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# Temporal Variation in the Textural Characteristics of Clastic Sediments from Geregu, Ajaokuta, Nigeria

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**Abstract**— Sediment samples from a sedimentary sequence on the bank of River Ero in Geregu are evaluated to decipher the temporal variability in textures of unit layers FL_G (lowermost) to FL_A (uppermost). Sand predominates in the sediment samples and varies between 0.3 and 68.57%; particles with silt-size fraction vary between 3.01 and 26.31%. Gravel size fraction is low and occurs only in sediment samples of Units E and B, and varies between 0.2 and 4.44%. The studied sediment sequence is dominated by sand units that are very fine-grained (e.g. FL_G, FL_F, FL_D and FL_C) to fine texture (FL_E and FL_A); the only exception is Unit FL_B that is medium grain sand. This deduction corroborates the computed mean size which varies between 1.309Φ to 3.293Φ. Computed standard deviation varies between 0.622Φ and 2.274Φ which illustrates that the sediments are very poorly sorted to moderately well-sorted sand. The skewness of the sediment samples ranges between -0.235 to 0.278, and this implies that the sedimentary units are negatively skewed to positively skew. Computed kurtosis varies between 0.856 and 1.84, and based on the kurtosis values, distribution of particle size of the sedimentary units is classed as leptokurtic (e.g. FL_G and FL_D), very leptokurtic (e.g. FL_C), mesokurtic (e.g. FL_F and FL_A) and platykurtic (e.g. FL_E and FL_B). Consequently, the studied sediments are inferred to have deposited in moderate low energy environment. Bivariant plots of skewness versus standard deviation (or sorting) and mean size versus standard deviation shows that the sediments are dominantly river sands. However, the linear discriminate functions show an overlap of shallow marine and fluvial conditions of deposition for the sequence of sediments. The energy condition of the transporting medium and that of the depositional environment is inferred to be the dominant control on temporal variation in the textural characteristics of the sedimentary units.

**Index Terms**— Ajaokuta, Clastic sediments, Gradistat, Grain size, River Ero.

## 1 INTRODUCTION

The analysis of the textural characteristics of sediments has continued to receive valuable attention in recent years. An understanding of sediment textural characteristics is useful to the construction-engineering and borehole drilling industries. It is also relevant in sedimentological, geophysical, environmental and hydrogeological studies [e.g. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10].

The study site is part of the bank of River Ero in Geregu, a town in the Ajaokuta area of Kogi State of Nigeria (Fig. 1). In the Ajaokuta area, the channel of River Ero is over 10km long and drains a large part of the area into the comparatively deeper channel of the River Niger. The area that is drain by River Ero and its tributaries is underlain by Precambrian basement rocks which are part of the south-western Basement Complex of Nigeria. The Nigerian Basement Complex consist of rocks that include biotite gneiss, banded gneiss, quartzite, calcareous rocks, quartz-mica schist, mica schist, talc schist, quartzite, the older granites, the younger granites and volcanic rocks [11, 12, 13]. Rocks such as quartzite, porphyritic granite, migmatite, mica schist, and granite gneiss dominate the local geology of the Ajaokuta area [14].


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In the study site, a sequence of sediments developed on the bank of Ero River at 50-100m distance from the river mouth. Information obtained from the study of the sediments may serve as an analogue that can lead to an understanding of the intrinsic characteristics of the sequence of sediments transported and deposited by River Ero and its distributaries. The present study is, therefore, focused on documenting the sedimentological characteristics of a sequence of clastic sediments on the bank of River Ero with a view to deciphering the temporal variation in textural characteristics and the depositional history of the sediments.

