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ESTIMATING THE HYDRAULIC CONDUCTIVITY AND DEPOSITIONAL ENVIRONMENT OF QUATERNARY DEPOSITS IN PARTS OF EASTERN DAHOMEY BASIN

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SARI

Penggunaan rumus empiris telah banyak digunakan untuk menentukan konduktivitas hidrolik tanah dengan cepat dan sederhana. Penelitian menunjukkan bahwa beberapa metode telah diadopsi menggunakan analisis dimensi dan pengukuran eksperimental untuk menentukan konduktivitas hidrolik sejak akhir abad 19. Meskipun demikian, metode ini belum diterapkan pada sedimen holosen di garis pantai Negara Bagian Ondo. Penelitian ini bertujuan untuk memperkirakan konduktivitas hidrolik, transmisitivitas dan menyelidiki karakteristik *Palaeo-Environmental* dari endapan kuarter di bagian timur Cekungan Dahomey, Nigeria melalui karakterisasi dan perkiraan ukuran butir. Hasil analisis ukuran butir menunjukkan nilai rata-rata bervariasi antara 0,84ϕ - 2,02ϕ dengan rata-rata 1,85ϕ, ditambah dengan standar deviasi (0,48 – 1,09; rata-rata 0,75ϕ), *skewness* (-8,74 – 0,267; rata-rata 0,035) dan kurtosis (0,95 – 2,21; rata-rata 1,01). Hasil konduktivitas hidrolik berkisar antara 0,17 – 1,75 m/s dengan nilai rata-rata 2,02, sedangkan transmisitivitas berkisar antara .8 x 10^{-1} – 5,3x10^{-1} M^2/s dengan nilai rata-rata 5,3x10^{-1}, menunjukkan prevalensi akuifer dengan kinerja baik. Unit akuifer sebagian besar tidak terkekang, dengan ketebalan dan kedalaman yang bervariasi. Fungsi diskriminatif multivarian mengungkapkan bahwa endapan kuarter *Ilaje* mungkin diendapkan secara dominan di Lingkungan pantai perairan dangkal yang bergelombang.

Kata kunci: Konduktivitas hidrolik, rumus empiris, lingkungan pengendapan, fungsi diskriminatif multivarian

ABSTRACT

The use of empirical formulae has been widely adopted to quickly and modestly determine the hydraulic conductivity of soils. Research shows that several methods have been adopted using dimensional analysis and experimental measurements to determine hydraulic conductivity since the end of 19th Century. Despite that, these have not been applied to the Holocene sediments in the coastlines of Ondo state. This research is aimed at estimating the hydraulic conductivity, transmisitivity and investigates the Palaeo-Environmental characteristics of the Quaternary deposits in parts of the eastern Dahomey basin, Nigeria via grain size characterization and approximation. The result of the grain size analysis indicated that the mean values vary from 0,84ϕ to 2,02ϕ with an average of 1,85ϕ, coupled with the standard deviation (0,48 - 1.09; av. 0,75ϕ), skewness (-8,74 – 0,267; av. 0,035) and kurtoses (0,95 - 2,21; av. 1,01) respectively. The hydraulic conductivity (m/s) results range from 0,17 – 1,75 with the mean value of 2,02, while that of transmisitivity (M^2/s) ranges between 4,8 x 10^{-1} – 5,3 x 10^{-1}

with the mean value of 5,3 x 10^{-1} respectively, indicating prevalence of aquifer of good performance. The aquiferous units are predominantly unconfined, with variable thickness and depth of occurrence. Multivariate discriminate functions revealed that Ilaje quaternary deposit may have been deposited dominantly in beach environment of shallow agitated water.

Keywords: *Hydraulic conductivity, empirical formulae, depositional environment, multivariate discrimnant function.*

INTRODUCTION

Despite various benefits associated with quaternary sediments, a recent deposit of the Cenozoic era, little has been heard of it in Nigeria geology, most particularly in this research area. This deposit has been of great importance as a great indicator to underground water development and reservoir for crude oil, tar sand and bituminous deposits. Obasi et al. (2013) noted that hydraulic conductivity is a very useful parameter in evaluating the under groundwater resources and depositional environment determination of rock samples that constitute the aquifer. It quantitatively measures the capacity of a geologic formation or other porous media to transmit a specific fluid. Salarashayeri & Siosemarde (2012) adopted Hazen (1911) formula for effective grain size D10, to predict hydraulic conductivity (K) from D_{10}, D_{50} to D_{90} data, they reported that the results were effective in predicting hydraulic conductivity. Odong (2008) & Abdullahi (2013) observed that Hazen's formula can be applied for uniformly graded sands, fine sand and gravel range respectively, provided the sediment has a uniformity coefficient less than 5 and effective grain size between 0.1 and 3mm. This further emphasis transmissivity as the effective hydraulic conductivity of an aquiferous water that can be transmitted horizontally by the full saturated thickness of the aquifer. This is expressed as the water bearing unit multiplied by the thickness of that unit. Both Sclater & Christie (1980) and Coudert et al. (1995) used geohistory analysis to research the vertical response of sedimentary basins to tectonics in both compression and tectonic settings relative to the underground water behaviour in subsurface. They found it as a useful tools for hydraulic conductivity determination.

