# Granulometric Analysis Of The Sandstone Facies Of The Ise Formation, Southwestern Nigeria

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***Abstract*—Granulometric analysis of the sandstone facies of the Ise Formation have been studied. The sand grains have low sphericity and range from angular to sub-rounded. Histograms of the sediments exhibit both unimodal and bimodal trends. The outlay is dominantly asymmetrical with varying modal class, which could be attributed to variation in the energy of the transporting medium. The cumulative curve of the studied samples is typical of beach sands. The graphic mean ranges from -0.25ф (very coarse grained) to 1.59ф (medium grained) with an average of 0.63ф (Coarse grained). The preponderance of coarse grained sediments and lack of fine sands suggests strong to moderate energy conditions of deposition and the particles move in the flow as bedloads. The graphic standard deviation ranges from -0.65ф-0.66ф (very well sorted to moderately well sorted), with an average of -0.18 ф (very well sorted). The well sorted nature of the sediments is probably due to rapid back and forth flow of the depositing medium. The values of inclusive graphic skewness ranges from -1.02ф-1.49ф (very coarse skewed to very fine skewed), with an average of 0.08ф (near symmetrical). The graphic kurtosis ranges from 0.25ф-2.31ф which indicates a very playtykurtic to very leptokurtic; with an average of 1.14ф (leptokurtic). This wide range value suggests that part of the sediment achieved its sorting elsewhere in high-energy environment. The bivariate plot of moment skewness vs. moment standard deviation shows the samples plotting in the beach sand zone, indicating in littoral environment. The sediments are texturally mature with moderate to high input of modifying kinetic energy. Linear discriminant functions analysis indicates a shallow marine beach environment. From the Passega diagram, majority of the samples plotted within the uniform suspension zone; while some appeared in the gradual suspension zone. The uniform suspension segment indicates the role of uniform suspension in transporting segments.**

***Keywords—grain size, standard deviation, skewness, kurtosis, graphic mean***

## INTRODUCTION

The knowledge of particle size distribution and the assemblages of heavy minerals in sedimentary rocks particularly in the earth crust make it possible to effectively locate and use essential minerals to predict their dispersal pattern when they re-enter the natural environment and information about the source of the sediment, provenance of the material as well as the environment of deposition may be obtained from an examination of the clast types present [1] [2]. Grain size frequency distribution and textural factors may reflect the mode of transportation and depositional history of an area. Several workers have endeavoured to infer depositional environment and hydrodynamics from grain size data [3, 4, 5, 6, 7, 8, 9, 10, 11, 12. 13, 14. 15, 16, 17, 18, 19, 20, 21].

Heavy minerals have been used for provenance, sediment spatial distribution, palaeodrainage pattern, palaeogeographic reconstructions, mapping the bedrock geology and correlation studies in both modern and ancient sediments [22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35].

The Dahomey basin is an extensive sedimentary basin extending almost from south-Ghana to Nigeria (precisely the Benin hinge-line). The Dahomey basin (Fig.1) is a marginal pull-apart basin [36] or Margin sag basin [37], which was initiated in the Late Jurassic to early Cretaceous [38] separation of African and South American lithospheric plates. A number of authors have identified and described the eight lithostratigraphic units in the Dahomey basin [39, 40, 41, 42]. In most parts of the basin, the stratigraphy is dominated by sand and shale alternations with minor proportion of limestone [42]. This investigative study was carried out at Irolu and J4 reserve area, Ogun State, in the south western part of Nigeria (Fig. 2). This present study intends to make precise deductions on the granulometry and heavy mineral studies of the sandstone facies of the Ise Formation.

## MATERIALS AND METHODS

Field work was carried out within the Dahomey basin between Irolu and J4 area in Ogun State. A systematic field mapping involving detailed surface section measurement and construction of lithologic sections; at each outcrop

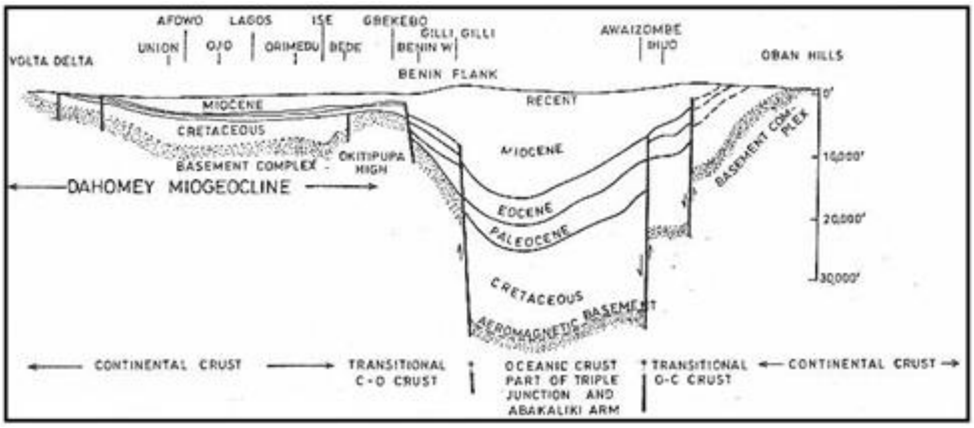


*Fig.1.East-West geological section showing position, extent and thickness variation in the onshore Dahomey basin and upper part of the Niger Delta, after [38].*


*Fig.2. Location map of the study area.*

samples were collected while lithologic units were described. Twenty (20) fresh samples were collected by cutting the inner part of the outcrop and in the process contamination and other exogenic transformations were avoided. The samples were placed in sample bags and labeled using appropriate code. A qualitative visual study was carried out on the samples to describe physical features such as colour, roundness, sorting, etc. Twelve (12) samples were chosen for granulometric analysis. The samples were dried in the oven to ensure proper dryness. After drying, the samples were removed from oven and allowed to cool inside the desiccators. After cooling, the samples were weighed then the sieves were arranged in descending order and mounted on the sieve shaker. The samples were poured into the upper sieves one after the other. The shaker was put on and allow to shake for 10 minutes, after the mounted set of sieves were removed from the shaker and the content in each sieves was weighed against the size of the sieve. Then the percentage retained was calculated and this was plotted against the sieve sizes. Sieving analysis was achieved by sieve shaker using set of eight sieves agitating for about 10min. The sieve used for this operation are as follows 1.18mm, 0.85mm, 4.50mm, 0.300mm, 0.150mm, 0.090mm, 0.075mm and 0.063mm. The percentage of the aggregate was estimated. The grain size of the $5^{th}$, $16^{th}$, $25^{th}$, 50th, $75^{th}$, $84^{th}$, and $95^{th}$percentiles were obtained from each cumulative curve drawn. These were used to calculate the parameters for the Graphic mean (M), Standard deviation (sorting) (SD), Graphic kurtosis (K) and Graphic skewness (SK) based on [6].

For petrographic analysis, the sample was oven dried to ensure proper dryness. Then, it was poured into sample tray. The representative sample was taken by using quartering method to ensure full representation of the sample. The representative sample was poured into the graduated plate. After mounting the grains in Canada Balsam on microscopic slides. More than 100 grains of each sample were counted with the ribbon count method under the petrologic microscope in order to ascertain different parameters such as grain size, shapes, the various mineral compositions and to estimate their modal percentages.

