Original Research DOI: 10.5281/zenodo.16534058
Volume 7, Issue 1, pp 83-96, June 2025

ACHIEVERS JOURNAL OF SCIENTIFIC RESEARCH
Opecn Access Publications of Achievers University, Owo
Available Online at www.achieversjournalofscience.org

Ancient Environment, Sedimentological Characteristics and Mechanism of Transport of Campanian - Maastritchian Sandstone, Lokoja Formation, Bida Basin, Nigeria

***[1]Ilevbare, M., [2]Ganiyu, B. O. and [3]Utsalo, A. E.**

[1]Department of Geology, Afe Babalola University, Ado-Ekiti, Nigeria
[2]Department of Mathematical and Physical Sciences, Afe Babalola University, Nigeria
[3]Department of Geology and Petroleum Studies, College of Natural and Applied Sciences, Western Delta University, Oghara, Delta State, Nigeria
Corresponding Author's Email Address: martins.ilevbare@abuad.edu.ng

Submitted: April 22, 2025; **Revised:** May 10, 2025; **Accepted:** June 2, 2025; **Published:** June 20, 2025

Abstract

The Campanian - Maastritchian Sandstone, Lokoja Bassange Formation, Bida Basin, was studied to decipher its ancient environment, the mechanism of transport and the sedimentological characteristics of the sandstone. The results of grain size analysis show that the sandstone has medium-sized grains that are leptokurtic to extremely leptokurtic, moderately well-sorted to moderately sorted, and primarily near symmetrical to coarsely skew. The medium-grained sediments imply that grains have been transported over a considerable distance. The near symmetry of the sediments suggests that the processes of erosion and deposition are almost in equilibrium with one another. Leptokurtic grains predominate in the sandstone, indicating compositionally immature and a texturally mature sandstone. The coarse positive skewedness indicates a fluvial (non-beach) paleoenvironment origin. Also, the sorting of Ifon Sandstone at Uzebba and Ori-Ohin ranges from 0.54-1.26 ϕ (0.90 average) and 0.62-1.42 ϕ (1.0. average) which are both of fluvial origin, after Folk' environmental classification. The results from the environmental discrimination plots which indicate an ancient fluvial depositional environment. The mechanism of transportation reveals that the sediments were moved and deposited by rolling, bottom suspension, and rolling, which are indicative of a high-energy, turbulent environment with high wave activity and tractive current deposits.

Keywords: Bida Basin; Environment; Pebble Morphology; Sedimentological; Transport

1.0 Introduction

The Lokoja Formation is a geological Formation in Nigeria that provides valuable insights into the region's tectonic evolution and paleoenvironmental conditions. The formation contains a rich fossil record, offering clues about evolution of life on earth and the regions paleoecological history. It is a stratigraphic unit in the region, which helps to construct the timing and correlation of geological events, (Vrbka *et al.,* 1999) through the use of grain size frequency distribution and textural characteristics. Several authors have highlighted and discussed the value of grain size analysis in the reconstruction of ancient depositional environments and sediment dynamics (Friedman, 1967; McLennan *et al.,* 1993; Oredein *et al.* 2014; Armstrong-Altrin *et al.,* 2019; Ayala-Perez *et al.,* 2021; Abimbola *et al.,* 1999; Ojo and Akande, (2003, 2006, 2009). Numerous studies have focused on the southernmost part of the late Cretaceous Bida (Mid-Niger) Basin (Fig.1b). While previous study focus mostly on textural characteristics, biostratigraphy, the environment of deposition, the potential for hydrocarbon production, sequence stratigraphy, the inherent nature of source rocks, the tectonic setting of the emplacement of sedimentary products, and the levels of weathering are being better understood through the use of geochemistry, (Armstrong-Altrin *et al.,* (2004, 2017, 2018); Dey *et al.,* 2009; Udensi and Osazuwa, 2004; Adeleye (1973, 1974, 1989); Jan du Chene *et al.,* 1978; Agyingi, 1991; Braide,1992; Ladipo *et al.,* 1994; Abimbola, 1997; Obaje, 2013). This study, examines the textural attributes of the Ifon Sandstone, of the Lokoja Formation, to infer the environment of deposition and the mechanism of transportation and deposition of the sedimentary rocks which is a gray research area that helps to determine ancient environmental processes.

2.0 Materials and methods

2.1 Location of Study Area

The research area is located in Lokoja formation within Bida Basin (Fig. 1b), mid-way between the Ifon-Uzebba and Ifon-Akure area, with the Coordinates of Ifon Sandstone, which is situated along Ifon-Uzebba (Fig. 2a) road (N 0060 055' 7.055" and E 0050 044' 37.6"); and that of Ifon-Akure in Ori-Ohin (Fig. 2b), with Coordinates of N 0060 057' 007.07" and E 0050 046' 043.98" as represented on the Geological map of the study area (Fig. 1a) The study area is drained with streams and several river channels with accessible roads and paths.

