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DETERMINATION OF THE VARIANCES OR SIMILARITIES IN PETROGRAPHIC AND SEDIMENTOLOGICAL PROPERTIES OF THE SEDIMENT SAMPLES OF TWO RIVERS, BY DETERMINATION OF THE TRANSPORTATION HISTORY AND DEPOSITIONAL ENVIRONMENT OF THE RIVER SANDS

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ABSTRACT

The sediment of the Rivers Ero and Adogo in Geregu, Ajaokuta, was studied to determine any variances or similarities in petrographic and sedimentological properties. The sediment samples had particle size parameters estimated, with mean values ranging from 0.45 to 0.94 (River Ero) and 0.15 to 0.67 (River Adogo), indicating that the sediment samples are all coarse grained. The sediment samples' standard deviations vary from 0.9 to 1.2 (River Ero) and 0.92 to 1.57 (River Adogo), indicating moderate to poor sorting. The sediment samples' estimated skewness ranges from -0.09 to -0.12 (River Ero) and -0.01 to -0.16 (River Adogo), showing coarse to strongly coarse skewed sediments that were deposited in a high energy environment. The sediment samples have computed kurtosis ranging from 0.63 to 1.01 (River Ero) and 0.65 to 1.06 (River Adogo), indicating platykurtic to Mesokurtic. The sediment samples from the Rivers Ero and Adogo all fall within the river sand field of Sahu 1964, according to bivariate statistics of skewness vs standard deviation. The depositional environment of the sediment samples was characterised using a linear discriminant function, which revealed that the sediment of River Ero is predominantly beach, shallow agitated marine, and shallow marine, whereas the sediment of River Adogo is entirely beach, shallow agitated marine, and shallow marine. The sediment samples are composed of >94 percent quartz and are most likely sourced from the cratonic interior, according to petrographic data.

Keywords: Sedimentological, Petrographic, Environment of Deposition, Statistics, Linear Discriminant function

INTRODUCTION

Grain size distribution studies of river sediments, when combined with other textural features; provide a wealth of information about the unique characteristics of sediments and their depositional history (Blott and Pye, 2001; and Martins, 2003). Folk & Ward presented a graphical method for performing granulometric analysis more than half a century ago (1957). This enabled Sedimentologists to determine approximate grain-size parameters from graphs using computerized data analytical tools, allowing for far more precise calculations of statistical parameters including average grain size, sorting, skewness, and kurtosis. According to Maju-Oyovwikowhe and Imasuen (2019), the size of the constituent sand grains vary between 2mm to 0.1 mm. Quartz is the chief mineral constituent of sandstones. However, other minerals are often present in small amounts. The cementing material may be siliceous, argillaceous, ferruginous or carbonate in nature (Maju-Oyovwikowhe and Imasuen, 2019). Some earth scientists believe that these factors are critical for classifying sedimentary ecosystems.

Extensive research has demonstrated a link between size factors and sediment transport processes as well as depositional mechanisms (Folk and Ward, 1957; Mason and Folk, 1958; Friedman, 1961, 1967). Grain size, being the most fundamental characteristic of sediment particles that affect their entrainment, transit, and deposition, gives crucial information on the sediment origin, transport history, and depositional settings (e.g. Folk and Ward, 1957; Friedman, 1979; Bui *et al.*, 1990; and Blott and Pye, 2001). Provenance analysis, in its broadest terms, pertains to every research that can help reconstruct the Earth's lithospheric history (Basu, 2003). The term provenance has been used in sedimentary petrology to refer to all aspects of sediment production, including the composition of parent rocks, as well as the physiography and climate of the source area from which sediment is formed.

The aim of sedimentary provenance studies is to reconstruct and interpret the history of sediment from the time parent rocks were first eroded to the time their detritus was buried. The ultimate purpose of provenance studies is to infer the characteristics of source places from measurements of sediment compositional and textural traits, which are reinforced by data from various sources (Pettijohn *et al.*, 1987).

River Ero is the main river in the study area, with River Adogo as its main tributary. River Adogo is an ephemeral river that dries up during the dry season. The Ero River feeds into the River Niger, and the drainage pattern in the area is dendritic, with an average channel width of 87 meters. The flow direction of the river is in the NW-SE direction.

The aim of this study is to establish the variances or similarities in petrographic and sedimentological properties of the sediment samples of the Ero and Adogo rivers. By careful determination of the transportation history and depositional environment of the river sands,

Geology of the Study Area

The study area is located along the River Ero in Geregu, a town in the Ajaokuta district of Nigeria's Kogi State. The River Ero's channel is over 10 kilometers long and drains a substantial portion of the land into the River Niger's considerably deeper channel. The River Ero and its tributaries drain an area that is underlain by Precambrian foundation rocks from Nigeria's south-western Basement Complex. Biotite gneiss, banded gneiss, quartzite, calcareous rocks, quartz-mica schist, mica schist, talc schist, quartzite, older granites, younger granites, and volcanic rocks make up the Nigerian Basement Complex. The local geology of the Ajaokuta area is dominated by rocks such as quartzite, porphyritic granite, migmatite, mica schist, and granite gneiss (Adiotomre, *et al* 2014). The river flows from the southwest to the northeast of Nigeria, and it is classified as a seasonal river that is refilled by rainwater due to the lack of groundwater in the area and rainwater that is not powerful enough to replenish it. As a result, when the tributaries dry up, the River Ero becomes dry. The riverbed is wet and characterized by various sand particles that serve as natural water filters. (Rahaman, 1976)

The geology of Kogi State is comparable to that of the rest of Nigeria, and the rocks found there are similar to those reported elsewhere in the country. The Basement Complex Rocks of the Precambrian age in the western half of the state, extending somewhat eastwards beyond the lower Niger valley, and the sedimentary rocks in the eastern half, happen to be the two principal rock types in Kogi State. The

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numerous sedimentary rock groups extend along the River Niger's bank and across the states of Enugu and Anambra to connect the Udi Plateau. In general, the Precambrian rocks of Nigeria can be divided into three categories: ancient magmatite complexes, low-grade schist, and the Plutonic series, as well as associated minor rocks that bear tectonic imprints from the Liberian (in 2700 Ma), Eburnean (in 2000 Ma), and Pan African (in 650 Ma) periods. The latter is the most widely used. However, older ages of >3.0 Ga have recently been reported in some areas, such as the Kaduna Migmatites, which supports the hypothesis that this migmatite-gneiss complex belonged to an Archean Protoshied that was subjected to the Proterozoic thermotectonic process (Elueze, 1992) and subsequent evolution of the Phanerozoic basin. Overlying the older assemblages are Tertiary sedimentary sequences deposited in five basins, including the Mid-Niger basin, Benue Trough, and Anambra Basin, all of which are Cretaceous in age, and the Sokoto, Chad, and Niger-Delta basins, which are Tertiary and Tertiary to Recent in age.

