Evaluation of the Spatial Distribution of Grain Size Characteristics and its Role in Determining the Environment of Deposition of sediments in Orlu and Environs, Imo State South Eastern Nigeria

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Abstract

The depositional environments of sediments around Orlu and environs, Imo state, was studied using various statistical parameters including Mean size, Standard deviation, Skewness, and Kurtosis. These parameters were obtained from sieve analysis of fifteen (15) sediment samples obtained within the area of the study at different depth. The grain size distribution curves for the study area showed that about 80% by weight of the sediments are medium to coarse-grained sand and fine gravels, while the remaining 18% and 2% are fine-grained sand and coarse silt. The sorting indicates that the samples are very poorly sorted around Afor-nta and Isiekenesi areas, and are moderately sorted at Ihioma, and others area within the study. Other textural analysis also shows that the samples ranges from strongly fine skewed, very platykurtic to extreme leptokurtic and are uniformly graded, except in Afor-nta and Isiekenesi with well-graded sediments. Analysis of the environment of deposition for the study area showed that the samples were deposited in beach/shallow agitated and fluvial agitated environments. Marine influence on the sediments seem to be dominant in the southern parts of the study area while fluvial influence is evident in the northern part of the area.

Keywords: Grain size, Depositional environment, Orlu and environs, spatial distribution.

1.0 Introduction

Understanding the sediment processes and the depositional environment of sediments around Orlu and environs has become a thing of interest having found the area to be part of two major basins in Nigeria. Orlu and environs fall within the south-eastern part of Nigeria with considerable sediment abundance that cut across the Niger delta basin and Anambra basin. Understudying the particle size distribution of the sediments is sensitive to the physical changes of the transporting media and the deposition of basin (Krumbein, 1934). This will bring to light the processes that have given rise to the sediments with the area. The geologic significance of grain size distribution of clastic sediments has been acknowledged as far back as 500 BC (Udden 1898). Since the nineties, sedimentologists have been using grain size data to interpret sedimentary processes. Early efforts for the systematic analysis of grain size data was made by Wentworth (1922) and Udden (1898, 1914). The application of statistical techniques to characterize the frequency distribution of clastic sediments was discussed by authors including Krumbein and Pettijohn (1938), Spencer (1952), Trask (1932), Krumbein(1934), Otto (1939),and others. Hjulstorm (1939), Passega (1957, 1964), Folk and Ward (1957), Mason and Folk (1958), Doeglas (1946), Inman (1949), and Bagnold (1946, 1956) emphasized the application of granulometric analysis in hydrodynamics and environmental interpretation.

Several researchers, like Joshep *et al* (1997), Mahendar (1996), Majumdar and Ganapati (1998), Hanamgond and Chavadi (1998),Murkute (2001a, 2001b)Raman and Reddy (2001), Bhat *et al* (2002), Rao *et al*(2005), Burhanuddin (2007), Rabindra *et al* (2008), Ashok and Rupesh (2009a, 2009b), and several others amply testify the significance of the grain size study. The objective of this study is to evaluate the grain size distribution, environment, and mode of deposition of sediments at Orlu and environs.

1.1 Location and Accessibility

The area of study falls within Imo state, encompassing towns like Orlu, Amucha, Nkwerre, Amigbo, Umuaka, Nduche and others. The area is located in the South-eastern part of Nigeria andlies between latitudes 5º 39ᴵ N - 5º 50ᴵ N and longitudes 7º 09ᴵ E -8º 20ᴵ E (Fig. 1). It is bounded by Okigwe town at the east, Mgbidi at the West, Urualla at the North, and Ogwa at the South. The study area well accessible from numerous neighboring towns and villages through various major and minor roads.

1.2 Geology of the Study Area

The study area is seen to be situated between two sedimentary basins namely; the Niger Delta Basin and the Anambra Basin of Nigeria. The Cenozoic Niger Delta complex which developed as a regressive offlap sequences consists of three major lithostratigraphic units namely Akata, Agbada and Benin Formation. The Akata Formation is composed of continuous shale and about 10% sandstone. Its age ranges from Eocene to Recent. The Agbada Formation conformably overlies the Akata Formation and it is a parallic sequence of alternating shale and sandstone with variable age ranging from Eocene in the north to Pliocene/Pleistocene in the south and Recent in the Delta surface. The Agbada Formation is thickest at the center of the Delta with thickness of up to 457.2 m. The continental Miocene-Recent Benin Formation conformably overlies the Agbada Formation. It is composed of loose fresh water-bearing sand with occasional lignite and clay and going up to 2,286m deep with no overpressures. It is made of more than 90% sands and about 10% shale/clays (Burke, 1996). On the other hand, the Anambra Basin is the most prominent basin formed during the Abakaliki tectonic episode (Igbokwe, *et al.* 2008). The Anambra Basin is dominantly filled with clastic sediments constituting several distinct lithostratigraphic units ranging from Upper Campanian to Recent in age. The lithostratigraphic units have a thickness of up to 2500m (Reyment, 1965), and includes Nkporo Shale, Mamu Formation, Ajali Sandstone, Nsukka Formation, Imo Shale, Ameki Formation, Nanka Sands(Fig.1). The study area is underlain by Ameki Formation, Ogwashi-Asaba Formation and Benin Formation (Fig.2).The study area is drained by two major river systems namely Njaba River in the south-west and Orashi River system extending from the north to the south of the study area.

