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GRANULOMETRIC AND GEOCHEMICAL ASSESSMENT OF AJALI SANDSTONE IN FUGAR AREA IN BENIN FLANK OF ANAMBRA BASIN, NIGERIA

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ABSTRACT

The aim of this study is to carry out granulometric and geochemical assessment of Ajali Sandstone outcrops in Fugar area in Benin Flank of Anambra Basin, Nigeria using results from grain size, major oxide and trace elements analyses. The study area lies between longitudes 06° 35' 04" E and 06° 35' 56" E and latitudes 07° 05' and 21" N 07° 05' 52" N. Five samples were collected from the study area for the analyses. Automated sieve shaking machine and Epsilon-5 x-ray fluorescence pAnalytical model were used. The sediments are fine-grained to coarse-grained poorly sorted to very well sorted. The sediments are strongly fine skewed to strongly coarse skewed. The sedimentary structures and the bimodal distribution of the grain size parameters pointed to intertidal environment of deposition for the sediments. SiO_2 has the average concentration of 81.78 wt. % with range of 81.6 – 82.0 wt. %. It is followed by Al_2O_3 with average concentration of 9.41 wt. %. Fe_2O_3 has average concentration of 5.61 wt. %. Zr has average concentration of 1,500 ppm followed by Ba with mean concentration values of 1,290 ppm. Cu has an average concentration of 280.5 ppm. Conversely, U, Th, Co, Ni, As, Au and Pb have low concentration in the analysed samples. The sandstone samples are highly ferruginised because of their high Fe_2O_3 contents. The presence of ferromagnesian trace elements such as Cr, V and Co enrichment and the high weight percentages of SiO_2 in the sandstone samples indicated origin from source rocks such as granites and migmatites. The sandstones from the study area are suitable raw materials for construction because of the negligible contents and non-pollution level of the radioactive elements in them.

Keywords: *Granulometric, geochemical, Ajali Sandstone, Fugar, Edo State*

INTRODUCTION

The goal of this study is to carry out granulometric and geochemical assessment of Ajali Sandstone outcrops in Fugar area in Benin Flank of Anambra Basin, Nigeria using results from grain size, major oxide and trace elements analyses with the objectives of determining the provenance of the source rock(s), the depositional environment(s) of the sandstones and their environmental usefulness. Although, much research work has been carried out in the region for petrological, mineralogical and structural studies by several workers; however, there is paucity of publications on the granulometric and geochemical assessment of the study area. The need to study the geochemical characteristics of the sandstones is justifiable and will also contribute to the economic development of the area of study. The study area is located in Fugar in Estako Central Local Government Area, Edo State. The area lies within the latitudes 07° 05' 25" and 07° 07' 35" N and longitudes 06° 31' 50" and 06° 37' 58" E. The elevation varies between 180 to 223 metres at different locations. Fugar is a commercial centre of Etsako Central Local Government Area with well-developed and moderately developed roads network for easy accessibility. The mapping and sampling was carried out along road cuttings of Fugar-Agenebode road. The climatic condition of Fugar and its environs fall within the warm tropical climate region where the wet and dry seasons are noticed prominently in the area. The dry season is between November and March while the rainy seasons are mostly between April and October. The climate in this region is warm tropical rainforest. The vegetation is dominated by moderately distributed trees, herbs, shrubs, and tall grasses. Cocoa, mango, cashew and sugar cane are grown in the study area in addition to rearing of cows, goats, sheep and livestocks. The drainage pattern in the study area is trellis pattern from the North-western area and dendritic towards the South-eastern direction. The major sources of water supply in the study area are rivers, streams, hand dug wells and boreholes.

Regional Geological Setting

The area is located in the Okpekpe-Imiegba-Fugar-Auchi-Bawa Hill area and lies within the Benin flank of the Anambra Basin (Figures 1 and 2). The Anambra Basin is situated in the Lower Benue Trough which an arm of an aborted rift valley system called aulacogen that provided accommodation space for sedimentation to occur (Burke *et al.,* 1971; Grant, 1971 and Hoque, 1977).

The Benue Trough undergone three cycles of sedimentation that occurred from Aptian to Paleocene age. The first cycle took place during Aptian-Albian age and led to the formation of Asu River Group. The second cycle of sedimentation that occurred during Cenomanian to Turonian led to the deposition of Eze-Aku Group which is made up of Keana, Makurdi, Agala and Amaseri Formations. During Santonian to Coniancian, Agwu Formation was deposited as the last phase of the second cycle of sedimentation. The third and last cycle of sedimentation led to the Campanian aged Enugu/Nkoro Formation followed by the deposition of the Maastrichtian aged Mamu Shale, over which was deposited Ajali Sandstone. Nsukka Formation which is also Maastrichtian in age was deposited over the Ajali Sandstone, while Paleocene aged Imo Shale was deposited over Nsukka Formation. The youngest is the Eocene Bende-Ameki Formation and Nanka Sandstone which were deposited over Imo Shale (Figure 2).

