Advanced Journal of Environmental Sciences
Volume.15, Number 4; April-2024;
ISSN: 2837-3928 | Impact Factor: 8.16
https://zapjournals.com/Journals/index.php/ajes
Published By: Zendo Academic Publishing

TEXTURAL ANALYSIS AND HYDRAULIC CHARACTERISTICS OF AJALI SANDSTONES OF UGBENE-AJIMA AND ENVIRONS IN ANAMBRA BASIN, SOUTHEASTERN, NIGERIA

Ezike, Ejiofor Chinedu and Aganigbo, Chigozie Ignatius

Article Info
Keywords: Textural analysis, Depositional Environment, Hydraulic Conductivity, Aquifer

DOI
10.5281/zenodo.11085658

Abstract
This study highlights the textural characteristics and hydraulic conductivity of sandstones of Ajali Sandstone in Ugbene-Ajima area (southeastern Nigeria). The investigation approach involved field sampling and collection of 8 sandstone samples from different outcrop locations followed by laboratory studies such as sieve analysis. Sieve analysis and textural studies show that the sandstones range of 0.647-1.616. Other parameters such as coefficient of uniformity (C_u) range from -27.5 to 6.83 (av. -10.25), while standard deviation (sorting) values of 0.603-1.022 (av. 0.972) imply moderately well sorted sediments. The sandstones are mostly platykurtic and negatively skewed indicating sand of fluvial origin ranging from channel floor, point bar to braided rivers, also suggesting moderately to high/turbulent energy conditions with presence of winnowing actions. The Ajali Sandstone porosity values range from 2%-54% (av. 28.312) and the hydraulic conductivity values of 16.89-103.06 (av. 45.87). These values of porosity and hydraulic conductivity are indications of high specific yield for the sandstone which release economic water quantity.

1. Introduction

The Anambra Basin constitutes the southeastern lower portion of the Benue Trough, which is divided into lower, middle and upper parts; and is one of the least studied inland sedimentary basins in Nigeria (Akande and Ertmann, 1998). The origin of the Benue Trough can be traced back to the opening of the South Atlantic Ocean. Benkheil (1989) indicated that the Benue Trough started during the geological period of the Lower Cretaceous in conjunction with the Atlantic Ocean rifting.

According to researches by Murat (1972), Obi et al (2001) and Oboh-Ikuenobe (2005), three tectonic phases controlled deposition within the Benue Trough and hence, its stratigraphy of the birthed successive depo-centres. Anambra Basin been a product of Santonian regional tectonism that led to the folding and uplift of the Abakaliki-Benue into an anticlinorium and the tectonic inversion and downwarping of the then Anambra Platform, contains postdeformational Campanian-Maastrichtian to Eocene strata (Murat, 1972; Ladipo et al, 1992). The Anambra Basin as a synclinal structure consists of more than 5000 m thick sediments from gravity measurements (Ladipo et al, 1992), out of which about 3000-3500 m were deposited during late Cretaceous (Upper Campanian-Maastrichtian).

Department of Geology and Mining, Enugu State University of Science and Technology, Enugu, Nigeria

Most sequence stratigraphic works done on the Anambra Basin were based on outcrop studies. Although some researchers (Nwajide, 2013) has interpreted some of the wells in the Anambra Basin, the sequence stratigrahic framework of the interpreted wells has not been full determined. The stratigraphic succession of the Anambra Basin comprises of the Campanian to Maastrichitian Nkporo/Owelli/Enugu Formations. The Maastrichtian Mamu Formation also known as Lower Coal Measures is overlain by Ajali Formatio (Obi, 2000) and followed by Nsukka Formation. The Paleocene Imo Formation and the Eocene Ameki Group follow successively.

The main focus of this work is the detailed geological mapping of Ugbene-Ajima and its environs in Enugu, Anambra Basin Nigeria and delineation of the paleoenvironment of deposition with emphasis laid on textural analysis.