For heavy mineral analyses, Bromoform was poured into the upper funnel with several clips on the representative sample of the sediment was taken and drop into the bromoform. The heavy minerals were seen settling down into the bromoform while lighter ones float. This was left for about five minutes to ensure complete settling of the heavy minerals. The clip was locked while the second clip is opened. This allows the separated heavy mineral to run into the filter paper inside the second funnel. It was allowed to drain, the mineral was allowed to run through the second filter paper and the bromoform was recovered. Acetone was used to wash through the first and second funnels to clean off the bromoform. Hot plate was put on and the glass slide was also placed on the hot plate. Canada balsam was dropped on the glass slide. The separated heavy minerals were carefully sprinkled on the Canada balsam. This was allowed to cool and later, it was properly labeled. The heavy minerals were later studied under petrographic microscope.

## STRATIGRAPHY OF DAHOMEY BASIN

Figure 3 shows a geological map of the Dahomey basin, while Table 1 shows the lithostratigraphy the basin. Previous work on the Cretaceous stratigraphy of the Dahomey basin has recognized three formations belonging to the Abeokuta group [41] as follows; (i) The Ise Formation which is Neocomian to Albian in age consist essentially of continental sands, grits and siltstones. This is directly overlying the south western Precambrian Basement Complex. (ii) The Afowo Formation which overlay Ise Formation consists of coarse to medium-grained sandstones with variable interbeds of shales, siltstones and clay. The sediments of this formation were deposited in a transitional to marginal marine environment during turonian to Maastritchtian age. (iii) The Araromi Formation consists basically of sand, overlain by dark-grey shales and interbedded limestone and marls occasional lignite bands. The formation conformably overlies the Afowo Formation and Maastrichtian to Paleocene age has been assigned [41].

The Abeokuta was conformably overlaid by Imo group which comprises of shale limestone and marls. The twolithosratigraphic units under this group are: Ewekoro formation which consists of thick fossiliferous limestone. [43] described the formation as consisting of shaly limestone 12.5m thick which tends to be sandy and divided it into three microfacies. [44] further modified this and proposed a fourth unit. It is Paleocene in age and associated with shallow marine environment due to abundance of coralline algae, gastropods, pelecypods, echinoid fragments and other skeletal debris. The Akinbo Formation overlies Ewekoro Formation and it consists of shale, glauconitic rock bank, and gritty sand to pure grey and with little clay. Limestone lenses from Ewekoro formation grades literally into the Akinbo shale towards the base. The base is characterized by the presence of a glauconitic rock. The age of the formation is Paleocene to Eocene. The Oshoshun Formation overlies the Imo group which is a sequence of mostly pale greenish-grey laminated phosphatic marls, light grey white-purple clay with interbeds of sandstones. It also consists of claystone underlain by argillaceous limestone of phosphatic and glauconitic materials in the lower part of the formation and were deposited during Eocene [42]. The sedimentation of the Oshoshun Formation was followed by a regression phase which deposited the sandstone unit of Ilaro Formation [45]. The sequence represents mainly coarse sandy estuarine deltaic and continental beds which show rapid lateral facies change. The coastal plain sands are the youngest sedimentary unit in the eastern Dahomey basin. It conceivably unconformably overlay the Ilaro Formation but lack convincing evidence [39]. It consists of soft, poorly sorted clayey sand and pebbly sands deposited during Oligocene to Recent.

## RESULTS AND DISCUSSION

Granulometric analysis provides quantitative information when a comparison of the character is required from sediments deposited within a known environment, such as a beach or along a river. It is therefore most commonly used in the analysis and quantification of present-day processes of transport and deposition [47]. The grain size parameters of the studied sandstones and their interpretations are presented in the Table 2. The sand grains have low sphericity and range from angular to sub-rounded. Figure 4 shows the cumulative curve of the studied samples typical of beach sands. Figure 5 are histograms of the individual weight percent of the sediments exhibiting both unimodal and bimodal trends. The outlay is dominantly asymmetrical with varying modal class, which could be attributed to variation in the energy of the transporting medium.

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***Graphic mean*** (Mz)

This is the average size category or a measure of the central affinity. The graphic mean ranges from -0.25ф (very coarse grained) to 1.59ф (medium grained) with an average of 0.63ф (Coarse grained). The preponderance of coarse grained sediments and lack of fine sands suggests strong to moderate energy conditions of deposition and the particles move in the flow as bedloads.

***Inclusive Graphic Standard Deviation*** (**σ**1)

This is a measure of sorting or variation in grain sizes and indicates the fluctuations in the kinetic energy or velocity conditions of the depositing agent [15]. The graphic standard deviation ranges from -0.65ф-0.66ф (very well sorted to moderately well sorted), with an average of -0.18 ф (very well sorted). The well sorted nature of the sediments is probably due to rapid back and forth flow of the depositing medium.

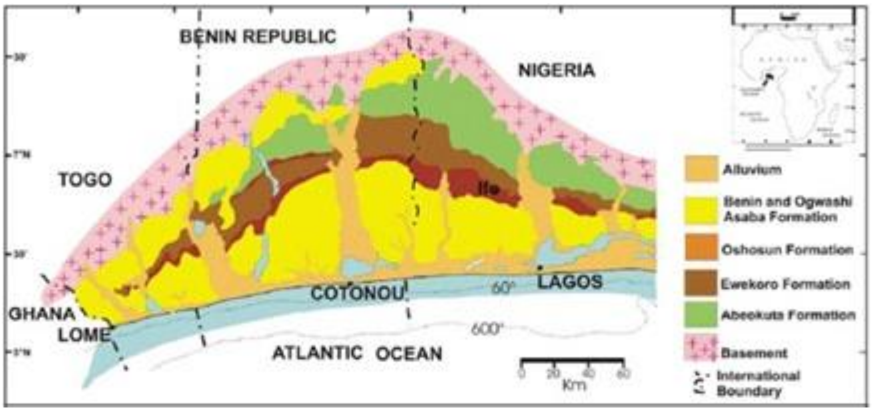


*Fig.3. Geological Map of the Dahomey Basin [46].*

TABLE I. STRATIGRAPHY OF THE DAHOMEY BASIN

| PERIOD | Jones & Hockey (1964) | | Adegoke & Omatsola (1981) | | Agagu (1995) | |
|---|---|---|---|---|---|---|
| | Age | Formation | Age | Formation | Age | Formation |
| **Quaternary** | Recent | Alluvium | | | Recent | Alluvium |
| **Tertiary** | Pleistocene – Oligocene | Coastal Plain Sand | Pleistocene – Oligocene | Coastal Plain Sand | Pleistocene – Oligocene | Coastal Plain Sand |
| | Eocene | Ilaro sandstone | Eocene | Ilaro sandstone/Oshosun shales | Eocene | Ilaro sandstone/Oshosun shales |
| | Paleocene | Ewekoro Limestone | Paleocene | Akimbo shale/Ewekoro Limestone | Paleocene | Akimbo shale/Ewekoro Limestone |
| **Late Cretaceous** | Late Senonian | Abeokuta Formation | Maastrichtian to Neocomian | Araromi shale<br>Afowo sandstone/shale<br>Ise sandstone | Maastrichtian to Neocomian | Araromi shale<br>Afowo sandstone/shale<br>Ise sandstone |
| Precambrian Basement Complex | | | | | | |

