Textural and Depositional Environment Analyses of Maastrichtian Ajali Sandstone Outcrops at Igbere-Abiriba Area Afikpo Basin South Eastern Nigeria

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DOI: https://doi.org/10.51584/IJRIAS.2023.8617

Received: 29 May 2023; Revised: 13 June 2023; Accepted: 20 June 2023; Published: 13 July 2023

Abstract: The study presents the Textural characteristics of the Ajali sandstone at Igbere-Abiriba area in Afikpo basin, southeastern Nigeria. The intent is to highlight possible constraints of the environment of deposition of the source material on one hand and to infer the provenance on the other hand. The investigation approach includes field studies involving grain size analysis. Field studies shows that the Ajali Sandstone is friable at all location and range in colour from white in freshly cut stone, to reddish brown on weathering. In addition, the Ajali Sandstone units are cross-bedded and show graded bedding, exemplified by fining upward sequence. Textural examination indicates that the sandstone ranges from fine to medium grain and few coarse grain sizes constituting about 76-99% sand fraction, with graphic mean grain size of 0.93-2.60. Standard deviation (sorting) ranges from 0.71-1.48 and implies poor - moderately sorted sediments, also symmetrical, mesokurtic to leptokurtic were observed in skewness and kurtosis. Bivariate plot from the grain size parameter combination gives a more satisfactory approach toward predicting the sedimentary environment. General studies inferred from the Textural index, the depo-environmental description of the Ajali Sandstone revealed a Fluvial-river system-dominated sedimentary process.

Keywords: Mesokurtic, Leptokurtic, Skewness, Kurtosis, Sandstone, Sediments, Basin

I. Introduction

The Maastrichtian Ajali Sandstone of the Afikpo basin, consist of thick, friable, poorly- medium sorted Sandstones typically white in colour, but sometimes iron stained. A marked banding of coarse, and fine layer is displayed. The sand grains are sub-angular in shape, with sparse cement of white clay. Large-scale cross bedding is characterize, and the angle of inclination of the forcet laminae with the underlying major bedding planes ranges up to 200. Thin bands of white mudstone and shale occur at intervals, which increases in thickness towards the top.

In terms of area coverage, the Maastrichtian Ajali sandstone Formations in the southern sedimentary basin of Nigeria is an extensive stratigraphic unit. It is referred to as false-bedded Sandstone in the report of the Nigeria geological survey (Bain, 1924; Grove, 1951; and Simpson 1954) and was formerly named the Ajali Sandstone by Rayment (1965). The formation is present all along Udi plateau and Ajali Sandstone is often overlaid by a considerable thickness of red earth (Reyment, 1965). On the Udi plateau, the red earth maybe as much as thirty meters in thickness. Different scholars have deduced various paleoenvironmental settings for the sandstone based on sedimentological studies, including fluvial (Murat, 1972), fluvio-deltaic (Reyment, 1965), and fluvial-tidal influenced (Ikoro et al, 2014). This study is aimed at determining the textural and depositional processes and characteristics of the Ajali sandstone in Afikpo basin.

Texture: is the general character of a rock shown by its component particles in terms of grain size, shape etc. It is the relationship between individual grains.

Texture of elastic sediments is a function of size, shape and arrangement of the component element (fragment) of the rock in space. These fundamental characters have direct relationship with porosity and permeability. Sediment texture can also be a function of moderate current, wave action, consistent energy, long transportation and highly matured sediment (Reyment, 1965).

The shape of grain has long been used to decipher the history of a deposit of which they are part (Pettijohn 1975; Reyment 1965) in proposing the name as Ajali sandstone, describe as moderately sorted, poorly cemented and unconsolidated, thick, friable sandstone typically white with iron stains. The sandstone displays a marked banding of coarse fine layers.

Most samples gotten from the study area are minimum grained, also the Ajali sandstone in the study are seen finely upward.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue VI June 2023

II. Location and Geology

The study area is located within latitude 050 441 501s and longitude 080 471 57.11s. The area is the north eastern part of Igbere-Abiriba towns within the Afikpo basin in the south eastern part of the Abakaliki Anticlinorium.

