FULafia Journal of Science & Technology
ISSN (print) 2449-0954 \ ISSN (online) 2636-4972
https://lafiascijournals.org.ng/index.php/fjst
Sponsored By TERTIARY EDUCATION TRUST FUND
Manuscript => Received: Oct., 2025; Accepted: Dec., 2025; Published: Dec., 2025 https://doi.org/10.62050/fjst2025.v10n1.641

SEDIMENTOLOGICAL AND PALEODE POSITIONAL STUDIES OF ROCKS WITHIN THE MIDDLE BENUE TROUGH

Japheth Haruna[1], Hamza Halidu[1], Sunday Adedeji[2] and Nengak Musa[1]*
[1]*Ahmadu Bello University, Zaria, Kaduna State*
[2]*Federal University of Lafia, Nasarawa State*
*Corresponding email: nengakmusa@gmail.com

ABSTRACT
The study area lies within the Middle Benue Trough. Previous studies were focused on Albian to Turonian sediments of the middle Benue Trough, which lies within Keana and Awe sheet 232 NW respectively. The present study extends to areas around Lafia town (Sheet 231NW) whose sediments range from Albian to Maastrichtian. Detailed field mapping on a scale of 1:50,000 was carried out and during this exercise, lithostratigraphic successions in the study area was established. Stratigraphic study of the area indicates the occurrence of three formations namely; the fluvial Lafia Formation, the shallow marine Awgu Formation and the transitional Awe Formation. 12 samples were collected for granulometric analysis and 8 samples for Petrographic analysis. The Lafia Formation consists of ferruginous sandstone capping the section, clay and clayed intercalated with sands at the base. Petrography and sieve analysis revealed that the Ferruginous sandstone ranged from fine to medium grain. It is moderately sorted, strongly fine skewed and is subarkosic arenite. More than 60 % of the crystals are monocrystalline which is indicative of igneous provenance. The Awe Formation consists of fine-grained white sandstone, with some intercalations of white clay and laminated shale. The sandstones are fine-grained and poorly-moderately sorted which coupled with the bivariate plot that indicates a transitional condition between shallow marine and fluvial systems. The Awgu Formation consists of sandstones that are fine grained, very poorly sorted and strongly fine-skewed. The presence of ostracodes, echinoderms, and ammonites within the shaley limestone of the Awgu Formation is indicative of marine environment.

Keywords: Lafia, Ferruginised, Fluvial, Subarkosic, Provenance

INTRODUCTION
The middle Benue Trough is one of the three segments of the larger NE-SW trending Benue. It is a depression filled with rocks of cretaceous age ranging from Albian to Maaastrichtian. As is the case with the Upper Benue Trough, there does not seem to be any recent work dedicated to the Geology of the Middle Benue Trough. The Benue Trough is a sediment-filled elongated NE-SW trending depression that originated from the opening of the Atlantic Ocean. It is a failed arm of a rift-rift-rift triple junction developed over a Cretaceous hotspot located below the present-day Niger Delta (Figure 1) (Cratchley and Jones 1965; Burke *et al*., 1970).

Many hypotheses have been advanced to explain the origin of the Middle Benue Trough. Lees (1952) regarded the Benue Trough as a compressional downwarp, the folding being deduced by deep-seated basement contraction. Kings (1950) on the other hand, regarded the Benue Trough as extensions due to stresses of the rifts, which produced the Atlantic Ocean. Zaborski (1998, 2003) envisaged that the Benue Trough shows features of rift and strike-slip structures. Its origin and evolution cannot be fully explained on the basis of just one of the theories mentioned above, but it is best regarded as rift with very strong sinistral strike-slip component superimposed upon it.

Stratigraphy of the Middle Benue Trough
In the Middle Benue Trough, the stratigraphic succession includes six formations. These successions are made up of Albian Arufu, Uomba and Gboko Formations, generally referred to as the Asu River Group (Offodile, 1976; Nwajide, 1990; Nwajide, 2013). The Precambrian basement is overlain unconformably by the Asu RiverGroup. The Asu River Group is overlain by the late Albian-early Cenomanian Keana and Awe Formations and the Cenomanian-Turonian Ezeaku Formation. The late Turonian-early Santonian coal bearing Awgu Formation lies conformably on the Ezeaku Formation. In the Markudi area, the Markudi sanstone interfingers with the Awgu Formation. The mid-santonian was a period of folding throughout the Benue Trough followed by the deposition of the post-folding Campano-Maastrichtian Lafia Formation after which there was widespread volcanic intrusion of basalts, phonolites and trachites mostly in the form of cone and lava sheets that seldom exceeds a few square kilometres in extent (Offodile, 1976; Obaje, 1994; Obaje, 2009).

Study Area

The study area is located within the middle Benue Trough of Nigeria. It lies between latitudes **8° 13' N to 8°28' N** and Longitudes **8°32' E to 8°47' E**. The study area covers about 770 km^2 (Figure 1). The study area was accessible by the major roads that extend from Lafia to Obi, Lafia to Makurdi and other minor roads. The study area is located in Nasarawa State of Nigeria as seen in Figure 1.