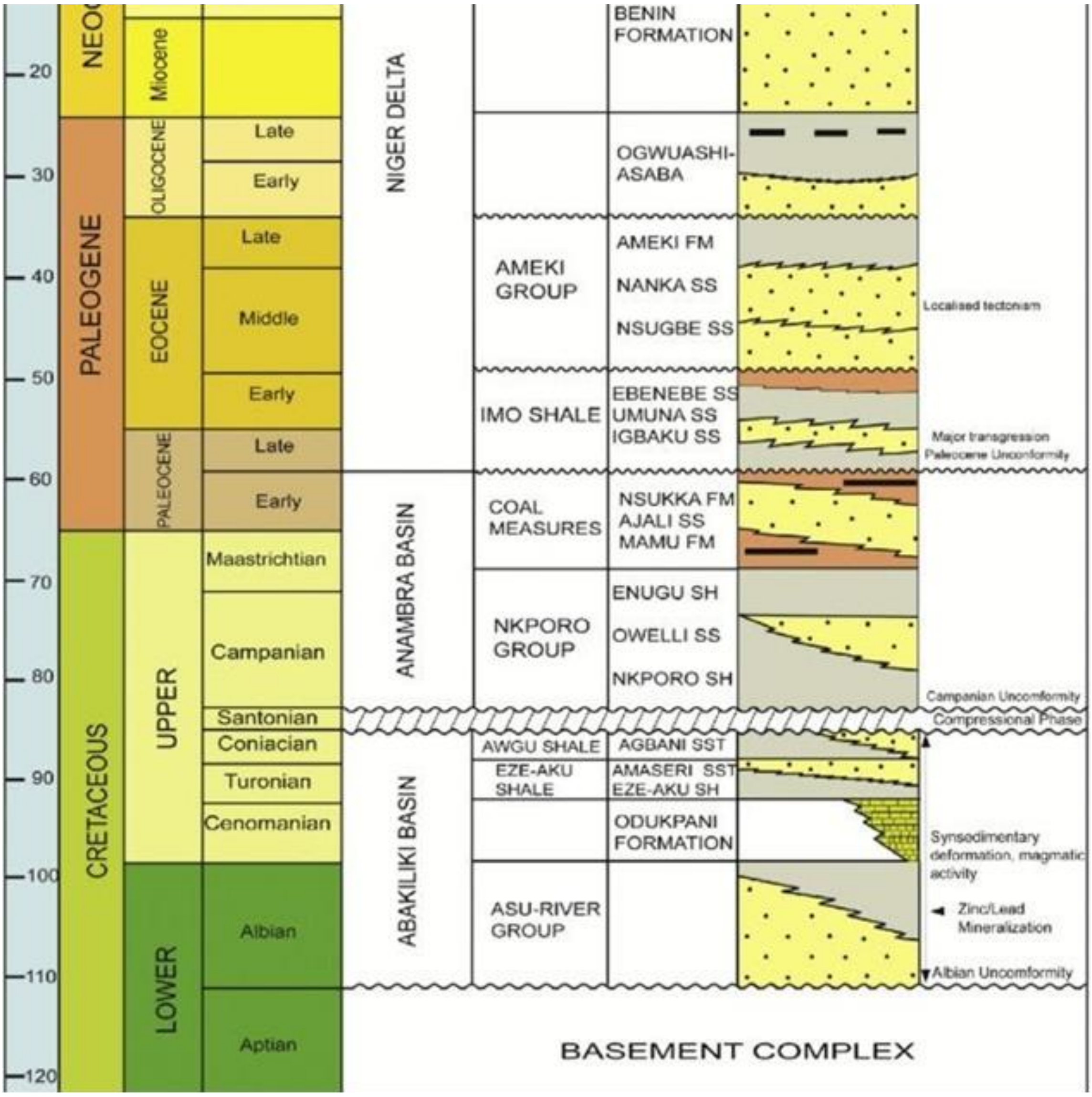

Fig. 1: Stratigraphic succession in the Anambra basin and niger Delta (as modified by Ekwenye *et al*., 2014).

