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PRELIMINARY PROCESS MINERALOGY OF AGBADO-OKUDU. IRON ORE DEPOSIT, KOGI SOUTH-WESTERN NIGERIA

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ABSTRACT

Preliminary studies were carried out on samples of the low grade Agbado-Okudu iron ore deposit to characterize the ore prior to beneficiation. The iron ore is metasedimentary in origin and belong to the Precambrian Basement Complex rocks of Nigeria. Methods employed in the study include the use of transmitted and reflected light microscopy, screen analysis and chemical analysis. The result of microscopy indicate that the major minerals in the Iron ore are hematite and quartz with minor magnetite chemical analysis reveals Fe as 34.00%, SiO_2 is 49.50%, Al_2O_3 is 2.5% and P and S less than 1%. Textural relationship of the minerals, grain size, locking characteristics and screen analysis coupled with chemical analysis of the ore indicates that the ore can be upgraded using relatively cheap and economical methods of Air-floatation and Gravity separation techniques to produce concentrates that meet the feed specifications of blast furnace operation of 60% Iron total (Fe_{total}).

KEYWORDS: Iron Ore, Beneficiation, Hematite, Magnetite and Agbado-Okudu.

INTRODUCTION

To sustain the Nigeria Iron and steel industries the Federal Government of Nigeria has been searching for supplementary iron ore deposits. The occurrences of iron ore deposit in Nigeria are in two main types, namely – metamorphic and sedimentary. They occur extensively in different parts of the country with the large concentration in Kogi state, south-western Nigeria. Agbado-Okudu, the ore under study is one of the many ores in the region that belong to the metamorphic types, which occur in bands and are generally referred to as "ferruginous quartzite".

Microscopic studies were carried out on the prepared polished blocks and thin section of the ore in order to obtain information on the mineralogical composition, grain size, locking type and textural relationship needed by the mineral processing engineer for the beneficiation of the ore. Chemical analysis and screen analysis were also carried out in order to develop a suitable process route for the beneficiation of the ore.

GEOLOGY OF AGBADO - OKUDU IRON ORE

The Agbado-Okudu is located in Kogi, South-Western Nigeria. The deposit falls within the Basement Complex of South Western, Nigeria. It occurs in the meta-sedimentary iron formation belonging to Lokoja-Okene-Kabba triangle which hosts most of the Nigerians Pre-Cambrian low-grade iron ore deposits (Fig. 1).

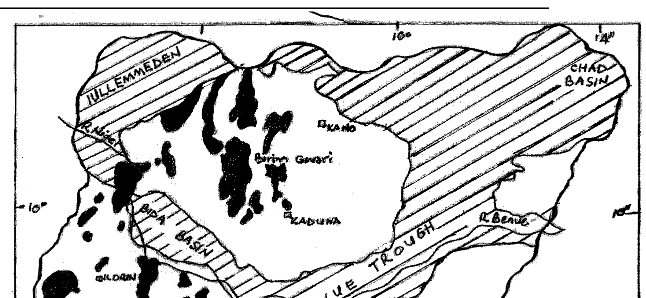

Fig1: Map of Nigeria showing the Study Area

The area is rich in banded Iron Formation (BIF) associated with sequences of gneiss, schist, and minor intruded granites masses, veins and dykes of pegmatite and quartz (Hockey, 1986).

METHODOLOGY

A total of 8 Polished and 4 thin sections of the sample were prepared at National Metallurgical Development Center (NMDC), Jos and University of Jos and studied using both reflected and transmitted microscope (Plate1**)**. Representative samples of the

Ore were crushed through the Jaw, cone and roll crusher respectively. 500g of the crushed Ore was weighed and placed on the top sieve of the following sequence of sieve series; 1.4mm, 1.0mm, 0.71mm, 0.50mm, 0.35mm, 0.25mm, 0.18mm, 0.125mm, 0.09mm and 0.063mm, set from coarsest to the finest fining downward, on a sieve shaker. The sample was shake for 15 min. each size fraction was weighted. The fraction size of cumulative retained and cumulative passing in weight percentages is thus calculated, and graph plotted,. Samples were analyzed using Mini-pal X-ray Fluorescence machine at National Metallurgical Development Center, Jos. Beneficiation of the ore after characterization was done on laboratory scale, using Winsfrey shaking table and Denver Air Float machine.