The study area (Figure 1) is one of the major town in Ajaokuta Local Government in Kogi State (Figure 2) and lies within latitude 07^o 34' 47.4'' N and longitude 08^o 37' 37.9" E respectively. The area is generally accessible and motorable, the availability of both tarred roads and footpaths provide good accessibility to the area and to Riverbed. Ajaokuta local government area was created from Okene Local Government on 27th August, 1991 and has its headquarters at Agodo. The Local Government is in the central senatorial district of the state and covers a landmass of 1362 square kilometers. Ajaokuta Local Government Area is bounded to the North East by Lokoja Local Government, Bassa Local Government to the Northwest, Ofu Local Government to the East, and South West by Okene and Adavi Local Government Areas respectively. Ajaokuta Local Government has its Headquarters in the town of Egayin in the South of the area at 6^o 40' 11" N,8^{o}48' 19" E. The research area is accessible by roads and footpaths. Due to the lack of rain, the majority of the rivers in the study are dried up, giving us plenty of time and opportunity to walk across the riverbed, which would have been impossible if the rivers hadn't dried up.

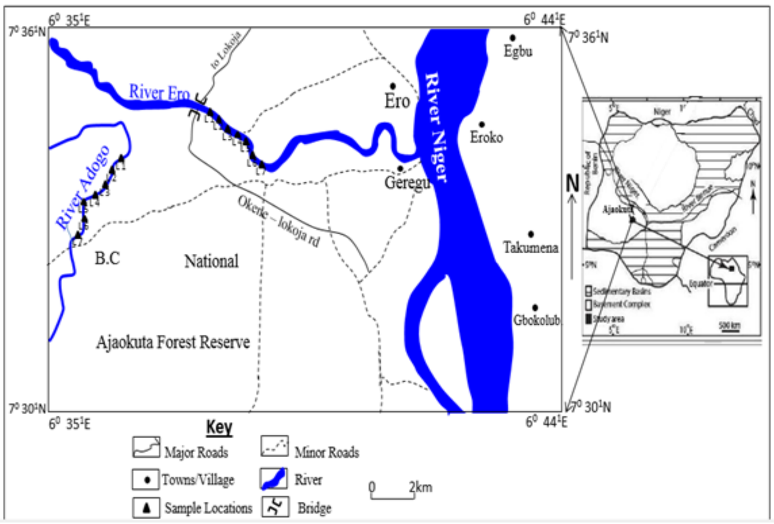

Figure 1: Map of study area showing location and accessibility. Inset: Geologic map of Nigeria after (Kogbe, 1976).

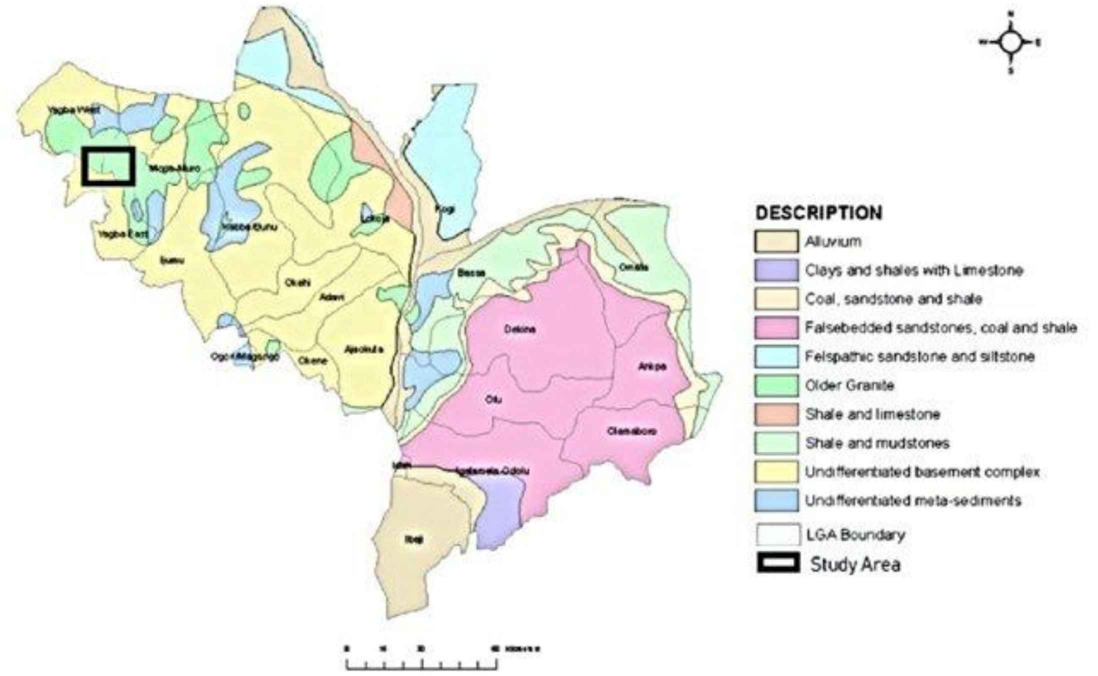

Figure 2: Geological map of the Kogi State, North Central Nigeria; insert study area (NGSA, 2009).

MATERIALS AND METHOD

A reconnaissance survey of the mapped area constituted the initial aspect of the geologic fieldwork exercise, gridding of the base map to get base stations were carefully done. Then, a detailed geological mapping of the study area was carried out.

The two major methods of investigations used in this study are;

1. Sample collection and preparation
2. Laboratory analysis.

Field Study

Samples of the Ero and Adogo rivers bottom sediments were collected along the river channels. Samples were obtained between 30-35cm using a hand trowel and a measuring tape. The collected samples were then labeled properly and stored in a sample bag. A distance of 200m is measured between each sample point before another sample is collected. A total distance of 1.2km (1200m) was covered for River Ero and 0.43km (430m) was covered for River Adogo. After that, the samples were sundried before taking them to the laboratory for analysis.

The equipment and items used during the field exercise include topographic Map or Base Map, Global Positioning System: Compass Clinometer, Hand Towel, Sampling Bags, Paper Tape, Measuring Tape, digital camera, Field Notebook, Pen and Pencils.

Laboratory Techniques

Grain size analysis

Grain size analysis was carried out to determine the relative composition of various grain sizes. The equipment used for this study includes a set of sieves, pan, and sieve shaker with model STSJ-4 and stopwatch following routine laboratory procedures. Samples were sundried and disaggregated manually because they were unconsolidated, and then the set of sieves were cleaned carefully using a soft brittle brush. The sieves were arranged in a descending order of sieve mesh size (i.e.

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coarsening upward). 100g of the disaggregated samples was poured into the most coarse sieve and then covered, thereafter the sieve with the measured portion in the set were shaken using the Ro-tap sieve shaker for 15 minutes and then allowed to settle for 3-5 minutes before the lid was opened to avoid too much loss of very fine particles. After settling, the sample portion of each sieved was weighed and recorded, then the percentage weight retained on each sample was computed and the curve of cumulative against particles size in phi (ϕ) was plotted using Microsoft excel and Gradistat packages (Blott, and Pye, 2001).

The gradistat program provides rapid (approximately 50 samples per hour) calculation of grain size statistics by both Folk and Ward (1957) and moments methods. While programs capable of analyzing grain size data have been published in the past (e.g. Isphording, 1970; Slatt and Press, 1976; McLane, cited in Pye, 1989; Utke, 1997), these are often cumbersome to use or allow little modification for individual requirements.

The program, written in Microsoft Visual Basic, is integrated into a Microsoft Excel spreadsheet, allowing both tabular and graphical output. The user is required to input the percentage of sediment present in a number of size fractions. This can be the weight retained on a series of sieves, or the percentage of sediment detected in size classes derived from a laser granulometer, X-ray sedigraph or Coulter counter. The following sample statistics are then calculated: mean, mode(s), sorting (standard deviation), skewness, kurtosis, and a range of cumulative percentile values (the grain size at which a specified percentage of the grains are coarser), namely D10, D50, D90, D90/D10, D90 –D10, D75/D25 and D75 –D25.