It is part of what is referred to as lower Benue trough or valley. The geologic area is made up of two formations, which are the Ezeaku formation and the Nkporo shale formation. The map area is quite accessible having all season road links with Igbere-Abiriba area.

The present geomorphic cycle in the area has attained sub-mature stage which is almost level in many areas but in the study area, there is a repetition of topographic high and low, which gives the area an undulating and erosion of some of the rock material over a geologic period Santonia. Eocene in the south western part of the area where there are few hills ranging from 30m. Points occur in the eastern and western parts with some undulating ridges moving several kilometers in the direction north east. The topographic highs are mainly sandstone, while the low is composed of very fine sands and shale.

Afikpo is moderately hilly area, rising from about 15m above sea level to about 250 m above sea level in the hilly area. The evolution of the present landscape began in the tertiary times, when erosion newly uplifted folded sediment (Whiteman, 1982).

The area is characterized by rain eight months of the year. We have four months of dry seasons with January and February being the highest with an average temperature of 70°C. Mean annual rainfall intensity of 2032- 2540mm with a 205.2mm, set as the highest rainfall within 24 hours. Four months of June to October enjoys the highest number of rainfalls with intermittent August break.

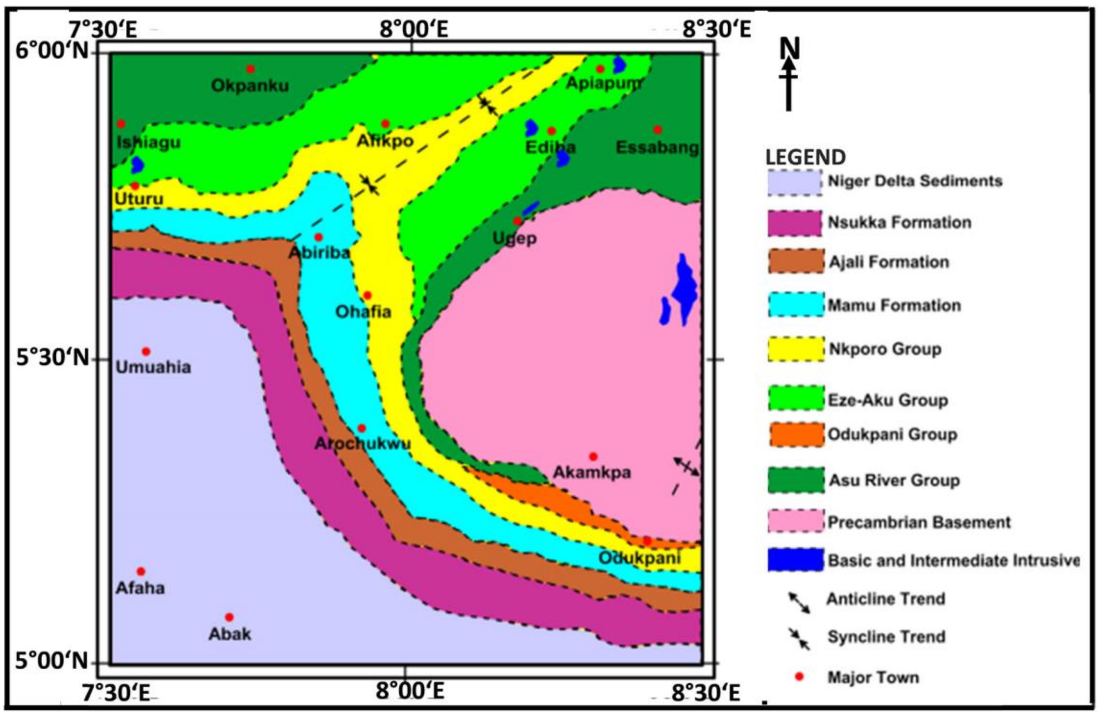


Fig 1: Geology Map of the study area (modified after NGSA, 2004)

III. Materials and Method

Field observations at various phases and laboratory analysis are both used in this study. The explanations include the steps and analysis.

Desk Study

Initial investigation on the study area was done through research of past work, journals and published literatures.