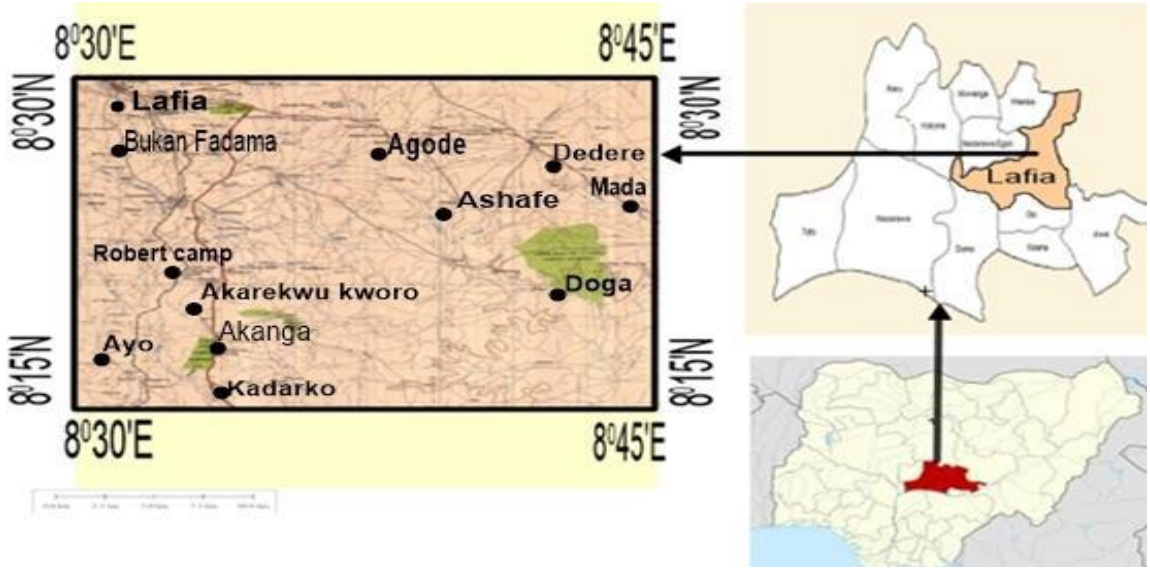


Figure 1: Map of Nigeria Showing the Study Area (Not to scale)

Table 1: Stratigraphic successions in the Middle Benue Trough (After Obaje and Ligouis, 1996)

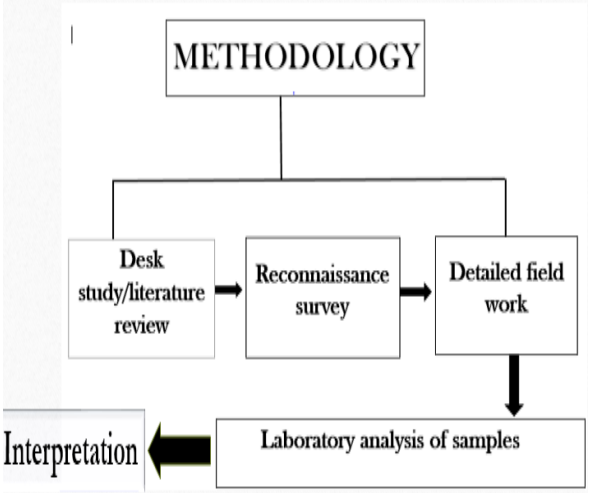
CHRONO-STRATIGRAPHY	FORMATION (approx. thickness)	LITHOLOGY	PALAEO-ENVIRONMENT
Tertiary - Quaternary	Alluvium Volcanics	Sands Volcanics	Alluvial Volcanics
Maastrichtian Campanian	**Lafia Fm** (800m)	Sandstones, Siltstones, Claystones	Fluvial
Santonian Coniacian	**Awgu Fm** (1000m)	Shales, Coals, Limestones, Sandstones, Siltstones	Shallow marine, deltaic
Turonian	**Ezeaku Fm** (500m)	Shales, Limestones	Shallow marine
Cenomanian	**Keana Fm** (500m) / **Awe Fm** (400m)	Sandstones, Siltstones, Claystones	Fluviodeltaic
Albian	**Arufu,Uomba,Gboko Fms (Asu River Group)** (1800m)	Shales, Limestones, Sandstones	Marine
Pre-Albian	Basement Complex	Granites, Gneisses, Schist,, Migmatites	Igneous, metamorphic

Minor Unconformity
Major Unconformity
Coal intercalations

MATERIALS AND METHODS

This involved a detailed literature search into the more relevant previous works carried out in the area. A reconnaissance survey was first carried out to identify the sedimentary structures, rock types and other geological structures within the area of study. This was followed by a more detailed fieldwork during which sections were logged, samples were collected and more geological structures were identified and recorded. 12 samples were collected for Granulometric analysis (Table 1) and 11 samples for Petrographic analysis. Equipments used for this work were as follows; Camera, Measuring Tape, Ruler, Global Positioning System (GPS), compass clinometre, hammer, chisel and topographic map. Geologic hammer was used to break samples for analyses and fieldwork was carried out during the dry season.

The Granulometric analysis was done in the sedimentology laboratory, Department of Geology Ahmadu Bello University, Zaria while the Petrographic analysis was carried out in the Thin section Laboratory, Geology department at the University of Jos. The following parameters were determined including: Graphic mean, Graphic skewness, Graphic standard deviation, and Graphic kurtosis. Finally, we established how this field knowledge could be applied to the interpretation of the paleoenvironment (Scheme 1).



Scheme 1: A Chat showing the methods used for the study

RESULTS AND DISCUSSION

The formations encountered in the study area include Awe (AE), Awgu (AW) and Lafia (L) Formation and their results and interpretations for each formation's sieve analysis is shown in Table 2.

Table 2: Results of granulometric analysis

Formation	Graphic Mean	Graphic Sorting	Graphic Skewness	Graphic Kurtosis
L_1	1.03 Medium-grained	0.72 Moderately well sorted	-0.33 Strongly coarse skewed	1.3 Lepturkotic
L_2	1.2 Medium-grained	1.0 Moderately sorted	-0.28 Negatively skewed	1.5 Very lepturkotics
L_3	0.9 Coarse grained	1.0 Poorly sorted	-0.25 Negatively skewed	1.05 Mesokurtic
L_4	1.4 Medium-grained	0.60 Moderately well sorted	-0.10 Near symmetrical	0.8 Mesokurtic
L_5	1.06 Medium-grained	0.68 Moderately well sorted	-0.15 Negatively skewed	1.1 Mesokurtic
AE_1	2.2 Fine grained sand	0.88 Moderately sorted	-0.071 Near symmetrical	1.48 Lepturkotic
AE_2	2.13 Fine grained sand	1.75 Poorly sorted	-0.27 Coarse skewed	0.8045 Platykutic
AE_3	1.8 Medium grained sand	0.85 Moderately sorted	-0.25 Coarse skewed	1.1 Lepturkotic
AE_4	2.1 Fine grained sand	1.55 Poorly sorted	-0.33 Strongly coarse skewed	1.20 Lepturkotic
AW_1	1.9 Medium grained sand	2.5 Very poorly sorted	-0.533 Strongly coarse skewed	0.65 Very platykutic
AW_2	2.2 Fine grained sand	1.55 Poorly sorted sand	-0.38 Strongly coarse skewed	1.01 Mesokurtic
AW_3	2.45 Fine grained sand	1.5 Poorly sorted sand	-0.26 Negatively skewed	0.99 Mesokurtic