In the program, the method of moments is used to calculate statistics arithmetically (based on a normal distribution with metric size values, seldom used in sedimentology but available with some Coulter sizing instruments), geometrically (based on a log-normal distribution with metric size values) and logarithmically (based on a log-normal distribution with phi size values), following the terminology and formulae suggested by Krumbein and Pettijohn (1938). Specified values are then extracted from the cumulative percentage curve using a linear interpolation between adjacent known points on the curve. These are used to calculate Folk and Ward parameters logarithmically (as originally suggested in Folk and Ward (1957), based on a log-normal distribution with phi size values) and geometrically (based on a log-normal distribution with metric size values).

Petrographic Analysis

Fresh loose samples were air dried for 24 hours, after which they were impregnated with epoxy A&B and allowed to core for at least 24 hours. The cored sample was then trimmed to fit on a glass slide, and the trimmed surface was lapped on a glass plate with water and silicon carbide 600grits to create a very smooth surface for bonding with the glass slide; one surface of the glass slide was also lapped and smoothed for bonding with the sample. The sample is then bonded to the glass slide using epoxy on a hot plate for 24 hours, then trimmed to 50 micron on the glass slide using a cut-off saw machine, then transferred to the lapping plate and lapped to 30 micron using silicon carbide and water. At 30 micron, the slide is ready for study under the petrographic microscope.

Microscopic examination

Photographs (Photomicrograph) of the digital images shot using a microscope to show magnified pictures of thin section slides are usually examined during this stage. It aids in the presentation of a clear picture of the minerals contained in the rock. This photo micrographic stage entailed obtaining plane and crossed polarized images of the samples collected during the field investigation in order to show details that were not visible to the naked eye. It also entails examining these samples under various magnifications to provide a clearer graphical representation.

RESULTS AND DISCUSSION

Granulometric Studies

River Ero's graphic mean size (Mz) varies from 0.45ϕ to 0.94ϕ with an average of 0.91ϕ, and River Adogo's graphic mean size (Mz) varies from 0.15ϕ to 0.67ϕ with an average of 0.36ϕ. River Ero's inclusive standard deviation (1) ranges from 0.9ϕ to 1.2ϕ with an average of 1.02ϕ, while that of River Adogo ranges from 0.97ϕ to 1.37ϕ with an average of 1.15ϕ. The graphic skewness (Sk) of River Ero ranges from -0.09ϕ to -0.12ϕ with an average of -0.11ϕ, whereas River Adogo's skewness (Sk) varies from -0.01ϕ to -0.16ϕ with an average of -0.07ϕ. The graphic Kurtosis for River Ero ranges from 0.63ϕ to 1.01 ϕ with an average of 0.94ϕ, while that of River Adogo ranges from 0.65ϕ to 1.06ϕ, with an average of 0.75ϕ. Using the Gradistat and Excel packages, the data from the grain size study was utilized to calculate the cumulative weight %, which was plotted against mesh sizes as shown in Figures 3 and 4.

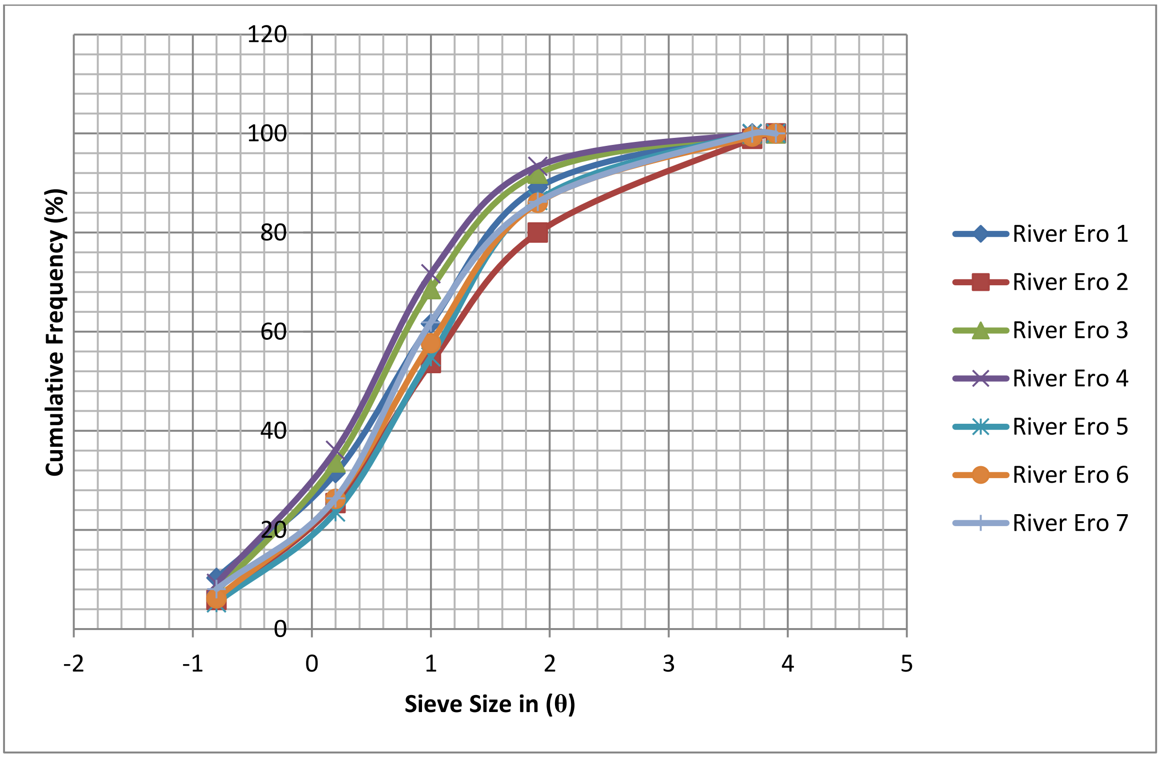

Figure 3: Grain size distribution curves for River Ero sands

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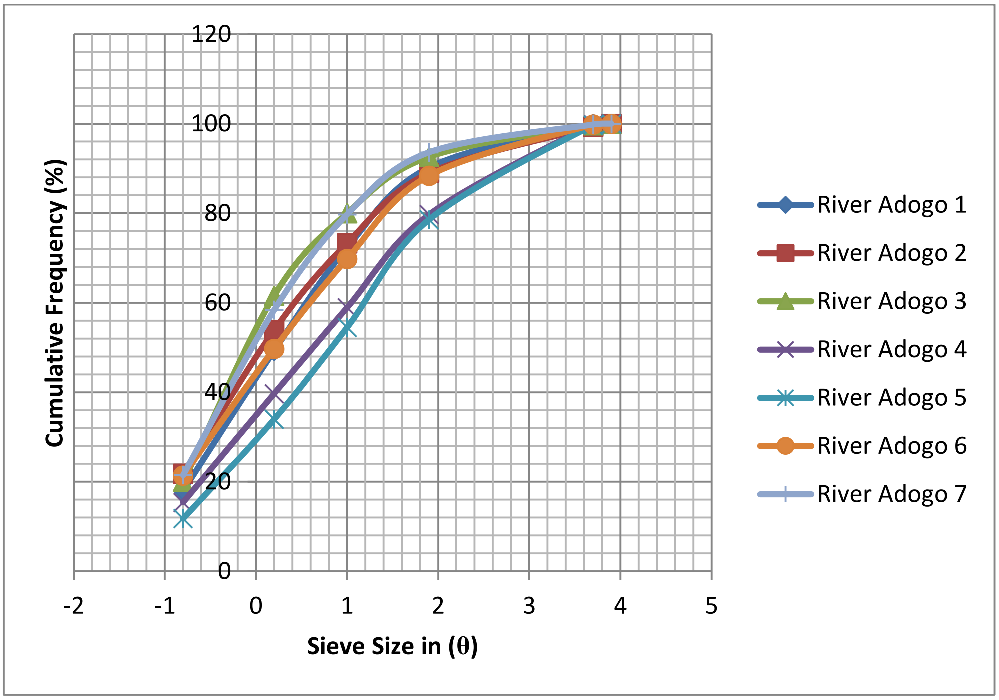