Field study

The field investigation included logging of outcrop, measuring the attitudes of the beds, defining facies, taking pictures, and gathering samples for lab testing. The location of each outcrop is identified using the GPS.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue VI June 2023

Sieving Analysis procedure

After crushing the samples to separate the particles, the representative oven-dried samples were weighed. Using a mortar and pestle, crushing was accomplished. The sieves were stacked from largest aperture size at the top to smallest aperture size at the bottom. Under each sieve is a receiver pan that is used to collect the samples. For 15 minutes, the ASTM mechanical shaker was put to work and vibrated. Every sieve that is kept is measured.

IV. Results

Facies Description/Analysis

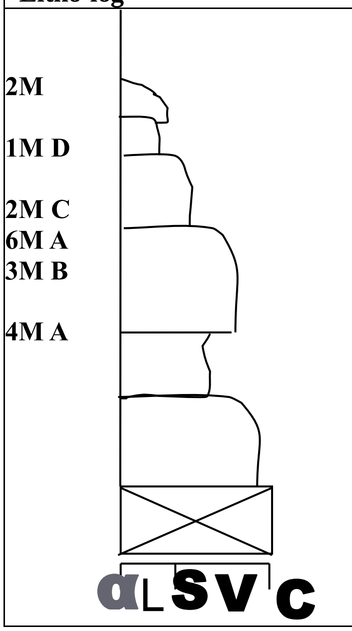
Litho-log	Description	Depositional environment
	Lateritic overburden	
	Mottled plastic mudstone, upper and lower contact sharp.	Fluvio-deltaic
	Yellowish to white, fine medium grained horizontal laminated sandstone with contacts Gradational.	Fluvio-deltaic
	Brown with greyish stain, fine-grained cosets of a planar cross bedded sandstone, moderately sorted with an upward fining sequence.	Fluvio-deltaic
	Whitish brown, lenticular bedded sandstone, moderately sorted with sharp contact.	Fluvio-deltaic
	Brownish grey, fine-medium grained planar cross bedded sandstone.	Fluvio-deltaic

Fig 2: Litho-Stratigraphic Log of the Outcrop in Location One.

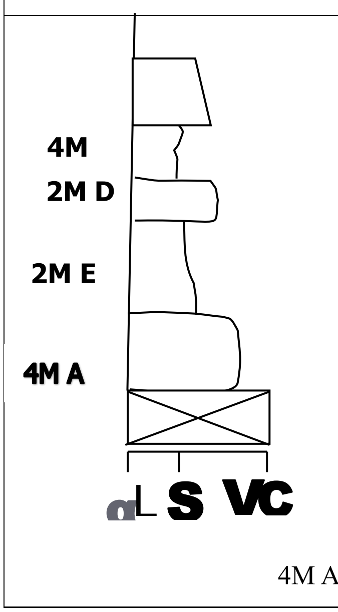
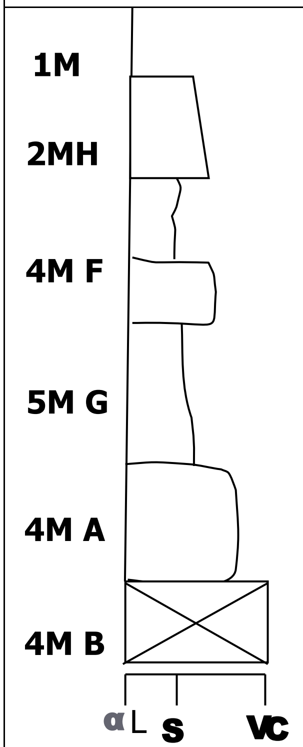
Litho-log	Description	Depositional environment
	Lateritic overburden	
	Mudstone with massive structure. Contacts are gradational.	Fluvio-deltaic
	Brownish grey, trough bedded sandstone with contacts gradational.	Fluvio-deltaic
	Whitish-light grey, clay-silt grained lenticular bedded sandstone and moderately sorted. Contacts are gradational.	Fluvio-deltaic
	Whitish grey, fine-medium grained, planar cross bedded sandstone, moderately sorted. Lower contacts sharp, upper contacts gradational.	Fluvio-deltaic

