

Full Length Research Paper

Sandclass classification scheme for Ajali sandstone units in Ohafia area, Southeastern Nigeria

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Twenty six (26) sandstone samples from the Ajali Formation in Ohafia area of southeastern Nigeria and two samples from the Gombe Formation in the Upper Benue valley, northeastern Nigeria, have been analysed for major elements and the results used in sandclass classification scheme. In the scheme, Log ratios of $\text{SiO}_2/\text{Al}_2\text{O}_3$ and $\text{Fe}_2\text{O}_3/\text{K}_2\text{O}$, which express and relate geochemical fractions of sands to the existing sandstone classification scheme have been used to re-classify the Ajali sandstone units from Ohafia area. Results of this method show that the Ajali sandstone in the area can be classified as Fe-rich quartz arenitic sandstone when taken as one unit. However, field and geochemical data indicate two major sandstone units grouped as quartz arenite and ironstone. About 50% of the samples from the area plot in the Fe-rich class, 41% in the quartz arenite class and 9% in the sub-arkosic class. In comparison with two samples from a similar Maastrichtian Formation, one of the samples in the sub-arkosic class belongs to the upper Benue valley Maastrichtian Gombe sandstone. These results indicate that the Ajali sandstone Formation in the area is made up of two units. The lower unit is composed of an Fe-poor variety, while the upper unit is Fe-rich.

Key words: Geochemical, petrographic, sandclass, classification scheme, Ajali sandstone.

INTRODUCTION

Classification of sandstone based on the scheme of Krynine (1984), has revealed a lot of inconsistencies. This is because most of the key parameters: quartz (Q), feldspar (F), rock fragment (R) and matrix element (M) are not properly defined. Although Pettijohn et al. (1972) and Pettijohn (1975) have successfully used the $\text{Na}_2\text{O}/\text{K}_2\text{O}$ ratios in isolating graywackes from arkoses. Herron (1988) has pointed out that this method cannot be employed successfully in isolating lithic fragments from feldspars. Thus a classification scheme developed from Herron (1988) has been applied to the geochemical data for the Ajali Sandstone samples from the Ohafia-Arochukwu area of southeastern Nigeria. Reymont (1965) suggested a sub division of the Ajali Formation into two (The Fe-rich and the Arkosic varieties). This can only be done using geochemical data. Similarly Reymont (1965) suggested a sub division of the Nsukka Formation into top Fe-rich and lower Arkosic varieties.

Hoque and Ezepue (1977) have classified the Ajali Sandstone as a quartz arenite on the basis of four para-

meters earlier mentioned. The present scheme is based on log plots of $\text{Fe}_2\text{O}_3/\text{K}_2\text{O}$ and $\text{SiO}_2/\text{Al}_2\text{O}_3$ of Herron (1988). The scheme has an added advantage of isolating shales from sandstones and lithic sands from feldspathic sands. While the $\text{Fe}_2\text{O}_3/\text{K}_2\text{O}$ ratio separates lithic fragments from feldspars in sandstones in a general sense, the $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio is used in the scheme to distinguish between quartz-rich (high ratio) sandstones from clay-rich (low ratio) shales as found by Braide (1993). Pettijohn et al. (1972) and Herron (1988) also pointed out that the two ratios are mineralogical maturity indicators.

The sandclass scheme is thus applied to expose sandstone samples from the Ajali Formation in the Ohafia-Arochukwu area in particular as a prelude to reclassification of the whole of Ajali Formation in Nigeria.

