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Original Article

Grain Size Analysis of Beach Sand around Eastern Dahomey Basin, Southwestern Nigeria: Implications for Coastal Flooding and Erosion

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Abstract - *Erosion vulnerability in Coastal areas around the eastern Dahomey Basin, southwestern section of Nigeria, has constituted momentous threats to the resident communities in this area, thereby resulting in colossal destruction to their infrastructure hence to address the courses and proper remedies to it. The study aimed to examine the grain size constraints of beach sand within the eastern Dahomey Basin. A total of 50 beach sand sediments were obtained from several locations and probed using laser diffraction techniques. Results show a dominant medium-grained sand of 96.0 per cent and 4.5 per cent coarse grained sand, while the fine-grained sand is 0.5 per cent, respectively. Statistical analysis results for grain size distribution revealed the average mean size to be medium-grained (1.63, Mz), sorting to be moderately well sorted (0.717, M. w. st), kurtoses to be symmetrical (0.06864, Syt) and skewness to be mesokurtic (1.44288 Msk) respectively. These also indicate polymodal distributions, otherwise mixed sediment sources. Further probe into this reveals major correlations between grain size parameters and coastal erosion susceptibility. Findings suggest that areas with loose, medium grain sizes and moderately well sorted are more susceptible to coastal flooding than erosion episodes.*

Keywords - *Erosion vulnerability, Flooding, Grain size, Laser diffraction, Mesokurtic.*

1. Introduction

Coastal erosion and flooding are major concerns in southwestern Nigeria, particularly in the eastern Dahomey Basin. Sandy beaches and mudflats characterize the region's coastal morphology. Beach sediments play a crucial role in determining coastal erosion susceptibility. The deterioration and erosion of pre-existing rocks produce them. These sediment compositions are variably dependent on the Indigenous source rocks, their environments of deposition, and the conditions through which they are transported from the source (Ikhane et al., 2013). Various authors (Sahu, 1964; Friedman, 1967; Septriono and Purna, 2017) have characterized beach sediments based on numerous parameters. These include grain size distribution (Tanner, 1991) and geochemistry (Adediran & Adegoke, 1987; Madubuke et al., 2015). These are done to determine the provenance, reconstruct the paleo-climatic nature of the deposits, and proffer solutions to the effect of climate changes experienced globally. Despite these, no effort has been made to examine the incessant and annual flooding and erosion affecting this coastline. Various methods have been used to interpret grain size data; among them is the use of statistical parameters such as the mean value, sorting, skewness, and kurtosis of the sediments (Folk, 1980; Ikhane et al., 2013). Others include graphic plotting of grain size distribution data on bivariate scattergrams to identify the particular depositional environment of the deposits (Mason and Folk, 1958; Moiola and Weiser, 1968; Passega, 1977; Friedman, 1979; Tanner, 1991; Ikhane et al., 2019)

2. Geology of Study Area

In the Gulf of Guinea lies a sizable sedimentary basin known as the Dahomey Basin. From southeast Ghana, it stretches through Togo and the Benin Republic west of the Niger Delta, west of the Okitipupa Ridge, and west of the Benin hinge line. The basin was formed during the breakup of the Gondwana land due to f continental drift (Brownfield & Carpenter, 2006; Fakolade. & Obasi, 2012). This caused the South Atlantic Ocean to open later in the Mesozoic Era (Mpanda, 1979; Storey, 1995). Various other assumptions were also supported based on numerous significant structures characterizing the eastern Dahomey basin. In the lower Jurassic-Early Cretaceous, during the rifting period, the African and South American plates first separated due to basement fracturing. Several marginal basins formed at this time as a result of the core Paleozoic basement rock's block faulting, fragmentation, and subsidence (Omotsola and

Adegoke, 1981; Olabisi *et al.,* 2010; Ola and Olabode, 2016). For the Gulf of Guinea, Adediran and Adegoke (1987) put forth a four-evolution model. (Dahomey Basin inclusive); in this manner: In the intracratonic basin, Stage 1 is characterized by the deposition of thick clastic sediment, primarily immature sandstones and freshwater shales; Stage 2 is characterized by reworked sands and silts intercalated with shale of fluvial-lacustrine origin deposited within the grabens during a period of tectonic activity, erosion, and sedimentation; and Stage 3 is characterized by the Paralic sequence (in the northern basins)

2.1. Study Area

The area understudy is situated within a coastal environment of the eastern Dahomey Basin, situated around the Ilaje community and its environs, in Ondo state coastlines. It falls within longitude 6.166667^{O}N and 6.4166667^{O}N and latitude 4.166667^{O}E and4.833333^{O}E respectively (Figures 1). Over seventy percent of this area of study can be accessed through

