Resource Assessment and Possible Industrial Applications of Bauxite Occurrences in Parts of the Mambila Plateau, NE Nigeria

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ABSTRACT

Bauxites are normally formed from underlying aluminosilicate rocks as a result of tropical weathering. In our previous two papers, we presented the Geology, possible host, mineralogy, and geochemistry of the bauxites of Mambila Plateau, NE Nigeria. The bauxite was formed from residual chemical weathering of trachyte and occurs as a blanket cover over saprolite. XRD results showed gibbsite as the major mineral with small amounts of hematite, kaolinite, and quartz. Geochemistry of the bauxite ore is characterized by enriched Al₂O₃ (39.50-78.20.0%), erratic amounts of SiO₂ (2.89-5.13%) and Fe₂O₃ (5.98-21.96%). In this study, the resources of Mambilla Bauxite Deposits (Block I and Block II) have been estimated to be 7,529,312.5 metric tons using block method of vertical geological cross-section bearing in mind that the Mambilla Bauxite Deposits have been explored by pitting on a regular grid pattern of 100 m × 100 m. The bauxite deposit in Block II has met the requirement for metallurgical grade bauxite as standard specification (IS: 5953-1985, Reaffirmed [1]). While, Block I deposit has not met such specifications. Sustained investment in bauxite exploration is required to upgrade the ore reserves for sustainable development of a mining enterprise.

Keywords: bauxite, gibbsite, Mambilla Plateau, metallurgical grade, metric tons, mining enterprise, resources, trachyte.

I. INTRODUCTION

The importance of bauxite in many industries including Iron and Steel industry and in production of Alumina (Al₂O₃) cannot be over-stressed. The lightness of metal aluminium, its high resistance to atmospheric corrosion and its electrical conductivity make it a popular metal. It is being used as household utensils, aero plane construction, automobile and electrical industry. The Aluminium metal being a good substitute for non-ferrous metals like copper, zinc, which are scarce and costly metals, has further necessitated development of aluminium industry throughout the world. Bauxite is typically classified according to its intended commercial application, such as abrasive, cement, chemical, metallurgical, and refractory. The demand for bauxite or aluminium is increasing day-by-day and since bauxite deposit has been suspected at Mambilla Plateau, Taraba state, Nigeria, this study is aimed at assessing the viability of the deposits through detailed quality and quantity assessments. The study area is bounded by latitudes 6°56’N and 7°130° N, longitudes 11°30’E and 11°6’30’E and covers approximately 770 square kilometers. Mambilla Plateau can be accessed through Makurdi – Katsina Ala – Takum – Baruwa – Maisamari to Nguroje or through Bauchi – Jalingo – Baruwa – Maisamari and then to Gurgu and Mayosumsum (Fig. 1). These routes are accessible throughout the year (Daya et al. [2]).

II. GEOLOGICAL FRAMEWORK

The area forms part of the Nigerian northeastern basement complex. Generally, the Pan-African granites represent diverse magmatic phase related to the Pan-African orogeny, which contribute about 70% of materials within the crustal domain [3]. Importantly, Falconer [4] introduced the term...
“Older Granite” to differentiate the granites, the basement complex granite from Younger Granites of the Jos Plateau. However, Dada [5] opines that the “Older Granites” be replaced with “Pan African Granitoids” as the former is solely synonymous to the age of emplacement while the latter covers a wider scope of petrological significance in the geological literature. The Nigerian Pan-African basement complex is categorized into three; the northern, western, and eastern basement complexes. In the northern section, there is an eastward abundant increase of the Pan-African granites, which forms the Nigerian northeastern basement complex constituting the Adamawa Massif, the Hawal Massif, and the Oban Massif [6], (Fig. 2). The Adamawa Massif and Oban Massif have relatively received considerable attention from various researchers (e.g., [7]-[14]). Similarly, the Hawal Massif was studied by several researchers (e.g., [15]-[23]). The abundant Pan-African granitoids in the area, which can serve as a natural geological laboratory for unraveling the intricacies of calc-alkaline granites has been poorly constrained.