GEOLOGICAL SETTING AND PETROGRAPHY

The Ohafia-Arochukwu area of southeastern Nigeria is underlain by four main geological formations. These include a mid-Cretaceous-Coniacian Npkoro Formation, made up of shales and sandstones, the Mamu Formation with shales, sandstone and coal seams (Reymont, 1965),

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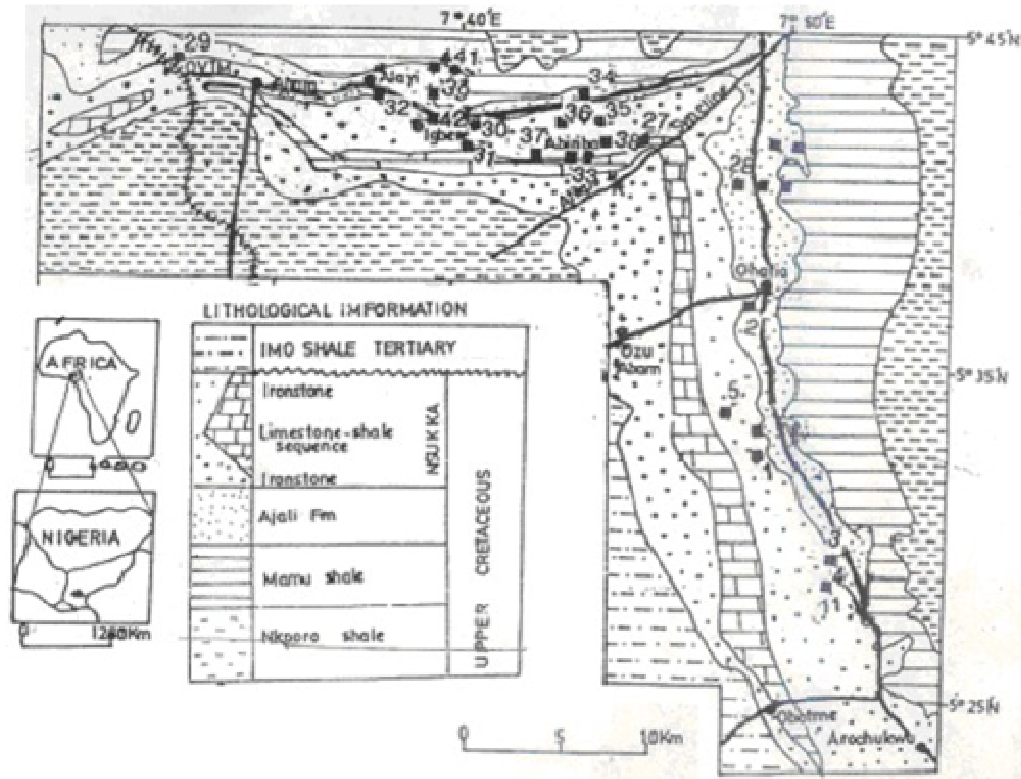


Figure 1. Geological map of Ohafia-Arochuku area showing the Ajali formation.

the Ajali Formation, consisting of Quartz arenitic sandstone (Hoque and Ezepue, 1977) and the late Cretaceous Nsukka Formation, characterized by ironstones, shales and limestones (Ibe and Ogezi 1999; Ibe, 2000).

The Ajali Sandstone in the area has two distinct units. These are the quartz-rich lower unit and the overlying iron-rich variety. The lower unit is cream-colored, passing through an iron-stained sandstone to the iron oxide cemented sandstone that contains glauconite. The ironstone unit underlies the foraminiferal limestone that distinguishes the Nsukka Formation in Ohafia area from the type locality where coal seams are recorded, (Reyment, 1965). However, no such coal seams were recorded in the study area. There is thus a prominent facies change from north to south in late Cretaceous sediments in eastern Nigeria, (Ibe, 1999). These formations are conformable with dip values of between 8° and 25° in the SW and W directions, respectively. These formations are shown in Figure 1.

MATERIALS AND METHODS

In the field, the Ajali sandstone units are exposed along gullies, stream valleys erosional surfaces and road cuts. In hand specimen, the loosely-cemented varieties are cream-coloured with sub-angular to sub-rounded quartz grains, unsorted and iron-stained toward the

top. The ironstone section grades into bands rich in trace fossils as recorded in the area south of Abiriba town, (Ibe, 1999). Field evidence reveals two types of sandstones. Firstly, there is the cream-coloured lower unit that is friable, cross-bedded with prominent SW palaeocurrent direction, (Hoque and Ezepue, 1977). Secondly there is the iron-stained section of the cream-coloured variety that grades into the hard iron oxide-cemented variety (Ibe, 2000).