TABLE 2. SUMMARY OF GRAIN SIZE ANALYSIS RESULT AND INTERPRETATION

| Samples | Mean (Phi) | Interpretation | Sorting (Phi) | Interpretation | Kurtosis | Interpretation | Skewness | Interpretation |
|---|---|---|---|---|---|---|---|---|
| **Irolu 1** | 1.30 | medium grained | 0.27 | Very well sorted | 2.31 | Very leptokurtic | -0.64 | Strongly coarse skewed |
| **Irolu 2** | 0.04 | Coarse grained | -0.50 | Very well sorted | 0.25 | Very platykurtic | 0.26 | Fine skewed |
| **Irolu 3** | 0.61 | Coarse grained | -0.56 | Very well sorted | 1.08 | Mesokurtic | 0.28 | Fine skewed |
| **Irolu 5** | 1 | medium grained | -0.5 | Very well sorted | 0.91 | Mesokurtic | -0.11 | Coarse skewed |
| **Irolu 6** | 1.59 | medium grained | -0.31 | Very well sorted | 1.77 | Very leptokurtic | -1.02 | Strongly coarse skewed |
| **Irolu 7** | -0.25 | very coarse grained | 0.5 | well sorted | 0.70 | Platykurtic | -0.90 | Strongly coarse skewed |
| **Irolu 8** | 0.64 | Coarse grained | 0.66 | Moderately well sorted | 0.68 | Platykurtic | 0.27 | Fine skewed |
| **Irolu 9** | -0.07 | very Coarse grained | -0.65 | Very well sorted | 1.29 | Leptokurtic | 0.09 | Near symmetrical |
| **Irolu 10** | 0.73 | Coarse grained | -0.51 | Very well sorted | 1.29 | Leptokurtic | 0.38 | strongly fine skewed |
| **Irolu 11** | 1.22 | medium grained | -0.31 | Very well sorted | 1.31 | Leptokurtic | 0.40 | Strongly fine skewed |
| **Irolu 12** | 0.14 | Coarse grained | -0.09 | Very well sorted | 1.12 | Leptokurtic | 1.49 | strongly fine skewed |
| **$J_4$** | 0.65 | Coarse grained | -0.2 | Very well sorted | 0.97 | Mesokurtic | 0.40 | Strongly Fine skewed |

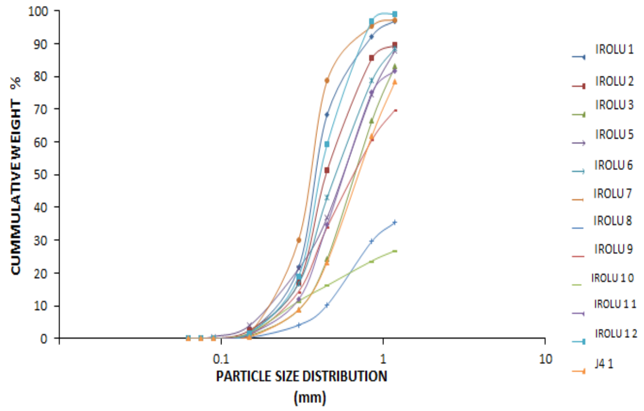


*Fig.4. Cumulative curve of the studied samples.*

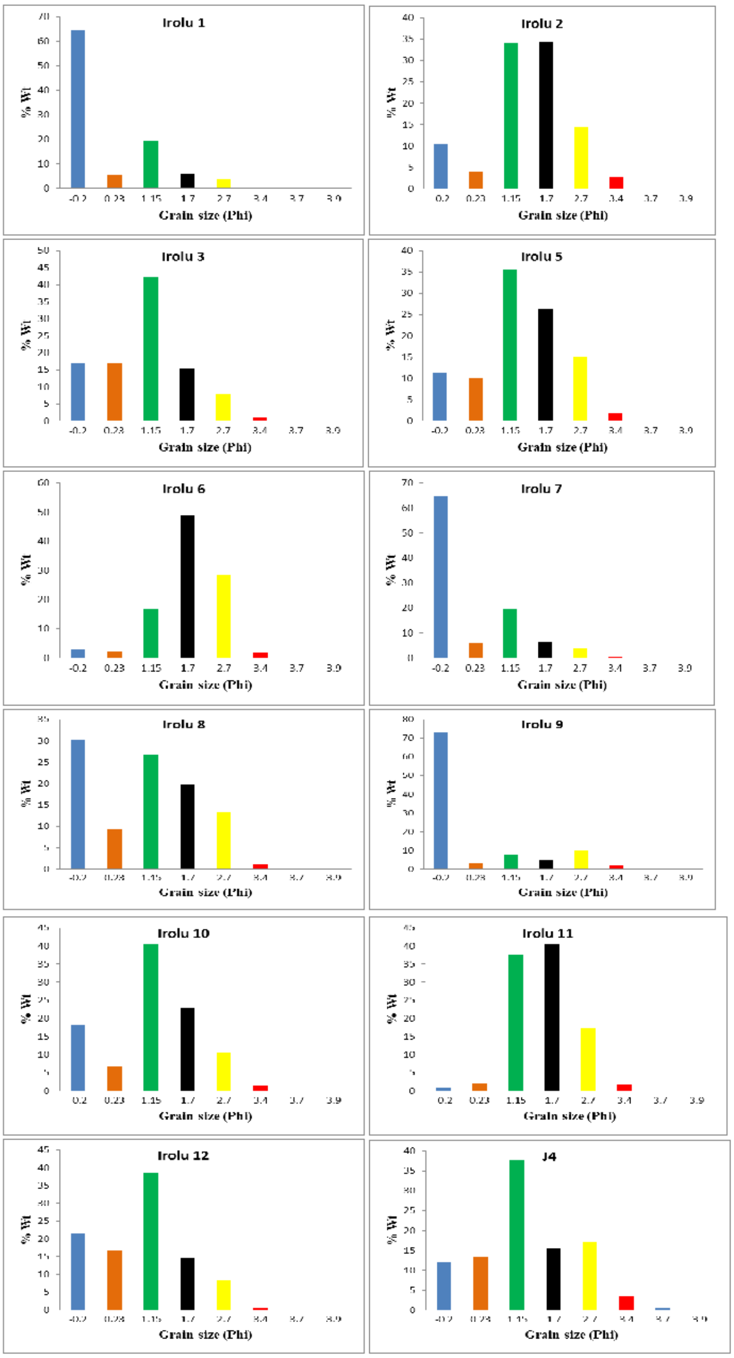


*Fig.5. Histograms of the individual weight percent of the sediments,*

***Inclusive Graphic Skewness*** **(SK)**
Is a measure of grain-size distribution that reflects the grain spread characteristics in the tails of the distribution. The values of inclusive graphic skewness ranges from -1.02ф-1.49ф (very coarse skewed to very fine skewed), with an average of 0.08ф (near symmetrical). The usually positive skewness of fluvial deposits results from suspension material overlapping the sediment transported on the bottom through traction and salting, due to the reduced turbulence of fluvial current [15]. Positive skewness is due to the competence of the transportation agent unidirectional flow, and the negative is caused by removal of fine grained tail of distribution by winnowing action [15] [48] [49] [50] [51]. [52] indicated that negative skewness has relationship with the intensity and duration of high energy depositional agent through a removal of fines (swash and back wash) of a high energy ocean beach, for instance [48] added that negative skweness can be caused by the addition of materials to coarse fractions like shell fragments. Generally, most beach sediments are slightly negative skewed because of a small proportion of coarse grains [53].