Billman (1992) & Hack (2000), recognized two structural elements, which comprises The Benin Basin proper and The Okitipupa structure respectively that has contributed to underground water potentiality. This research aimed at estimating the aquifer parameters and establishes the depositional environment of the siliciclastic sediment under research so as to determine their hydraulic conductivity and transmisivity using grain size distribution analysis and enumerate the relationship between hydraulic conductivity and grain size distribution respectively.

REGIONAL GEOLOGY OF THE RESEARCH AREA

The Dahomey basin, otherwise called Dahomey Embayment falls within the coordinates 3^0 00^1 to 4^0 00^1E and latitude 6^0 45^1 to 7^o 00^1E respectively. It is an extensive sedimentary basin on the continental margin of The Gulf of Guinea (Ejedawe, 1987 & Coker, 2002). The basin spreads from South-East Ghana, through southern Togo and Benin, to South-West Nigeria in an approximately arcuate form (Billman, 1992). The basin occupies the coastal areas of West Africa and overlaps the equatorial belt. The basin is bounded in the east by The Benin Hinge Line, in the north by the basement complexes south by The Atlantic Ocean respectively. The basins according to Clifford (1986) share structural and stratigraphic similarities as they are wrench-modified (Kjemperud et al, 1992) and contain rocks of Ordovician to Holocene age (Brownfield & Charpentier, 2006). According to Burke et al. (1971), Dahomey Basin with Okitipupa subsurface ridge was developed in the Mesozoic era due to the separation of the African and south America lithospheric plates.

The basin contains extensive wedge of cretaceous to recent sediment, up to 3000 meters which thickens towards the offshore. Burke et al. (1971) provided the basic stratigraphic framework and description of the different microfacies. Elueze & Nton (2005) used pebble morphometry to deduce that the siliclastics sediment within the Cretaceous sequence in eastern Dahomey Basin are dominantly fluvial sediments with minor marine influences suggested and that The Ewekoro limestones were deposited in shallow marine setting predominantly gas prone organic matter with low oil prone.
Billman (1992) & Hack (2000) have recognized two structural elements, which comprise The Benin Basin and The Okitipupa structure. Omotasola and Adegoke (1981) worked on the age, lithology, structure, petrology and geology of the different rock units in the eastern Dahomey Basin and explained that the formations range in age from Neocomian to Paleocene while Agagu (1985) confirmed the three members of the Abeokuta formation based on the lithological characteristics of the sediments and assigned a Neocomian to Maastrichtian to the sediment.

The origin of the tar sands, properties and source rock evaluation of interbedded shales associated with tar sands of the eastern Dahomey Basin. This was concluded that tar sand deposits represent products of reservoir transformation of conventional oil by micro-organisms. According to Onuoha et al. (1988) and Ejedawe (1987) the basin is bounded on the west by Ghana Ridge, and has been interpreted as the Romanche fracture zone. It is separated from Niger Delta in the Eastern section by Benin Hinge Line and Okitipupa Ridge and marks the continental extension of the chain fracture zone.

Stratigraphy of Dahomey Basin

According to Jones & Hockey (1964) and adopted by Brownfield & Charpentier (2006), Dahomey basin is one of the sedimentary basins on the continental margin of The Gulf of Guinea, extending from South Eastern Ghana in the west to the western flank of the Niger Delta. The evidence available based on stratigraphic unit shows a rift generated basement subsidence during the lower cretaceous. This resulted in the deposition of a very thick sequence of continental grifts and pebbly sand over the entire basin. During this time, the environment changed rapidly from initial continental to open marine which resulted in the deposition of relatively thick sequence of sands with inter-bed of organic shale. The sediments of The Dahomey Basin, the granites gneisses and associated pegmatite were subjected to tilting series of horst and graben structures by (Omatsola & Adegoke, 1981).

The coastal plain sand formation lacks fossils but contain plant debris which has been the source of dating. It also consist of soft, poorly sorted clays sand and pebbly sands which vary in colour from reddish pink to brownish due to the effect of weathering. The age ranges from Oligocene to recent (Reyment, 1965). The coastal plain sand formation are the youngest sedimentary in the eastern Dahomey basin (Table 1).

The siliciclastic deposit in Ilaje community and its environs is in a lowly environment. The sedimentary deposits are mainly of the quaternary sediments, a recent deposit of the three periods of the Cenozoic era in the geologic time scale. (Figures 1 & 2). The research area is lithological, made up of three strata which are the top soil, the whitish coarse to fine grained sand overlying the reddish brown clay at the bottom. Mineralogically, the sample is made up of about 90% wt of quartz grains while other minerals constitute the remaining 10% (Folk, 1974).

