Nigerian Research Journal of Engineering and Environmental Sciences 8(2) 2023 pp. 466-479
p ISSN: 2635-3342; e ISSN: 2635-3350

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Original Research Article

Pebble Morphometric Analysis and Sedimentology of Sandstone Facies of the Patti Formation Around Koton-Karfe and Ozi Environs, Southern Bida Basin, Nigeria

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http://doi.org/10.5281/zenodo.10441997

ARTICLE INFORMATION

Article history:
Received 22 Aug. 2023
Revised 06 Nov. 2023
Accepted 09 Nov. 2023
Available online 30 Dec. 2023

Keywords:
Pebbles
Morphometric analysis
Sandstone
Sedimentology
Formation

ABSTRACT

Pebble morphometric analysis, sedimentological and petrographic studies have been carried out on the sediments of the Patti Formation exposed at Koton-karfe and Ozi environs, Southern Bida Basin, Nigeria. This research aims to determine the paleodepositional environment, sedimentology, and mineralogy of outcropping sediments of the study area. Pebble morphogenesis and sieve analysis deduced that the sediments are fluvial deposits. The pebbles are angular to sub-angular in shape, indicating a short travel distance. The sandstones are coarse-grained and poorly sorted. This shows that the sediments have arisen due to sediment transportation in high-velocity energy flow. The poor sorting makes the sediments have poor porosity and hence poor reservoir characteristics. The minerals present in the studied sandstone samples are mainly quartz and feldspar. Quartz has the dominant percentage. The minerals generally have shapes ranging from angular to sub-angular. This implies that the sandstone facies are deposited close to the source. The mineral constituents have sutural contact, i.e. loosely packed. This suggests an early stage of diagenesis, i.e. shallow burial. The abundance of monocrystalline quartz is indicative of sediments derived either from volcanic–plutonic rock or pre-existing sedimentary rock.

1. INTRODUCTION

Pebble morphometric analysis, sedimentological and petrographic studies have been carried out on the sediments of the Patti Formation exposed at Koton-karfe and Ozi environs, Southern Bida Basin to determine the paleodepositional environment, sedimentology, and mineralogy of outcropping sediments of the study area. Various researchers have carried out research in the Southern Bida Basin. According to Obaje (2009), the Patti Formation is succeeded by the Agbaja ironstone Formation, which is the lateral equivalent of the North-west Bida Formations of Sakpe ironstone, Enagi siltstone and Batati ironstone (sandstone). These successions together form lateral equivalents of the Campano-Mastrichtian Mamu and Nsukka Formations in the adjacent Anambra Basin. The Campanian Basal Lokoja Formation unconformably overlies the Precambrian crystalline Basement migmatites, schist, and granite. The Lokoja Formation consists of conglomerates, sandstones, and claystone which were deposited in alluvial fan to shallow marine environments (Ojo and Akande, 2009). Overlying the Lokoja Formation is the Maastrichtian Patti Formation which consists of shale, claystone-siltstone, and sandstones, deposited in a meandering river.

According to Akinyemi et al., (2014), the medium to coarse-grained sandstone bodies of the Patti Formation are poorly sorted suggestive of deposition in a low energy setting, probably in a shelf or floodplain. The authors revealed that based on the mineralogical composition, two specific geochemical intervals can be established, viz: the first interval revealed quartz and kaolinite as major crystalline minerals with traces of hematite. The second geochemical interval showed quartz and kaolinite as the major crystalline minerals with minor quantities of grossite and halloysite.

The Lokoja Formation exposed at Mount Patti is made up of conglomerates, very thick, coarse-grained in texture pebbly sandstones, siltstones, ironstones, claystones, and lateritic overburden (Adeleye, 1971, 1973 and Braide 1992a). Lokoja sub–basin of the Bida Basin is an NW – SE thin trough which is downward ensued from the wrench fault displacement. It is thought to be associated with the tectonic structure of the sedimentary basins in Nigeria (Jones,1955 and Braide, 1992b) occupied with sediments of Campanian to Maastritichian age as shown by the paleontological and sedimentological studies of Ojo, (1992) and Abimbola (1993). Lokoja sandstone is the oldest Formation in the southern Bida basin being 90 – 280 m in thickness, covered by 70 – 100 m thick Maastritichian Patti formation, and approximately 5 – 20 m thick of Agbaja Ironstones on top of the central portion of Patti Formation (Braide, 1992b).

Although several works have been conducted in the Southern Bida Basin, there is however paucity of literature on the paleodepositional environment and mineralogy of the exposed sections of Patti Formation at Ozi and Koton-karfe. Thus, this study would provide relevant findings that can aid in filling this knowledge gap.

The Koton-Karfe area offers a unique opportunity to study and understand the depositional environment and petrographical characteristics in the Southern Bida Basin, as the highly indurated nature of the sediments allows for an abundance of outcrops that is unmatched anywhere else in the region.