## 2 METERIALS AND METHOD

A geologic field exercise is carried out as an initial part of the study during which samples are obtain from the different units of exposed sequence of sediments on the banks of River Ero. In order to perform the grain size analysis, samples are sun-dried and disaggregated manually since the sediments are unconsolidated. 100g of the samples are sieved through a sieve set using a Rotap Shaker (model STSJ-4) following routine laboratory procedures. The grain size data are process, and grain size distribution curves are developed using Microsoft Excel and Gradistat packages. In addition, the Gradistat software is used to compute grain-size parameters such as the mean size, sorting, skewness and kurtosis based on the concept of [1]. The computed parameters are used to augment the linear discriminate functions of [15] in reconstructing the depositional environments of the sequence of sediments.

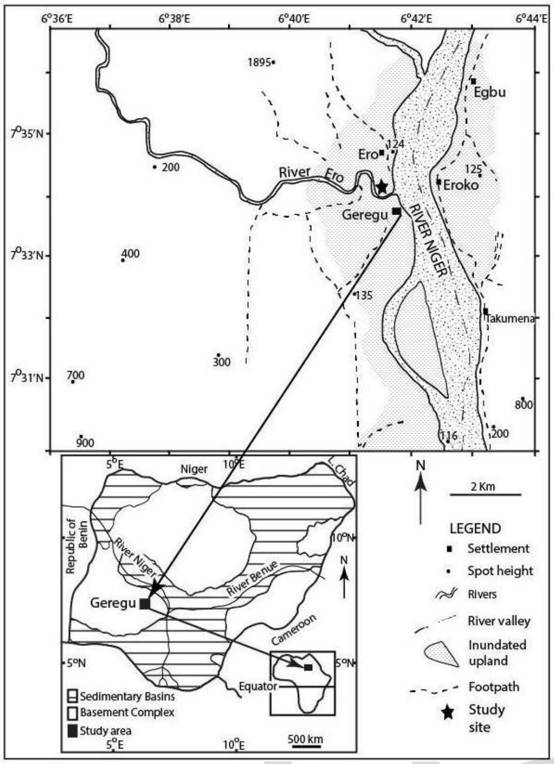


Fig. 1. Map of Geregu and Environs showing location of the study site. Inset: Geologic map of Nigeria after [16].

## 3 RESULTS AND DISCUSSION

### 3.1 Lithostratigraphy

An exposed sequence of sediments on the bank of River Ero in the Geregu area is about 121cm in thickness and comprise of seven-sediment units (FL_G to FL_A) that vary in thickness and physical characteristics (Fig. 2). The lowermost layer in the sequence is Unit FL_G that is sand and about 15cm in unit thickness. The sand is whitish-brown, very friable, slightly gravelly and coarsely laminated with laminae up to 1cm in thickness. Unit FL_G is overlain by Unit FL_F that is whitish-brown, very friable sand and about 22cm in layer thickness. Unit FL_F has fine lamination, and laminae are about 0.3cm thick. Unit FL_E directly overlies Unit FL_F, and it is ferruginous, slightly gravelly muddy sand. Unit FL_E is about 11cm thick and slightly consolidated, and exhibits no lamination. Unit FL_E is bound above by Unit FL_D that is slightly gravelly sand and has medium-size laminae (0.6cm thick). Unit FL_D is brownish, friable and is about 16cm in layer thickness. Directly overlying Unit FL_D is Unit FL_C, which is brownish, finely laminated slightly gravelly sand. The laminae of Unit FL_C are about 0.2cm in thickness. Unit FL_B occurs directly above Unit FL_C and is slightly consolidated and slightly ferruginous gravelly muddy sand. It has a layer thickness of about 15cm and shows no lamination. Directly overlying Unit FL_B is Unit FL_A, which is about 30m in layer thickness and is slightly gravelly muddy sand. Unit FL_A is uppermost in the sequence of sediments and is ferruginous and slightly consolidated. Similar to Units FL_E and FL_B, unit FL_A is also not characterized by lamination.