![Geological map of Nigeria showing the study area (after Obaje [24]).](image)

**Fig. 2.** Geological map of Nigeria showing the study area (after Obaje [24]).

### III. METHODOLOGY

**A. Resource Estimation**

The essence of this method is to estimate the resource of the Mambilla bauxite deposits (Blocks I and II).

**B. Procedure**

The mineral resource estimation of Mambilla Bauxite Deposits (Blocks I and II) was done using block method of vertical geological cross-section bearing in mind that the Mambilla Bauxite Deposits have been explored by pitting on a regular grid pattern of 100 m × 100 m.

In the estimation of the resource of the Mambilla bauxite Deposits, the following geological data/information were used:

1. Geological Map scale 1:5,000.
2. Geological cross sections along profiles I, II, III, IV, V, VI, VII, VIII, IX and X.
3. Geological logs of pits.
4. Result of chemical analysis.

**C. Calculation of Resource**

The weight of Bauxite of each block was calculated by using this formula:

\[ Q = Vd \]

where

- \( Q \) = Weight of ore in metric tons;
- \( V \) = Volume of each block in cubic meters (m³);
- \( d \) = Bulk density of bauxite mineral in tons/m³.

### IV. RESULTS

**A. Resource Estimation**

The block method of vertical cross section was employed. The polygon method was considered in the area calculation using ArcGIS software. The volume of the bauxite in each block is the product of area of each block by the average thickness of the ore body. The tonnage was derived by multiplying volume with density of the bauxite ore determined in the laboratory. The computed results are presented in Tables I and II. The two bauxite deposits have been classified according to degree of investigation. The resource classification for block 1 and block 2 bauxite resource are presented in Fig. 3 and 4.

### V. DISCUSSIONS

**A. Resource Estimation**

In computing the resource of block 1 and block 2 of the Mambilla bauxite resource, JORC Standard of reporting exploration results was considered suitable in this report. This is because JORC uses same definitions as other 13 reporting codes/guidelines/standards do. Hence, a report written as per JORC code can be understood by industry professionals in another country (subject to reciprocity process). A report written as per JORC guidelines in Brazil can be used for raising funds in Hong Kong Stock exchange. An investor from another country where a CRIRSCO template based code is used can use the reports written as per JORC code in Nigeria. The two bauxite blocks have been classified according to degree of investigation (Fig. 3 and 4).

The measured resource is that part for which quantity, grade or quality, densities, shape, and physical characteristics are so well established and estimated with confidence sufficient to allow the appropriate application of technical and economic parameters, to support production planning and evaluation of the economic viability of the deposit. The estimate was based on detailed and reliable exploration, sampling and testing information gathered through pitting that are spaced closely enough to confirm both geological and grade continuity (Fig. 4).

The inferred resource is that part of resource for which quantity and grade or quality were estimated on the basis of geological evidence and limited sampling and reasonably assumed, but not adequately verified. The estimate was based on limited information and sampling gathered from pits (Fig. 5).
### TABLE I: RESOURCE ESTIMATION FOR BLOCK I OF THE MAMBILLA BAUXITE DEPOSIT