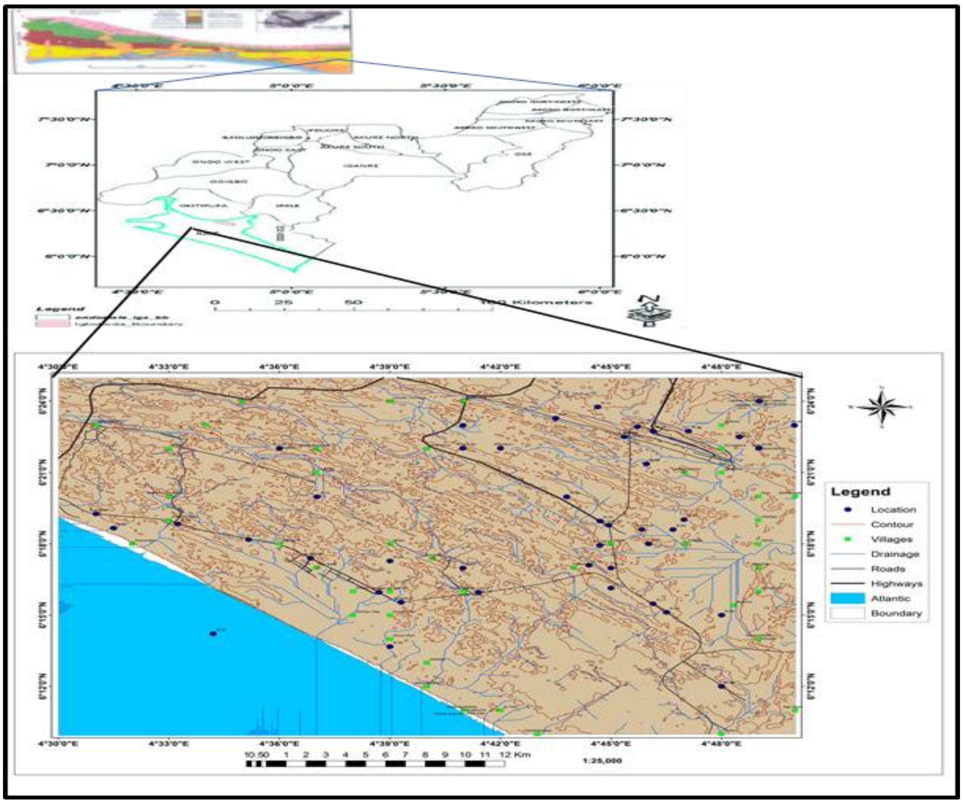

Figure 1. Map of the research area

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Table 1. Stratigraphy of The Dahomey Basin (Olabode, 2015)

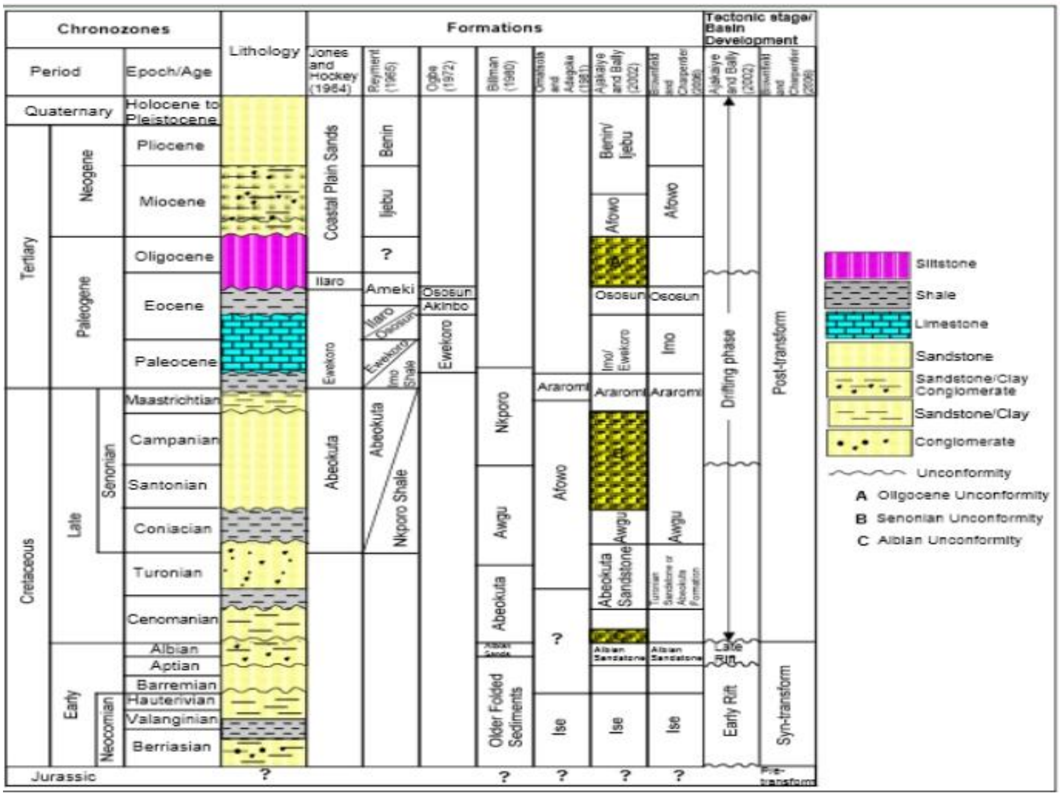

Figure 2. Pictorial view of the siliciclastic sediment under research

MATERIALS AND METHODS

Twenty samples (20) were collected from quaternary deposits in the research area. All samples were carefully collected, properly packed and well labeled. The sampling was collected with the use of hand held Global Positioning System (GPS) to locate the precise geographical locations of sampling points. Ten (10) grams of every sample was used for Laser Diffraction (LD). Each sample was treated with H_2O_2 at 30% concentration to remove organic material while the carbonate was removed with HCl at 30% for 40 minutes under a fume cupboard. This was dispersed with sodium hexametaphosphate to disaggregate it overnight. Twenty representative samples were sieved using Folk & Ward (1957) statistical formulae to calculate the grain size paramenters (mean, standard deviation, skewness and kurtosis). Hydraulic conductivity was determined using D_{10} value from cumulative frequency distribution graph. In order to characterize the depositional setting of the sediments, bivariate linear discrimination functions. (Y_1, Y_2, Y_3) as proposed by Sahu (1964) and Septriono & Pruna (2017) was applied.