2. MATERIALS AND METHODS

2.1. Site Description and Geological Setting

The field study was carried out in part of the Patti Formation exposed at Koton-Karfi and Ozi environs, southern Bida Basin, Nigeria. The study area is bounded by latitudes N 8° 06’ 34.1’’ to N 8° 08’ 43’ and longitudes E006° 47’ 08.1’’ to E006° 46’ 50’’E (Figure 1) on a topographic map. The area is accessible from Abuja via the Abuja-Lokoja highway through Abaji - Ahoko and through Koton-Karfe - Lokoja – Agbaja road. The Southern Bida Basin is characterized by undulating terrain with limited flat terrain. Indurated and ferruginous sandstones cap the highlands. The study area attains elevations such as 61 m, 59 m, 54 m, and 80 m above sea level as recorded from a GPS at Koton-karfe and Ozi environs as location 1, location 1.2, location 2, and location 3, respectively) described Mount Patti as a linear NW-SE ridge parallel to the Agbaja Plateau with an altitude of about 1450 m, following the Basin trend perpendicular to the central axis of the Benue Trough (Falconer, 1911; Kogbe, 1981). This hill extends across the Niger River toward Bassa and terminates around the Gboloko-Monzum area. The geomorphological features in the Southern Bida Basin consist of River Niger, its flood plain, and tributaries characterized by the belt of mesas and plains. Generally, the drainage pattern is dendritic in this region, where many tributaries join the significant rivers in a tree-branch-like manner.

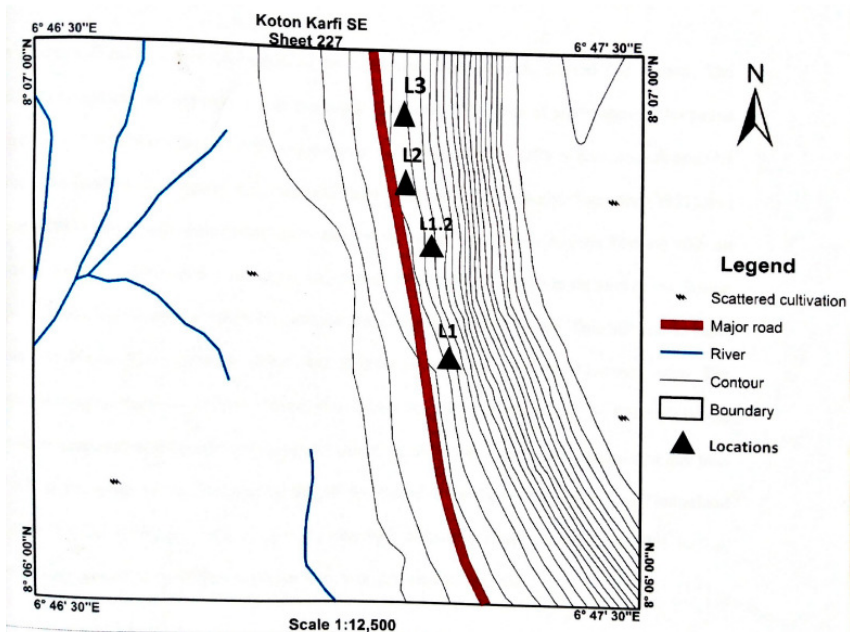

Figure 1: Topographic map showing the location of the study area (sheet 227, scale 1:12,500 modified after NGSA 2005)

The southern Bida Basin lies within the tropical climate marked by wet and dry seasons (Boubour *et al.*, 1984). The dry season sets in during November and lasts until March. It is followed by a wet or rainy season from April to October, with maximal rainfall in June and September. The annual rainfall within the area is between 1200 and 1500 mm. The relative humidity is about ninety percent in the morning and drops to about eighty percent in the dry season. The annual temperature range between 16 and 37 °C. During the rainy season, the area is influenced by moisture-laden southwest trade winds, which give way to the dry and sometimes dusty northeast winds (harmattan) during the dry season. The southern Bida Basin lies within the Guinea Savannah vegetation belt characterized by trees and grasses with numerous trees in a sparsely settled area. In addition, there are heavy forests along the river valleys. However, in most cases, the original vegetation has been tampered with through human activities.

2.2. Geology of the Study Area

The study location is in Mid-Niger Basin, the Bida Basin (Figure 2). It occupies most of the Lokoja Formation, Southern Bida Basin, Nigeria. The Southern Bida Basin, which is the focus of this study, extends from the confluence of the Niger-Benue River at Lokoja to Abaji, near the Federal Capital Territory. It comprises three Formations from oldest to youngest; Lokoja, Patti, and Agbaja.