### 3.2 Grain Size Analysis

The grain size analysis and evaluated particle size parameters illustrate different categories of sediment samples (Fig. 3, Table 1). There are sediment samples that are very fine sand and unimodal, moderately well sorted, coarse skewed and leptokurtic (e.g. FL_G, FL_D). The second category includes Unit FL_C sample that is fine sand, moderately sorted, unimodal, fine skewed and leptokurtic. The third group includes Unit FL_E sample which is a fine sand layer that is very poorly sorted, coarse skewed and platykurtic. The fourth group includes sediment sample that are fine sand, bimodal, very poorly sorted, coarse skewed and mesokurtic (e.g. FL_A). There is a fifth group of the sediment sample that is medium sand, trimodal, very poorly sorted, and fine skewed and platykurtic (e.g. FL_B). An additional group include sediment sample of Unit FL_F which is very fine sand, unimodal, moderately well sorted, coarse skewed and mesokurtic.

In previous studies, grain-size parameters such as the mean size, sorting (or standard deviation), skewness and kurtosis have been used in reconstructing sediments depositional history [17, 18]. The mean size parameter is dependent on the transporting mechanism and power of the depositional environment [15]. Studies have shown that coarse silt to fine sand sediment is associated with low to moderately low energy depositional conditions [19, 20]. In this study, the sediment samples dominantly range in size fraction from very fine to medium sand, which corroborates with the computed mean size of the sediments that varies between 1.309Φ and 3.293Φ (Table 1, Fig. 3). Specifically, the studied sediment sequence is dominated by sand units that are very fine (e.g. FL_G, FL_F, FL_D and FL_C) to fine texture (FL_E and FL_A). It is only sediment samples of Unit FL_B that are medium grained sand. Consequently, the studied sediments may have been deposited in moderate low energy environment [e.g. 21, 22].

Standard deviation measures the sorting (σ1) of sediments and is related to the level of fluctuations in the energy or velocity conditions of the depositing agent [15]. The standard deviation values of the sediments ranged from 0.622Φ to 2.274Φ with an average value of 1.322Φ (Table 1). On this basis, the studied sequence is composed of unit layers that are very poorly sorted (FL_E, FL_B and FL_A), moderately well-sorted (FL_G, FL_F and FL_D) and moderately sorted (Unit FL_C).