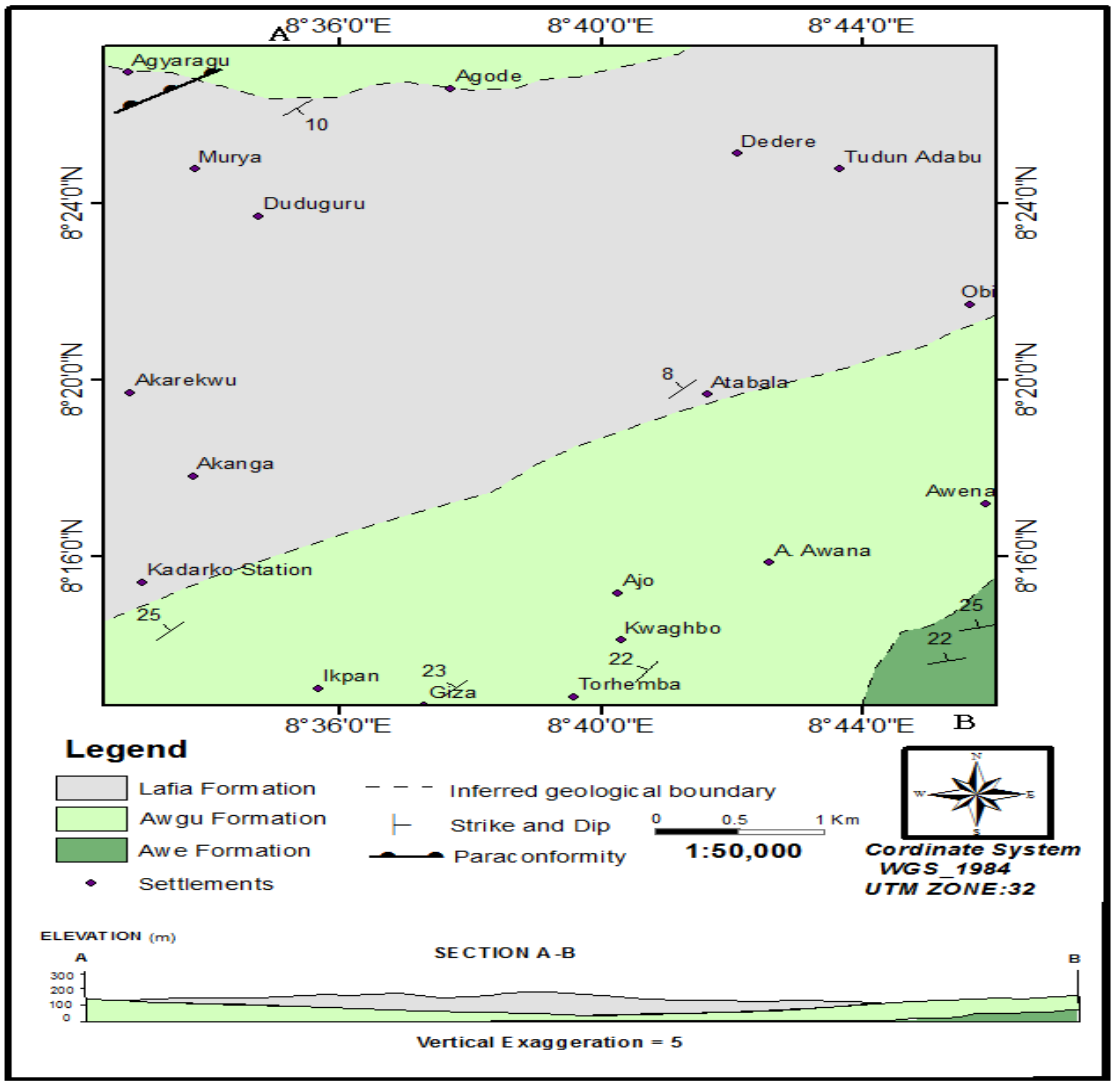


Figure 2: Geological map of the study area showing the three different formations

Plate 1: Lithologic section of Lafia Formation exposed along the road from Agyaragu to Doma. 08°22′16.4″N 08°21′03.2″E (b) Channel fill sediments within the Lafia Formation