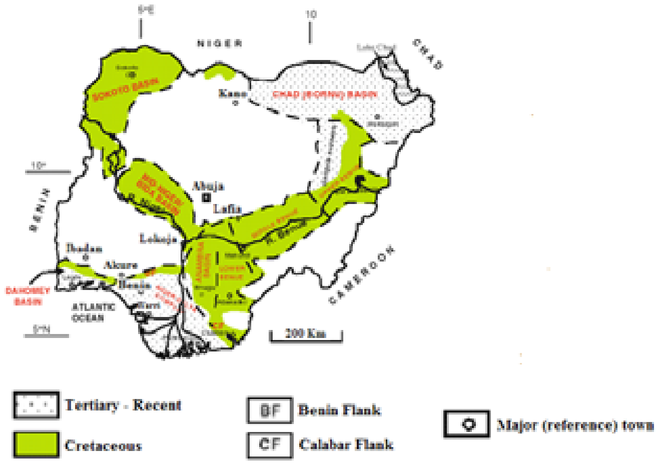

Figure 1: Map of Nigeria showing sedimentary basins on basis of age (Obaje, 2011)

Local Geology of the Study Area

Ajali Sandstone is a major clastic formation of Maastrichtian age occurring within the Anambra basin. The formation is extensively cross stratified into different types of cross-bedding including: planar, trough and herringbone cross-bedding which occur at different stratigraphic levels. The cross beds are large scale (over 1 meter high in some places). The

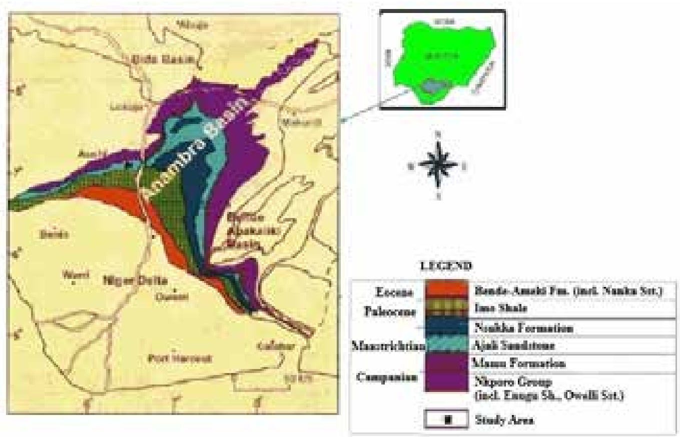

Figure 2: Map of Anambra Basin (after Nwajide, 2013)

thicknesses of the beds are not uniform but appear to be uniform with parallel bedding planes which have low dipping beds. The beds consist of friable, moderately to well sorted sands with shapes of grains ranging from subangular to subrounded. Initially, the formation was called the White False Bedded Sandstone and later changed to Ajali Sandstone (Reyment, 1965; Kogbe, 1976). Ajali Sandstone is fine- to coarse-grained quartz arenite, negatively skewed and platykurtic. Previous works on Ajali Sandstone indicate that its thickest section is in the Udi Plateau where it attains over 350m and extends continuously in thin outcrops to the southeast of Okigwi (Reyment, 1965; Ladipo, 1986). Its most conspicuous feature is its cross stratification having its foreset beds alternating between coarse- and fine-grained sands (Hoque and Ezepue, 1977).

MATERIALS AND METHODS

The field materials used in the collection of samples include global positioning system (GPS), Kraft envelops, markers, pen and field notebook. The laboratory materials used are weighing balance, set of sieves: 2.00mm, 0.85mm, 0.425mm, 0.3mm, 0.212mm, 0.15mm, 0.09mm and 0.063mm, Epsilon-5 x-ray fluorescence (XRF) pAnalytical model, Tema vibrating mill, pellitiser, beaker, platinum dish, silica crucible, small plastic containers, desiccators and oven.

Five samples were taken from Ajali Sandstone outcrops located along Fugar-Agenebode express road in Fugar at varying intervals between them and the samples were bagged and labelled SL1 to SL5. The coordinates and elevations of the sample locations were captured using GPS and recorded in the field notebook. Extreme care was taken to prevent possible contamination of the samples. Photographs of the outcrops in the sample locations were taken.

Sieve Method

This method was used to determine particle sizes distributions of the sediments. Particle sizes distributions were determined by weighing the materials retained in each sieve and dividing these weights by the total dry weight of the samples. Samples were split on sheet of paper and weighed using weighing balance.

Samples were placed into the automated sieve shaker. The sieving analysis was carried out using a sieve shaker with set of eight sieves with top cover agitated for about 25 minutes. The sieve sizes used are 2.00mm, 0.85mm, 0.425mm, 0.3mm, 0.212mm, 0.15mm, 0.09mm and 0.063mm. The fraction left in each sieve and those in the pan were weighed, recorded and used for calculations. The percentages of the aggregrates were estimated. The corrected weight of each fraction was used to calculate individual percentage. Each cumulative percentage was obtained as a percentage of the cumulative corrected weight to the total corrected weight. The grain sizes of the 5th, 16th, 25th, 50th, 75th, 84th and 95th percentiles were obtained from each cumulative curve drawn. These were used to calculate statistical parameters for the graphic mean (M), standard deviation (SD) and graphic skewness (SK) based on Folk and Ward (1957).