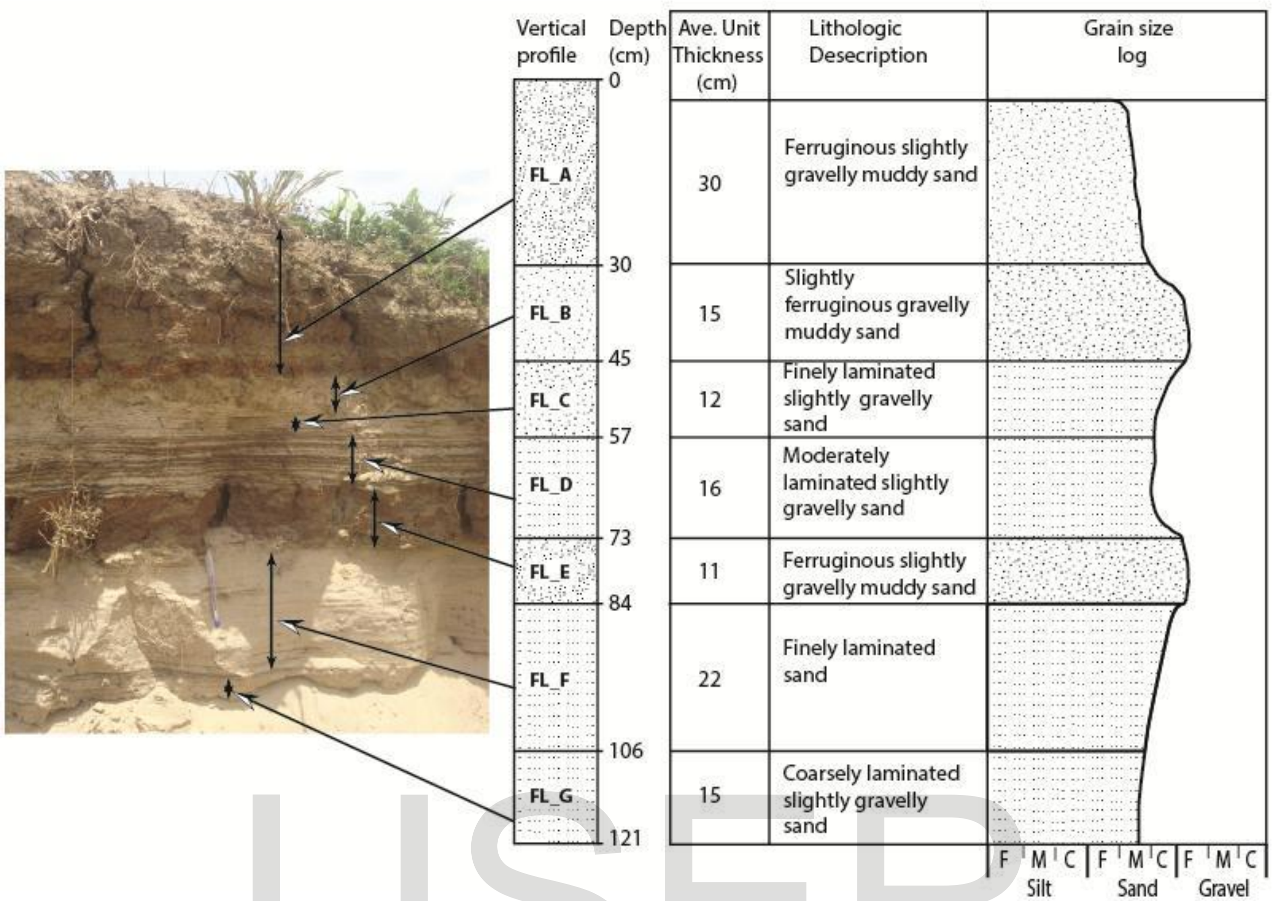




Fig. 2. Stratigraphic column showing the sequence of sediments and their characteristics. The pen shown in the picture is about 15cm in length.

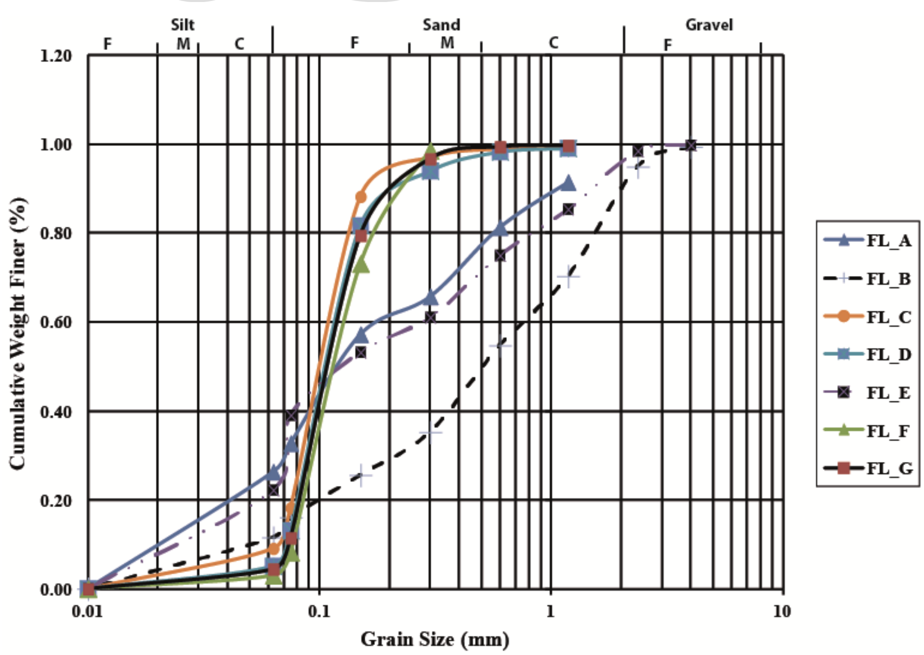


Fig. 3. Grain size distribution curves for the clastic sediments. The spread of the curves indicate sediment samples with size fractions that range from clay to very coarse sand.

