

Original Article

Mineralogy and Geochemistry of Bauxite Ore of Mambilla Plateau, NE Nigeria

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Abstract - The Nigerian economy is heavily dependent on oil and gas, with about 90% of her foreign exchange earnings coming from that sector. The need to diversify the economy has frequently been emphasized, and one of the key areas is solid minerals. Bauxite is one of the ingredients required for the refractory and production of aluminum metal by the Iron and Steel industries. The aim of this research is to determine the mineralogy and chemical composition of the bauxite ore in the Mambilla Plateau. The methods adopted for this study involved channel samples collection, mineralogical and geochemical studies. Sixty (60) pits were excavated at block I, and forty-two (42) pits were excavated at block II on a regular grid interval of 100m x 100m to an average depth of 5m each. A total of two hundred and thirty-eight (238) samples, comprising 120 samples from Block I and 118 samples from Block II, were analyzed. XRD results showed gibbsite as the major mineral phase 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% - 25.13%) and Fe₂O₃ (5.98 % - 21.96%).

Keywords — Mambilla Plateau, XRF, XRD, gibbsite, hematite, kaolinite, quartz

I. INTRODUCTION

The word bauxite is used mainly for lithified and non-lithified residual weathering product, which is rich in alumina and low in alkali metals and alkali earth metals. It comprises mainly one or more hydrated aluminum minerals; gibbsite (Al (OH)₃), diaspore (AlO (OH)), and boehmite (AlO (OH)(Plunkert, 2002), with other impurities such as silica, iron oxides, titanium oxide and other elements in minor to trace amount. Bauxite is typically classified according to its intended commercial application, such as abrasive, cement, chemical, metallurgical and refractory. A bauxite body that is economically mineable at present or in the foreseeable future currently should have chemical

composition of >45% Al₂O₃, <20% Fe₂O₃, and <5%SiO₂ (Gow and Lozej, 1993). The demand for bauxite or aluminum is increasing day by day, and since bauxite deposit has been suspected at Mambilla Plateau, Taraba State, Nigeria, Daya *et al.* (2021) assessed the detailed geology and possible host for the mineralization in the area. They reported that Mambilla Bauxite Deposits-Block I (Mayosumsum area) and Block II (Gurgu area) are located in Sardauna Local Government Area of Taraba State, Nigeria, as a product of residual chemical weathering of volcanic rocks, mainly trachyte. The bauxite occurred as a blanket cover over kaolinite and saprolite. This paper aimed to give the mineralogy and geochemistry of the bauxite deposits of the area. The area falls within the topographic maps of Mambilla and Gashaka sheets 295 and 276, respectively, on the scale of 1:30,000. It is bounded by latitude 6o 56'N and 7o 1' 30" N, longitude 11o 30'E, and 11o 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.

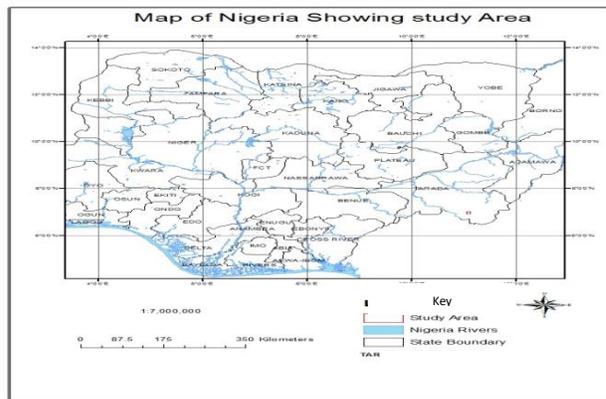


Fig. 1: Map of Nigeria Showing Study Area



II. LITERATURE REVIEW

Many previous workers (Simpson and Gibson, 1907; Saint-Smith, 1912; Simpson, 1912; Tomich, 1964; Grubb, 1966; Baker, 1971; Baker, 1972; Davy, 1979a; Murray, 1979; Loughnan and Sadleir, 1984) have noted the strong association between bauxite deposits and granitic parent rocks. The bauxite deposits at Jarrahdale, Huntly, Del Park, and Willowdale possess a chemical composition and mineralogy consistent with derivation from granite, whereas bauxite at Mount Saddleback (Ball and Gilkes, 1987) reflects a mafic parent rock. Grubb (1971) additionally postulated a fluvial sediment component to the bauxites at Jarrahdale. The major chemical components of bauxitic laterite are Al, Si, Fe, and oxygen. The relative concentrations of Al, Si, and Fe are a function of parent rock mineralogy and chemistry and variable enrichment and depletion processes that operate during the weathering and lateralization of these parent rocks. Because of Al, and particularly Al₂O₃, contents of bauxitic laterite are largely dependent on the variable concentration levels of Si and Fe; factors governing the behavior of these elements are considered first. Relatively high (generally 15-30%) SiO₂ contents in bauxitic laterite derived from granite (and other quartz-bearing materials such as quartzo-feldspathic sediments) are due to the fact that where SiO₂ in a parent rock is present chiefly in the form of quartz, the resistance to the breakdown of this mineral during lateralization results in its retention in the profile, with only moderate loss by dissolution. In contrast, mafic rocks such as basalt and dolerite contain less total SiO₂ (about 50% compared with 65-75% in granitoids), and this is present chiefly in the form of feldspar and ferromagnesian minerals. Feldspar and ferromagnesian minerals are far more reactive than quartz during lateralization and, as they break down firstly to clay and then gibbsite, SiO₂ is liberated and leached from the laterite residue.

