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Volumetric characteristics and mineralogy of Ogwashi Asaba Formation, Niger Delta Basin Nigeria

[1] I.E. Obiakonwa, [2] S.E. Odumoso, [3]O.W. Osisanya [4] A.S. Saleh, [5] E.R. Ogheneochuko
[1,2,5] Department of Geology, Federal University of Petroleum Resources Effurun, Delta State.
[3]Department of Applied Geophysics, Federal University of Petroleum Resources Effurun, Delta State.
[4]*Department of Petroleum Engineering and Geosciences, Petroleum Training Institute, Effurun, Nigeria.*
Corresponding author Email:
Email: osisanya.wasiu@fupre.edu.ng
ORCID ID: 0000-0001-7280-9771

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Abstract: *The aim of this study is to examine the Ogwashi-Asaba Formation's mineralogy and volumetric characteristics. During the fieldwork, a variety of well-preserved geological samples were collected from several locations within the research region. Standard laboratory and analytical procedures were used to the gathered samples. The sediments are medium to coarse grained, poorly sorted, almost symmetrical in terms of skewness, and leptokurtic in terms of kurtosis, according to the results of the various analyses. These characteristics typically indicate sediments from continental and/or mixed environments (transitional). Additionally, the petrographic examination reveals quartz to be the predominant mineral, making up over 85% of the entire mineralogy, suggesting a basement rock as the source. Other heavy minerals were also found, including sillimanite, zircon, and tourmaline. Overall, the study sheds more light on the lithology, different minerals, and depositional environment. Additionally, the study will help with the development and exploitation of natural resources, especially possible hydrocarbon deposits, and advance knowledge of the geology of the Niger Delta Basin.*

Keywords: Texture, Quartz, Thin Section, Skewed,

INTRODUCTION

One of the key aspects of geology that aid in our understanding of the chemical and physical qualities of rocks and minerals include volumetric features and mineralogy (Effam, et al., 2014; Ike, et al., 2021). Similarly, a mineral or rock's volume and shape are referred to as its volumetric properties. The physical features of rocks, such as their density, porosity, and permeability, are largely determined by their volumetric characteristics. Numerous studies have been conducted on the geological formations in Nigeria's Niger Delta, which is well-known for its rich oil and gas reserves. The Ogwashi-Asabi Formation is one of the important formations in this area and is particularly interesting because of its mineralogy and volumetric features. Its formation is thought to have occurred during the Paleocene. The Formation's distinctive mineralogy and volumetric features, which offer important insights into the region's geological past, are of great interest to geologists and other scientists. The Ogwashi-Asaba Formation is a highly sought-after location for exploration and production activities due to its enormous reserves of various minerals and hydrocarbons, including gas and oil. Ejedawe et al. (1982), sandstones, siltstones, and shales that were deposited between the Paleocene and Eocene epochs make up the formation (Okosun et al., 2016).The mineralogy of the Ogwashi-Asaba Formation has been studied in the past. For instance, a petrographic study of the sandstones of the Formation by Ejedawe et al. (1982) revealed that they were made up of quartz, feldspar, and lithic pieces. Additionally, they discovered clay minerals that can alter the porosity and permeability of the sandstones, such as illite and kaolinite. In a similar vein, Ojo and Ajibade(2013) examined the mineralogy of the shales in the Formation and discovered that they were made up of clay minerals such as chlorite, illite, and smectite. Okosun et al. (2016) estimated the Formation's reservoir characteristics, such as porosity and water saturation, using well log data. They discovered that the average porosity of the sandstones was 19.5%, with porosities ranging from 10% to 30%. Additionally, they discovered that the sandstones' water saturation ranged from 10% to 25%, which is comparatively low. While Okeowo et al. (2019) looked into the Formation's petrophysical characteristics and hydrocarbon potential, Oloto et al. (2015) examined the sedimentology and sequence stratigraphy of the Formation. Other research has concentrated on the Formation's provenance and depositional environment (Olabode et al., 2017; Adeleye and Olabode, 2018). Bassey and Eminue (2012) investigated the stratigraphic and petrographic analyses of the Palaeogene Ogwashi-Asaba Formation in the Anambra Basin, Nigeria. These analyses included sedimentological, geochemical, and petrographic investigations conducted on four subsurface and thirteen outcrop samples of the Paleogene Ogwashi-Asaba Formation. The objective was to draw conclusions about the hydrocarbon potential, tectonic setting, source rock, transport history, and depositional environment. Sandstones are fine to almost symmetrically skewed, coarse to medium grained, and moderately to poorly sorted. A river depositional environment is shown by bivariate plots of skewness against sorting and sorting against mean size. The majority of the sandstone shows bimodality, which suggests many sources. These are lithic arenites with 64% rock fragments, 31% quartz, and 5% feldspar, indicating that the sands are mineralogically young. The framework elements' ternary plot showed that they originate from an orogen, which is thought to be a molasse trough created between a craton and a basin. SiO_2 (5.84-84.57%) and total Fe (12.69-92.07%) were more common than all other oxides, according to geochemical research. This suggests a subaerial, oxidizing environment that promotes hematite formation. Chemical immaturity is indicated by the SiO_2/A_2O_3 ratio. Lignite's organic analysis yielded a TOC of 1.60–3.13%. Vitrinite-dominated maceral has the potential to be a gas source. Swamps were identified as the lignite depositional environment by scatter plots (tissue preservation vs. gelification index). Additionally, research by Ejedawe (1982) lays the groundwork for future investigations into the geological context of the Ogwashi-Asaba Formation. Future research on the Formation's petrophysical characteristics, reservoir potential, and exploration and production tactics can benefit from the identification of the Formation as a transgression sequence as well as the interpretation of its paleogeography and depositional environment. Comprehending the mineralogy and volumetric properties of this formation is essential for efficient exploration and production of oil and gas. Understanding the volumetric features and mineralogy of the Ogwashi-Asaba Formation has attracted more study recently. This is due to the fact that a deeper comprehension of the Formation's geological characteristics can help in hydrocarbon reserve prediction and exploration. Furthermore, understanding the Formation's mineralogical makeup might offer crucial information on its diagenetic history and depositional environment. The aim of this study is to expand on earlier research by thoroughly examining the volumetric characteristics and mineralogy of the Ogwashi-Asaba Formation. The objectives were use to achieve the aim of this study:

i. To conduct a petrographic analysis of the sandstones, siltstones, and shales in the Formation.
ii. To identify the lithologies and depositional environment of the Formation.
iii. To determine the textural characteristics, graphic skewness, and kurtosis of the Formation.
iv. To examine the hydrocarbon potential of the Formation based on its volumetric characteristics.

Description of the study area

The Ogwashi-Asaba Formation, located in southern Nigeria see Fig. 1. It is a rich hydrocarbon-bearing formation. According to Oboh-Ikuenobe et al. (2005), the Palaeocene Anambra Basin (Afikpo geosyncline) contains the Ogwashi-Asaba Formation. It is thought that this formation was deposited in a shallow marine environment between the Late Campanian and Early Maastrichtian ages, with a transgressive-regressive cycle. According to Bassey and Eminue (2012), the formation is distinguished by the alternation of clays, grits and lignites. The Formation is mostly found in the regions of Benin, Asaba, Onitsha, and Orlu. Reyment (1965) estimated the Formation's age to be Oligocene–Miocene, however palynological research by Cherie et al. (1978) gave the base portion an age of Middle Eocene.

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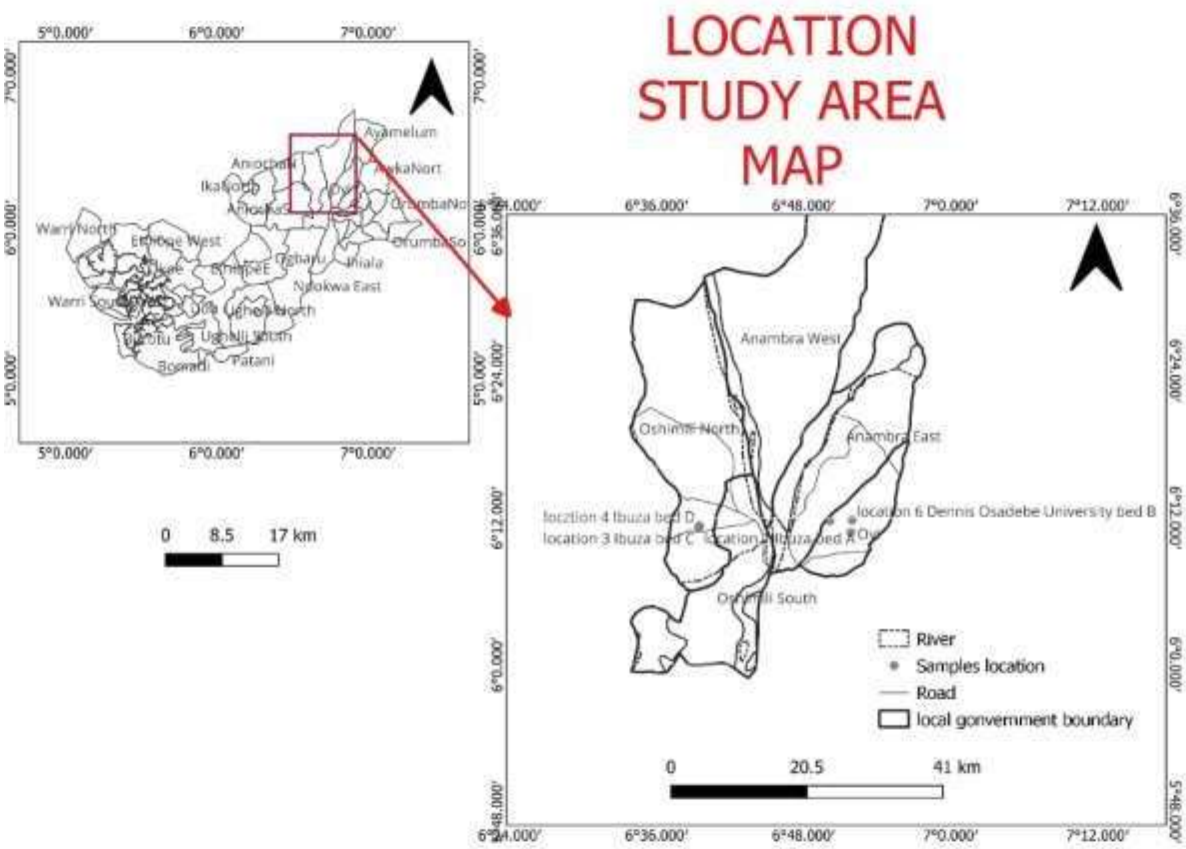

Fig. 1: Map of the study area

Geology of the study area

The Ogwashi-Asaba Formation (Reyment, 1965) of the outcropping Niger Delta Basin in Southern Nigeria is where the study area is situated. It is believed that the subsidence of the underlying rock during the early Cretaceous period (Albian stage) is connected to the deposition of the geological layer. This event, which took place along the Niger and Benue depressions, marked the beginning of the development of sedimentary basins in southern Nigeria (Reyment, 1965). The Abakaliki-Benue region underwent folding and elevation along a northeast-southwest pattern throughout the Santonian epoch. The Anambra Platform, which is located west and southwest of the Abakaliki fold belt, sank, creating the Anambra Basin (Fatoye and Gideon, 2013). The sediment that started the upper Cretaceous stratigraphic series within the Anambra Basin originated from the marine Campanian-Maastrichtian Enugu/Nkporo shales and their laterally equivalent deltaic Owelli sandstone. The lower middle Maastrichtian deltaic coalbearing formation, the middle Maastrichtian tidal Ajali sandstone, and the fluvial-deltaic Nsukka Formation (upper coal measures) eventually covered these basic units. Folding and uplift in a northeast-southwest axis occurred in the Abakaliki-Benue region during the Santonian era. The Anambra Platform, which is located west and southwest of the Abakaliki fold belt, subsided as a result of this geological activity, creating the Anambra Basin (Madukwe and Bassey, 2015; Bassey and Eminue, 2012). This geological development was also significantly influenced by the Campanian-Maastrichtian Enugu/Nkporo coastal shales and their lateral equivalents. The regressive Ameki Formation (Eocene), which covered the Imo and Nsukka marine shale formations deposited during the Paleocene, replaced the middle Maastrichtian deltaic coal-bearing Mamu Formation (lower coal measures) (Jan du Chériene et al., 1978; Jolayemi et al., 2023).