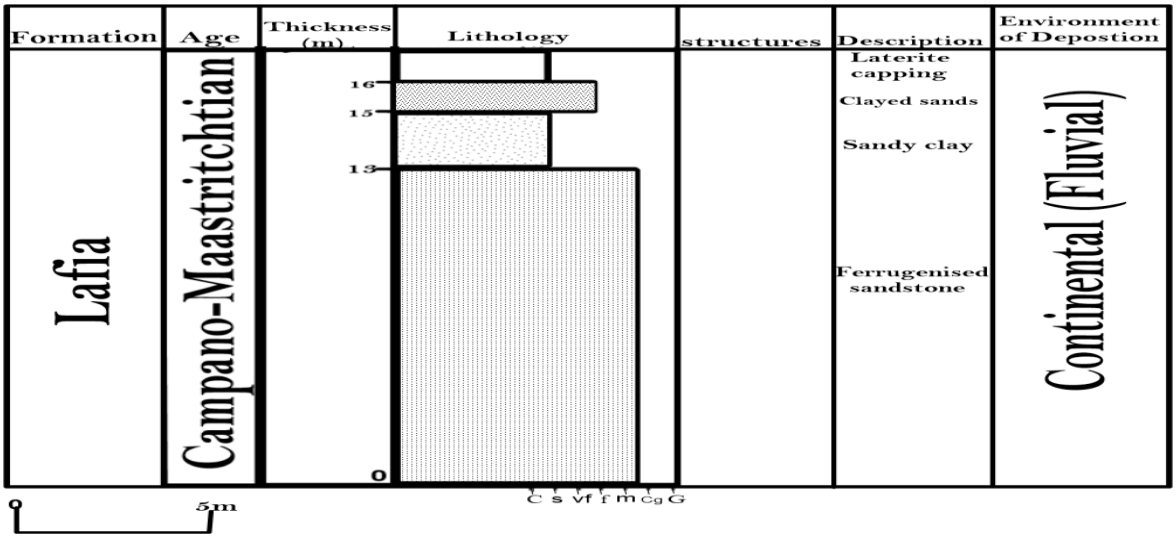


Figure 3: Lithostratigraphic log of the Lafia Formation exposed along the road from Agyaragu to Doma 08°22′16.4″N 08° 21′03.2″E

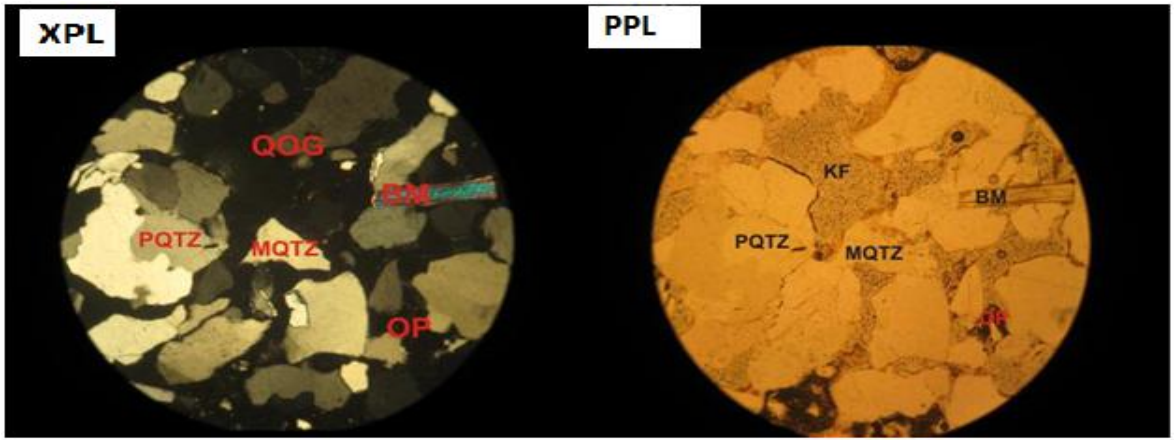


Plate 2: Sample L1--DM [Mg.x40] Photomicrograph of sandstone of the Lafia Formation showing quartz and muscovite (Quartz Arenite) PQtz: polycrystalline quartz Mqtz: monocrystalline quartz Ms: Biotite mica Op: Opaques KF: K-feldspar (Orthoclase)

Lafia Formation: The Lafia Formation occurs mostly on the northwestern part of the map within the town of Doma and along the road from Doma to Agyaragu. It is the youngest Formation in the Middle-Benue Trough (Figure 2). It consists of ferrugenised, and thickly bedded sandstone layer at the base, sandy clay and clayey loose sands with a lateritic capping. The first section of the Lafia Formation encountered along Agyaragu-Doma road consists of (i) Sandstone at the base with a thickness of 13 m, overlain by (ii) a second layer of sandy clay measuring up to 2 m in thickness and overlain by (iii) a layer of clayed loosed sands at the top measuring 1 m in thickness (Plate 1). The ferrugenised sandstone of this section consists of fine-grained angular grains which are moderately well sorted to well sorted (Table 2). These quartz crystals consists of a high percentage of monocrystalline and few polycrystalline quartz grains 95 % of the crystals are quartz therefore, the rock is a Quartz Arenite. The quartz grains are fine to medium grained. The maturity is evident by the fact that there are few grains of unstable minerals like muscovite and feldpars. The grains are subangular, moderately to well sorted and therefore texturally submature. There is also a presence of Opaques, which are Iron oxides (Plate 2).

Awe Formation: The Awe Formation covers a small portion in the southeastern part of the study area along the road from Obi to Awena (Figure 2). This formation consists of sandstones, clay, and shales (Plate 3). The sandstones appear to be fine grained, poor-moderately sorted, Coarse skewed and Leptokurtic (Table 3). These white and fine-grained sandstone of the Awe formation consists of equigranular grains making up about 80% of the rock mass. Quartz grains within these equigranular grains are majorly monocrystalline with few polycrystalline types. They are also subangular. The feldspars within the grains have undergone severe alteration. The crosshatched twinning represents microcline feldspars while albeit twinning are indicative of plagioclase feldspars (Plates 4 and 5).