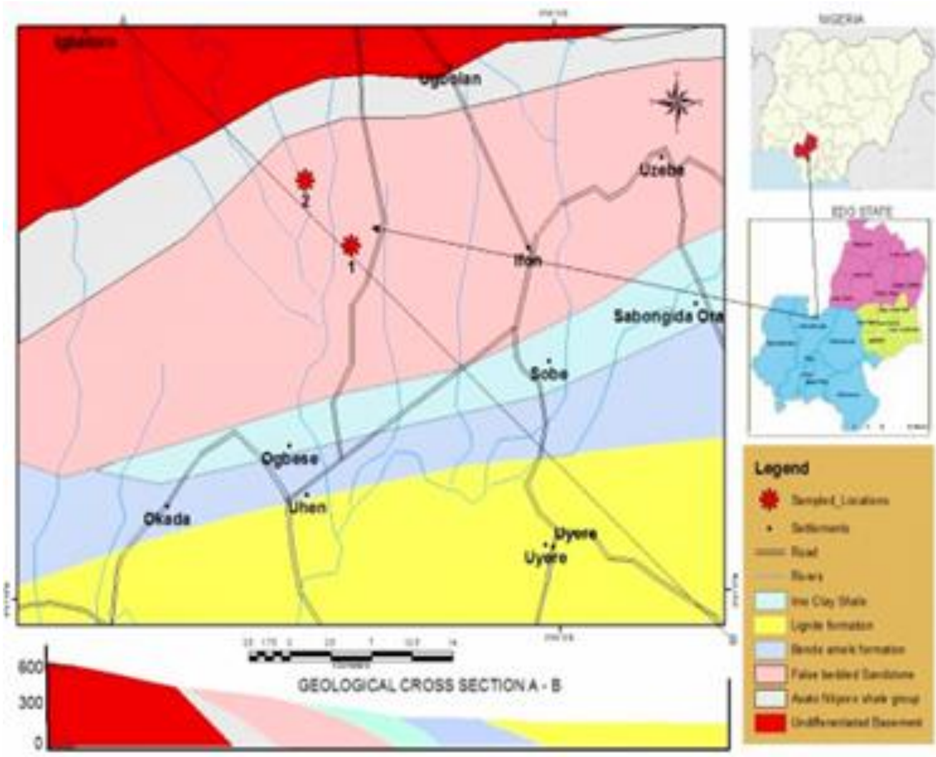

Figure 1a: Map of Ifon Ogbese and Sobe geology and sampled locations.

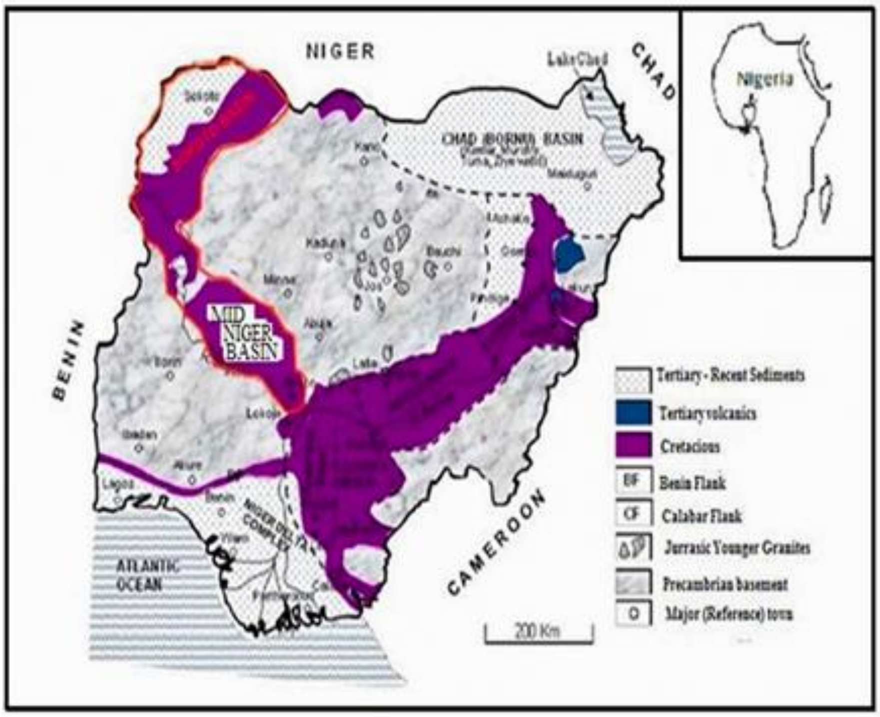

Figure 1b: Geological map of Nigeria showing the Bida basin (After, Adeniyi 1985; Udensi and Osazuwa 2004)

Figure 2a: Ifon Sandstone, along Ifon-Uzebba road

Figure 2b: Ifon Sandstone, along Akure road in Ori-Ohin

2.2 Sample Collection

Twenty (20) fresh sediment outcrop samples were collected along the Ifon-Uzebba (Figure 2a) and Ifon-Akure Ori-Ohin area (Figure 2b). Techniques for chip and grab sampling were employed. Hammer, chisel, GPS, compass clinometer, and sample bags were among the equipment utilized. From the collected samples, grain properties and pebble morphology were identified.

