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Estimated Iron (Fe) Percentage in Weathered and Ferruginized Ajali Sandstone in Western Anambra Basin, Nigeria

Akpofure, E.[*] and Debekeme, E.S.
Department of Geology, Niger Delta University, Wilberforce Island, Nigeria.
Corresponding E-mail: edirinakpofure@yahoo.com

Abstract
A total of Ten (10) samples from Ajali Sandstone in Ayogwiri, in Etsako West Local Government Area of Edo State, Nigeria, were collected: five representing fresh Sandstone and five representing ferruginized, weathered section of the Sandstones. They were taken to the laboratory for quantitative determination of some chemical elements: Fe, Cu, Mg, Na and Mn, in order to quantify the Fe percentage, using Atomic absorption spectroscopy (AAS). The result shows that the percentage of iron ranges from 18.4% – 32.2% with an average of 26.34% in the ferruginized sandstone - Ironstone, whereas, the percentage of iron ranges from 0.19% - 2-81% with an average of 1.61% in the fresh sandstone samples. There is also, a slight increase in the concentration of Manganese (Mn) in the Ironstone but no much noticeable difference in the concentration of Cu, Mg, and Na in both fresh sandstone samples and ironstone samples. The increase of Fe percentage in the Ironstone results from weathering, leaching and accumulation of released elements from the top layer of the Sandstone to a lower level and the hardening of the sesquioxide - rich materials and secondary minerals. The result indicates the viability of the "Ajali Ironstone" with an average Fe percentage of about 26.34% for the smelting of Fe at both small and large scale as the weathered zone is pervasive.

Keywords: *Sandstone, Ironstone, Weathering, Leaching, Fe percentage, Ferruginized Sandstone, Sesquioxide.*

Introduction

The Ajali Sandstone is a major clastic Formation of Campanian - Maastrichtian age occurring within the western and eastern parts of the Anambra Basin.

Regionally, the Sandstone comprises thick succession of sandstones with thin beds of mudstone near the base and shales which occur as secondary lithology.

The Formation is extensively cross stratified into different types of cross-bedding including: planar, trough and herringbone cross-bedding which occur at different stratigraphic levelsThe Ajali Sandstone is a quartz arenite that is white and pinkish in colour. (Akpofure and Etu-Efeotor, 2013).

The Sandstone is highly weathered at the top, with the formation of residual soil and ironstone below the residual soil. The residual soil and ironstone form a thick layer, with thickness varying from a few centimeters to as much as 4 m in some places.

The residual soil is absent where vegetation is scanty and the Ironstone pervades. The Ironstone is brick red in colour and very pervasive on the surface of the outcrop. The Ironstone is hard, non-banded and non-cherty. The study area is a tropical climate with wet and dry seasons and weathering is very intense.

The topography of the area is made up of hills and lowlands. The lowlands are well covered with vegetation, whereas, the gently sloping hillsides are covered by the Sandstone with scanty vegetation. Vegetation in this area is controlled by the prevailing climate. In the rainy season, the area is more vegetative and looks dry and less vegetative in dry season.

The aim of this work is to determine the Fe percentage in the weathered and ferruginized part of the Ajali Sandstone to encourage small or large scale smelting of Fe in the "Ajali Ironstone".

Literature Review

The literature is replete of information on the transformation of Sandstone to Ironstone. Ironstone is a sedimentary rock that contains more than 15% iron. It is hard, non-banded, non-cherty, it is either deposited directly as ferruginous sediment or created by chemical replacement, and contains a good concentration of iron ore compounds from which iron (Fe) can be smelted commercially. Ironstone occurs in a variety of forms. The various forms of ironstone include siderite nodules; deeply weathered saprolite, i.e. laterite and ooidal ironstone (Wikipedia). They are usually post –Precambrian Supergene enrichment, which occur near the surface, and involves water circulation with its resulting oxidation and chemical weathering. Deep weathering causes the formation of many secondary and supergene ores – bauxite, iron ores, saprolitic gold, supergene copper, uranium and heavy minerals in residual accumulations

The transformation of the Sandstone to Ironstone involves a lot of processes such as weathering, leaching, laterization which are influenced by: the climate, the physio – chemical composition of the Sandstone, the pH of the ground water and these determine the mineralogical composition, chemical and physical characteristics of the resultant soil.