Geochemical method

X-ray fluorescence spectrometry method was used for major and trace elements analysis. The samples were pulverised and weighed into a beaker and 1.0g of binding substance (starch soluble) was added. The mixture was thoroughly mixed to ensure homogeneity, which was later pressed under high pressure to produced pellets, labelled and packaged ready for analysis. The rock samples were reduced to less than 63 microns using a Tema vibrating mill.

The major elements were analysed and expressed in weight percentages. About 5.0g of 63µm of each sample was placed in silica crucible and ignited at 1,000^{o}C for 2 to 3 hours for the calcinations of impurities in the sample powder. The samples were then removed from the furnace and allowed to cool to room temperature in dessicators. Each ignited sample powder was then weighed again to determine the weight of the calcinated impurities. 1.0g of the stored ignited sample powder was weighed and exactly five times of flux was added to lower the vitrification temperature of the sample powder. The weighed mixture was mixed properly in a platinum dish and ignited in the pre-set furnace at 1,100^{o}C for 10 minutes to form a molten mixture. Then the molten mixture was poured into a mould in the furnace, then cooled and removed, over a compressed stream of air, tapping the edge with a small iron slab until the glass bead formed separated. Each glass bead was labelled and slotted into the computerised XRF for major elemental analysis.

Trace elemental analysis was carried out using compressed powder pellets. These pellets were prepared by weighing 3.0g of oven dried sample powder and 3.0g flux (cellulose-powder) added as a binder and dispersive agent and shaken in small plastic containers for 12 minutes till the mixture was very well mixed and then compressed by applying pressure of 1,500 Kgm^{-2} using both manual and electronic compressors. The pellets were placed in the computer programmed XRF for trace elemental analysis.

RESULTS AND DISCUSSION

Location SL1 lies on latitude 07° 05' 48" N and longitude 06° 33' 56" E and has an altitude of 223 metres. The sandstone in this location is cream to white in colour. The sedimentary structures present in this rock are cross bedding, graded beddings, cross beddings, ripple marks with paleocurrent directions with azimuth of 104°SE and 120°SE. Overlaying the whole strata is ferruginised overburden (Figure 3).

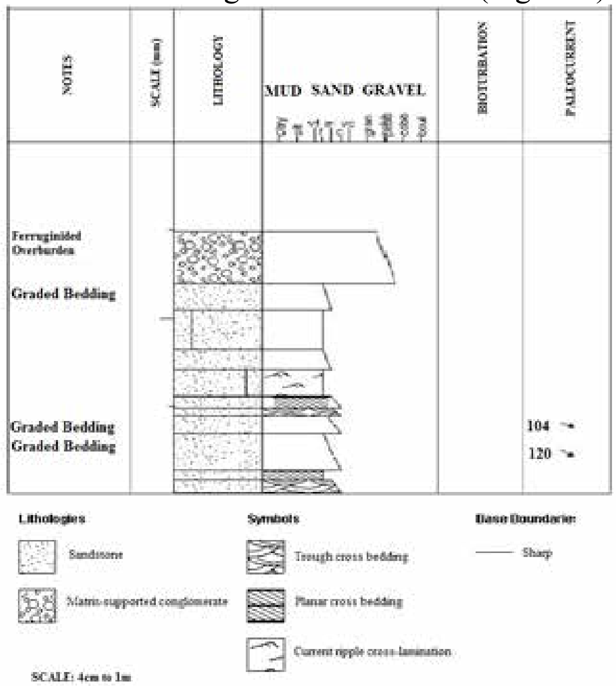

Figure 3: Facies Log of the Lithology of Location SL1

Location SL2 lies on latitude 07° 05' 21" North and longitude 06° 34' 06" East and has an altitude of 220 metres. The sandstone in this location is cream to white in colour. The sedimentary structures present in this location are channel structures, bioturbations (horizontal) and graded bedding. Overlaying the whole strata is overburden which is up to 4 metres in heights (Figure 4).

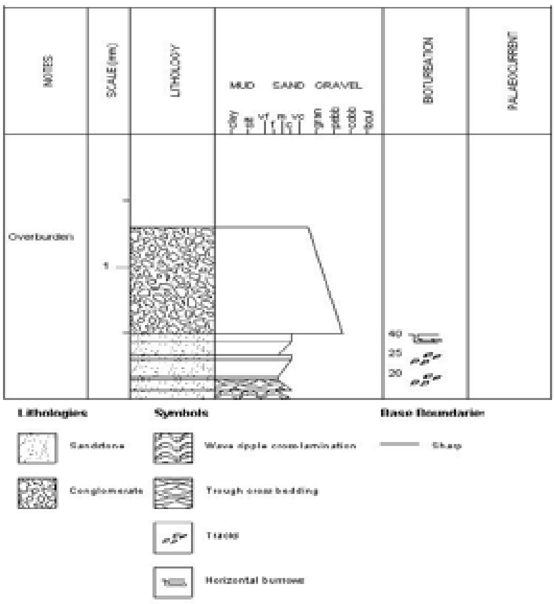

Figure 4: Facies Log of the Lithology of Location SL2

Location SL3 lies on latitude 07° 05' 37" N and longitude 06° 35' 04" E and has an altitude of 218 metres. The sandstone in this location has ash colour. The structures present in this sedimentary rock are graded bedding with paleocurrent direction of 234°SE, 224°SE and 220°SE. Overburden which is up to 4 metres in heights lies above the sandstone sequences (Figure 5).

