Characterization and Beneficiation of Ajabanoko Iron Ore, Kogi State, Nigeria

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Abstract*: Characterization and beneficiation of Ajabanoko iron ore was investigated using scanning electron microscopy, X-ray fluorescence, powder X-ray diffraction, magnetic separator and petrological microscopy. Chemical analysis of the ore principally revealed that the ore contained 36.4% SiO_2, 28.97% Fe_3O_4, 9.53% CaO, 7.2% TiO_2, 8.41% V_2O_5, 0.765% Al_2O_3, 0.23% PbO, 0.72% BaO, 0.65% Cr_2O_3, 0.19% Rb_2O and 0.27% Eu_2O_3, the mineralogical analysis of the ore contained majorly magnetic, biotite and quartz with other minor associated minerals, petrographic studies of the thin section of the ore sample observed under polarized light revealed that the iron bearing mineral is magnetite and biotite with quartz, SEM examination revealed that the lighter portion is majorly the iron ore, whereas the dark portions are the gangue minerals. Beneficiation of the iron ore indicated that the iron (Fe) of the ore can be upgraded from 47.56% to 51.73%Fe using low intensity magnetic separation technique. Ajabanoko iron ore is classified as a low grade iron ore

***Keywords*: Characterization, Beneficiation, Ajabanoko, Iron ore**

I. INTRODUCTION

Iron ore is the primary source of iron and steel industry, which is essential for steel production. Owing to relative abundance of iron ore, it is the most widely used metal with very wide area of utilization (Yersel, 1992). Iron ore is a mineral substance which when heated in the presence of a reductant will yield metalliferous iron (Fe), and it's the primary source of iron for the world iron and steel industries. The overburden in iron mines consists of weathered ore with clay particles and mainly lateritic layers along with low iron content (Weiss NL (ed) (1985)). For an iron ore deposit to be considered economically recoverable, it must contain at least 25% iron (USEPA (1994), however ores with iron content lower than 25% can be economically exploited if the ore deposit is large (economy of scale), can be concentrated (beneficiation), and can be transported cheaply.

The most widely available iron-bearing minerals are oxides and consist mainly of hematite (Fe_2O_3), which is red, magnetite (Fe_3O_4), which is black; limonite or bog-iron ore ($2Fe_2O_3 \cdot 3H_2O$), which is brown, and siderite ($FeCO_3$), which is pale brown. Hematite and magnetite are by far the most common types of iron ore. Pure magnetite contains 72.4 % Fe, hematite 69.9% Fe, limonite 59.8% Fe and siderite 48.2% Fe but since these minerals never occur alone, the main iron (Fe) content of the ores is lower due to other impurities (Salawu, 2015).

Based on the % Fe content, the iron ore deposits in Nigeria could be classified as rich ores (> 50 % Fe), medium grade ores (30 – 50 % Fe) and lean ores (25 – 30 % Fe) which respectively constituted 4.5%, 85.4% and 13.1% of the total iron ore reserves (Ohimain, 2013). Medium and low-grade ores require extra technology to process the ores to meet the required standard for iron and steel production (Singh *et al.*, 2015).

The Ajabanoko area consists of a set of three closely related hills of basement rocks in which some large bands of iron ore occur. The ferruginous quartzite is the source of the iron ore mineralization in the area (Olade, 1978). These three hills which mark the Southern, Central and Northern ore zones are made up mainly of magnetite and biotite gneisses which trend in a northeast-southwest direction and dip mostly westwards. The dominant lithologic units of Ajabanoko deposit area are gneiss of magnetite, biotite and granite, ferruginous quartzites, granites and pegmatite (Amigun and Ako, 2009). The nature of Ajabanoko iron ore deposit and the associated rocks indicate that they are residual concentrates derived from iron rich sediment, a volcanogenic sedimentary material (National Steel Development Authority (NSDA), 1976). This suggests that all the rocks in the area including the high grade metamorphic ones such as the gneisses and the low grade metamorphic ones such as the quartzite's may have been derived from sedimentary materials which in turn were probably derived from an ancient volcanic source (National Steel Raw Materials Exploration Agency (NSRMEA), 1994), four principal ore layers have been identified for the different ore zones (Nnagha, 1997). The sum total of iron ore reserves in the entire deposit (Ajabanoko) is 62.104 million tons. Oladunni *et al.,* (2016) investigated the froth flotation of Ajabanoko iron ore deposit in Kogi State and reported that the results obtained from the work fell short of this standard; hence, the use of floatation reagents is not advisable for upgrading low grade Ajabanoko iron ore.