In the laboratory chemical analysis and microscopic work were done on the samples. The friable variety is made up of sub-angular to sub-rounded quartz grains with occasional mica (Plates 1 and 2). However the ironstone variety is composed of quartz grains of similar morphology but cemented by iron oxide (Plates 3 and 4).

Fresh samples of the two varieties weighing between 0.5 and 1 kg were crushed to the powder with the Tema Agate grinder model No. DB 20-1-YB. About 0.005 kg of the fine powder from each variety was ignited in crucibles at 1000°C for one hour. The ignited samples were cooled and reweighed to determine loss on ignition, (LOI), using a Sartorius electronic balance model No. 3708 MP1 with accuracy of 0.001 g. About 0.4 g of the fine powder was introduced into weighed platinum +5% gold alloy crucibles into which about 4 g of spectroflux 110 were added. The contents were stirred to homogeneity and ignited at 1000°C for 30 min. The choice of spectroflux 110 is informed by the fact it is made up of 4 parts of LiBO_4 to 1 part of $\text{Li}_2\text{B}_4\text{O}_7$, an eutectic composition, formulated to dissolve silicates, calcareous materials and aluminosilicates ranging from 100% SiO_2 to 100% Al_2O_3 . After cooling, the loss in weight was made up with spectroflux 110.

The crucibles were heated over gas burners to get the samples re-melted. Each melt was cast into one copper ring and pressed down smoothly with aluminum hammer to form the melt into a disc of glass that was fed into an XRF machine model PW 1400 belonging to the Earth Sciences Department, University of Leeds.

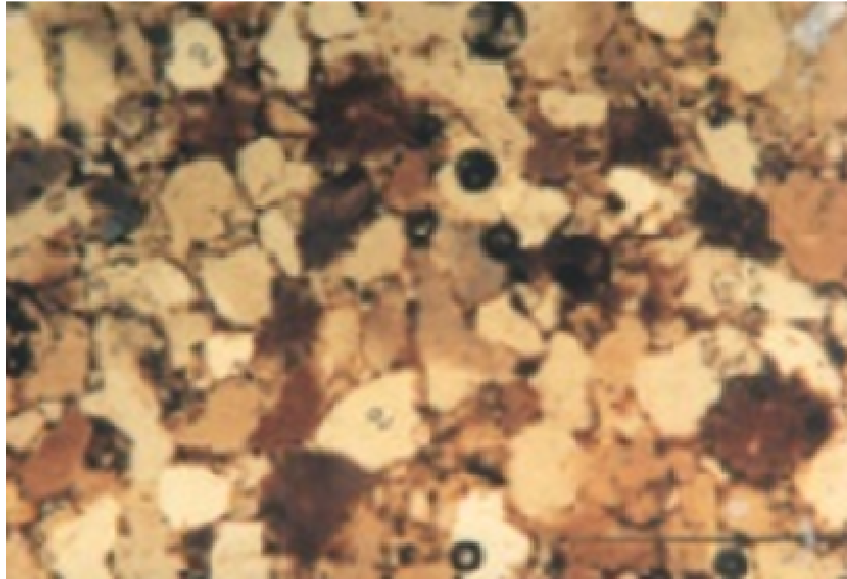


Plate 1. Photomicrograph of artificially-bound Ajali sandstone (Compare grain shapes with those in plates 3 and 4).