2.2.1 Grain-size Analysis

Twenty samples of sandstone were subjected to grain size analysis using the mechanical sieving method. About 100g of each sample was broken up using a porcelain mortar and pestle. Before being separated into quarters, the disaggregated samples were thoroughly mixed. The samples were weighed with a P20 model precision 0.011g meter balance.

The samples were received on a pan of set of US mesh sieves measuring (2.00, 1.18, 0.85, 0.60, 0.425, 0.5, 0.30, 0.10, 0.075, 0.025 and 0.063) mm. A balance was used to weigh the fraction that was kept in each sieve and pan, and the weight was recorded and calculated.

2.2.2 Pebble morphometric Analysis

Ten samples of 200g of sand were weighed; more than 80 Pebbles were selected. The collected stones were later examined to weed out any that was fractured or recently broken. These stones were cleaned, given a number, and brought to the lab for analysis. The lengths of the pebbles' long (L), intermediate (I), and short (S) axes were determined using a vernier caliper.

3.0 Results and Discussion

A systematic presentation of the findings from the textural and pebble morphometric analyses is made. In order to facilitate and comprehensively analyze the data, tables, bivariate plots, plates, and coarsest particles - median (CM) diagrams are employed. These results are presented in the order in which they were collected.

3.1 Textural characteristics and depositional environment of the Ifon Sandstone

The Ifon sandstone is medium to coarse grained, moderate to poorly sorted, coarsely skewed to nearly symmetric, and predominately leptokurtic (IFZ 1-10). The Ori-Ohin Ifon sandstone (IFA 1-10) is leptokurtic, fine-skewed to symmetrical, moderately sorted, and coarse-grained (Table 1). The median, mean, mode, sorting, skewedness and kurtosis of Ifon-Uzebba (IFZ) sandstone ranges are 1.13-2.37, 1.09-2.75, 1.25-2.75, 0.54-1.26, 0.01-0.20, and 0.97-1.72 (IFZ), respectively. Additionally, the median, mean, mode, sorting, skewedness and kurtosis of Ifon-Akure (IFA) sandstone ranges are as follows: 1.12-2.35, 1.10-2.33, 1.10-4.00, 0.62-1.42, 0.01-0.26, and 0.58-1.72, respectively (Table 1). Folk (1965) classified sorting values as: (1-3) ϕ for sand class; (0.25–0.5) ϕ for beach sand and (0.35-1.0) ϕ for fluviatile / shallow marine sand. The Sorting for Ifon Sandstone (IFZ and IFA) ranges from 0.54-1.26 (0.90 average) and 0.62-1.42 (1.0 average) ϕ which typifies a fluvial and /or shallow marine environment. This is corroborated by the results of the environmental discrimination plots, (Fig. 4a and 4b).

The Skewness vs. Standard deviation curve (Fig. 3b) for the investigated samples shows that 97% of the data points plot in the near symmetry field, with 1.5% plotting as both Coarse and Fine Skewed. The Kurtosis vs. Skewedness curve (Fig. 3c) reveals that the sediments are mostly Leptokurtic to extremely Leptokurtic, with around 1% of the grains being Mesokurtic. Only 1.5% of the sandstone grains are fine-grained, according to the standard deviation vs. mean curve (Fig. 3a) shows that 98.5% of the grains are medium-grained. Most of the Sandstone grains are well to moderately well sorted with a small percentage been poorly sorted, Sorting describes the distribution og grain sizes within a sediment. The sorting of this study indicates a uniform to variable energy environment typical of a mixed energy environment. This sorting is consistent with a beach and /or fluvial depositional environment, (Ilevbare and Imasuen, 2020). The fluvial environment of deposition is authenticated by the sedimentological discrimination plots of Skewness vs. Median (Fig. 4a) and Standard deviation vs. Median (Fig. 4b) both plots show the majority of the samples plotting in the fluvial/river paleoenvironment. This fluvial environment is further corroborated by the Sames' (1966) environmental delineation plots (Fig. 5a & 5b) which confirms a continental fluvial environment, (Ilevbare and Omodolor, 2020).

3.2 Pebble morphology, transport mechanism and environment of deposition

Pebble morphology can provide valuable insights into the transport mechanism besides been used as a tool for environmental discrimination. The transport mechanism associated with pebble could be fluvial transport, glacial transport and coastal transport. The roundness and sphericity index of this study are consistent with pebbles that have been transported by fluvial and coastal transport giving pebbles that are sub-rounded to rounded, smoothed and slightly polished which are of great significance in paleoenvironmental reconstruction and in Basin analysis, (Ilevbare and Omodolor, 2020). The samples have average values for the oblate probate (OP) index, flatness ratio, and elongation ratio are 0.48, 0.77, and 2.26 respectively. The average values for roundness, bladed shape, and maximum projection sphericity are 35%, 0.49, and 0.65. The bladed forms of the pebbles examined are Platy bladed, compact bladed, and bladed to compact elongate, (Table 2).