Silica values decrease markedly up the profiles above mafic parent rocks, with major reductions occurring at the clay-friable unit boundary. The SiO₂ content of bauxitic laterite over mafic volcanic rocks is less than 5%, but most of this is reactive silica within clay minerals. The Fe content of mafic parent rocks is far greater than that for granite (15-20% Fe, O, compared with 2-5% Fe, O. Iron retention or enrichment during lateralization results in bauxitic laterite derived from mafic rocks being far more ferruginous than granite-derived bauxitic laterite (Davy and El-Ansary, 1986). In the laterite profile, Fe is generally enriched towards the surface, except in the pallid clay zone where it is depleted. One reason for this behavior is the different solubility of the ferrous and ferric ions. In reducing and more acidic parts of the weathering profile, the more soluble ferrous ion predominates. Alumina contents in bauxitic laterite derived from granite and mafic rocks are similar and show enrichment to about three times the concentration in the parent rocks. The relatively high feldspar content of granite, compared with that of mafic rocks, is offset by the fact that

K-feldspar, and to a lesser extent sodic plagioclase, is less susceptible to weathering than calcic plagioclase (dominant in mafic rocks). Moreover, the quartz content of granite, which substantially remains in the laterite profile, effectively dilutes the Al, O, content of granite-derived bauxitic laterite. Alumina enrichment in granite derived profiles results from partial dissolution of quartz, and major SiO₂ loss from feldspar, combined with an almost total loss of Mg, Ca, Na, and K ions; Al₂O₃ enrichment in mafic rock-derived profiles results from almost total loss of SiO₂, with almost total loss of Mg, Ca and Na ions.

The concentrations of trace elements are also dependent on the source rock. In general, the concentration levels of elements such as Cr and Cu are higher in profiles over mafic rocks, whilst those of Zr and Ga are higher in profiles over intermediate-felsic rocks. Gallium and Cr, however, are enriched residually whilst Cu, Zn, Co, Ni, Mn, and rare-earth elements are grossly depleted near-surface (Sadleir and Gilkes, 1976; Davy and El-Ansary, 1986). Some secondary deposition of Co, Mn, and, possibly, rare-earth elements may occur near the base of the clay zone, where conditions change from reducing to oxidizing. It is doubtful whether any element can be classed as truly residual; estimates based on bulk density measurements at the Boddington Gold Mine (Davy and El-Ansary, 1986; Monti, 1987) suggest that at least minor loss of elements such as Ti and Zr has occurred. The nexus between bedrock geology and topography is noteworthy. Bedrock has influenced the evolution of the landscape on which bauxitic laterite formed, as well as having had a bearing on lateritic processes and products. The surface affected by lateralization and bauxitization had already been subjected to sufficient uplift and erosion to form a dissected plateau or 'range' of relief comparable with that seen today (Playford, 1954; Prider, 1966). The topographic characteristics of this eroded landscape were largely determined by the nature of the underlying bedrock.

III. METHODOLOGY

The methods and materials used in carrying out this research are as follows. They involve field methods, mineralogy, and geochemistry of major oxides, respectively.

A. Field Methods

a) Pitting

A total of one hundred and two (102) pits were excavated on a regular grid interval of 100m x 100m comprising sixty (60) and forty-two (42) pits at block I and block II, respectively. The projected depths of these pits were five (5) meters each. However, the actual depths were determined by the interception of saprolite, which generally underlies the bauxite in the two areas. The dimensional area of each pit is 1m x 1m (Fig. 2a).

b) Sampling

The channel sampling method was adopted for bauxite ore. In each of the excavated pits, chips of the bauxite ore were collected vertically and continuously from top to bottom along the walls of the pits into a container, using the flat end of the geologic hammer. The sampling interval was one meter. The samples were collected for Diffraction (XRD), X-Ray Fluorescence (XRF), and Scanning Electron Microscopic analysis. Care was taken to avoid contamination in the samples.