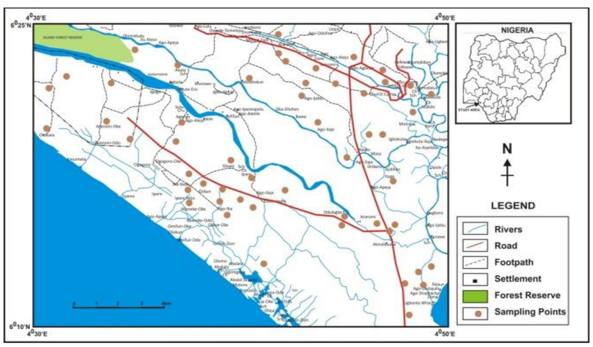

Fig. 1 Geological map of nigeria showing the Basement complexes and sedimentary basins (Fakolade et al., 2021, 2009)

Footpaths besides major roads. Many rivers within the study area are emptied into the Atlantic Ocean, including the Igbokoda, Oluwa, Ofara, Alape, and Talita rivers. Other streams that formed tributaries to the rivers are Ipare and Seja streams. Within this study area are the Omu and Mahin Creeks. The rivers and estuaries were detected as highly turbid; this was due to silt and clay sediments, which dominated the bottommost sediments. Walker and Cant (1984) said gravel, sand, and braided rivers in different ratios become extremely asymmetrically embedded in sheets, lenses, and channels as the separate stream branches Along the beaches, coasts, and riverbanks, and erosion gullies are also common. Typically created by dried saturated mud, mud cracks are a common sedimentary formation in the region during the dry season. The area understudy constitutes a sedimentary environment of quaternary deposits underlain by a deformed Post Cretaceous coastal siliciclastic sequence composed mainly of pure quartz-rich sand and silty sand/sandy silt deposits with little to slight presence of plant remains devoid of fauna. This location falls within the evergreen tree vegetation of the tropical rainforest zone of Nigeria. The region has identified four distinct seasonal phases, including the lengthy, intense wet season that lasts from March to July. From the Sahara, "August Break" refers to the brief lull in rainfall or the short dry season that occurs around August.

3. Materials and Methods

3.1. Sample collection

Fifty (50) representative sediment packs were collected and subjected to grain-size characterization. 50.0 grams of each sample was air-dried and disaggregated, and dead plants and visible organic matter were removed. The samples were then pretreated with 10 ml 10% H_2O_2 for 40 minutes to remove organic matter under a fume hood, after which it was allowed to cool down for ten minutes. Then, 10 ml 10% HCl was added for another 40 minutes to eliminate available carbonates in the samples. Then 2000 ml of distilled water was added,

Table 1. Central dispersion statistical description ((Blott and Pye, 2001)

Mean values	Descriptive term	Sorting values (Sd)	Descriptive term	Skewness (Sk)	Descriptive term	Kurtosis (Kr)	Descriptive term
-1.0 - 0.00	Very Coarse Sand	<0.25	Very Well Sorted	- 0.00 to - 0.30	Very Coarse Skewed	< 0.67	Very Platykurtic
0.00 – 1.00	Coarse Sand	0.25-0.50	Well Sorted	-0.30 to - 0.10	Coarse Skewed	0.67-0.90	Platykurtic
1.00 – 2.00	Medium Sand	0.50-0.70	Moderately Well Sorted	-0.10 to +0.10	Symmetrically Skewed	0.90-1.11	Mesokurtic
2.00 – 3.00	Fine Sand	0.70-1.0	Moderately Sorted	+0.10 to +0.30	Fine Skewed	1.11-1.50	Leptokurtic
3.00 – 4.00	Very Fine Sand	1.0-2.0	Poorly Sorted	+0.30 to +1.0	Coarse Silt	1.50-3.00	Very Leptokurtic
4.00 – 5.00	Coarse Silt	2.0-4.0	Very Poorly Sorted			>3.00	Extremely Leptokurtic
		Over 4.0	Extremely Poorly sorted				

Table 2. The result of grain size analysis of the siliciclastic sediment under study using gradistat (Blott and Pye, 2001)