MATERIALS AND METHODOLOGY

Equipment used for field mapping:

To help with their research, geologists employ a variety of tools. Compasses (compass clinometer), rock hammers, hand trowels, hand lenses, and field books are a few of the tools utilized in the field work.

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Sieve Grain Size Analysis

A collection of sieves with various mesh sizes is used to conduct the test. Squared apertures of a specific size are included in every sieve. Larger and smaller particles are separated by the sieve. While smaller diameter grains flow through the sieve as it is shaken by the sieve shaker, bigger diameter grains are held by the sieve. The soil sample is passed through the stacked sieve "tower," which is made up of several sieves with progressively decreasing mesh sizes piled on top of one another. As a result, the soil particles are dispersed while being retained by the various sieves. The particles that make it past the last filter are also gathered in a pan.

Detailed Sieve Analysis Test Procedure

Calculated skewness The following phases make up the standard testing process: Weigh a sample of dry dirt that weighs at least 500 grams. Note the weight of the pan and the sieves that will be used for the analysis. Before the test, each sieve needs to be completely cleaned. Put the sieves together in increasing order, starting with the ones with the biggest apertures. After inserting the soil sample into the top sieve, cover it with a lid or cap. For ten minutes, shake the stack in a mechanical shaker. Measure the weight of each sieve and the pan at the bottom of the stack after removing the sieve stack from the shaker. The drying oven is kept at 110 ± 5°C.

Data Manipulation

The weight of the soil retained on each sieve is determined by deducting the empty sieve's weight from the sieve's recorded weight following the test. The initial weight of the soil sample is compared to the total weights of the retained particles. It must be less than two percent. By dividing the masses of each sieve by the total dry mass of the sample and multiplying the result by 100, one can find the percentage retained on each sieve. It is common practice to interpret the outcomes of statistical parameters by contrasting them with benchmarks:

Graphic Mean: A measure of the average diameter of grains in the sediment. The interpretation was based on Folk and Ward Equation (1957).
Mean value interpretation

-1.0 to 0.00 very coarse sand, 0.0 to 1.0 coarse sand, 1.0 to 2.0 medium sand, 2.0 to 3.0 fine sand, 3.0 to 5.0 very fine sand,
and 4.0 to 5.0 coarse silt

Graphic standard deviation: This parameter measures the spread of the distribution around the mean and gives clues to the sediment sorting; based on Folk and Ward (1957).
Graphic standard deviation value interpretation
< 0.35 Very well-sorted, 0.35 to 0.50 Well-sorted, 0.50 to 0.70 Moderately well-sorted, 0.70 to 1.00 Moderately-sorted,
1.00 to 2.00 Poorly –sorted, 2.00 to 4.00 Very poorly-sorted, and > 4.00 Extremely poorly-sorted

Graphic Kurtosis: This indicates how far the distribution deviates from normalcy and is a measure of how peaked the distribution curves are. Equations 1 through 4 are also used to interpret the values.

$$\text{Mean size } (M_z) = \frac{\Phi 84 + \Phi 50 + \Phi 16}{3} \quad \text{-------------------------------------- (Equation 1)}$$

$$\text{Inclusive graphic standard deviation } (\sigma) = \frac{(\Phi 84 - \Phi 16)}{4} + \frac{(\Phi 95 - \Phi 5)}{6.6} \quad \text{--------------------------------- (Equation 2)}$$

$$\text{Inclusive graphic skewness } (SK_1) = (\Phi 84 + \Phi 16 - 2\,\Phi 50) + (\Phi 95 + \Phi 5 - 2\,\Phi 50) \quad \text{------------------------------- (Equation 3)}$$

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$2(\Phi 84 - \Phi 16) \qquad 2(\Phi 95 - \Phi 5)$

Graphic Kurtosis (KG) = $\dfrac{(\Phi 95 - \Phi 5)}{2.44(\Phi 75 - \Phi 25)}$ -------------------------------------- (Equation 4)

Petrographic Thin Sections of study area.
A thin slice is a laboratory preparation of a rock, mineral, soil, ceramic, bone, or even metal sample used with an electron microscope, polarizing petrographic microscope, or electron microprobe in optical mineralogy and petrography. A diamond saw is used to cut a small slice of rock from the sample, which is then optically flat. After mounting it on a glass slide, the sample is smoothed out using increasingly finer abrasive grit until it is barely 30 µm thick. The Michel-Lévy interference color chart was used in the procedure. Since quartz is one of the most common minerals, it is typically used as a gauge to determine thickness. The optical characteristics of the minerals in the thin slice change the color and intensity of the light as perceived by the observer when it is positioned between two polarizing filters that are positioned at right angles to one another. The majority of minerals that comprise rocks are clearly identifiable because they differ in their optical characteristics. For instance, the transparent mineral plagioclase has several parallel twinning planes. With some orthopyroxene exsolution, the big blue-green minerals are clinopyroxene. To examine the optical characteristics of the minerals in the rock, thin slices are created. This investigation, which is a component of petrology, reveals the parent rock's origin and evolution. Rock thin section analysis was performed on a few rock samples from the Ogwashi-Asaba Formation; the findings and interpretation are further addressed. Light mineral microscopy and heavy mineral analysis are two aspects of petrographic study for the Ogwashi-Asaba Formation.

Light Minerals: The analysed samples show that quartz consist of about 94-99% of the framework grains. Quartz overgrowths are absent to rare. The quartz grains show dominance of monocrystalline nature over polycrystalline. The high predominance of monocrystalline, unstrained grains indicate selective destruction of less stable polycrystalline and strained monocrystalline forms during transport and recycling.

RESULTS AND DISCUSSION

Results of all analytical techniques in the study are presented in Table 1 to 8, and Fig. 2 to 9 respectively. A critical assessment of each set of the results has aided its proper interpretation and discussion. The results of the sieve analysis performed on the field samples collected from the Ogwashi-Asaba Formation and the sand section on top of the Benin Formation from the outcrop in Dennis Osadebay University areas, Ibuza areas, and parts of the Chezrock Company areas Obunike, Enugu-Onitsha Expressway, are displayed in the table below. The sedimentological metrics (Mean, Median, Standard Deviation, Skewness, and Kurtosis) are displayed graphically. In southern Nigeria, there is a sedimentary formation named the Ogwashi-Asaba Formation. Sandstones, lignites, and siltstones are among the sedimentary rocks that make up this formation. The Ogwashi-Asaba Formation's volumetric features and mineralogy, which are crucial elements influencing its geological and economic significance, were clarified by the investigation as a whole. The Ogwashi-Asaba Formation's sediments are medium-grained sand with an average size of 1.73 mm, according to the results of the grain size analysis. This implies that the sediments were formed in a low energy depositional environment that alternated with a moderate to high energy environment. The average grain size is 1.24 mm, with a standard deviation ranging from 0.52 mm to 1.850 mm, suggesting that the sediments are not well sorted as shown in Table 9. This indicates that the silt has a broad spread of grain sizes, with some particles being significantly larger or smaller than others. This could be due to a number of things, including the sediment's distance traveled or the kind of rocks it was eroded from in the source area. With an average of -0.10 and a range of -0.24 to +0.20, the skewness of the grain sizes shows that the fine admixture outweighs the coarse components see Table 9. This indicates that there are more tiny particles than larger ones in the silt. Because finer particles are more easily carried by wind or water, this may be related to the sediment's origin. Grain size kurtosis varies from 0.65 to 4.28,

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with an average of 1.38 see Table 9. This suggests that there is generally good sorting of the silt at the tail. When a distribution is leptokurtic, more particles are concentrated around the mean size and fewer are at the extremes. This might be the result of things like sediment transport or wave action, which can sort particles according to size. The Ogwashi-Asaba Formation's sediment was deposited in a dynamic environment with fluctuating energy levels, according to the grain size analysis. This led to a poorly sorted sediment with a fine admixture and a generally well-sorted tail. Predicting future sedimentary processes and comprehending the region's geological past can both benefit from this formation. It is clear from the petrographic study results that the samples' mineralogy, texture, and form are all comparable. They are all mostly composed of quartz, which ranges in shape from anhedral to euhedral and has a fine to medium grain sand texture. Nonetheless, the samples' color, angularity, and sphericity differ slightly. The reddish-brown samples are not very spherical and may have experienced little movement, as evidenced by their subangular to angular angularity and zero sphericity. This may indicate that the samples have not experienced substantial weathering or erosion and are from a nearby source. The samples may have been deposited in a low-energy setting, like a lake or river delta, based on the fine to medium grain sand texture. The grey sample is slightly different in color and form, ranging from anhedral to subhedral, but it shares similar mineralogy, texture, and form with the reddish-brown samples. In comparison to the reddish-brown samples, this may indicate that the sample is from a different source or has experienced greater weathering or transportation. Compared to the other samples, the reddish-brown sample appears to have experienced more transportation due to its fine to medium to coarse grain sand texture. Additionally, the subhedral structure suggests that it has experienced more erosion and weathering than the other samples. Its subangular to angular angularity and low sphericity, however, show that it has not been significantly rounded and may have been moved over a shorter distance. Overall, the findings imply that although the samples have seen differing levels of weathering and transit, they are probably from a similar geological source. The differences in form, color, and angularity shed light on the geological processes and history that have shaped these samples.

Results of Sieve Analysis.