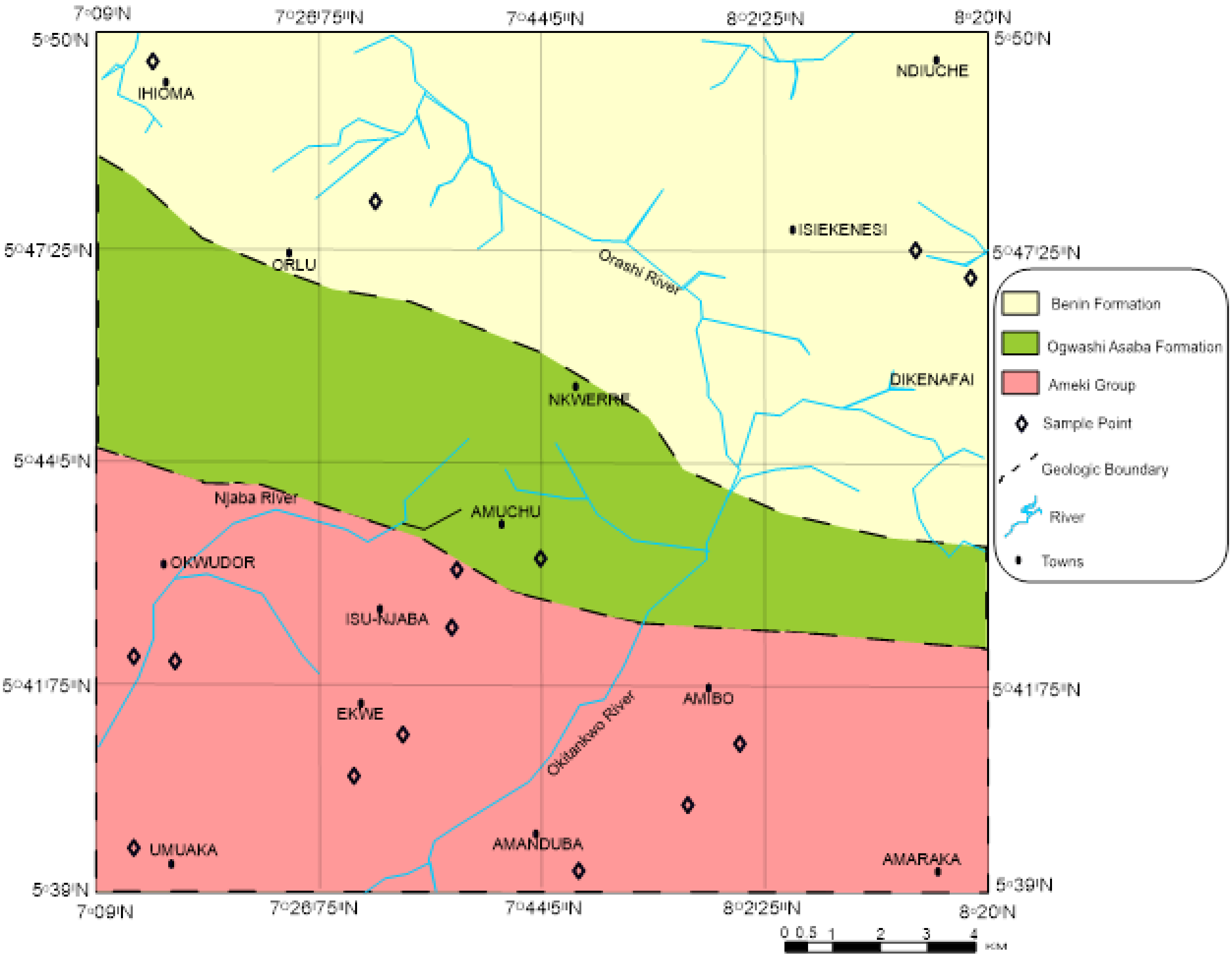

Fig. 2: Geologic map of the study area showing major sample locations

2.0 Methodology

Three objectives guided the methodology of this study. They are, description; this adds to the overall physical description of the sedimentary rocks or, the sediments. Comparison; where the size and distribution of the sediment are compared with that of the others. The third objective is interpretations; where interpretations are made concerning the depositional environment.

Fifteen (15) sediment samples used for this study and they were collected from the area at varying depth in the different locations within the area. Grain size distribution analysis was carried out (using a mechanical shaker) on the fifteen sediments samples. Grain size data of the 15 samples are presented graphically in the form of frequency curves, and cumulative frequency curves. The inflection points and percentage of sediment loads in different modes of transportation were determined from cumulative frequency curves prepared after sieve analysis. Statistical parameters calculated which include mean standard deviation, skewness, and kurtosis. Standard deviation and skewness were described according to Boggs, 1995, while kurtosis was described according to Folk and Ward, 1957. The depositional processes and environments of deposition were evaluated using different bivariate plots of discriminant function proposed by Sahu (1964).

