accessed through Makurdi – KatsinaAla – Takum – Baruwa – Maisamari to Nguroje or through Bauchi – Jalingo – Baruwa – Maisamari and then to Gurgu and Mayosumsum. These routes are accessible throughout the year.

II. GEOLOGICAL FRAMEWORK

Geologically, Mambilla Plateau is situated near the border with Cameroon; the Plateau forms the western extension of the Adamawa Highland. It belongs to the uplifted parts of the Eastern Nigeria Massif on the southern flank of the Benue Trough. The plateau consists of Gotel Mountains with Paleocene to Miocene basalts in the North and the Mambilla Mountains with Precambrian gneisses in the South. The Pan African basement complex is built up mainly of migmatite gneisses, some strongly folded metasediments, granites, and, in a few places, Charnokitic intrusions. Quartz veins mostly cut the migmatites. Basalt flows cover the northern part of the plateau. They belong to the 700km long NE trending Cameroon volcanic Line (Fig.2), a continental segment of a 1600km volcanic chain that straddles the West African continental margin, characterized by Maastrichtian – Recent alkaline magmatism (Wilson and Guiraud, 1992). In Nigeria, extensive lava flows have formed Biu Plateau, where alkaline olivine basalt is the dominant rock type while phonolite and Trachyte occur locally (Wright, 1976). At Bambouto and Oku (50 – 200km SSE of the Mambilla Plateau), K/Ar model ages range from 23 – 14 Ma. (Lower to Mid Miocene) (Fitton and Dunlop, 1985). The volcanism is strongly bimodal composed of alkali basalt, Trachyte, trachyphonolite, transitional alkali basalt, quartz Trachyte, and rhyolite. The geology of the study area is composed mainly of Basement Complex rocks of the Precambrian age, especially in the southern and northern part with a series of isolated granitic hills towards the north. The rocks are predominantly granite gneiss, migmatites, and coarse – medium-grained biotite granites. This granitic rock usually occurs in uplifted positions.

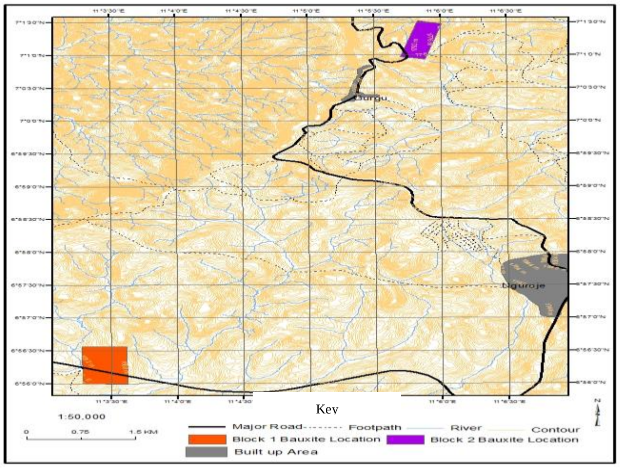

Fig. 1: Topographic Map of Part of Mambila Showing Locations of Block 1 and Block 2 Bauxite Deposits

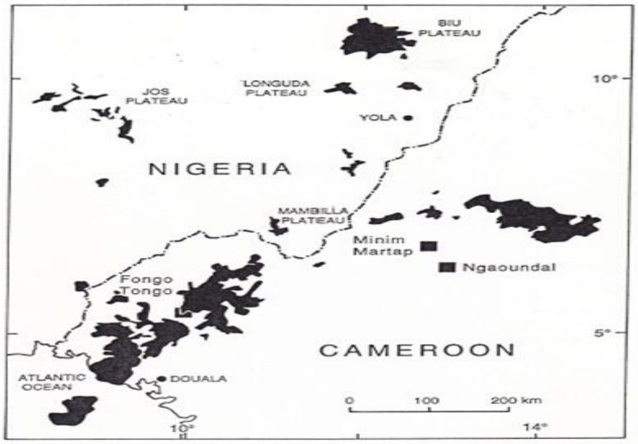

Fig. 2: Distribution of basalt related to the Cameroon Volcanic Zone (after Whiteman, 1992) and bauxite deposits of Cameroon (after Bardossyand Aleva, 1990)

III. METHODOLOGY

The area was studied using two methods, these are;