The environment discrimination plots of this study (Fig. 5a and 5b) help to infer the ancient environment in which the pebble was deposited. In both cases, the plot of roundness versus elongation (Fig. 5a) and that of sphericity versus Oblate probate index (Fig. 5b) have over 96% of it's data points of the pebble plotting in the fluvial environment. This shows that Ifon sandstone from the pebble morphology are of fluvial deposition environment. Therefore, these pebble morphometric plots provide a better understanding of the geological history and processes that have shaped sediments of the Lokoja sandstone in the area studied.

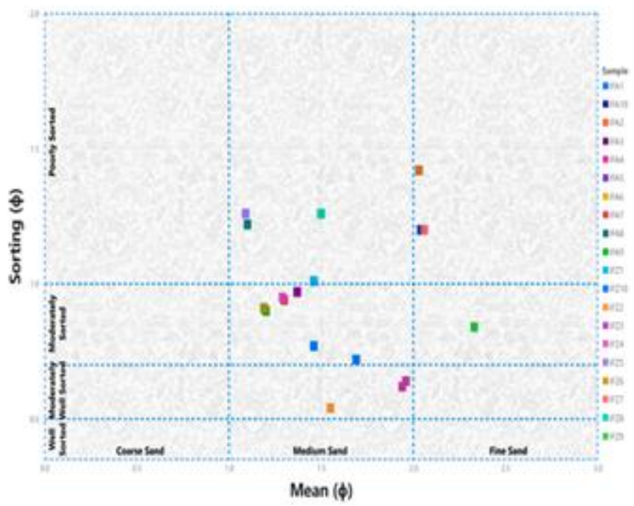

Figure 3a: Textural plot of sorting versus mean (after Ilevbare and Imasuen, 2020)

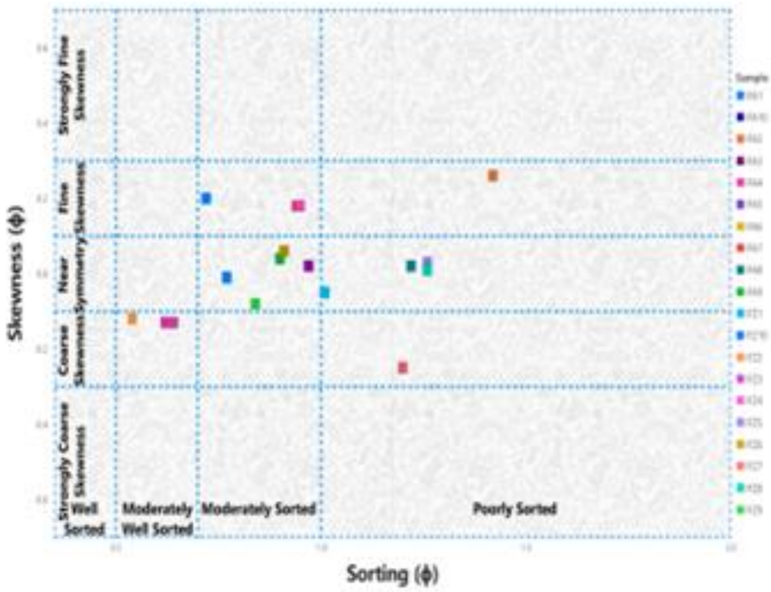

Figure 3b: Textural plot of skewness sorting versus mean (after Ilevbare and Imasuen, 2020)

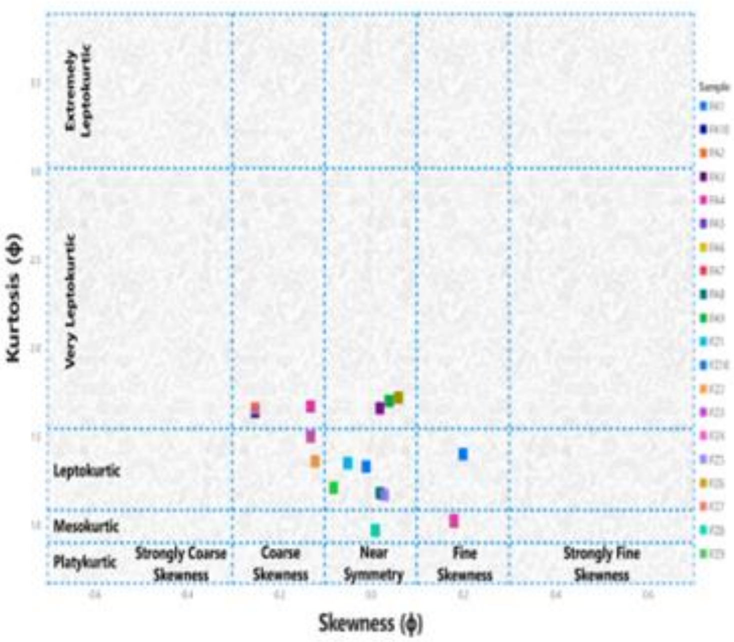

Figure 3c: Textural plot of kurtosis versus skewness (after Ilevbare and Imasuen, 2020)

Table 1: Summary of Results obtained from Grain Size Analysis and its Interpretation