B. Samples Preparation

A total of two hundred and thirty-eight (238) samples, one hundred and twenty (120) samples from block 1, and one hundred and eighteen (118) samples from Block II were prepared for mineralogical and chemical analysis. The samples were broken into pieces using a Jaw crusher and then finally pulverized to powder by vibrating cup miller (Herzog model). The ground samples were obtained having passed through 100 (0.15 micron) mesh sieves to ensure homogeneity of the samples. The powdered sample was mixed with binder Lithium tetra-borate (BORAX). Note that other binders available are Lime and Bentonite. The mixture of the borax and the sample was in the ratio of 4:1grams. This implies that 1g of sample is weighed using Mettler balance and mixed with 4g of the borax. This was mixed evenly and properly using Herzog vibrating cup miller at the speed of 8rpm. The mixture was therefore loaded onto a cup of size 22mm by 40mm made of aluminum material. The pelletizing machine was operated by allowing the stroke movement ups and down only. The pressing force was set at 240N, and the movement stroke was set at 6rpm. The cup containing the mixed sample is placed on the stroke and allowed to go down to the limitation point. On the return of the stroke with the plug already pegged at the loading point, the pressing force pressed the cup against the fixed point, and a Pellet was formed.

C. Laboratory Methods

a) X-Ray Diffraction Analysis (XRD)

An X-Ray diffraction machine (Schimadzu 6000 model) was used for this analysis. The sample was smeared evenly on the sample holder made of aluminum material, with the aid of a smooth slide. It was set between angles of 2 θ to 60 θ degree theta as the bulk sample scanning range running at 6 degrees per minute. The holder was carefully placed on the loading point of the movable Goniometer arm that contains a clamp capable of gripping the sample firmly. The analysis commenced automatically after commanding the software. The pronounced peaks of the Diffractograph are displayed to express the mineral's composition at the various angles of the degree theta.

b) X-Ray Fluorescence Analysis (XRF)

The required parameters were set according to standard. Such parameters are pressure values, set at 16 Pa (Pascal), the environmental chamber for the opening and the lifting of the CASSETTE (a holder that houses the pellet sample), the voltage recommended level was 45v, and the current recommended level was 40A. The equipment was allowed to run for at least 4 to 5hrs to enable the standards and other mechanical parts responsible for analysis to stabilize and initialize. The sample was loaded onto the cassette by placing the surface side facing downward with the help of a spring attached to the cassette, and the cassette was locked manually by turning it clockwise to keep the pellet safe from falling off or scattered on the goniometer when the analysis was going on. The loading point, and the cassette point, was in the position directly facing the Goniometer position for easy analysis. The analysis started immediately as the cassette had been 'lifted down with command L1, which resulted in the closure of the opening valve. After about twenty minutes, the analysis has finished, and the data generation of the raw was collated automatically, followed by the manual results 'drag-dropping technique' onto the save files where the results were produced in oxides forms. The results are produced once the concentration of the parameters involved is equal or greater than the already calibrated and installed standards.

IV. RESULTS

A. Pit excavation

The pits in the study area were excavated on a regular grid interval in order to determine the width and lateral extent of the bauxite ore body (Fig. 2a). The depth of the pits ranges from 4m-7m with a dimension of 1m x 1m. However, termination of the depths depends on the interception of saprolite that generally underlies the bauxite ore. Moreover, the bauxite is occurring under a thin overburden ranging from 0.00m – 0.20m, as clearly observed along with a road cut (Fig. 2b). Bauxite representative sample collected from the pit is usually reddish to brown with greyish stains; very hard and massive (Fig. 2c). The bauxite ridge contains large boulders of hard clay trending the NNE-SSW direction (Fig. 2d). Lithological logs of a few representative pits and the geological log description of all excavated pits are presented in Fig. 3a and 3b, respectively.

B. Laboratory Results

a) X-Ray Diffraction (XRD) Result

The XRD result showed gibbsite as the major mineral phase, kaolinite, and hematite as the minor mineral phases (Fig. 4a,b, and Table 1).

b) X-Ray Fluorescence (XRF) Results

The results of the composition of the major oxide of block 1 and block 2 bauxite deposits are given in Tables 2 and 3. The result of block 1 (Table 2) shows that alumina (Al₂O₃) ranges from 25.0 to 45.0%. Silica (SiO₂) ranges

from 11.50 to 40.50%. The iron (Fe₂O₃) content ranges from 12.74 to 44.90%, and the titanium (TiO₂) ranges from 3.10 to 6.67%. The result of block 2 (Table 3) shows that alumina (Al₂O₃) ranges from 28.79 to 78.20%. Silica (SiO₂) ranges from 2.89 to 38.46%. The iron (Fe₂O₃) content ranges from 7.10 to 38.12%, and the titanium (TiO₂) ranges from 0.21 to 2.38%.