Sample Loc	Folk and Ward Method					(Description)		
	Mean	Sorting	Skew	Kur	Mz	Std	Sk	K
RT1	1.115	0.635	-0.048	1.055	M. S	M. W St	Syt	M.S.K
RT-2	0.839	0.799	-0.295	1.227	C. S	M. St	C. Sk	L.P.K
RT-3	1.711	0.703	0.184	1.666	M. S	M. St	F. Sk	V.L. P. K
RT-4	1.113	0.941	0.034	1.774	M. S	M. St	Syt	V.L. P. K
RT-5	1.670	0.574	-0.018	1.116	M. S	M. W St	Syt	L.P.K
RT-6	1.651	0.763	-0.052	1.164	M. S	M. St	Syt	L.P.K
RT-7	1.013	0.476	0.039	0.954	M. S	W. St	Syt	M.S.K
RT-8	1.023	0.786	-0.154	1.342	M. S	M. St	C. Sk	L.P.K
RT-9	1.042	1.021	0.123	1.988	M. S	P. St	F. Sk	V.L. P. K
RT-10	1.703	0.874	0.267	2.085	M. S	M. St	F. Sk	V.L. P. K
RT-11	1.564	0.723	-0.023	1.076	M. S	M. St	Syt	M.S.K
RT-12	1.386	0.861	-0.131	1.260	M. S	M. St	C. Sk	L.P.K
RT-13	1.559	0.638	-0.001	1.060	M. S	M. W St	Syt	M.S.K
RT-14	1.554	0.647	0.014	1.035	M. S	M. W St	Syt	M.S.K
RT-15	1.516	0.626	0.037	1.047	M. S	M. W St	Syt	M.S.K
RT-16	1.289	0.722	-0.029	1.228	M. S	M. St	Syt	L.P.K
RT-17	1.458	0.686	0.111	1.288	M. S	M. W St	F. Sk	L.P.K
RT-18	1.376	0.590	0.044	1.026	M. S	M. W St	Syt	M.S.K
RT-19	1.965	1.088	0.368	2.212	M. S	P. St	V F. Sk	V.L. P. K
RT-20	2.022	0.557	0.029	1.086	F. S	M. W St	Syt	M.S.K
RT-21	1.323	0.722	0.162	1.295	M. S	M. St	F. Sk	L.P.K
RT-22	1.573	0.798	-0.073	1.119	M. S	M. St	Syt	L.P.K
RT-23	1.680	0.671	0.121	1.576	M. S	M. W St	F. Sk	V.L. P. K
RT-24	2.035	0.599	0.035	1.184	F. S	M. W St	Syt	V.L. P. K
RT-25	1.935	0.578	-0.056	1.143	M. S	M. W St	Syt	L.P.K
RT-26	1.856	0.798	0.265	1.917	M. S	M. St	F. Sk	V L.P.K
RT-27	1.005	0.770	-0.138	1.386	M. S	M. St	C. Sk	L.P.K
RT-28	1.677	0.696	0.114	1.464	M. S	M. W St	F. Sk	L.P.K
RT-29	1.094	0.611	-0.085	1.072	M. S	M. W St	Syt	M.S.K
RT-30	1.374	0.572	-0.062	1.061	M. S	M. W St	Syt	M.S.K
RT-31	1.369	0.724	-0.310	1.410	M. S	M. St	V. C. Sk	L.P.K
RT-32	1.671	0.607	-0.019	1.197	M. S	M. W St	Syt	L.P.K
RT-33	2.375	0.547	0.148	1.235	F. S	M. W St	F. Sk	L.P.K
RT-34	2.293	0.765	0.340	2.003	F. S	M. St	V. F. Sk	V L.P.K
RT-35	1.330	0.750	-0.127	1.296	M. S	M. St	C. Sk	L.P.K.
RT-36	1.370	0.702	0.180	1.341	M. S	M. St	F. Sk	L.P.K
RT-37	1.430	0.714	0.149	1.383	M. S	M. St	F. Sk	L.P.K
RT-38	2.107	0.504	0.172	1.172	F. S	M. W St	F. Sk	L.P.K
RT-39	2.131	0.549	0.218	1.354	F. S	M. W St	F. Sk	L.P.K
RT-40	1.671	0.710	-0.032	1.485	M. S	M. St	Syt	L.P.K
RT-41	1.616	0.640	-0.064	1.191	M. S	M. W St	Syt	L.P.K
RT-42	1.491	0.607	-0.026	1.060	M. S	M. W St	Syt	M.S.K
RT-43	1.075	0.659	-0.152	1.201	M. S	M. W St	C. Sk	L.P.K
RT-44	2.291	0.938	0.389	2.559	F. S	M. St	V. F. Sk	V L.P.K
RT-45	2.312	1.022	0.423	2.852	F. S	P. St	V. F. Sk	V. L.P.K
RT-46	2.355	0.528	0.134	1.182	F. S	M. W St	F. Sk	L.P.K
RT-47	2.354	0.578	0.207	1.370	F. S	M. W St	F. Sk	L.P.K
RT-48	2.015	1.009	0.338	2.339	F. S	P. St	V. F. Sk	V.L.P.K
RT-49	2.200	0.927	0.365	2.511	F. S	M. St	V. F. Sk	V.L.P.K
RT-50	1.974	0.850	0.317	2.097	M. S	M. St	V. F. Sk	V.L.P.K

Afterwards, the samples were carefully kept for 48 hours to get rid of acid ions. Each sample was later disaggregated, and 10 ml of 0.05 M $(NaPO_3)_6$ was further positioned on an ultrasonic vibrator for 10 min before measuring the grain size (Konert and Vandenberghe, 1997).

The samples were examined using a laser diffraction Master-sizer 2000 equipment with a measurement ranging from 0.02 to 2000 μm with a precision of ±1%. The experiments were run at the Keys Laboratory of Tourism and Environment Taishan University, Tian City, China. The absorption and refractive indexes applied during the measurements are 0.1 and 1.52, respectively. The results obtained were subjected to statistical parameters adopting the Gradistat program (Blott and Pye, 2001). The graphic means, standard deviation (sorting), skewness, and kurtosis were calculated using the following four equations.