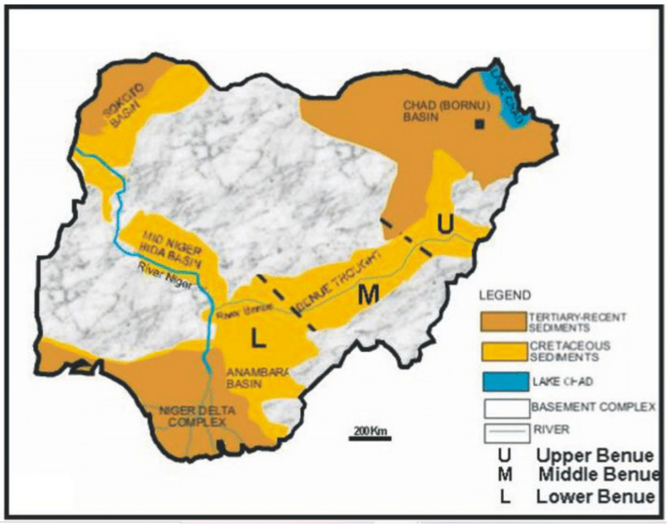

Figure 2: Geological map of Nigeria showing the sedimentary Basins (Shettima *et al.*, 2017)

2.3. Desk Study

This involved examining and producing the base maps of the study area. Furthermore, information was collected and reviewed from publications and journals on the Southern Bida basin, which helped inform stages implemented in carrying out the research project work, identifying important locations for sampling, having foreknowledge of accessibility of the study area, and also having good knowledge about the settlement pattern of the area. Geologic report on sedimentary deposits of different parts of sedimentary Basins of Nigeria, especially the Mid-Niger Basin, was also studied in this phase.

2.4. Field Methods

The fieldwork was conducted during the dry season (in March 2021) and commenced with a reconnaissance survey to acquire general information about the area; detailed field mapping was carried out at the Koton-Karfe area to establish the local geology of the area. The method of investigation involved intensive fieldwork, which lasted for six days. Traverses were along road cuts and footpaths. On the field, logging of the sedimentary rocks encountered was carried out. This involved the construction of the graphic log of the succession. The exposures were observed and described based on their colors, textures, and structures. Photographs and sketches of the essential features were also made. Representative samples from four different locations within the study areas were collected for further study in the laboratory.

2.4.1. Reconnaissance mapping

The method of the study area began with a reconnaissance survey to have a general overview of the area. The purpose of this mapping is to eliminate unfeasible routes or sites from the desk study and identify the more promising routes for accessing the study area.

2.4.2. Detailed mapping

Fresh samples were carefully collected from each outcrop to avoid distortion of the result due to weathering. Vital information like location, sample number, and horizon description such as; lithologies, textures, colors, numerology, and structures from each exposure and date of sampling were indicated on the sample bags, and all the relevant data were written in the field notebook.

2.4.3. Graphic logging

This is the standard method for collecting field data of sediments/sedimentary rocks to construct a graphic log of the succession, also known as the lithologic section. The logs immediately give a visual impression of the section and are a convenient way of making correlations and comparisons between equivalent sections from different areas. A total of four lithologic sections were studied and drawn.

2.5. Laboratory methods

In the laboratory, petrography, sieve analysis, and pebble morphogenesis were carried out on samples collected from the field.

2.5.1. Petrographical analysis (Thin section)

Petrography involves the examination of rocks to determine their mineralogical constituents as well as their textures and structures. A total of seven (7) selected sandstone samples were analyzed petrographically. The undisturbed sediments were examined for a range of recognized microstructures, such as those first described by van der Meer (1993) and Menzies and Maltman (1992).

2.5.2. Sieve analysis

Eleven sandstone samples were used for this analysis. These are samples L1A1, L1.2A, L2A, L3A, L3B1, L3B2, L3B3, L3C1, L3C2, L3E1 and L3E2. The sieve analysis can be used as an interpretation tool to determine texture, sorting, and the depositional environment of sediments. The equipment and material used for the sieve analysis include a set of sieves, a sieve shaker, a weighing balance, spatula sample divider. The sieve shaker was used to shake the sieve and the sample for about 10 minutes, and 100 g of the sample was used. The sieve analysis was done by disaggregating the collected sandstone samples by hand. This was then poured on a clean piece of paper and weighed on the weighing balance. The required sieves were built into a pile of sieves with the tiniest opening at the bottom and an empty container below (base pan). The sample was poured into the top sieve and shaken gently by an automatic shaker. A cover was then placed on the sieve-shaking machine connected to an electrical source, and sieve shakers were used to shake the sample for about 10 minutes. The material retained on each sieve was carefully weighed and recorded. The percentage retained of the material passing each sieve was calculated, and the data obtained were plotted on the graph. Grain size parameters were used in drawing a cumulative frequency curve. The cumulative frequency curves resulting from the analysis are used to calculate critical percentages, which are, in turn, used in calculating grain size parameters such as graphic mean, sorting (graphic standard deviation), graphic skewness, and graphic kurtosis. The statistical parameters of the grain size frequency distribution were obtained and computed using the method of ASTM D422-63, (1998).