Table 1: Ibuza Sample A (IBS-A).
Outcropping coordinates: Longitude: N6^{0}11’19’’

Latitude: E6^{0}39’30’’

Mesh Size (mm)	**Mesh Retained (Φ)**	**Weight Retained (g)**	**Percentage Weight Retained**	**Cumulative Weight (%)**
2.360	-1.24	3.35	6.70	6.70
1.180	-0.24	3.62	7.24	13.94
0.850	0.23	6.50	13.00	26.94
0.600	0.74	3.72	7.44	34.38
0.425	1.23	3.73	7.46	41.84
0.300	1.74	3.54	7.08	48.92
0.212	2.24	4.46	8.92	57.84
0.150	2.74	8.32	16.64	74.48
0.075	3.74	11.47	22.94	97.42
<0.075	Pan Size	1.29	2.58	100.00
TOTAL		50.00	100	

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Table 2: Ibuza Sample B (IBS-B).
Outcropping coordinates: Longitude: N6^{0}11’18’’
Latitude: E6^{0}39’28’’

Mesh Size (mm)	Mesh Retained (Φ)	Weight Retained (g)	Percentage Weight Retained	Cumulative Weight (%)
2.360	-1.24	2.89	5.78	5.78
1.180	-0.24	1.06	2.12	7.90
0.850	0.23	1.54	3.08	10.98
0.600	0.74	0.76	1.52	12.50
0.425	1.23	0.83	1.66	14.16
0.300	1.74	0.95	1.90	16.06
0.212	2.24	2.02	4.04	20.10
0.150	2.74	26.22	52.44	72.54
0.075	3.74	13.35	26.70	99.24
<0.075	Pan Size	0.38	0.76	100.00
TOTAL		50.00	100	

Table 3: Ibuza Sample C (IBS-C).
Outcropping coordinates: Longitude: N6^{0}11’18’’
Latitude: E6^{0}39’28’’

Mesh Size (mm)	Mesh Retained (Φ)	Weight Retained (g)	Percentage Weight Retained	Cumulative Weight (%)
2.360	-1.24	0.28	0.56	0.56
1.180	-0.24	0.16	0.32	0.88
0.850	0.23	0.09	0.18	1.06
0.600	0.74	0.04	0.08	1.14
0.425	1.23	0.56	1.12	2.26
0.300	1.74	7.49	14.98	17.24
0.212	2.24	21.26	42.52	59.76
0.150	2.74	13.58	29.16	86.92
0.075	3.74	6.04	12.08	99.00
<0.075	Pan Size	0.50	1.00	100.00
TOTAL		50.00	100	

Table 4: Ibuza Sample D (IBS-D).
Outcropping coordinates: Longitude: N6^{0}11’21’’
Latitude: E6^{0}39’29’’

Mesh Size (mm)	Mesh Retained (Φ)	Weight Retained (g)	Percentage Weight Retained	Cumulative Weight (%)
2.360	-1.24	0.03	0.06	0.06
1.180	-0.24	1.04	2.08	2.14
0.850	0.23	3.25	6.50	8.64
0.600	0.74	2.44	4.88	13.52
0.425	1.23	2.60	5.20	18.72
0.300	1.74	9.34	18.68	37.40
0.212	2.24	16.61	33.22	70.62
0.150	2.74	8.99	19.98	88.60
0.075	3.74	5.14	10.28	98.88
<0.075	Pan	0.56	1.12	100.00
TOTAL		50.00	100	

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Table 5: Obunike, Enugu-Onitsha Express way Sample A (OEOS- A)
Outcropping coordinates: Longitude: N6^{0}11'50''
Latitude: E6^{0}52'1''

Mesh Size (mm)	Mesh Retained (Φ)	Weight Retained (g)	Percentage Weight Retained	Cumulative Weight (%)
2.360	-1.24	6.53	13.06	13.06
1.180	-0.24	5.38	10.76	23.82
0.850	0.23	8.18	16.36	40.18
0.600	0.74	4.27	8.54	48.72
0.425	1.23	3.38	6.76	55.48
0.300	1.74	2.81	5.62	61.10
0.212	2.24	2.41	4.82	65.92
0.150	2.74	3.43	6.86	72.78
0.075	3.74	11.16	22.32	95.10
<0.075	Pan	2.45	4.90	100.00
TOTAL		50.00	100	

Table 6: Dennis Osadebe Sample A (DOS-A).
Outcropping coordinates: Longitude: N6^{0}11'49''
Latitude: E6^{0}52'11''

Mesh Size (mm)	Mesh Retained (Φ)	Weight Retained (g)	Percentage Weight Retained	Cumulative Weight (%)
2.360	-1.24	0.45	0.90	0.90
1.180	-0.24	0.55	1.10	2.00
0.850	0.23	3.63	7.26	9.26
0.600	0.74	4.29	8.58	17.84
0.425	1.23	4.58	9.16	27.00
0.300	1.74	4.66	9.32	36.32
0.212	2.24	6.28	12.56	48.88
0.150	2.74	11.73	23.46	72.34
0.075	3.74	11.64	23.28	95.62
<0.075	Pan	2.19	4.38	100.00
TOTAL		50.00	100	

Table 7: Dennis Osadebay Sample B (DOS-B).
Outcropping coordinates: Longitude: N6^{0}11'52''
Latitude: E6^{0}39'1''

Mesh Size (mm)	Mesh Retained (Φ)	Weight Retained (g)	Percentage Weight Retained	Cumulative Weight (%)
2.360	-1.24	1.22	2.44	2.44
1.180	-0.24	1.58	3.16	5.60
0.850	0.23	9.88	19.76	25.36
0.600	0.74	12.27	24.54	49.90
0.425	1.23	11.03	22.06	71.96
0.300	1.74	6.70	13.40	85.36
0.212	2.24	4.06	8.12	93.48
0.150	2.74	1.87	3.74	97.22
0.075	3.74	1.15	2.30	99.52
<0.075	Pan	0.24	0.48	100.00
TOTAL		50.00	100	

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Table 8: Chezrock Company, Obunike Sample A (CCOS-A)
Outcropping coordinates: Longitude: N6^{0}10'49''
Latitude: E6^{0}51'53''

Mesh Size (mm)	Mesh Retained (Φ)	Weight Retained (g)	Percentage Weight Retained	Cumulative Weight (%)
2.360	-1.24	0.88	1.76	1.76
1.180	-0.24	4.38	8.76	10.52
0.850	0.23	6.98	13.96	24.48
0.600	0.74	5.13	10.26	34.74
0.425	1.23	3.95	7.90	42.64
0.300	1.74	3.75	7.50	50.14
0.212	2.24	3.55	7.10	57.24
0.150	2.74	5.40	10.80	68.04
0.075	3.74	15.08	30.16	98.20
<0.075	Pan	0.90	1.80	100.00
TOTAL		50.00	100	

GRAPHICAL REPRESNTATIONS OF THE ABOVE TABLES:
N:B; For each of the graphs;
Y-axis represent the cumulative weight; X-axis represent the mesh retained
Fig. 2: Graph representation for Table 1

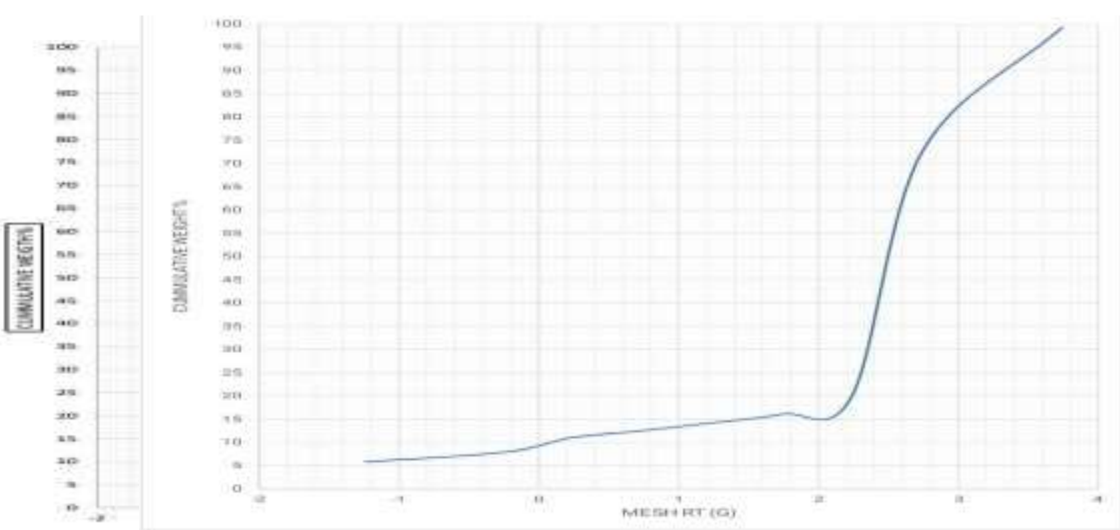

Fig. 3: Graph representation for Table 2

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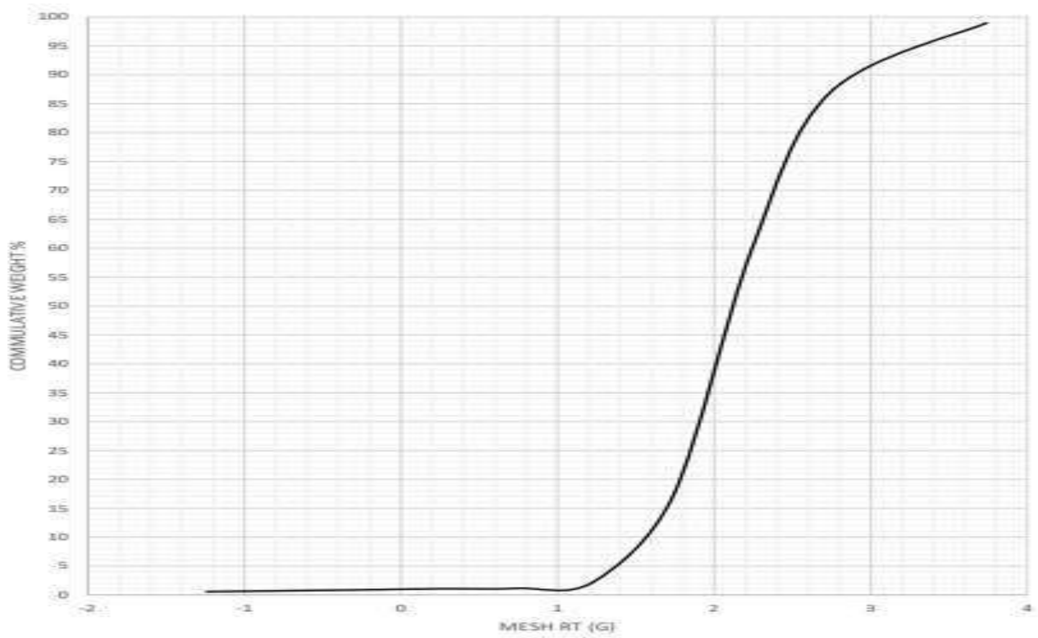