Hydraulic Conductivity (K)

Hydraulic Conductivity values (cm/s) for Ilaje quaternary deposit was calculated using (Hazen, 1911) formular $K = (D_{10})^2$. The calculated K range from 0.17 to 1.75 with the mean value of 2.02, indicating relatively easy transmission of groundwater in the aquifer zones (Freeze & Cherry, 1979; Odong, 2008). Movement of dissolved substances (including pollutant and contaminants) is thus enhanced. The hydraulic conductivity increases towards the eastern part of the research area and most prominent at Ilaje and its environs.

Grain Size Distribution Statistical Parameters

The statistical parameters used in calculation of the sieve analysis data are as follow:

Percentage weight retained (%wt)

$$(\text{weight retained} \div \text{total mass of sample}) \times 100\ \%\ \text{passing} \quad (1)$$

cumulative weight percentage for each sieve from 100.

$$\text{Mean} = \frac{16+\emptyset 50+\emptyset 84}{3} \quad (2)$$

Standard deviation

$$\text{Sd} = \frac{\emptyset 84+\emptyset 16}{4} + \frac{\emptyset 95+\emptyset 5}{6{,}6} \quad (3)$$

Skewness (Sk)

$$\text{Sk} = \frac{\emptyset 84+\emptyset 16-2(\emptyset 50)}{2(\emptyset 84-\emptyset 16)} + \frac{\emptyset 95+\emptyset 5-2(\emptyset 50)}{2(\emptyset 95-\emptyset 5)} \quad (4)$$

Kurtosis (Kr)

$$\text{Kr} = \frac{\emptyset 95-\emptyset 5}{2{,}44(\emptyset 75-\emptyset 25)} \quad (5)$$

RESULTS AND DISCUSSION

Results

The results of the analysis conducted on the samples are as presented in table 2. The average values of the sediments shows 0.7% gravel, 97.1% sand and 2.2% mud respectively. This revealed the sand concentration to be the highest, indicating a matured, sand dominant environment. This is observed to be quartz rich, matured and arenitic in nature as shown in figure 3. The mean grain size is an important tool for interpretations of sediment data in relation to bottom dynamics.

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Table 2. Summary of the grain size parameters (Folk & Ward, 1957)

Sample	% Gravel	% Sand	% Mud
R-1	1.0	99.0	0.0
R-2	3.5	96.5	0.0
R-3	0.0	95.8	4.2
R-4	2.1	94.4	3.5
R-5	0.3	97.9	1.8
R-6	0.7	96.5	2.8
R-7	0.0	100.0	0.0
R-8	2.3	96.9	0.8
R-9	1.7	93.9	4.5
R-10	0.4	93.7	5.9
R-11	0.3	97.9	1.8
R-12	1.3	97.1	1.6
R-13	0.0	99.7	0.3
R-14	0.1	99.6	0.3
R-15	0.0	99.7	0.3
R-16	1.1	97.4	1.5
R-17	0.0	97.5	2.5
R-18	0.0	98.7	1.3
R-19	0.0	90.2	9.8
R-20	0.0	98.8	1.2
Mean	**0.7**	**97.1**	**2.2**

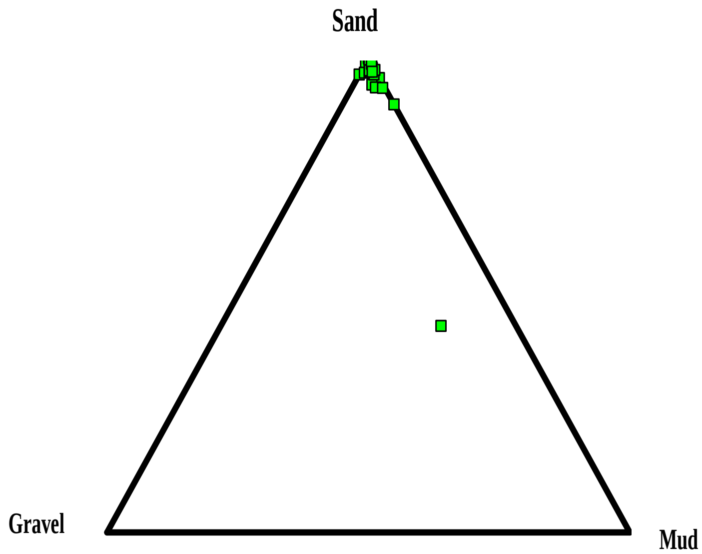

Figure 3. The percentage concentration of sand in the sediment under *research*, indicating a matured arenitic sand

Grain size

The grain size characteristics have been helpful to determine depositional environment and can be used as a proxy for hydraulic conductivity characterization. The mean size is the average size of the sediments represented by ϕ mean size and mainly an index of energy conditions. In the research sample, the mean size varies from 0.84ϕ to 2.02ϕ with an average of 1.85ϕ and thus falls in the slightly fine sand to medium grained category. Considering the standard deviation (δi), the samples range from 0.48 to 1.09 with the average of 0.75ϕ. It is observed that all the samples falls within the moderately sorted to well sorted nature. This measure of sorting sediments, it indicates the fluctuations in kinetic energy of the transportation agent about its average velocity (Table 3).