Figure 4: Grain size distribution curves for River Adogo sands

Textural parameters (Mean, Standard Deviation, and Skewness) from Rivers Ero and Adogo were utilized to create bivariate plots of mean against standard deviation and skewness against standard deviation as seen in Figures 5, 6, 7, and 8.

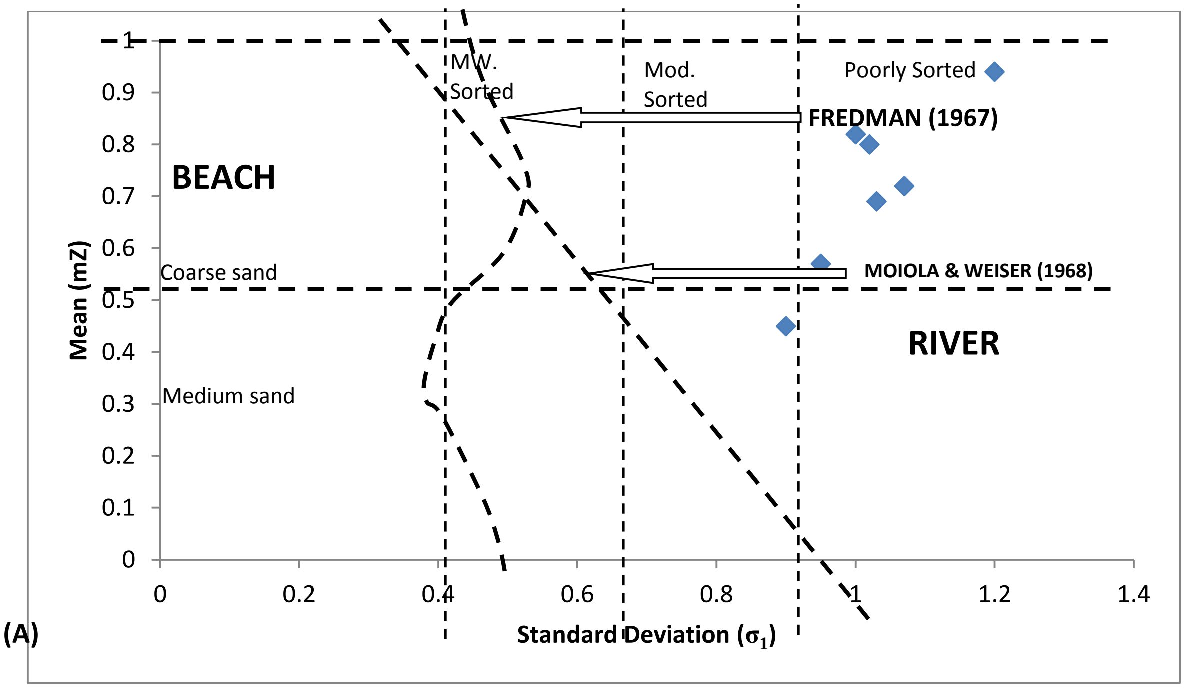

Figure 5: Bivariate plot of mean against standard deviation for Ero River sands

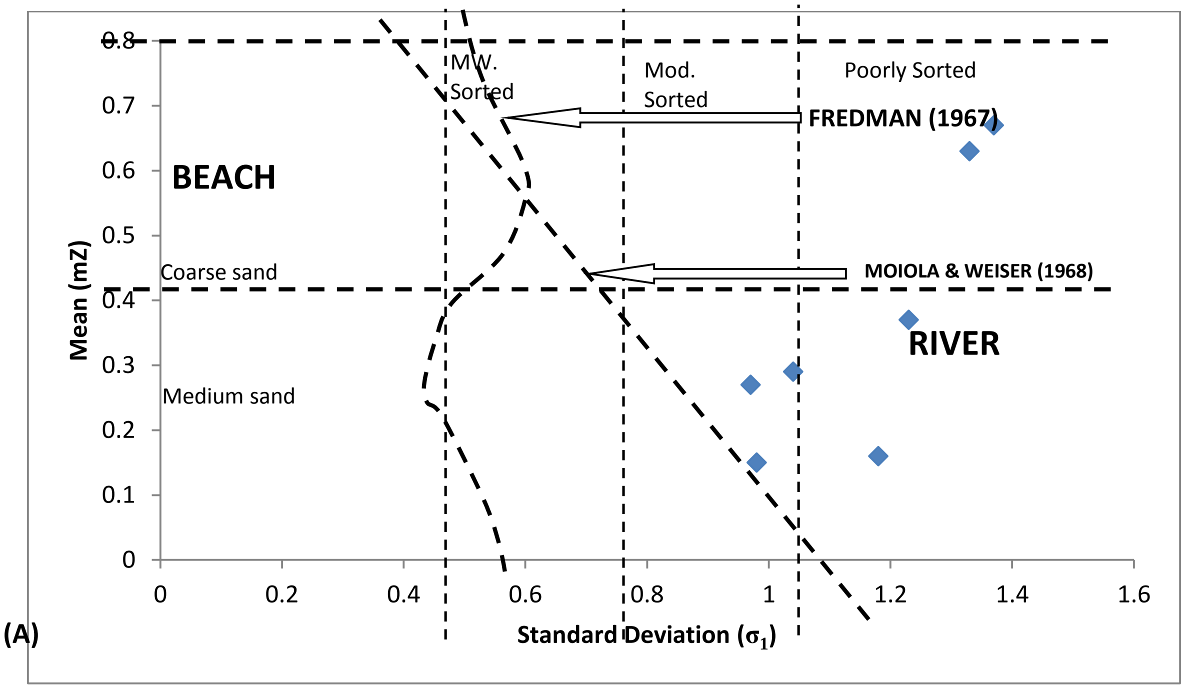

Figure 6: Bivariate plot of mean against standard deviation of Adogo River sands

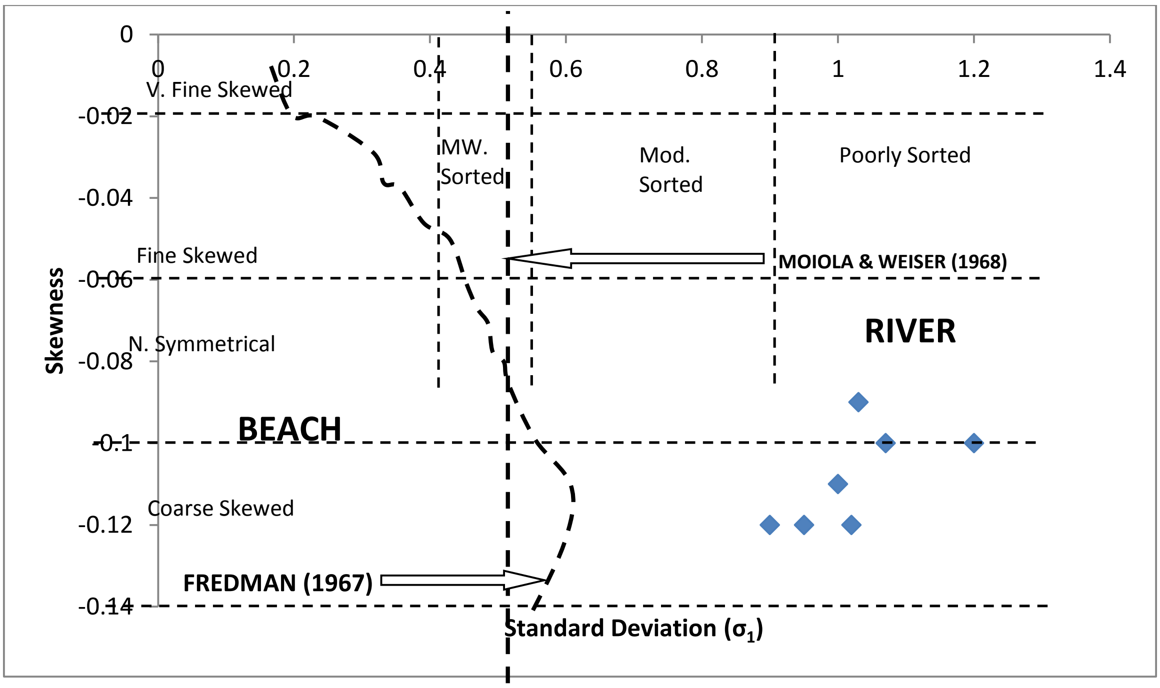

Figure 7: Bivariate plot Skewness against standard deviation for Ero River sand

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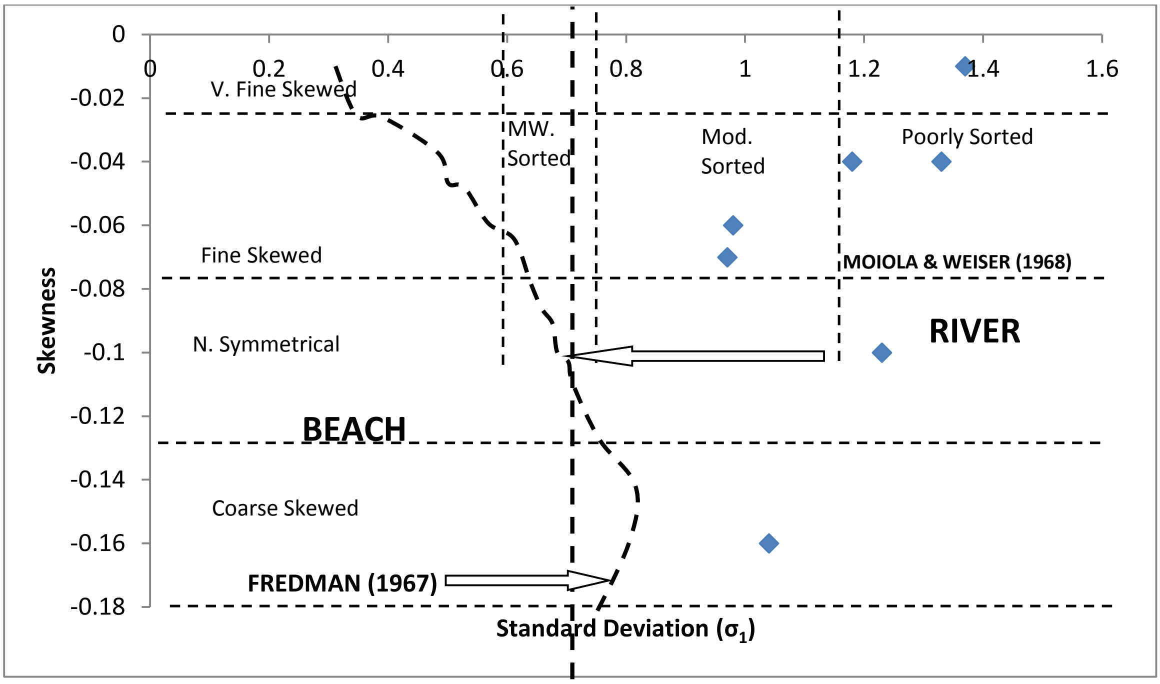

Figure 8: Bivariate plot of Skewness against standard deviation for Adogo River sands

The computed mean size of the sediment samples from the rivers Ero and Adogo in this investigation is all in the coarse grain range (Tables 1 and 2). The depositional environment's transportation method and energy influence the mean size parameter. This indicates that sediments were deposited near a likely source region and were transported by saltation, rolling, and sliding. (Friedmann, 1967).

Table 1: Results and interpretation of statistical parameters based on grain size analysis for Ero River sands

Sample code	Graphic Mean (Ø)	Graphic sorting (Ø)	Graphic skewness	Graphic Kurtosis	Interpretation	Channel Character
ER1	0.69	1.03	-0.09	1.01	Coarse grained, Poorly sorted, strongly Coarse Skewed Mesokurtic	Straight