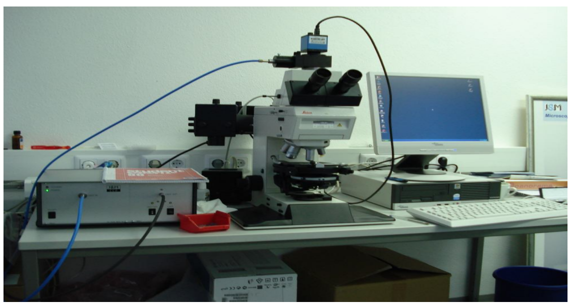

Plate 1: Leica Microscope Spectroscopy for Transmitted and Reflected light Studies.

RESULTS AND DISCUSSION

Macroscopically, the Ore is in the form of ferruginous quartz. It is banded with alternate layers of iron bearing minerals and quartz. The ore is hard, compact and crystalline. It is fine to medium grained, layered non homogenous rock. The color varies from light grey to dark grey with metallic luster. The Ore is densely fractured and form boulders with sharp edges. Microscopically, the iron Ore consists of hematite and quartzite with minor occurrence of magnetite. Quartz occurs as the principal gangue mineral accounting for about 50% of the mineral content. The quartz in the ore varies in shape from angular to sub-angular; while the hematite is characterized by a specula texture. Sub-idiomorphic magnetite is characterized by martitization which is the replacement of magnetite to hematite along cleavage planes (Craig, 1981). The mineral constituents identified in the Ore are described below

Quartz:

Quartz (SiO_2) is the major gangue mineral in the Ore. It is dark grey in reflected light (Plate 2a**)** while under transmitted light it appears whitish and/or light grey (Plate 3).It varies in shape from angular to sub-angular. They have straight to slightly sutured boundaries.

Hematite: -

Hematite (Fe_2O_3) is the major Iron bearing mineral in the Ore. It is characterized by specula texture. It is bright yellow in reflected light (Plate 2b) with light bluish tint, but dark in transmitted light (Plate 3).

Magnetite:

Magnetite ($Fe_3 O_4$) occurs in minor amounts in the Ore. It is characterized by matitization which is a replacement texture or alteration of magnetite to hematite (Ramdohr, 1969) resulting from decrease in temperature after the Ore forming processes (Plates 4a, and 4b)**.**

Texture

The texture of an Ore, that is, the size and arrangement of its constituent Ore minerals and gangue (Jones, 1987) relates to grain growth (Spray, 1976) and is useful in ascertaining liberation size and amenability to beneficiation of iron and quartz. There is inter- banded specula hematite and quartz (Plate 5). Hematised-

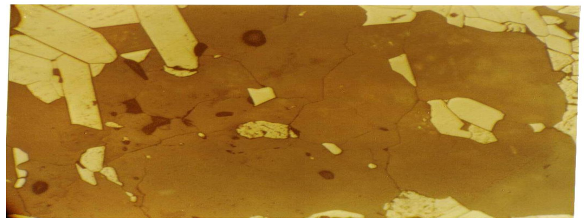

Plate2a: Quartz, dark grey in Reflected light showing mutual grain boundaries, few Hematites are locked within the Quartz boundaries. (x10)

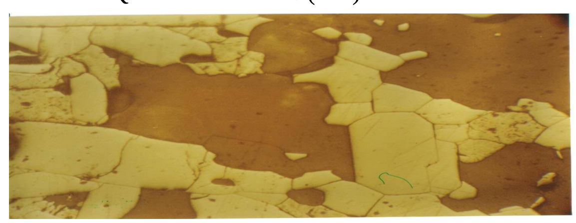

Plate 2b: Hematite bright yellow in reflected light with quartz (grey) (x10

Magnetite occurs as scattered crystals. The quartz exhibit re-crystallized polygonal (granoblastic) texture, with mutually straight to suture grain boundaries between the quartz **Plate3**. The texture indicates that quartz will tend to break along grain boundaries rather than across grain boundaries when grounded.

Locking Types

Locking of minerals in rocks and ore occurs when there is inter-growth, core or rim growth and disseminated intergrowth texture. Intergrowth, or disseminated or felted aggregate of minerals are difficult to liberate, whereas a more open textured mineral is comparatively easy to treat (Jones, 1987).

Agbado-Okudu iron Ore has simple locking texture, most of the minerals have mutual grain boundaries and there are no replacement locking types except in the case of magnetite. The ore shows no leaching or disseminated locking type. In some places, the quartz interlocks with iron bearing minerals. In general, the Ore has simple primary and secondary locking types.