Fig. 4: Graph representation for Table 3

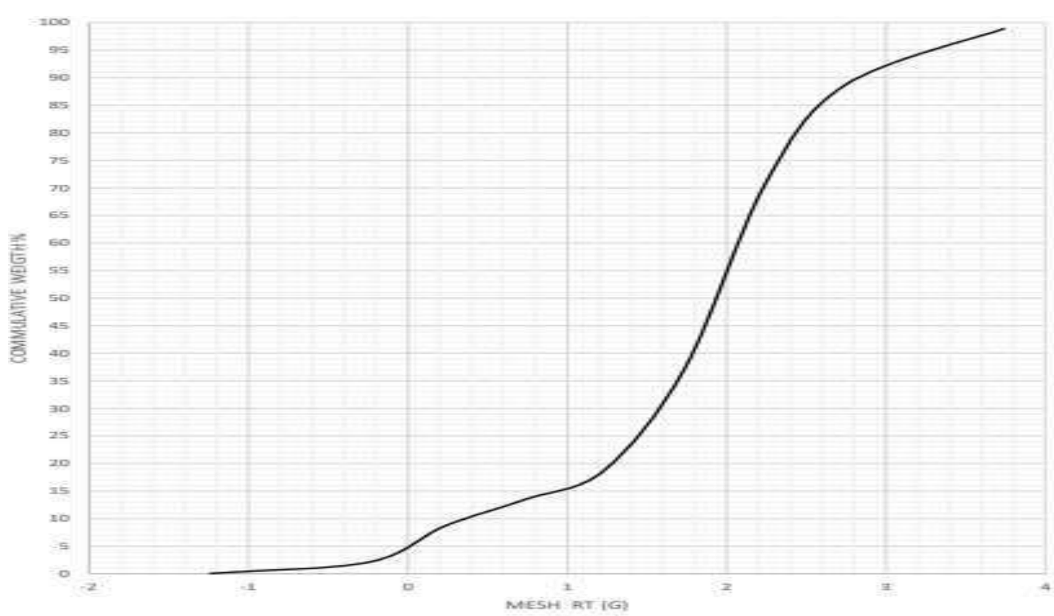

Fig. 5: Graph representation for Table 4

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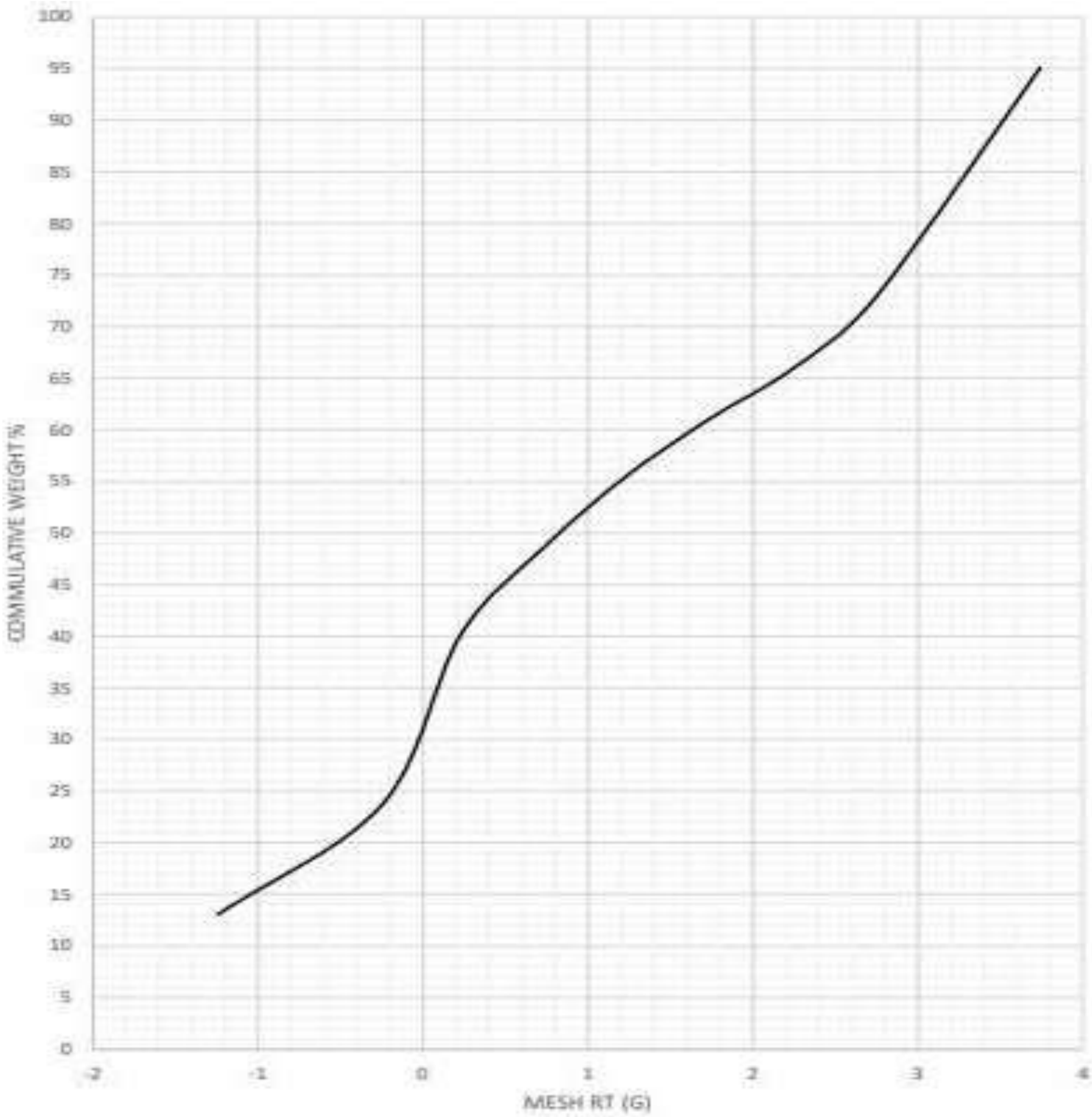

Fig. 6 Graph representation for Table 5

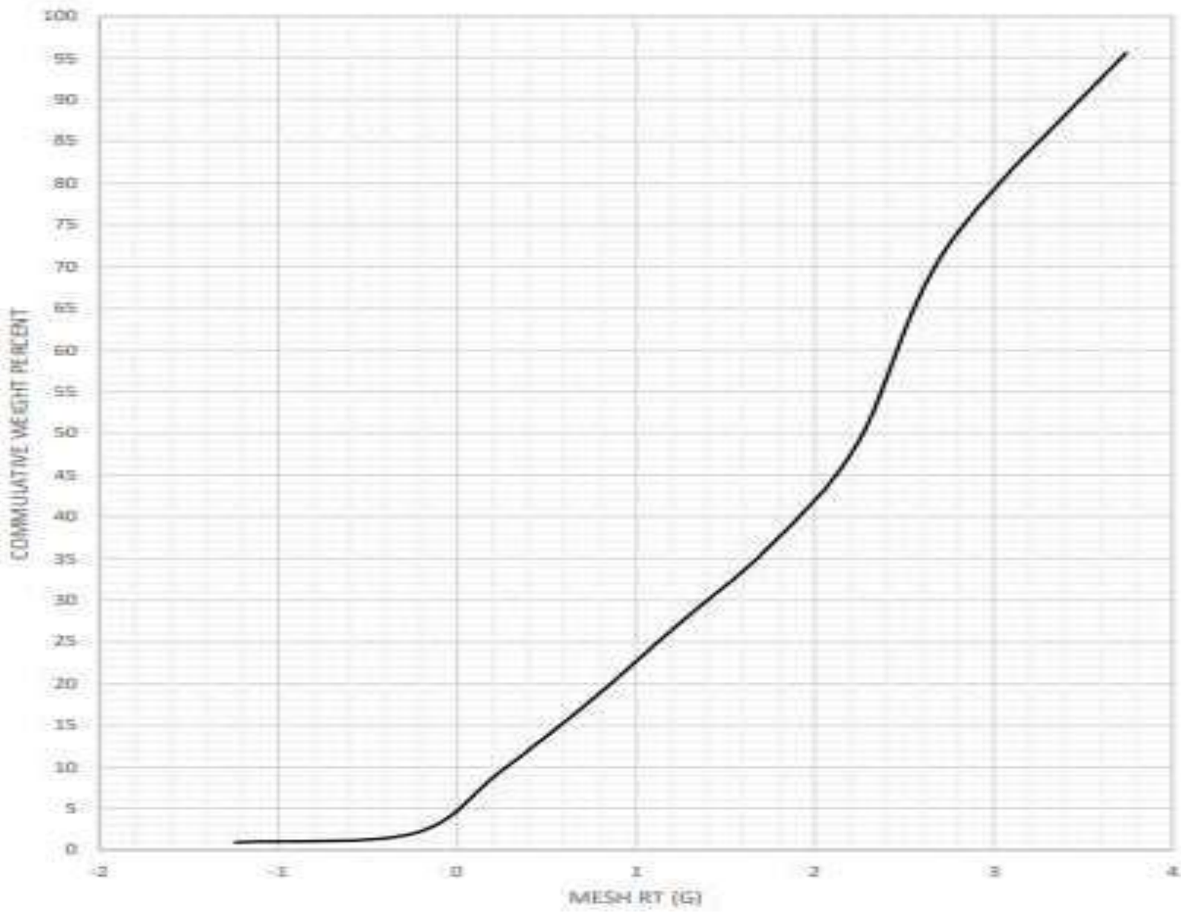

Fig. 7: Graph representation for Table 6

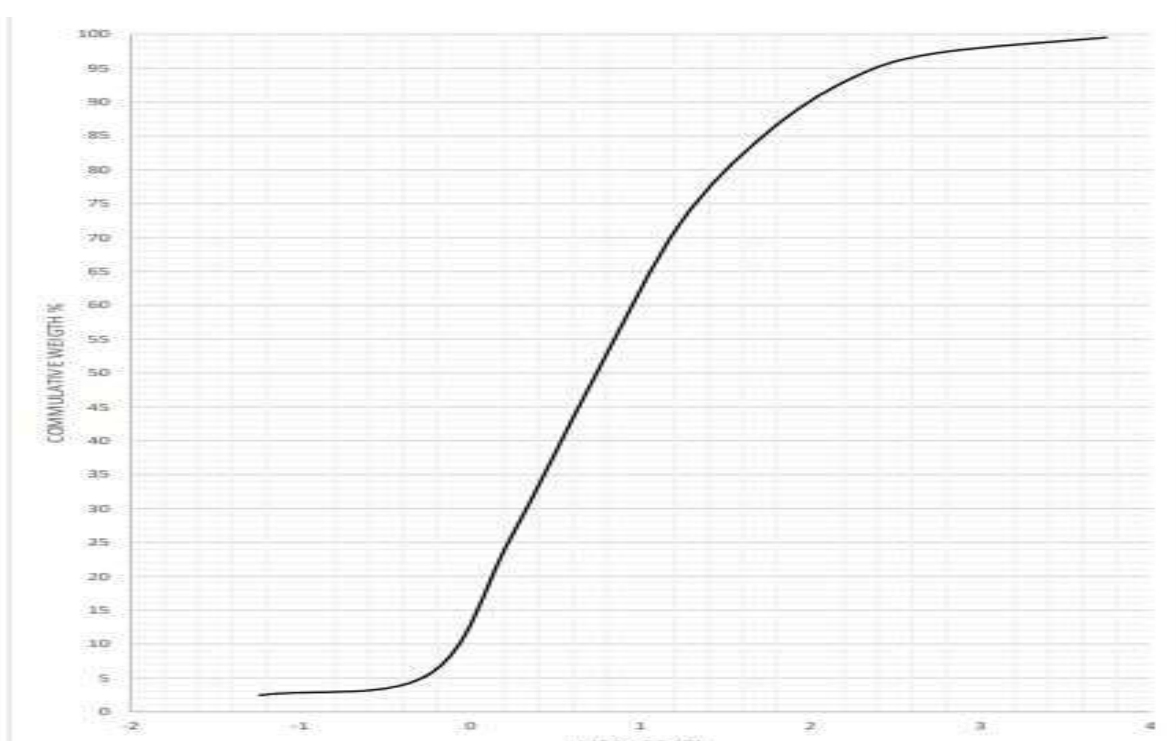

Fig. 8: Graph representation for Table 7

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Graph representation for table (8)