A. Field Methods

The reconnaissance geological survey of the target area was done using parts of a topographic base map of Gashaka and Mambilla Sheets 276 and 295, respectively, on the scale of 1:50,000. During the mapping exercise, traverses were made across the whole length and breadth of the target area, mostly along the river channels, several footpaths, valleys, and ridges; hence topographic features were studied. Photographs of all outcrops were taken; rock types were identified, and their positions and orientations were recorded using the GPS and Bruton compass, respectively. Both surface channel samples of various rock types were collected. The total area covered during the exercise is about seven hundred and seventy-five square kilometers (775Km^2).

a) Topographic profiling

- A central line axis (CLA 1 kilometre long was cut, produced, and established on a bearing of approximately 10^o NNE.
- Six other lines parallel to (CLA) 4 to the West and 2 to the East were established at 100m intervals from the central line.
- A Baseline (BL/0) 500m in length and perpendicular to the CLA was also established on a bearing of 280^o Azimuth.
- Ten (10) other lines. Parallel to the baseline (BL/0) was established at 100m intervals to form a 100m grid pattern as they cross the central line axis and those parallel to it.
- The grid corners were pegged with angle iron to enable pit locations (Figs. 3 and 4).

b) Detailed geological mapping

The two blocks (Blocks I and II) of the bauxite deposits were mapped in detail using the topographic profile lines produced using ArcGIS on the scale of 1:5000. The conventional technique of traversing along the profiles was used. Measurement of the rock's attitude was taken from one locality to the other using a Bruton compass, and the GPS recorded precise rocks and outcrops location. The data collected were used to produce the detailed geologic maps for Blocks I and II.

i) Sampling

Two methods of sampling were used for this study. Three prominent geologic units were sampled; basalt, trachyte, and bauxite. The basalt and trachyte, which are the parent rock for bauxite mineralization, were collected using the grab method of sampling in which a fresh representative sample of adequate sizes was broken using a sledge hammer, labeled in a sample bag, and documented for petrographic studies, while channel sampling method was adopted for the bauxite.

B. Laboratory Methods

The laboratory method was required to confirm the inferred results from the fieldwork through petrographic study and granulometric analysis. The thin sections were prepared in the petrological laboratory of AbubakarTafawaBalewa University, Bauchi. The thin section of each sample was viewed in two modes, the first with the analyzer out to produce or give the Plane-Polarized Light (PPL). In this mode, properties such as color, pleochroism, form, cleavage, relief, and alteration could be seen. After this, the same slide, this time with the analyzer, produced the Cross-Polarized Light (XPL). In this mode, mineral properties such as interference colors, extinction angle, twinning, and birefringence could be observed. Hence, the best slide pictures are taken using a phone camera mounted on the microscope with the aid of an adopter.

IV. RESULTS

A. Field Relationship, Morphology and Petrography

The rock types encountered within the study area are basalt and trachyte.