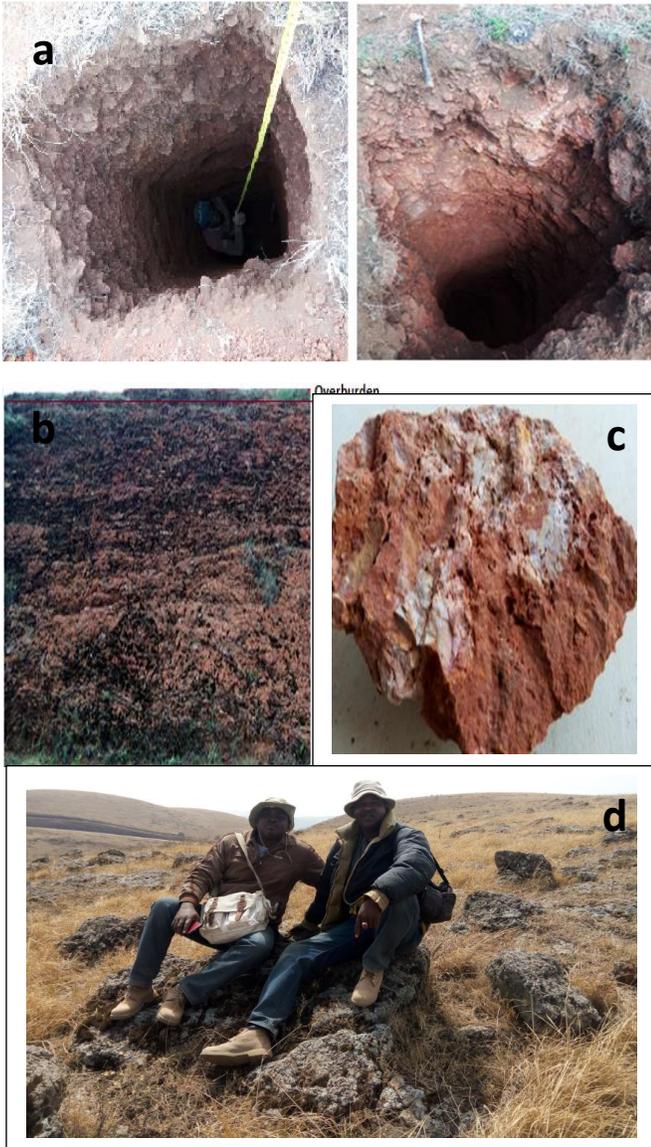


Fig. 2: a) Typical pits excavated on the bauxite deposits
 b) Section of bauxite ore along with road cut
 c) Representative samples of bauxite collected from pits
 d) Outcrop of bauxite ridge at block II

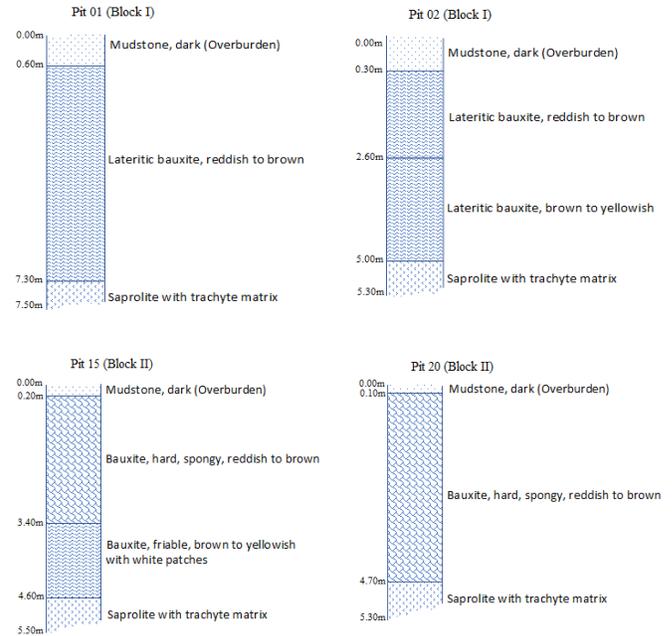


Fig. 3: Documented logs for a few representative pits

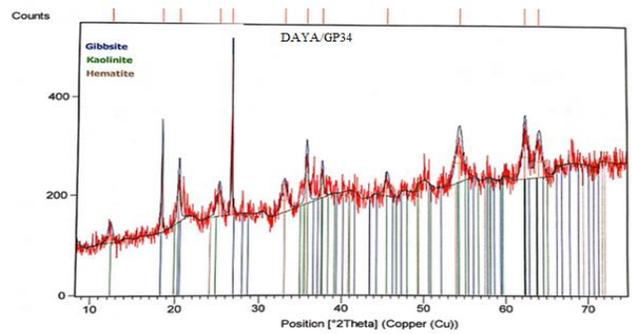


Fig. 4a: XRD Spectrograph

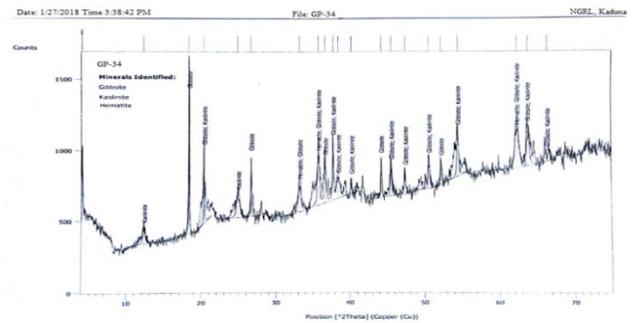


Fig. 4b: XRD Spectrograph

Table 1: Quantitative XRD Result of Representative Sample

Sample ID	Hematite/Goethite	Anatase	Gibbsite	Quartz	Kaolinite/Chlorite
GP-34	4	-	81	3	12
GP-16	3	-	88	2	8
GP-04	3	-	84	2	11
MSS-P01-01	9	2	76	5	13
MSS-P03-01	10	3	69	2	16