2.5.3. Pebble morphogenesis

This analysis involves the measurement of the external shape and dimension of pebbles and conglomerates found within the study area. Moreover, these recordings are used to make a specific estimation about the rock, such as flatness ratio (S/L), elongate ratio (I/L), Maximum Projection Sphericity Index (M. P. S. I), and Oblate Prolate Index (O P I). Roundness is also estimated. A total of two hundred (200) pebbles were picked from location 1 within the study area. The magnitude of the pebbles' long, intermediate, and short axes was measured using a Vernier caliper, and these dimensions were recorded as reported in literature (Danga *et al.,* 2021).

3. RESULTS AND DISCUSSION

3.1. Lithofacies Descriptions and Textural Characteristics

The study area consists of sandstone facies intercalated with a thin ironstone bed. A total of two to four lithologic sections were studied and drawn. These are locations 1, 1.2, 2, and 3. The lithofacies descriptions and textural characteristics are as follows:

3.1.1. Sandstone Facies at Location 1

This locality was found at Koton-karfe along the Lokoja-Abuja expressway. The exposed section is a sandstone bed at longitude N08^0 6' 34.1 and latitude E006^0 47' 08.1". It had an elevation of about 61 m and a thickness of about 6.1 m. The area extent was approximately 1.1 km². This lithologic unit is labelled L1A. It is pebbly, medium to coarse-grained, highly ferrugenised sandstone intercalated with grayish-colored sandstone. It was clayey and contains mud crack structures. The stratification of this bed was very weak. The overburden was lateritic and about 2.8 m thick (Figure 3).

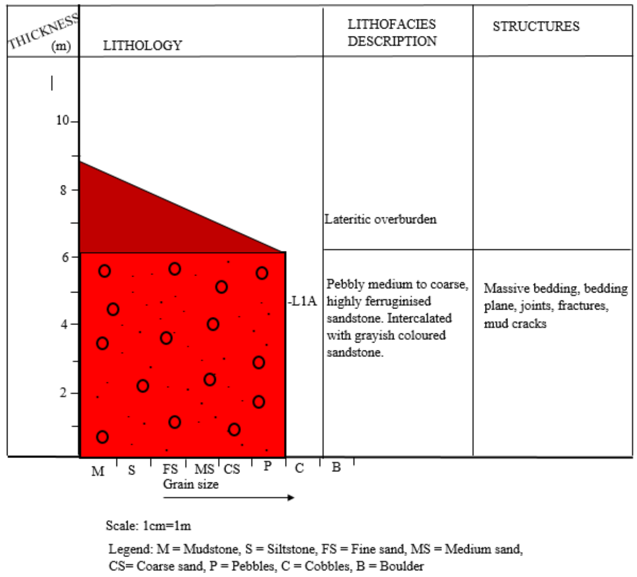

Figure 3: Stratigraphic section of sandstone facies at location 1

3.1.2. Sandstone Facies with Ironstone Cobbles and Boulders at Location 1.2

This locality was also found along the Lokoja-Abuja expressway. The exposed section was at longitude N08^0 06' 52.7" and latitude E006^0 47' 05.0". It had an elevation of about 70 m and a thickness of about 3.5 m. The section consists of one lithologic unit labelled L1.2A. It was a fine to medium-grained sandstone, reddish and contains ironstone cobbles and boulders. In addition, oolitic ironstone cobbles were present. The overburden was lateritic and had a thickness of about 1.3 m (Figure 4).

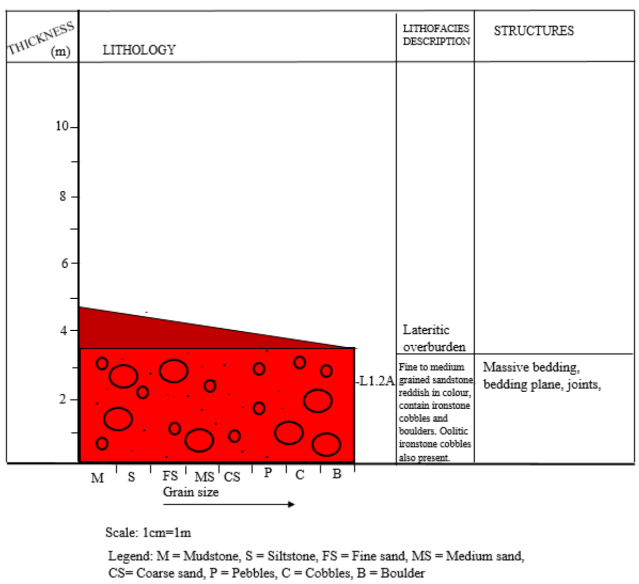

Figure 4: Stratigraphic section of sandstone facies at location 1.2

3.1.3. Sandstone facies at Location 2

This locality was found at Ozi village along the Lokoja-Abuja expressway. The exposed section was at latitude N08^0 08' 36" and longitude E006^0 36' 50". It had an elevation of about 54 m and a thickness of about 15 m. The area extent was approximately 2.8 km². The section consisted of one lithologic unit labelled L 2A. It was medium to coarse-grained, pebbly, light brown to reddish in color sandstone. It was muddy and contained mud cracks. The overburden was lateritic and about 0.2 m thick (Figure 5).