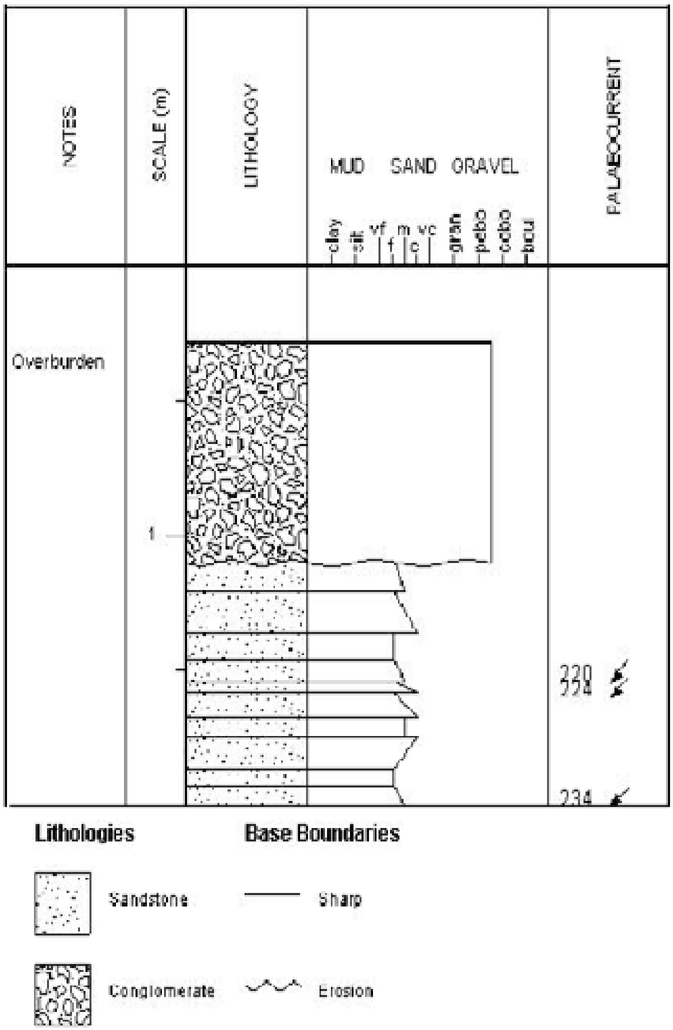

Figure 5: Facies Log of the Lithology of Location SL3

Location SL4 lies on latitude 07° 05' 52" North and longitude 06° 35' 14" East and has an altitude of 221 metres. The sandstone in this location is reddish-brown to white in colour (Figure 6) with its texture varying from fine to medium at each lithostrata. The structures present in this sedimentary rock are graded bedding, ripple marks, cross beddings with paleocurrent directions with azimuth of 118° SE and 106° SE (Figure 7).