***Kurtosis*** **(KG)**
It shows if the distribution is bell shaped, very flat, or very peaked. That is: it reflects the sharpness or peakedness of a grain-size frequency curve. Sharppeaked curves indicate better sorting in the central portion of the grain-size distribution than in the tails, and flat-peaked curves indicate the opposite [54]. The graphic kurtosis ranges from 0.25ф-2.31ф which indicates a very playtykurtic to very leptokurtic; with an average of 1.14ф (leptokurtic). This wide range value suggests that part of the sediment achieved its sorting elsewhere in high-energy environment. According to [55] and [56] variation in the kurtosis values shows the reflection of the flow characteristic of the depositing medium. Most sands are leptokurtic and are either positively or negatively skewed [57]; because most sands consist of two populations (coarse, leading to negative skewness and fine, leading to positive skewness): one predominant population and one very subordinate population.

***Relationship between granulometric parameters***
The relationship between granulometric parameters is significant for the interpretation of the transport and depositional environment of sediments as pointed out by several authors (e.g., [6] [7] [12] [17] [11] [13] [58] [59]. The bivariate plot (fig. 6) shows the samples plotting in the beach sand zone, indicating in littoral environment. The bivariate plot between mean grain size and sorting (standard deviation) reveals that the grains are sands (fig.7a) that are very well sorted made up of coarse to medium grained sand particles (fig,7b). Only two samples are very coarse and both are sorted. The energy medium may have caused the removal of fine particles via winnowing action of tidal waves. The scatter plot between mean grain size and sorting kurtosis shows a wide range of plots in several Kurtosis fields except the extreme leptokurtic zone (fig. 8). Figures 9A and 9B are bivariate plots between Skewness and Sorting against Kurtosis .respectively; these also show the wide range of kurtosis fields. Figures 10A and 10B are graphical relationships between Mean size and Skewness; Sorting and Skewness.

***Textural maturity***
Textural maturity of sandstones encompasses three textural properties: (i) the amount of clay-size sediment in the rock, (ii) the sorting of the framework grains, and (iii) the rounding of the framework grains [61]. Figure 11 is the textural maturity concept of [61]; sandstones containing more than five percent clay is in the immature stage [54]. The framework grains in immature sediments are poorly sorted and poorly rounded. Presumably, immature sediments have not undergone sufficient sediment transport and reworking to remove fine-size material and produce sorting and rounding of grains [54]. The sandstones studied have clay less than five percent, with majority well sorted and the grains not rounded; they can thus be classified as texturally mature with moderate to high input of modifying kinetic energy.

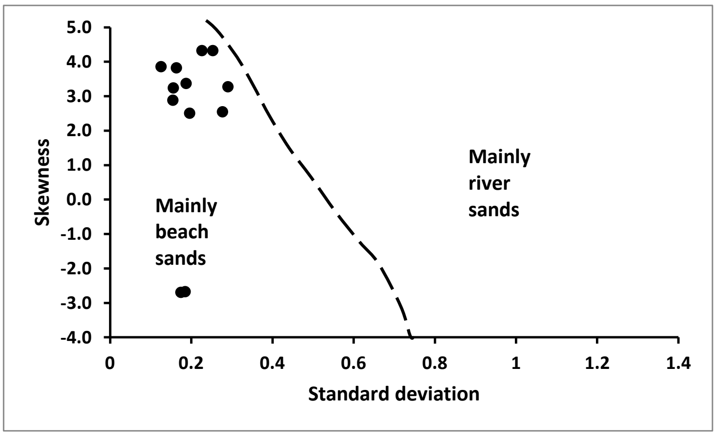


*Fig.6.Grain-size bivariate plot of moment skewness vs. moment standard deviation, showing the fields in which most beach and river sands plot. The sediments plotted in the beach sands field, [13]*

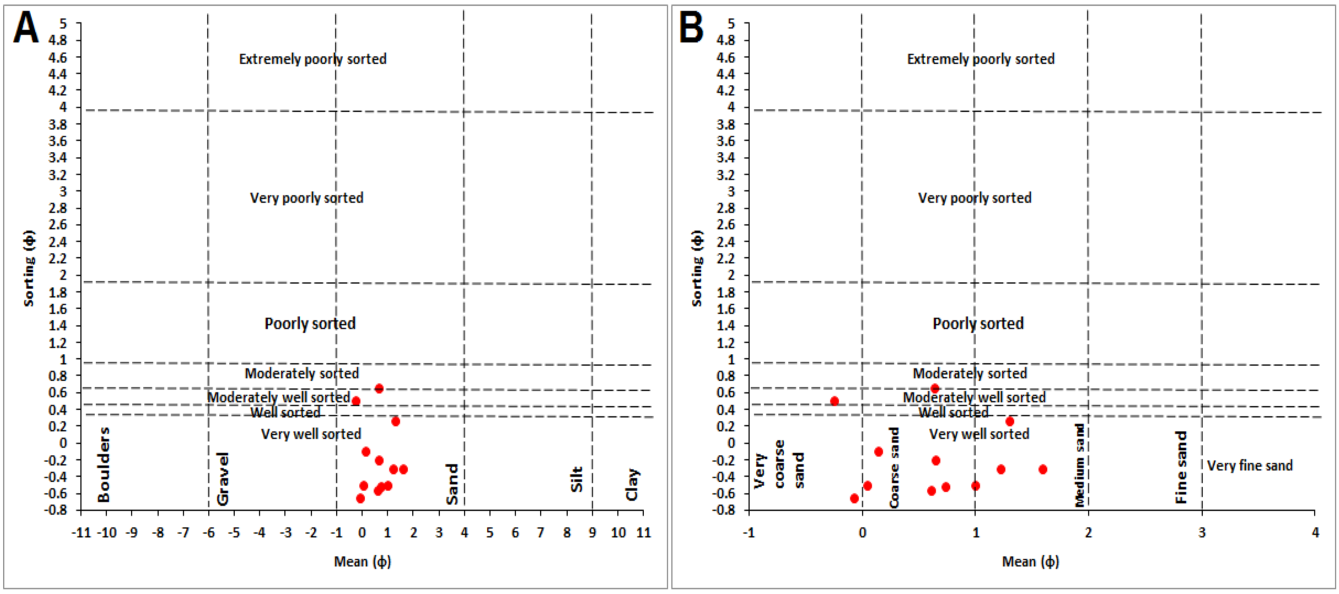


*Fig.7. Bivariate plot between mean grain size and sorting (standard deviation), fields based on [60].*