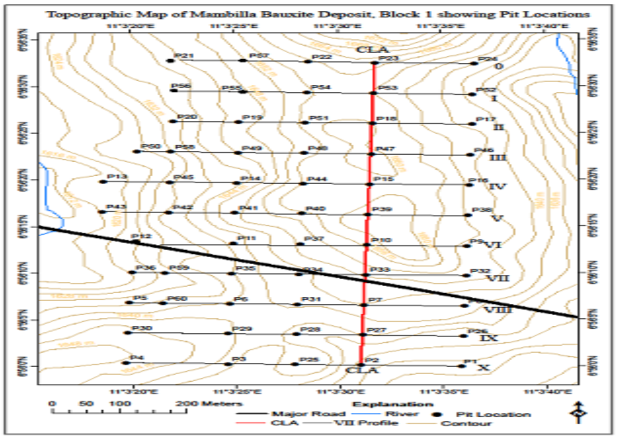

Fig. 3: Topographic Map Mambila bauxite Deposit, block 1 Showing Pit Locations

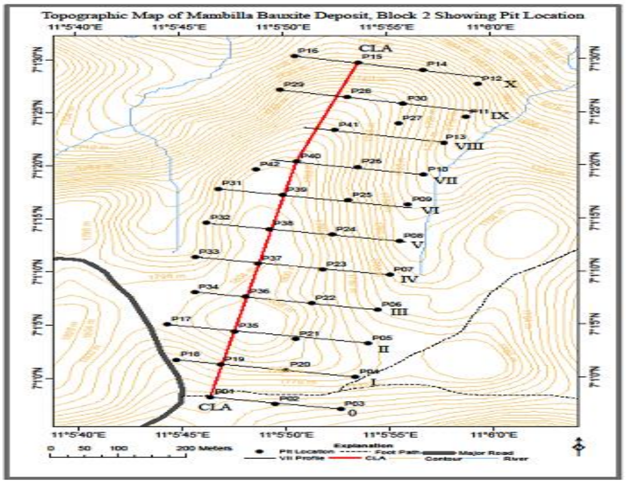

Fig. 4: Topographic Map Mambila bauxite Deposit, block 2 Showing Pit Locations

a) Morphology

i) Basalt

This is one of the dominant rocks in the study area. They outcrop in the surrounding environment further away from the bauxite deposit. It is black to dark green in hand specimen and generally displays columnar jointing structures.

ii) Trachyte

This is the dominant rock in the study area. They are the host rock to bauxite and usually mark the end of the bauxite mineralization. They are generally light grey in hand specimen, massive, and display non-directional brecciation pattern.

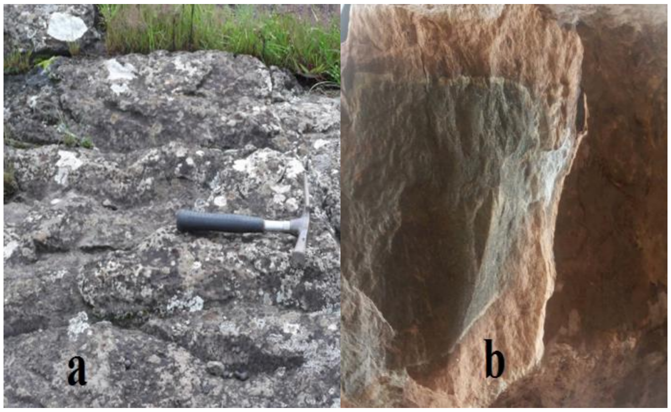

Fig. 5: (a)Field photograph showing massive trachyte. (b)Field photograph of trachyte altering to clay

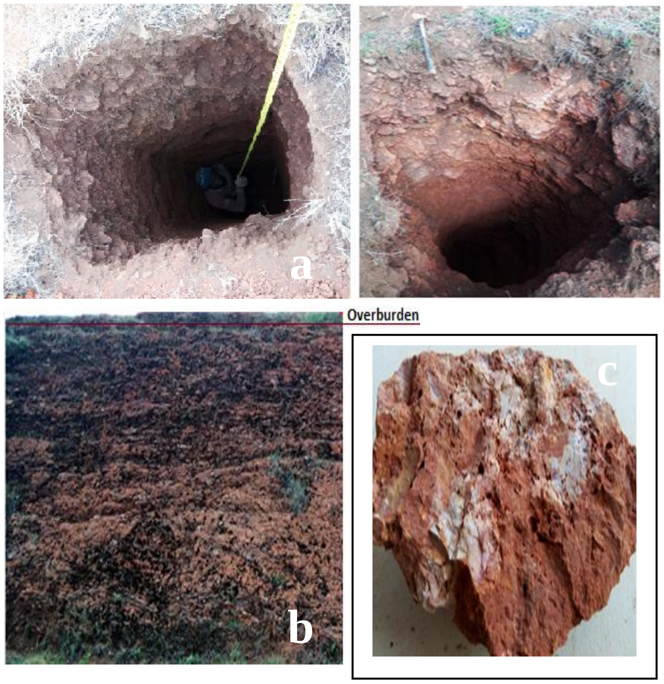

Fig. 6: a) Typical pits excavated on the bauxite deposits b) Section of bauxite ore along road cut c) Representative samples of bauxite collected from pits

b) Petrography (Thin Section)

i) Microscopic Description of Basalt

The thin section (Figs. 7a, b and 8a, b) comprises lots of pyroxenes, phenocryst of plagioclase feldspar, and opaque minerals. The spherulitic groundmass is a mixture of feldspar, biotite, and opaque minerals. It is feldsparphyric, which is a large phenocryst of plagioclase feldspar embedded in a normal basaltic groundmass. It consists of a variolitic structure, which is delicate brush-like radially dispose fiber usually of feldspar, less commonly pyroxene, which indicates late stage material. The image showed plagioclase feldspar 55.33%, pyroxene 30.33%, and opaque mineral 14.33%.

ii) Microscopic Description of Trachyte

In thin section (Figs. 9a, b, and 10a, b) contained large phenocryst of sanidine (potassic feldspar), clinopyroxene, hornblende, biotite, oligoclase (sodic feldspar), and opaque minerals, which also fill the groundmass. The texture is porphyritic. The groundmass is microlithic; it consists of closely packed lath-like in shape grains that are several times longer than they are broad. The slide is potassic trachyte. The image showed sanidine 49.33%, augite 21.33%, oligoclase 11.00%, hornblende 9.00%, and opaque mineral 9.33%.