3.0 Result and Discussions

The geologic significance of grain size parameters is clearly seen when parameters are plotted against each other which shows their inter-relationship in terms of scatter diagrams (Folk and Ward, 1957). Textural attributes of sediments like grain size distribution, mean, standard deviation, skewness, and kurtosis are widely used to reconstruct environment of deposition. These textural attributes were calculated from cumulative frequency graphs from sieve analysis results. A summary of the textural attributes is presented in Table 1.

3.1 Grain Size Distribution Analysis

The grain size distribution curves (Fig. 2) indicate that about 80% (by weight) of the sediments are medium to coarse-grained sand and fine gravels, while the remaining 18% and 2% are fine-grained sand and coarse silt. Majority of the samples are coarse grained suggesting deposition under moderate to high energy conditions. The samples were found to be uniformly graded across the study area, except in the Afor-nta,Isiekenesi areas where well-graded sediments prevails (Fig. 2).

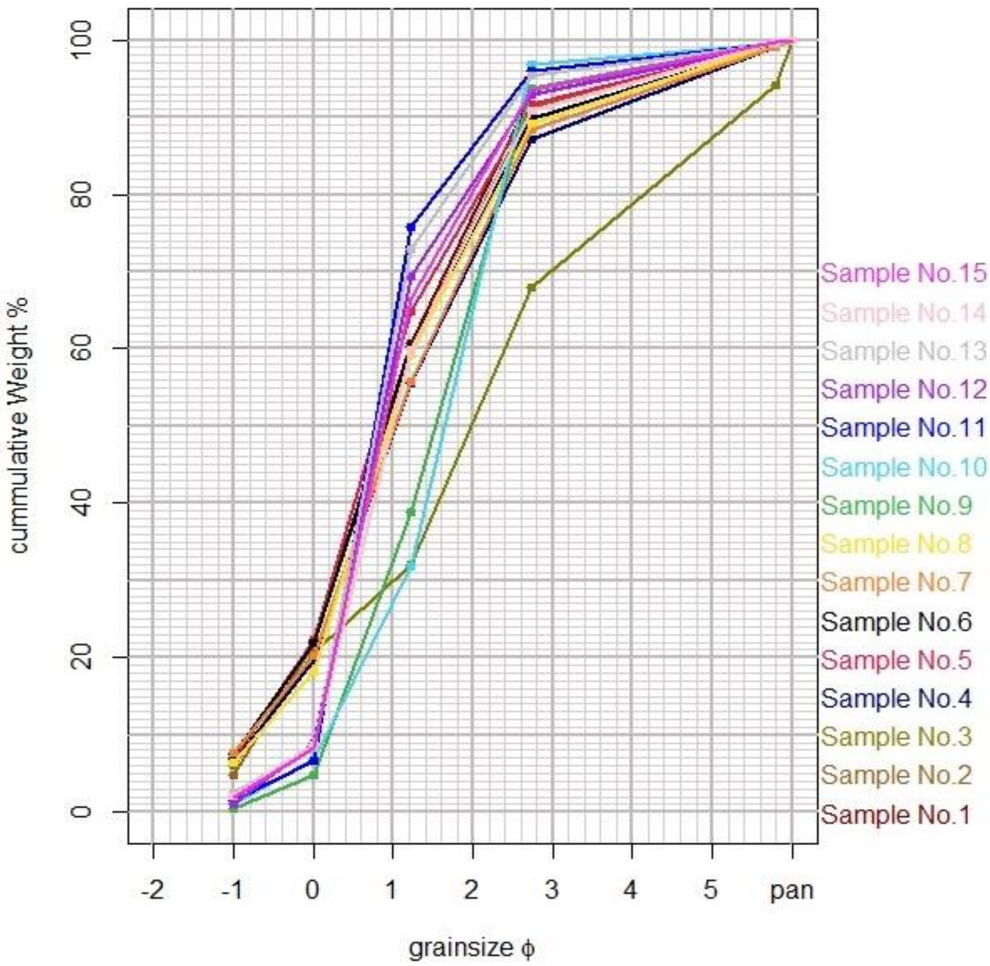

Fig 2: Grain size analysis graph for the study samples

3.2 Graphic Mean (Mz)

The mean phi size of the samples ranges from 0.8 to 2 ϕ with an average mean of 1.18 ϕ (Fig. 3a). This range puts the sample sizes between coarse to fine sand (Boggs, 1995). This puts about 60% of the sample within coarse sand range. This indicates that the majority of the sand sediments were deposited in moderately high energy conditions while about 40% was deposited in relatively quiet energy conditions.

3.3 Inclusive Graphic Standard Deviation (δi)

The standard deviation is a measure of the sediment sorting. This reflects the kinetic energy of the deposition agent and its fluctuations. The standard deviation of the rock samples ranges from 0.5 to 2.7 ϕ with a mean of 1.2 ϕ (Fig. 3b). According to the Folk and Ward (1957) classification, the sorting ranges from very poorly sorted to moderately well sorted. 53% of the sample is poorly sorted while 40% is moderately well sorted, and only 7% is very poorly sorted. This indicates a relatively high fluctuating energy of deposition. Geologically, the sorting indicates that the samples range from very poorly sorted at Afor-nta, Isiekenesi to moderately sorted at Ihioma, and other areas.