Sample	Median ϕ	Mean ϕ	Mode ϕ	S.D (Sorting) ϕ	Skewness ϕ	Kurtosis ϕ	Interpretation of the textural attributes
IFZ1	1.43	1.46	1.25	1.01	-0.05	1.35	Poorly sorted, near symmetrical and leptokurtic
IFZ2	1.60	1.55	1.75	0.54	-0.12	1.36	Moderately well sorted, coarse-skewed and leptokurtic
IFZ3	1.99	1.96	2.75	0.64	-0.13	1.50	Moderately well sorted, coarse-skewed and leptokurtic
IFZ4	1.27	1.29	1.25	0.95	0.18	1.03	Moderately sorted, fine skewed and mesokurtic
IFZ5	1.13	1.09	1.25	1.26	0.03	1.17	Poorly sorted, near symmetrical and leptokurtic
IFZ6	1.26	1.19	1.25	0.91	0.06	1.72	Moderately sorted, near symmetrical and very leptokurtic
IFZ7	2.37	2.06	2.75	1.20	-0.25	1.66	Poorly sorted, coarse-skewed and very leptokurtic
IFZ8	1.48	1.50	2.75	1.26	0.01	0.97	Poorly sorted, near symmetrical and mesokurtic
IFZ9	2.37	2.33	2.75	0.84	-0.08	1.21	Moderately sorted, near symmetrical and leptokurtic
IFZ10	1.67	1.69	1.75	0.72	0.20	1.40	Moderately sorted, fine skewed and leptokurtic
IFA1	1.47	1.46	1.75	0.77	-0.01	1.33	Moderately sorted, near symmetrical and leptokurtic
IFA2	1.64	2.03	4.00	1.42	0.26	0.58	Poorly sorted, fine skewed and very platykurtic
IFA3	1.40	1.37	1.75	0.97	0.02	1.66	Moderately sorted, near symmetrical and very leptokurtic
IFA4	1.97	1.94	2.75	0.62	- 0.13	1.67	Moderately well sorted, coarse skewed and very leptokurtic
IFA5	1.26	1.19	1.25	0.91	0.06	1.72	Moderately sorted, near symmetrical and very leptokurtic
IFA6	1.99	1.96	2.75	0.64	-0.13	1.50	Moderately well sorted, coarse-skewed and leptokurtic
IFA7	1.26	1.30	1.25	0.94	0.18	1.02	Moderately sorted, fine skewed and mesokurtic
IFA8	1.12	1.10	1.25	1.22	0.02	1.18	Poorly sorted, near symmetrical and leptokurtic
IFA9	1.25	1.20	1.25	0.90	0.04	1.70	Moderately sorted, near symmetrical and very leptokurtic
IFA10	2.35	2.04	2.70	1.20	-0.25	1.64	Poorly sorted, coarse-skewed and very leptokurtic

Table 2: Pebbles morphometric data for the Ifon Sandstone

Sample	L (cm)	I (cm)	S (cm)	S/L	I/L	OP Index	Form Name	Roundness %	Bladed form (L-1)/(L-5)	Maximum Projection Sphericity
IFZ1	1.29	0.95	0.48	0.37	0.74	-2.50	B	20	0.57	0.40
IFZ2	1.27	0.99	0.66	0.52	0.78	-0.77	B	20	0.46	0.70
IFZ7	1.31	0.87	0.66	0.58	0.77	0.86	CB	20	0.55	0.72
IFZ8	1.52	1.27	0.66	0.43	0.84	-4.88	P	20	0.29	0.60
IFZ10	1.36	1.11	0.77	0.57	0.82	-1.40	B	40	0.42	0.72
IFA1	1.22	1.05	0.57	0.47	0.86	-5.11	P	20	0.26	0.63
IFA2	1.63	1.17	0.65	0.40	0.72	-0.75	B	30	0.47	0.61
IFA7	1.49	0.04	0.65	0.44	0.70	0.91	B	100	0.54	0.65
IFA8	1.13	0.82	0.71	0.53	0.73	3.81	CE	40	0.74	0.80
IFA10	1.69	1.20	0.85	0.50	0.71	1.60	CB	40	0.58	0.70

Where: L = long dimension; P =Platy Bladed; I =Intermediate dimension; CB = Compact Bladed; S = Short dimension; S/L = Flatness; I/L = Elongation; B =Bladed; CE= Compact Elongate; Cube root of S^2/LI = Maximum Projection Sphericity

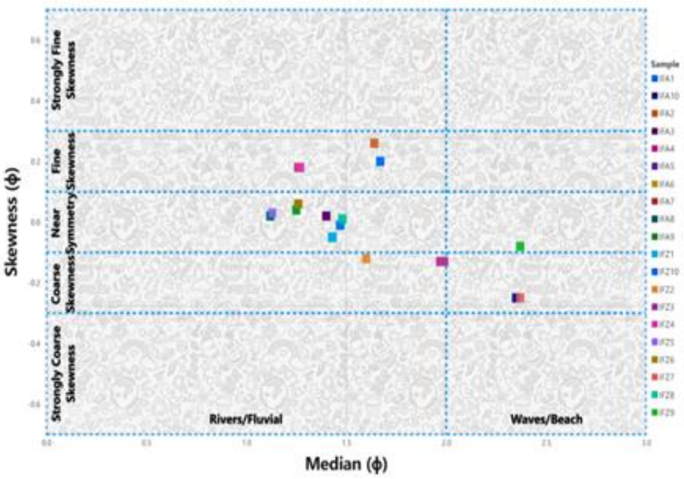

Figure 4a: Environmental discrimination of skewness (after Ilevbare and Imasuen, 2020)