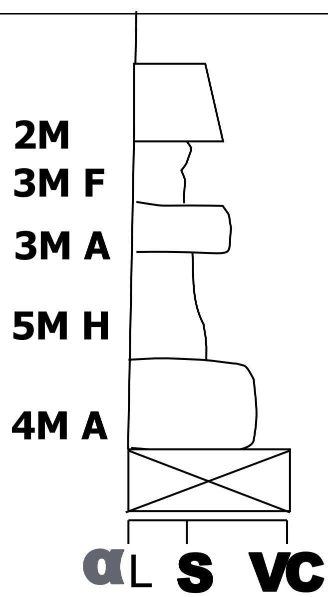
Fig. 3: Litho-Stratigraphic Log of the Outcrop in Location Two

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue VI June 2023



Litho-log	Description	Depositional environment
	Lateritic overburden	
	White, Massive, fine-medium grained sandstone. Contactgradational.	Fluvio-deltaic
	Brownish white, fine-medium grained cross laminated sandstone with Liesegang structure imprint.	Fluvio-deltaic
	Whitish brownish, fine-medium grained planar cross bedded sandstone with imprint of a herringborne structure. Contacts gradational.	Fluvio-deltaic
	Greyish white with yellow stains, fine-medium planar cross bedded sandstone with reactivation surfaces. Contacts gradational.	Fluvio-deltaic
	Greyish, lenticular bedded sandstone, moderately sorted with fining upward sequence. Lower contacts sharp, upper contact gradational.	Fluvio-deltaic

Fig 4: Litho-Stratigraphic Log of the Outcrop in Location Three.



Litho-log	Description	Depositional environment
	Lateritic overburden	
	Whitish brown, fine grained, moderately sorted cross laminated sandstone. Contacts gradational.	Fluvio-deltaic
	White, fine-medium grained, moderately sorted planar cross bedded sandstone. Contacts gradational.	Fluvio-deltaic
	White, Massive, medium-grained poorly sorted sandstone with contacts gradational.	Fluvio-deltaic
	Yellowish-white, medium-coarse grained, poorly sorted planar cross bedded with a fining upward sequence. Lower contact sharp, upper contact gradational.	Fluvio-deltaic

Fig 5: Litho-Stratigraphic Log of the Outcrop in Location Four.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue VI June 2023

Data Presentation

Table 1- Location 1 (section 1 Unit A)

Sieve size (mm)	**Size phi (0)**	**Weight retained (g)**	**Corrected weight (g)**	**Cumulative weight (g)**	Individual weight (0/0)	**Cumulative weight (%)**
2.00	-1.0	9.4	9.529	15.878	9.4	16.096
1.00	0.0	11.7	11.860	19.764	21.1	36.130
0.50	1.0	15.1	15.307	25.507	36.2	61.986
0.25	2.0	13.3	13.482	22.466	49.5	84.760
0.125	3.0	6.5	6.589	10.986	56.0	95.890
0.063	4.0	2.2	2.230	3.716	58.2	99.658
Pan	5.0	0.2	0.203	0.338	58.4	100.000
			59.2			

Table II- Location 1 (Section 2 Unit A)

Sieve size (mm)	**Size phi (0)**	**Weight retained(g)**	**Corrected weight (g)**	**Cumulative weight (g)**	**Individual Weight (%)**	**Cumulative weight (%)**
2.00	**-1.0**	0.00	0.000	0.000	0.000	0.000
1.00	0.00	0.2	0.201	0.2	0.263	0.264
0.50	1.00	0.3	0.301	0.5	0.394	0.659
0.25	2.00	1.8	1.807	2.3	2.362	0.030
0.125	3.00	66.8	67.064	69.1	87.664	91.041
0.063	4.00	6.4	6.425	75.5	8.399	99.473
Pan	5.00	0.4	0.402	75.9	0.525	100.000
			76.2			

Table III- Location I (section 2 Unit B)

