Stratigraphic Report of the Middle Benue Trough, Nigeria: Insights from Petrographic and Structural Evaluation of Abuni and Environs Part of Late Albian–Cenomanian Awe and Keana Formations.

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ABSTRACT

The study area covered Abuni and its environs in the Awe Local Government area of Nasarawa State, Nigeria. The area is part of the Middle Benue Trough of Nigeria and the area is composed of the Late Albian - Cenomanian Awe and Keana Formations (consisting essentially of sandstones with intercalations of bands of shales and clays) and Cenozoic volcanics. Structures observed on the field include bedding, lamination, massive bedding, graded bedding, mud cracks, cross bedding, folds and joints. The major structural trends are oriented in NE-SW, NNW-SSE, WNW-ESE and NW-SE directions. The mineral suites identified from the thin section of the volcanic include hornblende, plagioclase feldspar, olivine and accessories minerals which include opaque minerals and are believed to be iron oxides due to the high concentration of iron in almost all the samples. The Sandstones are also made up essentially of quartz so they are quartz arenites.

(Keywords: Abuni, stratigraphy, petrography, Middle Benue Trough)

INTRODUCTION

The Benue Trough of Nigeria is an intra-cratonic rift structure, which extends from the Northern limit of the Niger Delta to the Southern margins of Chad Basin. The valley which is occupied by up to 600m of marine and fluviodeltaic sediments, that have been compressionally folded in non-orogenic shield environment has been subdivided geographically into the Lower, Middle and Upper Benue Trough for the ease of mapping.

The Middle Benue Trough which is of particular interest in this project work encompasses the study area located in Abuni and its environs (Awe Local Government of Nasarawa State). The study area which is located in the south-eastern part of Nasarawa State covering about 36 km^2 and consists of two formations out of the six sedimentary formations in the Middle Benue Trough.

The six formations include the Asu River Group, Awe Formation, Keana Formation, Ezeaku Formation, Awgu Formation and finally the youngest which is the Lafia Formation, while the two formations exposed in the studied area are the Awe Formation and Keana Formation which are essentially sandstones with intercalations of calcareous shale and claystone which are covered by laterite resulting from the weathering of volcanic rocks which were emplaced during the widespread volcanic activities that took over in the Tertiary Period.

The earliest work done in the Middle Benue Trough of Nigeria was reported by Falconer (1911) who reported the Asu River Group to be the oldest marine sedimentary formation which he then referred to it as the “Lower Shale”, Tattam (1944) described the lithological unit as the “Cross River Series” and the name “Asu River Group” was obtained. The Keana Formation is thought to be equivalent to the “Muri Sandstone” in the north. Cratchley and Jones (1965) subsequently used the “Keana Sandstone” to describe the formation in Lafia-Awe area. Simpson (1954) first mentioned the “Ezeaku Formation” in the literature where he described a sequence of hard dark grey to black flaggy calcareous shale, siltstone and sandstone in the stream south of the Okigwe-Afikpo road. The formation was first recognized by Shell-BP geologist. The most recent study of the Keana area which was complementary to the work of Offodile (1976) was carried out by Obaje *et al.,*

1994, 1996, 2004 and Sabo, 2001 and their study has reveal and confirmed the different geologic units similar to those of previous workers. The mines development of Nigeria also carried out a preliminary survey of Lead-Zinc in 1948 and 1949 using student geologist from United Kingdom.

The study on the structural geology of the area was carried out by Benkhelil (1982, 1987, 1989) and suggested that sinistral wrenching that dominated tectonics processes is responsible for the structural arrangement and geometry of the sub-basins in the Lower, Middle and Upper Benue region, earlier on, he had described the Benue Trough of Nigeria as an intra-cratonic rift structure which extends from the Northern limit of Niger Delta on the southern margin of the Chad Basin. However, in a bid to investigate the regional structure of the Middle Benue, a detailed gravity survey was carried in 1979 by Ajayi and Ajayi *et al.,* 1986 and their work discussed in detail folds, faults and intrusions which are the main regional structure of interest. On the economic aspect, worker such as Offodile (1976) carried out a mineral resource survey of the Benue Trough and was able to delineate zones characterized by particular mineral resources. Similarly, Akande *et al* (1992) also carried out a systematic study of the formation of Lead-Zinc-Fluorite-Barite deposit of the Benue Trough. Hydrogeologically, Offodile (1992) delineated water bearing aquifer and discuss the water chemistry and quality of the Middle Benue Trough as good. The focus of this paper is to study the general geology, stratigraphy, and economic mineral resources of the Abuni and environs.