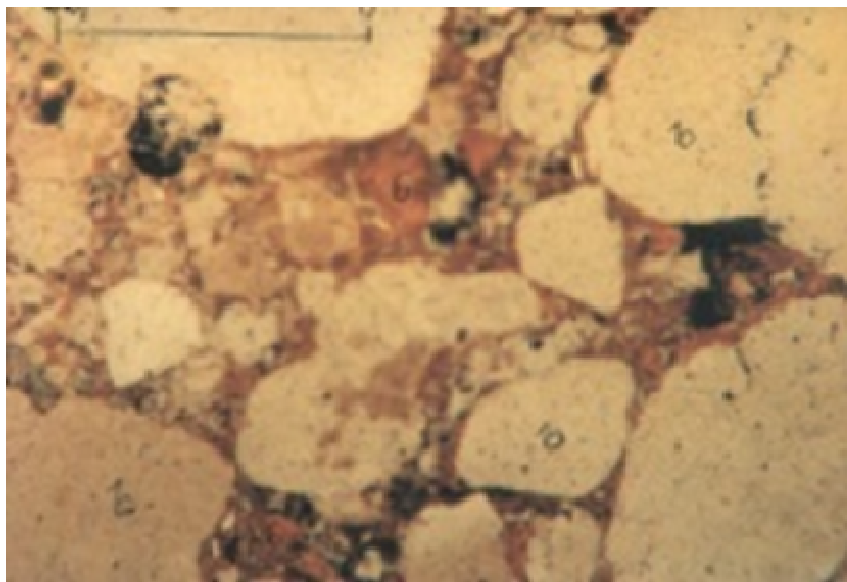


Plate 2. Photomicrograph of artificially-bound Ajali sandstone (Compare grain shapes with those in plate 3 and 4).

Results were read and printed out from and an Elonex computer attached to the XRF machine.

RESULTS AND DISCUSSIONS

Results of the major element geochemistry are shown in Tables 1 and 2 while the calculated log ratios of $\text{Si}_2/\text{Al}_2\text{O}_3$ and $\text{Fe}_2\text{O}_3/\text{K}_2\text{O}$ are shown in Table 3. Plots, of $\log(\text{Fe}_2\text{O}_3/\text{K}_2\text{O})$ against $\log(\text{SiO}_2/\text{Al}_2\text{O}_3)$ are as shown in Figure 2. From the plots, it is clear that what was original-

ly called quartz arenite is basically made up of iron rich member (50%) and quartz arenite (41%). Of the 3 samples that plotted under the subarkosic class (4, 5 and 8) samples 5 and 8 are from the Gombe Formation in the Upper Benue valley, signifying entirely different sedimentological and geochemical situations from that of the Ajali Formation even though these distant formations are said to be lateral equivalents Reymont, (1965).

In the past, the Ajali sandstone has been classified on the basis of mineralogy using the four parameters: quartz

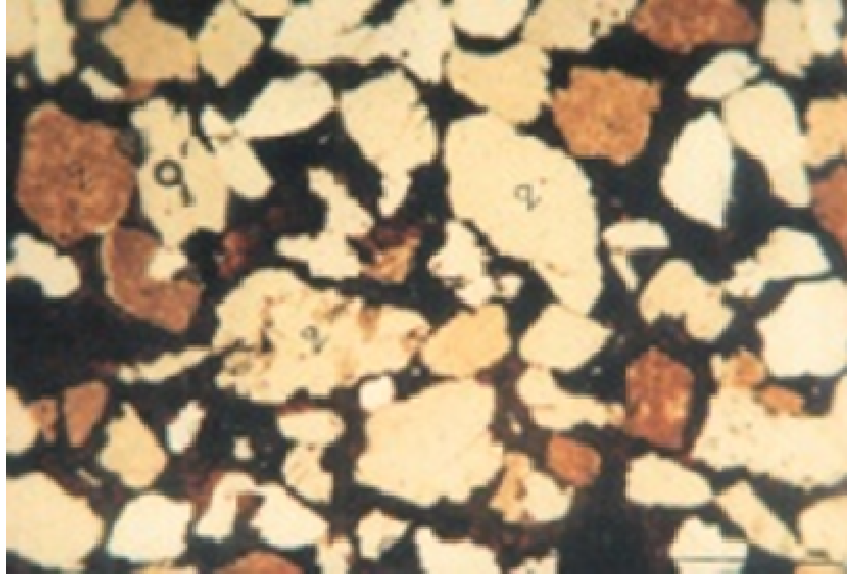


Plate 3. Photomicrograph of iron oxide-cemented Ajali sandstone (Note similar grain morphology as a plates 1 and 2 and mica plates).