| Block No. | Location of Block | Shape of ore body | Classification of Resource | Area of ore body within profile (m²) | Area of ore body in adjacent profile (m²) | Average area of ore body (m²) | Average thickness of ore body (m) | Volume of ore body in block (m³) | Bulk density of ore (Tons/m³) | Average Al₂O₃ content per block C (%) | Reserve of ore per block Q = VD tons | Total tonnage (B + C) |
|-----------|------------------|------------------|----------------------------|-------------------------------------|-------------------------------------------|-----------------------------|---------------------------------|---------------------------------|-----------------------------|---------------------------------|---------------------------------|-----------------|
| 1         | Between profile I and profile II | Prism | Measured (B) | 35708 | 115617 | 75662.5 | 3 | 226987.5 | 45.20 | 567468.75 | 753952.5 |
|           |                  |                  | Inferred (C) | 14168 | 35561 | 24864.6 | 24864.6 | 24864.6 | 319418 | 74593.5 | 798545 |
| 2         | Between profile II and profile V | Prism | Measured (B) | 35956 | 9837 | 22999 | 4 | 90796 | 46.26 | 226900 | 102535 |
|           |                  |                  | Inferred (C) | 44092 | 10943 | 10390 | 10390 | 10390 | 39142 | 41560 | 420130 |
| 3         | Between profile V and profile VI | Prism | Measured (B) | 44092 | 9837 | 22999 | 4 | 90796 | 46.26 | 226900 | 102535 |
|           |                  |                  | Inferred (C) | 39934 | 39136 | 39535 | 39535 | 39535 | 36236 | 158140 | 393530 |
| 4         | Between profile VI and profile VII | Prism | Measured (B) | 39136 | 132307 | 85721.5 | 4 | 342886 | 42.36 | 857215 | 971940 |
|           |                  |                  | Inferred (C) | 7175 | 15770 | 11472.5 | 4 | 45890 | 42.36 | 857215 | 971940 |
| 5         | Between profile VII and profile VIII | Prism | Measured (B) | 132307 | 39136 | 85721.5 | 4 | 342886 | 42.36 | 857215 | 971940 |
|           |                  |                  | Inferred (C) | 15770 | 7175 | 11472.5 | 4 | 45890 | 42.36 | 857215 | 971940 |

Measured = 3,895,923.75; Inferred = 837,413.75; Grand Total = 4,733,337.5 metric tons.

### TABLE II: RESOURCE ESTIMATION FOR BLOCK II OF THE MAMBILLA BAUXITE DEPOSIT

| Block No. | Location of Block | Shape of ore body | Classification of Resource | Area of ore body within profile (m²) | Area of ore body in adjacent profile (m²) | Average area of ore body (m²) | Average thickness of ore body (m) | Volume of ore body in block (m³) | Bulk density of ore (Tons/m³) | Average Al₂O₃ content per block C (%) | Reserve of ore per block Q = VD tons | Total tonnage (B + C) |
|-----------|------------------|------------------|----------------------------|-------------------------------------|-------------------------------------------|-----------------------------|---------------------------------|---------------------------------|-----------------------------|---------------------------------|---------------------------------|-----------------|
| 1         | Between profile I and profile II | Prism | Measured (B) | 19510 | 3290 | 23851.5 | 4 | 95406 | 50.20 | 238515 | 254965 |
|           |                  |                  | Inferred (C) | 28193 | 28409 | 28301 | 1645 | 6580 | 50.20 | 283010 | 291955 |
| 2         | Between profile II and profile III | Prism | Measured (B) | 28409 | 1789 | 28607.5 | 4 | 113204 | 46.26 | 8945 | 286075 | 304245 |
|           |                  |                  | Inferred (C) | 28806 | 1845 | 115372 | 894.5 | 3578 | 46.26 | 18170 | 288430 |
| 3         | Between profile III and profile IV | Prism | Measured (B) | 28806 | 1845 | 28843 | 4 | 115372 | 50.67 | 288430 | 297655 |
|           |                  |                  | Inferred (C) | 1845 | 2877 | 3690 | 28828.5 | 4 | 115372 | 50.67 | 288285 |
| 4         | Between profile IV and profile V | Prism | Measured (B) | 28880 | 2877 | 28828.5 | 4 | 115372 | 50.67 | 288285 | 282825 |
|           |                  |                  | Inferred (C) | 2877 | 23973 | 26375 | 4 | 105500 | 43.40 | 263750 | 263750 |
| 5         | Between profile V and profile VI | Prism | Measured (B) | 2877 | 23973 | 26375 | 4 | 105500 | 43.40 | 263750 | 263750 |
|           |                  |                  | Inferred (C) | 2877 | 23973 | 26375 | 4 | 105500 | 43.40 | 263750 | 263750 |
| 6         | Between profile VI and profile VII | Prism | Measured (B) | 23973 | 17931 | 20952 | 4 | 83808 | 42.36 | 209520 | 271115 |
|           |                  |                  | Inferred (C) | 3569 | 8750 | 6159.5 | 20952 | 42.36 | 271115 |
| 7         | Between profile VII and profile VIII | Prism | Measured (B) | 17931 | 22405 | 20168 | 4 | 80672 | 43.21 | 201680 | 270760 |
|           |                  |                  | Inferred (C) | 8750 | 5066 | 6908 | 20168 | 43.21 | 201680 |
| 8         | Between profile VIII and profile IX | Prism | Measured (B) | 22405 | 1493 | 25649.5 | 4 | 102598 | 43.38 | 256495 | 289285 |
|           |                  |                  | Inferred (C) | 5066 | 1493 | 25649.5 | 4 | 102598 | 43.38 | 256495 |
| 9         | Between profile IX and profile X | Prism | Measured (B) | 25649.5 | 1493 | 25649.5 | 4 | 102598 | 44.74 | 256495 | 263960 |
|           |                  |                  | Inferred (C) | 1493 | 1493 | 25649.5 | 4 | 102598 | 44.74 | 256495 |