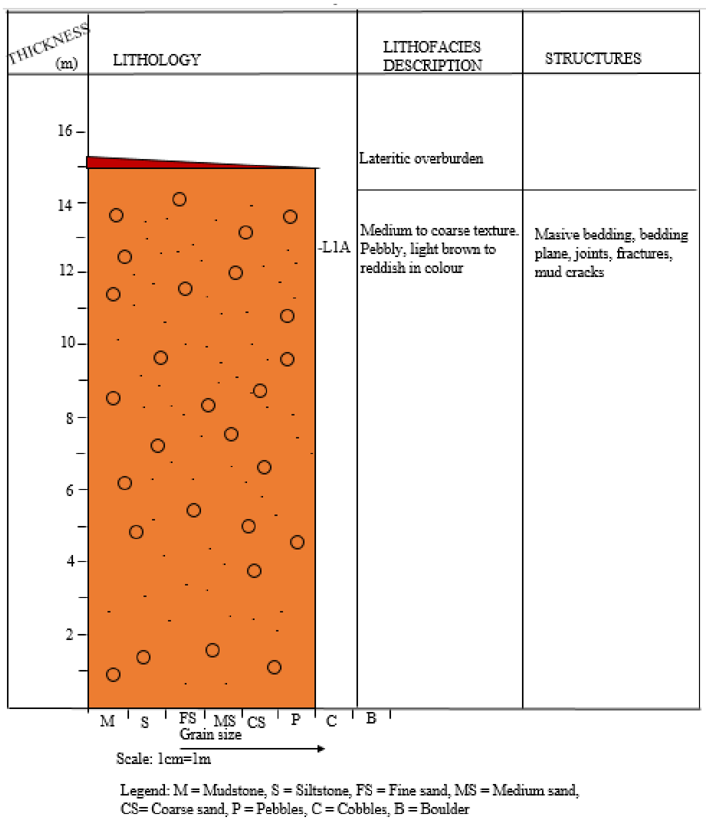

Figure 5: Stratigraphic section of sandstone facies at location 2

3.1.4 Sandstone facies with ironstone intercalation at Location 3

This locality was also found at Ozi village along the Lokoja-Abuja expressway. The exposed section was predominantly sandstone intercalated with a thin ironstone bed (Plate 1). It was located at longitude N08^0 08' 43" and latitude E006^0 46' 50". It had an elevation of about 80 m and a total thickness of about 6.64 m. There were about five lithologic units labelled from the base to the top as L3A, L3B, L3C, L3D, and L3E. These lithologic units have different characteristics and features which distinguish them from one another (Figure 6).

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Plate 1: Exposure of sandstone facies intercalated with ironstone bed at location 3

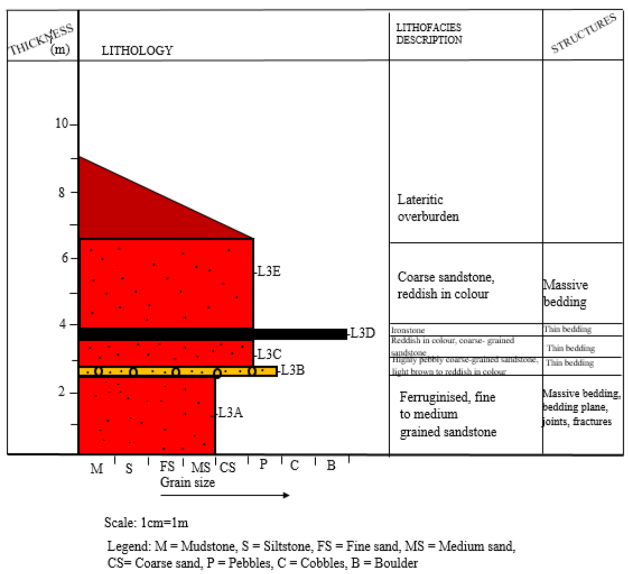

Figure 6: Stratigraphic section of sandstone facies at location 3

L3A was the basal lithologic unit. It is light brown to reddish (ferrugenised) and fine to medium-grained sandstone. This bed was massive and about 2.6 m thick. It is overlain by L3B, which was about 0.2 m thick. This was a thin bed. It was light brown to reddish, highly pebbly sandstone. Immediately above this bed was L3C. This was also a thin bed about 0.8 m thick. It was a coarse sandstone bed that was reddish in colour. Above this bed lies the thin ironstone bed, which was labelled L3D. It was about 0.4 m thick. Overlying the thin ironstone bed was a massive reddish (highly ferrugenised) bed of coarse sandstone. It was about 2.9 m thick. This lithologic unit was labelled L3E. Above this bed was the lateritic overburden of about 2.5 m thick.