Location, Extent and Accessibility

The study area lies within latitudes $08^0$10'31.6" N and $08^0$13'31.6" N and between longitudes $009^0$02'25.3" E and $009^0$05'12.6" E (Figure 1). The mapped area covers about 36 km^2. The area is accessible by the Lafia-Obi road down to Kanje junction to other localities with a minor road and a lot of foothpaths. The plot is bounded in the north by the Lafia-Obi road, Keana to the west and Awe town to the south east.

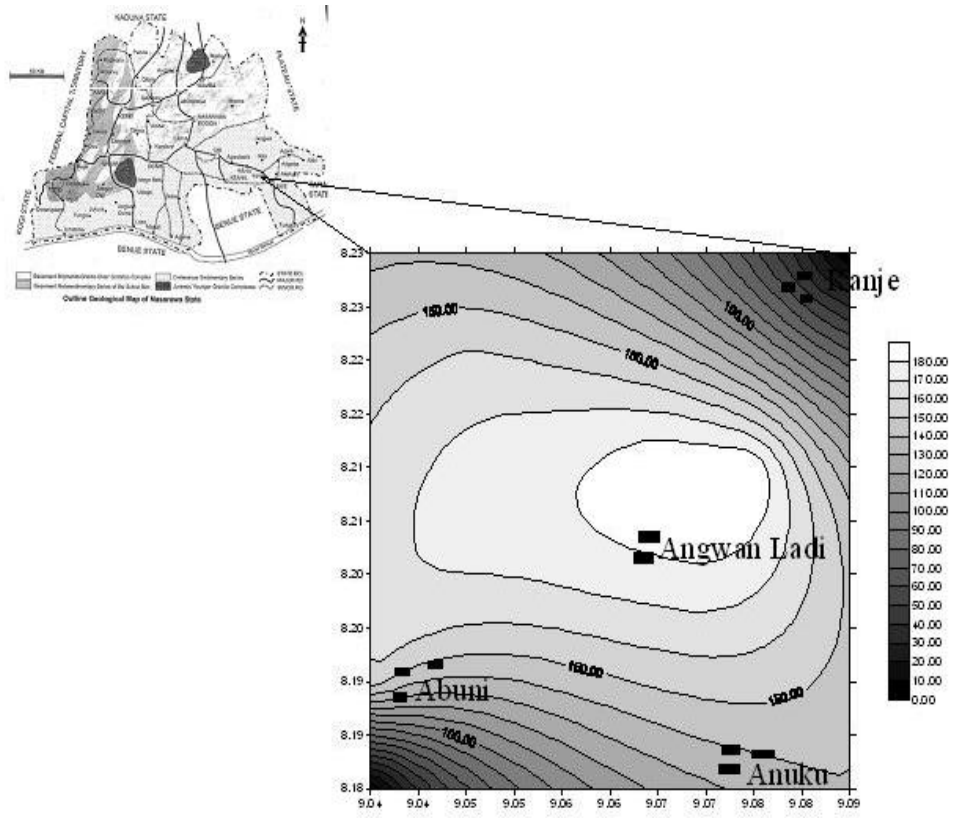


Figure 1: Topographic map of Abuni and its Environs. (Scale = 1cm: 0.66km. Contour Interval = 10m).

Geology of the Benue Trough

The linear NE-SW trending Benue Trough (Figure 2) has a length of approximately 800km and open into the Gulf of Guinea where the Cenozoic Niger Delta has built out upon oceanic crust (Avbovbo, 1980). Proximately it bifurcates into an E-W trending Yola arm and a N-S trending Gongola Basin. The Benue Trough is conventionally subdivided into a "Lower Benue Trough", "Abakaliki Trough" of Whiteman (1982), a "Middle Benue Trough" and an "Upper Benue Trough" ("Benue valley" respectively of Whiteman (1982). The Benue Trough was terminated by a Late Santonian episode of compressional folding. Subsequent sedimentation was centered on basins developed on the North-Western flank of the resultant deformed sediments. The stratigraphic succession of the Benue Trough is shown below (Figure 2).