Grain Size

The grain size of Agbado-Okudu iron Ore were measured with a research microscope**,** after being calibrated with a stage micrometer (Plate 1). 1500 grains were measured and treated statistically. The obtained results are shown in Table 1.

Table 1: Grain size Analysis of Agbado-Okudu Iron Ore

Class interval	mid point (x)	Freq. (F)	Fx
001 – 100	50.5	263	13281.5
101 – 200	150.5	568	85484
201 – 300	250.5	296	74148
301 – 400	350.5	188	65894
401 – 500	405.5	87	39193.5
501 – 600	550.5	53	29176.5
601 – 700	650.5	19	1239.5
701 – 800	750.5	9	6754.5
801 – 900	850.5	8	6804
901 – 1000	950.5	9	8554.5
		Σf = 1,500	Σfx = 341650.5

Source: (Authors Survey, 2012)

$$X = \frac{\Sigma fx}{\Sigma f} = \frac{341650.5}{1,500} = \frac{227.767}{1000} = 0.228 = \sim \mathbf{0.23}$$

A screen analysis of the Ore was also carried out. Screen analysis categories particles according to their ability to pass through an aperture of specified size and shape, under a prescribed set of screening conditions (Jones, 1987). The result of the sieve analysis is shown in Table 2. Figure 2 shows the meeting point of the plotted cumulative % passing against cumulative % passing which is 0.25, thus marked as the liberation size. The results of the grain size analysis and that of the sieve analysis indicated that the Ore is fine to medium grained with liberation size of 0.25mm.

Table 2: Sieve Analysis of Agbado-Okudu Ore

Sieve Size Fraction (mm)	Weight (gm)	Weight (%)	Cumulative weight retained(Series1)	Cumulative weight passing(Series2)
1.40	91.50	18.36	18.36	100
1.00	19.33	5.89	24.25	81.64
0.71	27.06	5.43	29.68	75.75
0.50	34.98	7.02	36.70	70.32
0.355	40.10	8.05	44.75	63.30
0.25	59.03	11.85	56.60	55.25
0.18	65.89	13.22	69.82	43.40
0.125	55.15	11.07	80.89	30.18
0.09	40.46	8.12	89.01	19.11
+0.063	27.68	5.55	94.56	10.99
-0.063	27.13	5.44	100	5.44
TOTAL	498.31	100		

Source: (Authors Survey, 2012)

CHEMICAL ANALYSIS

The chemical analysis showing the composition of Agbado-Okudu iron Ore for four different sample locations is shown in Table 3.

Table 3: Chemical analysis of Agbado-Okudu

	SiO_2	Al_20_3	TiO_2	Fe_20_3	Na_2O	K_2O_5	Ca0	MnO	MgO	Fe(total)
AGBI	51.15	1.86	0.03	44.50	0.03	0.01	0.01	0.03	0.04	31.41
AGB2	56.70	0.77	0.04	41.85	0.07	0.00	0.01	0.02	0.03	37.14
AGB3	55.40	0.66	0.03	43.73	0.06	0.01	0.01	0.05	0.07	37.00
AGB4	54.41	0.43	0.03	44.70	0.07	0.02	0.01	0.02	0.04	29.41

Source: NMDC, Jos (2012)

The result of the chemical analysis indicates that silica assays average about 54% while Iron total is 33% average.

Ore Beneficiation

Complete (or practical) Ore – mineral liberation and mineralogical characterization, prior to upgrading is

vital in mineral beneficiation and subsequent metallurgical utilization (Hagni, 1978). These investigations of Agbado-Okudu Iron Ore, through microscopic analysis and sieve analysis show that the Ore minerals will practically be dissociated from the gangue minerals at 0.25mm particle size.

The crushed Agbado-Okudu Ore responded to gravity concentration technique on a Wilfrey shaking table. Air-Floatation of the ore yielded a fairly positive result. The results are shown in Table 4**.** Both techniques produced concentrates of 62.65% and 60.21% Fe for shaking and Air float tables which are within the specifications;62%Fe for the blast furnace operation.