Plate 3: (a) Lithologic section of the Awe Formation occurring along Lafia-Awena road. 08°11′12.9″ N 08°47′51.6″E (a) The first exposure along the road cut showing sandstones, clay and shale

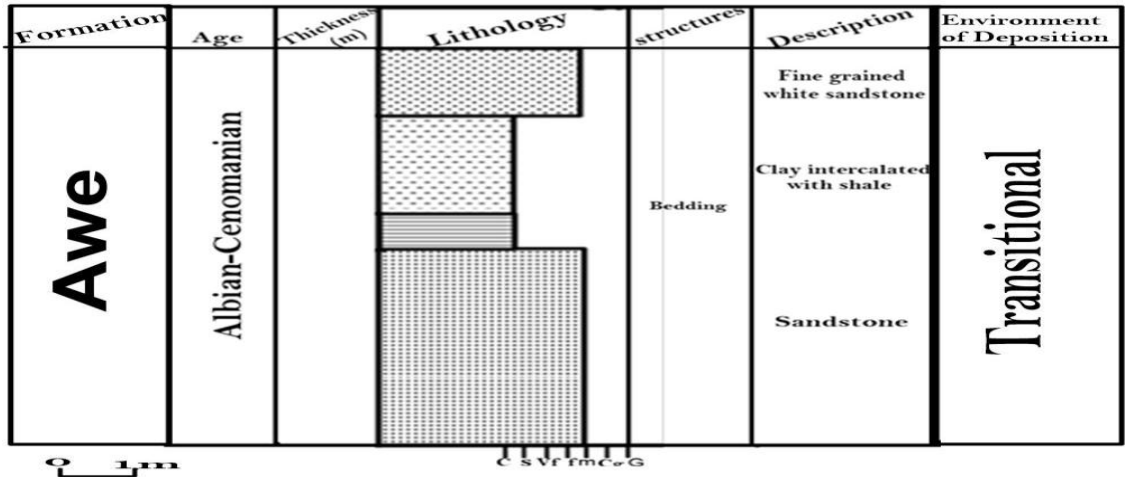
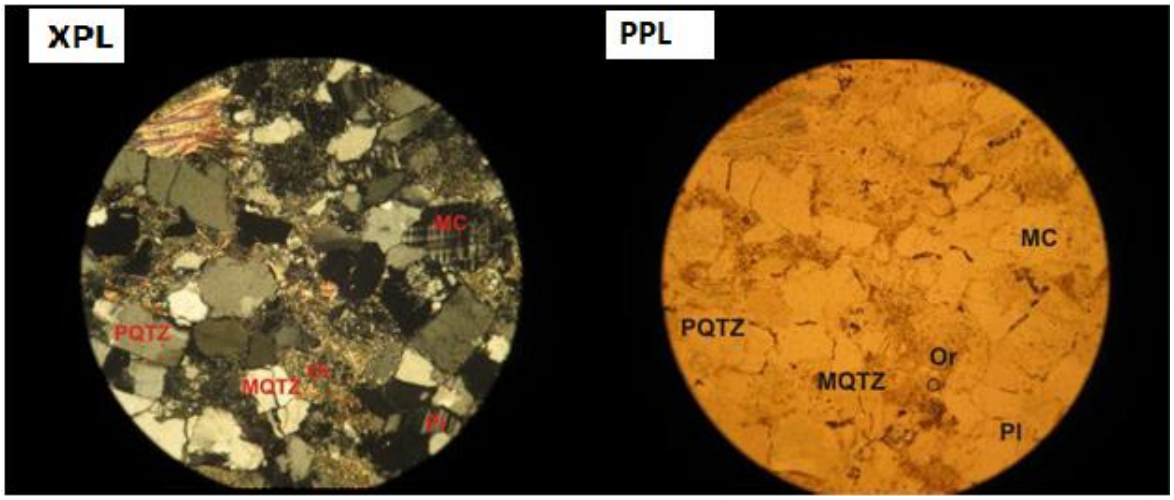
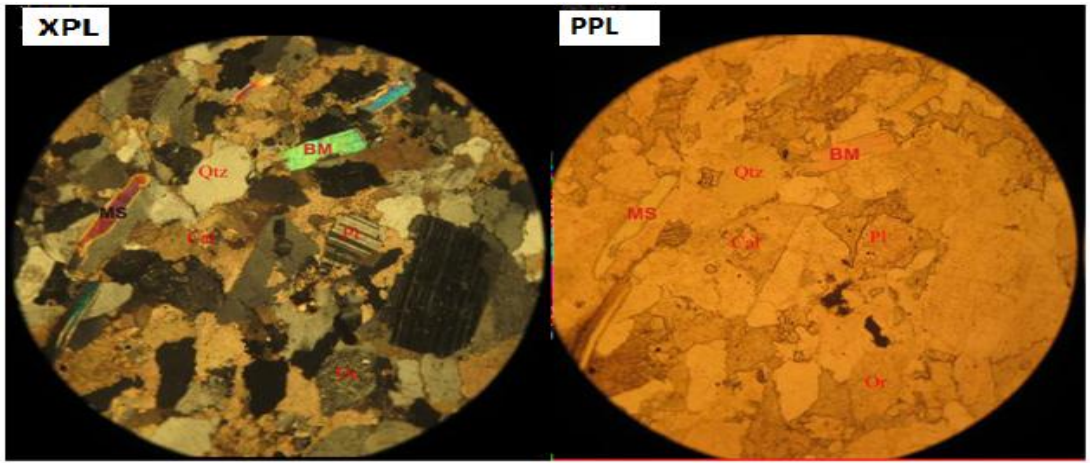


Figure 4: Lithostratigraphic log of the Lafia Formation exposed along the road from Agyaragu to Doma 08°22′16.4″N 08° 21′03.2″E



NB: MQtz: monocrystalline quartz, **PQtz**: polycrystalline quartz **Pl:**plagioclase feldspar **Mc:** microcline feldspar, **Or:** orthoclase feldspar

Plate 4: Sample AE-1 [Mg.x40] Photomicrograph of sandstone of the Awe Formation (Arkose)



NB: MQtz: monocrystalline quartz, **PQtz**: polycrystalline quartz **Pl:** plagioclase feldspar, **Or:** orthoclase feldspar **Cal**: Calcite

Plate 5: AE-2 [Mg. x40] Photomicrograph of the Sandstone of the Awe Formation [Subarkose]

Awgu Formation: The Awgu Formation has few sections at the northern part of the map around the town of Bukan Fadama and many sections at the southern part of the map around the town of Giza (Figure 2). This Formation consists of carbonaceous shales, shaley limestone, limestone, sandstones and coal seams; the coal seam found within a section at Bukan Fadama was seen exposed to the surface (Plate 6).