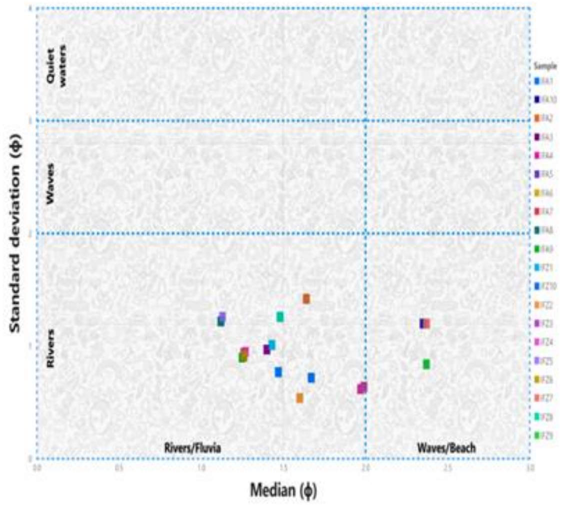

Figure 4b: Environmental discrimination plots of standard deviation versus median (after Ilevbare and Imasuen, 2020)

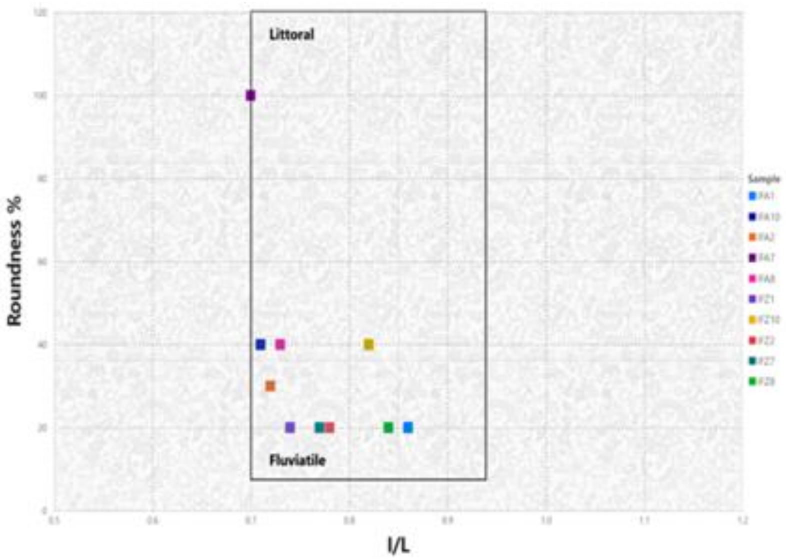

Figure 5a: Roundness versus elongation (after Ilevbare and Imasuen, 2020)

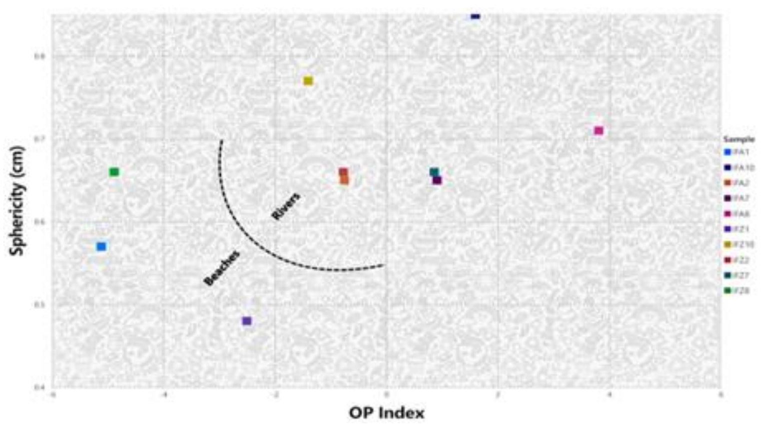

Figure 5b: Sphericity versus oblate probate index (after Ilevbare and Imasuen, 2020)

3.3 Mechanism of transportation and deposition of the Ifon Sandstone

The distinction between the sediments of various habitats of fluvial and deltaic deposits is made possible by grain size analysis and plot of CM patterns (Passega, 1964; Rajganapathi et al., 2012; Ilevbare and Omodolor, 2020). The CM diagrams (Fig. 6a & 6b) help to infer the transportation history. The letters NO (rolling), OPQ (bottom suspension with rolling), QR (graded suspension no rolling), RS (uniform suspension), and S (pelagic suspension) set apart three parts of the CM pattern. The data points of the samples fit into one of three categories—rolling, bottom suspension, or rolling—according to Ifon sediment data (Fig. 6b). The result shows that the Ifon sandstone was transported and deposited in the present location by bottom suspension and rolling which is attributed to a very turbulent environment characteristic of a tractive current.