Graphic Mean (Mz):

$$\frac{Mz{=}(\emptyset 16+\emptyset 50+\emptyset 5}{3} \quad (1)$$

Sorting or Inclusive Graphic Standard Deviation

$$\text{(SD):} \quad SD = \frac{(\emptyset 84-\emptyset 16)}{4} + \frac{(95-\emptyset 5)}{6.6} \quad (2)$$

Graphic Skewness (Sk):

$$SK = \frac{\emptyset 16+\emptyset 84-2\emptyset 50}{2(\emptyset 84-\emptyset 16)} + \frac{\emptyset 5+\emptyset 95-2\emptyset 50}{2(\emptyset 95-\emptyset 5)} \quad (3)$$

Graphic Kurtosis

$$\text{Kr} = \frac{\emptyset 95-\emptyset 5}{2.44(\emptyset 75-\emptyset 25)} \quad (4)$$

The results were plotted per sample to detect the attitude of samples in relation to their environmental depositional. Then, bimodal graphs of the means versus sortings, skewness against kurtosis (Friedman, 1967) and (Sahu, 1964) were conducted respectively. The data acquired from the analysis were subjected to the graphical presentation, which included Histograms and Cumulative frequency curves.

4. Results and discussion

4.1. Results

4.1.1. Graphic Mean

In these studies, the mean size varies between 0.839 and 2.393, and the mean value is (1.605), indicating medium-grained sediments dominate samples. This deduces a sub-matured to mature sediments (Septriono and Purna, 2017). Grain size distribution is governed by factors which include source rock characteristics, weathering processes, abrasion, and selective sorting in transportation.

The large quantity of medium-grained sand in this study area might have resulted from the regressive nature of the beach during the Holocene sea-level fluctuation (Woodroffe and Horton, 2005).

4.1.2. Graphic Standard Deviation

Standard deviation (sorting) results obtained from the grain size analysis vary between 0.476 and 1.660 (Table 2), indicating moderately sorted to moderately well sorted, through an average value of 0.738, respectively, indicating the sediments are dominated by moderately sorted (Blott and Pye, 2001) sediments. It was observed that the siliciclastic sediments experienced smooth and stable currents with a little turbulent nature that contributed to erosion occurrence in the study area in consonance with Amaral and Pryor's (1977) work.

4.1.3. Graphic Skewness

The result from the study area as classified shows that the sediments vary from -0.310 to 0.423, with an average value of 0.086 indicating symmetric (Folk, 1980). This generally varies from slightly very coarse to slightly very fine skewed (Table 2). The skewness parameter deduces the normality and regularity of the sample grain size distribution. Two (2) percent of the sample is very coarse skewed, 10 percent coarse skewed, 48 percent symmetrically skewed, 27 percent fine skewed, and 13 percent very fine skewed respectively. It indicates the unstable energy regime in this environment coupled with different wave directions. This resulted in mixtures of coarse and fine grained sediments. Sediments from rivers are typically right-skewed, whereas beach sediments show a regular distribution, with slightly right and left-skewed sediments (Friedman, 1967). This has variably contributed to incessant flooding in this study area.

4.1.4. Kurtosis

The results of graphic kurtosis from the study area show that it varies from mesokurtic to very leptokurtic (0.954 - 2.852), with a mean of 1.490 indicating leptokurtic. The sample shows that about 19 percent is mesokurtic, 52 percent leptokurtic, and 29 percent is very leptokurtic, respectively. This revealed multiple fields, an indication of a mixed environment. (marine/beach and fluvial environment). It is observed that near the river channels, the effect of erosion is conspicuous, while flooding is more experienced in the backshore of this study area (Blott and Pye, 2001). The kurtosis values define the state of sediments deposited within medium- to low-energy

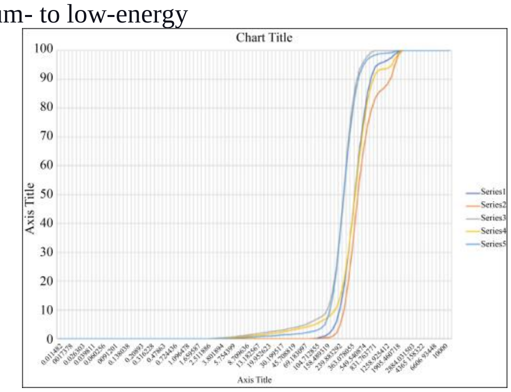

Fig. 3 Frequency distribution plot with particle size in micron-meter and transportation history (Sahu 1964; Septriono and Purna, 2017; Ikhane *et al.*, 2019; Pye & Blott,. (2004).

Depositional environment (Friedman, 1967), which gives room for flooding occurrence.

4.2. Discussion

4.2.1. Grain Size Parameters

Statistical approaches have been employed in this study to assess grain size parameters. Figure 4 shows the frequency distribution plot with particle size in micron-meter. The statistical approach includes the mean, sorting, kurtosis and skewness (Blott & Pye, 2006) to delineate the depositional environment (Figure 3).