2. Location of Study Area

The study area Ugbene-Ajima and its Environs is within Coal measure Group which overlain the Nkporo Group in the lithostratigraphic unit of the Late Campanian–Maastrichtian successions of the Anambra Basin, Nigeria. The study area location is within Enugu State and geographically, stretches by latitudes 6º47'0"N and 6º50'0"N and longitudes 7º12'0"E and 7º17'0"E. The present investigation covers an estimated area of about 86.49km^2. The climate of the area is hot and humid split into rainy season; March – October, which is characterized by heavy shower accompanied by thunderstorms and soil erosion, and dry season; November – February characterized by dry and dusty harmattan wind causing high evapo-transpiration rate. Two distinctive vegetations exist within the study area; guinea savannah and tropical rainforest. The study area is bounded with villages as follows Akalbite Agu, Abi, Amaogbo, Ugwuokwa, Nrobo, Owa, Okpala, Enugu Atta, Umuoyo, Umuduesu.

3. Geology of Study Area

The study area is underlain by two geologic formations which are mainly (from the oldest to the youngest), Ajali Formation and Nsukka Formation. Fig.1 shows the geologic map of Ugbene-Ajima and environs. Ajali Formation (Maastrichtian-Danian) consists of medium to coarse grained, poorly consolidated and cross-bedded Sandstones with subordinate shale and clays. Nsukka Formation which consists of an alternating succession of sandstones, dark shale and sandy shale. All formations regionally dip 2˚-5˚ to the NW direction. An interesting geomorphic characteristic of the study area is that the Nsukka Formation occurs mainly as outliers on the Ajali Sandstone. These outliers of Nsukka form ridge-like hills while the valleys are underlain by Ajali Formation (Umeji, 1980). The ridge and the valley are not reflective of deep-seated structures but are the resultant of weathering and differential of the erosion of classic materials, which are remnants of Nsukka formation overlying the area. The trend of the ridge reflects the direction of eroding current. Ofomata (1978a) described the shapes of these outliers.