Table 3. Statistical parameters of the samples under research

STATISTICAL PARAMETERS				DESCRIPTION			
Mean	**Sorting**	**Skewness**	**Kurtosis**	**Mean**	**Sorting**	**Skewness:**	**Kurtosis**
1.01	0.48	0.04	0.95	Medium	M. W. S	Symmetrical	Mesokurtic
1.02	0.79	-0.15	1.34	Medium	M. Sorted	C. Skewed	Leptokurtic
1.12	0.64	-0.05	1.06	Medium	M. Sorted	Symmetrical	Mesokurtic
0.84	0.80	-0.30	1.23	Coarse	M. Sorted	C. Skewed	Leptokurtic
1.71	0.70	0.18	1.67	Medium	M.W. S.	Fine Skewed	Leptokurtic
1.11	0.94	0.03	1.77	Medium	M. Sorted	Symmetrical	Leptokurtic
1.67	0.57	-0.02	1.12	Medium	W. Sorted	Symmetrical	Leptokurtic
1.65	0.76	-0.05	1.16	Medium	M. Sorted	Symmetrical	Leptokurtic
1.04	1.02	0.12	1.99	Medium	P. Sorted	Fine Skewed	Leptokurtic
1.70	0.87	0.27	2.09	Medium	M. Sorted	Fine Skewed	Leptokurtic
1.56	0.72	-0.02	1.08	Medium	M. Sorted	Symmetrical	Mesokurtic
1.39	0.86	-0.13	1.26	Medium	M. Sorted	C. Skewed	Leptokurtic
1.56	0.64	-8.74	1.06	Medium	M. W. S	Symmetrical	Mesokurtic
1.55	0.65	0.01	1.04	Medium	M. W. S	Symmetrical	Mesokurtic
1.52	0.63	0.04	1.05	Medium	M. W. S	Symmetrical	Mesokurtic
1.29	0.72	-0.03	1.23	Medium	M. Sorted	Symmetrical	Leptokurtic
1.46	0.69	0.11	1.29	Medium	M.. W. S	Fine Skewed	Leptokurtic
1.38	0.59	0.04	1.03	Medium	M. W. S	Symmetrical	Mesokurtic
1.97	1.09	0.37	2.21	Medium	P. Sorted	Symmetrcal	Mesokurtic
2.02	0.56	0.03	1.09	Fine	M. W. S	Symmetrical	Mesokurtic

Skewness measures asymmetry of frequency distribution and marks the position of mean with respect to median. In the present research, skewness values ranges between -8.74 and 0.37, while the mean value 0.035 indicating coarse skewed to nearly symmetrical in nature. The samples fall in the mostly in symmetrical to fine skewed nature. In a material sufficient quantity of different sizes, a coarsely skewed sample implies that the velocity of the deposition agent operated at a high value than the average velocity for a greater length of time. The near symmetrical nature of the sediments clearly exhibits sediment input from mixed sources. This also implies a low velocity than normal. This skewness data indicate that in the sediments median class of the sediments dominate almost throughout their distribution.The grain size of the quaternary deposit in Eastern Dahomey Basin varies from coarse to medium grained (Goldberg & Munir, 2010). This can be characterized with fining upward other statistical parameters determined for the sands include standard deviation (SD), Kurtosis (K) and skewness (SK). Skewness and kurtosis display positively skewed and mesokurtic respectively. A very poorly sorted value for the sample indicates that they have a great amount of variability among the diameters pf their particles. This indicates that the sediments are not matured and can probably be said to be residual because they have not been transported (if at all) not far away from its source (Chamley, 1979). A moderately well sorted value for the sample shows that there is a fair amount of variability amount the diameters of their particles.

Many curves designated as normal by the skewness measure turns out to markedly non-normal when the kurtosis is computed. It is the ratio between the sorting in tail of the curve to that of the central portion. Kurtosis is a measure used to describe the departure from normality of distribution. The minimum and maximum values of kurtosis of the sediments are 0.95 and 2.21 respectively with an average value of 1.01. The dominance of leptokurtic nature of the research sediments exhibits mixing two populations in sub-equal amount. The polymodal characteristic of sediment frequency is responsible for the leptokurtic values.

DISCUSSION

Depositional environment

Grain size distribution has been used as one of the tool or indicator to explain depositional environment (Moiola & Weiser, 1968). The bivariate plots of graphic mean against and graphic standard deviation (sorting) of Friedman (1979) and Septriono & Purna (2017) were adopted in this research. The plot proved the sediment to be beach sedimentary environment whereas the modified plots of Septriono & Purna (2017) also supported the assertion of the previous research to bebeach dominant settings with some traces of fluvial environment, thereby suggesting a mixed environment (Figure 4a-b). This plot also explain the characteristics of the sediments to be of medium grained dominant and well sorted as described by Folk (1974). The mean when plotted against the standard deviation (sorting) shows about 90% of the samples fall within beach environment. as suggested by Friedman (1979) indicating a beach environment.