3.2. Results of the Thin-Section (Petrographic analysis)

The thin-section study of seven (7) selected sandstone samples obtained within the study area showed varying proportions of minerals (Table 1). The minerals present in the studied sandstone samples were mainly quartz and feldspar. Quartz had the dominant percentage composition in all the sandstone samples,

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followed by feldspar. The minerals generally had shapes ranging from angular to sub-angular. This implied that the sandstone facies were deposited close to the source. The cementing material was mainly iron oxide material like hematite. Sandstones are usually cemented together with calcite or hematite making the fragments breakdown easily during transport (Sandstone and Conglomerates-Tulane, 2023)

Table 1: Mineral composition of Sample L1A from thin section study

Sample no	Monocrystalline quartz	Polycrystalline quartz	Total quartz	Feldspar	Mica	Rock fragment
L1A	90%	-	90%	8%	-	2%
L1.2A	90%	-	90%	2%	-	8%
L2A	95%	-	95%	3%	-	2%
L3A	90%	-	90%	5%	-	5%
L3B	90%	-	90%	8%	-	2%
L3C	90%	-	90%	5%	-	5%
L3E1	90%	-	90%	7%	-	3%

3.2.1. Diagenesis

Diagenesis refers to the state of sediment burial. It was inferred from the optical properties of the minerals. This was observed from the type of contact occurring between different mineral constituents. There are three main types of mineral contact: sutural (loosely packed), point contact, and long contact (closely packed). When mineral constituents are loosely packed, it implies the early stage of diagenesis, i.e. immature stage and when mineral constituents are closely packed, it implies the late stage of diagenesis, i.e. mature stage (Geologyscience, 2023). Mineral constituents of the study area had sutural contact, i.e. loosely packed. This suggested an early stage of diagenesis, i.e. shallow burial of the sandstone facies.

3.2.2. Porosity

Primary porosity in sandstone was principally inter-particle, which depended on the sediments' textural maturity. Textural maturity refers to the sorting and packing of the particles. In good sorting, this is good porosity, while in poor sorting, there is poor porosity. Porosity, along with permeability, determines the reservoir characteristics of sandstones. Good porosity produces high reservoir characteristics of sandstones, and poor porosity produces low reservoir characteristics (Geologyscience, 2023). The mineral constituents of 7 selected sandstone samples (L1A, L1.2A, L2A, L3A, L3B, L3C, and L3E) in the study area were all poorly sorted, which implied poor porosity and hence low reservoir characteristics.

3.2.3. Sandstone classification

Sandstone can be classified as quartz arenite, arkose, and greywacke. Quartzarenite is sandstone in which more than 90% of the grains are quartz. Because quartz is not subject to chemical weathering, it tends to concentrate residually in the sand as less resistant minerals such as feldspars are weathered away (Britannica, 2023). Arkose is sandstone with more than 25% of grains consisting of feldspar. Because feldspar grains are preserved in the rock, the original sediment did not undergo severe chemical weathering, or the feldspar would have been destroyed (Britannica, 2023). *Greywacke* is a sandstone in which more than 15% of the rock volume consists of a fine-grained matrix. Greywackes are often dense and are generally dark or green (Britannica, 2023). The sandstone observed in the study area was classified as quartz arenite because of its abundant quartz content, which ranges from 90-95% of the total mineral constituents.

3.2.4. Provenance

Provenance helps to discover the source and transportation history of the sediments. The type of quartz observed in all the sandstone samples is monocrystalline. The abundance of monocrystalline quartz is indicative of sediments derived either from volcanic–plutonic rock or pre-existing sedimentary rock (Molinero-Garcia *et al.* 2022).

3.3. Pebble Morphogenesis Results

This result was used to determine the paleoenvironment and transportational history of the pebbles.

3.3.1. Determination of Paleoenvironment

Scatter plots of M.P.S.I vs OP index (Figure 7) was used to discriminate paleoenvironment using the sphericity of 0.65 to 0.66 as a discriminate value. Above the value is the river environment, and below is the beach. From the plot shown below paleoenvironment of the pebbles was a river environment.

3.3.2. Transportational history

These sediments have short transportational history reflected from the dominant angular to sub-angular shapes of the sediments.

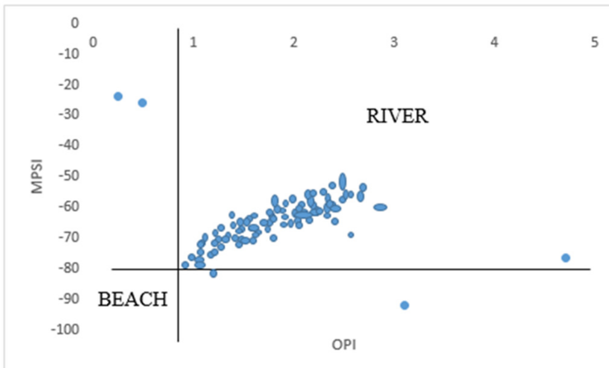

Figure 7: Scatter plot of M.P.S.I versus O.P.I

3.4. Result of Sieve Analysis

Eleven (11) sandstone samples were selected for this analysis. Parameters such as graphic mean, standard deviation, sorting, skewness, and kurtosis were obtained. Representative plots are presented in Figures 8-10.

