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Dear Editorial Manager,

I am enclosing herewith a manuscript entitled "*Sedimentological Characteristics, and Provenance of the Late Cretaceous Sediment in the Eastern Dahomey Basin*" for publication in the editorial manager for possible evaluation. The author of this manuscript is Mafimisebi O. Peter, and the contribution of the author is Nsodikwa B. Ngozi.

This work reflects research on deciphering the Sedimentological characteristics and depositional environments of the sandstone facies exposed at Idobilayo, Southwestern Nigeria. The research corroborates previous studies indicating that the study area is made of medium to coarse-grained sand. Likewise, the sands are moderately well sorted.

I believe this submission will be useful to your readers, as it addresses some critical methodologies for discovering the depositional environment of the study area. This manuscript has been submitted to sedimentary geology journal. The current version is a preprint which has not yet been peer reviewed. Subsequent versions of this manuscript may have slightly different content. If accepted, the final version of this manuscript will be available via the 'Peer-reviewed Publication DOI' link on the right hand side of this webpage"

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Sedimentological Characteristics, and Provenance of the Late Cretaceous Sediment in the Eastern Dahomey Basin

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Abstract

Field studies of outcrop samples from part of the Dahomey basin, southeastern Nigeria, were investigated to unravel the lithofacies distribution and provenance of the basin. Granulometric analysis of the sandstone facies of the Araromi Formation has been studied. Histograms of the sediments exhibit both unimodal and bimodal trends. The cumulative curve of the studied samples Is typical of fluvial sands. 1.19 ϕ is the mean value for the grain size distribution within the analyzed sediments with a graphic mean distribution for these sediments ranging from 0.84 ϕ to 1.47 ϕ, indicative of medium to coarse-grained sand. The standard deviation (sorting) shows a spread of 0.50ϕ to 0.96 ϕ and a mean value of 0.78 ϕ. Most of the samples are moderately well sorted. The skewness values of the samples ranged from 0.14 to 0.37, thus indicating the presence of fine fraction and coarse fraction in the particle population. The kurtosis is between 0.01 to 1.78, indicating that 33% are very leptokurtic, 33% are mesokurtic and 33% are very platykurtic.

Keyword: Sedimentology, Provenance, Palaeoenvironment, Dahomey Basin

1. Introduction

Dahomey basin is a sedimentary extensive basin located in West Africa; it covers much of the continental margin of the Gulf of Guinea, extending from Volta-delta in Ghana through the Togo and

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republic of Benin to southwestern Nigeria, where it is separated from and cut off by stratigraphically younger Niger delta (Jones and hockey, 1964; Omatsola and Adegoke 1981). The basin is bounded in the west by faults and other tectonic structures associated with the landward extension of the fracture zone. Its Eastern limit is similarly marked by the hinge line, a major fault structure marking the western limit of the Niger delta (Adegoke, 1969; Omatsola & Adegoke, 1981). It is also bounded in the north by Precambrian basement rock and the bright of Benin in the south (Fig. 1). The basin fill covers a broad arc-shape profile, attaining about 13km maximum width onshore at the basin axis along Nigeria and the republic of Benin boundary. This narrows westwards and eastwards to about 5km (Coker and Ejedawe, 1987; Coker, 2002). This research aims at determining the sedimentological characteristics and depositional environments of the sandstone facies exposed at Idobilayo, Southwestern Nigeria.

1.1 Location of Study area and Stratigraphy of Dahomey Basin.

The study area is located in the Idobilayo area, Southwestern Nigeria. The study area lies within Latitude N 06^{o}38'36" and longitude E 04^{o}34'48". The sedimentary succession in this area is part of the basal sediments of the Araromi Formation of the Dahomey basin, which was well exposed having a total thickness of about 30.1 m.

The Dahomey Basin evolved in the Late Jurassic - Early Cretaceous as a result of the separation of the African and South American plates which led to the opening of the South Atlantic Ocean. The Romanche, Chain, and Charcot fractures zone which develops during the drifting stages of South America away from Africa enhances the development of numerous horst and graben features in the Dahomey basin. The horst and graben structural features control the deposition of Cretaceous to Tertiary sediments in the basin (Ako *et al.,* 1980; Omatsola and Adegoke, 1981). The stratigraphic

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setting of the Dahomey Basin has been described in detail in the works of Adegoke (1969), Ogbe (1970), Kogbe (1970), Billman (1976), Omatsola and Adegoke (1981), Ako *et al.,* (1980), Okosun (1990), Idowu *et al.,* (1993), and Adekeye *et al.,* (2006). These authors reported five lithostratigraphic formations covering the Cretaceous to Tertiary ages. The formation from the oldest to the youngest includes; The Abeokuta Group comprising Ise, Afowo, and Araromi formations (Cretaceous), Ewekoro Formation (Paleocene), Akinbo Formation (Late Paleocene-Early Eocene), Oshosun Formation (Eocene) and Ilaro Formation (Middle-Late Eocene) Fig. 2.