3.4 Inclusive Graphic Skewness (Ski)

Inclusive graphic skewness is a measure of frequency distribution which indicates the position of the mean with respect to the median. Skewness results from mixing of two different normal populations in different proportions and, may imply the dominance of coarse over fine and vice versa. It is geometrically independent of the sorting nature of the sample. For this analysis, skewness ranges from -0.029 to 0.790, with a mean of 1.3, according to Folk and Ward's (1957) classification, skewness ranges from strongly coarsely skewed to strongly finely skewed. 20% of the sample is near symmetrical, coarse skewed, and fine skewed, 27% is strongly fine skewed, and 7% is strongly coarsely skewed(Fig. 3c). Skewness values also indicate the kinetic energy of the depositing medium. Negative values of skewness indicate coarsely skewed sediments and therefore indicates a higher than average deposition agent velocity, working for a greater length of time than normal, while positive skewness value is indicative of finely skewed sediments and low energy of the medium, (Sahu, 1964).

3.5 Graphic Kurtosis (K_G)

Graphic Kurtosis is a sensitive and valuable parameter for testing normalities of a distribution (Sahu, 1964). For a normal distribution, the kurtosis value is 1.00. When it is less than 1.00, the curve is called platykurtic and it indicates better sorting in the tail portion of the sediments. When kurtosis value is more than 1.00, it is leptokurtic and indicates better sorting in the central portion of size curve. Kurtosis value thus reflects the fluctuation of energy conditions of the depositing medium (Folk and Ward, 1957). Kurtosis for this study ranges from 0.66 to 3.55 with a mean of 1.3(Fig. 3d). 27% of the sample is mesokurtic, 47% is leptokurtic. Extremely leptokurtic, very leptokurtic, platykurtic, and very platykurtic are 1% each. The relatively high values of kurtosis imply that a part of the sediment was sorted in a high energy environment.

Table 1: Statistical analysis of grain size parameters for samples and descriptions.

Sample No:	Location	Mean	Median	Sorting Value	Sorting Remark	Skewness Value	Skewness Remark	Kurtosis Value	Kurtosis Remark	Coeff. Of Uniformity Value	Coeff. Of Uniformity Remark
1	Orlu (Mgbee)	0.87	0.90	1.2614	Poorly Sorted	-0.0294	Strongly Coarse Skewed	1.0125	Mesokurtic	3.4118	Uniformly Graded
2	AfforUkwu Isiekenesi	0.97	0.90	1.2515	Poorly Sorted	0.0998	Near Symmetrical	1.1091	Leptokurtic	3.7500	Uniformly Graded
3	Affor-NtaIsiekenesi	2.00	1.90	2.6735	Very Poorly Sorted	0.0958	Near Symmetrical	0.9751	Mesokurtic	11.0000	Well Graded
4	Okwudor	1.00	1.10	1.4229	Poorly Sorted	0.1754	Coarse Skewed	3.5519	Extremely leptokurtic	5.0000	Uniformly
5	UmusekeOkwudor	1.10	0.80	1.2720	Poorly Sorted	0.0870	Near Symmetrical	1.2568	Leptokurtic	3.5294	Uniform Graded
6	Amucha	0.97	0.90	1.4076	Poorly Sorted	0.7901	Strongly Fine Skewed	1.2054	Leptokurtic	3.8000	Uniformly Graded
7	ObiatoUmuakah	1.10	1.00	1.4129	Poorly Sorted	-0.0169	Coarse Skewed	1.1217	Leptokurtic	4.4167	Uniformly Graded
8	ObaraEkwe	1.03	0.90	1.3273	Poorly Sorted	0.1667	Fine Skewed	1.3115	Leptokurtic	4.1538	Uniformly Graded
9	ObamaraEkwe	1.77	1.50	0.6390	Moderately well Sorted	0.4828	Strongly Fine Skewed	0.9904	Mesokurtic	2.3529	Uniformly Graded
10	Amandugba	1.47	1.60	0.5242	Moderately well Sorted	-0.2321	Coarse Skewed	1.0432	Mesokurtic	2.1053	Uniformly Graded
11	Isunjaba	0.80	0.70	0.7179	Moderately well Sorted	0.3324	Fine Skewed	1.3320	Leptokurtic	2.2222	Uniformly Grade