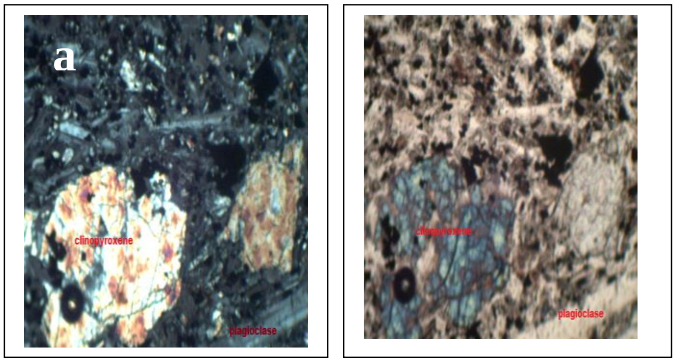

Fig. 7: Photomicrograph of basalt under a) plane polarized light (PPL) b) cross polarized light (XPL) 10x

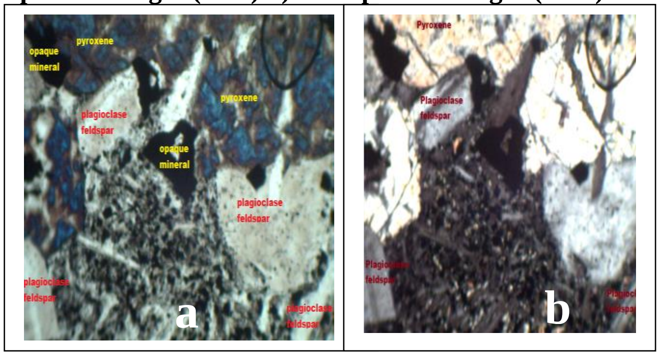

Fig. 8: Photomicrograph of basalt under a) PPL b) XPL 10x

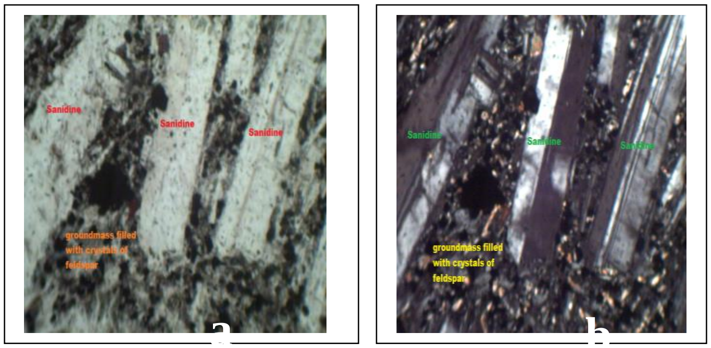

Fig. 9: Photomicrograph of trachyte under a) PPL b)XPL 10x

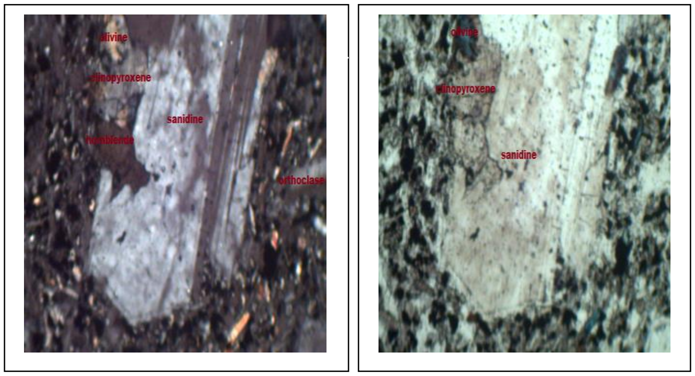

Fig. 10: Photomicrograph of trachyte under a) PPL b) XPL 10x

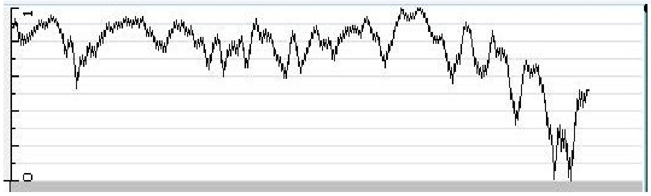

Fig. 11a: Granulometry of the vertical profile of basalt

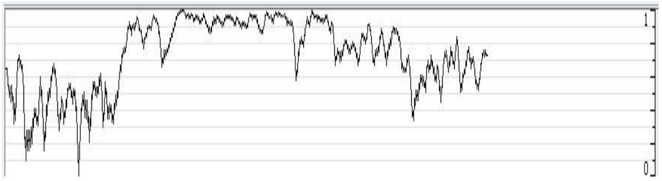