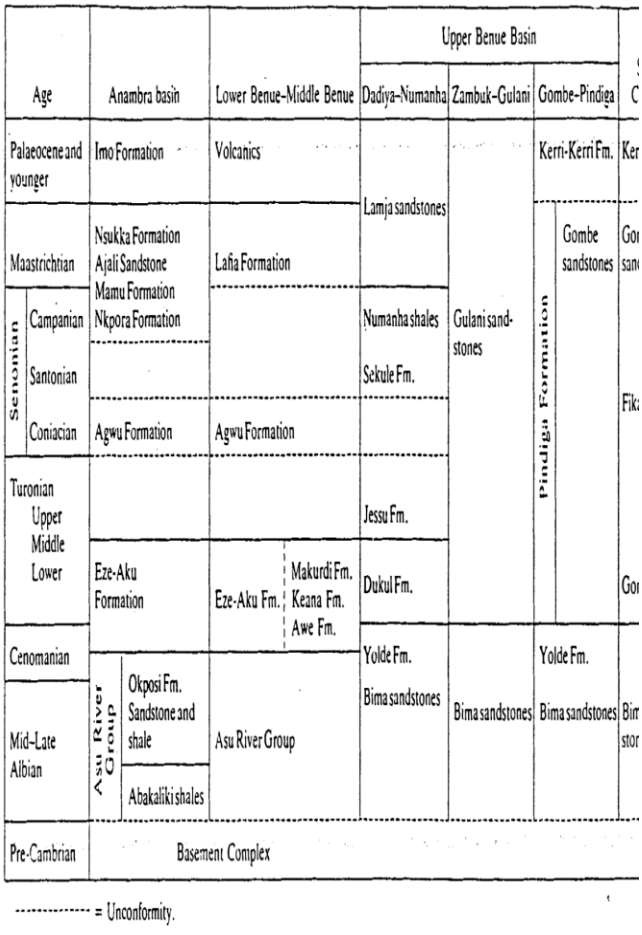


Figure 2: Stratigraphic Succession in the Benue Trough and the Nigerian Sector of the Chad Basin (Cratchley & Jones,1965).

The Middle Benue Trough

The Middle Benue Trough extends Northeast ward approximately as far as line joining Bashar and Mutum Biyu. This boundary marks the Southern limit of the Gombe and Keri-Keri Formation while the older sediments of the Upper Benue Trough undergo lateral facies change in this area. The Middle Benue Trough is relatively poorly known, especially in its Northeastern part; no detailed geological maps of this portion are available but the area immediately south of Bashar was included in a photogeological map. Maps of the Lafia-Keana-Awe region were presented by Offodile (1976) and Offodile and Reyment (1977) and of the area around makurdi by Kogbe *et al* (1978) and Nwajide (1985). The geological map of the Middle Benue Trough after Geological Survey of Nigeria, 1984 is shown in Figure 3.

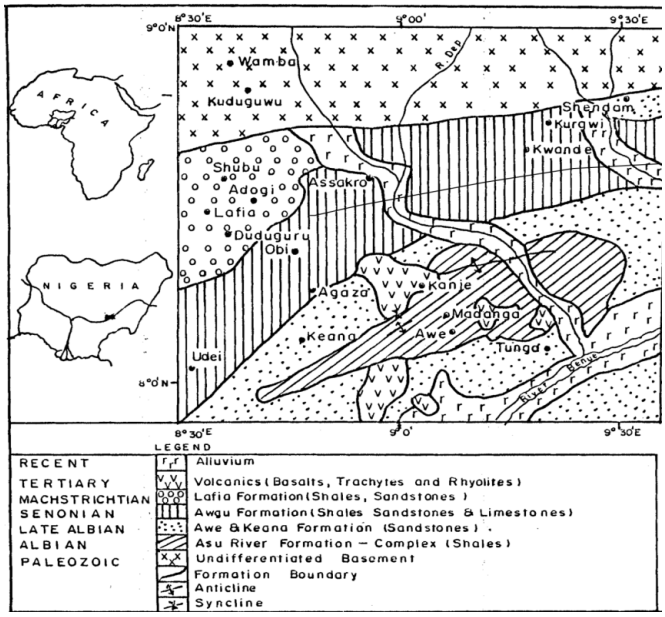


Figure 3: Geological Map of the Middle Benue Trough (Source: Geological Survey of Nigeria,1984).

Structure

The axial basement high of the Middle Benue Trough (the Keana ridge of Ajayi and Ajakaiye, 1986), coincides with its main surface structural features, the NE-SW trending Keana anticline. Either side of the basement high sedimentary sub-basin were identified by Benkhelil (1988, 1989) through gravity and aeromagnetic data. On the south-eastern flank a "Wukari" and a Mutum

Biyu Basin with inferred sediment thickness of 1.9 to 3.8km and on the North-western flank a minor "Shendam Basin" and a more important "Kadarko Basin" with sediment thickness of 2.4 to 5.3km.