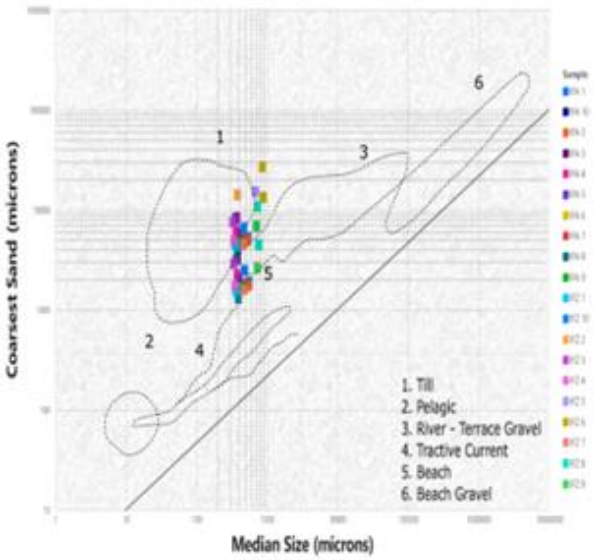

Figure 6a: Coarsest sand versus median (CM) diagram for water current type (after Ilevbare and Omodolor, 2020)

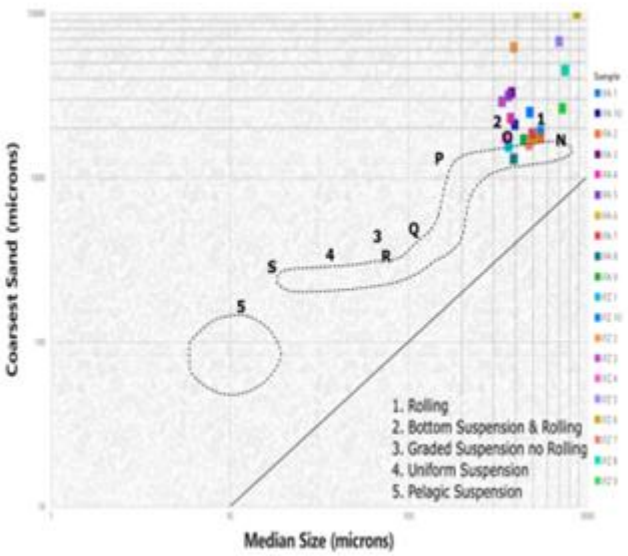

Figure 6b: Coarsest sand versus median (CM) diagram for transport (after Ilevbare and Omodolor, 2020)

4.0 Conclusions

The findings of the study on the ancient sedimentological characteristics and mechanism of transport of Lokoja formation, Bida basin reveals the textural characteristics of the sandstone as medium-grained, moderately well sorted, with moderately to poorly sorted grains that are primarily near symmetrical to coarsely skewed and leptokurtic. The paleoenvironment of the Ifon Sandstone is continental fluvial and/or river environment with the mode of sediment transport and deposition of the sandstone as rolling, bottom suspension, and rolling, which is typical of a high-energy, turbulent environment.

Overall, study have provided insights into the ancient environments, climates and geological processes that has helped to shape the region. Also, an understanding of the Sedimentological characteristics and transport mechanisms of the Ifon Sandstone can inform hydrocarbon exploration and production in this region while ensuring a more effective and sustainable use of geological resources.

Credit authorship contribution statement

Martins Ilevbare, Conceptualise and Design the research. Martins Ilevbare, and Utsalo Ambrose were responsible for data acquisition. Literature searches were conducted by Martins Ilevbare, Ganiyu Olabode Badmus, and Ambrose Utsalor. Martins Ilevbare analysed the data and interpreted, while all authors contributed to the drafting and revising the manuscript. All authors reviewed and approved the final version of the manuscript.

Conflict of Interest

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work presented in this paper.

References

Abimbola, A. F. (1997). Petrographic and paragenetic studies of the Agbaja Ironstone Formation, Nupe Basin, Nigeria. Journal of African Earth Sciences. 25:169-181

Abimbola, A. F., Badejoko, T. A., Elueze, A. A., and Akande, S. O. (1999). The Agbaja Ironstone Formation, Nupe Basin, Nigeria. A product of replacement of a Kaolinite precursor. Global Journal of Pure and Applied Sciences. 5:375-384

Adeleye, D. R. (1974). Sedimentology of the fluvial Bida Sandstones (Cretaceous) Nigeria. Sedimentary Geology. 12:1-24

Adeleye, D. R. (1989). The Geology of the Mid Niger Basin. In: Kogbe, C. A. (Ed.), Geology of Nigeria, 2nd ed. Elizabethan Publishing Co., Lagos. 283–287

Agyingi, C. M. (1991). Geology of Upper Cretaceous rocks in the eastern Bida Basin, Central Nigeria. Unpublished Ph.D. Thesis, University of Ibadan, Nigeria, 501pp

Armstrong-Altrin, J. S., Botello, A. V., Villanueva, S. F. and Soto, L. A., (2019). Geochemistry of surface sediments from the northwestern Gulf of Mexico: implications for provenance and heavy metal contamination. Geological Quarterly. 63(3):522–538.