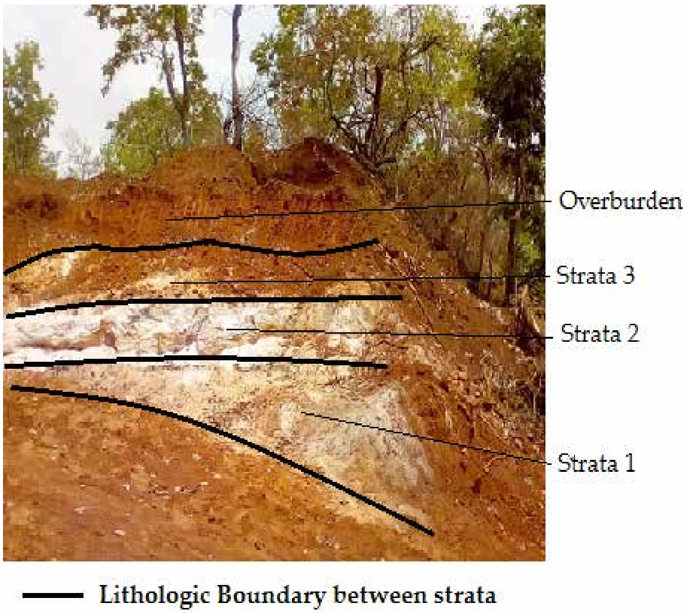

Figure 6: Lithostrata of Location SL4

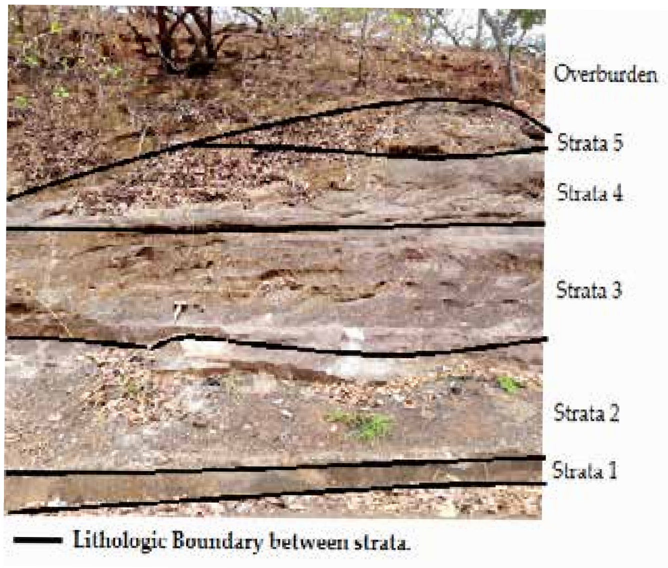

Figure 8: Lithostrata of Location 5

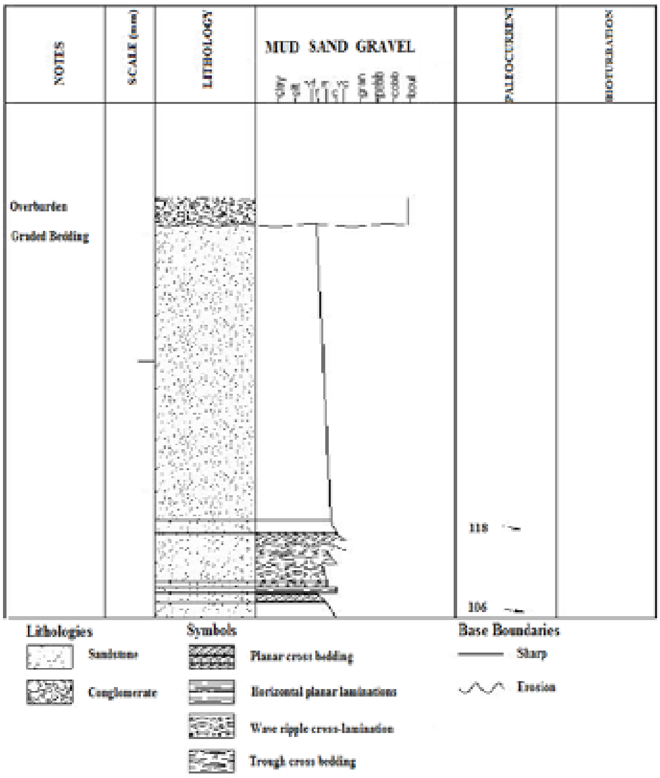

Figure 7: Facies Log of the Lithology of Location SL4

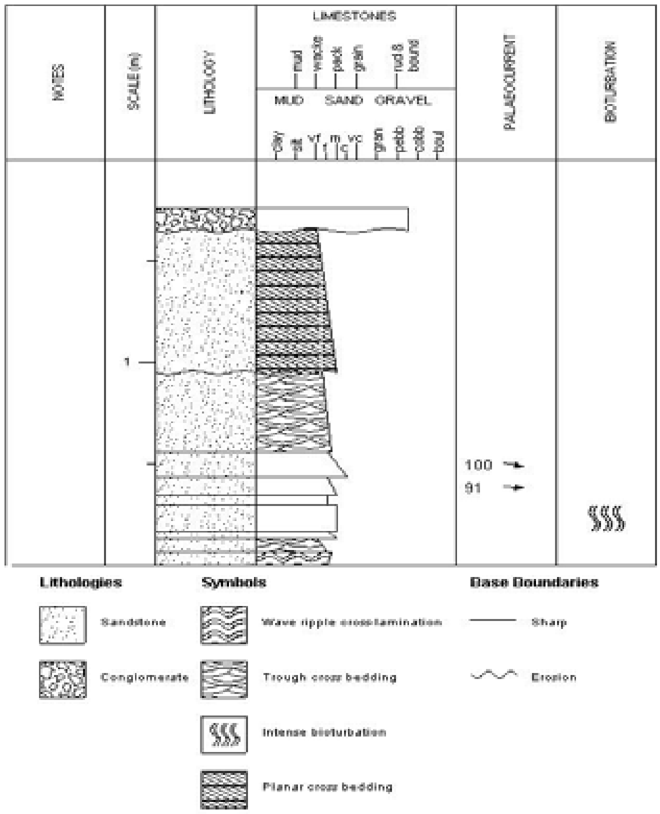

Fig. 9: Facies Log of the Lithology of Location 5

Location SL5 lies on latitude 07° 05' 38" North and longitude 06° 35' 56" East and has an altitude of 204 metres. The sandstone in this location is light grey to white in colour (Figure 8) and mostly fine-grained in sizes with slight variation of course, medium, fine grains at each lithostrata (Figure 9). The structures present in this sedimentary rock are bioturbation, graded bedding and ripple marks with paleocurrent directions with azimuth of 91°SE and 100°SE.

The results of the size analysis for locations SL1-SL5 are shown in Tables 1 - 6. Furthermore, the frequency distribution curves for samples SL1 - SL5 are shown in Figures 10 - 14. The result of the granulometric analysis shows that the sediments are fine- to coarse-grained, poorly sorted to very well sorted, and strongly fine-skewed to strongly coarse-skewed. The varying sorting values suggest that the sediments were from different provenance before deposition and lithification to form the present Ajali Sandstone.