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The transformation process is made up of various stages, the first stage is eluviation stage which is characterized by physico-chemical breakdown of primary rock forming minerals and the release and translocation of constituent elements (SiO_2, $A1_2O_3$, Fe_2O_3, CaO, MgO, K_2O, Na_2O, etc.) which appear in simple ionic forms (Loughnan, 1969).

The second stage is characterized by laterization, which, is characterized by intensive removal of the released elements: silica (SiO_2) and bases of Na, K, Ca, and Mg, on the one hand, and the accumulation of oxides of Al, Fe, and Ti ($A1_2O_3$, Fe_2O_3 and TiO_2) in the residual rocks below. In the third stage, which is characterized mainly with dehydration and/or desiccation, involves an incomplete or inclusive dehydration which may sometimes involve the hardening of the sesquioxide - rich materials and secondary minerals. The drying out of colloidal hydrated iron oxides involves loss of water leading to the concentration and crystallization of the amorphous iron colloids into dense crystalline iron minerals (Sherman, 1959; MacKenzie, 1959) in the following sequence: limonite, goethite and goethite with hematite to hematite. The hardening of the sesquioxide – rich material and secondary minerals leads to the formation of ironstone from sandstone undergoing a change process.

Stratigraphy of the Area

The Ajali Sandstone is one of the Campanain –Maastrichtian Sedimentary fills of the Anambra basin. The Anambra basin became a depocenter after the Santonian tectonic activity that resulted to the folding and uplift of the Abakiliki Anticlinorium which was flanked to the right by the Anambra basin and to the left by the Afikpo basin. The first lithic fill of the Anambra basin is the transgresive marine Nkporo Group. The Nkporo Group includes the Nkporo Formation, the Owelli Sandstone and the Enugu Shale. The Mamu Formation of the Coal Measures Group conformably overlies the Nkporo Group. Overlying the Mamu Formation is the Ajali Sandstone. The Nsukka Formation is the Upper Coal Measure overlying the Ajali Sandstone. These sediments form the sediments of the proto Niger Delta. (Umeji and Nwajide, 2007). During the Quaternary, the Imo Formation, Ameki Formation/Nanka Sand/Bende Formatiom and the Ogwashi - Asaba were deposited (Fig. 1).