Sieve size (mm)	**Size phi (0)**	**Weight retained (g)**	**Corrected weight (g)**	**Cumulative weight (g)**	Individual weight (%)	**Cumulative weight (%)**
2.00	-1.0	1.4	1.413	1.4	2.157	2.184
1.00	0.0	2.7	2.734	4.1	4.160	6.396
0.50	1.0	11.0	11.137	15.1	16.947	23.557
0.25	2.0	24.3	24.603	39.4	37.442	61.466
0.125	3.0	18.7	18.933	58.1	28.814	90.640
0.063	4.0	4.8	4.860	62.9	7.396	98.128
Pan	5.0	1.2	1.215	64.1	1.849	100.000
			64.9			

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue VI June 2023

Table IV - Location 2 (section 1 Unit A)

Sieve size (mm)	Size phi (0)	Weight retained (g)	Corrected weight (g)	Cumulative weight(g)	Individual weight (%)	Cumulative weight (%)
2.00	-1.0	0.1	0.105	0.1	0.200	0.210
1.00	0.0	1.6	1.677	1.7	3.206	3.571
0.50	1.0	9.8	10.274	11.5	19.639	24.160
0.25	2.0	20.2	21.176	31.7	40.481	66.597
0.125	3.0	12.0	12.580	43.7	24.048	91.807
0.063	4.0	3.5	3.669	47.2	7.014	99.160
Pan	5.0	0.4	0.419	47.6	0.802	100.000
			49.9			

Table V- Location 2 (section 1 Unit B)

Sieve size (mm)	Size phi (0)	Weight retained (g)	Corrected weight (g)	Cumulative weight (g)	Individual weight (%)	Cumulative weight (%)
2.00	-1.0	1.2	1.218	1.2	1.387	1.408
1.00	0.0	7.7	7.817	8.9	8.902	10.446
0.50	1.0	24.1	24.468	33.0	27.861	38.732
0.25	2.0	32.7	33.199	65.7	37.803	77.113
0.125	3.0	15.0	15.229	80.7	17.341	94.718
0.063	4.0	4.0	4.061	84.7	4.624	99.413
Pan	5.0	0.5	0.508	85.2	0.578	100.000
			86.5			

Table VI- Location 2 (section 2 Unit A)

Sieve size (mm)	Size phi (0)	Weight retained (g)	Corrected weight (g)	Cumulative weight (g)	Individual weight (%)	Cumulative weight (%)
2.00	-1.0	0.10	0.102	0.1	0.136	0.139
1.00	0.0	4.1	4.180	4.2	56.586	5.833
0.50	1.0	25.4	25.894	29.6	34.605	41.111
0.25	2.0	29.0	29.564	58.6	39.510	81.389
0.125	3.0	10.2	10.398	68.8	13.896	95.556
0.063	4.0	3.0	3.058	71.8	4.087	99.722
Pan	5.0	0.2	0.204	72.0	0.272	100.000
			73.4			

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue VI June 2023

Bivariate Analysis

Friedman's (1967) and Moiola and Weiser, (1968) discrimination diagram for differentiating sediments of Beach or Fluvial (River) origin was applied to the sandstone samples collected in the study area (Fig 6 and 7). In both scenario, there is a dominance of fluvial regime over beach processes.

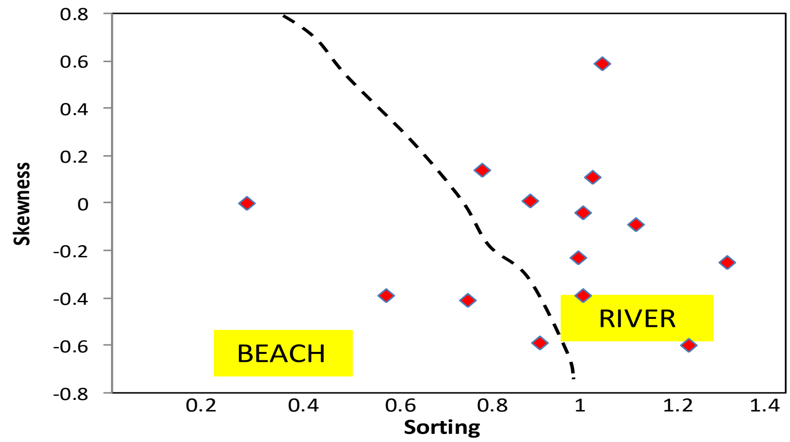


Fig.6: Bivariate plot of Skewness versus Sorting for sandstone samples (After Friedman, 1967)