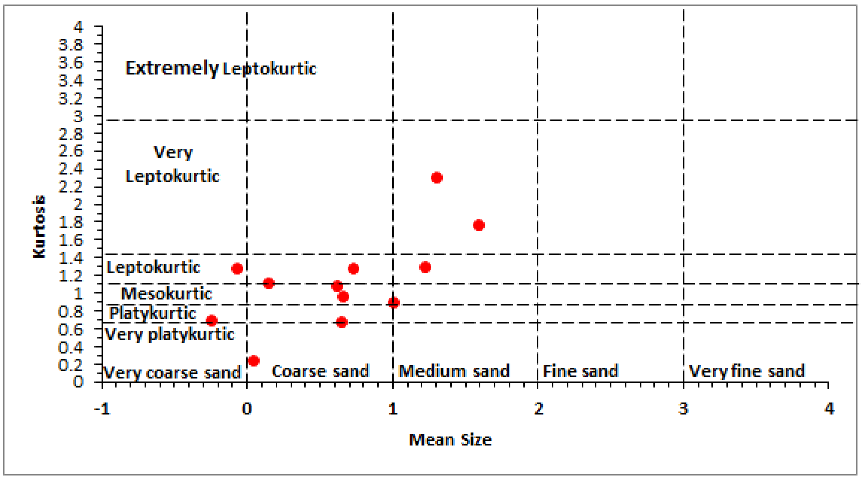


*Fig.8. Bivariate plot between mean grain size and Kurtosis, fields based on [60].*

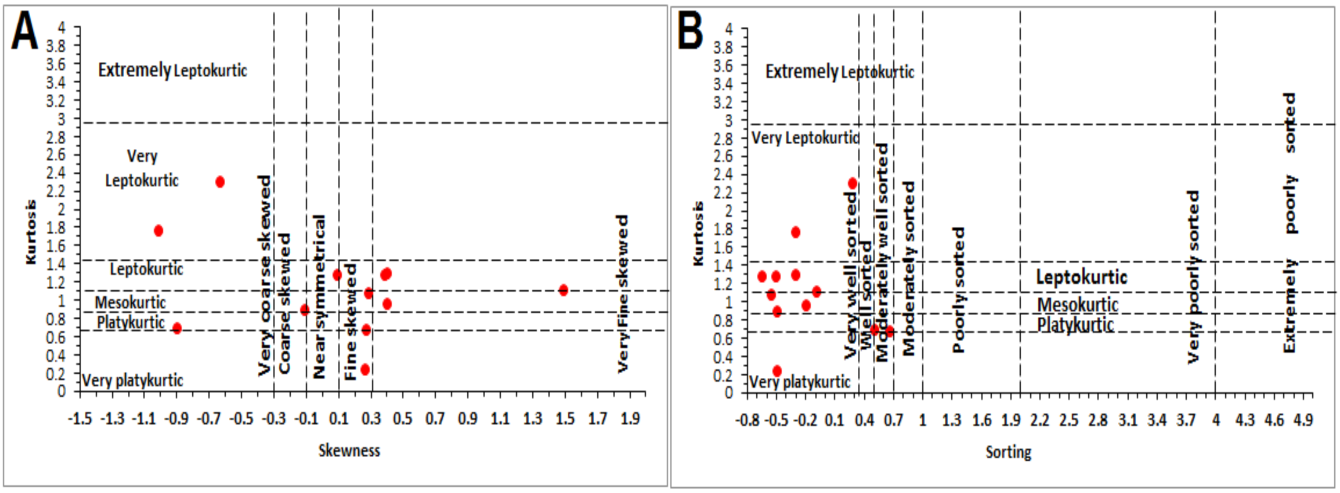


*Fig.9. Bivariate plots: (A) Skewness vs. Kurtosis; (B) Sorting vs. Kurtosis, fields based on [60].*

## *Linear discriminant functions*

Statistical method of analysis of the sediments to interpret the variations in the energy and fluidity factors seems to have excellent correlation with the different processes and the environment of deposition [15] Linear discriminant function analysis of the sediments was established in order to characterize the depositional setting based on the following equations (Where MZ is the grain size mean, δ1 is inclusive graphic standard deviation (sorting), SK is skewness and KG is the graphic kurtosis):

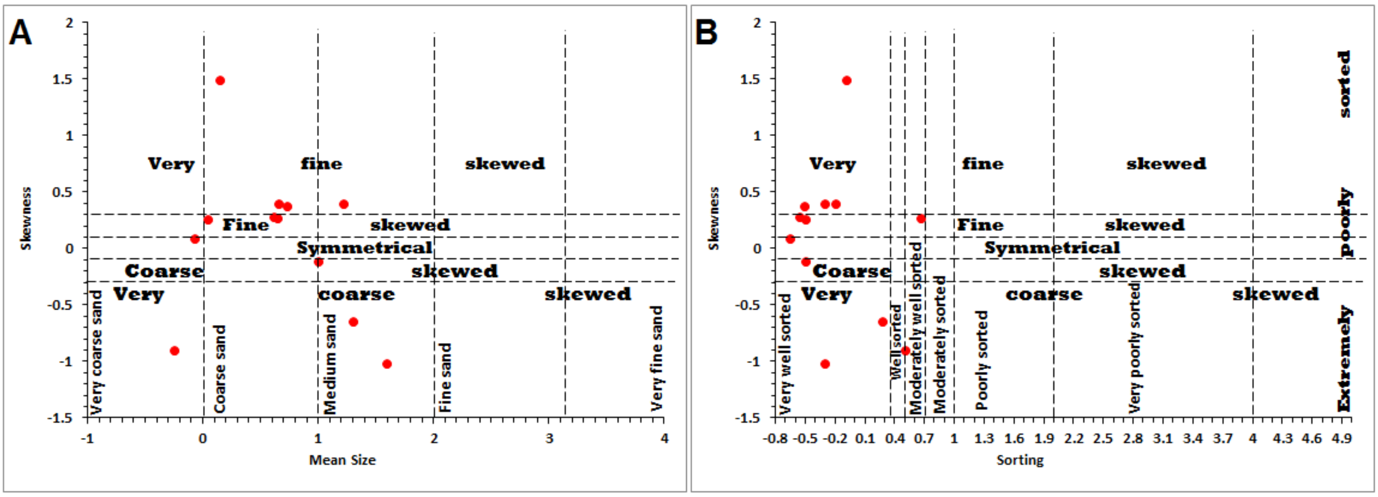


*Fig.10. Bivariate plots: (A) Mean size vs. Skewness; (B) Sorting vs. Skewness, fields based on [60].*