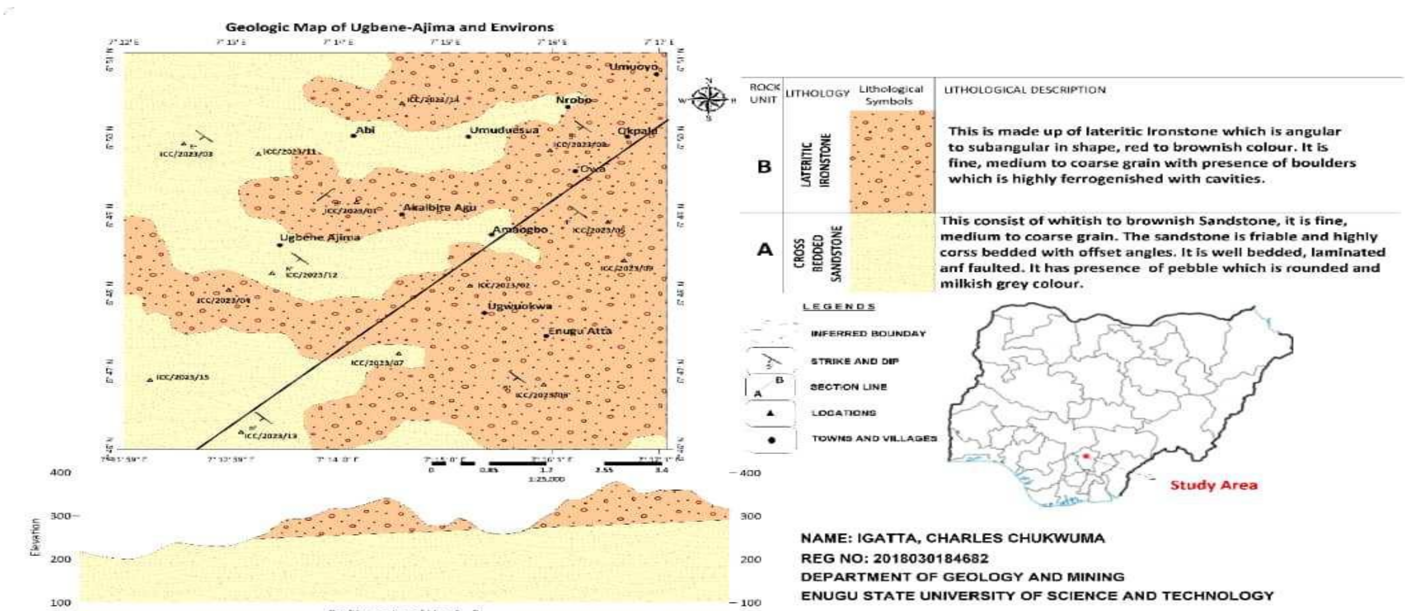

Figure 1. Geological Map of the Study Area

4. Materials and Methods

Eight sandstone samples were collected from various locations, samples were disaggregated in the laboratory with a rubber padded pestle as suggested by PettiJohn, (1975) 100g of each disaggregated sample was measured using a weighing balance as test portions for sieve analysis. The test portions were sieved with a Rotag electrical automatic shaker for 15 minutes using a set of sieves with mesh size 0.5 phi apart. Cumulative curves of the grain size distribution were plotted from the sieve result. The univariate, and bivariate parameters were computed based on Folk and Ward (1957), Miola and Weiser (1968), and Sahu (1964). And also the Hydraulic conductivity of the samples was calculated. The sieve technique was used to determine the grain size distributions. The effective grain size was characterized by the coefficient D_{10}, the value corresponding to 10% finer by weight. We characterized the sorting by the uniformity coefficient defined to be $Cu = D_{60}/D_{10}$ where D60 is the grain size corresponding to 60% finer by weight. If Cu > 4, the sample is commonly referred to as "poorly sorted", and if Cu < 4 the sample is "well sorted" (Fetter, 1994).

Table 1: Descriptive Measures of Grain Size Distribution (Folk and Ward, 1957) expressed in Phi units.

Mean Size	**Sorting**	**Skewness**	**Kurtosis**
$\mathbf{M_z} = \frac{\Phi_{16}+\Phi_{50}+\Phi_{84}}{3}$	$\sigma_1 = \frac{\Phi_{84}-\Phi_{16}}{4} + \frac{\Phi_{95}-\Phi_5}{6.6}$	$Sk_1 = \frac{\Phi_{16}+\Phi_{84}-\Phi_{50}}{2(\Phi_{84}-\Phi_{16})} + \frac{\Phi_5+\Phi_{95}-2\Phi_{50}}{2(\Phi_{95}-\Phi_5)}$	$K_G = \frac{\Phi_{95}-\Phi_5}{2.44(\Phi_{75}-\Phi_{25})}$
Coarse sand 0-1	Very well sorted <0.35	Very finely skewed $^{+}0.3$ to $^{+}1.0$	Very platykurtic <0.67
Medium sand 1-2	Well sorted 0.35 - 0.50	Finely skewed $^{+}0.1$ to $^{+}0.3$	Platykurtic 0.67 – 0.90
Fine sand 2-3	Moderately well sorted 0.50 - 0.70	Symmetrical $^{+}0.1$ to $^{-}0.3$	Mesokurtic 0.90 – 1.11
	Moderately sorted 0.70 - 1.00	Coarsely skewed $^{-}0.1$ to $^{-}0.3$	Leptokurtic 1.11 – 1.50
	Poorly sorted 1.00 - 2.00	Very coarsely skewed 0.3 to $^{-}1.0$	Very Leptokurtic 1.50 – 3.00
	Very poorly sorted 2.00 – 4.00		Extremely leptokurtic <3.00
	Extremely poor sorted >4.00		

5. Results and Discussions

The average mean size (1.276) result shows that the sandstones are dominantly medium grained. The average standard deviation result (0.972) shows that the sandstone exposures are moderately well sorted. The average skewness and kurtosis (-0.0184 and 0.705) respectively shows that the sandstone is near symmetrically skewed and platykurtic.