SiO_2 is the dominant major element in Ajali Formation sandstone samples with range values of 81.6 – 82.0 wt. % with a mean value of 81.78 wt. %. Location SL2 has the highest value for SiO_2 which is 82.0 wt. % (Table 8). Al_2O_3 values range from 8.71 – 10.46 wt. % with its mean 9.41 wt. %. Location SL1 having the highest value for Al_2O_3 which is 10.46 wt. %. Fe_2O_3 values range from 4.36 – 7.62 with a mean of 5.61 wt. %. Location SL4 has the highest concentration of Fe_2O_3 which is 7.62 wt. %. Other Oxides present like CaO, K_2O, TiO_2, MgO, Na_2O, MnO, P_2O_5 and LOI have mean values of 0.57 wt. %, 0.71 wt. %, 0.28 wt. %, 0.78 wt. %, 0.39 wt. %, 0.02 wt. %, 0.07 wt. % and 0.57 wt. %, respectively. The SiO_2 concentration is indicative of silica-rich source rock before becoming a sandstone rock.

Zr concentration range between 640–2,800 ppm with the highest mean concentration of 1,500 ppm. The highest Zr concentration was found in SL2. Ba has its concentration values ranging between 940 to 2,000 ppm with a mean concentration of 1,290 ppm and its highest concentration, 2,000 ppm found at SL2. Cu has its concentration values ranging between 210 to 352 ppm with a mean concentration of 280.5 ppm. Sr has a concentration range of 162 to 215 ppm with its mean concentration at 183.5 ppm. In has its concentration values ranging between 120 to 184 ppm with its mean concentration at 154.75 ppm (Table 9).

Table 1: Grain Size Analysis Result for Sample Location SL1

Sieve size (mm)	**Phi(φ) = -log2 S**	**Sample Weight Retained (g)**	**Percentage Weight Retained (Wt. %)**	**Cumulative weight percentage (%)**
2.00	-1.0	5.5	1.1	1.1
0.85	0.23	35	7	8.1
0.425	1.23	191.2	38.26	46.36
0.3	1.74	147.2	29.46	75.82
0.212	2.24	85.4	17.09	92.91
0.15	2.74	24	4.8	97.71
0.09	3.47	7.7	1.54	99.25
0.063	3.99	1.6	0.32	99.57
Pan		2.1	0.42	99.99
Total		**499.8**		
Initial Wt.		**500.9**		

Table 2: Grain Size Analysis Result for Sample Location SL2

Sieve size (mm)	**Phi (φ)**	**Sample Weight Retained (g)**	**Percentage Weight Retained (Wt. %)**	**Cumulative weight percentage (%)**
2	-1	3.5	0.7	0.7
0.85	0.23	7.4	1.49	2.19
0.425	1.23	66.4	13.32	15.51
0.3	1.74	117.1	23.5	39.01
0.212	2.24	187.1	37.55	76.56
0.15	2.74	73.6	14.77	91.33
0.09	3.47	29.8	5.98	97.31
0.063	3.99	5.2	1.04	98.35
Pan (0)		8.2	1.65	100
Total		**498.3**		
Initial Wt.		**499.4**		

Table 3: Grain Size Analysis Result for Sample Location SL3

Sieve size (mm)	**Phi (φ)**	**Sample Weight Retained (g)**	**Percentage Weight Retained (Wt. %)**	**Cumulative weight percentage (%)**
2	-1	2.3	0.46	0.46
0.85	0.23	22	4.41	4.87
0.425	1.23	159.2	31.93	36.8
0.3	1.74	134.6	27	63.8
0.212	2.24	128.7	25.81	89.61
0.15	2.74	36.5	7.32	96.93
0.09	3.47	9.1	1.83	98.76
0.063	3.99	2.4	0.48	99.24
Pan (0)		3.8	0.76	100
Total		**498.6**		
Initial Wt.		**500.8**		

Table 4: Grain Size Analysis Result for Sample Location SL4

Sieve size (mm)	Phi (φ)	Sample Weight Retained (g)	Percentage Weight Retained (Wt. %)	Cumulative weight percentage (%)
2	-1	1.7	0.34	0.34
0.85	0.23	13.4	2.69	3.03
0.425	1.23	88.3	17.7	20.73
0.3	1.74	110.7	22.18	42.91
0.212	2.24	151.8	30.42	73.33
0.15	2.74	86.1	17.25	90.58
0.09	3.47	37.9	7.6	98.18
0.063	3.99	4.2	0.84	99.02
Pan (0)		4.9	0.98	100
Total		**499.0**		
Initial Wt.		**500.3**		

Table 5: Grain Size Analysis Result for Sample Location SL5

Sieve size (mm)	Phi(φ)	Sample Weight Retained (g)	Percentage Weight Retained (Wt. %)	Cumulative weight percentage (%)
2	-1	3.5	0.7	0.7
0.85	0.23	18.8	3.77	4.47
0.425	1.23	66	13.24	17.71
0.3	1.74	83.3	16.71	34.42
0.212	2.24	205.1	41.15	75.57
0.15	2.74	90.5	18.16	93.73
0.09	3.47	25.5	5.12	98.85
0.063	3.99	2.7	0.54	99.39
Pan (0)		3	0.6	99.99
Total		**498.4**		
Initial Wt.		**500.1**		