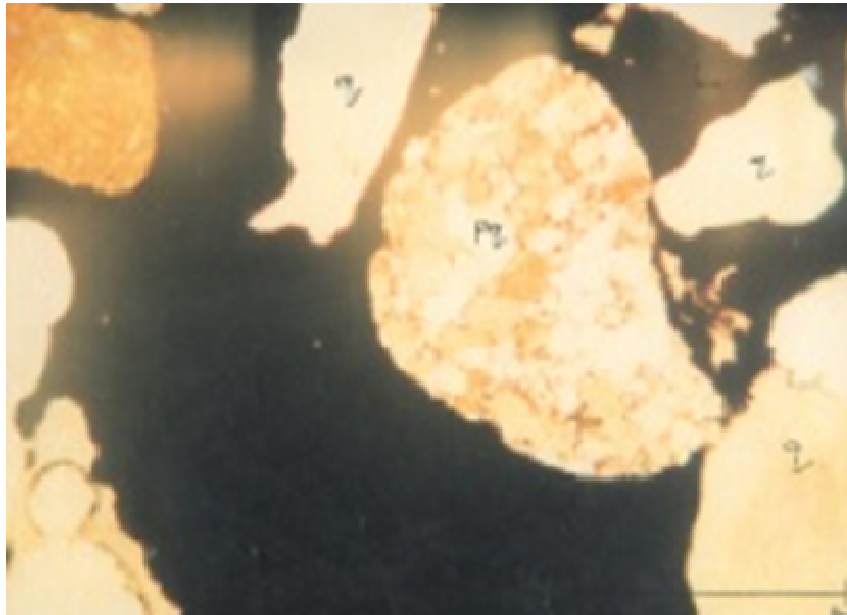


Plate 4. Photomicrograph of iron oxide-cemented Ajali sandstone (Note similar grain morphology as a plates 1 and 2 and mica plates).

(Q), feldspar (F), rock fragment (R) and matrix element (M). Very often the accurate determination of the proportions of these parameters is in error since it is not possible to determine their modes in rock slides. Based on field and petrographic work, Hoque and Ezepeue (1977) have classified Ajali sandstones as a quartz arenite. No attention has been paid to the iron-rich top unit of the Ajali Formation and many workers have described it merely as a duricrust. However, Reymont,

(1965) drew attention to the peculiarity of the iron-rich geological unit at the top of Ajali Formation based on the iron content and suggested the subdivision of this portion into more geological formations in eastern Nigeria. This has not been done, hence this classification method. From the results presented, it is quite clear that distinctions are made with respect to the Ajali Formation in the area; (a) the Ajali Formation is not purely a quartz arenite unless the upper unit is separated from the lower

Table 1. Result of chemical analysis of uncemented Ajali sandstones.

% Oxide	Samples															Range	Mean
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
SiO ₂	78.40	66.40	65.0	63.59	63.60	53.60	57.19	57.99	53.20	52.07	48.8	41.55	46.20	48.80	13.70	13.70 - 78.40	53.97
TiO ₂	0.99	0.25	0.20	0.05	0.17	0.63	0.03	0.12	0.20	0.15	0.53	0.39	0.19	0.19	0.40	0.03 - 0.99	0.32
Al ₂ O ₃	1.39	1.84	2.72	0.98	1.79	3.20	1.28	1.39	1.47	1.77	4.63	4.13	3.26	4.01	3.07	0.98 - 4.63	2.46
Fe ₂ O ₃	15.37	25.74	28.60	29.87	30.38	34.22	35.25	35.55	37.54	38.97	38.97	46.39	45.76	42.61	70.20	15.37 - 70.20	37.03
MnO	ND	ND	ND	0.01	ND	ND	0.01	0.01	ND	0.02	ND	0.06	ND	ND	ND	0.0 - 0.06	0.01
MgO	0.26	0.28	0.28	0.07	0.25	0.20	0.09	0.06	0.23	0.04	0.19	0.05	0.23	0.20	0.20	0.07 - 0.28	0.18
CaO	0.35	0.88	0.73	0.08	0.78	0.58	0.36	0.02	0.76	0.02	0.29	0.02	0.55	0.29	0.50	0.02 - 0.88	0.41
Na ₂ O	0.02	0.02	0.02	0.05	0.02	0.02	0.05	0.09	0.02	0.01	0.02	0.04	0.03	0.04	0.03	0.01 - 0.09	0.03
K ₂ O	ND	ND	0.01	0.13	0.01	ND	0.03	0.02	ND	1.16	0.02	0.04	0.01	0.05	0.01	0.0 - 1.16	0.10
P ₂ O ₅	0.47	0.97	0.07	0.91	0.07	1.10	0.29	0.28	0.39	1.16	0.18	0.51	0.09	0.18	0.88	0.07 - 1.16	0.50
LOI	2.9	3.5	2.0	4.65	2.72	6.78	5.15	5.13	5.43	5.48	5.78	7.01	3.28	3.46	10.54	2.0 - 10.54	4.92
Total	100.15	99.88	99.63	100.39	99.79	99.83	99.75	100.66	99.24	100.85	99.41	100.28	99.83	99.83	99.53	99.24 - 100.85	99.93