Table 2: Result of the Grain Size Analysis

Sample Number	Mean (M_z)	Sorting (σ_i)	Skewness (Sk_i)	Kurtosis (K_G)	Interpretation
L1	1.616	0.986	-0.319	0.892	Medium grained, moderately sorted, very negatively skewed and platykurtic
L2	0.977	0.944	0.387	0.579	Coarse grained, moderately sorted, very positively skewed, very platykurtic
L3	1.463	1.017	0.417	0.595	Medium grained, moderately sorted, very positively skewed and very platykurtic
L4	1.433	1.022	-0.362	0.576	Medium grained, moderately sorted, very negatively skewed and very platykurtic
L5	0.647	0.603	0.255	1.284	Medium grained, moderately sorted, positively skewed and leptokurtic
L6	1.347	1.059	-0.157	0.553	Medium grained, poorly sorted, symmetrical skewed and very platykurtic
L7	1.183	1.077	0.070	0.572	Medium grained, poorly sorted, symmetrical skewed, very platykurtic
L8	1.543	1.068	-0.440	0.586	Medium grained, poorly sorted, very negatively skewed, very platykurtic
Average	1.276	0.972	-0.018	0.705	Medium grained, moderately sorted, near symmetrical skewed and platykurtic

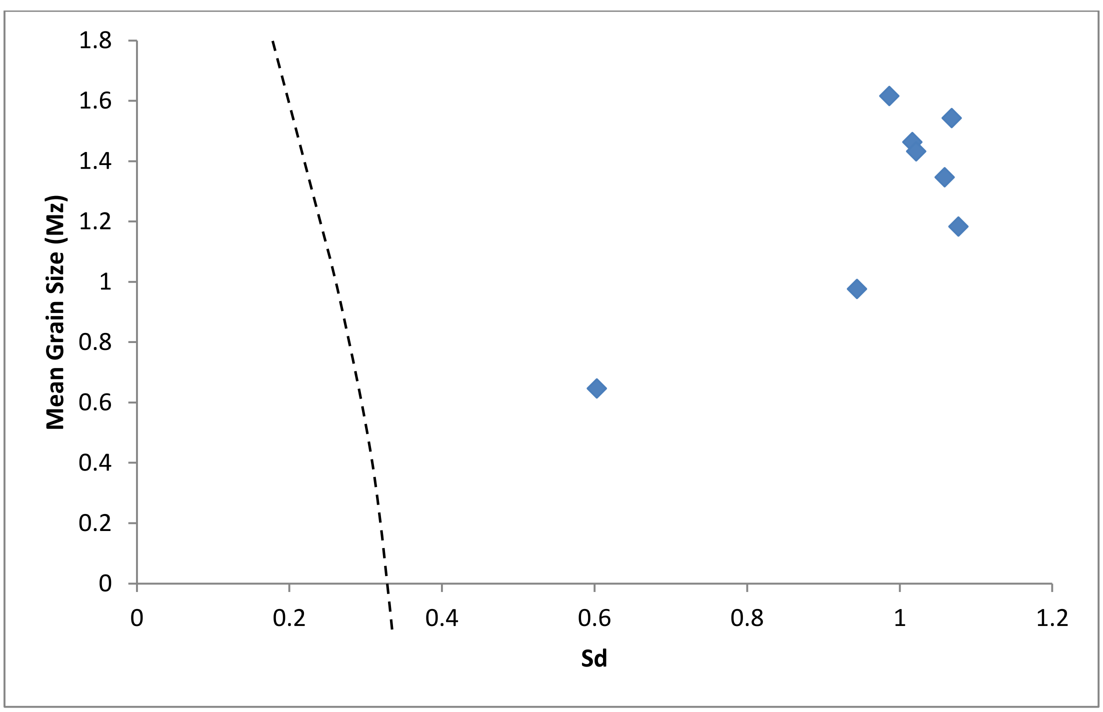

Figure 2. Depo-Environmental Discrimination of Bivariate plot of Mean size and Sorting adopted (Miola and Weiser, 1968)