2. Materials and Methods

The fieldwork took place for about a week in the month of December 15, 2019, in the Dahomey basin. In this exercise, bed-to-bed lithology mapping and logging of sections were carried out. Sedimentary structures, textures, and color were observed, and measurements were taken using the measuring tape. Fresh samples were collected inside the sample bag by scraping the surface with the use of a hammer and chisel. The Coordinate of each location was taken using the global positioning system (GPS). All the measurements and observations were recorded in the field note. Each sample collected was labeled to avoid missing. Granulometric analysis (sieve analysis) was carried out on samples taken from the study (Idobilayo area) in the sedimentology laboratory of the Department of Geology University of Ilorin, Ilorin.

The grain size analysis was carried out on three (3) samples collected from the field and this was done using a stack of sieves which are of different sizes ranging, from an automatic vibrating machine (vibrator), electronic weighing balance, and a plane paper to collect samples and a stopwatch for timing. The analysis is aimed at determining the weight retained based on the size of grains with respect to the

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sieve size. 100 grams of each sample were weighed using an electronic weighing balance and poured into a stack of connected sieves which are of different sizes ranging from 1.18mm, 1.00mm, 0.71mm, 0.60mm, 0.50m, 0.42mm, 0.30mm, 0.25mm, 0.112mm, 0.075mm, 0.063mm and less than 0.063mm. The required sieves were arranged according to decreasing mesh sizes with the smallest opening at the bottom and the pan which collects the finest grain and the top is covered with a lid. The sieves and the bottom pan were fastened to the mechanical shaker, and 100g of the samples were poured into the upper sieve. The machine was allowed to shake for ten (10) minutes. The sediments retained in each of the sieved bottom pans were weighed and their weight was recorded.

3. Results and Discussions

3.1 Lithology Description

The total thickness of the exposed section is approximately 30.1m from the base. It is made of shale having parallel lamination with a thickness of 10m. Overlying this is Sandstone which has reddish color having a thickness of 12m, followed by a silty-claystone with a thickness of 10.1m, and capping the exposed section is the medium grain sandstone bed of about 6.0m thick (Fig 3).

3.2 Grain Size Analysis Result

The grain size analysis was carried out on three (3) carefully selected samples; I.B 2A, I.B 2B, and I.B 3A. A table composed of sieve size diameter, phi(ϕ), weight retained(g), percentage weight retained (%), cumulative weight retained(g), and percentage cumulative weight retained (%) are recorded in Appendix A. Graph of cumulative weight retained (%) was plotted against phi (ϕ). The results obtained were used for the construction of the environment of deposition of the sediments which includes; the energy of deposition, transportation history, and maturity of the sedimentary rock. The cumulative

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curves of sediments are recorded in (Fig. 7-9). From the histogram charts in (Fig. 10-12), the percentage weight retained (g) against phi(φ) shows that the samples from the study area are poly-modal, this shows fluctuation in the energy of transportation. Results from grain size analysis show that the sediments are characterized by predominantly moderately sorted, medium to coarse grain. The study area shows that the sediments are sparsely distributed i.e. the sediments are moderately sorted.

Grain size analysis provides clues to sediment depositional conditions and transpositional history according to Folk and Ward, (1957); the standard plots of Friedman, (1967, 1979) have been characterized into beach and river deposits. The main purpose of the analysis is to determine the environment of deposition, mode of transportation, and particle grain size distribution in the sandstone facies and silt claystone facies of the study area. A total of two (2) sandstone and one (1) Silty-claystone samples were selected from the lithologic sections for granulometric analysis. The formula used in calculating the respective parameters was adopted from Folk and Ward, (1957). Scatter plots of mean versus sorting (Fig. 4), sorting versus skewness (Fig. 5), and skewness versus kurtosis (Fig. 6) were also plotted. These plots show that the analyzed samples are essentially fluvial deposits of continental environment. The cumulative plot (Fig. 7-9), shows that the dominant mode of transportation for the sandstone and silty-claystone samples is mainly saltation and little amount of suspension which means medium-fine sand and fine particles were transported.

3.2.1 Graphic Mean

The mean is the average size of grain particles deposited in the sediment. It majorly characterizes the index of energy conditions during sediment transportation and deposition. In general, the mean grain size of the samples from the study area ranges from 0.84 ϕ (coarse sand) to 1.47 ϕ (medium sand)

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with an average value of (1.78 ɸ). From the average value for mean grain size, medium to coarse grain sands predominate the study area. This indicates that the energy condition of the depositing agent was moderate (Wentworth, 1922).

Below is the mathematical formula for the mean according to Folk and Ward, (1957).

$$\text{Graphic mean} = \frac{\Phi 16 + \Phi 50 + \Phi 84}{3}$$

3.2.2. Graphic Standard Deviation (Sorting)

Sorting describes the distribution of grain size of sediments, either in unconsolidated deposits or in sedimentary rocks. It can also be defined as the degree of sediment arrangement as well as the grain size distribution and it corresponds with the standard deviation. The degree of sorting in sandstones generally depends on the sediment source, grain size, and the depositional regime. It is indicative of hydrodynamic condition (i.e. range of velocities and degree of turbidity) operating within the transporting medium and to some extent, it is suggestive of the distance traveled (Krumbein and Sloss, 1963). The value of the standard deviation tends to show most of the samples are moderately sorted with a few moderately well sorted. The values for this study area range from 0.50ɸ to 0.96 ɸ, with an average value of 0.78 ɸ. Samples from the study are moderately sorted. The transport process (river) is responsible for laying down the sediment.