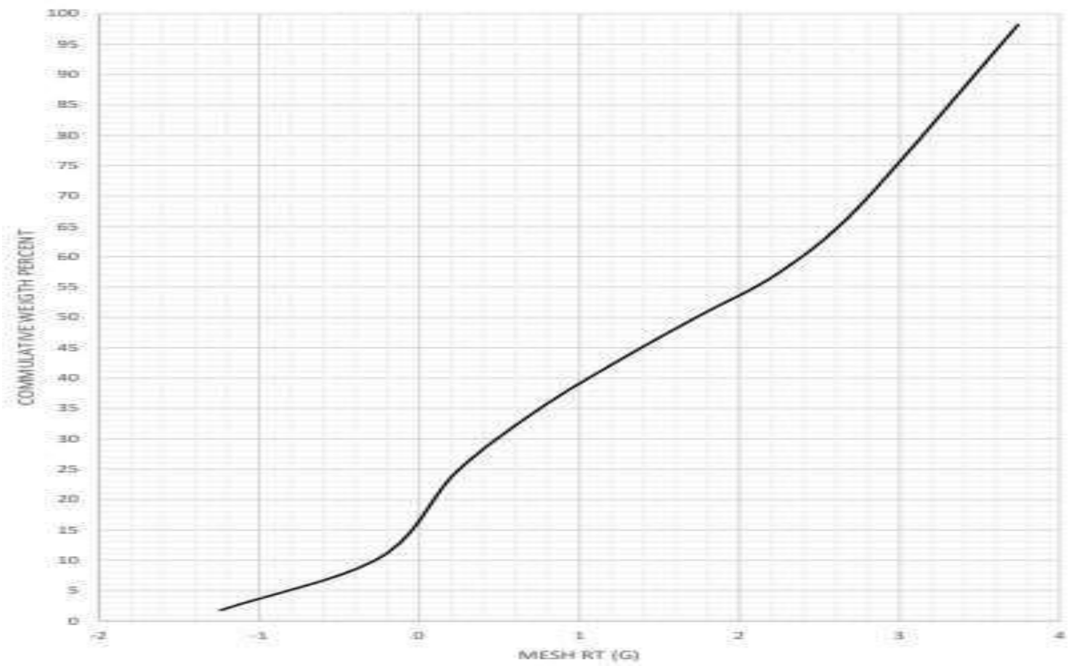

Fig. 9: Graph representation for Table 8

Table 9: Summary of sieve analysis of the Ogwashi-Asaba Formation (method based on Folk and Ward 1957)

S/N	Sample No	Median Φ50	Mean M	Standard Deviation	Inclusive Graphic Skewness (Sk1)	Graphic Kurtosis (KG)	Interpretation
1	IBS-A	1.80	1.60	1.61	-0.22	0.81	Medium sand, poorly sorted, coarse skewed, platykurtic.
2	IBS-B	2.50	2.25	1.27	-0.48	4.28	Fine sand, poorly sorted, strongly coarse skewed, extremely leptokurtic.
3	IBS-C	2.17	2.17	0.52	0.10	1.26	Fine sand, moderately well sorted, fine skewed, leptokurtic.
4	IBS-D	1.93	1.86	0.85	-0.16	1.52	Medium sand, moderately sorted, coarse skewed, very leptokurtic.
5	OEOS-A	0.18	1.04	1.85	0.12	0.62	Medium sand, poorly sorted, fine skewed, very platykurtic.
6	DOS-A	2.24	2.01	1.21	-0.24	0.91	Fine sand, poorly sorted, coarse skewed, mesokurtic.
7	DOS-B	0.93	1.22	1.08	0.20	1.01	Medium sand, poorly sorted, fine skewed, mesokurtic.
8	CCOS-A	1.73	1.68	1.50	-0.10	0.65	Medium sand, poorly sorted, near symmetrical, very platykurtic.

Table 10: Average value interpretation

Size Parameter	Average Value	Interpretation
Median	1.69	
Mean	1.73	Medium sand
Sorting	1.24	Poorly sorted
Skewness	-0.10	Nearly symmetrical
Kurtosis	1.38	Leptokurtic

Mean:
According to the grain size study results above, the Ogwashi-Asaba Formation's sediments range from 1.04 to 2.25, with an average of 1.73, indicating medium-grained sand. The outcome implies that a low energy depositional environment fluctuated with deposition in a predominantly moderate to high energy environment.

Graphic standard deviation:
The findings of the analysis range from 0.52 (moderately well sorted) to 1.850 (poorly sorted), with an average
of 1.24 (poorly sorted).

Graphic Skewness:
The analyzed samples have an average of -0.10 ϕ (almost symmetrical) and vary from -0.24 ϕ (coarse skewed) to +0.20 ϕ
(positively/fine skewed). The outcome shows that there is more fine admixture than coarse components.

Graphic Kurtosis:
The average value of the analyzed samples is 1.38 ϕ (leptokurtic), with values ranging from 0.65 ϕ (platykurtic) to 4.28ϕ
(leptokurtic). This suggests that sorting is often better near the tail.

Thin Section Analysis of the Ogwashi Asaba Formation*:*
Thin Section Sample.
INTERPRETATION.
Color: Reddish brown. Mineralogy: Mainly quartz. Texture: Fine sand.
Form: Ranging from anhedral to euhedral.

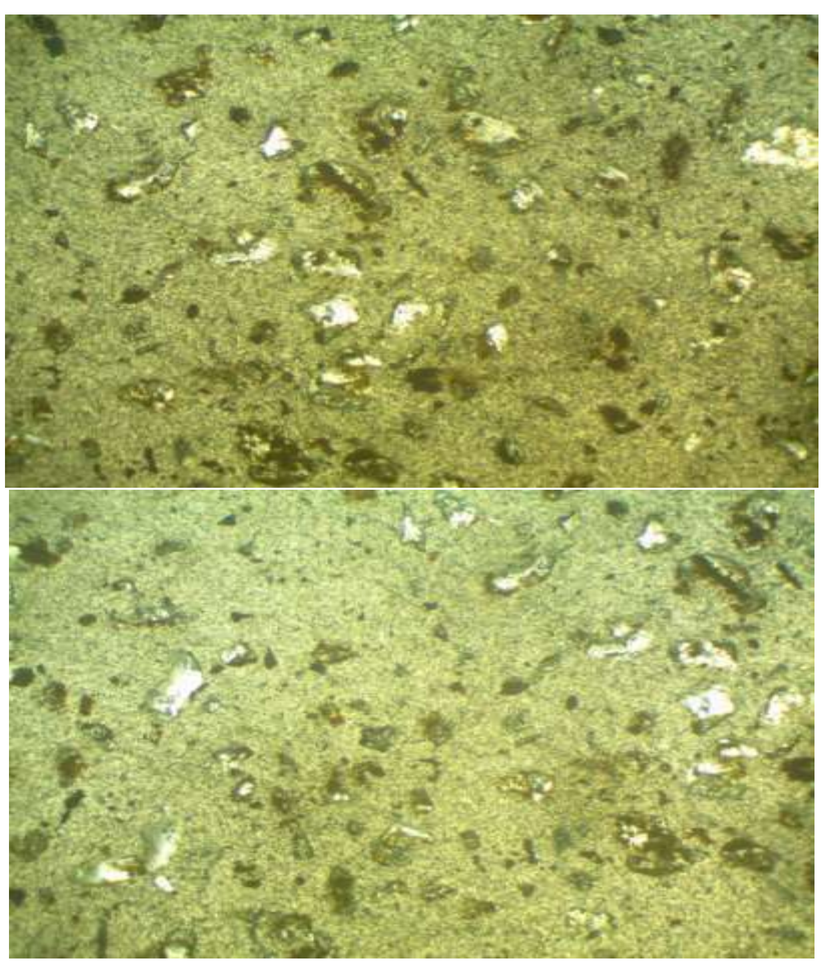

Fig. 10: Thin Section Analysis of the Ogwashi Asaba Formation*:*
Angularity: subangular to angular Sphericity: Nil.

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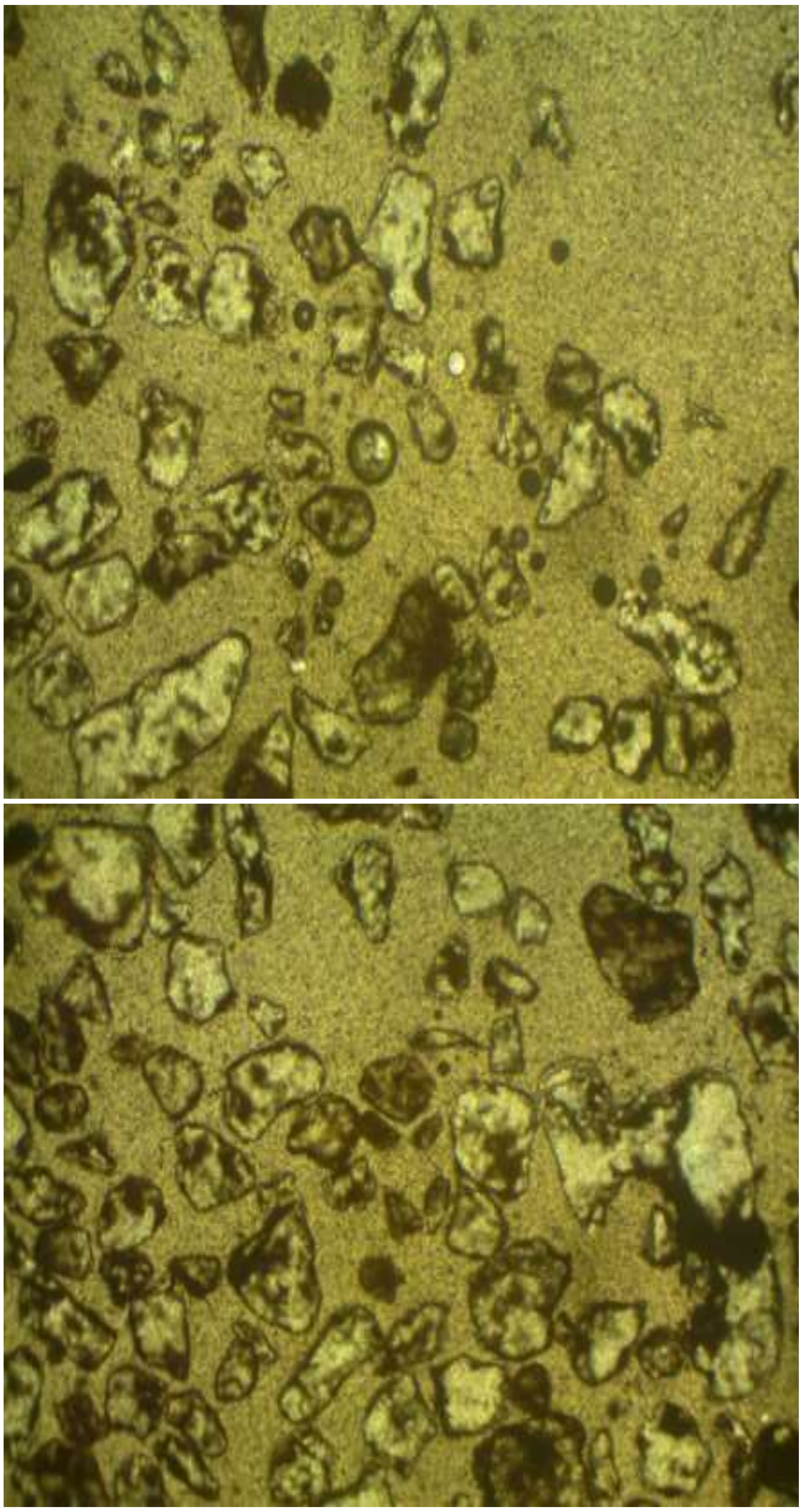
THIN SECTION SAMPLE.



INTERPRETATION:

Color: Reddish brown. Mineralogy: Mainly quartz.
Texture: Fine to medium grain sand. Form: Ranging from anhedral to euhedral. Angularity: subangular to angular
Fig. 11: Angularity: subangular to angular Sphericity: Nil.
Sphericity: Nil.