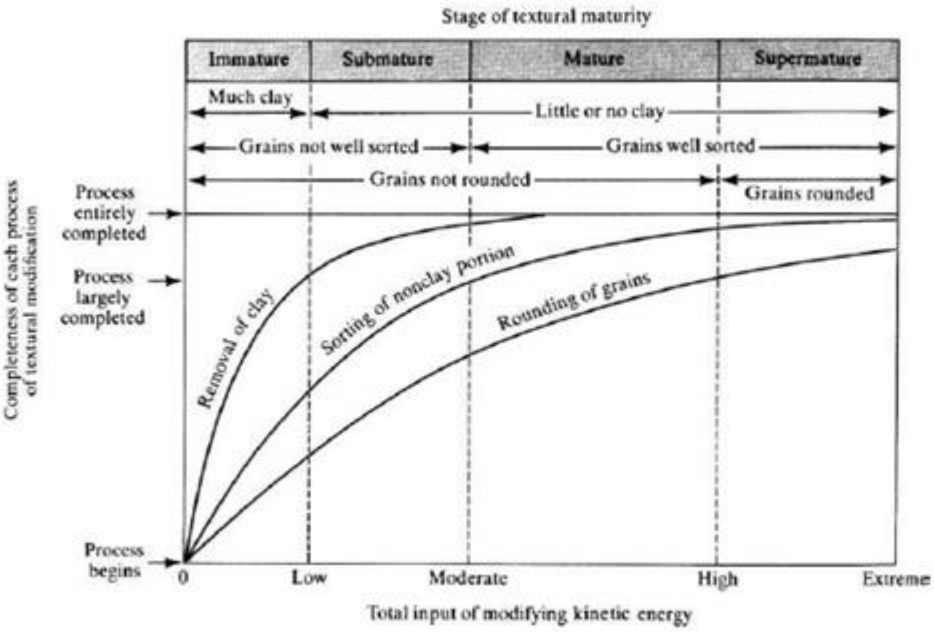


*Fig.11. Textural maturity classification of Folk. Textural maturity of sands is shown as a function of input of kinetic energy [61].*

**(a)** Discrimination between Aeolian and beach environment ($Y_1$)
$Y_1 = -3.5688\ Mz + 3.7016\ \delta 1^2 - 2.0766\ SK + 3.1135\ KG$
If Y1 is less than -2.7411, Aeolian deposition is indicated and if greater than -2.7411, the environment is beach. All the samples have $Y_1$ values that are greater than -2.7411 (Table 3), which imply beach environment.

$Y_3 = 0.2852\ Mz - 8.7604\ \delta 1^2 - 4.8932\ SK1 + 0.0482\ KG$
If $Y_3$ is less than -7.419 the environments is fluvial, and if greater than -7.419 the environment is shallow marine. All the samples have $Y_3$ greater than -7.419, which indicates shallow marine environment.

**(d)** Discrimination between Fluvial and turbidity ($Y_4$)
$Y_4 = 0.7215\ Mz + 0.403\ \delta 1^2 + 6.7322\ SK + 5.2927KG$

**(b)** Discrimination between beach and shallow agitated marine environment ($Y_2$)
$Y_2 = 15.6534\ Mz + 65.7091\ \delta 1^2 + 18.1071\ SK + 18.5043\ KG$
If $Y_2$ is less than 65.3650, beach deposition is indicated and if greater than 65.3650, it is shallow agitated marine environment. All the sediments have $Y_2$ less than 65.3650 which imply beach environment.
**(c)** Discrimination between shallow agitated marine and the fluvial environments ($Y_3$)
If $Y_4$ is less than 10.000, the environment is Fluvial and .If greater than 10.000, the environment is Turbidity. 75% of the samples have $Y_4$ less than 10, this implies a fluvial environment. While 25% were deposited by turbidity action.
Figure 12 show the cross plots of the linear discriminant functions of the sandstone facies of the Ise Formation which indicates a shallow marine beach environment.

TABLE 3. VALUES OF THE LINEAR DISCRIMINANT FUNCTIONS

| Samples | Irolu 1 | Irolu 2 | Irolu 3 | Irolu 5 | Irolu 6 | Irolu 7 | Irolu 8 | Irolu 9 | Irolu 10 | Irolu 11 | Irolu 12 | $J_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Y_1$ | 4.1516 | 1.0211 | 1.765 | 0.4183 | 2.3104 | 5.866 | 0.8849 | 5.6433 | 1.5849 | -0.7502 | -0.0767 | 0.0178 |
| $Y_2$ | 56.296 | 26.3873 | 55.2096 | 46.9278 | 45.4869 | 9.1705 | 56.1129 | 52.1665 | 59.2692 | 56.8953 | 50.4281 | 37.9951 |
| $Y_3$ | 2.9751 | -3.4389 | -3.8913 | -1.3228 | 4.688 | 2.1762 | -4.9219 | -4.0994 | -3.8676 | -2.3881 | -7.2679 | -2.0756 |
| $Y_4$ | 8.8849 | 3.2032 | 8.1676 | 4.8981 | 3.6871 | -2.4337 | 6.054 | 7.5532 | 10.0173 | 10.5453 | 16.0631 | 8.3119 |

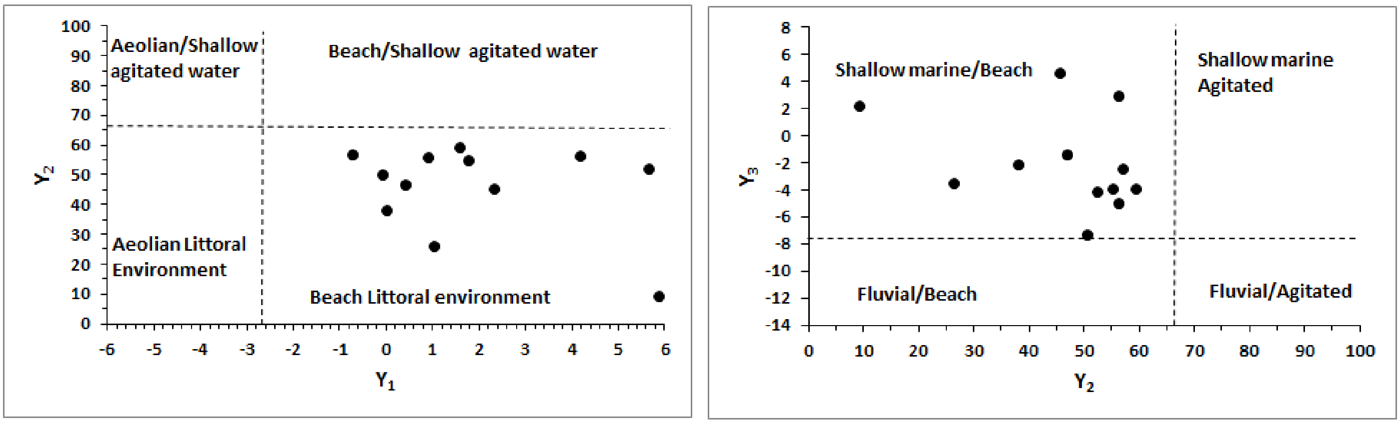


*Fig.12. Cross plots of the linear discriminant functions of the sediments, $Y_1$-$Y_2$ and $Y_2$-$Y_3$.*

### *C-M Pattern*

The way to determine the environmental conditions in which sediment was deposited is to use the CM pattern or the Passega diagram based on the Parameter C (one percentile of the grain size distribution) and M (the Median: $50^{th}$ percentile of the grain size distribution), as useful in the hydrodynamic interpretation of grain size data. The Passega diagram in Figure13 features several fields, pelagic suspension (T field), uniform suspension (SR field), gradual suspension (QR field), suspension and rolling (QP field), rolling and suspension-PO, rolling (ON field) corresponding to the various transports and sedimentation conditions in the marine, littoral or fluvial domains. From the Passega diagram majority of the samples plotted within the uniform suspension-SR zone; some appeared in the QR zone, while two of the samples plotted in the pelagic suspensions (field T). SR (uniform suspension) segment indicates the role of uniform suspension in transporting segments.