The mathematical formula for Graphic Standard Deviation (Sorting) as derived from Folk and Ward (1957) is given as;

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$$\text{Graphic sorting} = \frac{(\Phi 84 - \Phi 16)}{4} + \frac{(\Phi 95 - \Phi 5)}{6.6}$$

3.2.3. Graphic Skewness

It is the measure of the symmetry or bias in the grain size distribution. It determines whether the sediments are characterized by predominantly coarse or fine sediments. Positively skewed samples have an excess of fine grains an indication of a low-energy environment; negatively skewed samples have an excess of coarse grains; an indication of a high-energy environment. The samples analyzed have skewness values ranging from 0.14 to 0.37 which indicates fine skewed to strongly fine skewed. The result shows that samples from the study are positively skewed.

Skewness can be obtained using the formula according to (Folk and Ward, 1957)

$$\text{Skewness} = \frac{(\Phi 16 + \Phi 84 - 2\Phi 50)}{2(\Phi 84 - \Phi 16)} + \frac{(\Phi 5 + \Phi 95 - 2\Phi 50)}{2(\Phi 95 - \Phi 5)}$$

3.2.4. Kurtosis

The graphic kurtosis quantitatively measures how the sediments depart from normality. It clearly describes the sorting at the tails of the curve and relates them to the central portion. Kurtosis is the measure of the flatness of grain size or the measure of the peakedness of distribution as it will appear on the simple frequency curve. Flat distributions are platykurtic and peaked distributions are leptokurtic and the intermediate between these two is called mesokurtic. The various samples analyzed show that samples from the study area are very platykurtic mesokurtic and Very Leptokurtic, the kurtosis value ranges from 0.01 (very platykurtic) to 1.78 (very leptokurtic) character. This showed that the sediments are transported by low to higher -energy environments before being redeposited in a different environment completely different environment.

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$$\text{Kurtosis} = \frac{(\Phi95 - \Phi5)}{2.44(\Phi75 - \Phi25)}$$

4. Conclusion

Sedimentological studies have been used to understand the provenance of sediment samples. Nearly poly-modal frequency distribution indicates a single provenance for the sediments. Textural studies indicate that the sediments belong to the medium to coarse-grained sand fraction, suggesting that the sediments were deposited under moderate energy conditions, with the sediments being moderately sorted, indicating texturally immature to sub-matured sediments of a fluvial environment.

Declarations

Author contribution statement

Mafimisebi O. Peter Contributed materials, analysis tools, or data; Wrote the paper and Nsodikwa B. Ngozi Contributed materials, analysis tools, or data.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interest statement

The authors declare no conflict of interest

Additional information

No additional information is available for this paper.

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Acknowledgments

We acknowledge the Department of Geology and Mineral Sciences, University of Ilorin, for the support towards the completion of this work.

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Reference List

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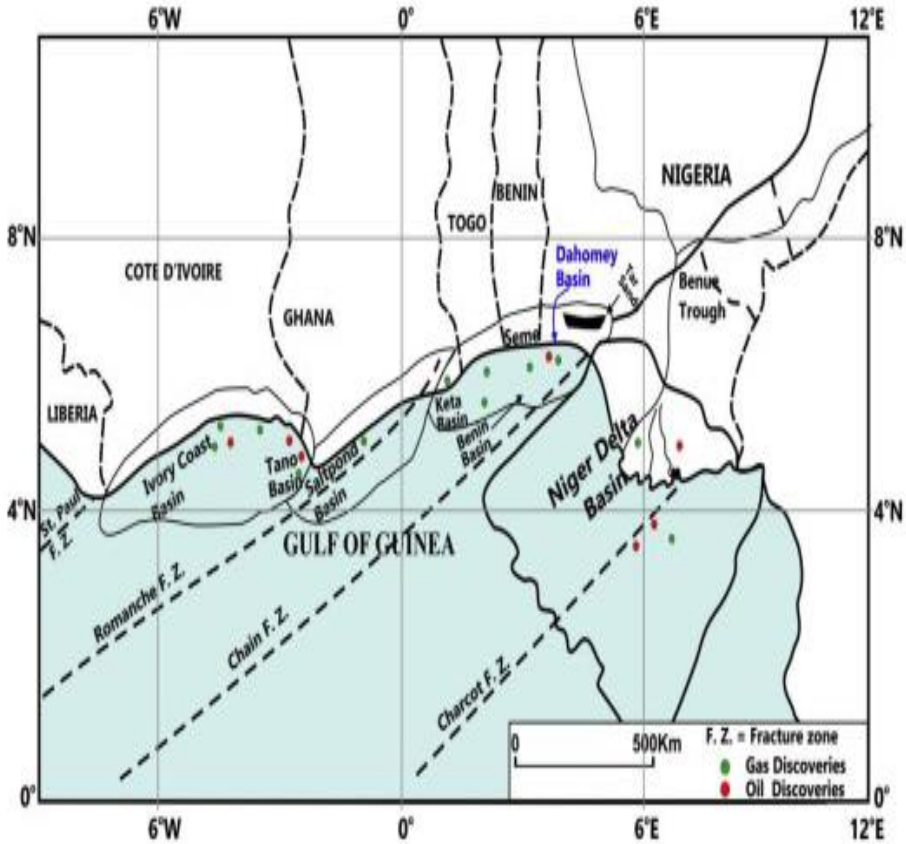