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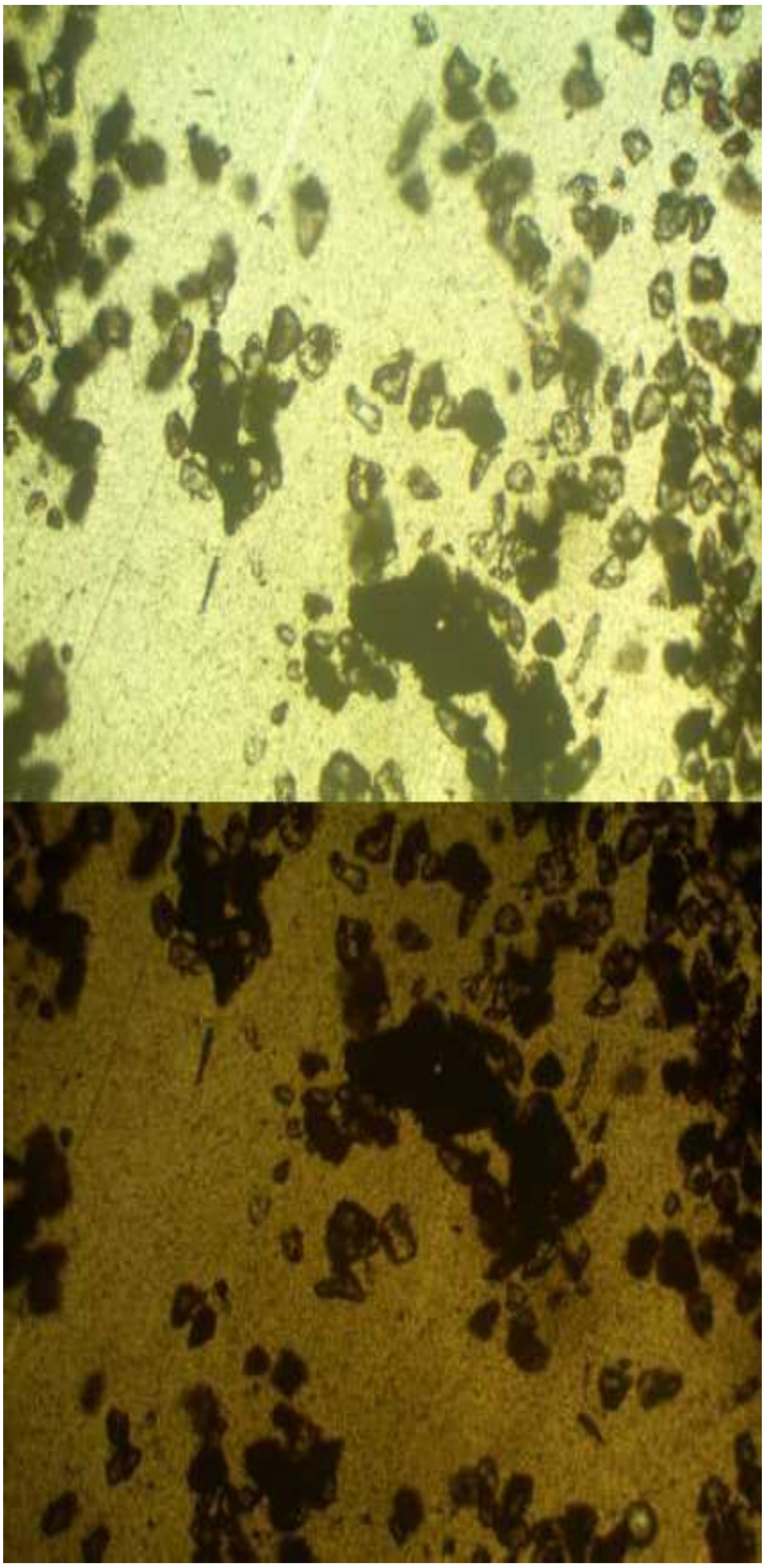
THIN SECTION SAMPLE.



INTERPRETATION:

Color: Reddish brown. Mineralogy: Mainly quartz.
Fig. 12: Texture: Fine to medium grain sand. Form: Ranging from anhedral to euhedral.
Angularity: subangular to angular Sphericity: Nil.

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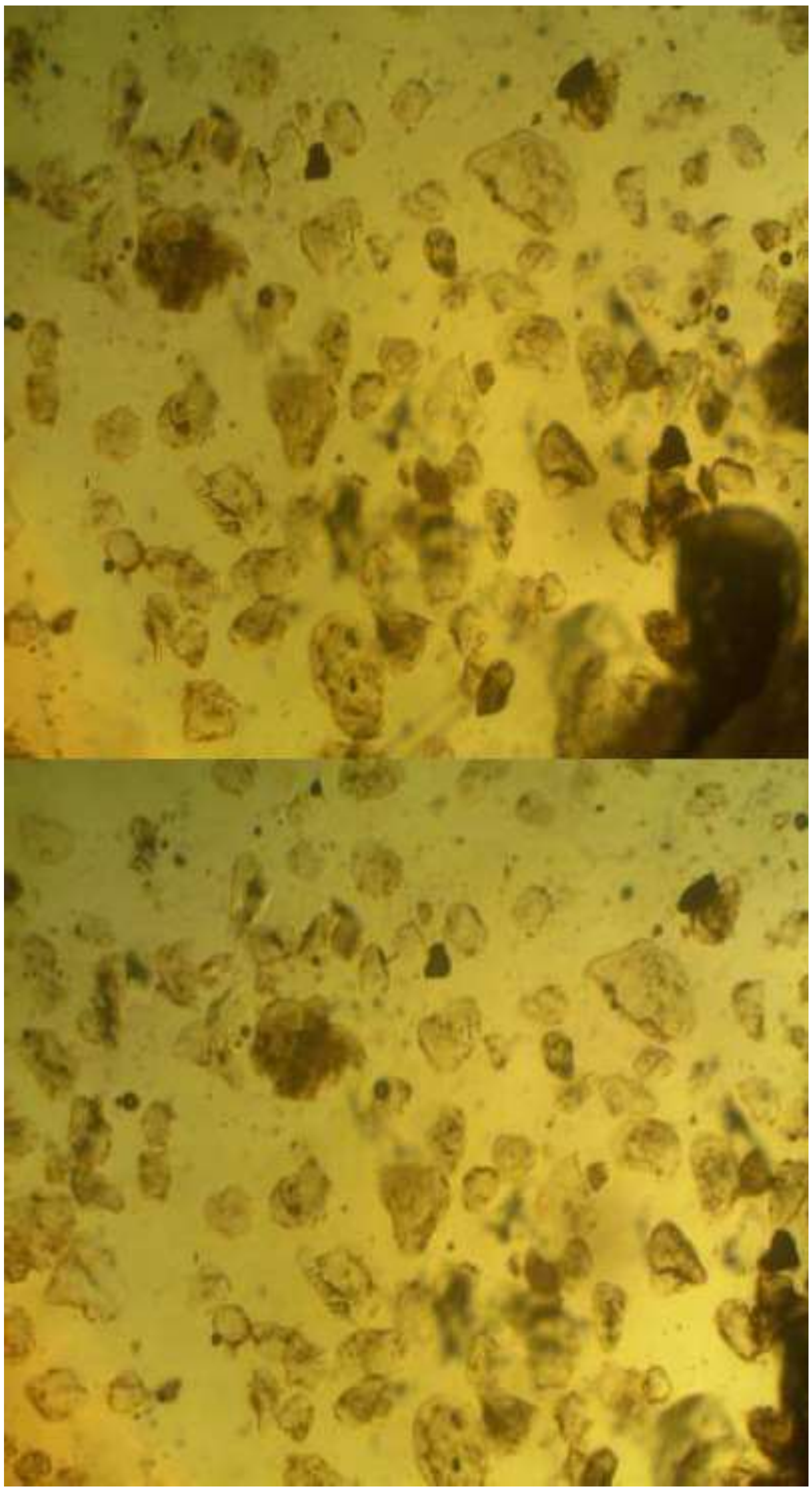
THIN SECTION SAMPLE.



INTERPRETATION:

Color: Grey
Fig.13: Mineralogy: Mainly quartz. Texture: Fine to medium grain sand.
Form: Ranging from anhedral to subhedral. Angularity: subangular to angular Sphericity: Nil.
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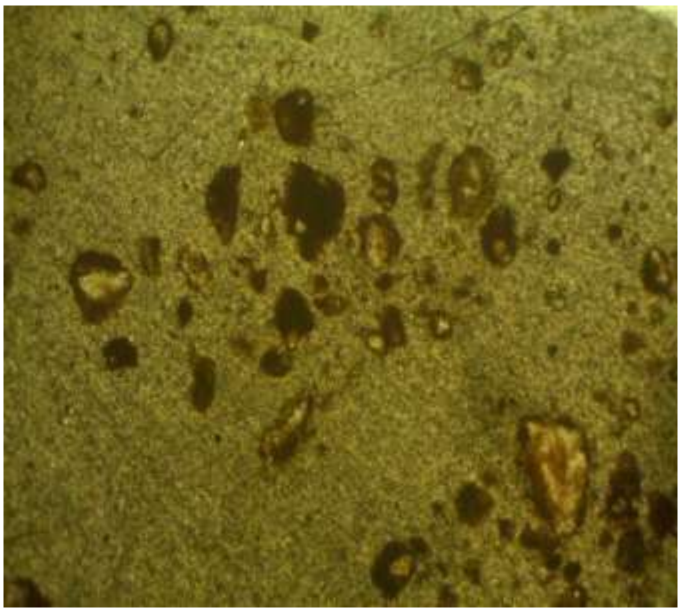
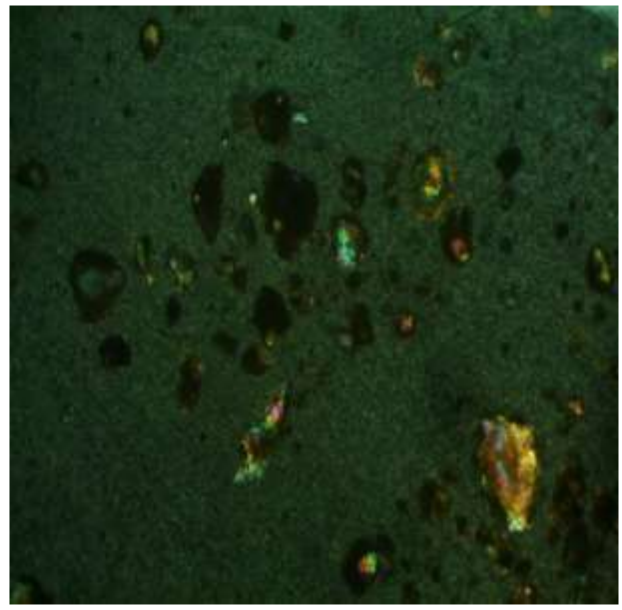
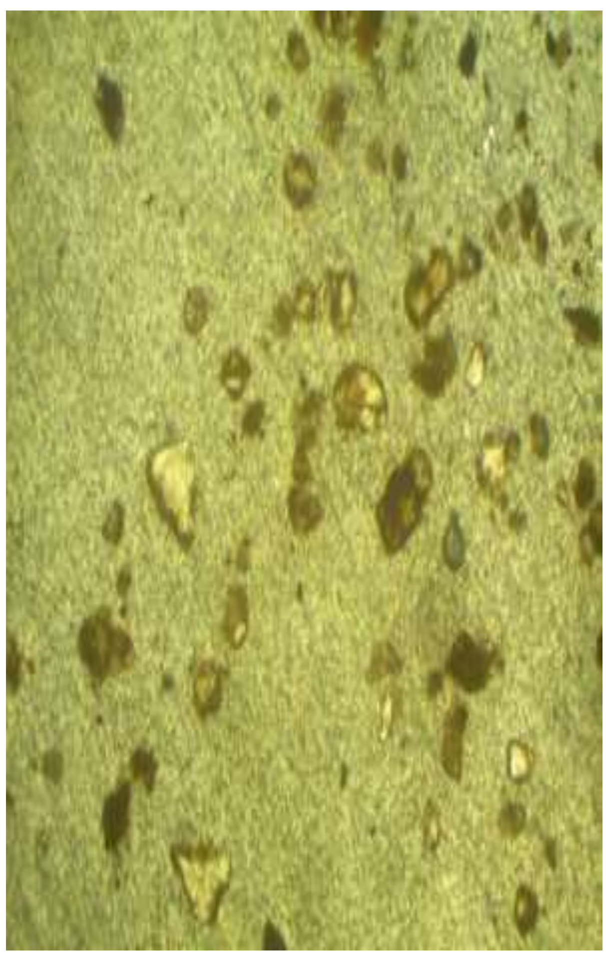

INTERPRETATION:

Color: Reddish brown Mineralogy: Mainly quartz.