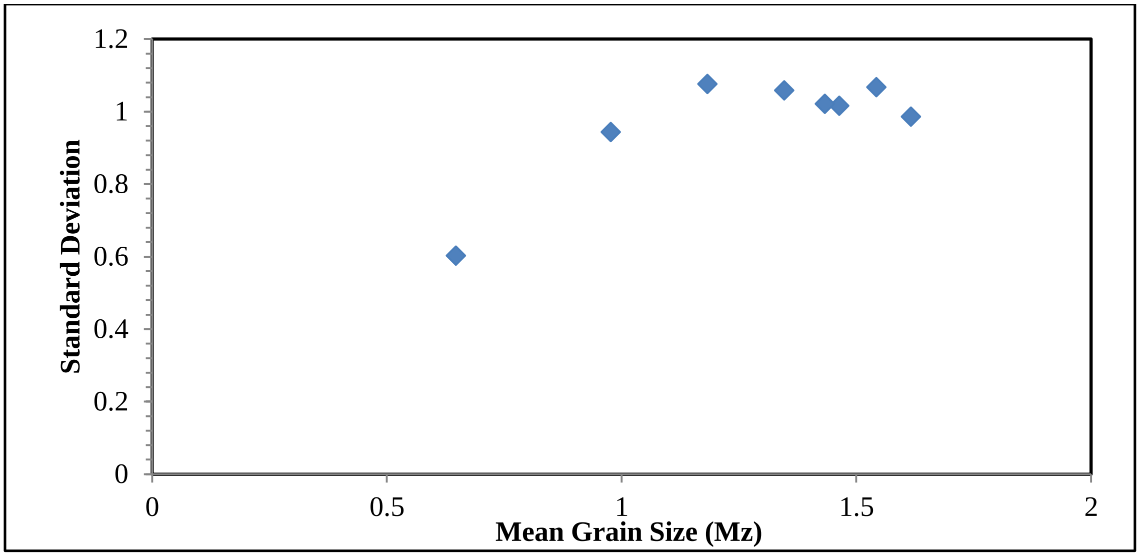

Figure 3. Bivariate plot of Mean size and Sorting adopted (Blott and Kenneth, 2000)