Fig. 11b: Granulometry of the horizontal profile of basalt

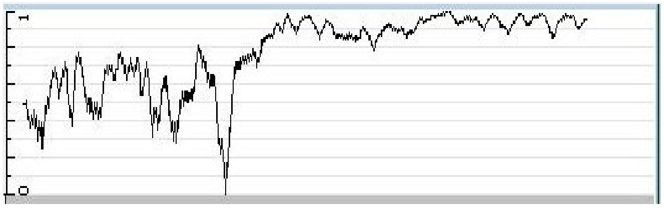

Fig. 12a: Granulometry of the vertical profile of Trachyte 1

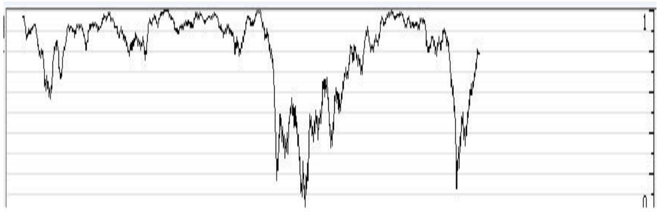

Fig. 12b: Granulometry of horizontal profile of Trachyte 1

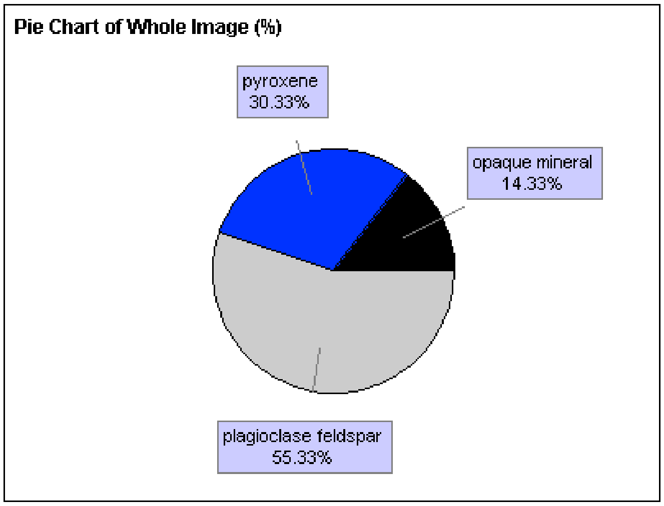

Fig. 13: Pie Chart of Basalt Image

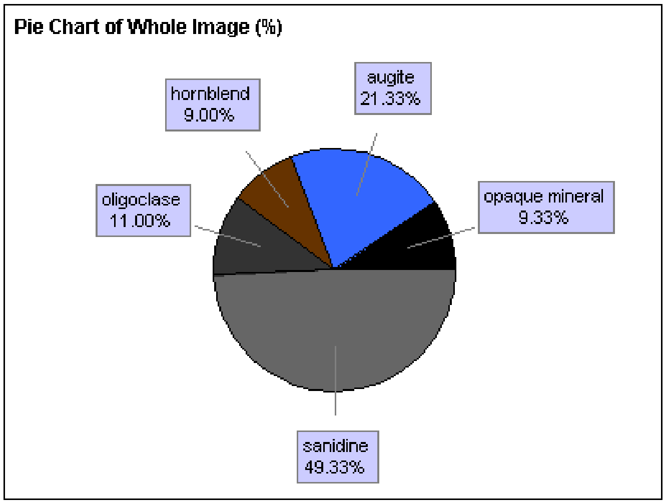

Fig. 14: Pie Chart of Trachyte Image

B. Detailed geological map

Figs. 15 and 16 show different rock units observed and mapped in the study area with superimposed pits locations. Two main outcrops, namely bauxite, and trachyte, were identified.