The first section (Figure 5) was encountered at the southern part of the map in a village called Nyitameri with a total thickness of 2.4 m while the second section (Figure 6) was encountered at the bridge around Bukan Fadama with a thickness of 3.6 m. The first section includes beds of fossilised shaley limestone with 0.8 m thickness at the base, sandstone with a thickness of 0.6 m, a second fossilised shaley limestone with a thickness of 0.4 m, a second sandstone with a thickness of 0.35 m and a third fossilised shaley limestone with a thickness of 0.25 m at the top (Plate 7). The sandstones of this section are very fine-grained and consist of equigranular grains with few cementing materials. The quartz grains within the sandstone makes up about 70 % of the crystals while the orthoclase feldspars and muscovites together make up about 20 %. The fine grained quartz grains are angular. The feldspars appear to be altered forming sericite (Plate 8). The photomicrograph of limestone within this formation shows it consists of echinoderms, ostracodes and foraminifera (Plates 9 and 10). The forams belong to the species *Heterophelix globulosa* while the ostracodes belong to the species *Buntonia vanmorkhoveni Sp.* which corroborates earlier findings by Reyment (1965). The Granulometric analysis of this sandstone reveals that it is fine-grained, very poorly sorted, strongly coarse skewed, and very platykurtic. Sedimentary structures include mudcracks, beddings, little evidence of resting trace fossils and abundant presence of ammonites macro fossil (Plate 6). Nwajide (2013) named the species of the ammonite to be *Texanites* sp. This work has corroborated his earlier findings.

Plate 6: A Lithologic section of the Awgu Formation sandstone overlain by shaley limestone at Nyimateri 08°07′45.1″N 08°42 ′ 13.4″E

Plate 7: (a) Ammonite within shaley limestone of the Awgu Formation (b) Shaley limestone of the Awgu Formation