Fig. 14: Texture: Fine to medium to coarse grain sand. Form: Ranging from anhedral to subhedral.
Angularity: subangular to angular
Sphericity: Nil.

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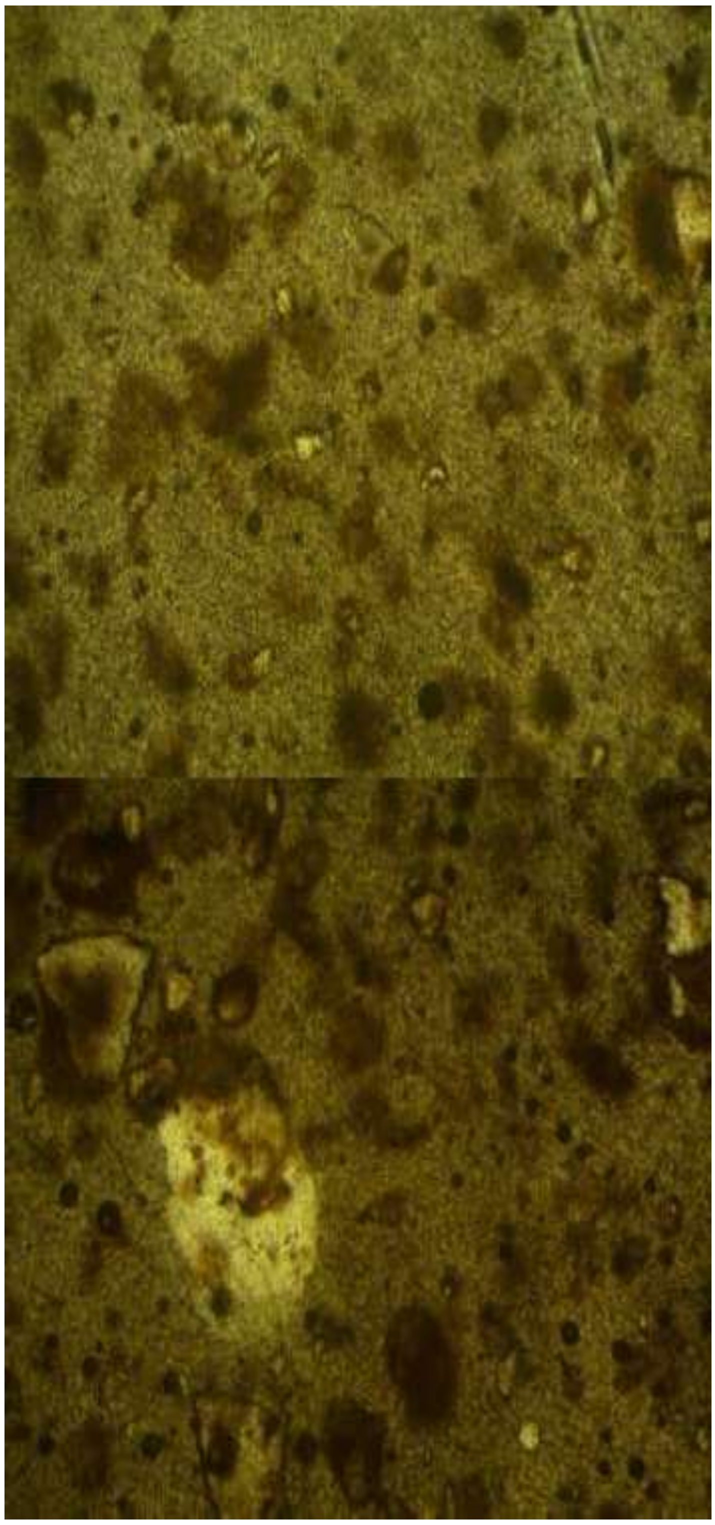

INTERPRETATION:
Color: Grey

Fig. 15: Mineralogy: Mainly quartz. Texture: Fine to medium grain sand.
Form: Ranging from anhedral to subhedral. Angularity: subangular to angular Sphericity: Nil.
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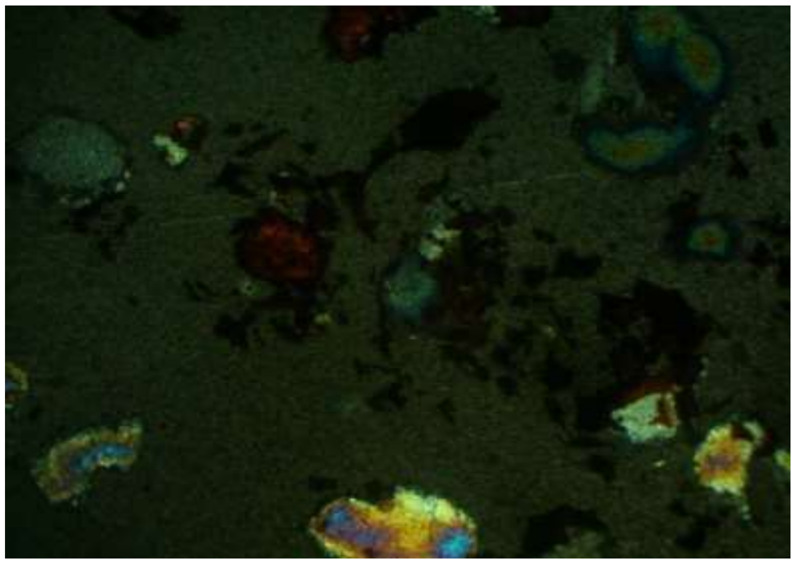

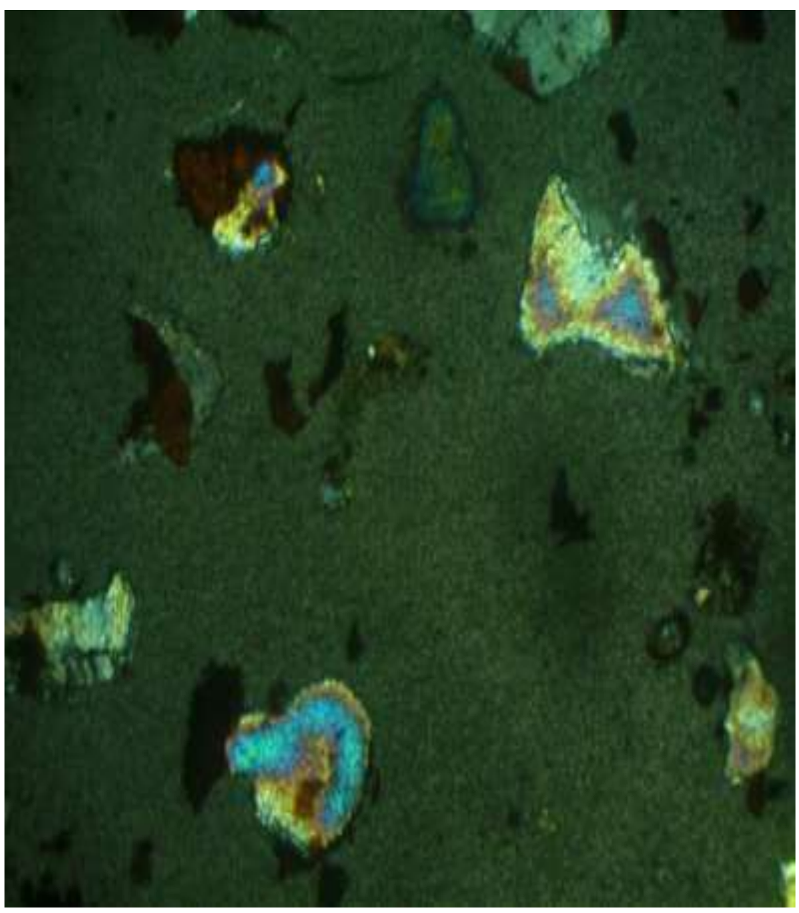

INTERPRETATION:

Color: Dark brown
Fig. 16: Mineralogy: Quarts and traces of heavy minerals. Texture: Fine to medium grain sand. Form: Ranging from anhedral to subhedral. Angularity: subangular to angular Sphericity: Nil.

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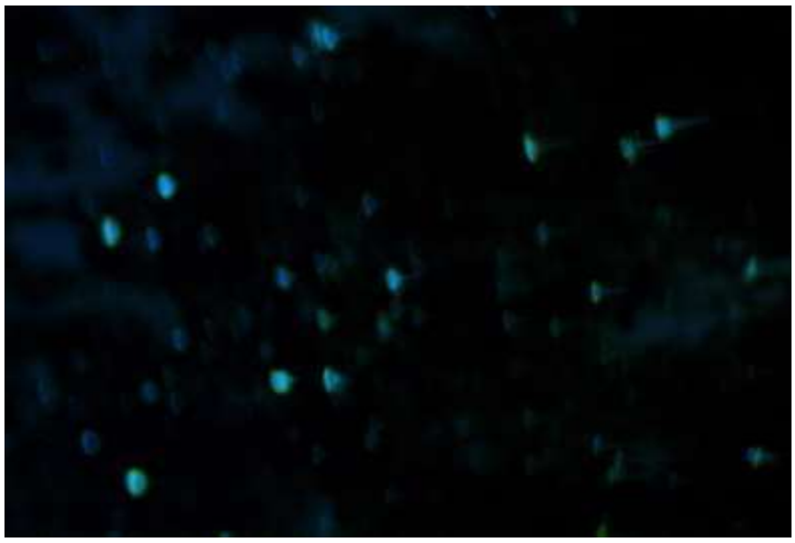