Figure 1

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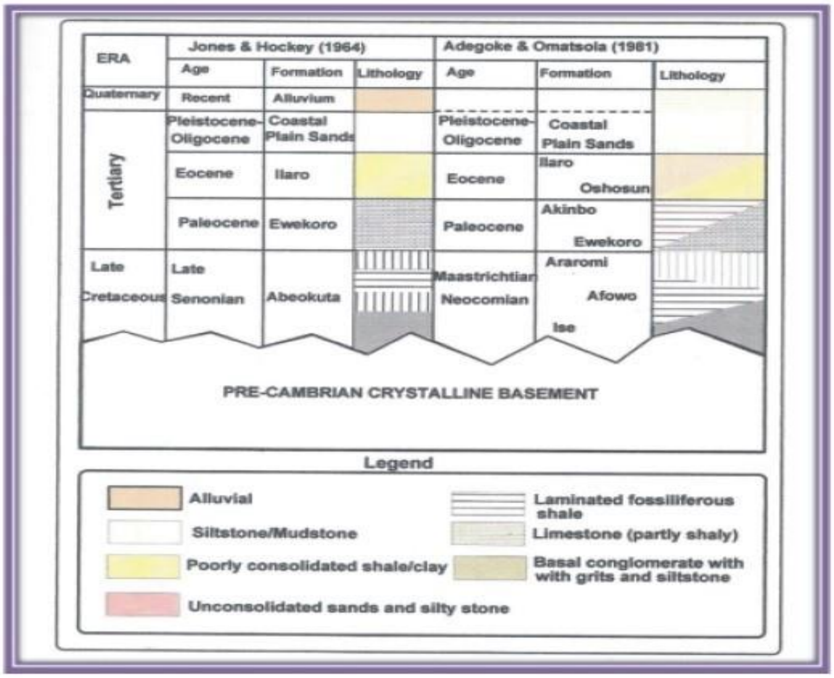

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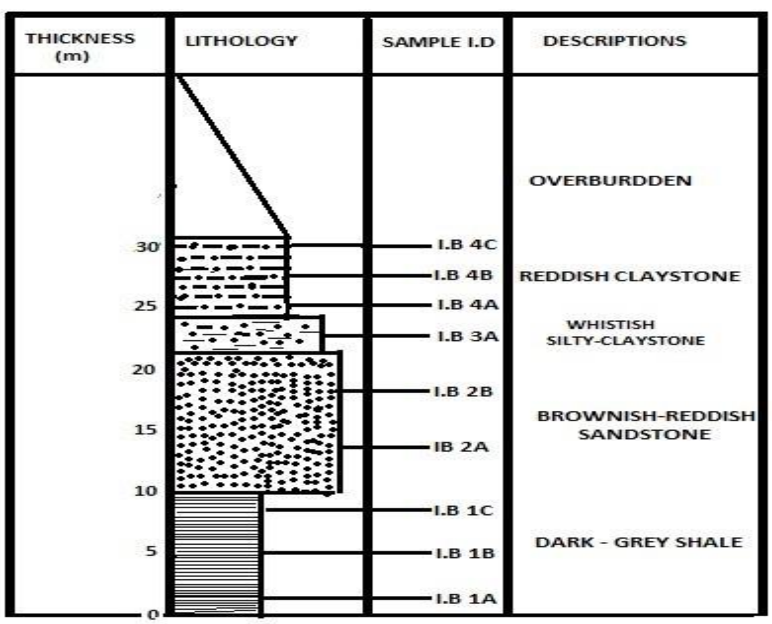

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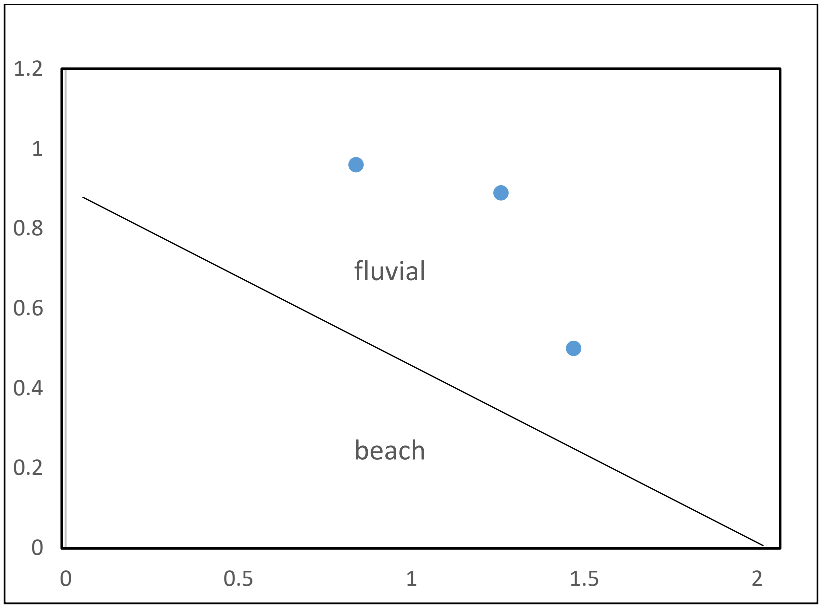