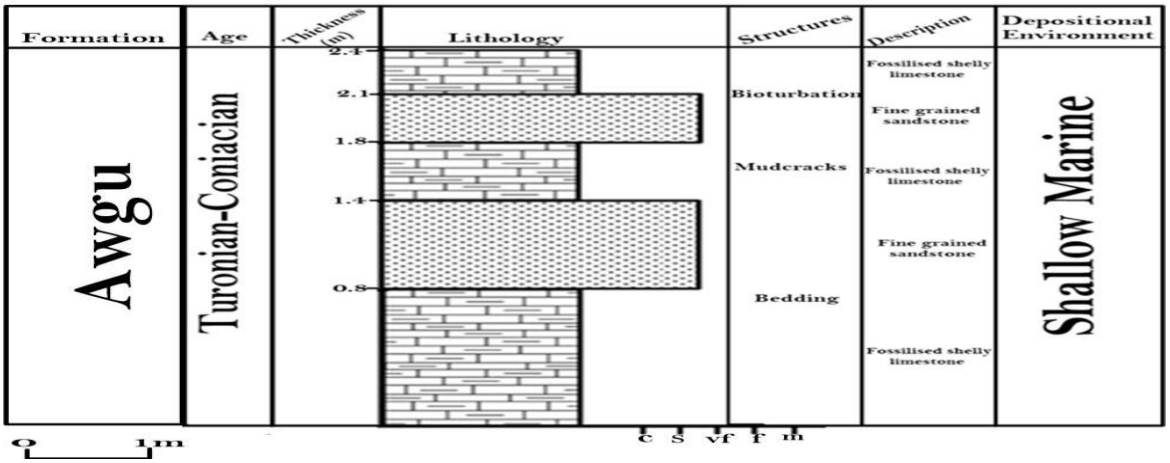


Figure 5: A Lithostratigraphic log of Awgu Formation occurring around Giza town

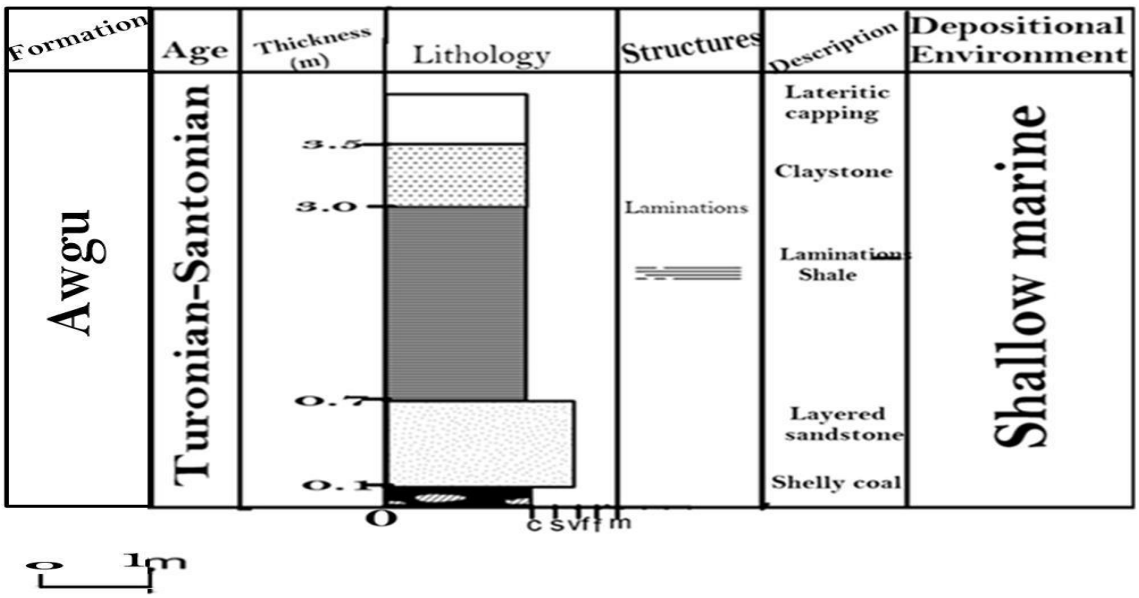
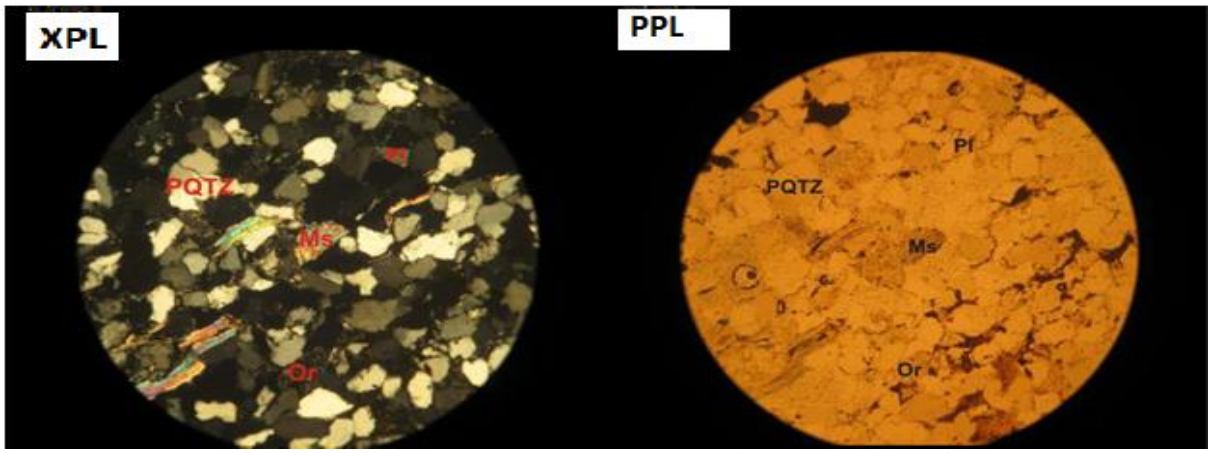
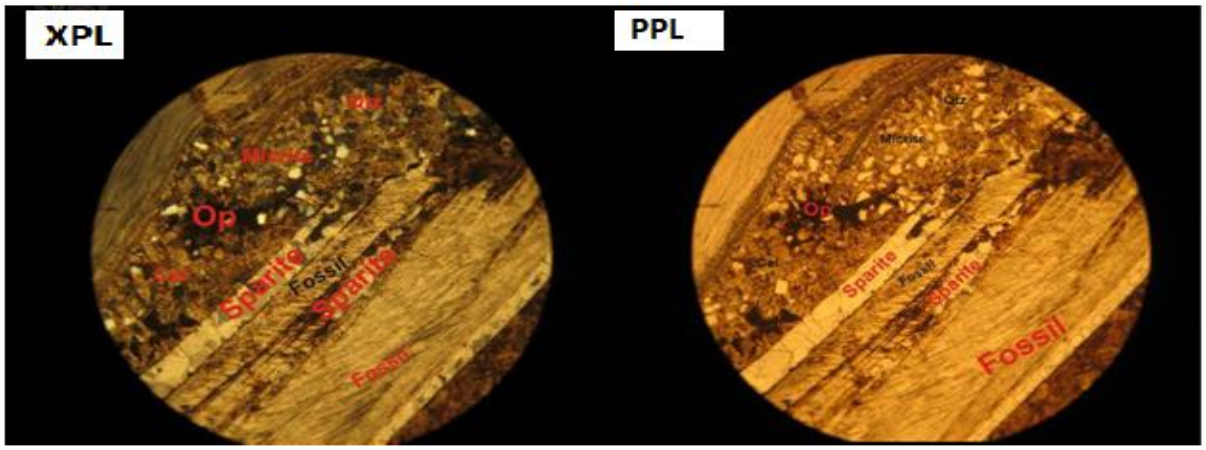


Figure 6: Lithostratigraphic Log of the Awgu Formation found around the town of Bukan Fadama



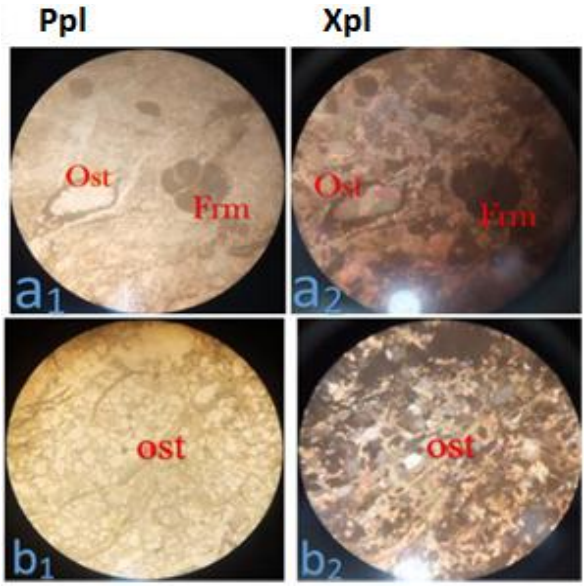
NB: MQtz: monocrystalline quartz, **PQtz:** polycrystalline quartz **Pl:** plagioclase feldspar **Or:** orthoclase feldspar, **Ms:** muscovite mica

Plate 8: AG-2 [Mg.x40]. Photomicrograph of the micaceous sandstone from the Awgu Formation (Quartz Arenite)



NB: Qtz:quartz, **Op:** Opaque mineral **Mr:** Micrite **Sp:** Sparite **Fossil:** Fossil **Cal:** calcite cement

Plate 9: Sample AG-L [Mg.x40]. Photomicrograph of a limestone of the Awgu Formation showing a fossil echinoderm cemented by calcite



NB: Ost: Ostracodes **Frm:** Foraminifera **Cc:** calcite cement

Plate 10: Sample AG-SL [Mg.x40] Photomicrograph of shaley limestones showing fossils

The study area consists of three formations namely Awe, Awgu and Lafia Formations. The Awe Formation was deposited during the Late Albian-Early Cenomanian regression while the Awgu Formation was deposited during the Turonian-Santonian cycle. Finally, Lafia Formation was deposited during the Campano-Maastrichtian cycle.