ER2	0.94	1.2	-0.1	0.96	Coarse grained, Poorly sorted, coarse Skewed, Mesokurtic.	Straight
ER3	0.57	0.95	-0.12	1.01	Coarse grained, Moderately sorted, coarse skewed, mesokurtic.	Straight
ER4	0.45	0.9	-0.12	0.63	Coarse grained, Moderately sorted, Coarse skewed, mesokurtic.	Straight
ER5	0.82	1.0	-0.11	0.99	Coarse grained, moderately sorted, coarse skewed, mesokurtic.	straight
ER6	0.80	1.02	-0.12	0.99	Coarse grained, poorly sorted, coarse skewed, mesokurtic.	Meander
ER7	0.72	1.07	-0.1	0.99	Coarse grained, poorly sorted, coarse skewed, mesokurtic.	Meander

Table 2: Results and interpretation of statistical parameters based on grain size analysis for the Adogo River Sands

Sample Code	Graphic Mean (M_2)	Graphic sorting (Ø)	Graphic skewness	Graphic Kurtosis	Interpretation	Channel Character
AD1	0.29	1.04	-0.16	1.03	Coarse grained, poorly sorted, coarse skewed, mesokurtic.	
AD2	0.16	1.18	-0.04	1.03	Coarse grained, Poorly sorted, strongly coarse skewed, Mesokurtic	Meander
AD3	0.27	0.97	-0.07	1.04	Coarse grained, moderately sorted, strongly coarse skewed, Mesokurtic	Straight
AD4	0.67	1.37	-0.01	0.65	Coarse grained, poorly sorted, strongly coarse skewed, Very platykurtic	Meander
AD5	0.63	1.33	-0.04	0.97	Coarse grained, poorly sorted, strongly coarse skewed, mesokurtic	Meander
AD6	0.37	1.23	-0.1	0.65	Coarse Grained, poorly sorted, coarse skewed very Platykurtic	meander
AD7	0.15	0.98	-0.06	1.06	Coarse grained, moderate sorted, strongly coarse skewed, mesokutic	Burficate