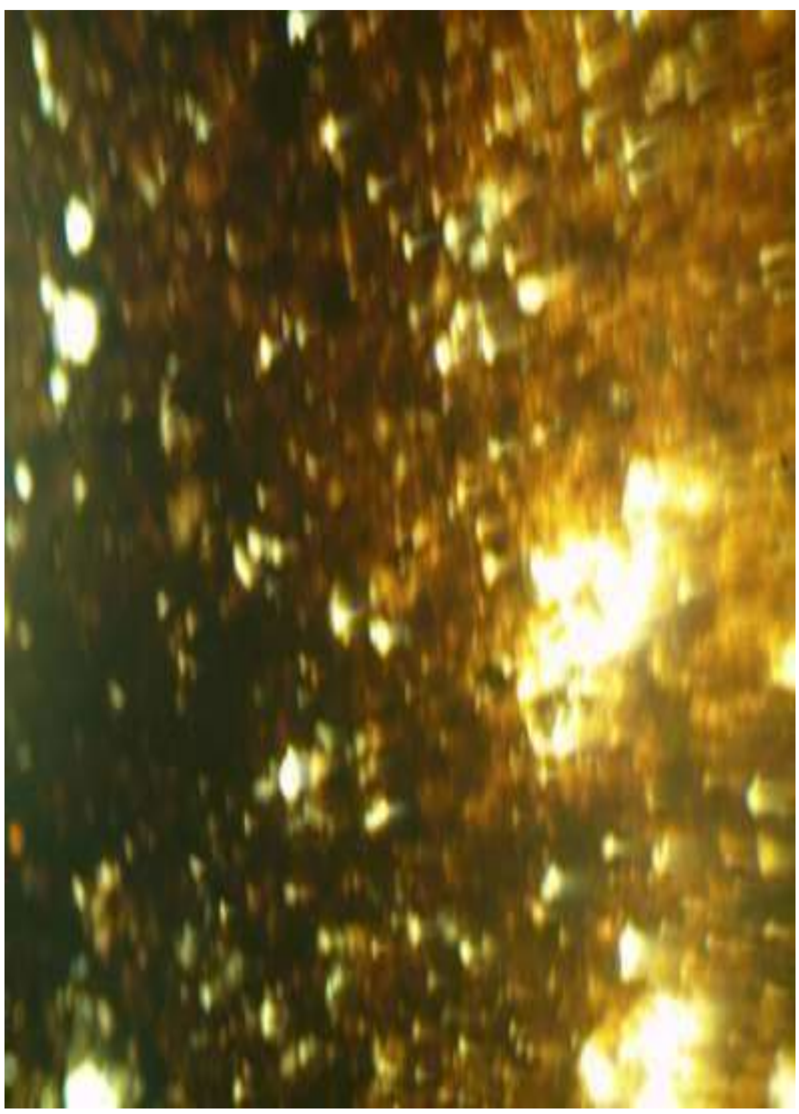

INTERPRETATION:
Color: Grey
Fig. 17: Mineralogy: Mainly Quarts Texture: Fine to medium grain sand.
Form: Ranging from anhedral to subhedral. Angularity: subangular to angular Sphericity: Nil.

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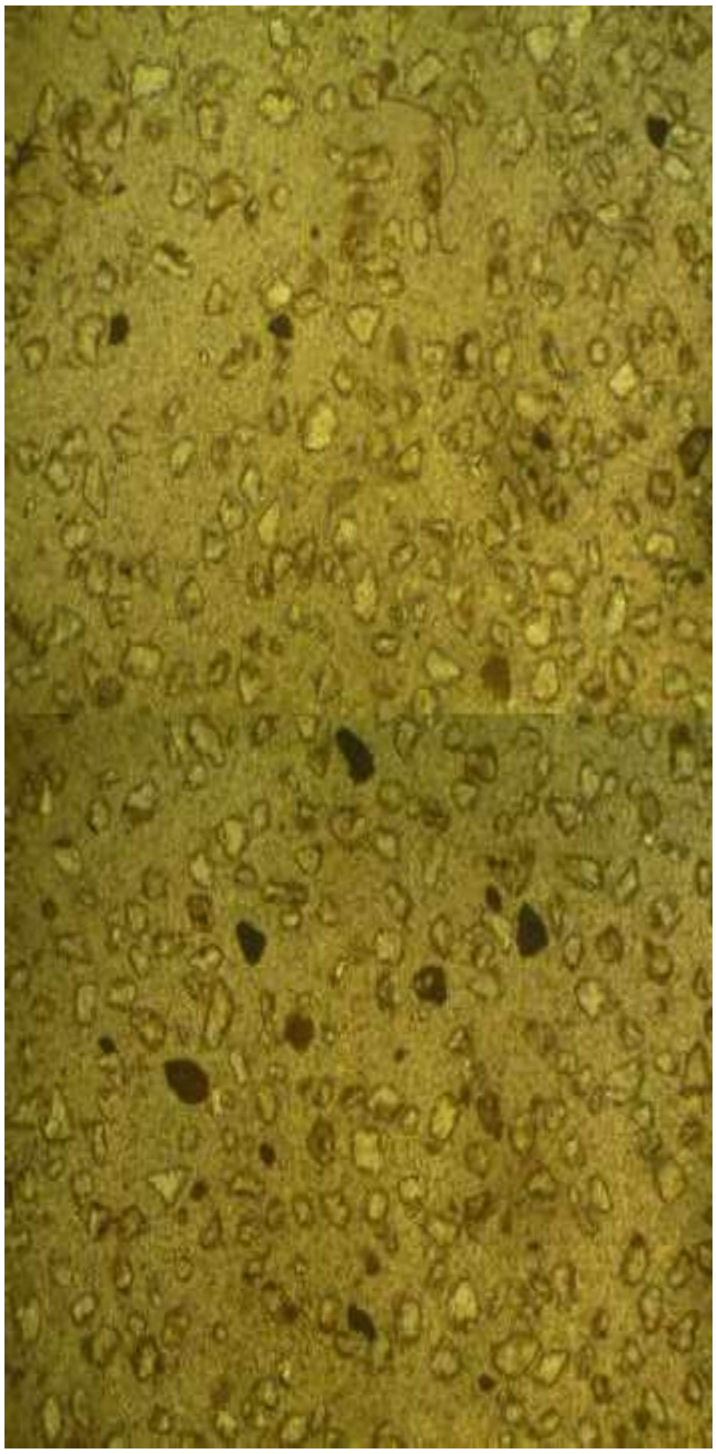

INTERPRETATION:

Color: Light brown. Mineralogy: Mainly Quarts
Fig. 18: Texture: Fine to medium grain sand.
Form: Ranging from anhedral to subhedral. Angularity: subangular to angular
Sphericity: Nil.

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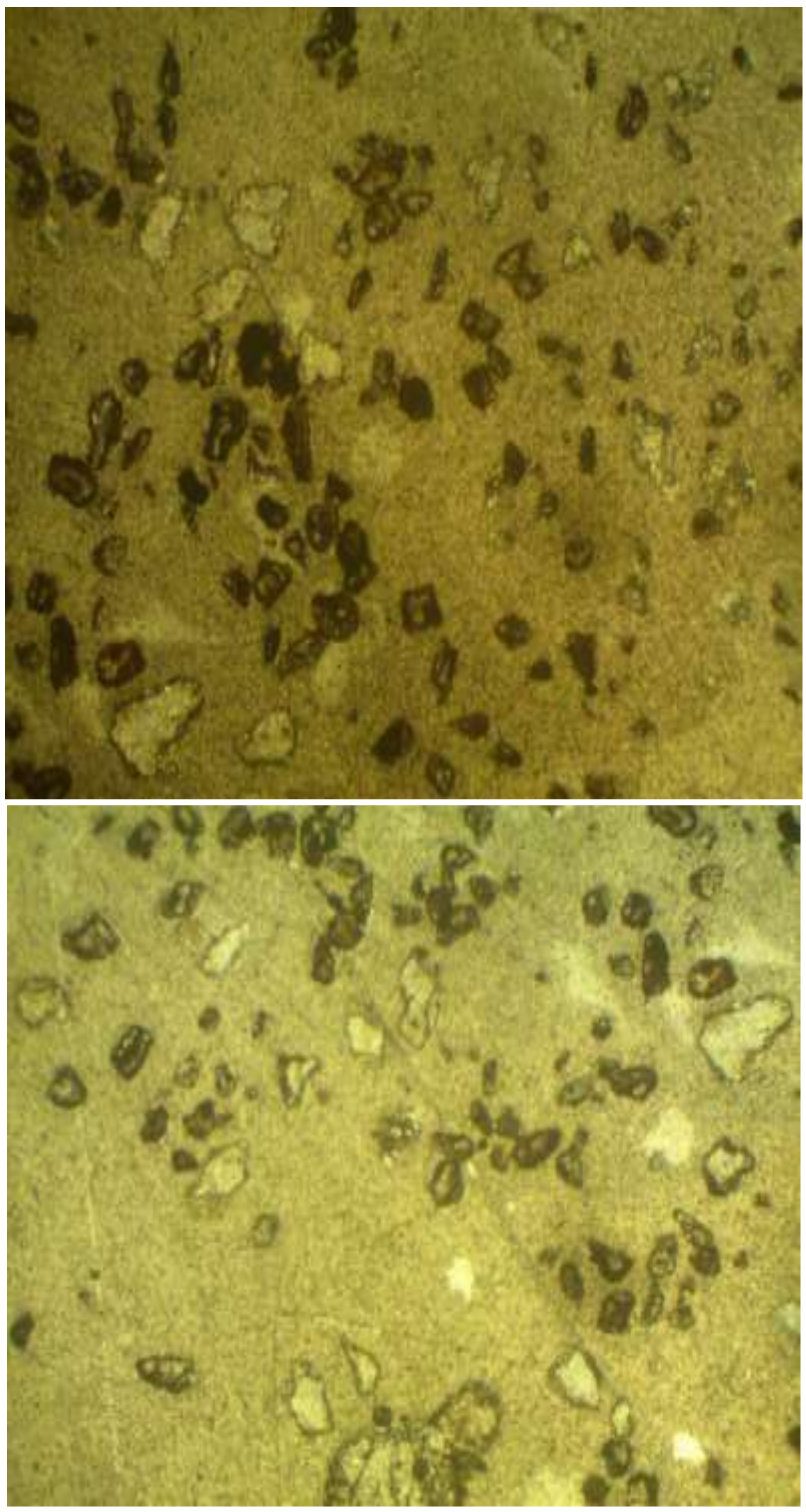

INTERPRETATION:

Color: Reddish brown.
Mineralogy: Quartz with traces of heavy mineral.
Fig. 19: Texture: Fine to medium to coarse grain sand.
Form: Ranging from anhedral to subhedral. Sphericity: Nil.

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CONCLUSION

In order to investigate the Ogwashi-Asaba Formation from the Middle Eocene to the Oligocene, a great deal of fieldwork and laboratory examination were required, including sample collections from the Ibusa, Obunike, and Asaba localities. There are three primary lithofacies described. These are shale, sandstone, and lignite. The sandstones are primarily coarse to medium grained and have a bimodal distribution, according to grain size studies (Fig 2 to Fig 9). Additionally, their skewness ranges from nearly symmetrical to extremely fine. This suggests that the fine sediments were deposited at a lower current velocity than the average velocity. Sedimentary rock fragments predominated and the sands generally displayed moderate to poor sorting, indicating a short history of transit from a high relief. Reorked sediment can be identified by the sediments' mesokurtic to leptokurtic behavior. Sands transported by rivers in a continental setting are depicted in bivariate plots of skewness against sorting and sorting against mean size. With sandstones making up a sizable fraction of the rock volume, the Formation is distinguished by a high net-to-gross ratio. Quartz dominates the Ogwashi-Asaba Formation's mineralogy. With more than 80% of the mineralogy, quartz is the most prevalent mineral in the sandstones (Fig 10 to Fig. 19) Everything being taken into account, this study has advanced our knowledge of the Ogwashi-Asaba Formation's geology and economic significance. The results of this study can be utilized to guide future investigations into the hydrocarbon potential of the Formation and to shed light on the diagenetic processes and depositional environment that shaped its formation.

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