Limited studies have been conducted on the Ajabanoko iron ore deposit. The geological location of the study area is shown in Figure 1

Figure 1: Geological location of the study area (Ajabanoko deposit): (Adebimpe and Akande, 2017)

II. EXPERIMENTAL PROCEDURE

The iron ore deposit is located in Eika, Okehi Local Government Area of Kogi State, Nigeria. The deposit is bounded by latitudes 7^0 33' 0"N' and longitudes $6^o14'0"E$, and the location is along Okene/Lokoja express way. It is about 4 km away from itakpe iron ore deposit and shown in Plates I a and b respectively

Plates I: (a) Outcrop of the iron ore deposit;

(b) Sourced iron ore sample

The equipment used are Global positioning system (GPS), Laboratory sledge hammer, Laboratory jaw crusher, Ball mill, Set of sieves, X-ray florescence (XRF) machine, X-ray diffractometer (XRD) machine, Petrological microscope, Scanning electron microscope (SEM) and Low intensity magnetic separator. Comminution process (size reduction) such as grinding and crushing were carried out; the sample was crushed by jaw crusher and pulverized using ball mill into composite sample. The powder composite samples were taken for XRF analysis to determine the chemical composition, XRD analysis to determine the mineral phases, petrographic analysis to identify rocks and minerals in thin sections and low intensity magnetic separator was used to separate the ore into concentrate and tailing mainly to increase the iron content of the concentrates.

III. RESULTS AND DISCUSSION

A. Results

XRF studies

Table 1: Results for chemical analysis result of the ore Head Sample as determined using XRF

Oxide Composition	Assay(%)
SiO_2	36.4
CaO	9.53
K_2O	6.35
TiO_2	7.2
V_2O_5	8.41
MnO	ND
Fe_3O_4	**28.97**
CuO	0.215
Al_2O_3	0.765
ZnO	ND
Rb_2O	0.19
PbO	0.23
BaO	0.72
Cr_2O_3	0.65
Eu_2O_3	0.27
P_2O_5	ND

Mineralogical analysis

The XRD pattern is shown (Figure 2)

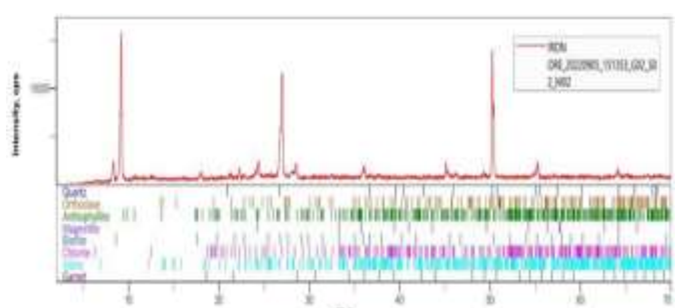

Figure 2: The XRD pattern of Ajabanoko iron ore

Table 2: Shows the XRD analysis result of the composite sample

Mineral Name	Chemical Name	Chemical Formula
Quartz	Silicate	SiO_2
Magnetite	Iron Oxide	Fe_3O_4
Biotite	PotassiumIron Magnesium AluminumSilicateHydroxide	$(K(Mg,Fe)_3AlSi_3O_{10}(OH)_2)$

Microscopic examination

Scanning electron microscopy

The SEM micrograph is shown in plate II

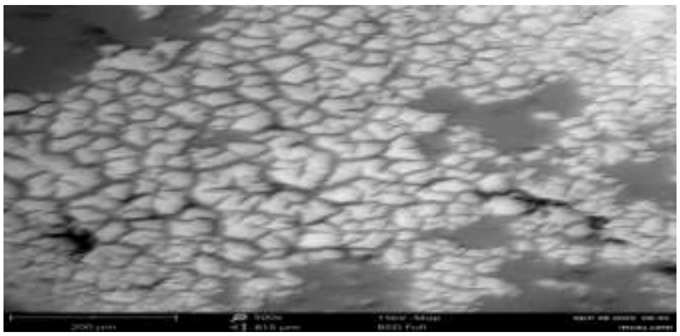

Plate II: SEM of the Head Sample

The petrographic micrograph is shown in plate III

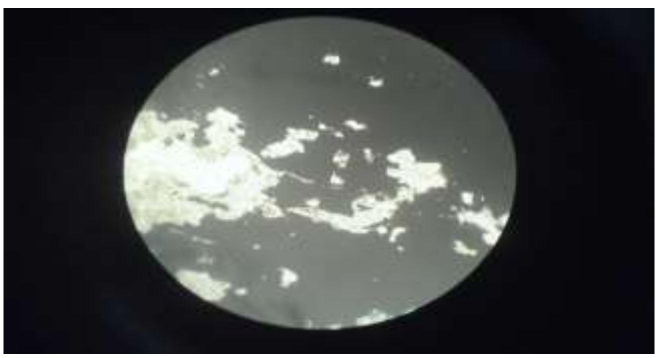

Plate III: Micrograph of Head Sample

Beneficiation process (using magnetic separator)