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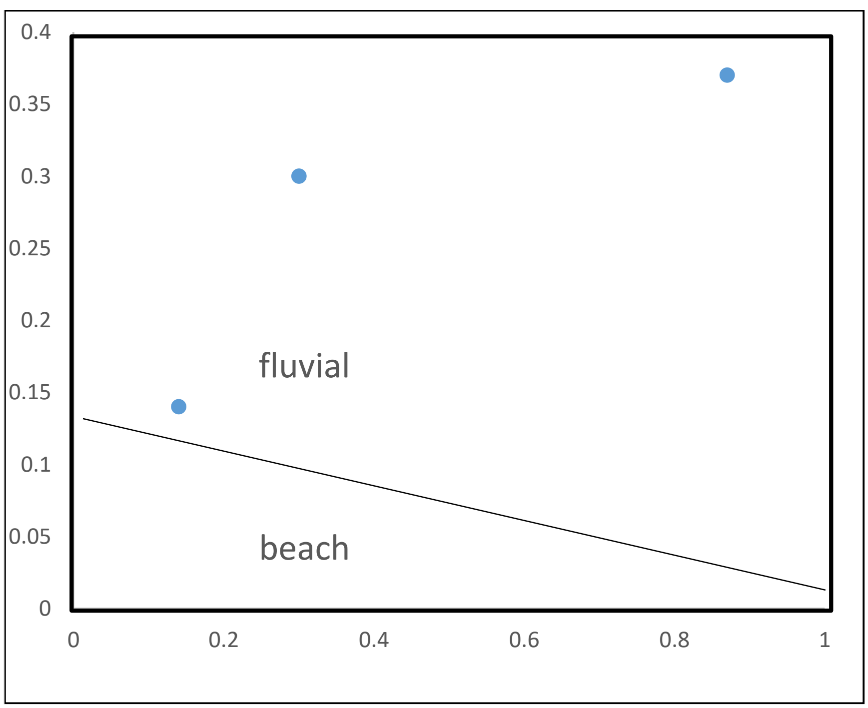

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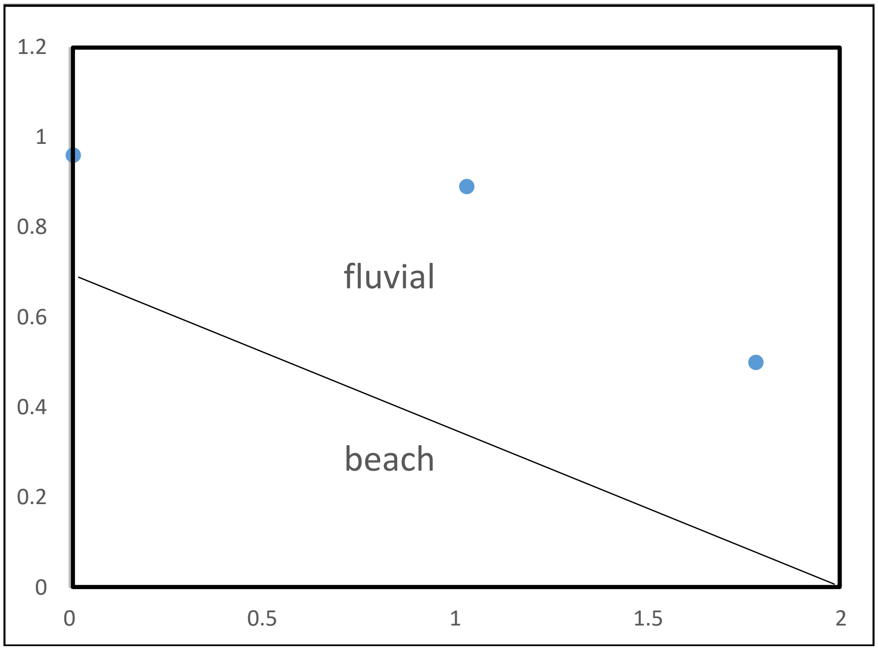