Table 1. Interpretation of graphic measure of sediment grain size distribution

| Unit code | Mean (ϕ) | Sorting (ϕ) | Skewness | Kurtosis | Description of Sediment Samples | Sample Type | Textural Group |
|---|---|---|---|---|---|---|---|
| FL_A | 2.847 | 2.166 | -0.104 | 0.935 | Fine sand, very poorly sorted, coarse skewed and mesokurtic | Bimodal, very poorly sorted | Slightly gravelly muddy sand. |
| FL_B | 1.309 | 2.155 | 0.278 | 0.856 | Medium sand, very poorly sorted, fine skewed and platykurtic | Trimodal, very poorly sorted | Gravelly muddy sand. |
| FL_C | 3.293 | 0.736 | 0.106 | 1.84 | Very fine sand, moderately sorted, fine skewed and very leptokurtic | Unimodal, moderately sorted | Slightly gravelly sand. |
| FL_D | 3.148 | 0.671 | -0.235 | 1.428 | Very fine sand, moderately well sorted, coarse skewed and leptokurtic | Unimodal, moderately well sorted | Slightly gravelly sand. |
| FL_E | 2.527 | 2.274 | -0.195 | 0.896 | Fine sand, very poorly sorted, coarse skewed and platykurtic | Trimodal, very poorly sorted | Slightly gravelly muddy sand. |
| FL_F | 3.007 | 0.632 | -0.203 | 1.014 | Very fine sand, moderately well sorted, coarse skewed and mesokurtic | Unimodal, moderately well sorted | Sand |
| FL_G | 3.104 | 0.622 | -0.208 | 1.189 | Very fine sand, moderately well sorted, coarse skewed and leptokurtic | Unimodal, moderately well sorted | Slightly gravelly sand. |
| **Minimum** | 1.309 | 0.622 | -0.208 | 0.856 | | | |
| **Maximum** | 3.293 | 2.274 | 0.278 | 1.84 | | | |
| **Average** | 2.748 | 1.322 | -0.08 | 1.165 | | | |

Skewness is a measure of the symmetry or asymmetry of the frequency distribution of sediments or sedimentary rocks. Computed skewness of the studied sediments ranged from -0.235 to 0.278 with an average value of -0.080 (Table 1). On the basis of the computed skewness, the units range from fine or positively skewed (e.g. FL_C and FL_B) to coarsely or negatively skew (e.g. FL_G, FL_F, FL_E, FL_D and FL_A). The occurrences of positively skew distribution of sediments have been indicated to suggest a surplus of fine size fractions or the depletion of the coarse-grained fractions [23]. In this study, coarse or negative skewness occurs dominantly with the sediment samples. Specifically, samples of Units FL_G, FL_F, FL_E, FL_D and FL_A are coarsely or negatively skewed whereas samples of Units FL_C and FL_B are finely or positively skewed. Consequently, the sediment units that are finely skewed probably deposited in a feeble energy condition. In addition, the units that are coarsely skewed may have deposited when the power of the depositional environment was comparatively moderately high. Therefore, it is deduced that a slight variation from moderately high to low energy of the depositional environment occurred after the deposition of Units FL_G, FL_F, FL_E, FL_D and FL_A. It is during this period that the deposition of the positively skewed Units FL_C and FL_B occurred. This change in energy of the depositional environment is inferred to be instantaneous considering the overall thickness of the sedimentary sequence and the thickness of the different sedimentary units. The predominance of the negatively skewed sediments over the positively skewed sedimentary units is indicative of the nearness of the studied sedimentary sequence near the mouth of River Ero. Similar results have been documented for sediments at Mandvi, Gulf of Kuchchh in India where negative skewness of the sediments is attributed to the dominance of winnowing over deposition that occurs close to the river mouth [20].