Table 3: Shows the composition of the concentrate and the tailing after magnetic concentration

Compound	Concentrate	Tailing
SiO_2	18.83	30.14
Al_2O_3	2.3	5.71
K_2O	1.07	0.63
CaO	3.01	2.89
Cr_2O_3	<LOD	4.0
PbO	<LOD	3.23
Fe_3O_4	73.16	38.11
Eu_2O_3	<LOD	4.21
BaO	0.13	0.58
Zr_2O	2.14	0.044

Table 4: Shows the percentage distribution of material after the magnetic concentration and recovery

Product	Weight (g)	% Assay		Unit		% Recovery	
		Fe	SiO_2	Fe	SiO_2	Fe	SiO_2
Feed	250	47.56	21.08	12570	3462	100	100
Concentrate	168.12	51.73	17.31	8731.05	2018.41	75.21	47.15
Tailing	68.52	28.79	30.19	1990.22	2231.07	16.23	49.1
Loss	13.34	-	-	-	-	8.56	3.75

B. Discussion

From Table 1, the XRF results revealed that the ore contained 36.4% SiO_2, **28.97% Fe_3O_4,** 9.53% CaO, 7.2% TiO_2, 8.41% V_2O_5, 0.765% Al_2O_3, 0.23% PbO, 0.72% BaO, 0.65% Cr_2O_3, 0.19% Rb_2O and 0.27% Eu_2O_3, the iron content of the ore is within the acceptable range of 25-50% Fe for low grade iron ore standard. The low content of phosphorus as well as the absence of sulphur in the ore result shows that the ore can be exploited in iron and steelmaking. From (Figure 1& Table 2), the mineralogical composition of the ore sample; it can be observed that the ore contained quartz (SiO_2), magnetite (Fe_3O_4), and biotite ($K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$) as the major mineral phases while other associated mineral phases are minor, this could be due to ore geochemical mineralization processes resulting in minerals assemblage in the ore matrix; the mineralogical composition of the ore is similar and comparable with some major iron ore deposits earlier worked upon and cited in the literature (Thomas and Yaro, 2007). From SEM micrograph (Plate II), the image of the Ajabanoko iron ore revealed the clarity of the oolitic nature of the ores; the lighter portion is majorly the iron ore, whereas the dark portions are the gangue minerals. From the micrograph, it is observed that the minerals are separated by grain boundaries and the mineral particles differ in sizes as reported by Salawu *et al.,* (2015). From the petrographic micrograph (plate III), three mineral phases were revealed under polarized light, namely magnetite and biotite (black), quartz (colourless), the result correlate with the XRD analysis which revealed that the major mineral phases are magnetite, biotite and quartz. From Table 3, the chemical analysis shows that the concentrate contained 73.16%Fe_2O_3 (51.73%Fe) and 17.31% SiO_2, while the tailing gave 38.11% Fe_2O_3 (28.79%Fe) and 30.19% SiO_2.The result is attributed to the fact that the iron mineral (magnetite) is liberated from its associated minerals since iron mineral of magnetite type is magnetic in nature, and SiO_2 mineral present in the tailing. From Table 4, the metallurgical balance of the processed Ajabanoko iron ore shows that the concentrate contained 51.73%Fe with recovery of 75.21%Fe. This means that there is an upgrade in the iron content from 47.56%Fe in the feed to 51.73%Fe in the concentrate after magnetic separation.

IV. CONCLUSIONS AND RECOMMENDATION

Conclusions

i. The chemical analysis revealed that the iron ore contained 36.4% SiO_2, **28.97% Fe_3O_4,** 9.53% CaO, 7.2% TiO_2, 8.41% V_2O_5, 0.765% Al_2O_3, 0.23% PbO, 0.72% BaO, 0.65% Cr_2O_3, 0.19% Rb_2O and 0.27% Eu_2O_3
ii. The mineralogical analysis of the ore revealed that the iron bearing minerals are predominantly Magnetite and Biotite
iii. Beneficiation of the iron ore indicates that the iron (Fe) of the ore can be upgraded from 47.56% to 51.73%Fe using low intensity magnetic separation technique.
iv. Based on the results, Ajabanoko iron ore is a low grade ore can be used in iron and steel production.

Recommendation

Other beneficiation procedures like gravity separation and electrostatic separation is recommended for the production of super concentrate Ajabanoko iron ore.

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