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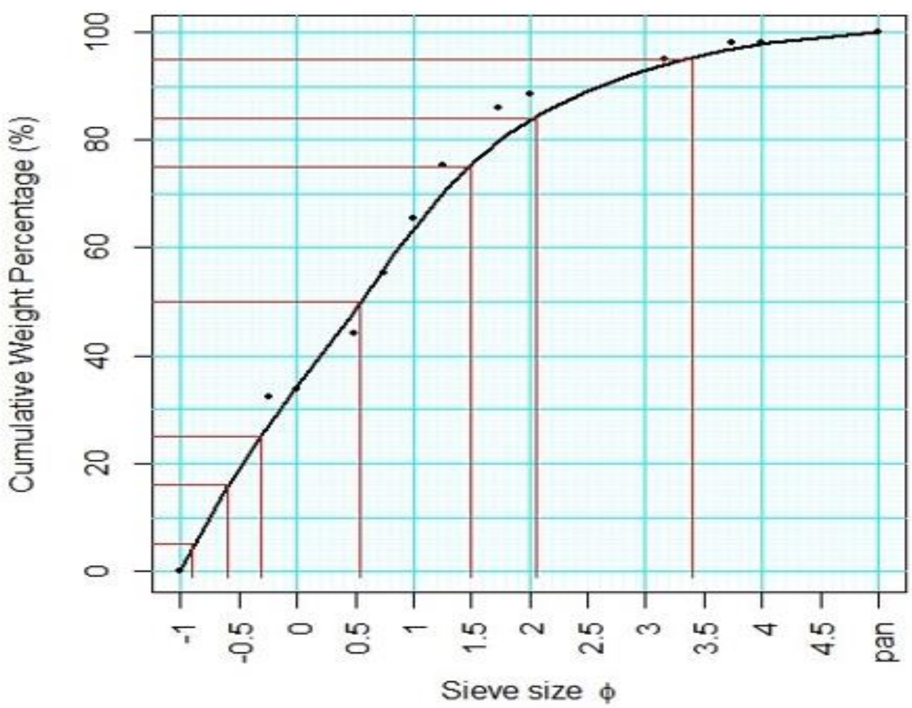

Figure 7

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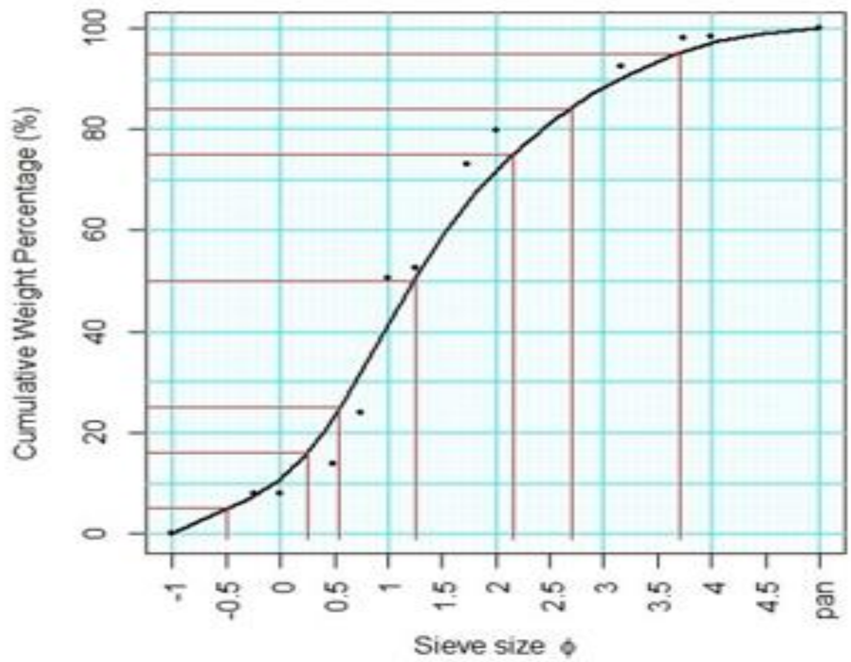

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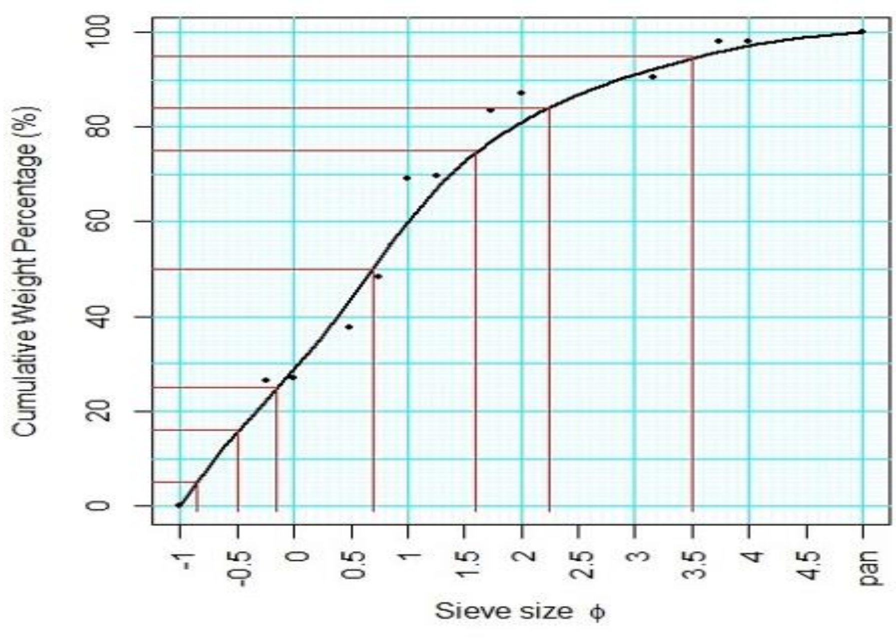