Standard deviation measures the sorting (σ_1) of sediments and it is related to the level of fluctuation in the energy or velocity conditions of the depositing agents (Sahu, 1964). The standard deviation values of sediments samples taken from the Ero and Adogo rivers all reveal poor to moderate sorting (Tables 1 and 2). Fluvial low energy environment as meandering point yields poorly sorted sediment. Selly (1985) and Tucker (1988) e.g (ER6, ER7, AD2, AD4 and AD6), although sampling point (ER1), taken along straight channel also displays poor sorting. Moderately sorted sediments may give an indication of nearness to some area and rapid sedimentation typical of sampling point (ER3, ER4, ER5, AD3), while sampling point (AD7) was taken along a river bifurcate.

Skewness is a measure of sediment symmetry or asymmetry; the computed skewness ranges of sediment derived from River Ero and Adogo indicate coarse to strongly coarse skewed sediments. (Tables 1 and 2). These sediments may have been deposited when the energy of the depositional environment was moderately high.

The computed Kurtosis illustrates that the sediment of River Ero and Adogo are Mesokurtic (ER1, ER2, ER3, ER5, ER6, ER7, AD1, AD2, AD3, AD5, AD7), and very platykurtic (ER4, AD4, and AD6).(Tables 1 and 2). Sediments of River Ero computed to be very Platykurtic was obtained along meandering points, while that of River Adogo was obtained along straight channels. Sediments that are mesokurtic to platykurtic have been described to be moderately to poorly sorted e.g Folk and ward (1966), this is in conformity with sediments obtained from Rivers Ero and Adogo (Figure 9 and 10).

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To further narrow the palaeoenvironment in accordance with Freidman (1967, 1979) and Miola and Wieser (1968). The bivariate statistic plots for the sediment samples of River Ero illustrates that the samples are river sands. Similarly, sediment samples of River Adogu also falls within the river sand field (Fig 5, 6, 7, 8).

Linear Discriminant Function

The results of the analysis of the linear discriminant function (LDF) are presented in Tables 3 and 4. The mean, standard deviation, skewness and Kurtosis were also used to delineate the depositional environments in accordance with Sahu (1964).

Table 3: Proportional percentage of Quartz, Feldspar, Rock fragment and calculated Mineral maturity index for sediment samples of River Ero

Sample Code	Quartz	Feldspar	Rock Fragment	Total	Mineral Maturity Index (MMI)
ER1	95	3	2	100	95%
ER3	96	2	2	100	96%
ER5	96	2	2	100	96%
ER6	96	2	2	100	96%
ER7	95	3	2	100	95%
					$\frac{TQ}{Q+F+RF} \times 100$
					Where: **TQ** = Total Quartz **Q** = Quartz **F** = Feldspar **RF** = Rock Fragment

Table 4: Proportional percentage of Quartz, Feldspar, Rock fragment and calculated Mineral Maturity index of sediment samples of River Adogo

Sample Code	Quartz	Feldspar	Rock Fragment	Total	Mineral Maturity Index (MMI)
AD1	96	2	2	100	96
AD3	95	3	2	100	95
AD5	95	3	2	100	95
AD6	96	2	2	100	96
AD7	95	2	3	100	95
					$\frac{TQ}{Q+F+RF} X 100$
					Where: **TQ** = Total Quartz **Q** = Quartz **F** = Feldspar **RF** = Rock Fragment

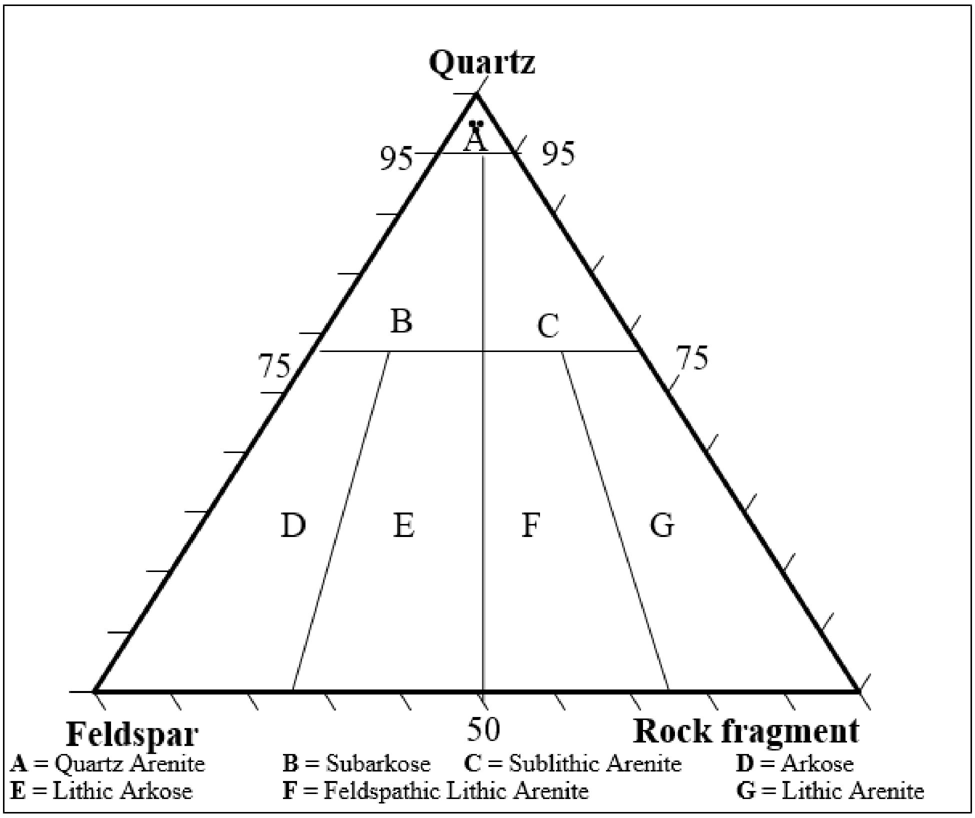

Figure 9: The Ero River sandstone classification scheme (after Folk 1974)