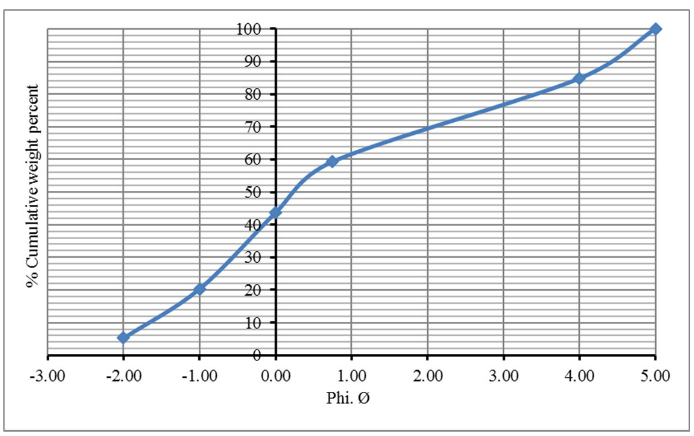

Figure 8: Graph of percentage cumulative weight against phi sizes of sample L1A

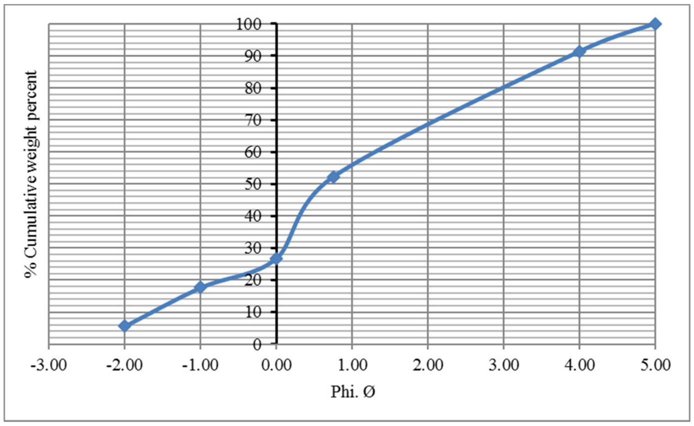

Figure 9: Graph of percentage cumulative weight against phi sizes of sample L1.2A

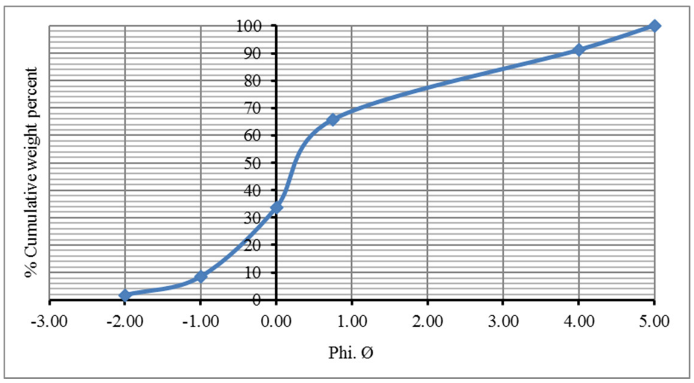

Figure 10: Graph of percentage cumulative weight against phi sizes of sample L2

3.4.1. Interpretation of sieve Analysis

From the comparison of the calculated mean, standard deviation, skewness, and kurtosis with the standard classification (Wentworth, 1922). A summary of grain-size data interpretation (Table 2) is discussed as follows:

The mean grain size in a deposit is a function of the energy of the process controlling transport and deposition. i.e. particles are segregated according to their hydrodynamic behaviour, which depends on size, specific gravity, and shape (Patrick and Bowles 1985). The mean was calculated for 11 selected samples. The mean grain size for sandstone samples in the study area was coarse-grained. This shows that the coarse sandstone component of the study area has arisen as a result of sediment transportation in high velocity and energy flow inferred to be fluvial (river) deposition (Maju-Oyovwikowhe and Olowu 2023; Ojo and Akande 2009). In contrast to mean grain size, the degree of sorting of grains in a deposit is a function of the persistence and stability of energy conditions, except where constrained by the availability of grains that can be deposited in the environment. The standard deviation was calculated for 11 sandstone samples. In the study area the sandstone sediments are all poorly sorted. The textural maturity of the sediment refers to the sorting and packing of the particles. In poor sorting, there is poor porosity which indicates poor reservoir characteristics of the sandstone in the study area (Maju-Oyovwikowhe and Olowu 2023). Skewness also shows a reflection of the depositional process. It reflects sorting in the tails of a grain-size population. The population with a tail of excess fine particles is said to be positively or fine-skewed. i.e. skewed towards positive phi (ϕ) values.

