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This themed issue honors Professor Ekedimogu Eugene Nnuka, celebrating his distinguished career upon his retirement. His legacy of exemplary scholarship, mentorship, and commitment to advancing knowledge is commemorated in this collection of works.

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Preliminary Characterizations of Lejja Iron Ores for Steel Making Processes

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Abstract

There is need to characterise the iron ore to determine their grade based on the iron and other mineral contents before usage. Comprehensive research has been carried out on the characterisation of Jaruwa, Agbaja and other deposits in Nigeria. But little or no work has been carried out on the characterisation of the iron deposit at lejja village. This research will help to reduce the over dependence of Nigeria on imported iron ore. In this study, iron ores from deposits from three Lejja villages: Amankwo, Dunoka and Umuakpo were characterised using X-ray diffractometer, X-ray florescence spectrometer, and scanning electron microscope. Phase identification and chemical compositions revealed that the iron ore content of the Amankwo village deposit is higher (73.50%) than that of the Dunoka village (71.57%), and the Umuakpo village (57.14%). The phosphorus contents of the deposits were higher than 0.04% recommended for high grade iron ore. Iron ore from Umuakpo contained more silica and alumina than Amankwo and Dunoka deposits. A spherical ooids (concentric layer) that shows partial and whole replacement by hematite (iron precipitates around a nucleus) was observed on the petrograph of Umuakpo ore as against the darker areas which signified more iron contents in Amankwo ore. Based on the findings, Amankwo village and Dunoka village deposits can be classified as high-grade hematite iron ore while Umuakpo village deposits can be classified as lean grade, although all can serve as feedstock for production of iron through the direct reduction route.

Keywords: Characterisation; Lejja; Steel; Compositions; deposit; Hematit.

1. Introduction

Most of the minerals found in Nigeria still remain unexploited due to inadequate knowledge on their status, economic viability and requisite mining technologies. Importing metallic products such as lead, iron, zinc, copper etc. from other countries are very expensive despite Nigeria's potential to exploit existing mineral resources. A successful characterization of the Lejja Iron Ore deposit in Nsukka Local Government Area of Enugu State Nigeria can mean an economic boom for the country with quite substantial multiplier effects in the area of job creation and downstream sectors of iron and steel industry. Though not the most expensive items, iron and steel are among the most sought-after commodities on planet earth. Moreover, the use of iron and steel-based products has come to be associated with the industrialization of economies (Ruth, 2004). This is due to the fact that iron possesses good mechanical properties and has a low cost associated with its production. In addition, steel is easily recyclable back to the production of new products. The production of crude steel (a product from iron processing) was standing at 1414 million metric tons by the end of 2010 (Ruth, 2004). Moreover, an increase of 565 million metric tons of crude steel production within a decade was seen. Two thirds of steel is produced using natural iron ore and entails an intermediate product

called "pig iron". Iron ore consumption for steelmaking was around 850 million tonnes at the end of the twentieth century and was estimated to reach more than 1.3 billion tonnes over the first quarter of the century (Brill-Edwards et al, 1965). However, most of the known deposits contain low grade ores with iron contents less than 30%. The remaining one third of steel is produced through the recycling of scrap metal and direct reduction processes (Watanabe & Yoshinaga, 1968).

Characterization of a mineral ore is a very important step to perform before any processing takes place whereby quantity, grade or quality, densities, shape, and physical characteristics are determined to allow for appropriate application of technical and economic parameters to support production planning and evaluation of the economic viability of deposits. Iron ore is the most abundant rock forming element and composes about 5% of the Earth's Crust. The most importantly used iron-bearing minerals from which iron compounds can be extracted includes: hematite, Fe_2O_3 (70% Fe); magnetite, Fe_3O_4 (72% Fe) and of much less importance: limonite, $2Fe_2O_3 \cdot 3H_2O$ (60% Fe); siderite, $FeCO_3$ (48.3% Fe); pyrite, FeS_2 (46.6% Fe) (Biswas, 2005), where these iron percentages are in their pure states. Nigeria has ample iron ore deposits which are yet to be fully exploited and utilized for the development and economic growth of the nation. There are iron ore deposits in counties like Taita Taveta (Manyatta), Tharaka (Marimanti) and Siaya (Samia) which have not been fully exploited and thus there is need to amass information on the quality of the iron ore deposits and the method for pre-processing as a precursor to setting up a steel plant (Bett et al, 2012).