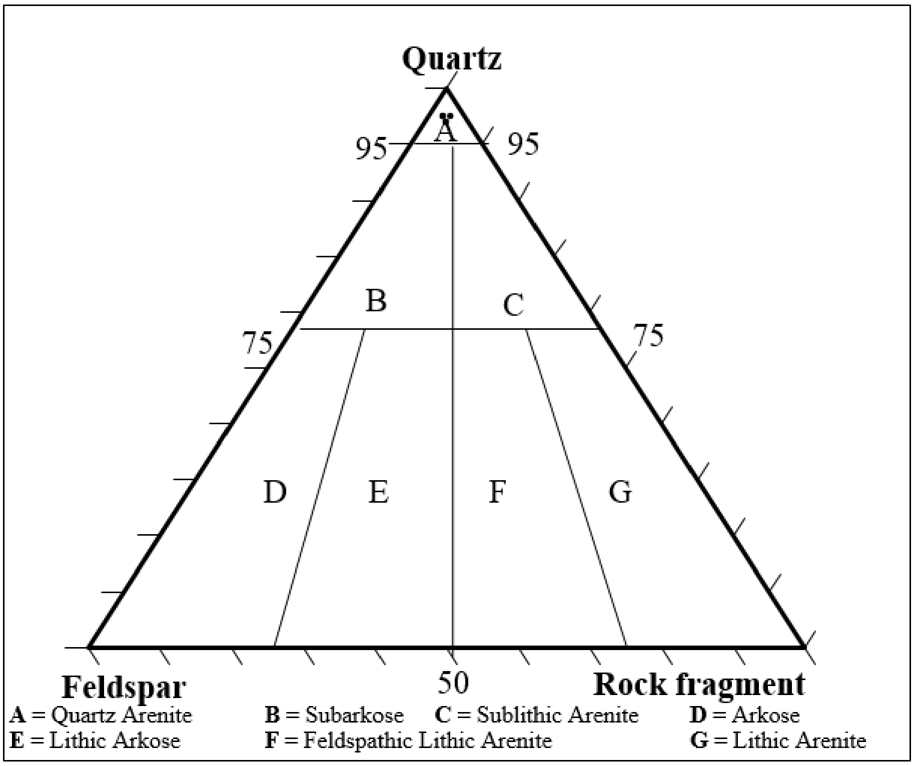

Figure 10: The Classification Scheme of sandstone of the Adogo River sands (after Folk 1974)

The following classification by Sahu, (1964) was used in order to distinguish the depositional environment of the sediment samples obtained from Rivers Ero and Adogo.

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Y:aeolain:Beach>-2.7411 → Beach Environment

Y:aeolain: Beach>-2.7411 → Shallow agitated marine

Y:marine: Fluvial<-7.4190 → Fluvial Deltaic

Y:marine: Fluvial>-7.4190 → Shallow marine

Tables 5 and 6 are the results of the linear discriminant function outputs for sediments obtained from Rivers Ero and Adogo with that of River Ero (Table 5) showing Y_1 to be entirely beach environment, Y_2 mostly beach in exception of sampling points (ER3 and ER4) which proved to be fluvial deltaic origin. (Table 6) shows the LDF output for River Adogo showing Y_1 to be entirely beach environment, Y_2 entirely shallow agitated and Y_3 entirely shallow marine conditions.

Table 5: Interpretation of processes and environment of deposition by linear discriminant function of River Ero Sediment Sample. Sahu (1964)

Sample Code	Graphic Mean (MZ)	Graphic sorting	Graphic Skewness	Graphic kurtosis	Y1	Y2	Y3	Remarks		
								Y1	Y1	Y3
ER1	0.69	1.03	-0.09	1.01	4.796084	97.57138	-8.55076	Beach	Shallow agitated Marine	Shallow marine
ER2	0.94	1.2	-0.1	0.96	5.172252	125.288	-11.7635	Beach	Shallow agitated Marine	Shallow marine
ER3	0.57	0.95	-0.12	1.01	4.700305	84.7414	-7.0591	Beach	Shallow agitated Marine	Fluvial deltaic
ER4	0.45	0.90	-0.12	0.63	3.603033	69.7532	-6.30629	Beach	Shallow agitated Marine	Fluvial deltaic
ER5	0.82	1.00	-0.11	0.99	4.085975	94.8724	-7.88657	Beach	Shallow agitated Marine	Shallow deltaic
ER6	0.8	1.02	-0.12	0.99	4.327662	97.0329	-8.19508	Beach	Shallow agitated Marine	Shallow deltaic
ER7	0.72	1.07	-0.10	0.99	4.95845	103.0094	-9.22558	Beach	Shallow agitated Marine	Shallow deltaic
Aeolian or Beach				$Y1=-3.5688.M_z + 3.7016.\ \sigma_1^{2`}$ -2.0766.SK +3.1135.KG If Y1>-2.7411=Beach; if Y1<-2.7411=Aeolian						
Backshore or Sub tidal				$Y2=15.6534.M_z + 65.7091.\ \sigma_1^{2`}$ +18.1071.SK+18.50435.KG If Y2=≤65.365=Beach (backshore); if Y2>65.365=shallow agitated marine						
Shallow marine or Fluvial (Deltaic)				$Y3=0.2852.M_z -8.7604.\ \sigma_1^{2`}$ -4.8932.SK+0.0482.KG, If Y3=-74190=Fluvial (Deltaic); if Y3>-7.4190= Shallow Marine						

Table 6: Interpretation of Processes and environment of deposition by Linear discriminant function of River Adogo Sediment Samples (Sahu, 1964)

Sample Code	**Graphic Mean (MZ)**	**Graphic sorting**	**Graphic Skewness**	**Graphic kurtosis**	**Y1**	**Y2**	**Y3**	**Remarks**		
								Y1	**Y1**	**Y3**
1	0.29	1.04	-0.16	1.03	6.50786	91.77279	-8.5015	Beach	Shallow agitated marine	Shallow marine
2.	0.16	1.18	-0.04	1.03	7.873069	112.3331	-11.831	Beach	Shallow agitated marine	Shallow marine
3.	0.27	0.97	-0.07	1.04	5.902661	84.0291	-7.7222	Beach	Shallow agitated marine	Shallow Marine
4.	0.67	1.37	-0.01	0.65	6.600978	145.663	-16.069	Beach	Shallow agitated marine	Shallow Marine
5.	0.63	1.33	-0.04	0.97	7.402575	143.394	-12.545	Beach	Shallow agitated marine	Shallow marine
6.	0.37	1.23	-0.10	0.65	6.51113	115.4202	-12.545	Beach	Shallow agitated marine	Shallow marine
7.	0.15	0.98	-0.06	1.06	6.444603	83.9832	-7.9744	Beach	Shallow Agitated marine	Shallow marine
Aeolian or Beach				$Y1=-3.5688.M_z + 3.7016.\ \sigma_1^{2`}\ -2.0766.SK\ \ +3.1135.KG$ If Y1>-2.7411=Beach; if Y1<-2.7411=Aeolian						
Backshore or Sub tidal				$Y2=15.6534.M_z + 65.7091.\ \sigma_1^{2`}\ +18.1071.SK+18.50435.KG$ If Y2=≤65.365=Beach (backshore); if Y2>65.365=shallow agitated marine						
Shallow marine or Fluvial (Deltaic)				$Y3=0.2852.M_z\ -8.7604.\ \sigma_1^{2`}\ -4.8932.SK+0.0482.KG,$ If Y3=-74190=Fluvial (Deltaic); if Y3>-7.4190= Shallow Marine						

Petrographic study of the River Deposit

Tables 5 and 6 show the results of the petrographic examination of the Rivers Ero and Adogo deposit. The results suggest that the quartz content of River Ero sediment samples varies from 95%-96% (Average 95.6%), Feldspar content in the sample ranges from 2%-3% (Average 2.4%) while the Rock fragment is 2% (Average 2%). The computed mineral maturity index for the sediment samples ranges from 0.95%-0.96%. River Adogo reveals a Quartz content of 95%-96% (Average 94.5%), Feldspar ranges from 2%-3% (Average of 2.4%), Rock fragment of 2%-3% (average 2.2%) from the Petrographic data of the sediment samples. The computed mineral maturity index from the sediment samples ranges from 0.95%-0.96%.