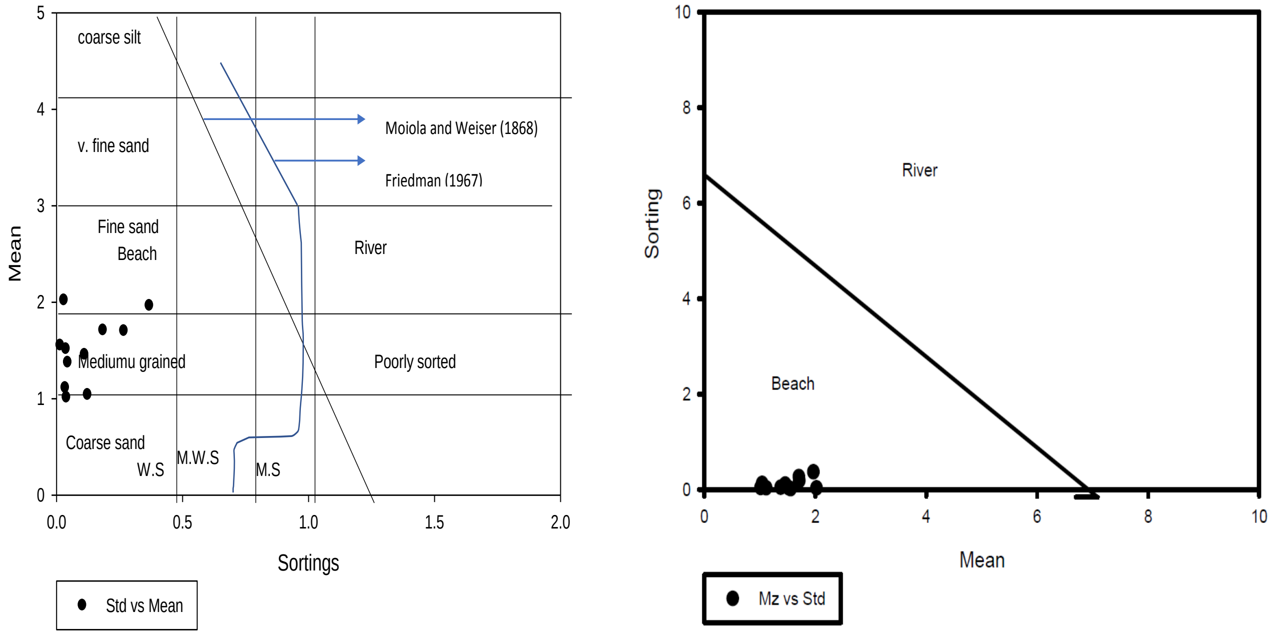

Figure 4a-b. Bivariate plots of mean against graphic standard deviation of the sediments under research

1) In order to further determine the depositional environment and various processes through which the sediments were transported and deposited, a linear discrimination function equations were calculated (Sahu, 1964). The results is presented in table below, the following equation was used:

$$Y1 = -3.5688MN + 3.701ST - 2.0766SK + 3.1135KT \quad (6)$$

Where MN is the mean grain size, ST is the inclusive graphic standard deviation (sorting), SK is the skewness, and KT is the kurtosis. When Y_1 is less than -2.7411, Aeolian deposition is indicated, whereas when Y_1 is greater than -2.7411, a beach environment is indicated. The value of Y_1 calculated from the sample under research range from -1.23- 6.08 (Table 4). 90% of the sediments have Y_1>2.7411. Therefore the sands are deposited dominantly by beach process.

2) For the discrimination between beach (back shore) and shallow agitated marine environment (subtidal environment), the following equation was used:

$$Y2 = 15.6534MN + 65.7091ST + 18.10871SK + 18.5043KT \quad (7)$$

When the value of Y_2 is less than 65.3650, beach deposition is suggested. If it is greater than 65.3650, a shallow agitated marine environment is indicated. The values of Y_2 calculated for the sediment under research ranges 49.09 - 156.14, indicating that 90% of the sediments were deposited in shallow agitated marine environment while the remaining 10% were in beach process (Table 4 and Figure 5a & b).

3) For the discrimination between shallow marine and fluvial environment, the following equation was used:

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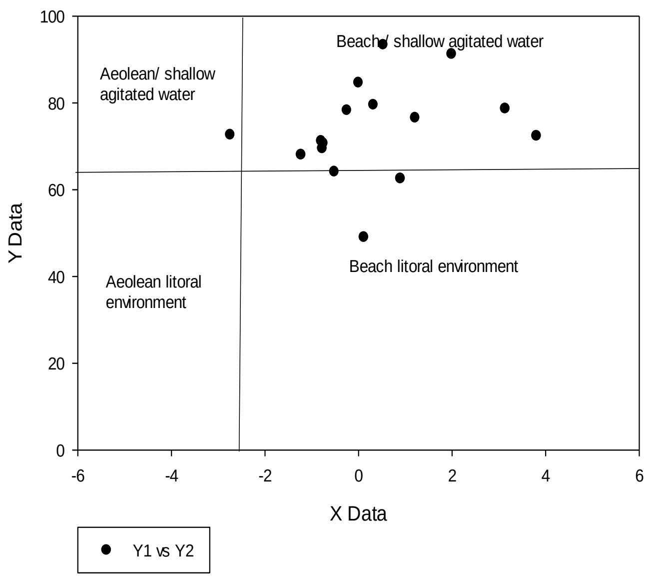
$$Y3 = 0.2852MN - 8.7604ST - 4.8932SK + 0.0482KT \quad (8)$$