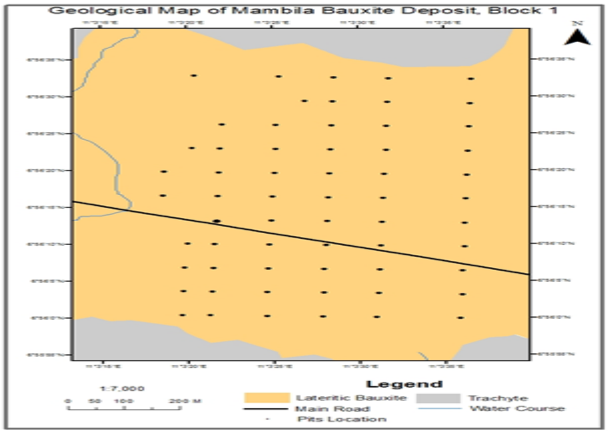

Fig. 15: Geological Map of Mambila Bauxite Deposit, Block 1

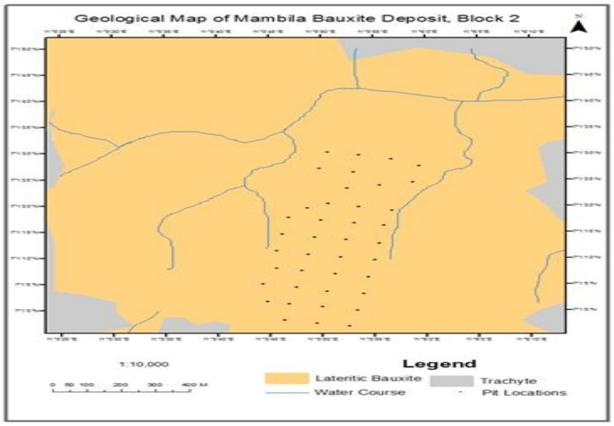

Fig. 16: Geological Map of Mambila Bauxite Deposit, Block 2

V. DISCUSSIONS

A. Geology and factors responsible for bauxite formation and deposition on Mambilla Plateau

Bárdossy(1982) had opined that bauxite deposits could be classified by their bedrock into two main categories. Bauxite deposits overlying carbonates are called karstic bauxites; those overlying on aluminosilicate rocks are named lateritic bauxites; this theory has contributed to the understanding of Mambila bauxite deposit.

B. Parent rock

The geology of the study area comprised of two major rock types, basalt, and trachyte. Many previous workers (Simpson and Gibson, 1907; Saint-Smith, 1912; Simpson, 1912; Tomich, 1964; Gmbb, 1966; Baker, 1971, 1972; Sadleir and Gilkes, 1976; Davy, 1979a; Murray, 1979; Loughnan and Sadleir, 1984) have noted the strong association between bauxite deposits and parent rocks. During lateritic weathering, alkali feldspars are altered to kaolinite, and with continued chemical reaction, bauxite is formed (Sadleir and Gilkes, 1976; Gilkes and Suddhiprakam, 1981). Bauxites formed upon trachytes are preserved in the southern part of the Bamboutovolcano, which erupted at 16±0.39 Ma (Nkouathio*et al.*, 2006). Massif outcrops of trachytes occur on the slope and in talwegs. These rocks are made up essentially of a microlithic assemblage of plagioclases, clinopyroxenes Fe-Ti oxides, phenocrysts. According to Nkouathio*et al.* (2008), these minerals include anorthoclase and alkali feldspar, i.e., sanidine to sodic clinopyroxene or hedenbergite and titanomagnetite.

The parent rock for bauxite deposition on the Mambilla Plateau is trachyte. Trachyte is an igneous volcanic rock with an aphanitic to porphyritic texture. It is the volcanic equivalent of syenite. The rock contained large phenocryst of sanidine (potassic feldspar), clinopyroxene, hornblende, biotite, oligoclase (sodic feldspar), and opaque minerals (Figs. 8a, 8b, and 9a and 9b). The microphotograph showed sanidine 49.33%, augite 21.33%, oligoclase 11.00%, hornblende 9.00% and opaque mineral 9.33% (Fig. 14). These rock characteristics have conformed with suitable parent rock (aluminosilicate) to accumulate bauxite ore on the Mambilla plateau.