Tanner (1991) observed that the bivariate statistical measures of grain size have been used as a veritable tool to identify depositional mechanisms. Among the useful bivariate plots are means versus sorting and sorting versus skewness. These have been applied by various researchers (Sahu, 1964; Friedman, 1967; Moiola and Weiser, 1968; Racinowski *et al.,* 2001; Flemming, 2007; Szmańda, 2007, 2010; Scott *et al.,* 2014)

This research was corroborated by Tanner's work (1991), where he adopted a bivariate graph of mean versus standard deviation in determining the depositional environment (Figure 6). This indicates a correlation between sorting and graphic average values for sediment distribution within this study, thus indicating that all the siliciclastic sediments fall within fluvial and stream zones of the depositional environment. Standard deviation (sorting) values were plotted against the graphic mean value from the study area (Septriono and Pruna, 2017).

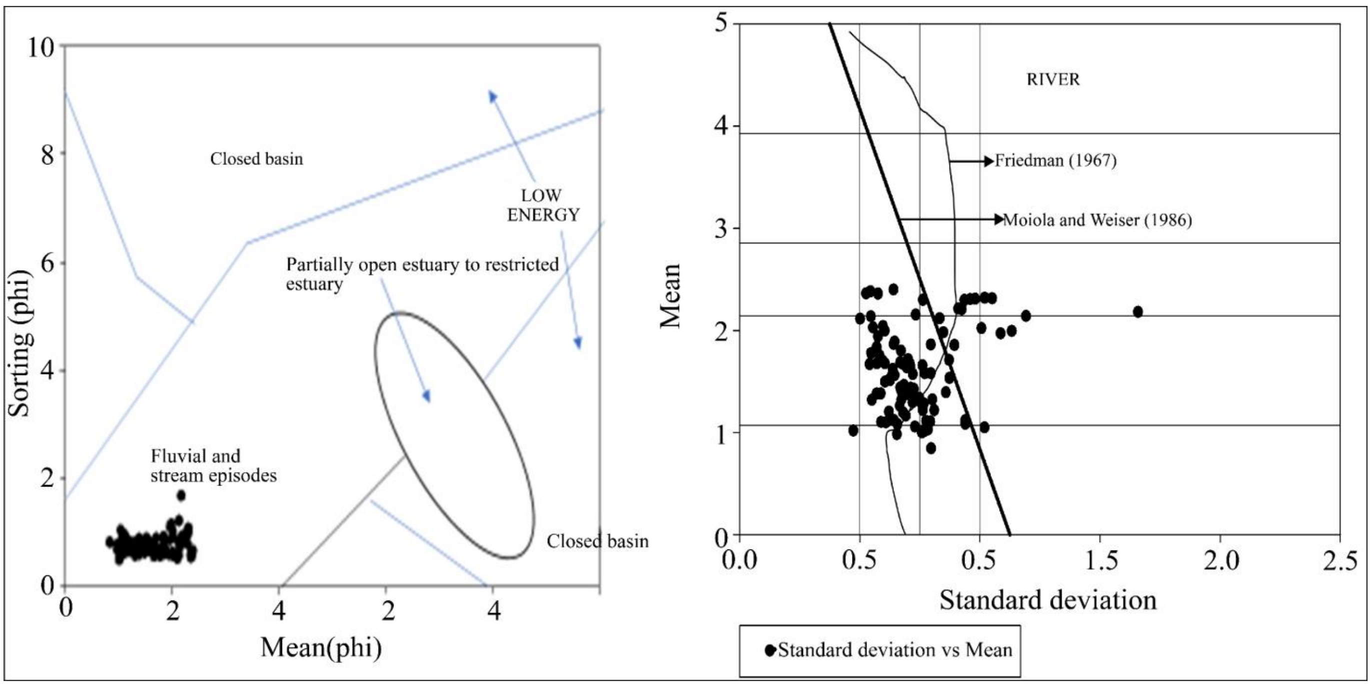

Fig. 4 Bivariate plot of mean size versus sorting to determine depositional environment (Tanner, 1991) b. Bivariate plots of Standard deviation versus Mean to distinguish between beach and river environment (Septriono and Pruna, 2017)

Were distributed within coarse cum fine-grained and slightly poorly sorted zone (Blott and Pye, 2001).

It was observed the majority of the sediments clustered around the medium-grained, moderately sorted to moderately well-sorted sections. This proved that most of the sediments fall around the beach environment, and few fall within the fluvial or river environment. This also indicates that the sediments under study are of bimodal (mixed) environments (Figure 4).

In furtherance to this research (Figure 4a), granulometric parameters plots (Ayodele and Madukwe, 2019) were adopted to differentiate amid river channel deposits, overbank deposits, coupled with overbank-pool deposits (Mycielska-Dowgiallo and Ludwikowska-Kedzia, 2011), over 80 percent of the siliciclastic sediment samples were felled within the river channel area while remaining ones fell within the overbank deposit field, an indication that the samples are bimodal.