Table 2: Major Oxides of Block 1

S/No.	Sample No.	Compound/Oxide (%)			
		Al ₂ O ₃	SiO ₂	Fe ₂ O ₃	TiO ₂
1.	B1/P01/01	43.0	19.0	30.76	5.35
2.	B1/P2/01	36.0	25.0	22.74	4.95
3.	B1/P2/02	39.0	20.1	13.07	5.88
4.	B1/P2/03	25.0	22.5	24.90	3.55
5.	B1/P03/01	36.1	21.5	30.53	6.10
6.	B1/P04/02	33.0	26.5	25.25	6.9
7.	B1/P05/01	38.0	31.0	23.07	5.84
8.	B1/P05/02	31.0	32.0	26.89	6.65
9.	B1/P06/01	40.0	26.0	26.04	6.10
10.	B1/P07/02	36.0	32.0	23.28	5.29
11.	B1/P08/01	45.0	24.0	23.73	5.06
12.	B1/P08/02	36.0	33.0	22.46	5.72
13.	B1/P09/01	43.0	25.0	23.29	5.15
14.	B1/P09/02	37.0	36.0	19.51	5.40
15.	B1/P10/01	30.17	27.40	21.15	6.63
16.	B1/P10/02	34.0	35.0	22.68	5.38
17.	B1/P11/01	35.0	29.0	26.40	6.13
18.	B1/P11/02	37.0	38.0	18.39	4.61
19.	B1/P12/01	34.0	31.0	24.35	5.71
20.	B1/P13/01	34.0	38.0	20.17	4.77
21.	B1/P13/02	32.0	32.0	25.74	6.08
22.	B1/P14/01	36.0	33.0	22.65	5.18
23.	B1/P15/01	36.0	29.0	26.57	6.67
24.	B1/P15/02	37.0	36.0	20.35	5.15
25.	B1/P15/03	32.0	35.0	23.43	6.66
26.	B1/P16/01	41.0	24.0	27.26	4.54
27.	B1/P16/02	38.0	38.0	17.77	4.83
28.	B1/P16/03	36.0	38.0	18.50	4.73
29.	B1/P17/01	42.0	19.0	28.66	6.21
30.	B1/P18/01	38.0	28.0	24.99	6.28
31.	B1/P19/01	37.0	23.0	28.89	6.31
32.	B1/P20/01	43.0	17.0	29.39	6.57
33.	B1/P21/01	45.0	21.0	26.32	5.45
34.	B1/P22/01	36.0	28.0	27.50	6.37
35.	B1/P23/01	33.0	36.0	23.16	5.73
36.	B1/P24/01	33.0	32.0	27.34	4.27
37.	B1/P25/01	41.0	20.0	20.04	5.10
38.	B1/P26/02	33.0	24.0	21.28	5.29
39.	B1/P27/01	46.0	22.0	22.73	5.06
40.	B1/P27/02	38.0	30.0	22.46	5.72

41	B1/P28/01	45.0	21.0	23.29	5.15
42	B1/P28/02	39.0	30.0	14.51	5.40
43	B1/P29/01	35.17	21.40	20.15	4.63
44	B1/P29/02	36.0	31.0	20.68	3.38
45	B1/P30/01	37.0	23.0	23.40	5.13
46	B1/P30/02	36.0	32.0	16.39	3.61
47	B1/P31/01	35.0	28.0	23.35	4.71
48	B1/P32/01	34.0	31.0	20.17	4.77
49	B1/P32/02	32.0	30.0	21.74	4.08
50	B1/P33/01	45.0	12.0	22.66	3.21
51	B1/P34/01	38.0	21.0	20.99	4.28
52	B1/P35/01	37.0	23.0	28.89	6.31
53	B1/P35/02	43.0	17.0	29.39	6.57
54	B1/P35/03	45.0	21.0	26.32	5.45
55	B1/P36/01	36.0	25.0	22.74	4.95
56	B1/P36/02	39.0	40.1	13.07	5.88
57	B1/P36/03	25.0	32.5	44.90	3.55
58	B1/P37/01	36.1	21.5	30.53	6.10
59	B1/P37/02	33.0	26.5	25.25	6.9
60	B1/P38/01	38.0	31.0	23.07	5.84
61	B1/P38/02	31.0	32.0	26.89	6.65
62	B1/P39/01	40.0	26.0	26.04	6.10
63	B1/P39/02	36.0	32.0	23.28	5.29
64	B1/P40/01	37.0	23.0	28.89	6.31
65	B1/P40/02	43.0	17.0	29.39	6.57
66	B1/P40/03	45.0	21.0	26.32	5.45
67	B1/P41/01	36.0	25.0	22.74	4.95
68	B1/P41/02	39.0	40.1	13.07	5.88
69	B1/P41/03	25.0	32.5	44.90	3.55
70	B1/P42/01	38.1	21.5	30.53	6.10
71	B1/P42/02	34.0	26.5	25.25	6.9
72	B1/P43/01	38.0	31.0	23.07	5.84
73	B1/P43/02	33.0	32.0	26.89	6.65
74	B1/P44/01	44.0	22.0	21.04	6.10
75	B1/P44/02	36.0	25.0	22.28	4.29
76	B1/P45/01	42.0	21.0	25.04	5.10
77	B1/P45/02	35.0	23.0	23.28	5.29
78	B1/P46/01	33.0	24.0	16.89	4.31
79	B1/P46/02	43.0	15.0	19.39	3.57
80	B1/P46/03	46.0	17.0	20.32	4.45
81	B1/P47/01	38.0	20.0	21.74	5.95
82	B1/P47/02	40.0	32.1	13.07	5.88
83	B1/P47/03	35.0	32.5	40.90	3.55
84	B1/P48/01	38.1	11.5	30.53	4.10
85	B1/P48/02	36.0	16.5	22.25	5.9
86	B1/P49/01	37.0	21.0	21.07	5.84
87	B1/P49/02	35.0	22.0	22.89	4.65
88	B1/P50/01	42.5	21.0	16.04	3.10
89	B1/P50/02	38.9	22.0	20.28	3.29
90	B1/P50/03	35.40	20.12	19.23	4.09
91	B1/P51/01	36.32	22.0	21.74	4.55
92	B1/P51/02	38.0	30.1	13.07	5.0
93	B1/P51/03	29.0	28.5	24.90	3.40
94	B1/P52/01	39.0	20.0	27.74	4.30