12	AbahIsunjaba	0.93	0.80	0.8848	Moderately well Sorted	0.3125	Fine Skewed	1.3115	Very Platykurtic	2.4737	Uniform graded
13	AmaujuAmaigbo	0.87	0.80	0.8500	Moderately well Sorted	0.7591	Strongly Fine Skewed	0.6510	Platykurtic	2.3810	Uniformly Graded
14	UmuokwaraohaAmaigbo	1.87	1.00	1.0455	Poorly Sorted	0.2667	Strongly Fine Skewed	1.5574	Very Leptokurtic	2.6667	Uniformly Graded
15	Ihioma	1.00	0.90	0.8947	Moderately well Sorted	0.2657	Strongly Fine Skewed	1.1550	Leptokurtic	2.5263	Uniformly Graded

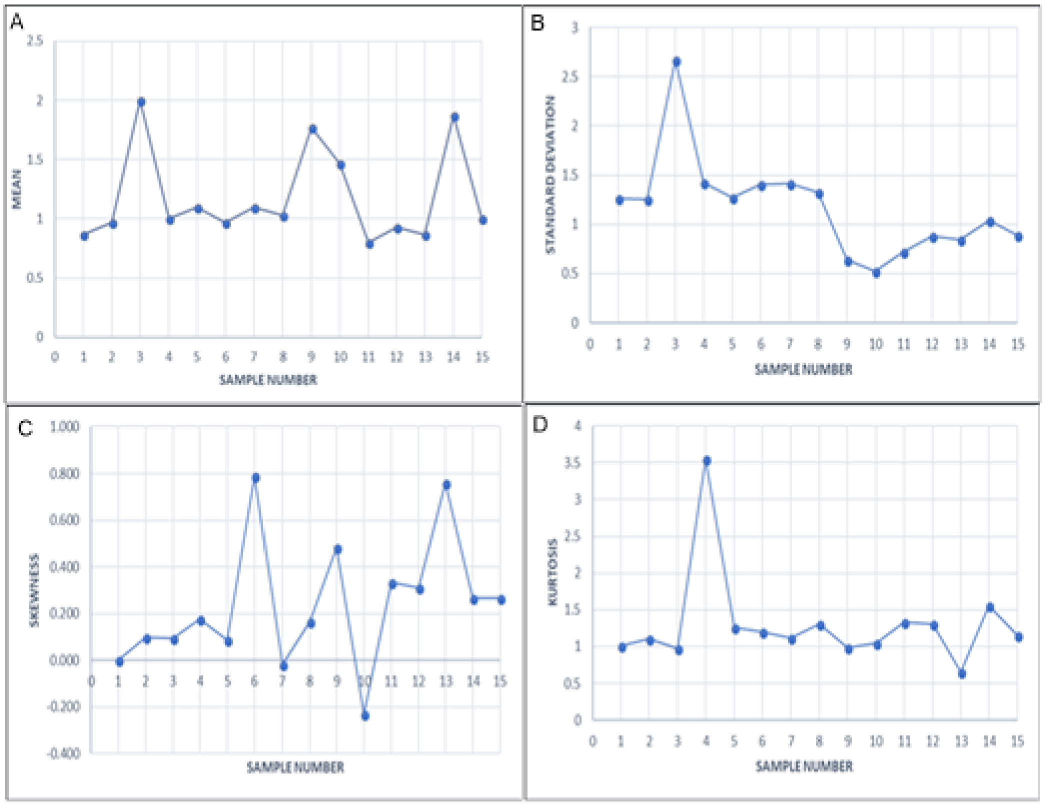

Fig. 3: Horizontal variations of grain size parameters of the samples for mean (A), standard deviation (B), skewness (C), and kurtosis (D).

3.6 Linear Discriminant Functions (LDF)

The linear Discriminant function of Sahu (1964) was used for multivariate analysis of the samples. The discriminant functions are methods of analysis of the sediments which indicates that variations in the energy and fluidity factors seem to have excellent correlation with different processes and environment of deposition. The following formulae (with their limitation to a particular environment) were used to interpret the environment of deposition of sample sediments.

Furthermore, in order to distinguish environment of deposition between aeolian and beach, the following equation has been applied:

$Y1_{Aeol: Beach} = -3.5688Mz + 3.7016\delta i^2 - 2.0766\ Ski + 3.1135K_G$ (1)

Where if Y is ≥ -2.7411, the environment of deposition is beach, and if Y is ≤ -2.7411, the environment of deposition is aeolian.

To delineate and to confirm the environment of deposition between beach and shallow marine, the following equation has been applied:

$Y2_{\text{Beach: Shallow marine}} = 15.6534Mz + 65.7091\delta i^2 + 18.1071\ Ski + 18.5043K_G$ (2)

Where if Y is ≥ 63.3650, the environment of deposition is shallow marine, and if Y is ≤63.3650, the environment of deposition is beach.