Table 2. Result of chemical analysis of ironoxide-cemented sandstone samples.

% Oxide	Samples															Range	Mean
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
SiO ₂	98.65	97.41	97.15	92.90	91.16	95.69	93.21	93.21	90.45	88.69	87.84	81.53	81.01	80.56	80.10	80.10 - 98.65	89.97
TiO ₂	0.01	0.05	0.07	0.09	0.55	0.42	0.85	0.22	0.27	0.17	0.49	0.79	0.72	0.70	0.75	0.01 - 0.79	0.41
Al ₂ O ₃	0.22	0.56	1.34	3.90	4.28	1.88	3.15	3.40	1.02	6.03	7.73	0.67	0.81	0.83	0.81	0.22 - 4.28	2.44
Fe ₂ O ₃	0.04	0.84	0.31	0.28	0.32	0.47	0.34	0.52	6.53	1.54	0.88	13.40	11.90	10.90	11.20	0.04 - 13.40	3.57
MnO	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.02	0.0 - 0.03	0.01
MgO	0.06	0.05	0.05	0.08	0.07	0.07	0.08	0.11	0.05	0.09	0.03	0.08	0.10	0.09	0.06	0.03 - 0.11	0.07
CaO	0.02	0.01	0.01	0.01	0.03	0.09	0.01	0.07	0.04	0.08	0.05	0.09	0.08	0.07	0.08	0.01 - 0.09	0.05
Na ₂ O	0.03	0.02	0.22	0.02	0.12	0.04	0.00	0.28	0.03	0.05	0.02	0.08	0.07	0.06	0.05	0.0 - 0.28	0.07
K ₂ O	0.05	0.01	0.02	0.41	1.98	0.01	0.04	0.95	0.01	0.05	0.03	0.01	0.01	0.02	0.01	0.01 - 1.98	0.24
P ₂ O ₅	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.06	0.05	0.01	0.00	0.62	0.56	0.59	0.45	0.0 - 0.62	0.16
LOI	0.14	0.51	0.57	1.50	0.73	0.77	1.28	1.16	0.93	2.84	3.14	2.19	3.10	3.44	3.25	0.14 - 3.44	1.60
Total	99.22	99.46	99.94	99.19	99.26	98.97	98.97	99.98	99.38	99.55	100.21	99.47	99.38	99.09	98.68	98.38 - 100.21	99.35

Nd = Not in determinable amount.