Table 4 Result of Chemical Analysis of processed Agbado-Okudu Iron Ore

S/No	Sample	Ca0	$Si0_2$	Al_2O_5	K_20	MnO	MgO	NaO	Fe_20_3	Fe_{Total}
1	**Shaking table concentrate**	0.06	3.07	0.05	0.01	0.03	0.03	0.03	89.58	60.21
2	**Shaking table tailing**	0.08	64.55	0.06	0.05	0.02	0.02	0.07	23.61	19.23
3	**Air float concentrate**	0.06	2.70	0.12	0.01	0.12	0.14	0.13	86.09	62.65
4	**Air float tailing**	0.04	60.97	0.09	0.01	0.02	0.04	0.07	27.20	16.51

Source: (Authors Survey, 2012)

For a "complete" recovery of the iron, the Ore requires grinding to 75um, which requires design of a more capital intensive process of treatment, thus increasing energy cost and use of expensive chemicals, e.g. Froth flotation. The cheap process route employed in this investigation was similarly used in processing Muro Iron Ore (Uwadiale and Nwoke, 1985, Mokwe 2002) an ore with similar characterization, with similar out come.

CONCLUSIONS

The results of the study indicate that Agbado-Okudu Iron Ore consists principally of hematite, minor magnetite and quartz as the main gangue mineral. The Ore is characterized by simple lamellar and specula textures with mutual grain boundaries between individual minerals, suggesting the minerals breakage along grain boundaries. Based on the mineralogical, sieve and chemical analysis, the Ore can be beneficiated by grinding to 250um and using Gravity and Air Flotation techniques. These techniques are conventional, cheap and easy to operate.

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APPENDIX

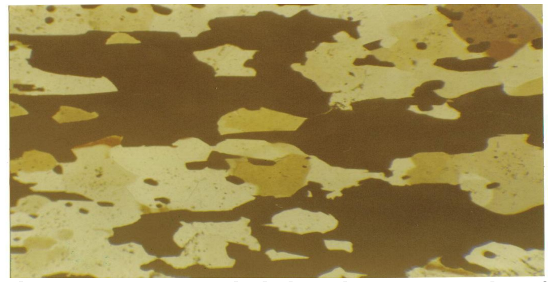

Plate 3: Transmitted light photomicrograph of Obajana showing whitish to light grey Quartz and dark (opaque) iron minerals. Note the straight to slightly sutured boundaries of the Quartz. (x10)

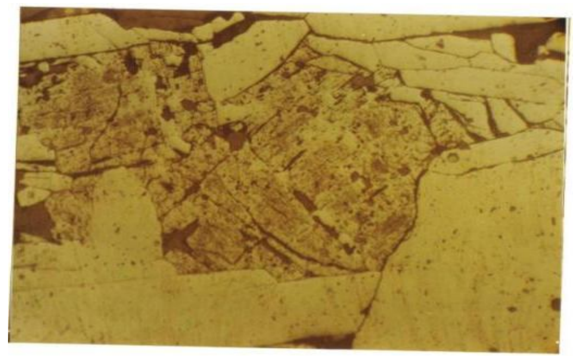

Plate 4a: Magnetite grains in Reflected Light at the center, characterized by martitization with hematite (bright yellow) and quartz (grey). (x10)

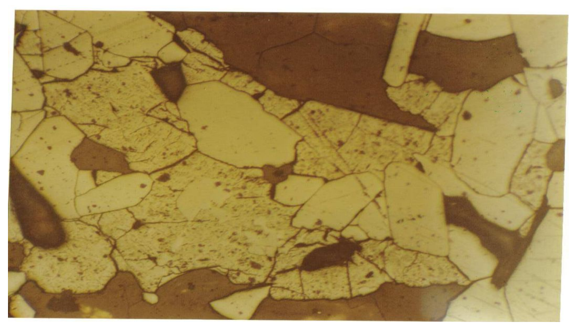

Plate 4b: Magnetite characterized by martitization with few hematite and quartz. (x10)

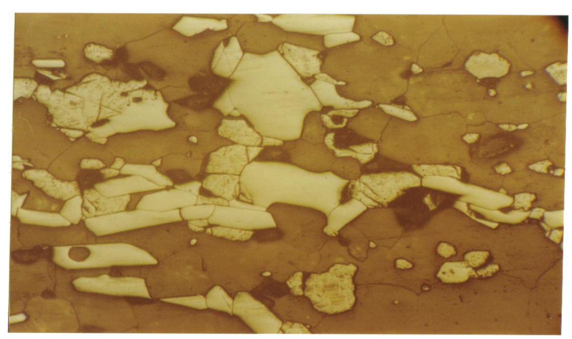

Plate 5: Inter-banded Specula Hematite in reflected light, the Transparent Quartz appears grey. (x10)