95	B1/P52/02	39.0	33.1	18.07	3.18
96	B1/P52/03	28.0	27.5	33.90	4.45
97	B1/P53/01	36.0	21.0	17.74	4.05
98	B1/P53/02	40.0	22.1	19.07	5.58
99	B1/P53/03	27.0	18.5	29.90	4.05
100	B1/P54/01	38.0	17.0	25.74	4.0
101	B1/P54/02	39.0	31.1	14.07	5.20
102	B1/P54/03	27.0	23.5	31.90	3.50
103	B1/P55/01	40.0	20.0	18.64	4.0
104	B1/P55/02	38.0	27.1	12.27	5.65
105	B1/P55/03	35.0	26.5	32.80	3.25
106	B1/P56/01	46.0	21.0	22.04	4.95
107	B1/P56/02	29.0	20.1	13.0	5.0
108	B1/P56/03	35.0	31.2	16.90	3.55
109	B1/P57/01	39.0	22.0	23.35	3.95
110	B1/P57/02	39.0	24.1	14.75	5.88
111	B1/P57/03	32.0	31.5	26.80	4.55
112	B1/P58/01	39.0	22.0	22.74	4.95
113	B1/P58/02	39.70	33.1	13.07	5.88
114	B1/P58/03	25.80	28.5	44.90	3.55
115	B1/P59/01	38.0	25.0	22.74	4.95
116	B1/P59/02	39.0	40.1	13.07	5.88
117	B1/P59/03	27.0	32.5	44.90	3.55
118	B1/P60/01	42.0	21.0	22.04	4.95
119	B1/P60/02	40.0	380.1	13.37	5.88
120	B1/P60/03	33.0	30.5	43.30	3.55

Table 3: Major Oxides of Block 2

S/No	Samples ID	Compound/Oxide (%)				
		Al ₂ O ₃	SiO ₂	Fe ₂ O ₃	TiO ₂	LOI
1.	GP02/01	39.61	12.21	15.21	0.89	
2.	GP02/02	39.40	5.80	7.50	0.22	
3.	GP02/03					
3.						
4.	GP03/02	56.31	9.47	20.83	1.08	
5.	GP03/03	48.87	18.56	19.99	0.95	
6.	GP03/04	49.6	12.27	13.87	0.80	20.10
7.	GP04/01	43.37	38.46	15.73	1.02	
8.	GP04/02	37.06	31.85	13.94	0.89	
9.	GP04/03	40.49	10.76	16.78	0.93	
10.	GP04/04	38.16	21.52	12.36	0.68	
11.	GP05/01	39.32	23.20	15.51	-	22.74
12.	GP05/02	38.94	24.80	0.03	0.13	20.66
13.	GP05/03	39.70	24.30	15.81	0.80	23.00
14.	GP05/04	44.50	22.88	12.97	0.70	
15.	GP06/02	48.02	18.39	14.46	1.04	
16.	GP06/03	46.15	15.89	17.48	1.08	
17.	GP07/01	40.64	17.32	11.95	0.87	
18.	GP07/02	52.33	11.91	17.76	0.76	
19.	GP08/01	46.30	18.26	13.81	1.08	
20.	GP08/02	44.11	16.12	14.28	1.21	