To distinguish environment of deposition between shallow marine and fluvial, the following equation has been applied:

$Y3_{\text{Shallow marine: Fluvial}} = 0.2852Mz - 8.7604\delta i^2 - 4.8932\ Ski + 0.0428K_G$ (3)
Where if Y is ≥-7.4190, the environment of deposition is shallow marine, and if Y is ≤-7.4190, the environment of deposition is fluvial.
To distinguish environment of deposition between fluvial and turbidity current, the following equation has been applied:

$Y4_{\text{Fluvial: Turbidity current}} = 0.7215Mz - 0.4030\delta i^2 + 6.7322\ Ski + 5.2927\ K_G$ (4)
Where if Y is ≤ 9.8433, the environment of deposition is turbidity deposition, and if Y is ≥9.8433, the environment of deposition is fluvial.
(Mz= mean, δi = standard deviation, Ski= skewness and K_G= kurtosis)

Y1 values did not show much discrimination among the samples as it interprets all the samples as beach deposits, while Y2 values show that 14 samples (93%)fall in the shallow marine deposits category while 1 sample (7%) fall in the beach deposit category. In addition, 12 samples (80%) of the samples indicate a fluvial-deltaic depositional environment according to Y3 discrimination and 3 samples (20%) are of shallow marine depositional environment. According to Y4, 12 samples (80%) fall in the turbidity current deposits while 3 samples (20%) fall in the fluvial depositional environment.

Scatter plot of Y1 and Y2 shows that majority of the samples (about 94%) fall in Beach/shallow agitated environment (Fig. 4a). The scatter plot of Y2 and Y3, indicate that about 27% of the samples are deposited in Shallow marine agitated, while the other 73% are fluvial agitated (Fig. 4b).

Table 2: Grain size parameters for sediments samples

Sample No	Location	Mean (Mz)	SD (δi)	Skewness (Ski)	Kurtosis (K_G)	Y1	Y2	Y3	Y4	Y1	Y2	Y3	Y4
1	Orlu (Mgbee)	0.87	1.2614	-0.0294	1.0125	5.998341	136.3734	-13.4981	5.147412	Beach	Shallow marine	Fluvial (deltaic)	Turbidity
2	AfforUkwuIsiekenesi	0.97	1.2515	0.0998	1.1091	5.581841	140.431	-13.8792	6.610662	Beach	Shallow marine	Fluvial (deltaic)	Turbidity
3	Affor-NtaIsiekenesi	2	2.6735	0.0958	0.9751	22.157	520.7475	-62.4672	4.368373	Beach	Shallow marine	Fluvial (deltaic)	Turbidity
4	Okwudor	1	1.4229	0.1754	3.5519	14.62023	217.5924	-18.1386	19.88554	Beach	Shallow marine	Fluvial (deltaic)	Fluvial
5	UmusekeOkwudor	1.1	1.272	0.087	1.2568	5.795832	148.3665	-14.2256	7.379169	Beach	Shallow marine	Fluvial (deltaic)	Turbidity
6	Amucha	0.97	1.4076	0.7901	1.2054	5.984675	181.9872	-20.8887	11.60031	Beach	Shallow marine	Fluvial (deltaic)	Fluvial
7	ObiatoUmuakah	1.1	1.4129	-0.0169	1.1217	6.991281	168.8432	-17.0378	5.812194	Beach	Shallow marine	Fluvial (deltaic)	Turbidity

8	ObaraEkwe	1.03	1.3273	0.1667	1.3115	6.582524	159.1712	-15.8921	8.096803	Beach	Shallow marine	Fluvial (deltaic)	Turbidity
9	ObamaraEkwe	1.77	0.639	0.4828	0.9904	-2.72431	81.60569	-5.38695	9.604698	Beach	Shallow marine	Shallow marine	Turbidity
10	Amandugba	1.47	0.5242	-0.2321	1.0432	-0.49901	56.16744	-0.80199	4.908667	Beach	Beach	Shallow marine	Turbidity
11	Isunjaba	0.8	0.7179	0.3324	1.332	2.509612	77.05443	-5.84908	9.657161	Beach	Shallow marine	Shallow marine	Turbidity
12	AbahIsunjaba	0.93	0.8848	0.3125	1.3115	3.013309	95.92627	-8.05894	9.400687	Beach	Shallow marine	Fluvial (deltaic)	Turbidity
13	AmaujuAmaigbo	0.87	0.85	0.7591	0.651	0.020091	86.88468	-9.76431	8.892498	Beach	Shallow marine	Fluvial (deltaic)	Turbidity
14	Umuokwaraoha Amaigbo	1.87	1.0455	0.2667	1.5574	1.667589	134.7443	-10.2724	10.94703	Beach	Shallow marine	Fluvial (deltaic)	Fluvial
15	Ihioma	1	0.8947	0.2657	1.155	2.438627	94.43627	-7.97185	8.300717	Beach	Shallow marine	Fluvial (deltaic)	Turbidity