Computed kurtosis values range from 0.856 to 1.840 with an average of 1.165 (Table 1). This range of kurtosis illustrates the sediment samples as mesokurtic (FL_F and FL_A), leptokurtic (FL_G and FL_D), platykurtic (FL_E and FL_B) and very leptokurtic (FL_C). [24] suggests the association of high (4.23) or low (0.866) values of kurtosis in sediment samples as indicative of sediment sorting or reworking in a high energy environment. In the present study, sediment samples that are leptokurtic have high kurtosis and are moderately to moderately well sorted, whereas those sediment samples that are mesokurtic to platykurtic have moderate to low kurtosis and very poorly sorted. The only exception to this generalisation is Unit FL_F that has moderate kurtosis, is mesokurtic and also moderately well sorted. The kurtosis (1.014) obtained for this unit is 0.826 lower than the highest kurtosis and 0.158 higher than the lowest computed kurtosis for the studied sequence of sediments.

### 3.3 Bivariate Statistics

An analysis of the plot of skewness against the standard deviation (or sorting), and the plot of mean size versus against the standard deviation illustrate that the studied sequence of sediment are river sand and fluvial in origin (Fig. 4) [e.g. 17, 24].

### 3.4 Linear Discriminate Functions

Linear discriminate functions proposed by [15] are employed to augment the information from bivariate statistics so as comprehend the environment of deposition of the different sedimentary units in the studied sequence. The discriminate functions of [15] that are use in this study are Y1 ≥ -2.7411 (beach), Y1≤-2.7411 (Aeolian); Y2<65.3650 (beach confirmed), Y2≥65.3650 (shallow agitated conditions); Y3≥-7.4190 (shallow marine), Y3<-7.4190 (fluvial). The discriminate functions of Y1, Y2 and Y3 computed for the studied sequence of sediments illustrates that with reference to Y1, 57% and 43% of the sediment samples falls into Aeolian and beach depositional environments respectively. With reference to Y2, 57% are of the beach environment while 43% falls into a shallow agitated setting. In respect of the value obtained for Y3, 57% of the sediment samples belong to shallow marine environment whereas 43% of the sediment samples relate to fluvial conditions (Table 2). In general, the discriminate functions as applied to the studied sedimentary sequence show a dominance of shallow marine and fluvial deposits.

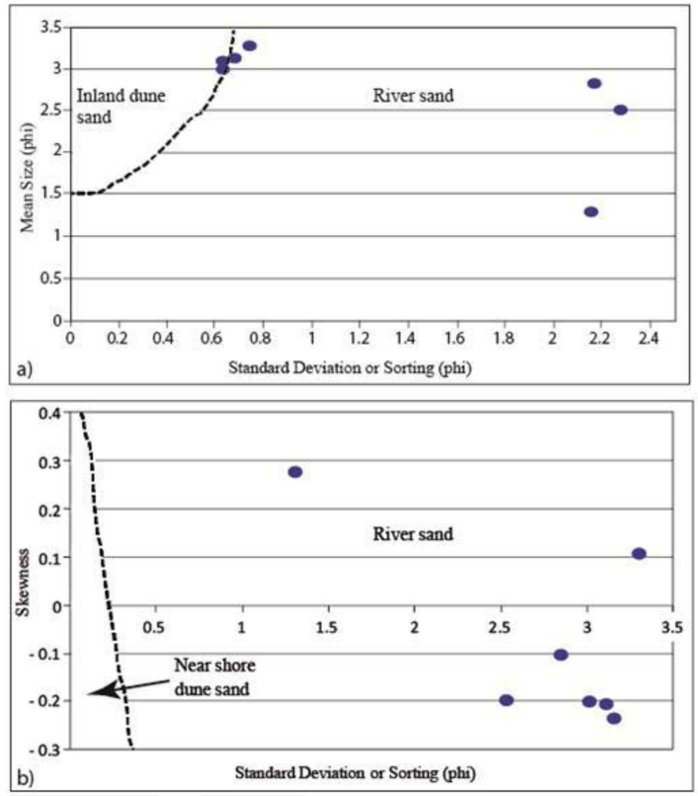


Fig. 4. Depositional environmental discrimination of the clastic sediments: (a) Mean grain size against standard deviation or sorting, (b) skewness against Standard Deviation.