21.	GP08/03	41.31	17.28	14.45	1.13	
22.	GP08/04	41.23	20.06	16.41	0.94	
23.	GP09/01	38.60	27.08	13.81	0.95	
24.	GP09/02	45.29	12.01	11.87	0.46	
25.	GP09/03	43.04	18.18	14.48	0.61	
26.	GP09/04	36.72	7.28	6.49	0.18	
27.	GP10/01	39.35	11.73	16.65	1.27	
28.	GP10/02	38.10	13.29	8.47	0.57	
29.	GP10/03	41.16	21.24	15.15	0.90	
30.	GP10/04	39.52	20.84	14.55	0.49	
31.	GP11/01	42.68	20.2	17.03	0.95	26.13
32.	GP11/02	54.10	10.10	17.40	1.13	25.77
33.	GP11/03	48.86	7.21	18.29	1.00	24.02
34.	GP12/01	47.07	16.58	14.42	0.80	
	GP12/02					
35.	GP12/03	42.23	9.35	18.42	1.08	
36.	GP13/01	37.27	21.54	12.09	0.31	
37.		41.79	15.38	14.63	0.75	
38.	GP14/01	43.03	7.99	14.28	0.78	28.94
	GP14/02					
39.	GP14/03	46.82	13.75	15.06	0.62	21.57
40.	GP14/04	48.28	5.05	15.94	0.94	26.76
41.		54.8	5.75	19.25	1.04	25.79
42.	GP15/01	51.95	15.47	18.13	1.00	
43.	GP15/02	55.48	6.53	22.66	1.123	
44.	GP15/03	44.47	5.87	14.75	0.92	
45.	GP15/04	44.50	10.10	15.07	0.72	
46.	GP16/01	48.49	14.23	16.16	1.06	
47.	GP16/02	47.47	18.51	19.40	1.30	
48.	GP16/03	42.44	22.99	13.81	0.90	
49.	GP17/01	49.00	23.0	31.44	2.36	23.76
50.	GP17/02	40.00	22.1	32.88	2.38	22.47
51.	GP17/03	45.00	21.4	38.12	2.37	20.76
52.	GP18/01	49.72	16.23	11.42	0.93	
53.	GP18/02	48.75	11.53	11.79	0.68	
54.	GP18/03	45.17	14.16	13.15	0.76	
55.	GP19/01	28.79	4.93	7.69	0.29	
56.	GP19/02	45.05	13.11	17.11	1.03	
57.	GP19/03	43.69	8.67	17.80	0.95	
58.	GP19/04	48.07	5.93	11.31	0.47	
59.	GP20/02	48.36	22.48	11.24	0.24	
60.	GP20/03	46.86	27.79	15.82	0.78	
61.	GP20/04	42.83	25.14	20.17	1.06	
62.	GP21/01	39.52	20.22	13.69	0.74	
63.	GP21/02	42.16	5.25	16.97	0.88	
64.	GP21/03	44.33	11.31	12.73	0.52	
65.	GP21/04	41.59	14.55	12.71	0.24	
66.	GP22/01	49.97	22.55	15.45	1.14	
67.	GP22/02	48.32	21.29	12.24	0.51	
68.	GP22/03	47.61	24.25	12.54	0.75	
69.	GP23/01	48.0	13.0	20.03	2.52	26.54
70.	GP23/02	42.0	5.37	11.45	2.52	22.98
71.	GP23/03	67.5	4.00	8.75	2.04	28.77

72.	GP23/04	61.9	4.13	14.88	1.70	25.82
73.	GP24/01	47.0	15.9	13.45	2.45	24.27
74.	GP24/02	39.0	22.9	16.60	2.37	22.03
75.	GP24/03	39.4	21.8	28.37	1.97	18.03
76.	GP24/04	38.0	27.3	29.45	1.95	21.50
77.	GP25/01	43.61	38.17	16.02	1.18	
78.	GP25/02	42.20	13.31	13.89	0.63	
79.	GP25/04	35.23	15.50	0.01	0.12	
80.	GP26/01	40.85	16.23	12.67	0.73	
81.	GP26/02	39.71	11.90	12.63	0.71	
82.	GP26/03	49.64	10.10	18.42	0.94	
83.	GP27/01	42.65	13.07	12.77	0.53	
84.	GP27/02	47.39	14.35	12.74	0.70	
85.	GP27/03	66.99	11.17	8.87	0.22	
86.	GP27/04	45.97	15.87	12.92	0.55	
87.	GP28/01	39.47	21.20	12.16	0.86	
88.	GP28/02	43.67	16.14	10.48	0.77	
89.	GP28/03	38.37	20.02	13.22	0.80	
90.	GP29/01	40.47	22.96	14.78	1.12	
91.	GP29/02	39.78	15.78	10.68	0.67	
92.	GP29/03	43.44	19.92	12.97	0.81	
93.	GP29/04	38.67	15.18	8.73	0.39	
94.	GP30/01	42.00	20.57	15.42	0.99	
95.	GP31/01	49.48	13.01	20.86	1.42	
96.	GP31/02	45.25	8.94	13.79	0.74	
97.	GP31/03	44.58	20.03	12.70	0.69	
98.	GP32/02	44.92	2.89	20.41	1.26	
99.	GP3/01	29.73	6.36	5.50	0.21	
100.	GP33/02	45.78	13.35	15.02	1.06	
101.	GP34/01	78.20	5.72	5.98	0.20	
102.	GP35/01	55.0	9.00	16.29	1.91	21.09
103.	GP35/02	77.5	3.14	18.71	1.46	18.21
104.	GP35/03	56.0	4.00	16.09	1.91	22.52
105.	GP36/01	42.4	5.09	28.97	1.32	20.28
106.	GP36/02	45.0	19.0	31.31	1.69	20.75
107.	GP37/01	43.53	13.32	16.14	1.16	
108.	GP37/02	29.73	11.34	13.16	0.93	
109.	GP38/01	48.96	14.79	12.44	1.01	24.05
110.	GP38/02	39.46	17.27	20.68	1.36	
111.	GP39/01	49.45	20.08	15.06	1.20	
112.	GP39/02	41.95	13.62	20.23	1.78	
113.	GP40/01	33.52	15.16	13.57	1.02	
114.	GP40/02	44.47	13.82	18.88	1.25	
115.	GP41/01	41.84	20.79	15.49	0.81	
116.	GP41/02	47.77	15.72	13.89	0.59	
117.	GP42/01	46.89	12.15	21.88	1.21	
118.	GP42/02	48.08	4.37	12.27	0.68	