Stratigraphy of the Middle Benue Trough

Stratigraphically, the Middle Benue Trough consists of six formations namely;

Asu River Group: The oldest outcropping beds occurring in the core of the Keana Anticline are Micaceous siltstone, shale, mudstone,clays and fined grained sandstones which Cratchley and Jones (1965), Offodile (1976) and Offodile and Reyment (1977) referred to the Asu River Group. They contain the Middle Albian ammonite *Oxytropidocera* (Reyment,1955a,1957; Offodile, 1976; Offodile and Reyment,1977). Reyment (1964) proposed the term Uomba Formation for these beds. In the south-eastern extremity of the Middle Benue Trough, the locally-developed Arufu (Arufa) limestone (Reyment 1964), lying directly upon the Precambrian Basement Akande et al., 1988), contains the ammonite *Elobiceras* and is Late Albian (Spath, 1928; Reyment, 1965). The Uomba Formation represents the first transgression into the Benue Trough and is probably the age equivalent of the marine slumps and turbidities that make up the Ekebeligwe Formation in the Lower Benue Trough. This transgression entered the Benue Trough from the newly opened Equatorial Atlantic Ocean and reached its peak towards the end of Middle Albian. The sea apparently shoaled somewhere towards the north-eastern boundary of the middle Benue Trough. The nature of any sediment underlying the Uomba Formation is speculative. Benkhelil *et al.,* (1988), reported shale-dominated lacustrine facies with channel-fill sequences in the lower Asu River Group east of Keana. Popoff (1988) suggested that "great interior lakes" occupied the Benue Trough during Birrimian to Middle Albian times.

Awe Formation: The Awe Formation is lying above the Asu River Group. Its lithological composition consists mainly of about 100m flaggy, pale colored medium to fine grained sandstone with interbedded carbonaceous shales and clays, the Awe formation (Offodile, 1976) ["passage beds" of Falconer (1911); "unnamed transition deposits" of Cratchley and Jones (1965)]. Brine springs issue from these beds in places. Offodile (1976) and Offodile and Reyment (1977) attributed the Awe Formation to the gradual regression which took place during the later part of the Albian (Reyment and Tait, 1972) but thought it may also include Cenomanian beds.

Keana Formation: The Keana Formation overlies the Awe Formation, the contact between the two being variously described as gradational and unconformably (Offodile, 1976, 1984; Reyment and Offodile, 1977). The Keana Formation consists mainly of thickly bedded, cross-bedded, fine to very coarse grained, sometimes conglomeratic, gritty arkosic sandstone of inferred fluvial or deltaic origin (Murat, 1972; Offodile, 1976). Offodile (1976) and Offodile and Reyment (1977) described the Keana Formation as in places lying below beds referred to the Ezeaku formation and elsewhere interfingering with them. Although not directly dated, the Keana Formation has generally been regarded as late Albian to Cenomanian and representing the southern part of a fluvio-deltaic system discharging into the receding sea. Its laterally equivalent to the north is the "Muri sandstone" (Cratchley and Jones, 1965; Whiteman 1982; Benkhelil *et al.,* 1988). To the South the Keana Formation passes laterally into Makurdi Formation (Nwajide, 1985; Benkhelil *et al.,* 1988). Offodile (1976) suggested that this fluvio-deltaic system was diachronous, Late Albian to Cenomanian in the Upper Benue Trough, the Keana Formation being Cenomanian and the Makurdi Formation Cenomanian to Turonian. While it is probable that a deltaic system prograded south-west wards along the Benue Trough during the Late Albian and early part of the Cenomanian, marine conditions were established throughout the Trough in the later part of the Cenomanian and the Early Turonian. Benkhelil (1988) interpreted the Makurdi Formation as the product of a local Turonian side-delta. Such an origin for parts at least of the Makurdi Formation would accord with the regional stratigraphy of the Benue Trough.

Ezeaku Formation: In the Keana-Awe region, the Ezeaku Formation consists mainly of grey to black shales with clay horizons, fine to medium grained sandstones and limestone beds (Offodile 1976; Offodile and Reyment 1977). Its basal part includes shelly limestones containing the bivalve *Costagyra olisiponensis* (Sharpe) and a marly horizon has yielded the Late Cenomanian

ammonite *Euomphaloceras septemseriatum.* Higher in the formation a diverse *"vascoceratid"* dominated ammonite fauna occurs, containing Late Cenomanian to Early Turonian species almost all of which are known from the Upper Benue Trough. West and South of Keana black shales, marls, limestones and micaceous sandstones occur in the Ezeaku Formation, with fine to coarse-grained feldspathic sandstones appearing in its upper part (Obaje, 1994).