2.0 Experimental procedure

2.1 Materials collection and preparation: Outcropped iron ore samples were collected from Lejja town in Nsukka Local Government Area, Enugu State, Nigeria (7^0 22'E and 6^0 45´N). The iron ore was crushed using jaw crusher at the National Steel Raw Materials Exploration Agency, Kaduna, Nigeria and then pulverized using vibratory cup miller (Herzog model) in Kaduna, Nigeria in order to obtain fine particle sizes of about 100 mesh (0.15 microns). The various equipment used for crushing and pulverization were set at 6 - 8 rpm. Quadripull sample divider was used to divide the pulverized samples into four smaller portions which were used for different analyses.

2.1.1 Characterization techniques: X-ray fluorescence (XRF) spectrometer (Thermoscientific advant'x 1200 model. Kaduna, Nigeria) was used to obtain the elemental/chemical composition of the iron ore samples in oxide forms. Powdered sample of 1 g was mixed thoroughly with 4 g of sodium tetra-borate (borax). The mixture was made into pellet using pelletizing machine at Kaduna, Nigeria. The sample was then placed in sample holder and transferred into the XRF for analysis. X-ray Diffractometer (XRD) (Schimadzu 6000 model, was used to identify the phases present in the iron ore samples at Kaduna, Nigeria. The machine was set at a scanning rate of 2 theta from 0 – 60^o Bragg's angle and scanning speed of 6^o/min. The sample was spread evenly on the sample holder and carefully placed on the loading point of the movable arm of the XRD for analysis. Petrographic microscope at Kaduna, Nigeria was used to visually identify the minerals present in the iron ore samples. Thin sections of the samples were formed and examined under the combination of both plane and cross-polarised light of the microscope. Microscopic identification of the iron ore minerals was carried out using Scanning Electron Microscope (Phenom 821 model at South Africa) and the SEM images were taken at 1mm magnification.

3.0 Results and Discussion

Table 1 shows the result of chemical analyses of Lejja iron ores in weight percentages. Predominantly, Fe_2O_3, SiO_2, Al_2O_3 are the most enriched oxides constituting above 75% of the oxides, indicating the presence of haematite, clay minerals and quartz, respectively, in the ores. The SiO_2 (11%) and Al_2O_3 (8.83%) of Amankwo, SiO_2 (11.11%) and Al_2O_3 (11.69%) of Dunoka iron ores are also lower than Umuakpo iron ore; SiO_2 (19.02%) and Al_2O_3 (19.33%).This is an indication that Amankwo and Dunoka iron ores will be preferred to Umuakpo iron ore for the production of pig iron or direct reduced iron. However, associate elements such as sulphur and phosphorus of Dunoka iron ore are considered to be poisonous since their values are higher than the recommended benchmarks of 0.60% and 0.04%, respectively (Brooks & Lambert,1978). Additionally, all the iron ores contain high level of impurities such as TiO_2, MnO, Nb_2O_5 and MgO while other oxides are in negligible amounts as presented in Table 1. These impurities will constitute major challenge in the beneficiation process of the ores (Joan et al 2015). Based on the iron contents, Dunoka and Amankwo iron ores can be classified as high-grade hematite and Umuakpo iron ore as low-grade hematite (Semukaaya, 2007). The quantities of gangue present in the iron ores imply that their exploration can be useful for the production of direct reduced iron only since they do not meet commercially graded blast furnace ore quality (<6% SiO_2 and <4% Al_2O_3). (Joan et al, 2015).