V. DISCUSSIONS

A. Mineralogical Characteristics

Bauxite must generally be composed of one of the hydrated minerals; boehmite, gibbsite, or diaspor. Both

quantitative and spectrographic analyses of Mambilla bauxite showed gibbsite as the major mineral phase, while kaolinite and hematite occurred in minimal percentages. The quantitative analysis showed gibbsite ranging from 69% to 88%, Kaolinite from 8% to 16%, and Hematite 4% to 10%, corresponding to the spectrographic result proportionately

(Fig. 4a and 4b respectively). Other minor mineral phases are Anatase 2-3% and Quartz 2-3% (Fig. 3).

B. Major Oxides Geochemistry

Bauxite is the principal ore for aluminum production. The aim is to extract alumina from the aluminum compound. A bauxite body that is economically mineable at present or in the foreseeable future currently should have chemical composition of >45% Al₂O₃, <20% Fe₂O₃, and <5% SiO₂ (Gow and Lozej, 1993). The result of XRF analysis showed Al₂O₃ constituting the higher percentage of oxides, followed by Fe₂O₃ and SiO₂. Therefore, Fe₂O₃ and SiO₂ are the major impurities. Other minerals compounds occurred in trace amounts. The results of the composition of the major oxide of block 1 and block 2 bauxite deposits are given in Tables 2 and 3. The result of block 1 (Table 2) shows that alumina (Al₂O₃) ranges from 25.0 to 45.0%. Silica (SiO₂) ranges from 11.50 to 40.50%. The iron (Fe₂O₃) content ranges from 12.74 to 44.90%, and the titanium (TiO₂) ranges from 3.10 to 6.67%. The result of block 2 (Table 3) shows alumina (Al₂O₃) ranges from 28.79 to 78.20%. Silica (SiO₂) ranges from 2.89 to 38.46%. The iron (Fe₂O₃) content ranges from 7.10 to 38.12%, and the titanium (TiO₂) ranges from 0.21 to 2.38%, displaying alumina to be higher in percentage compared to silica and iron oxides. It is clear from the comparative chemical analysis results (Table 3) that the result of the major oxide analysis of block 2 has seemingly conformed to the metallurgical bauxite requirement IS 5953-1985 (Reaffirmed 2008)(Indian Bureau of Mines, 2015). While the result of block 1 shows the deficiency of such requirement and cannot be used in the metallurgical industry but can be considered for other purposes with improvement in technology in the future.

VI. CONCLUSIONS

The bauxite of the Mambilla area was studied by exploratory pitting. Sixty (60) pits and forty-two (42) pits with the depth of 5m and area 1m x 1m each, on a grid pattern of 100m x 100m, were dug on Block 1 and Block 2 of the deposits, respectively. The pits were carefully logged and documented. A total of two hundred and thirty-eight (238) samples, comprising 120 samples from Block I and 118 samples from Block II, were obtained and analyzed. The deposits are found to be 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). The characteristics of the ore are: For Block 1: Alumina (Al₂O₃) ranges from 32.10% to 45.0%, Silica (SiO₂) 17.0% to 33.0% and Iron oxide (Fe₂O₃) 17.46% to 30.70%. For Block 2: Alumina (Al₂O₃) ranges from 39.50% to 78.20.0%, Silica (SiO₂) 2.89% to

25.13% and Iron oxide (Fe₂O₃) 5.98% to 21.96%. Details of the reserve estimates are underway in our last article on this subject.

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