Figure 9

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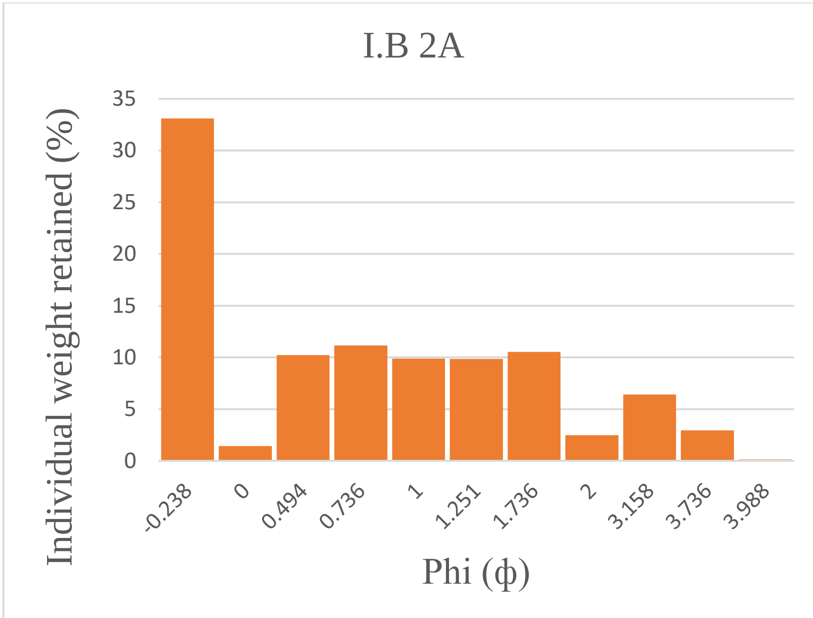

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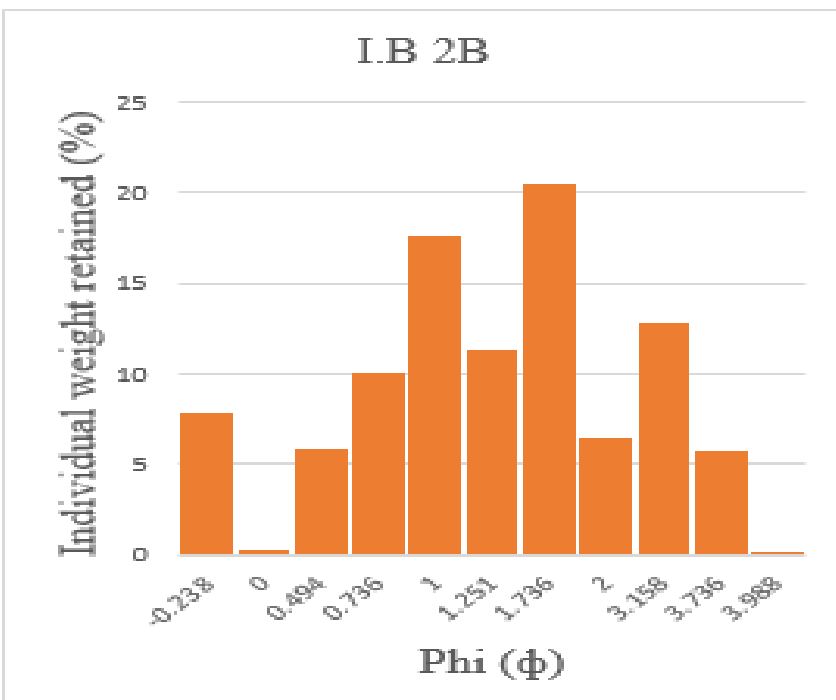

Figure 11

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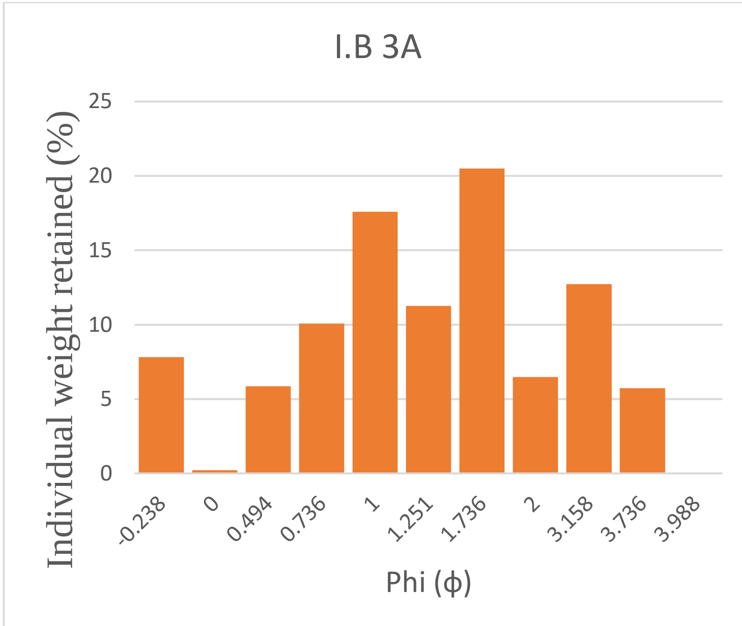