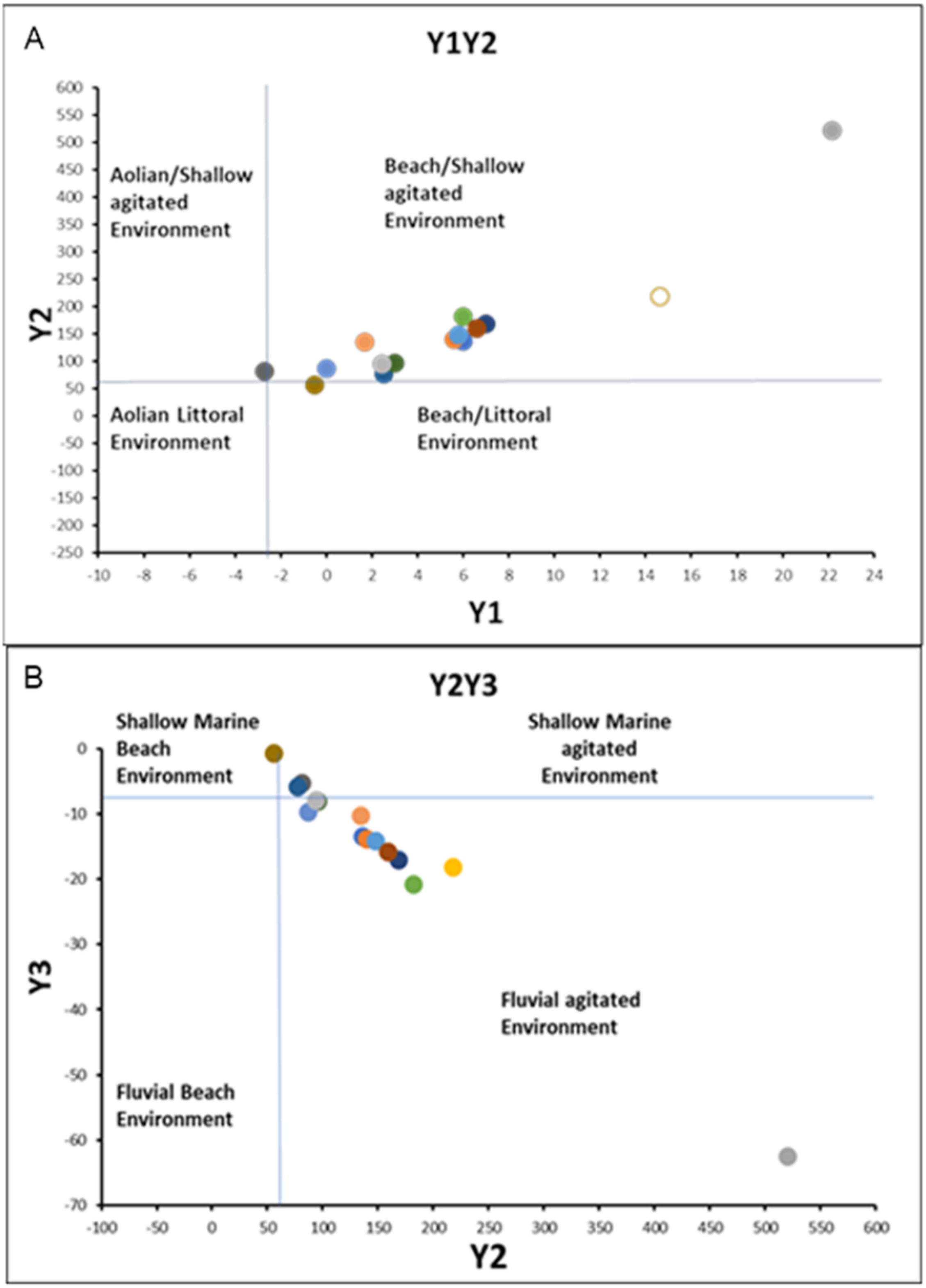

Fig. 4: Linear Discriminate Function (LDF) sector plots for Y1 vs Y2 (a), and Y2 vs Y3 (b) for the sediments at Orlu and its environs.

4.0 Conclusion

The grain size distribution curves (Fig. 2) indicate that about 80% (by weight) of the sediments are medium to coarse-grained sand and fine gravels, while the remaining 18% and 2% are fine-grained sand and coarse silt. The sorting indicates that the samples range from very poorly sorted at Afor-nta, Isiekenesi to moderately sorted at Ihioma, and other areas. Majority of the sediments in the study area are medium to coarse grained pointing to the short distance of travel for the sediments as they would have been well sorted if they had been transportedfrom a longer distance. Other textural analysis also shows that the samples ranges from strongly fine skewed, very platykurtic to extreme leptokurtic and are uniformly graded, except at Afor-nta and Isiekenesi with well-graded sediments. The environment of deposition of the study area using LDF is seen to be beach/shallow agitated and fluvial agitated environments. Based on the grain size analysis results, removal and transportation of the sediments grains by runoff water are easier and this increases the erodibility potential of the sediments units. This accounts for the numerous gullies dotting the landscape in the study area.

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