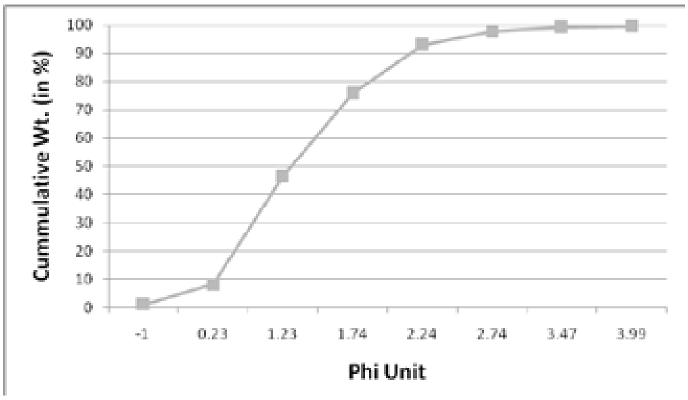

Figure 10: Frequency Distribution Curve of Sample Location SL1

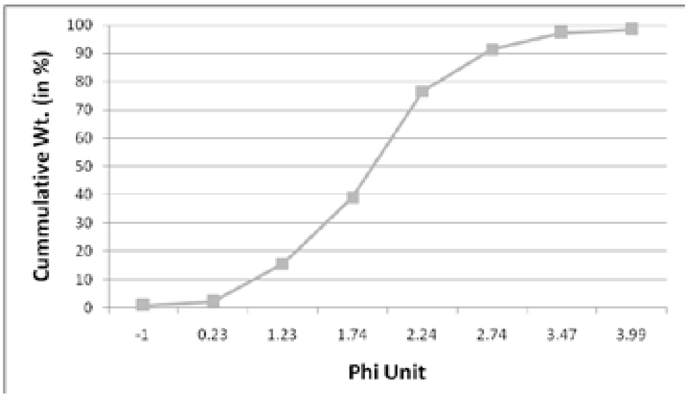

Figure 11: Frequency Distribution Curves of Sample Location SL2

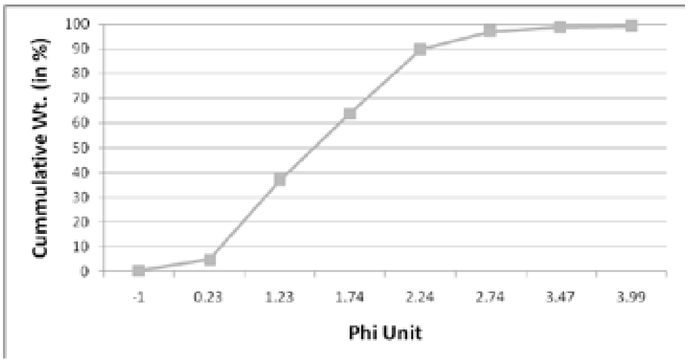

Figure 12: Frequency Distribution Curves of Sample Location SL3

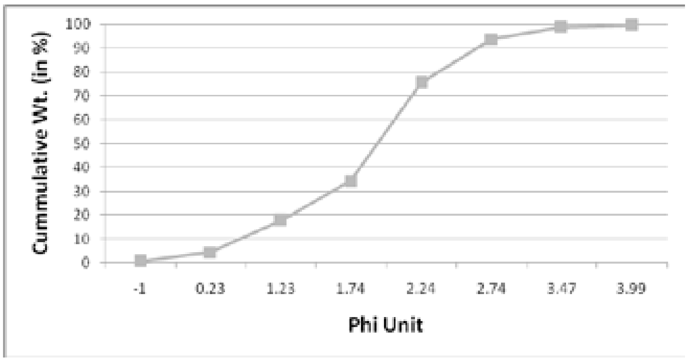

Figure 14: Frequency Distribution Curves of Sample Location SL5

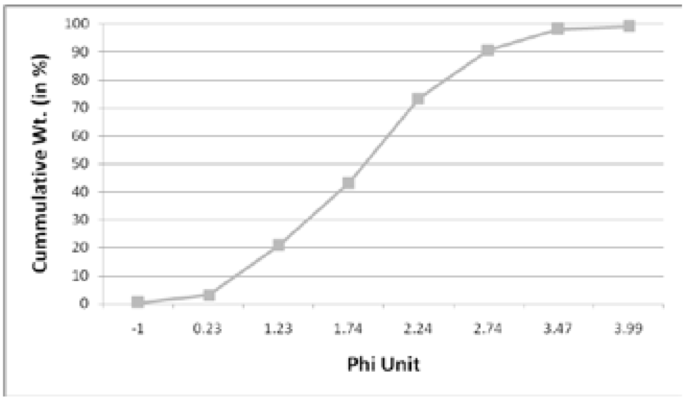

Figure 13: Frequency Distribution Curves of Sample Location SL4

Table 6: Summary of Grain size analysis of outcrop samples in Fugar area.