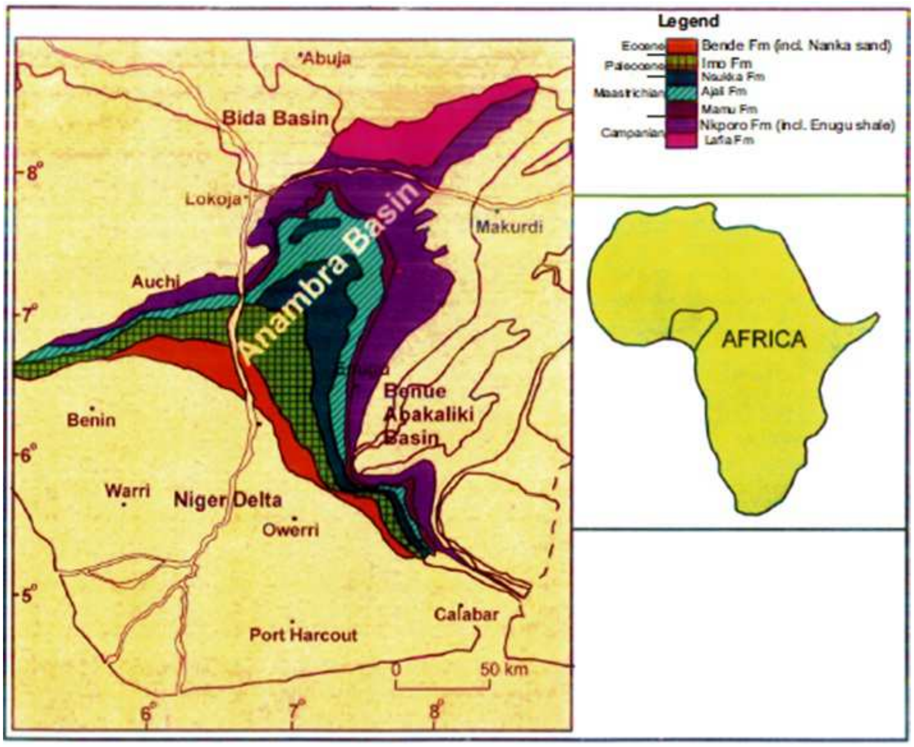

Fig. 1: Anambra Basin Showing the Extension of Ajali Sandstone within Auchi Environs (Drawn from Geological Map of Nigeria, GSN1994).

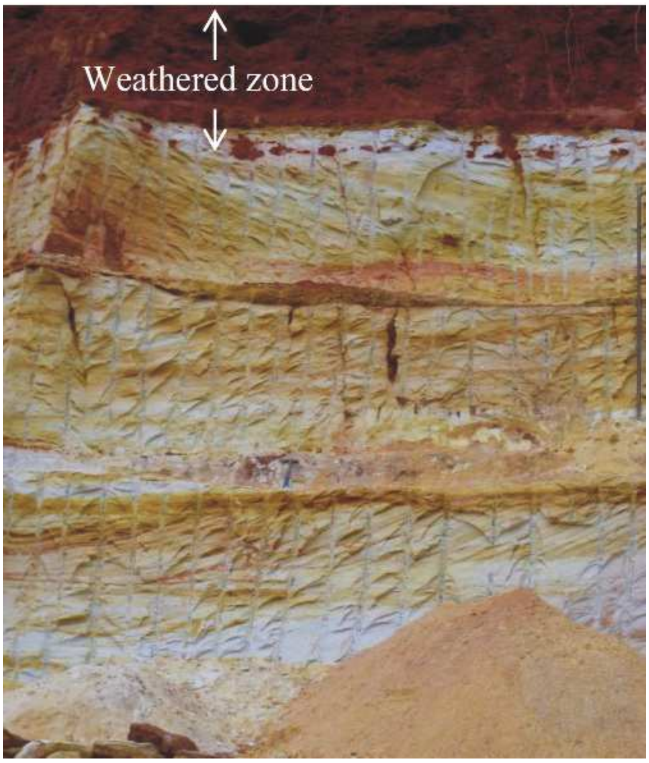

Fig. 2: Fresh cut surface of Ajali Sandstone

Fig. 3: Thickness of weathered zone in Ajali Sandstone

Methodology

The Ironstone and Sandstone samples were brought to the laboratory for analysis. The samples were reduced to 2mm size and digested. The samples were then transferred into plastic container for Atomic Absorption Spectroscopic (AAS) Analysis using Air/Acetylene gas combination. The samples were aspirated on the AAS machine to obtain the absorbance results.

Discussion

Tables 1 and 2 show the percentages of Iron in both the un-weathered Sandstone and the Ironstone. The concentration of the iron mineral is highly increased in the Ironstone due to leaching and laterization processes. The Tropical climatic conditions of the study area favour the occurrence of rainfall during the wet season, which, enables the physico-chemical breakdown of primary rock forming minerals and the release and translocation of constituent elements (SiO_2, $A1_2O_3$, Fe_2O_3, CaO, MgO, K_2O, Na_2O from the upper soil horizons (Loughnan, 1969). Favourable climatic conditions also aided laterization process, which, is characterized by intensive removal of the released elements:

silica (SiO_2) and bases of Na, K, Ca, and Mg, on the one hand, and the accumulation of oxides of Al, Fe, and Ti ($A1_2O_3$, Fe_2O_3 and $TiO_{2)}$ in the residual rocks below. The third stage of Ironstone formation, according to Sherman, 1959; MacKenzie, 1959, also occurred. The third stage which involves dehydration and/or desiccation and hardening of the sesquioxide - rich materials and secondary minerals, also occurred. The Ajali Ironstone is brick red, hard and oolithic in places, reflecting the effect of desiccation as can be seen from Figures 4 and 5. The percentage of iron ranges from 18.4% – 32.2% with an average of 26.34% in the Ironstone (Table 1), whereas, the percentage of iron ranges from 0.19% - 2-81% with an average of 1.61% in the fresh sandstone samples (Table 2). There is a slight increase in the percentage of Manganese (Mn) in the Ironstone but no much noticeable difference in the concentration of Cu, Mg, and Na in both fresh sandstone samples and ironstone samples.

Prehistoric societies used laterite as a source of iron ore. Historically, much of the iron ore utilized by industrialized societies has been mined from predominantly hematite deposits with grades of around 70% Fe. Ironstone, although widespread, is a limited source of iron (Wikipedia). The iron (Fe) content of the Ironstone derived from the weathered Ajali Sandstone has an average Fe percentage of (26.34%) and the ironstone is pervasive above the outcrops and is littered as regoliths around the outcrops (Fig. 4).

The "Ajali Ironstone" therefore, with the Fe content and spread, can be smelted and put into meaningful and economic uses such as in ceramics production, in the building industries and in local iron smelting, at both small and large scale, since it spans the stretch of the weathered surface of the Formation from the Western to Eastern Anambra Basin.

Table 1: Showing results from samples of Ironstone for AAS analysis

SAMPLE CODE	Fe mm/g	%	Cu mm/g	%	Mg mm/g	%	Na mm/g	%	Mn mm/g	%
Ironstone 1										
(i)	322.088	32.2	0.054	0.0054	0.855	0.086	1.406	0.141	0.11	0.011
(ii)	322.086	32.2	0.055	0.0055	0.856	0.086	1.404	0.140	0.111	0.011
(iii)	322.09	32.2	0.053	0.0053	0.854	0.085	1.408	0.141	0.109	0.011
Ironstone 2										
(i)	240.142	24.0	0.037	0.0037	0.84	0.08	1.538	0.154	0.094	0.009
(ii)	240.14	24.0	0.038	0.0038	0.838	0.084	1.54	0.154	0.095	0.010
(iii)	240.144	24.0	0.036	0.0036	0.836	0.084	1.536	0.154	0.093	0.009
Ironstone 3										
(i)	184.181	18.4	0.056	0.0056	0.792	0.079	1.87	0.187	0.027	0.003
(ii)	184.182	18.4	0.055	0.0055	0.79	0.079	1.868	0.187	0.028	0.003
(iii)	184.18	18.4	0.057	0.0057	0.794	0.079	1.872	0.187	0.026	0.003
Ironstone 4										
(i)	251.82	25.1	0.05	0.005	0.825	0.083	1.74	0.174	0.132	0.013
(ii)	251.818	25.1	0.004	0.0004	0.827	0.083	1.742	0.174	0.131	0.013
(iii)	251.822	25.1	0.006	0.0006	0.826	0.083	1.738	0.174	0.13	0.013
Ironstone 5										
(i)	320.136	32.0	-0.010	0.001	0.929	0.093	1.606	0.161	0.222	0.022
(ii)	320.136	32.0	-0.012	0.0012	0.93	0.093	1.602	0.160	0.22	0.022
(iii)	320.134	32.0	-0.011	0.0011	0.928	0.093	1.604	0.160	0.224	0.022
Average		**26.34**								