Figure 12

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Table 1

Mean range (Ø)	Description
-1.00 - 0.00	Very coarse sand
0.00 - 1.00	Coarse sand
1.00 - 2.00	Medium sand
2.00 - 3.00	Fine sand
3.00 - 4.00	Very fine sand
>4.00	Silt

Table 2

Sorting range(Ø)	Description
< 0.35	Very well sorted
0.35 – 0.50	Well sorted
0.50 – 0.71	Moderately well sorted
0.71 – 1.0	Moderately sorted
1.0 – 2.0	Poorly sorted
2.0– 4.0	Very poorly sorted
>4.0	Extremely poorly sorted

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Table 3

Skewness Range (Ø)	Description
> + 0.30	Strongly fine skewed
+0.30 to +0.1	Fine skewed
+0.10 to -0.10	Near symmetrical
-0.10 to -0.30	Coarse skewed
< -0.30	Strongly coarse skewed

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Table 4

Kurtosis range (Ø)	Description
<0.67	Very Platykurtic
0.67 – 0.90	Platykurtic
0.90 – 1.11	Mesokurtic
1.11 – 1.50	Leptokurtic
1.50 – 3.00	Very Leptokurtic
>3.00	Extremely Leptokurtic

Table 5

S/N	Sample Name	Graphic Mean	Standard Deviation (Sorting)	Coefficient of Skewness	Kurtosis
1	I.B 2A	1.26 (Medium grain)	0.89 (Moderately sorted)	0.37 (Strongly fine skewed)	1.03 (Mesokurtic)
2	I.B 2B	1.47 (Medium grain)	0.50 (Moderately well sorted)	0.14 (Fine skewed)	1.78 (Very Leptokurtic)
3	I.B 3A	0.84 (Coarse- grain)	0.96 (Moderately sorted)	0.30 (Strongly fine skewed)	0.01 (Very Platykurtic)

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Table 6

Sieve size (mm)	Phi (ϕ)	Individual weight retained (g)	Individual weight retained (%)	Cumulative weight retained (g)	Cumulative weight retained (%)
1.18	-0.238	32.98	33.10	32.98	33.11
1.00	0.000	1.42	1.43	34.4	34.53
0.71	0.494	10.22	10.22	44.62	44.79
0.60	0.736	11.10	11.14	55.72	55.93
0.50	1.000	9.84	9.87	65.67	65.77
0.42	1.251	9.82	9.85	75.31	75.59
0.30	1.736	10.48	10.52	85.79	86.11
0.25	2.000	2.47	2.48	88.26	88.59
0.112	3.158	6.40	6.42	94.66	95.02
0.075	3.736	2.93	2.94	97.59	97.96
0.063	3.988	0.11	0.11	97.7	98.07
Pan		1.92	1.93	99.62	100

Table 7

Sieve size (mm)	Phi (ϕ)	Individual weight retained (g)	Individual weight retained (%)	Cumulative weight retained (g)	Cumulative weight retained (%)
1.18	-0.238	7.78	7.82	7.78	7.82
1.00	0.000	0.23	0.23	8.01	8.05
0.71	0.494	5.84	5.87	13.85	13.92
0.60	0.736	10.03	10.08	23.93	24.05
0.50	1.000	17.53	17.59	41.21	41.55
0.42	1.251	11.18	11.27	52.47	52.73
0.30	1.736	20.40	20.50	72.87	73.23
0.25	2.000	6.46	6.49	79.33	79.72
0.112	3.158	12.67	12.73	92.00	92.46
0.075	3.736	5.72	5.74	97.72	98.21
0.063	3.988	0.01	0.01	97.73	98.22
Pan		1.82	1.83	99.55	100

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Table 8

Sieve size (mm)	Phi (ϕ)	Individual weight retained (g)	Individual weight retained (%)	Cumulative weight retained (g)	Cumulative weight retained (%)
1.18	-0.238	26.37	26.49	26.37	26.49
1.00	0.000	0.56	0.56	26.93	27.05
0.71	0.494	10.50	10.54	37.43	37.60
0.60	0.736	10.74	10.78	48.17	48.39
0.50	1.000	9.60	9.64	56.88	57.99
0.42	1.251	11.64	11.69	69.31	69.63
0.30	1.736	13.67	13.73	82.98	83.30
0.25	2.000	3.60	3.62	86.58	86.98
0.112	3.158	3.59	3.60	90.17	90.58
0.075	3.736	7.46	7.49	97.63	98.08
0.063	3.988	0.01	0.01	97.64	98.09
Pan		1.90	1.91	98.54	98.99

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