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Table 2: Interpretation of grain size data

Sample	Sample values	Graphic mean	Graphic standard deviation	Inclusive skewedness	Graphic kurtosis
L1A1	M= 1.0 S.D= 1.99 Ski= -0.99 Ka= 0.55	Coarse grained sand	Poorly sorted	Strongly coarse skewed	Very platykurtic
L1.2A	M= 0.97 S.D= 1.78 Ski= -0.73 Ka= 0.68	Coarse grained sand	Poorly sorted	Strongly coarse skewed	Platykurtic
L2A	M= 0.9 S.D= 1.78 Ski= -0.88 Ka= 1.19	Coarse grained sand	Poorly sorted	Strongly coarse skewed	Leptokurtic
L3A	M= 0.86 S.D= 1.90 Ski= -0.87 Ka= 0.89	Coarse grained sand	Poorly sorted	Strongly coarse skewed	Platykurtic
L3B1	M= 0.43 S.D= 1.59 Ski= -0.62 Ka= 0.89	Coarse grained sand	Poorly sorted	Strongly coarse skewed	Platykurtic
L3B2	M= 0.43 S.D= 1.4 Ski= -0.99 Ka= 1.39	Coarse grained sand	Poorly sorted	Strongly coarse skewed	Leptokurtic
L3B3	M= 0.32 S.D= 1.96 Ski= -0.98 Ka= 0.68	Coarse grained sand	Poorly sorted	Strongly coarse skewed	Platykurtic
L3C1	M= 0.7 S.D= 1.76 Ski= -0.88 Ka= 0.80	Coarse grained sand	Poorly sorted	Strongly coarse skewed	Platykurtic
L3C2	M= 0.53 S.D= 1.77 Ski= -0.88 Ka= 0.57	Coarse grained sand	Poorly sorted	Strongly coarse skewed	Very platykurtic
L3E1	M= 0.20 S.D= 1.72 Ski= -0.73 Ka= 1.15	Coarse grained sand	Poorly sorted	Strongly coarse skewed	Leptokurtic
L3E2	M= 0.27 S.D= 1.93 Ski= -0.82 Ka= 0.99	Coarse grained sand	Poorly sorted	Strongly coarse skewed	Mesokurtic

M: Graphic mean, S.D= Inclusive graphic standard deviation, Ski= Graphic skewness, Ka= Graphic kurtosis:

Population with a tail of excess coarse particles are negatively skewed or coarse skewed, i.e. skewed towards negative phi (ϕ) values. This is useful in environmental diagnosis because it is directly related to fine and coarse tails of size frequency distribution and environmental energetics. The skewness values obtained for the 11 selected sandstone samples are strongly coarse skewed (negative), which indicated coarse particles. Hence, fluvial deposition with high energy conditions was inferred in accordance with Maju-Oyovwikowhe and Olowu (2023), Ojo and Akande 2009).

Kurtosis values measure the peak of a curve from normal. It describes the departure of the distribution from normality by comparing the sorting at the tails with the central position. Sharp-peaked curves are said to be leptokurtic, flat-peaked curves are platykurtic, and the intermediate between these two curves is mesokurtic. The calculated kurtosis values for the 11 selected sandstone showed more platykurtic to very platykurtic sediments. This indicated better sorting at the flat peaked position in the departure of distribution from the normality Maju-Oyovwikowhe and Olowu 2023)

4. CONCLUSION

The study area (Koton-karfe and environs), a part of the Patti Formation, mainly comprises sandstone sediments with overlaying lateritic capping. The typical sedimentary structures in the study area include bedding, bedding planes, burrows, and mud cracks. The sieve analysis results show that the sandstone is coarse-grained and poorly sorted. This suggests the palaeoenvironment of the sandstone facies is fluvial, where a wide range of particle sizes are commonly available for transport by the river with high energy conditions. The poor sorting of the sediments indicates low reservoir characteristics of the sandstone facies in the study area. The petrographic analysis shows that the mineral compositions of all the rock samples include quartz, feldspars, and rock fragments. The sandstone is classified as quartz arenite due to its abundant quartz content, which ranges from 90-95% of the total mineral constituents. They are loosely packed, which suggests the early stage of diagenesis, i.e. shallow burial of the sandstone facies. The abundance of monocrystalline quartz is indicative of sediments derived either from volcanic–plutonic rock or pre-existing sedimentary rock. The scatter plots of M.P.S.I vs OP index from pebble morphogenesis further suggests the paleoenvironment of the sediments is fluvial. The sediments have short transportational history reflected by the dominant angular and sub-angular shapes of the sediments.

5. ACKNOWLEDGMENT

The authors wish to acknowledge the contributions of the anonymous reviewers whose comments helped to improve the quality of this paper.

6. CONFLICT OF INTEREST

The authors declare that they have no conflict of interest regarding this work.

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