Table 4. The discriminate function and environment of deposition of each sample

Sample No.	Y1	Environment of Deposition	Y2	Environment of Deposition	Y3	Environment of Deposition
RT-1	0.90	Beach	62.61	Beach process	-2.93	Fluvial deltaic
RT-2	3.80	Beach	72.44	Shallow agitated	-3.85	Fluvial deltaic
RT-3	0.53	Beach	93.43	Shallow agitated	-4.66	Fluvial deltaic
RT-4	4.76	Beach	109.08	Shallow agitated	-7.53	Fluvial deltaic
RT-5	-1.23	Aeolian	68.11	Shallow agitated	-2.27	Fluvial deltaic
RT-6	0.00	Beach	84.71	Shallow agitated	-4.32	Fluvial deltaic
RT-7	0.11	Beach	49.09	Beach process	-1.84	Fluvial deltaic
RT-8	3.14	Beach	78.72	Shallow agitated	-4.31	Fluvial deltaic
RT-9	6.08	Beach	123.85	Shallow agitated	-9.35	Fluvial deltaic
RT-10	2.69	Beach	120.24	Shallow agitated	-7.41	Fluvial deltaic
RT-11	-0.25	Beach	78.32	Shallow agitated	-3.97	Fluvial deltaic
RT-12	1.99	Beach	91.31	Shallow agitated	-5.39	Fluvial deltaic
RT-13	-0.76	Aeolian	70.72	Shallow agitated	-3.06	Fluvial deltaic
RT-14	-0.80	Aeolian	71.28	Shallow agitated	-3.25	Fluvial deltaic
RT-15	-0.78	Aeolian	69.52	Shallow agitated	-3.13	Fluvial deltaic
RT-16	1.21	Beach	76.62	Shallow agitated	-4.00	Fluvial deltaic
RT-17	0.32	Beach	79.60	Shallow agitated	-4.19	Fluvial deltaic
RT-18	-0.52	Beach	64.18	Shallow agitated	-2.82	Fluvial deltaic
RT-19	3.49	Beach	156.14	Shallow agitated	-11.50	Fluvial deltaic
RT-20	-2.74	Beach	72.70	Shallow agitated	-2.24	Fluvial deltaic



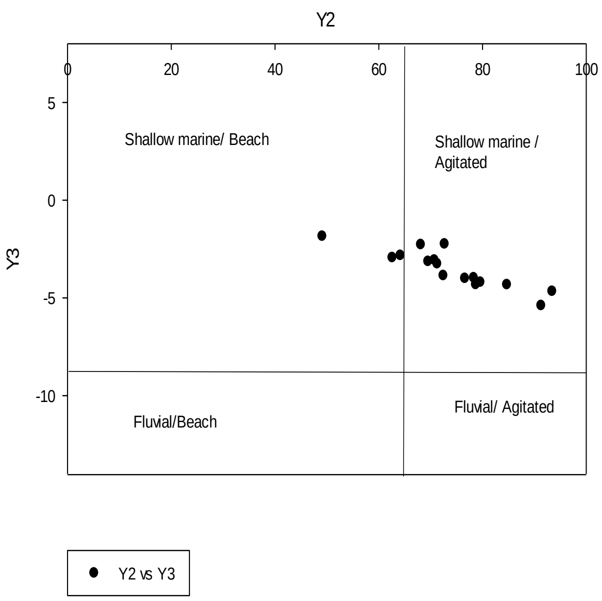


Figure 5a-b. Linear discrimination function plot showing the sediment to belong to beach environment

Hydraulic Conductivity (K)

The results of hydraulic conductivity values for Ilaje quaternary deposit was calculated using Hazen, (1911) formula K= $(d^{10})^2$. The hydraulic conductivity ranges from 0.002 to 1.75. The hydraulic conductivity increases towards eastern part of the research and most prominent at Ilaje communities (Table 5 and Figure 6a & b). This indicate the subsurface groundwater potential is prolific (Cheong, 2008; Abdullahi, 2013).

Table 5. The hydraulic conductivity and transmissivity nature of different rock samples analysed (Hazen, 1911)

Sample No	Location	N	E	D10 (ϕ)	Aquifer thickness(m)	Hydraulic Conductivity (m^3/s)	Transmisivity
1.	R-1	6.4	4.8	0.308	0.4	0.09	0.036
2.	R-2	6.4	4.8	-0.677	0.6	0.45	0.270
3.	R-3	6.9	5.3	1.007	0.5	1.01	0.505
4.	R-4	6.5	4.7	0.182	0.8	0.03	0.024
5.	R-5	6.3	4.8	0.933	1.2	0.87	0.044
6.	R-6	6.3	4.7	0.650	1.0	0.42	0.420
7.	R-7	6.4	4.8	0.410	0.6	0.17	0.102
8.	R-8	6.4	4.7	0.046	0.4	0.002	0.0008
9.	R-9	6.3	4.7	0.067	0.5	0.004	0.002
10.	R-10	6.3	4.7	0.945	1.2	0.89	0.107
11.	R-11	6.3	4.7	0.624	1.4	0.39	0.546
12.	R-12	6.3	4.8	0.304	1.2	0.09	0.108
13.	R-13	6.4	4.8	0.734	1.1	0.54	0.594
14.	R-14	6.4	4.7	0.726	1.0	0.53	0.530
15.	R-15	6.1	4.7	0.725	1.2	0.53	0.636
16.	R-16	6.4	4.8	0.409	0.8	0.17	0.136
17.	R-17	6.3	4.8	0.675	0.4	0.46	0.184
18.	R-18	6.3	4.8	0.641	0.6	0.41	0.246
19.	R-19	6.3	4.7	1.046	0.8	0.09	0.872
20.	R-20	6.3	4.7	1.322	0.5	1.75	0.875