Table 2: Showing Results from samples of Sandstone for AAS analysis

SAMPLE CODE	Fe mm/g	%	Cu mm/g	%	Mg mm/g	%	Na mm/g	%	Mn mm/g	%
Sandstone 1										
(i)	28.066	2.807	0.044	0.0044	0.778	0.0778	1.576	0.158	0.095	0.0095
(ii)	28.068	2.807	0.042	0.0042	0.776	0.0776	1.578	0.158	0.093	0.0093
(iii)	28.064	2.806	0.046	0.0046	0.78	0.078	1.574	0.157	0.097	0.0097
Sandstone 2										
(i)	23.241	2.324	0.007	0.0007	0.656	0.0656	1.368	0.137	0.088	0.0088
(ii)	23.24	2.324	0.006	0.0006	0.654	0.0654	1.367	0.137	0.087	0.0087
(iii)	23.242	2.324	0.008	0.0008	0.658	0.0658	1.366	0.137	0.086	0.0086
Sandstone 3										
(i)	1.858	0.185	-0.013	-0.0013	0.911	0.0911	1.811	0.181	-0.041	-0.0041
(ii)	1.86	0.186	-0.011	-0.0011	0.91	0.0910	1.812	0.181	-0.038	-0.0038
(iii)	1.856	0.186	-0.014	-0.0014	0.912	0.0912	1.81	0.181	-0.04	-0.004
Sandstone 4										
(i)	5.384	0.538	-0.010	-0.001	0.827	0.0827	1.436	0.144	0.05	0.005
(ii)	5.388	0.539	-0.008	-0.0008	0.828	0.0828	1.437	0.144	0.048	0.0048
(iii)	5.386	0.539	-.0.012	0.0012	0.826	0.0826	1.438	0.144	0.046	0.0046
Sandstone 5										
(i)	21.988	2.199	0.004	0.0004	1.103	0.1103	1.305	0.131	0.002	0.0002
(ii)	21.99	2.199	0.006	0.0006	1.101	0.1101	1.302	0.130	0.001	0.0001
(iii)	21.986	2.199	0.002	0.0002	1.105	0.1105	1.308	0.131	0.003	0.0003
Average		**1.612**								

Summary

The Ajali Sandstone is a major clastic Formation of Campanian-Maastrichtian age occurring within the Anambra basin. The formation is quite extensive in the Anambra Basin, occurring in both Western and Eastern parts of the Basin. The study area is in the tropical climate of Nigeria and weathering is very intense. As a result, the Sandstone is highly weathered at the top, with the formation of residual soil and ironstone below the residual soil. The Ironstone is brick red in colour and very pervasive on the surface of the outcrop. The Ironstone is hard, non-banded and non-cherty. It has an average Fe percentage of 26.34%, which qualifies it as a

Fig. 4: Ajali Ironstone

good source of Fe for economic uses, such as in the building industry, production of ceramics and others.

Fig 5: Sample of "Ajali Ironstone"

References

Akpofure, E. and Etu-Efeotor, J.O., (2013). Petrography of Ajali Sandstone in Ayogwiri-Fugar-Orame Area of Western Anambra Basin: Implication for diagenetic and depositional history. Journal of Environmental and Earth Sciences. Vol. 3, No. 5, pp. 104-113.

MacKenzie, F.D., (1959). Pyrometasomatic deposits at the Mineral Hill and Daisy mines, in Ariz. Geol. Soc., Guidebook 2, Apr. 1959: Ariz. Geol. Soc. Digest, 2d Ann., pp. 1993–1994.

Loughnan, F.C., (1969). Chemical Weathering of the Silicate Minerals. Amsterdam and New York (Elsevier Publ. Co.), pp. 154, 62 figs.

Sherman, G.D., and Ikawa, H., (1959). Occurrence of gibbsite amygdules in Haiku Bauxite area of Maui (Hawaii): Pacific Science, vol. 13, no. 3, pp. 291 – 294.

Umeji, O.P., and Nwajide, C.S., (2007). Age control and designation of the standard stratotype of Nsukka Formation of Anambra basin, southeastern Nigeria. *Journal of Mining and Geology*. 43(2) pp.147-166.

Wikipedia contributors. (2021, June 17). Iron ore. In *Wikipedia, The Free Encyclopedia*. Retrieved 11:00, June 22, (2021), from

Pictorial view of the new NMGS House under construction at Abuja.