4.2.2. Bivariate Plots

This graph indicates a diverse departure between the beach and the foreshore field. Figure 4b explains the behavior of the sediments under study. It was observed that sediments remain dominated within moderately sorted to moderately well sorted with the skewness concentrated around close symmetrical to left-skewed. This explains sorting through winnowing activities and possibly the samples must have undergone a regressive process during the deposition (Mycielska-

Dowgiałło, 2007). Figure 5: Discrimination of the siliciclastic sediment to be a mixed source with the sediments greater percentage belong to the beach environment. Figure 5a-b illustrates the bivariate plot correlation between the standard deviation and skewness (Friedman, 1979; Septriono and Pruna, 2017). Most sediments clustered around the near-symmetrical and fine to very fine Skewed range, whereas the remaining sediment falls on a coarse skewness section. This was adopted to discriminate the samples from beach and river environments. About 55 percent of sediments fall well around the beach regime, while the other 45 percent fall within the fluvial environment, indicating a bimodal (mixed) environment. This is suggested to have occurred during the Holocene sea-level fluctuation. They are situated at higher elevations while the depressions between these beaches are being eroded incessantly. The swamps situated within the low-lying areas filled by muddy, stagnant water and mangrove forests are consequents of flooding around the study area. The presence of various beach ridges has possibly fashioned within these low relief shorelines due to prograding conditions, an indication of sea level fluctuations in this environment. Aside from all the factors that have contributed to coastal flooding and erosion, human activity, mainly weir and reservoir construction on the rivers coupled with farming activities, also indirectly affects coastal erosion and flooding (Plate 1).

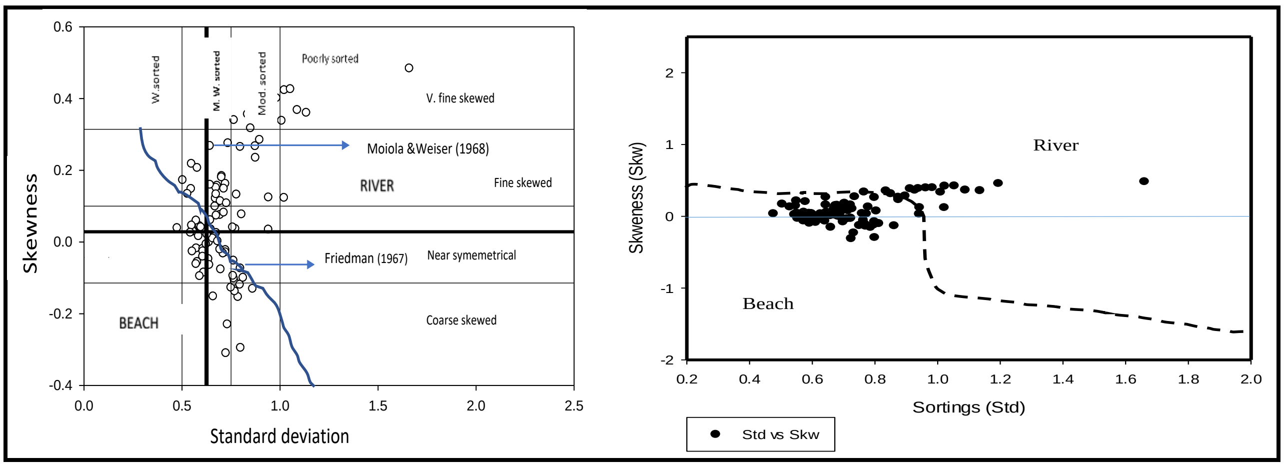

Fig. 5a-b Bivariate plots of sortings versus skewness distinguishing beach with river environment. (a) Septriono and Pruna (2017), (b) Friedman, 1967)

Plate 1: The pictorial view of the study area revealing the flooding and erosion activities in the study area

5. Conclusion and Recommendation

5.1. Conclusion

This research work reveals grain size characteristics around coastal sediments, which have a large spatial spread within the eastern Dahomey Basin. The understanding of these beach sediments to flooding and erosion was observed through central dispersion statistical parameters attitude of the sediments under study. These vary spatially from northeast to southwest of the study area. This indicates they resulted from regressive depositional incidences that manifested within the area under study. The sediments are products of a mixed depositional environment, with beach depositional settings dominated more than the fluvial sediments. The sediments are texturally matured, with quartz minerals constituting 95 percent of the sediment. Grain size analysis of beach sands helps to assess a beach's vulnerability to erosion and flooding. It is understood that the energy dynamics of beach environments and the characteristics of sediments contributed to the flooding and erosion susceptibility in the study area. Another factor is the occurrence of sea-level fluctuation during deposition, which leads to severe coastal slump, thereby increasing coastal flooding and erosion. Most of the study area is dominated by Unconsolidated medium-grained sediments with a reduced percentage of fine-grained sand, indicating low-energy depositional conditions. Therefore, the interrelationship of the grain size distribution parameters displays an all-inclusive framework for assessing beach flooding and erosion susceptibility.

5.2. Recommendations

The grain size distribution has played a key role in the studies of flooding and erosion, which are sequels to paleoenvironment studies and climate changes. It is recommended that a possible medium could be deployed to curb the flooding and erosion within the study area. These sand deposits can be exploited to create an avenue for the proper draining of water during the rainy season to cater to both flooding and erosion.