Measured = 2,572,255; Inferred = 223,720; Grand Total = 2,795,975 metric tons.
B. Summary of Mambilla Mineral Resource Estimate

Over the last three years, there have been great progress and increase in size of geological confidence in the Mambilla bauxite mineral resource and resource estimate, as the level of knowledge and geological understanding of the Project has grown. The general relationship between the exploration phase (Mineral Resources) and the development phase (Ore Reserves) is best illustrated by Fig. 5, which is taken from the JORC Code [25] and is populated with the updated Mineral Resource and Ore Reserve numbers of Mambilla bauxite.

VI. Conclusion

The block method of vertical geological cross-section was employed for mineral resource estimation of the Mambilla Bauxite Deposits (Block I and Block II) which have been explored by pitting on a regular grid pattern of 100 m × 100 m. This was done strictly in compliance with JORC reporting standard. The total mineral resource of Mambilla Bauxite Deposits has been estimated to be 7,529,312.5 metric tons – Block I (Mayosumsum area) stand at 4,733,337.5 metric tons with an area of 500,248 m² and Block 2 (Gurgu area) stand at 2,795,975 metric tons covering an area of 276,797 m². The bauxite deposit in Block 2 has met the requirement for metallurgical grade bauxite as compared to the standard specification. While, result of Block 1 show deficiency of such requirement and cannot be used in metallurgical industry but can be considered for other purposes with improvement in technology in the future.

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TABLE III: UPDATED MINERAL RESOURCE FOR MAMBLIA BAUXITE

| Classification | Tons (Mt) | Al₂O₃ | SiO₂ | Fe₂O₃ | TiO₂ | LOI |
|----------------|-----------|-------|------|-------|------|-----|
| Block 1        |           |       |      |       |      |     |
| Measured       | 3,895,923.7 | 45.45 | 22.5 | 21.50 | 4.0  | 20.0|
| Inferred       | 837,413.75 | 37.15 | 25.6 | 23.80 | 5.12 | 17.3|
| Total          | 4,733,337.5 |       |      |       |      |     |

| Block 2        |           |       |      |       |      |     |
| Measured       | 2,572,255 | 49.0  | 12.3 | 14.80 | 0.85 | 23.2|
| Inferred       | 223,720   | 45.80 | 14.5 | 15.50 | 0.98 | 20.2|
| Total          | 2,795,975 |       |      |       |      |     |

| Combined Block 1 and Block 2 |       |       |      |       |      |     |
| Total                    | 6,468,178.7 |       |      |       |      |     |
| Measured                 | 5       |       |      |       |      |     |
| Total                    | 1,091,133.7 |       |      |       |      |     |
| Inferred                 | 5       |       |      |       |      |     |
| Total                    | 7,559,312.5 |       |      |       |      |     |
CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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