## 4 CONCLUSION

The evaluation of the textural characteristics of the sequence of sediments illustrates that they are characterized predominantly by very fine to medium grained sand fractions. Results also show that energy conditions of the depositional environment were moderately high early in the depositional history of the sedimentary sequence during which the deposition of sedimentary units FL_G, FL_F, FL_E and FL_D occurred. A weakening in the power of the depositional environment from moderately high to low may have occurred after the deposition of the aforementioned units leading to the deposition of sedimentary Units FL_C and FL_B. A later change to moderate high flow conditions occurred during the deposition of Unit FL_A. The change in energy of the depositional environment is inferred to be instantaneous considering the overall thickness of the sedimentary sequence and the thickness of component sedimentary units. Bivariant plots of skewness versus standard deviation (or sorting) and mean size versus standard deviation (or sorting) shows that the sediments are dominantly river sands. However based on the results of the linear discriminate functions, an overlap of shallow marine and fluvial conditions of deposition may have occurred. The energy condition of the transporting medium and that of the depositional environment is inferred to be the dominant control on temporal variation in the textural characteristics of the sedimentary units.

Table 2. Estimated linear discriminate function values of sediment samples following the method of [15].

| Sample Code | Y1 | Remark on environment | Y2 | Remark on environment | Y3 | Remark on environment |
|---|---|---|---|---|---|---|
| FL_A | 10.1249 | Beach | 21.2757 | Beach | -39.7340 | Fluvial |
| FL_B | 7.9802 | Beach | -10.7100 | Beach | -41.6292 | Fluvial |
| FL_C | -4.0262 | Aeolian | 80.3304 | Shallow agitated conditions | -4.2363 | Shallow marine |
| FL_D | -5.1038 | Aeolian | 72.9067 | Shallow agitated conditions | -1.8277 | Shallow marine |
| FL_E | 12.9275 | Beach | 11.8691 | Beach | -43.5826 | Fluvial |
| FL_F | -6.0802 | Aeolian | 63.3273 | Beach | -1.5993 | Shallow marine |
| FL_G | -5.9275 | Aeolian | 68.2182 | Shallow agitated conditions | -1.4289 | Shallow marine |

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## REFERENCES

[1] R.L. Folk and W.C. Ward, "Brazo river bar: A study of the significance of grain size parameters", *Journal of Sedimentary Geology*, vol. 27, pp. 3–26, 1957.

[2] H. Blatt, G. Middleton and R. Murray, *Origin of Sedimentary Rocks*. New Jersey: Prentice-Hall, 1972.

[3] T.J. Griffin, "Extended range particle size distribution using laser diffraction technology: A new perspective", SCA Conference Paper Number 9126, 1991.

[4] I.N. McCave and J.P.M. Syvitski, Principles and methods of particle size analysis, In J.P.M. Syvitski (ed.), Principles, Methods, and Applications of Particle Size Analysis, New York, Cambridge University Press, p. 3-21, 1991.

[5] B.W. Flemming and K. Ziegler, "High-resolution grain size distribution patterns and textural trends in the backbarrier environment of Spiekeroog Island, southern North Sea", *Senckenbergiana Maritima* vol., 26, nos 1 and 2, pp. 1-24, 1995.

[6] L.M. Arya, F.J. Leij, M.Th. van Genuchten and P.J. Shouse, "Scaling parameter to predict the soil-water characteristic from particle-size distribution data", *Soil Science Society of America Journal*, vol. 63, pp. 510-519, 1999.

[7] D.G. Fredlund, "The 1999 R.M. Hardy Lecture: The implementation of unsaturated soil mechanics into geotechnical engineering", *Canadian Geotechnical Journal*, vol. 37, pp. 963-986, 2000.