C. Relief and drainage

Playford (1954), Mulcahy (1960), and Prider (1966) supported the theory that relief may have had a positive influence on lateritic weathering. Based on the evidence available, Clarke (1919) pointed out that laterites on the highest ground were richer in soluble alumina than those occurring at lower levels. Geidans(1973) asserted, however, that altitude had no direct bearing on bauxite formation. There is no reason why various laterite types could not have developed at any elevation above sea level, provided that physical and chemical conditions were favorable. Tomich (1964) and Baker (1971) used exploration and mining data to comment on the relationship between relief and the occurrence of bauxite. They noted that bauxite deposits occur in gently undulating plateau areas and tend to be confined to ridge slopes rather than hill crests or valleys.

In a grade contour plan of a portion of the typical orebody, Baker (1971) illustrated diagrammatically the considerable lateral variation of Al content and the tendency for thicker and higher-grade bauxite to occur on hill slopes. Most of the ‘potentially mineable’ deposits lie on ‘mid slopes between 250 m and 350 m above sea level. That bauxite formation is promoted by topographic relief, comparatively high elevation, and several workers suggested good drainage (Tomich, 1964; Baker, 1971; Butt, 1976; Owen and Hargreaves, 1975). It was agreed that the ‘best bauxite’ was generally associated with well-drained areas where hill slope gradients are appreciable. Topography plays an essential role in determining the ore body shapes and ore quality for both laterite and karstic bauxites (Grubb, 1973; Hutchison, 1983).

Mambilla bauxite deposit is confined to the highest topographic relief of 1400m to 1800m above sea level (Figs. 3 and 4). The area is well-drained, evidenced by running water shades surrounding the deposit (Fig. 4).

D. Climatic factors

Nkouathio*et al.* (2006) postulated that the Fongo-Tongotrachytes (Cameroun highlands) erupted during the Burdigalian ca. 16 Ma ago (intense bauxitic weathering illustrated by primary gibbsite formed by weathering of plagioclase was first initiated in mid-Miocene under warm and humid climatic conditions. Mambilla Plateau is the western extension of the Cameroun highlands, and the same trachytic rocks weathered to gibbsite mineral, under humid climatic condition bauxite was formed.

There is general agreement that high temperatures favor laterite formation, but uncertainty about whether such warm to hot conditions need to be continuous or merely seasonal (Bordossy and Aleva, 1990). Tomich (1964) drew attention to the relationship between present-day rainfall and bauxite distribution. He observed that the better class bauxite corresponded with high rainfall areas (i.e., 1000 mm). The Mambilla Plateau receives over 1850 millimeters of rainfall annually. This amount of rainfall is adequate to enhance densification and decomposition, leading to chemical reactions for bauxite formation.

Tropical conditions of high temperatures and heavy rainfall were prevalent over the southwest corner of Western Australia during much of the early to mid-Tertiary. This is deducted from the recognition of palaeo-drainage channels (van de Graaff*et al.*, 1977), particularly ones filled by debris indicative of former high-energy water flow (Wilde and Walker, 1982) from plant remains and from palaeogeographic and palaeoclimatic reconstructions (Scotese, 2001). Mambilla bauxite correlates to the palaeo-climatic reconstruction of Scotese 2001 during the late Eocene and early Oligocene periods.

VI. CONCLUSIONS

Mambilla bauxite deposits – Block I (Mayosumsum area) and Block II (Gurgu area) are situated on Mambilla Plateau, Sardauna Local Government Area of Taraba State, Nigeria. The two bauxite-bearing hills at Mayosumsum and Gurgu areas extend 500m x 1000m and 300m x 1000m respectively and occur as a blanket capping. They are situated on the tops of two hills at elevations of about 1800m above mean sea level.

The Precambrian basement rocks underlie the area; migmatite and gneisses intruded by the tertiary to recent volcanic rocks. Laterite is developed on gneisses and basalt. While on trachytic parent rock, low silica bauxite is formed with gibbsite as the main mineral phase.

The two bauxite deposits – Block I around Mayosumsum village and Block II near Gurgu village were mapped in detail using the topographic profile lines, and a detailed geologic map on a scale of 1:5000 was produced.

The Mambilla bauxite deposits are a product of residual chemical weathering of volcanic rocks, mainly trachyte. It occurs as a blanket cover over kaolinite and saprolite. The major mineral is gibbsite with a minor amount of other minerals (goethite, quartz, hematite, and kaolinite). Details of the mineral chemistry and reserve estimates are underway in our subsequent articles.

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