Armstrong-Altrin, J. S., Lee, Y. I., Kasper-Zubillaga, J. J. and Trejo-Ramírez, E., (2017). Mineralogy and geochemistry of sands along the Manzanillo and El Carrizal beach areas, southern Mexico: implications for palaeo-weathering, provenance, and tectonic setting. Geological Journal. 52:559–582.

Armstrong-Altrin, J. S., Lee, Y. I., Verma, S. P. and Ramasamy, S., (2004). Geochemistry of sandstones from the Upper Miocene Kudankulam Formation, southern India: Implications for provenance, weathering, and tectonic setting: Journal of Sedimentary Research. 74(2):285-297

Armstrong-Altrin, J. S., Ramos-Vazquez, M. A., Zavala-Leon, A. C. and Montiel-García, P. C., (2018). Provenance discrimination between Atasta and Alvarado beach sands, western Gulf of Mexico, Mexico: constraints from detrital zircon chemistry and U-Pb geochronology. Geological Journal. 53, 2824–2848.

Ayala-Perez, M. P. Armstrong-Altrin, J. S., and Machain-Castillo, M. L., (2021). Heavy metal contamination and provenance of sediments recovered at the Grijalva River delta, southern Gulf of Mexico. Journal of Earth System and Science. 130:862-880.

Braide, S. P., (1992). Geological development, origin and energy mineral resources potential of the Lokoja Formation in the southern, Bida Basin. Journal of Mining and Geology. 28:33 – 44

Dey, S., Rai, A. K. and Chaki, A., (2009). Palaeoweathering, composition and tectonics of provenance of the Proterozoic intracratonic Kaladgi–Badami basin, Karnataka, southern India: Evidence from sandstone petrography and geochemistry. Journal of Asian Earth Sciences. 34:703–715.

Dobkins, J. E. and Folk, R. L. (1970). Shape development on Tahiti-Nui. Journal of Sedimentary Petrology. 40:1167-1203.

Folk, R. L. and Ward, W. C., (1965). Brazo River bar: A study in the significance of grain size parameters. Journal of Sedimentary Petrology. 27:23 – 26

Freidman, G. M. (1962). Distinction between dune, beach and river sands from the textural characteristics, Journal Sedimentary Petrology. 31:514 – 529

Friedman, G. M., (1967). Dynamic processes and statistical parameters compared for the size-frequency distribution of beach river sands. Journal of Sedimentary Petrology. 37:327–354

Ilevbare, M. and Imasuen, O. I. (2020). Sedimentology and Maturity of Ajali Formation, Benin Flank, Anambra Basin, Nigeria. Ife Journal of Science. 22(1):123-136

Ilevbare, M. and Omodolor, H. E., (2020). Ancient deposition environment, mechanism of deposition, and textural attributes of Ajali Formation, western flank of the Anambra Basin, Nigeria. Case studies, chemical and Environmental Engineering, 2: 1-8.

Ladipo, K. O., Akande, S. O. and Mucke, A., (1994). Genesis of ironstones from middle Niger Sedimentary basin, evidence from sedimentological, ore microscope, and geochemical studies. Journal of Mining and Geology. 30:161–168

McLennan, S. M. (1993). Weathering and global denudation. Journal of Geology. 101:295–30

Obaje, N. G., Balogun D. O., Idris-Nda A., Goro I. A., Ibrahim S. I., Musa M. K., Dantata S. H., Yusuf I., Mamud-Dadi N. and Kolo I. A., (2013). Preliminary Integrated Hydrocarbon Prospectivity Evaluation of the Bida Basin in North Central Nigeria. Petroleum Technology Development Journal. 3(2):36 – 65.

Oredein, O. S., Adewumi, A. J. and Odunsi, O. M. (2014). Grain Size and Depositional Pattern of Sediment from Okeluse Area, Southwestern Nigeria. Global Journal of Science Frontier Research: H Environment & Earth Science, 14(15), 2.

Passenga, R. (1964). Grain Size representation by CM patterns as a geological tool. Journal Sedimentary Petrology. 34:830-847.

Rajganapathi, V.C., Jitheshkuma, N., Sundarajan, M., (2012). Grain size analysis and characterization of Sedimentary environment along Tiruchendor Coast, Tamilnadu, India – Arabian Journal of Geosciences. 1–13.

Sames, C. W. (1966). Morphometric data of some recent pebble associations and their applications to ancient deposits. Journal Sedimentary Petrology. 36:126–142.

Sneed, E. D. and Folk, R. L. (1958). Pebbles in the lower Colorado River, Texas: a study in particle morphogenesis. Journal Sedimentary Petrology. 66:114 – 150

Udensi, E. E. and Osazuwa, I. B. (2004). Spectra determination of depths to magnetic rocks under the Nupe Basin. Nigeria Association of Petroleum Explorationists Bulletin. 22-27.

Vrbka, P., Ojo, O. J. and Gebhardt, H. (1999). Hydraulic characteristics of the Maastrichtian sedimentary rocks of the Southeastern Bida basin, Nigeria. Journal of African Earth Sciences. 29(4):659–667.