[8] G.C. Santamarina, "Soil behaviour: The role of particle shape", *Proc. Skempton Conf*., pp. 1-14, 2004.

[9] A. Rabiu, E.A. Akinnigbagbe, D.O. Imo, T.M. Imhansoloeva, M.P. Ibitola, B.R. Faleye and O. Shonde, "Textural Characteristics of Bottom Sediments in Parts of the Lagos Atlantic/Seabed Coastal Waters," *actaSATECH Journal of Life and Physical Sciences*, vol. 4, no. 1, pp. 64-73, 2011.

[10] E.E. Adiotomre, E.O. Adaikpoh, O. Erhisere, The gravel packing characteristics of Ethiope River sediments, southern Nigeria, *World Applied Sciences Journal*, vol. 24, no. 6, pp. 759-764, 2013.

[11] M.A. Rahaman, "Review of Basement of southwestern Nigeria", *Geology of Nigeria*, C. Kogbe, ed., Lagos: Elizabethan Press, pp 41-58, 1976.

[12] N.G. Obaje, "Geology and mineral resources of Nigeria", *Lectures Notes in Earth Sciences,* vol. 120, pp. 13-30, 2009.

[13] C. Obiora and V.U. Ukaegbu, "Petrology and geochemical characteristics of Precambrian granitic basement complex rocks in the southernmost part of North-Central Nigeria", *Chinese Journal of Geochemistry*, vol. 28, no. 4, pp. 377-385, 2009.

[14] E.E. Adiotomre, "Usability of Crystalline Basement Rocks as Construction Materials: Case Study of Ajaokuta Area, Kogi State, Nigeria", *International Journal of Scientific and Engineering Research*, submitted for publication.

[15] B.K. Sahu, "Depositional mechanisms from the size analysis of clastic sediments", *Journal of Sedimentary Petrology,* vol., 34, pp. 73-83, 1964.

[16] C.A. Kogbe, *Geology of Nigeria*. Lagos: Elizabethan Publishing Company, 1976.

[17] R.L. Folk, *Petrology of Sedimentary Rocks*. Texas: Hemphill Publication Company, 1968.

[18] E.J. Amaral, "Depositional environment of the St. Peter sandstone deduced by textural analysis", *Journal of Sedimentary Petrology*, vol. 47, no. 1, pp. 32-52, 1977.

[19] G. Kumar, A.L. Ramanathan and K. Rajkumar, "Textural characteristics of the surface sediments of a Tropical mangrove ecosystem, Gulf of Kachchh", Gujarat, India", *India Journal of Marine Sciences*, vol. 39, no. 3, pp. 415-422, 2010.

[20] D. Trivedi, M.C. Raicy, K. Devi, D. Kumar, I. Buynevich, P. Srinivasan, N.R. Iyer, R. Guin , D. Sengupta, R.R. Nair, "Sediment Characteristics of Tidal Deposits at Mandvi, Gulf of Kuchchh, Gujarat, India: Geophysical, Textural and Mineralogical Attributes", *International Journal of Geosciences*, vol. 3, pp. 515-524, 2012.

[21] A. Rabiu, E.A. Akinnigbagbe, D.O. Imo, T.M. Imhansoloeva, M.P. Ibitola, B.R. Faleye and O. Shonde, "Textural Characteristics of Bottom Sediments in Parts of the Lagos Atlantic/Seabed Coastal Waters," *actaSATECH Journal of Life and Physical Sciences*, vol 4, no. 1, pp. 64-73, 2011.

[22] R. Thirunavukkarasu and V. Senapathi, "Grain size characteristics of the Coleroon Estuary sediments, Tamilnadu, east coast of India", 2011.

[23] S. Shahbuddin, "Sediment accretion and variability of sedimentological characteristics of a tropical estuarine mangrove, Kemaman, Terengganu", Master thesis, Universiti Perta-nian Malaysia, 1996.

[24] G.M. Friedman, "Differences in size distribution of populations of particles among sands of various origins", *Sedimentology,* vol. 26, pp. 3-32, 1969.