The percentage proportion of quartz is observed to be greater than 90% based on the observed mineralogical composition of the sediment samples of Rivers Ero and Adogo. This indicates that the sediments are most likely magmatic in origin. The sediment's transportation history was determined by the shape of the quartz grains, which seemed to be angular to sub-angular, indicating a brief period

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of movement and erosion prior to weathering, while the low feldspar concentration could be owing to strong weathering after erosion. The glassy nature of the quartz grains revealed that the sediment samples from the Rivers Ero and Adogo were transported by a fluvial process (Figure 11-14).

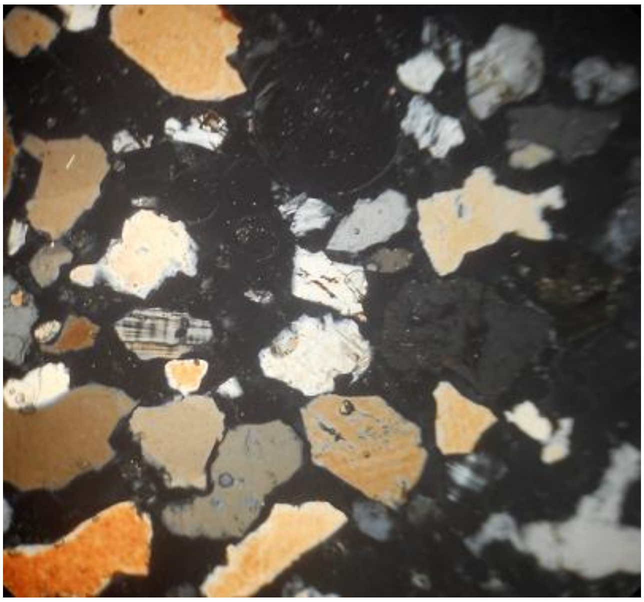

Figure 11: Photomicrograph of Adogo River sand A1 under plane polarized light.

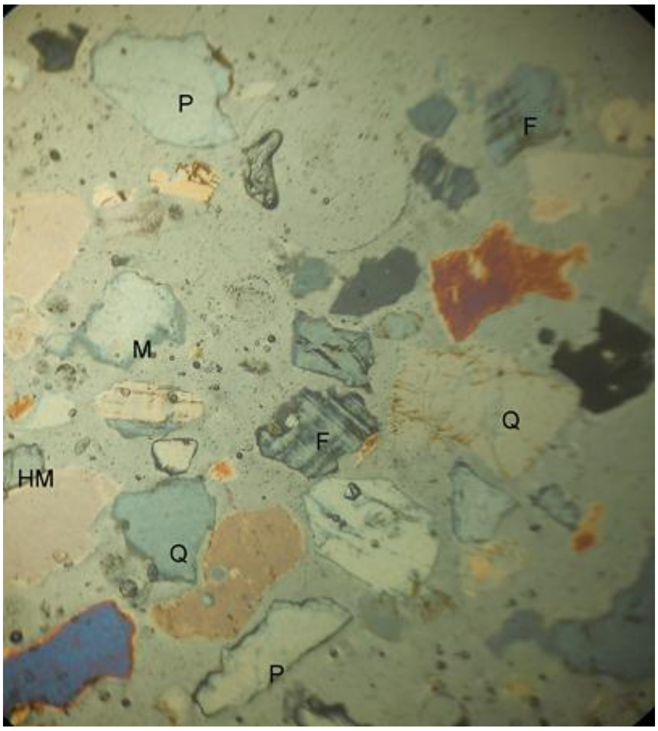

Figure 12: Photomicrograph of Adogo River sand A1 under cross polarized light (Q quartz, F feldspar, M muscovite HM heavy mineral, P plagioclase)

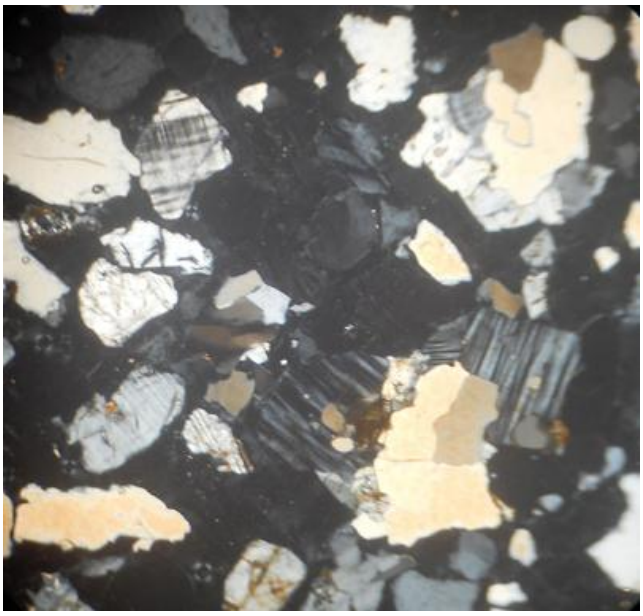

Figure 13: Photomicrograph of Adogo River sand E1 under plane polarized light.

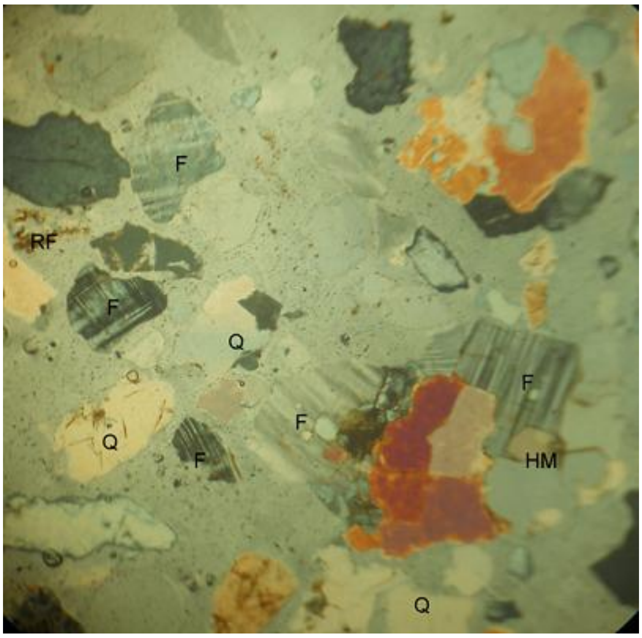

Figure 14: Photomicrograph of Adogo River sand E1 under cross polarized light (Q quartz F feldspar RF Rock fragment, HM heavy mineral)

The sedimentary ternary plot after Folk (1974) reveals that the sediment samples from the Rivers Ero and Adogo are dominated by quartz arenites (Figure 9 and 10).

CONCLUSION

This study has been able to reveal that the Sedimentological and Petrographic characteristics of Ero and Adogo rivers are similar. Analysis of the sediments showed that the sediments are coarse grained and moderately to poorly sorted. This is due to the sediments being sorted by the river's energy as it passes between straight and meandering spots along the river channels. The sediment samples' transport history and depositional

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environment were interpreted using statistical parameters of grain size characteristics. Petrographic analysis of sediment samples indicated a preponderance of subangular quartz grains larger than 90%, with minor feldspar and rock fragments, defining them as quartz arenites of cratonic interior magmatic origin.

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