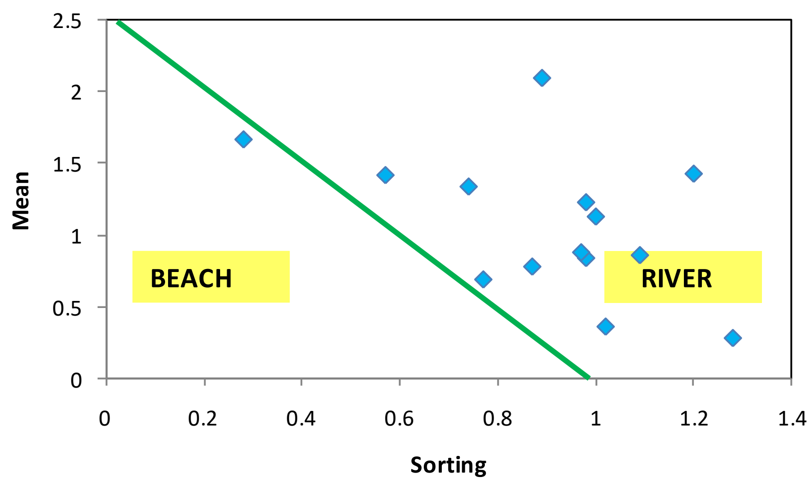


Fig.7. Bivariate plot of Mean versus Sorting for samples (After Moiola and Weiser, 1968)

Table VII - Cumputation of Multivariate Parameters

S/N	SAMPLES	MULTIVARIATE RESULT	INTERPRETATION
1	Ll S1 Unit A$^{t°}$P	-8.5841	Fluvial Deposition
2	Ll S2 Unit A	-2.2334	Shallow marine
3	L.1 S2 Unit B	-8.5073	Fluvial Deposits
4	L2 S1 Unit A"	-8.1713	Fluvial Deposits
5	L2 S1 Unit B^{il}	-8.0875	Fluvial Deposits
6	L2 S2 Unit A	-7-6784	Fluvial Deposits
7	L2 S2 Unit C	-5.9614	Shallow marine

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue VI June 2023

8	L3 Unit 1	-4.3599	Shallow marine
9	L3 Unit 2	-7.4652	Fluvial Deposits
10	L3 unit 3	-5.9324	Shallow marine
11	L3 unit 4	-6.6001	Shallow marine
12	L3 Unit 5	-6.4298	Shallow marine
13	L4 FA	-8.9696	Fluvial Deposits
14	L4 S 1	-10.2378	Fluvial Deposits

Yu = 0.2852 M_z— 8.7604 ʒi — 4.8932 Ski + 0.0482 kG

Yu <-7.419 → Interpretated as fluvial deposits

Yu > -7.419 → Shallow marine (sahu, 1964)

V. Discussion

Interpretation From Facies Analysis

The rocks of the study area are characterized by tabular and planar cross bedding, horizontally laminated sands, mud clasts and bioturbated beddings reflecting tidal influence (Reineck and Sinsh, 1975). The textural characteristics, sedimentary structures and stratigraphic relationship of the study area could be interpreted as tidally influenced fluvial-deltaic environment. The lithology is characterized by poorly moderately sorted sandstone which indicates rapid sedimentation and near origin margin provenance the presence of trace fossils indicates a restricted near shore environment. It indicates low energy, quiet water marine environment.

Interpretation From Sedimentary Structures

Sedimentary structures are those features found on sediment which are formed during or shortly after deposition (primary sedimentary structures) or those structures formed after sedimentation (secondary sedimentary structures). According to Mail, (1984), sedimentary structures are very important indicators of depositional environment. This is because they cannot be recycled.