Table 1: Major oxides in Lejja iron ore samples

ID	DUNOKA (%)	AMANKWO (%)	UMUAKPO (%)
SiO_2	11.11	11.00	19.02
MgO	-	2.80	-
Cr_2O_3	0.07	0.04	0.06
MnO	0.04	0.04	0.04
Fe_2O_3	71.57	73.50	57.14
V_2O_5	0.21	0.25	0.24
ZrO_2	0.04	-	0.14
Co_3O_4	0.24	0.28	0.20
Nb_2O_3	0.29	-	0.30
CuO	0.06	0.05	0.04
P_2O_5	0.09	-	-
SO_3	0.88	0.14	0.19
CaO	0.23	0.09	0.19
K_2O	0.06	0.04	0.24
BaO	0.17	0.13	0.03
Al_2O_3	11.69	8.82	19.33
Ta_2O_5	0.07	0.21	0.03
TiO_2	2.45	1.57	2.25
WO_3	0.16	0.57	0.07

Figures 1-3 are representative X-ray diffractograms of Dunoka, Amankwo and Umuakpo iron ores, respectively.

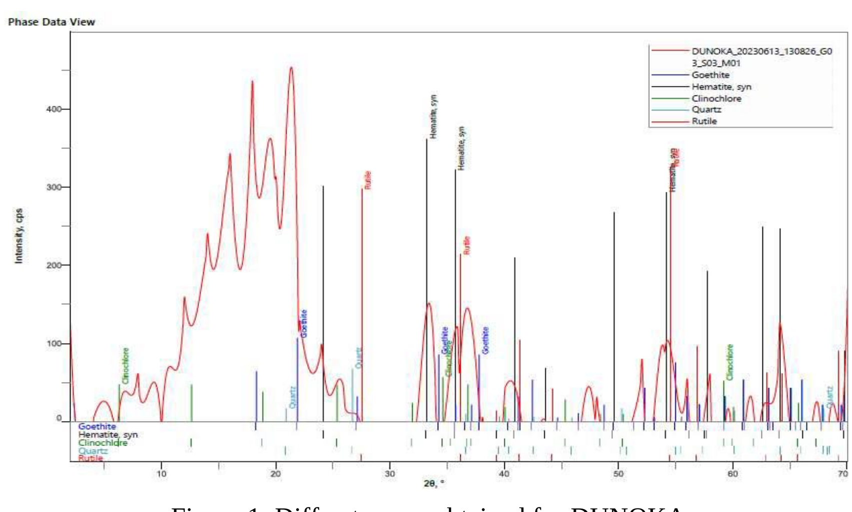

Figure 1: Diffractogram obtained for DUNOKA

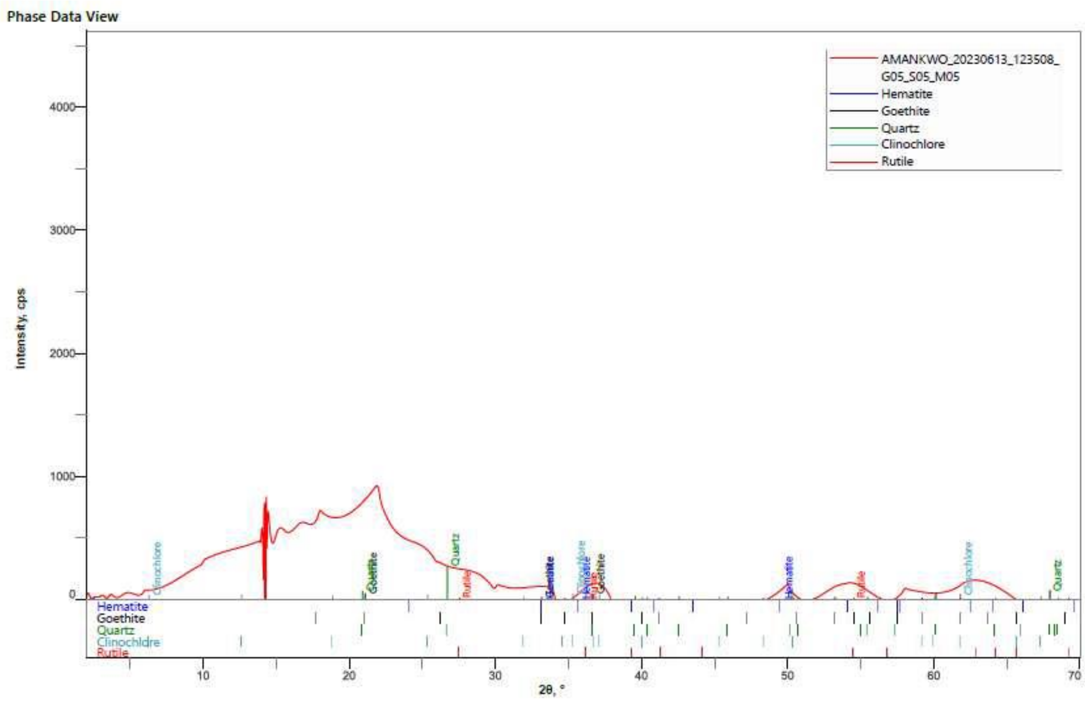

Figure 2: Diffractogram obtained for AMANKWO

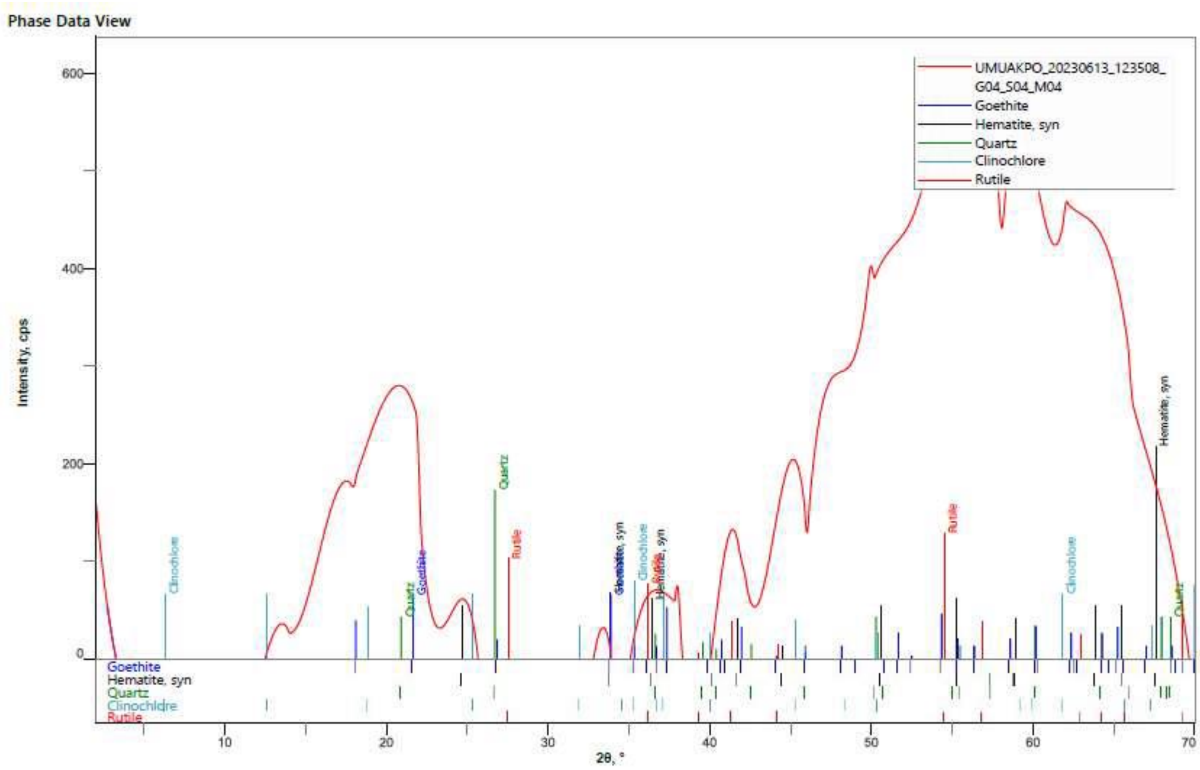

Figure 3: Diffractogram obtained for UMUAKPO

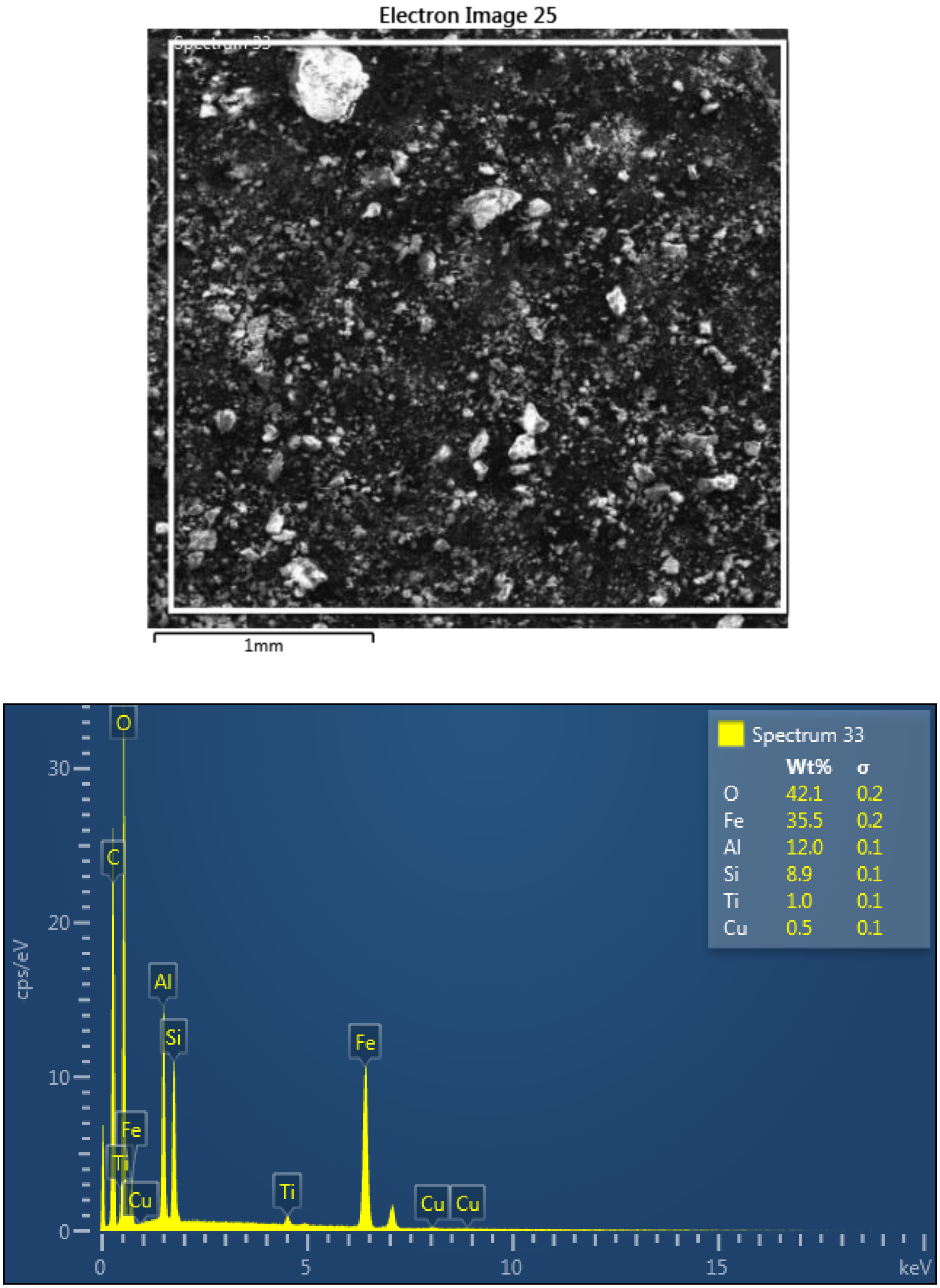

Fig 3a.The SEM micrograph of Amankwo

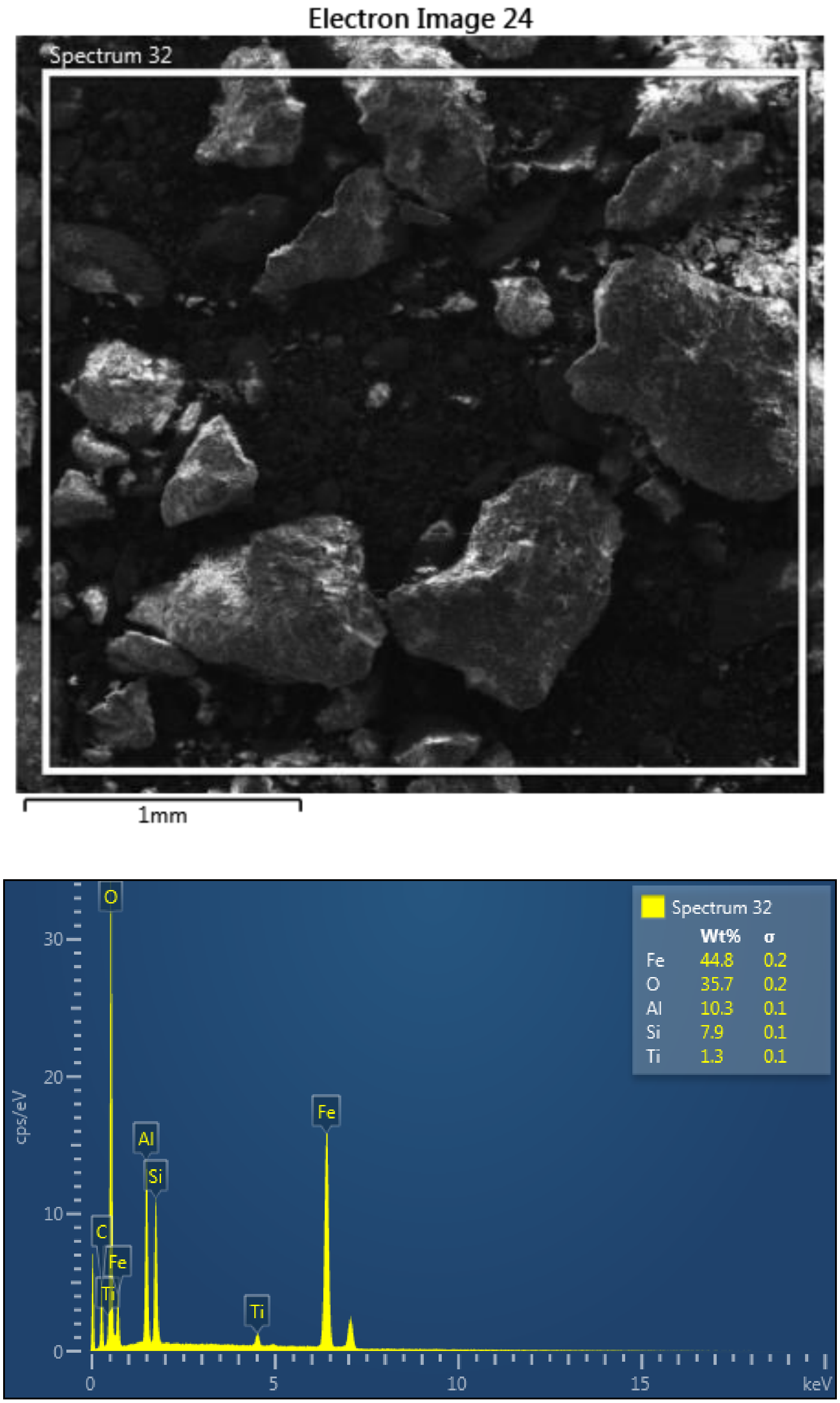

Fig 3b.Dunoka SEM analysis

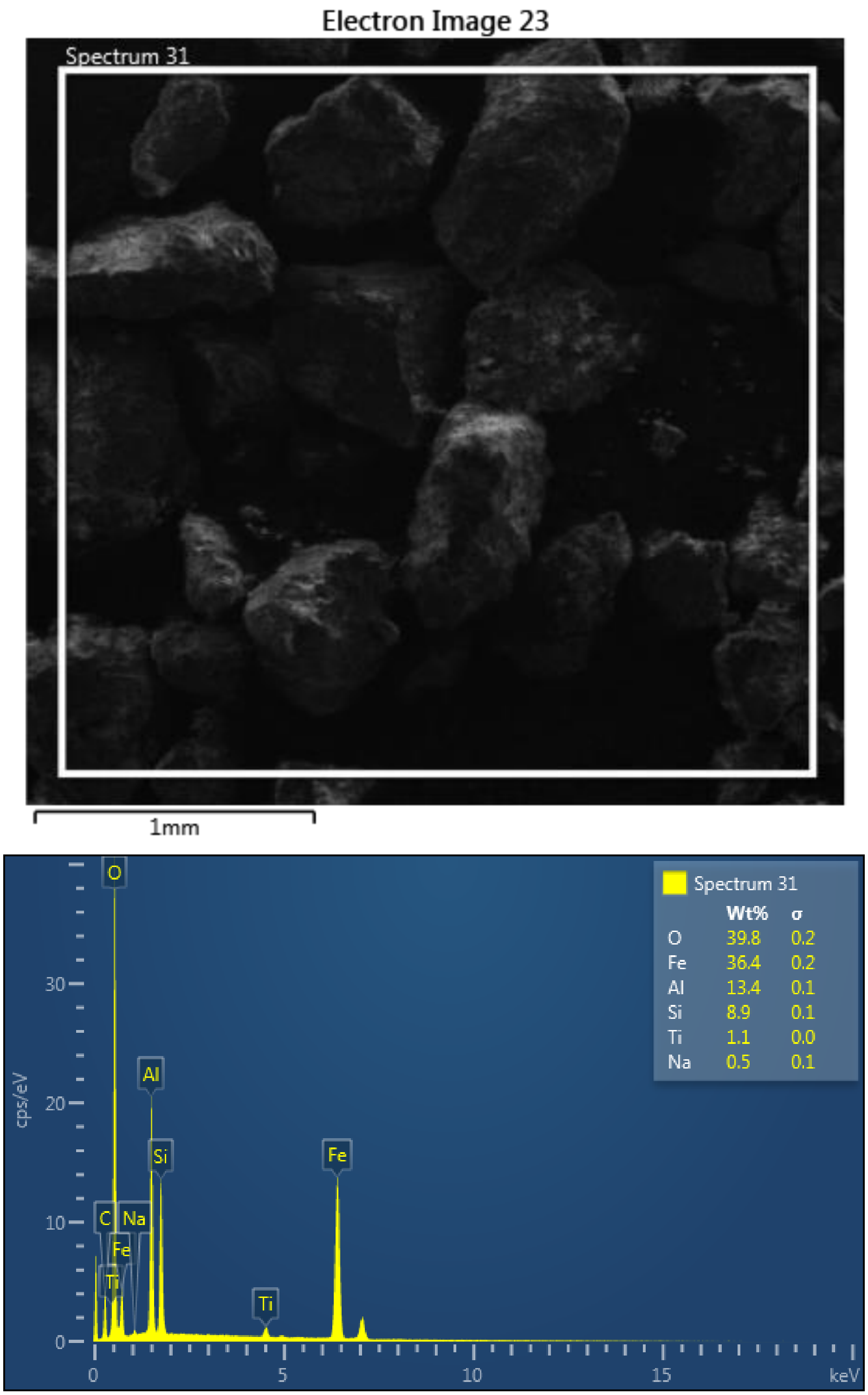

Fig.3c. Umuakpo SEM analysis.

4.0 Conclusions

The iron ores from Lejja deposits have been characterised to determine their suitability for iron and steel making processes. The Dunoka and Amankwo iron ores can be classified as high-grade hematite iron ore rich in hematite with silica and alumina as the major impurities while the phosphorus and sulphur content of Dunoka revealed that the ore will require beneficiation (especially through direct reduction route) before it can be successfully utilised as feedstock for iron making. Amankwo iron ore is ooilitic ore consisting of hematite, high silica and alumina contents and other impurities. It can also be better used as raw material for production of iron via direct reduction route. From the figures, dominant mineral phases in the iron ores are; hematite (H), quartz (Q) and kaolinite (A). From Figure 3a, the iron minerals have relatively smaller grains and smooth boundaries that created segregations between the iron and other minerals. This phenomenon enhances easy liberation of valuable minerals from the gangues. This is contrary for Umuakpo and Dunoka iron ore where the grains are relatively large with rough boundaries and this could limit communition process.

5.0 Recommendation

The need for the use of local iron ore to feed the iron and steel industries in Nigeria for the production of iron and steel is important to mitigate over-dependence on imported iron ore. This will help to boost the dwindling economy of Nigeria.

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