Author contributions

- Richard Omotoso Fakolade — Intellectualized the idea of the work, contributed to the data gathering and analysis, data curation and writing of the initial draft
- Rotimi Isaac Ayodele — Developed and designed the methods, participated in data collection, and contributed to the research leadership.
- Adewumi O.A — Participated in the validation of the laboratory results, data curation and revised the write up

References

[1] S.A. Adediran, and O.S. Adegoke, "Evolution of the Sedimentary Basins of the Gulf of Guinea," *Colloquium on African Geology*, vol. 14, pp. 283-286, 1987. [Google Scholar]

[2] O.S. Adegoke, B.D. Ako, and E.I. Enu, "*Geotechnical Investigations of the Ondo State Bituminous Sands*," Obafemi Awolowo University, Nigeria, Report of Geological Consultancy Unit, Geology Department, vol. 257, pp. 27-36 1980. [Google Scholar]

[3] O.A. Adekeye et al., "Hydrocarbon Potential Assessment of the Upper Cretaceous-Lower Tertiary sequence in the Dahomey Basin Southwestern Nigeria," *NAPE Bulletin*, vol. 19, no. 1, pp. 50-60, 2006. [Google Scholar]

[4] O.A. Agagu, "*A Geological Scale Guide to Bituminous Sediments in Southwestern Nigeria*," University of Ibadan, Technical Report, pp. 1-16, 1985. [Google Scholar]

[5] B.D. Ako, O.S. Adegoke, and S.W. Petters, "Stratigraphy of the Oshosun Formation in Southwestern Nigeria," *Journal of Mining Geology*, vol. 17, pp. 9-106, 1980. [Google Scholar]

[6] Terence Allen, *Particle Size Measurement*, Springer Netherlands, pp. 1-806, 1990. [CrossRef] [Google Scholar] [Publisher Link]

[7] E.J. Amaral, and W.A. Pryor, "Depositional Environment of the St. Peter Sandstone Deducted by Textural Analysis," *Journal of Sedimentary Research*, vol. 47, no. 1, pp. 32-52, 1977. [CrossRef] [Google Scholar] [Publisher Link]

[8] Olusiji S. Ayodele, and Henry Y. Madukwe, "Granulometric and Sedimentologic Study of Beach Sediments, Lagos, Southwestern Nigeria," *International Journal of Geosciences*, vol. 10, no. 3, pp. 295- 316, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[9] H.G. Billman, "Offshore Stratigraphy and Paleontology of Dahomey Embayment, West Africa," *Mediterranean Geology*, vol. 11, no. 1, 1984. [Google Scholar] [Publisher Link]

[10] Simon J. Blott, and Kenneth Pye, "Gradistat: A Grain Size Distribution and Statistics Package for the Analysis of Unconsolidated Sediments," *Earth Surface Processes and Landforms*, vol. 26, no. 11, pp. 1237-1248, 2001. [CrossRef] [Google Scholar] [Publisher Link]

[11] Simon J. Blott, and Kenneth Pye, "Particle Size Distribution Analysis of Sand-Sized Particles by Laser Diffraction an Experimental Investigation of Instrument Sensitivity and the Effects of Particle Shape," *Sedimentology*, vol. 53, no. 3, pp. 671-685, 2006. [CrossRef] [Google Scholar] [Publisher Link]

[12] Michael E. Brownfield, and Ronald R. Charpentier, "*Geology and Total Petroleum Systems of the Gulf of Guinea Province of West Africa*," U.S. Geological Survey Bulletin 2207-C, pp. 1-39, 2006. [Google Scholar] [Publisher Link]

[13] Richard Omotoso Fakolade, and Romanus Obasi, "The Geochemical Assessment of Subsurface Coastal Plain Clastic Deposits of Eastern Dahomey Basin around Lagos Area, South West Nigeria," *International Journal of Science and Technology*, vol. 1, no. 6, pp. 300-307, 2012. [Google Scholar]

[14] Burghard W. Flemming, "The Influence of Grain-Size Analysis Methods and Sediment Mixing on Curve Shapes and Textural Parameters: Implications for Sediment Trend Analysis," *Sedimentary Geology*, vol. 202, no. 3, pp. 425-435, 2007. [CrossRef] [Google Scholar] [Publisher Link]

[15] Robert L. Folk, *Petrology of Sedimentary Rocks*, Hemphill Publishing Company, pp. 1-182, 1980. [Google Scholar] [Publisher Link]

[16] Gerald M. Friedman, "Dynamic Processes and Statistical Parameters Compared for Size Frequency Distribution of Beach River Sands," *Journal of Sedimentary Research*, vol. 37, no. 2, 1967. [CrossRef] [Google Scholar] [Publisher Link]

[17] Gerald M. Friedman, "Differences in Size Distribution of Population of Particles among Sands of Various Origin," *Sedimentology*, vol. 26, no. 6, pp. 859-862, 1979. [CrossRef] [Google Scholar] [Publisher Link]

[18] Ikhane P.R. et al., "An Evaluation of a Section of the Campano-Maastrichtian Nkporo shale, Anambra Basin, South-Eastern Nigeria: Implications for Provenance and Palaeo Environment of Deposition," *Journal of Applied Geochemistry*, vol. 21, no. 2, pp. 258-268, 2019. [Google Scholar] [Publisher Link]