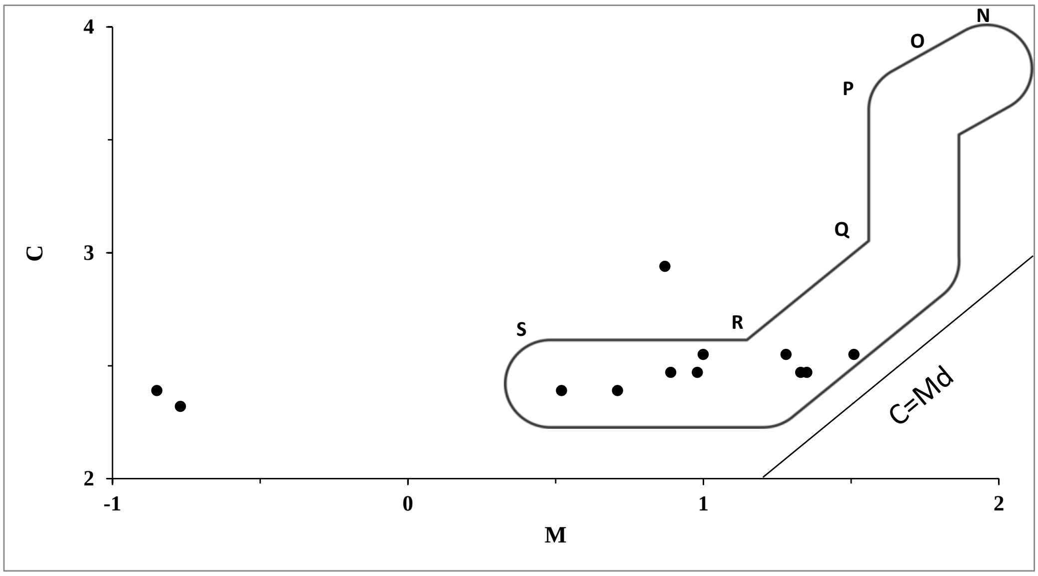


*Fig.13. Passega diagram for the studied samples*

## Conclusion

The granulometric analysis reveals that the sandstone facies of the Ise Formation have low sphericity and range from angular to sub-rounded. The outlay is dominantly asymmetrical with varying modal class, which could be attributed to variation in the energy of the transporting medium. The graphic mean ranges from very coarse grained to medium grained, which suggests strong to moderate energy conditions of deposition. The graphic standard deviation ranges from very well sorted to moderately well sorted; graphic skewness ranges from very coarse skewed to very fine skewed; while the graphic kurtosis ranges from very playtykurtic to very leptokurtic. A Bivariate plot (moment skewness vs. moment standard deviation)shows the samples plotting in the beach sand zone. The sediments are texturally mature with moderate to high input of modifying kinetic energy. Linear discriminant functions analysis indicates a shallow marine beach environment. From the Passega diagram, majority of the samples plotted within the uniform suspension zone; while some appeared in the gradual suspension zone. The uniform suspension segment indicates the role of uniform suspension in transporting segments.

*References*

[1] Pettijohn, F.J. 1975., Sedimentary Rocks (3rd edition). Harper and Row, New York.

[2] Basu A. 2003., Provenance. In: Encyclopedia of Sediments and Sedimentary Rocks (Ed. Middleton, G.V.). Kluwer Academic Publishers, Dordrecht; 544–549.

[3] Trask, PD. 1932., Origin and environment of source sediments of petroleum, Gulf Pub. Co., Houston

[4] Inman, D.L.1952., Measures for describing the size distribution of sediments. Jour. Sediment. Petrol. 22, 125-1-15.

[5] Shepard, F.P., Moore, D.G. 1955., Central Texas Coast sedimentation: Characteristics of sedimentary environment, recent history and diagenesis. Am. Ass. Petrol. Geologists Bull. 39, 1463-1593.

[6] Folk, R.L., and Ward, W.C., 1957. Brazos river bar: A studv in the significance of gram size parameters . Jour. Sediment. Petrol. 27,3-26.

[7] Passega, R. 1957., Texture as characteristic of clastic deposition. Am. Ass. Geologists Bull. 41, 1952-1984.

[8] Mason, C.C., Folk, R.L., 1958 Differentiation of beach, dune and aeolian flat environments by grain size analysis. Mustang Island, Texas. Jour. Sediment. Petrol. 28, 211-226.

[9] Shepard, F.P., 1960. Gulf coast barriers. In: Recent sediments, Northwest Gulf of Mexico. Am. Ass. Petrol. Geologists Bull. 197-220.

[10] Cadigan R.A., 1961. Geologic interpretation of grain size distribution measurement of Colorado Plateau sedimentary rocks journal of geology vo1.69; 121- 142.

[11] Friedman, G.M.,1961. Distinction between dune, beach and river sands from their textural characteristics. Jour. Sediment. Petrol. 31, 514-529.

[12] Passega, R., 1964. Grain size representation by CM patterns as a geological tool. Jour. Sediment. Petrol. 34. 830-847.

[13] Friedman, G.M., 1967. Dynamic processes and statistical parameters compared for grain frequency distribution or beach and river sands; Jour. Sediment. Petrol. 37, 327-354.

[14] Friedman, O.M.,1979. Dillerences in size distributions of populations of particles among sands or various origrns Sedimentology. 26, 3-32.

[15] Sahu, B.K.,1964. Depositional mechanisms from the size analysis of clastic sediments. Jour. Sediment. Petrol. 34, 73-83.

[16] Klovan, J.E., 1966. The use of factor analysis in determining depositional environments from grain-size distributions. Jour. Sediment. Petrol 36, 115-125.

[17] Passega, R., and Byrarnjee, R., 1969. Grain-size image of clastic deposits. Sedimentology. 13, 233-252.

[18] Visher, G.S.,1969. Grain-size distribution and depositional processes. Jour. Sediment. Petrol. 39,1074-1106.

[19] Solohub, J.T., Klovan, J.E., 1970. Evolution of grain size parameters in lacustrine environments; Jour. Sediment. Petrol. 40, 81-10l.

[20] Tiara.A. and Scholle.P., 1979. Discrimination of depositional environments using settling tube data. Journal of sedimentary petrology vol 49(3) 787-800 Tulsa-USA.

[21] Sly, P.G., Thomas, R.L., and Pelletier,B.R., 1983. Interpretation of measures derived from water laid sediments. Sedimentology. 30,219-233.

[22] Russell, R.D., 1937. Mineral composition of Mississippi River sands. Bulletin of the Geological Society of America, 48: 1307-1348

[23] Shukri, N.M., 1949. The mineralogy of some Nile sediments. Quarterly Journal of the Geological Society of London, 105(4): 511-535.

[24] Van Andel, T.H., 1950. Provenance, transport and deposition of Rhine sediments: a heavy mineral study on river sands from the drainage area of the Rhine. Veenman en Zonen, Wageningen, The Netherlands.

[25] Morton, A.C. and Smale, D., 1990. The effects of transport and weathering on heavy minerals from the Cascade River, New Zealand. Sedimentary Geology, 68: 117-123.

[26] Morton, A.C. and Johnsson, M.J., 1993. Factors influencing the composition of detrital heavy mineral suites in Holocene sands of the Apure River drainage basin, Venezuela. In: M.J. Johnsson and A. Basu (Editors), Processes Controlling the Composition of Clastic Sediments. Geological Society of America Special Paper, Boulder, Colorado, pp. 171-185.