Sample Location	Graphic Mean (Mz)		Standard Deviation (Sorting)		Skewness (SKI)	
	Result	**Interpretation**	**Result**	**Interpretation**	**Result**	**Interpretation**
1	0.4	Coarse grained	1.24	Poorly sorted	19.29	Strongly fine-skewed
2	1.66	Medium grained	0.59	Moderately well sorted	1.53	Strongly fine-skewed
3	1.29	Medium grained	0.59	Moderately well sorted	-0.40	Strongly coarse-skewed
4	2.43	Fine grained	1.62	Poorly sorted	0.22	Fine-skewed
5	1.79	Medium grained	0.08	Very well sorted	-0.31	Strongly coarse-skewed

Table 7: Major Oxides Geochemical Analysis Result of Samples from Study Area (in Wt. %)

Oxides	Sample Locations				Min.	Max.	Mean	Median
	SL1	**SL2**	**SL3**	**SL4**				
SiO_2	81.72	82.0	81.8	81.6	81.6	82.0	81.78	81.76
TiO_2	0.22	0.20	0.29	0.4	0.20	0.4	0.28	0.255
Al_2O_3	10.46	9.06	9.40	8.71	8.71	10.46	9.41	9.23
$Fe2O_3$	4.36	5.36	5.13	7.62	4.36	7.62	5.61	5.245
MgO	0.58	0.98	0.87	0.68	0.58	0.98	0.78	0.775
CaO	0.81	0.03	0.8	0.63	0.03	0.81	0.57	0.715
K_2O	0.62	0.93	0.73	0.57	0.57	0.93	0.71	0.675
Na_2O	0.37	0.46	0.41	0.32	0.32	0.46	0.39	0.39
MnO	0.02	0.01	0.01	0.02	0.01	0.02	0.02	0.015
P_2O_5	0.06	0.06	0.07	0.08	0.06	0.08	0.07	0.065
LOl	0.58	0.71	0.43	0.56	0.43	0.71	0.57	0.57

Table 8: Trace Element Geochemical Analysis Result of Ajali Sandstone Outcrops in the Study Area (values in ppm).

Trace Element	Sample Locations				Min.	Max.	Mean	Median
	SL1	SL2	SL3	SL4				
Ag	0.6	0.3	1.2	1.0	0.3	1.2	0.775	0.8
As	2	2	4	3	2	4	2.75	2.5
Au	0.4	0.5	1.6	1.2	0.4	1.6	0.925	0.85
Ba	1,120	2,000	1,100	940	940	2,000	1,290	1,110
Be	8	14	12	10	8	14	11	11
Co	8	13	10	8	8	13	9.75	9
Cr	40	120	89	73	40	120	80.5	81
Cu	240	210	320	352	210	352	280.5	280
In	120	136	184	179	120	184	154.75	157.5
Ir	64	60	89	96	60	96	77.25	76.5
Nb	28	34	26	31	26	34	29.75	29.5
Ni	6	20	14	12	6	20	13	13
Pb	9	15	44	38	9	44	26.5	26.5
Rb	42	30	111	112	30	112	73.75	76.5
Re	54	92	70	116	54	116	83	81
Sb	2	5	3	2	2	5	3	2.5
Sn	26	41	30	28	26	41	31.25	29
Sr	186	215	162	171	162	215	183.5	178.5
Ta	5	17	15	19	5	19	14	16
Th	2	3	2	1	1	3	2	2
U	1.2	1	1.2	1.3	1	1.3	1.175	1.2
V	10	16	21	23	10	23	17.5	18.5
W	0.6	0.2	0.3	0.3	0.2	0.6	0.35	0.25
Zr	640	2,800	1,300	1,260	640	2,800	1,500	1,280

CONCLUSION AND RECOMMENDATION

The goal of the study was achieved. The result of the granulometric studies shows that the sediments are fine- to coarse- grained, poorly sorted to very well sorted, and strongly fine-skewed to strongly coarse-skewed. The varying sorting values suggest that the sediments were from different provenance before deposition and lithification to form the present Ajali Sandstone. The sedimentary structures and the bimodal distribution of the grain size parameters pointed to intertidal environment of deposition for the sediments.

On the other hand, the high content of Al_2O_3 and Fe_2O_3 in the samples analysed elucidated the source of ferrogenisation of the sandstone. The geochemical results of the study area indicate low concentrations of both radiogenic elements like U and Th, and associated elements such as As, Co, Sb, Ni and W indicated the absence of radiogenic impact of the sandstones thus making them to be useful for construction purposes. The different skewness variations suggest that the sediments have been transported from their source rock with relatively high to low energy before their deposition, compaction and sedimentation. The presence of ferromagnesian trace elements such as Cr, V and Co enrichment and the high weight percentages of SiO_2 in the sandstone samples indicated origin from source rocks such as granites and migmatites. The sandstones from the study area are suitable raw materials for construction because of the negligible contents and non-pollution level of the radioactive elements in them.

The preservation of Ajali Sandstone outcrops in Fugar area as a national geological monument for the education of students from various tertiary institutions in Nigeria is recommended.

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