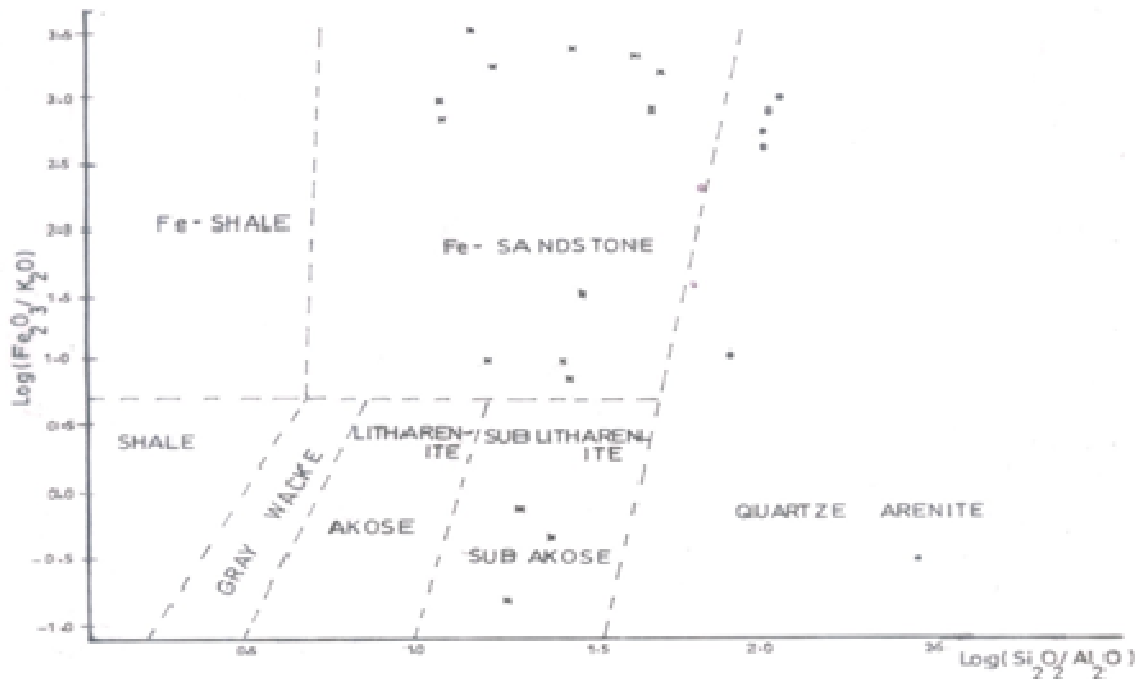
arenitic unit, (b) it is not purely an ironstone unit unless also a distinction is made between the

lower and upper units as suggested by Reymont (1965). This sub-division has been made from

field, petrographic and geochemical data in the present study. Unless this distinction is made,

Table 3. Log ratios of sandstone samples from Ajali formation.

Friable sandstone			Cemented sandstone		
Sample No.	Log (SiO ₂ /Al ₂ O ₃)	Log (Fe ₂ O ₃ /K ₂ O)	Sample No.	Log (SiO ₂ /Al ₂ O ₃)	Log (Fe ₂ O ₃ /K ₂ O)
1	2.65	-0.097	1	1.75	> 4.0
2	2.24	1.920	2	1.56	> 4.0
3	1.86	1.190	3	1.38	3.45
4	1.38	-0.165	4	1.81	2.36
5	1.32	-0.791	5	1.55	3.48
6	1.71	1.67	6	1.22	> 4.0
7	1.47	0.92	7	1.65	3.07
8	1.44	-0.26	8	1.62	3.25
9	1.95	2.81	9	1.56	> 4.0
10	1.17	1.49	10	1.47	1.52
11	1.06	1.47	11	1.02	3.29
12	2.08	3.08	12	1.00	3.06
13	2.00	3.08	13	1.15	3.66
14	1.98	2.74	14	1.09	2.93
15	1.99	3.05	15	0.65	3.85

**Figure 2.** Sandclass classification of Ajali sandstone.

there is no scientific basis to continue to refer to Ajali Formation in the area as a quartz arenite. The high mineralogical maturity association with the Ajali sandstone, (Hoque and Ezepue, 1977), can only be upheld if supported by geochemical data as has been done within the Ajali sandstone in the Ohafia area (Odigi and Amajor, 2008).

Conclusion

The application of sandclass classification scheme to geochemical data obtained from the Ajali Formation in Ohafia area in southeastern Nigeria indicates that the whole formation is not a quartz arenite. Rather two units are evident: the quartz-rich lower unit and the iron-rich

upper unit. There is thus the need to sub-divide the Ajali Formation of southeastern Nigeria, into at least two geological formations for easy field, petrographic and geochemical studies.

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