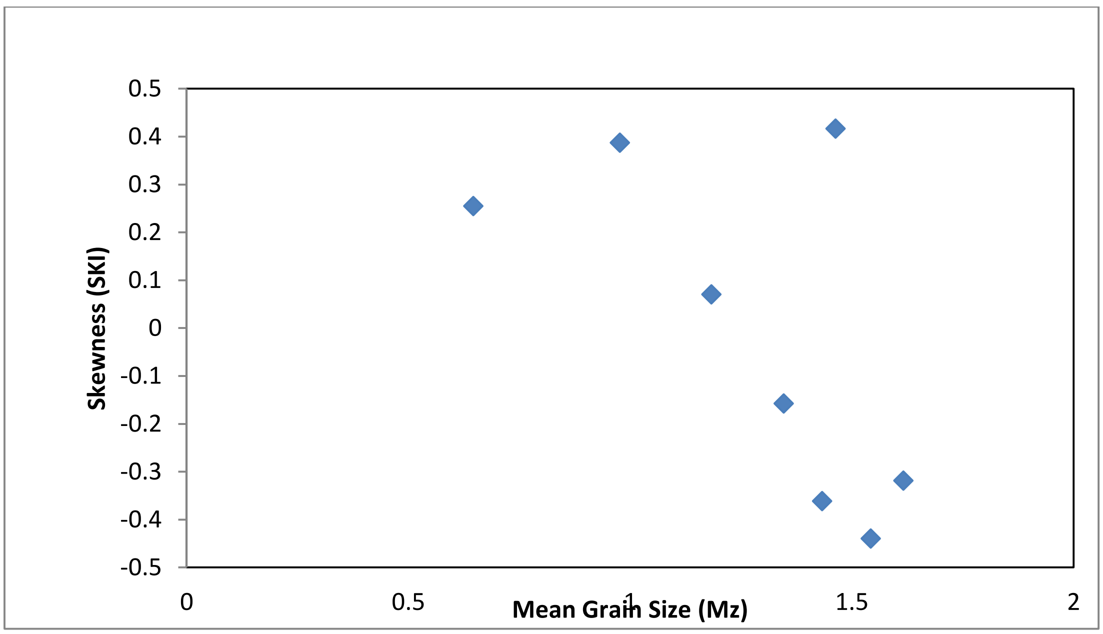

Figure 4. Bivariate plot of Mean size and Skewness adopted (Blott and Kenneth, 2000)

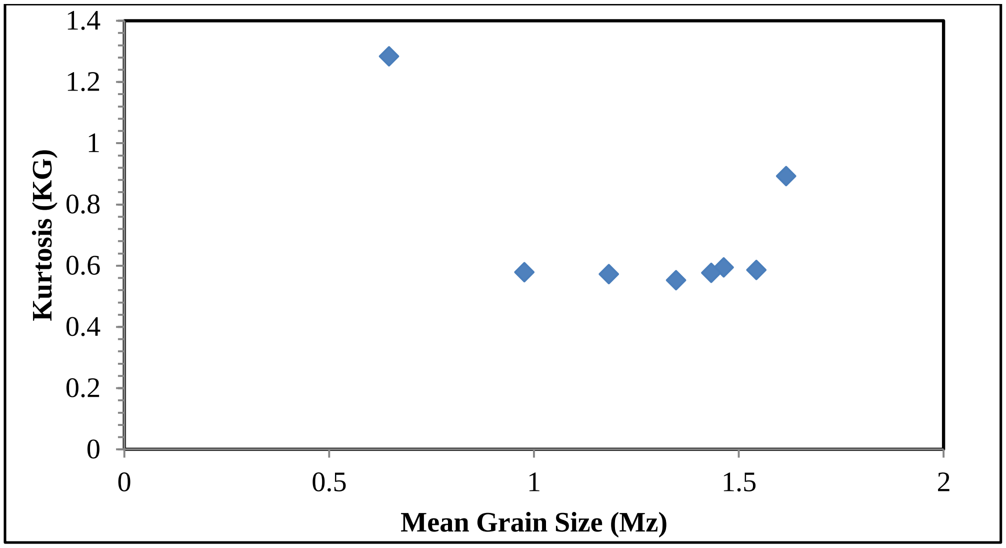

Figure 5. Bivariate plot of Kurtosis and Mean Grain Size adopted (Blott and Kenneth, 2000)

5.1 Environment of Deposition

The sandstone sediment within the study area is predominately by medium grained and poorly sorted sandstone which indicates an evidence of moderate fluctuation in the hydrodynamic energy conditions of depositional environment and moderate-high energy environment (Friedman, 1961; Ayodele et al, 2019); the poor sorting is denotes closeness of the sediment to its source. The skewness is near symmetrically skewed which implies a sheltered quiet area, where wave surges do not disturb bottom sediments i.e. the absence of extreme conditions like tidal variation, wave breaking and supply of detrital materials. The presence of negatively skewenes shows influence of cyclic current pattern of the depositing medium within a high energy prevailing environment. The kurtosis is platykurtic which indicates curves; the variation in the kurtosis values shows the changes in the flow characteristics of the depositing medium (Duane, 1964).

Bivariate plots of mean versus standard deviation (Fig. 2 and Fig. 3) clearly define the sandstone to be fluvially deposited with possible beach interaction during deposition and are probably deposited close to its source or deposited quickly. The bivariate plot of mean size and skewed showed a wide range of plots in very negatively skewed and very positively (Strong finely) skewed (Fig. 4). Fig. 5 is a bivariate of mean and kurtosis showing a plot in platykurtic zone up to the leptokurtic zone.

5.2 Aquifer Characteristics of the Sediment

Determine D10, D30 and D60 where weight of 10, 30 and 60, intercept with the particle sizes distribution.