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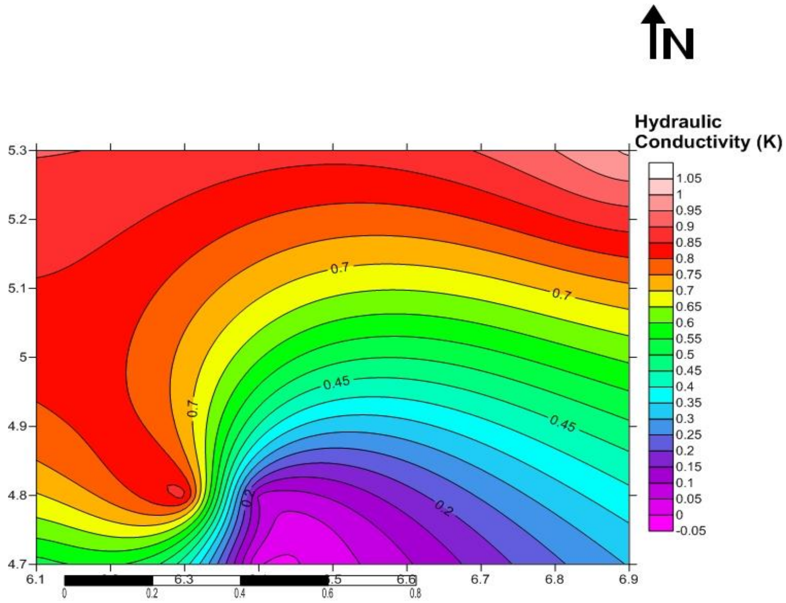

Figure 6a. Map of the research area showing the hydraulic conductivity distribution

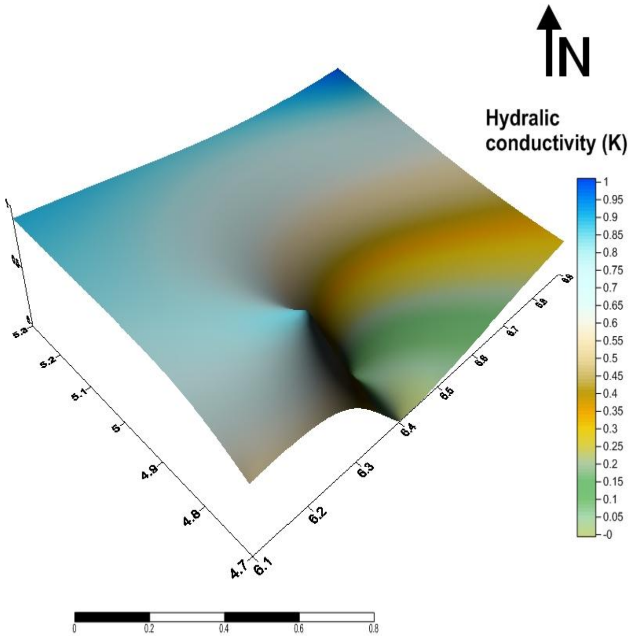

Figure 6b. 3D map of the research area showing the hydraulic conductivity distribution

Transmisivity (T)

Transmisivity values in the research area range from 8.0 x 10^{-4} -5.3x10^{-1} m^2/s with the mean value of 3.11x10^{-1}. The values are indicative of good aquifer in conformity with the hydraulic conductivity values (Table 6).

CONCLUSION AND RECOMMENDATION

Conclusion

The hydraulic conductivity, transmisivity and depositional environment to quaternary, has been investigated using grain size analysis as a proxy. Laser diffraction (LD) from the interpretation of the analysis carried out on the twenty samples collected, the values shows that the samples are mainly very coarse grained sands from the subsurface samples. The medium grained and well sorted particles coupled with particles content indicate that The Ilaje quaternary deposit is of good quality. The Ilaje quaternary deposit, Eastern Nigeria has been determined using data on grain size distribution analysis. The results revealed the ranging values of hydraulic conductivity and transmisitivity (m^2/s), to be 2.0 x 10^{-3}–17.5 x 10^{-1} and 8.0 x 10^{-4} - 5.3x10^{-1} respectively. These indicate aquifer of good performance of the quaternary deposit in this research area. It was also observed that the sediment might have been deposited dominantly by beach process, shallow agitated marine environment. The hydraulic conductivity of the quaternary deposit indicate the aquifer has good yield potentials and that groundwater development potential of the area is very high. The likely problem that could lead to inadequate supply of water will be related to its availability rather than hydraulic properties of the aquifer. Accordingly, abstraction should go on with caution in the face of prevailing climate change that may adversely affect recharge. The environment of deposition is endowed with abundant surface and groundwater with prolific aquifers in existence well record indicate shallow groundwater sources that are concontained.

Recommendation

From the above, level of hydraulic conductivity in the quaternary deposit under research, it is recommended that boreholes can be drilled to supply water the community and its environs. More research work should be done on Ilaje quaternary deposit to determine other hidden properties present in the location (Ilaje) other than water resources potentiality and management.

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