Ajali sandstone of the study area shows sedimentary structures like horizontal bedding, cross bedding, heringbone structure, tidal bundle, sygnmodal structure, e.t.c which indicates that it is a fluvial deposit. Occurrence of pebble on some of the lithologic units of the outcrop also indicates fluvial environment.

Interpretation From the Multivariate Computation

The multivariate computation of Ajali sandstone of the study area indicates that the samples are mainly fluvial deposits and some concordance of shallow marine deposit, which show that the sandstone is deposited by fluvial-deltaic environment, since they all occurred in the range, <-7.419 and some, > -7.419.

Interpretation Of the Depositional Environment

The graphic mean of the samples show that Ajali sandstone of the study area is medium grained, meaning that it may have been deposited by saltation with influence of traction mechanism. Samples like L4FA and L4S1 which are coarse refers that it was deposited by traction current.

Ajali sandstone of the study area shows an upward fining sequence, which ranges from poorly to moderately sorted. Tabular cross bedding formed by dunes on the channel floor and the lateral variation in sediment types are considerably due to channel switching and current variation. The study area can be confidently said to be tidal depositional environment due to the above characteristics that it exhibits.

Generally, the interpretation of the grain size analysis result shows that Ajali sandstone of lgbere-Abiriba area is deposited mainly by fluvial environment.

VI. Conclusion

This work was carried out to infer the depositional environment of Maastrichtian Ajali sandstone from lgbere-Abiriba area of Afikpo basin, South-eastern Nigeria using textural analysis.

Information from the field data shows that Ajali sandstone is profusely cross-bedded, characterized by Herringbone structures and ophiomorpha borrows. The presence of these structures indicates tidal environment with high energy. Thus, these field observations show that Ajali sandstone was deposited under a tidal & fluvial channels interaction that is littoral environment.

The interpretations were made possible through the study of the grain size analysis of the sediments, (which includes sorting, mean size, skewness, kurtosis), log-probability curves, Histogram plot, multivariate computations, facie analysis, sedimentary structures, depositional environment. The Bivariate plots of the samples confirmed a fluvial environment.

Analysis of these parameters indicated the same conclusion that Maastrichtian Ajali sandstone of the study area is a fluvial channel deposit, which is a supportive of an earlier environmental interpretation on Ajali sandstone by favored fluvial deltaic. At this point I can confidently conclude that my research work on the depositional environment of Maastrichtian Ajali sandstone was deposited in a fluvial-marine environment of fluctuating velocity.