Use the values in (i) above to calculate C_u (Uniformity Coefficient) and C_G (Gradation Coefficient) using the formula below.

Uniformity Coefficient $C_u = D_{60}/D_{10}$ (Fetter, 2001)

Gradation Coefficient $C_G = D_{30}^2/D_{60} \times D_{10}$ (Fetter, 2001)

Use the values in (i) to calculate for porosity, void ratio and hydraulic conductivity

Porosity (n)

Porosity (n) = $0.255(1+0.83^{cu})$ (Vukovic, and Soro, 1992)

Void ratio (e)

Void ratio (e) = n/1-n (Hamill, and Bell, 1986)

Hydraulic Conductivity (k)

Hydraulic Conductivity (k) $= g/v * 6*10^{-4} [1+ 10(n-0.26)] \times D10^2$ (Hazen, 1892)

Table 3: Summary of the hydraulic conductivity of the soil samples

LOCATION	UNIFORMITY COEFFICIENT	GRADATION COEFFICIENT	POROSITY	VOID RATIO	HYDRAULIC CONDUCTIVITY
Location 3	6.83	2.54	33	0.49	40.33
Location 11	-0.6	-0.24	54.02	-1.12	34.55
Location 12	-19.2	-1.2	9.38	-1.12	34.55
Location 13	-10.8	-0.04	2.16	-1.862	16.86
Location 15	-27.5	-0.04	43.00	-1.024	103.06

From sieve analysis curves for the sediment, the aquifer characteristics of different location differ from the calculated parameters. The estimated value of hydraulic conductivity K in the study area ranges from 16.86 m/day to 103.06 m/day, giving a differential value of 49.01 m/day while porosities values of the sandstone range from 2.16% to 54.02%. This value is good for geologic materials of sandstone. Freeze and Cherry (1979), also indicated that unconsolidated sands have porosity values of 25%-50% while Todd, (1980) gave porosity values of 33% and 37% for fine and medium grained sandstone respectively. Low porosity values of these sandstones may be due to external factors like transportation which might increase compaction. A comparison of the results of the various methods is presented in Table 3. The values from sieve analysis laboratory parameter tests and those from the empirical estimations for the Ajali Formation fall within a range of 10^{-4} to 10^{-3} m/day for clean sands; interpreted to be permeable to highly permeable (Freeze and Cherry, 1979).

The grain size of sandstone outcrops ranges from fine to medium quartz arenite, they are poorly to moderately sorted- this indicate a high degree of sorting for the sandstone aquifer. Aquifer of such sandstone has specific yields which are reasonable for economic water supply (Obasi et al, 2013). Based on this parameter, the formation indicates moderate energy and high energy depositional medium. The sedimentary structures seen within the study area suggest a tidal high energy current deposition processes.

6. Conclusion

In conclusion, sieve analysis provides information on the particle size distribution of a soil sample, which aids in determining hydraulic conductivity. The arrangement of the soil particle and the size of pores spaces are impacted by the particle size distribution, and these changes in turn impact hydraulic conductivity which is derived by examining the particle size distribution acquired by sieve analysis, and they can use knowledge for the variety of geotechnical and hydrogeological applications. The result indicate medium to coarse sand with minor amounts of silt. The evaluated textural parameters (Cu = -27.5-6.83, n = 2.16-54.02% and K = 16.86-103.06 m/day) in addition to statistical parameters (such as skewness, kurtosis, graphic mean and standard deviation) are indications of high aquiferous potentials of the sandstone in terms of groundwater occurrence for economic supply.

References

Akande, S. O., & Erdtmann, B. D. (1998). Burial metamorphism (Thermal maturation) in Cretaceous sediments of the Southern Benue Trough and Anambra Basin, Nigeria. *American Association of Petroleum Geologists Bulletin*, 82, 1191-1206.

Ayodele, O. S., & Madukwe, H. J. (2019). Granulometric and sedimentologic study of beach sediments, Lagos, Southwestern Nigeria. *International Journal of Geosciences*, 10(3), 295-316.