Lafia Formation

Offodile (1976) reported that the Lafia Formation is fluviatile. The presence of a channel fill (Plate 1b) in the study area within the Lafia Formation indicates fluvial environment and hence affirms his findings. The fine to medium-grained sandstones indicates transition in energy regimes. The fine-grained sandstone indicates low energy while the medium-grained sandstone indicates moderate energy condition. The Lafia Formation has a fining upward sequence that suggests a meandering river. The sediments are minerallogically mature as indicated by their lack of unstable minerals like muscovites and feldspars. The ferruginous sandstones of the Lafia Formation is indicative of the

presence of iron (Fe). The iron reacted with oxygen in the presence of water thereby forming a ferric oxide (Fe2O3) that is responsible for the brown colour of the sandstone. The brown colour within the sandstones of the Awe Formation is indicative of deposition in an oxygen-abundant and non-marine environment. The dorminance of the monocrystalline quartz is an indication of igneous provenance.

Awe Formation

Different workers have suggested that the Awe Formation is fluvial with some evidence of shallow marine conditions (Offodile, 1976; offodile and Reyement, 1976; Ishaya, 2015). This work corroborates their conclusion in the sense that the bivariate plot indicates fluvial conditions while the poor to sorted and calcareous sandstones associated with brine are indicators of a transitional environment. The abundance of monocrystalline quartz among other grains indicates igneous provenance. It is a transitional environment between fluvial and shallow marine. The poorly sorted sediments indicate fluctuating depositional currents and variable current velocity.

Awgu Formation

The fine grained and poorly sorted sandstones of this formation is a typical characteristic of shallow marine environment.

The presence of echinoderms, mudcracks and bioturbation are pointers to deposition in shallow silliclastic marine environment. The presence of fossils within the sandstones of the Awgu Formation is accounted for by the presence of bioturbation and giving the shale a very dark colour. The lack of abundant sedimentary structures within the sandstones and the dark to grey colour of the shaley limestones of this formation are typical of deposition in quiet water, reducing/anaerobic marine environment. The environment of deposition of the Awgu Formation is shallow marine. The presence of Ammonite and echinoderm indicates Cretaceous age. The foraminifera species *Heterophelix globulosa* and ostracodes species *Buntonia vanmorkhoveni* sp. are indicators of shallow marine environment while the ammonite species Texanite sp. indicates Cretaceous age.

CONCLUSION

Stratigraphy and sedimentological studies remains one of the most reliable tools in basins analyses and the interpretation of past environments of deposition. This work has been able to examine sediments to look for clues such as fossils; sedimentary structures; grain shape, size, and composition in determining the source area of the sediment and their environment of deposition. Based on the stratigraphy and sedimentological studies of the sediment in this portion of Middle Benue Trough, the Awe Formation has been established to be transitional between fluvial and marine, the Lafia Formation has been established to reflect fluivial conditions while the Awgu Formation has been established to reflect shallow marine conditions.

REFERENCES

Burke, K. C., Whiteman, A. J. and Dessauvagie, T. F. J. (1970). Geological history of the Benue Valley and the adjacent areas. In: T. F. J. Dessauvaggie and A. J Whiteman (Edition), *African Geology*. Ibadan University Press, pp. 187 - 205.

Cratchley and Jones, G. P. (1965). An interpretation of the geology and gravity anomalies of the Benue Valley, Nigeria. *Overseas Geological Surveys Geophysical Paper*, 1, 1-26.

Ishaya, E. D. (2015). Lithostratigraphy and sedimentological studies of the Albian to Cenomanian successions, part of the Middle Benue Trough, Nigeria.

King, L. C. (1950). Outline and disruption of gondwanaland. *Geological magazine*, 87, 353-359.

Lees, G. M. (1952). Foreland folding. *Quarterly Journal of the Geological Society of London*, 108, 1-34.

Nwajide, C. S. (1990). Sedimentation and palaeogeography of the central Benue Trough, Nigeria. In: C.O. Ofoegbu, (Ed.). *The Benue Trough Structure and Evolution, View* eg & Sohn, Braunschweig, pp. 19-38.

Nwajide, C. S. (2013). *Geology of Nigerian Sedimentary Basins*. CSS Bookshops Ltd, Lagos.

Obaje, N. G. (1994). Coal petrology, microfossils and paleoenvironments of cretaceous coal measures in the Middle Benue Trough of Nigeria. *Tiibinger Mikropaleontologische Mitteihengen*, 11, 15-24.

Obaje, N.G. (2009). *Geology and Mineral Resources of Nigeria*. Lecture notes in Earth Science 120. DOI: 10.1007/978-3-540-92685-6_5, Springer – Verlag Berlin Heidelberg.

Obaje, N. G. and Ligouis, B. (1996). Petrographic evaluation of the depositional environments of Cretaceous Obi/Lafia coal deposits in the Benue Trough of Nigeria. *Journal African Earth Sciences*, 22, 159-171.

Offodile, M. E. (1976). The Geology of the Middle Benue Nigeria. *Special volume Palaeontological Institution University Uppsala*, 4, 1-166.

Offodile, M. E. and Reyment, R. A. (1976). Stratigraphy of Keana-Awe area of the Middle Benue region of Nigeria. *Bulletin of the Geological Institutions of the University of Upsala, N.S.*, 7, 37-66.

Zaborski, P. M. (1998). A review of the cretaceous system in Nigeria. *Afr. Geo. Rev.*, 5, 385-483.

Zaborski, P. M. (2003). Guide to the cretaceous system in upper part of the Upper Benue Trough, North-Eastern Nigeria. *Africa Geoscience Review*, 10, 13-32.