[27] Allen, P. and Mange-Rajetzky, M., 1982. Sediment dispersal and palaeohydraulics of Oligocene rivers in the eastern Ebro Basin. Sedimentology, 29: 705-716.

[28] Preston, J. et al., 2002. The provenance of Triassic continental sandstones from the Beryl Field, Northern North Sea: mineraological, geochemical, and sedimentological constraints. Journal of Sedimentary Research, 72(1): 18-29.

[29] Flores, R.M. and Shidler, G.L., 1978. Factors controlling heavy mineral variations on the south Texas outer continental shelf. Journal of Sedimentary Petrology, 48: 269-280.

[30] Mange-Rajetzky, M.A., 1983. Sediment dispersal from source to shelf on an active

continental margin, S. Turkey. Marine Geology, 52: 1-26.

[31] Callahan, J.E., 1980. Heavy minerals in stream sediments from Churchill Falls, Labrador - an aid to bedrock mapping. Canadian Journal of Earth Sciences, 17: 244-253.

[32] Weissbrod, T. and Nachmias, J., 1986. Stratigraphic significance of heavy minerals in the Late Precambrian- Mesozoic clastic sequence ("Nubian Sandstone") in the Near East. Sedimentary Geology, 47: 263-291.

[33] Morton, A.C., Humphreys, B., Dharmayanti, D.A. and Sundoro, 1994. Palaeogeographic implications of the heavy mineral distribution in Miocene sandstones of the North Sumatra Basin. Journal of Southeast Asian Earth Sciences, 10(3/4): 177-190.

[34] Morton, A.C., 1992. Provenance of Brent Group sandstones: Heavy mineral constraints. In: A.C. Morton, R.S. Haszeldine, R.S. Giles and S. Brown (Editors), Geology of the Brent Group. Geological Society of London, London, pp. 227-244..

[35] Lihou, J.C. and Mange-Rajetzky, M.A., 1996. Provenance of the Sardona Flysch, eastern Swiss Alps: example of high-resolution heavy mineral analysis applied to an ultrastable assemblage. Sedimentary Geology, 105: 141-157.

[36] Klemme, H.D., 1975. Geothermal gradient, heat flow and hydrocarbon recovery. In: A.G. Fisher and S. Judson (eds). Petroleum and global tectonics. Princeton University Press. p. 251-304.

[37] Kingston, D. R., Dishroon, C. P. and Williams, P. A., 1983. Global Basin Classification System. AAPG. Bull., Vol. 67:2175-2193..

[38] Whiteman, A. J., 1982. Nigeria: Its Petroleum Geology, Resources and Potential, Graham and Trotman, London, Vol 2: 394pp.

[39] Jones, H.A. and Hockey R.D., 1964., The Geology of part of Southwestern Nigeria. Bull. Geol. Surv. Nig., 31: 101.

[40] Omatsola, M.E. and Adegoke, O.S., 1980. Tectonic Evolution of the Dahomey basin [West Africa] and its implication in the opening of the North and South Atlantic. Broc. 26th Int. Geol. Paris pp 268.

[41] Omatsola, M.E and Adegoke O.S., 1981. Tectonic and Cretaceous Stratigraphy of the Dahomey basin. Journal of Mining Geology, 154 (1): p.65-68.

[42] Agagu, O.A., 1985. A geological guide to Bituminous sediments in Southwestern Nigeria. Unpublished Report, Department of Geology University of Ibadan.

[43] Adegoke, O.S., 1977. Stratigraphy and Paleontology of the Ewekoro Formation (Paleocene) of Southwestern. Nig. Bull. Am. Paleontol., 71(293): 375.

[44] Ogbe, F.G.A., 1972. Stratigraphy of Strata Exposed in Ewekoro Quarry, Southwestern Nigeria. In: African Geology, p. 305-322.

[45] Kogbe, C.A., 1976. Geology of Nigeria.Second revised edition, Published by Rockview Nig. Ltd. 538pp.

[46] Bankole, S. I., Schrank, E. Erdtmann, B. D and Akande, S. O., 2006. Palynostratigraphic Age and Paleoenvironments of the newly exposed section of the Oshosun Formation in the Sagamu Quarry, Dahomey Basin. Nigerian Association of Petroleum Explorationists Bulletin. vol. 19, 1 p. 25 – 30.

[47] Nichols, G., 2009. Sedimentology and stratigraphy, 2nd ed. Wiley-Blackwell Publishers, UK, 419pp.

[48] Martins, L.R., 1965.Significance of skewness and kurtosis in Environmental interpretation journal of sedimentary petrology vol.35 (3):768-770 Tulsa USA.

[49] Martins, L.R., 1967. Aspestis texturais edeposicio nais dos sediments praicias e ecolicos da planicie costera do Rio Grande do sul. Escola de gelogia. UFRGS publicacao especial 13, 102p.

[50] Awasthi. A.K., 1970. Skewness as an environmental indicator in the Solami River System rookec India .sedimentary geology vol. 4: 177-183.

[51] Cronan, D.S.,1972 Skewness and kurtosis in polymodal sediments from Irish Sea. Journal of sedimentary petrology vol. 42(1):102-106. Tulsa, USA.

[52] Friedman, G.M., 1961. Distiction between Dune, Beach and river sands from textural characteristics, Journal of Sedimentary petrology, 31:514-529.

[53] Folk R.L (1966). A review of the grain size parameters. Sedimentology 6:73–93.

[54] Boggs, S.Jr., 2009. Petrology of Sedimentary Rocks, Second Edition. Cambridge University Press, UK, 600pp.

[55] Baruah J, Kotoky P, Sarma J., 1997. Textural and geochemical study on river Sediments: a case study on the Jhanji River, Assam. J Indian Assoc Sedimental 16:195–206.

[56] Ray A.K, Tripathy S.C, Patra S, Sarma V.V.,2006. Assessment of Godavari estuarine mangrove ecosystem through trace metal studies. Environ Int 32:219–223.

[57] Friedman, G. M., 1962. On sorting, sorting coefficients, and the lognormality of the grain-size distribution of sandstones. J. Geoll., 70, 737-753.

[58] Moiola R. 1. and Weiser D., 1968. Textural parameters: An evaluation. Journal of Sedimentary Petrology. Vol. 38. pp. 45-53.

[59] Mycielska-Dowgiałło, E., 2007. Metody badań cech teksturalnych osadów klastycznych i wartość interpretacyjna wyników [Research methods for textural features of clastic deposits and the significance of interpretational results]. [In:] E. Mycielska-Dowgiałło & J. Rutkowski (Eds): Badania cech teksturalnych osadów czwartorzędowych i wybrane metody oznaczania ich wieku [Research into the textural features of Quaternary sediments and some dating methods]. The Family Alliance School of Higher Education Press, Warsaw, 95–180.

[60] Blott, S.J. and Kenneth, P., 2001. Gradistat: A Grain Size Distribution and Statistics Package for The Analysis of Unconsolidated Sediments. Earth Surf.. Process. Landforms 26, 1237–1248

[61] Folk, R. L., 1951, Stages of textural maturity in sedimentary rocks: J. Sediment. Petrol., 21, 127–130.