Benkhelil, J. (1989). The origin and evolution of the Cretaceous Benue Trough (Nigeria). *Journal of African Earth Sciences (and the Middle East)*, 8, 251-282.

Blott, S. J., & Kenneth, P. (2000). Gradistat: A grain size distribution and statistics package for the analysis of unconsolidated sediments. *Earth Surface Processes and Landforms*, 26, 1237-1248.

Duane, D. B. (1964). Significance of skewness in recent sediments, Western Pamlico Sound, North Carolina. *Journal of Sedimentary Petrology*, 34, 864-874.

Fetter, C. W. (1994). Applied hydrogeology (3rd ed.). Macmillan College Publishing Company.

Fetter, C. W. (2001). Applied hydrogeology (4th ed.). Prentice Hall.

Folk, R. L., & Ward, W. C. (1957). Brazos River bar: A study of the significance of grain size parameters. *Journal of Sedimentary Petrology*, 27(1), 3-26.

Freeze, R. A., & Cherry, J. A. (1979). Groundwater. Prentice-Hall.

Friedman, G. M. (1961). Dynamic processes and statistical parameters compared for size frequency distribution of beach and river sands. *Journal of Sedimentary Petrology*, 37, 327-354.

Hamill, L., & Bell, F. U. (1986). Groundwater resources development. Britain Library Cataloguing in Publication Data London, 151-158.

Hazen, A. (1892). Some physical properties of sands and gravels, with special reference to their use in filtration. *24th annual report, Massachusetts State Board of Health, Pub. Doc.*, 34, 539-556.

Ladipo, K. O., Nwajide, C. S., & Akande, S. O. (1992). Cretaceous and Paleogene sequences in the Abakaliki and Anambra basins. Presented at the National Symposium on Geology of Deltas, Port Harcourt, May 1992.

Miola, R. J., & Weiser, D. (1968). Textural parameters: An evaluation. *Journal of Sedimentary Petrology*, 38, 45-53.

Murat, R. C. (1972). Stratigraphy and palaeogeography of the Cretaceous and Lower Tertiary in southern Nigeria. *African Geology*, 251-266.

Nwajide, C. S. (2013). Geology of Nigeria's sedimentary basins. CSS Bookshops Limited.

Obasi, P. N., Aghamelu, O. P., & Akudinobi, B. E. B. (2013). Determination of hydraulic conductivity of sandstones of Ajali Formation in Uturu Area (Southeastern Nigeria) using grain size analysis. *Journal of Natural Sciences Research*, 3(3), 49-54.

Obi, G. C. (2000). Depositional model for the Campanian-Maastrichtian succession, Anambra Basin, Southern Nigeria. Unpublished Ph.D. thesis, University of Nigeria, Nsukka, 291.

Obi, G. C., Okogbue, C. O., & Nwajide, C. S. (2001). Evolution of the Enugu Cuesta: A tectonically driven erosional process. *Global Journal of Pure and Applied Sciences*, 7(2), 321-330.

Oboh-Ikuenobe, F. E., Obi, C. G., & Jaramillo, C. A. (2005). Lithofacies, palynofacies, and sequence stratigraphy of Palaeogene strata in Southeastern Nigeria. *Journal of African Earth Sciences*, 41, 79-101.

Ofomata, G. E. K. (Ed.). (1978). Relief and drainage in the Nsukka Environment. Fourth Dimension Publishers, 58-68.

Pettijohn, F. J. (1975). Sedimentary rocks (2nd ed.). Harper and Row Publishers.

Sahu, B. K. (1964). Depositional mechanisms from the size analysis of clastic sediments. *Journal of Sedimentary Petrology*, 34, 73-83.

Todd, D. K. (1980). Groundwater hydrology (2nd ed.). John Wiley and Sons.

Vukovic, M., & Soro, A. (1992). Determination of hydraulic conductivity of porous media from grain-size distribution. Water Resources Publications, LLC.