[19] Ikhane P.R. et al., "Granulometric Analysis and Heavy Mineral Studies of the Sandstone Facies Exposed near Igbile, Southwestern Nigeria," *International Research Journal of Geology and Mining*, vol. 3, no. 4, pp. 158-178, 2013. [Google Scholar] [Publisher Link]

[20] Martin Konert, and Jef Vandenberghe, "Comparison of Laser Grain Size Analysis with Pipette and Sieve Analysis: A Solution for the Underestimation of the Clay Fraction," *Sedimentology*, vol. 44, no. 3, pp. 523-535, 1997. [CrossRef] [Google Scholar] [Publisher Link]

[21] H.Y. Madukwe et al., "Provenance, Tectonic Settings and Source Area Weathering of the Coastal Plain Sediments South West Nigeria," *Scientific Research Journal (SCIRJ)*, vol. 1, no. 5, pp. 20-31, 2013. [Google Scholar] [Publisher Link]

[22] R.J. Moiola, and D. Weiser, "Textural Parameters: An Evaluation," *Journal of Sedimentary Research*, vol. 38, no. 1, pp. 45-53, 1968. [CrossRef] [Google Scholar] [Publisher Link]

[23] Samson Mpanda, *Geological Development of the East African Coastal Basin of Tanzania*, Stockholm University, Department of Geology & Geochemistry, vol. 45, no. 1, pp. 1-121, 1997. [Google Scholar] [Publisher Link]

[24] Elzbieta Mycielska-Dowgiallo, and Malgorzata Ludwikowska-Kedzia, "Alternative Interpretations of Grain-Size Data from Quaternary Deposits," *Geologos*, vol. 17, no. 4, pp. 189-203, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[25] Nuhu George Obaje, *Geology and Mineral Resources of Nigeria*, 1st ed., Springer Berlin, Heidelberg, 2009. [CrossRef] [Google Scholar] [Publisher Link]

[26] Peter S. Ola, and Solomon O. Olabode, "Implications of Horsts and Grabens on the Development of Canyons and Seismicity on the West Africa Coast," *Journal of African Earth Sciences*, vol. 140, pp. 282-290, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[27] Olabisi A. Adekeye, and Samuel O. Akande, "The Principal Source Rock for Petroleum Generation in the Dahomey Basin, Southwestern Nigeria," *Continental Journal of Earth Sciences*, vol. 5, no. 1, pp. 42-55, 2010. [Google Scholar]

[28] S.O. Olabode, "Subsidence Patterns in the Nigerian Sector of Benin (Dahomey) Basin: Evidence from Three Offshore Wells," *IFE Journal of Science*, vol. 17, no. 2, pp. 455-475, 2015. [Google Scholar] [Publisher Link]

[29] M.E. Omatsola, "Tectonic Evolution and Cretaceous Stratigraphy of the Dahomey Basin Nigeria," *Journal Mining and Geology*, vol. 18, pp. 130-137, 1981. [Google Scholar]

[30] F.J. Pettijohn, Paul E. Potter, and Raymond Siever, *Sand and Sandstone*, Springer New York, pp. 1-553, 2012. [Google Scholar] [Publisher Link]

[31] Kenneth Pye, and Simon J. Blott, "Particle Size Analysis of Sediments, Soils and Related Particulate Materials for Forensic Purposes Using Laser Granulometry," *Forensic Science International*, vol. 144, no. 1, pp. 19-27, 2004. [CrossRef] [Google Scholar] [Publisher Link]

[32] Roman Racinowski, and Tadeusz Szczypek, *Presentation and Interpretation of the Results of Grain Size Studies of Quaternary Sediments*, Katowice: UŚ Publishing House, 2001. [Publisher Link]

[33] M.A. Rahaman, "Recent Advances in the Study of the Basement Complex of Nigeria," *Pre cambrian Geology of Nigeria*, pp. 11-41, 1988. [Google Scholar]

[34] Basanta K. Sahu, "Depositional Mechanisms from the Size Analysis of Classic Sediments," *Journal of Sedimentary Research*, vol. 34, no. 1, pp. 73-83, 1964. [CrossRef] [Google Scholar] [Publisher Link]

[35] Septriono Hari Nugroho, and Purna Sulastya Putra, "Spatial Distribution of Grain Size and Depositional Process in Tidal Area along Waikelo Beach, Sumba," *Marine Georesources & Geotechnology*, vol. 36, no. 3, pp. 299-307, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[36] William F. Tanner, *Suite Statistics: The Hydrodynamic Evolution of the Sediment Pool*, Principles, Methods and Application of Particle Size Analysis, Cambridge University Press, pp. 225-236, 2010. [CrossRef] [Google Scholar] [Publisher Link]

[37] Arthur Whiteman, *Nigeria: Its Petroleum Geology, Resources and Potential*, Graham and Trottam, London, 1982. [Google Scholar]

[38] S.A. Woodroffe, and B.P. Horton, "Holocene Sea-Level Changes in the Indo-Pacific," *Journal of Asian Earth Sciences*, vol. 25, no. 1, pp. 29-43, 2005. [CrossRef] [Google Scholar] [Publisher Link]