References

1. Adeleye, D.R. (1975). Nigeria late Cretaceous Stratigraphy and Paleogeography. Bull American Association Geol. Vol. 59(12), pg. 2302-2313
2. Agagu, O.K., Fayose, E.A. and Peters, S.W. (1985). Stratigraphy and Sedimentation in the Santonian Anambra Basin of Eastern Nigeria, Nig.I.Min. Geol. vol. 22, P.25-36.
3. Allen, J.R.L. (1963). The Classification of Cross-Stratified units, with notes on their Origin; Sedimentology, Vol 2, PG. 93-114.
4. Allen, J.R.L. (1965). A review of the Origin and Characteristics of recent AlluviaI sediments. Sedimentology, 5: pg. 89-191.
5. Andrew, D, M. (1984). Principles of Sedimentary Basin Analysis. Springer verlag, New York Berlin Heidelberg Tokyo, pg. 133-202.
6. Amajor, L.C. (1986). Sedimentary facies analysis of the Campono-Maastrichtian Ajali Sandstone, south eastern Nigeria; Bull. Nig. Min. Geosci. Soc; Vol. 21.
7. Banerjee, I. (1979). AnaIysis of cross-bedded sequence: An example from the Nall Sandstone (Maastrichtian) of Nigeria; Quartji, Geol. Min, and Met. Soc, India, 51, pg.69-81.
8. Bloatt, S. Jr. (1987). Principles of Sedimentology and Stratigraphy. Macmillian Publishing. New York.
9. Folk R.L and Ward,W.C. 1957. Brazos Rivers Bar. A study of the significance of rain size parameters journ. sed. petrol. 27 pg 3-27.
10. Folk R.L 1974. Sediments and Sedimentary Rocks.Hemphillis, Austin, Tex. 1st edition pg170.
11. Frey R.W, Howard, J.D; and Prayor, W.A. 1978. Ophiomorpha:its Morphologic, Texanomic and Environmental Significance, Paleogeol. paleoclimatology, paleoecology.23 pg 199-229.
12. Friedman, G.M. (1961). Distinction between dune, beach and River Sands from their textural characteristics for sed. pet. 31 pg574-579.
13. Friedman, G.M. (1962). Sorting coefficients and the lognormality of the grain size distribution of clastic sandstones.J Geol. Vol. 70 pg 737- 753
14. Friedman, G.M and Sander, (1978). Principles of sedimentology pg 76.
15. Groove, A.T. (1951). Land use and Soil Conversation in parts of Onitsha and Owerri province Nigeria, Geol. Survey of Nigeria, Bull No.21
16. Greensmith, J.T. (1989). Petrology of Sedimentary Rocks seventh edition Union Hyman, London pg 395-415.
17. Hogue, M. and Ezepue, M.C., (1978) Petrology and Paleogeography of Ajali Sandstone. Journal of Mining and Geoe32logy vol. 14 — 22.
18. Ikoro, D. O, Amajor, L. C, Inyang, D. O, Okereke, C. N, Ekeocha, N. O. (2014) Facies Model Determination Using Markov Chain Analysis: A case study of Ajali Sandstone in Ohafia – Igbere Southeastern Nigeria. International Research Journal of Geology &Minning 4(7) 198, 2014.
19. Pettijohn, F.J., (1975). Sedimentary Rock 3rd Edition. Harp and Row, N.T. 628 pp.
20. Pettijohn, F.J., Potter, P.Eand Siever, R., (1987). Sand and Sandstone, 2ndEdition Spring Verglag. ISBN 0-387-96350-2.
21. Philip, K., (1996). The New Penguin Distionary of Geology.
22. Ehaman, M.A. (1976). Review of the Basement Geology of Southwestern Nigeria. In Geology of Nigeria (Edited by Kogbe) pp 41-58. Elizabeth Publishing Company Lagos.
23. Reading, H.G. (1996). Sedimentary Environment Process, Facies and Stratigraphy. Blackwell Scientific Publications, Oxford. Pp. 671.
24. Reinck, H.E. and Singh, I.B., (1975). Depositional Sedimentary Environments. Springer-Verlage Berlin Heidelberg New York pp 44.
25. Reyment, R.A. (1965). Aspect of the Geology of Nigeria. lbadan University Press. Pp 145.
26. Simpson, A., (1954). The Nigerian Coal Field and Geology of Part of Onitsha, Owerri and Benue Provinces. Bulletin

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue VI June 2023

Geological Survey Department. Vol. 24.
27. Smith, M.D., (1970). The Braided Stream Deposition Environment. Comparison of the Plate River With Silvian Clastic Rocks, North Central Appalachians. Geol. Society American Bulletin. Vol. 81 pp 2993 -3014.
28. Steinmetz, G. (1972). Paleocurrent and Provenance Determination of Sandstone Mustrang Island, Texas, J. Sed. Petrol., Vol. 30 pp 753 — 780.
29. Tucker, M.E. (1996). Sedimentary Rocks in the Field, John Willey and Sons, Chishaster, New York, pp. 150.
30. Visher, G.S., (1969). Grain Size Distribution and Depositional Processes. Journ. of Sed. Pet.vol. 39, No. pp 1074 — 1106.
31. Walker, R.G. (1975). From Sedimentary Structures to Facies Models Example from Fluvial Environment, In (J.C. Harms, 1.B. Southard, D.R. Spearing and R.G. Walter), Depositional Environment as Interpreted from Primary Sedimentary Structures and Stratification Sequences. SEPM short course No 2: pp 63 — 79.
32. Whiteman, A, (1982). Its Petroleum Geology, Resources and Potential. Vol. 1 and 2 Graham and Trotman London. Pp. 394.
33. Wright, J.B., (1987). Geology and Mineral Resources. African Oxford University Press Pub. New York.