Awgu Formation: In the Keana-Awe area the beds overlying the Ezeaku Formation were referred to the Awgu Formation by Offodile (1976) and Offodile and Reyment (1977) who, by comparison with the Nkalagu area in the Lower Benue Trough, suspected that the boundary between the two may be unconformable, the upper part of the Turonian being missing. Obaje (1994) believed the contact to be conformable and dated the Awgu Formation as Turonian to Coniacian (or Early Santonian). The beds referred to the unit here are lithologically more variable than those in the Lower Benue Trough. Numerous sections obtained from outcrop and boreholes drilled in the course for exploration for coal were described by Obaje (1994). Deltaic conditions developed in the Keana-Obi area during the Late Turonian and Coniacian, alternation of clays, shales, siltstones, sandstones, limestones and coal forming. Turonian and concacian Foraminiferas and Ostracods were reported from marine horizons by Obaje (1994). Offodile (1976) suggested that the Awgu Formation recorded numerous oscillations between continental and shallow marine conditions with marine marls or shales enclosing coals and associated non-marine beds. The coals, of bituminous rank, were subdivided into three facies types by Obaje (1994), Obaje and Ligouis (1996) and Obaje *et al* (1994, 1996):

i. a vitrinite–fusinite facies believed to have formed in telmatic wet forest swamps along and within lagoons;

ii. a trimaceratic facies, dominated by vitrinite with subordinate liptinite and inertinite, believed to have formed within deltaic plain, limno-telmatic clastic marsh environments; and

iii. a shaly coal facies, containing more than 25% mineral matter, mostly clay minerals and pyrite, believed to have formed under greater marine influence.

The environments of deposition of the coal-bearing sequences were thought to range from shallow marine through lagoonal to delta plain. On the basis of the miospore *proteacidites*, correlated the upper part of Awgu Formation in the Obi-Lafia area with the Late Campanian part of Nkporo Shale in the Lower Benue Trough. He also inferred the presence of Santonian horizons, but without firm evidence, suggesting that a continuous Coniacian-Campanian succession existed. Most or all of the Santonian and Campanian stages is generally believed to be missing in the Middle Benue Trough. Offodile (1976), Offodile and Reyment (1977) and Obaje (1994) related this hiatus to the Santonian compression which they believed produce the main NE-SW trending fold structures including the Keana anticline. Offodile (1976) and Offodile and Reyment (1977) postulated additional Cenomanian and Post-Maastrichtian folding. Benkhelil (1989) proposed that a single compressional event took place in the middle Benue Trough. In accordance with this belief that the Benue compression was diachronous, he suggested that it might have occurred between Santonian and Maastrichtian times but did not rule out a Maastrichtian age. Although the Lafia Formation is only weakly disturbed, Benkhelil related this to its outcrop being marginal to the main deformed zone.

Lafia Formation: The Lafia Formation comprises the youngest sediments in the southern part of the Middle Benue Trough. It is confined to the Kadarko sub-basin. A thickness of 500-1500m was quoted by Offodile (1976) though only about 50m was reported east of Lafia where wedging out is apparent. It consists of red, poorly consolidated, commonly cross-bedded frequently ferruginous sandstones, flaggy mudstones and clays, with a palaesol horizon identified just south of Lafia (Offodile, 1976). Carbonized plant remains are the only fossils. Although not precisely dated, the formation is generally regarded as Maastrichtian. Offodile (1976) and Offodile and Reyment (1977) suggested an origin within a south-westerly flowing fluviatile system discharging into the Anambra Basin.

Volcanics (Basalts): No Post-Cretaceous sediments, apart from superficial deposits, occur in the Middle Benue Trough. Volcanic activity was relatively minor in scale and was concentrated in its southern part. Carter *et al.,* 1963 reported several volcanic plugs and basalt flows from southeastern Nigeria with similar occurrences found in the Upper Benue Trough. A notable occurrence is the phonolitic trachyte of Wase Rock (Wright, 1989), dated as 14.4 ±0.4Ma by Grant *et al* (1972). Basalt flows occur around Awe and dolerite sills, of presumed Cenozoic age, have been encountered within the Lafia Formation (Offodile, 1976; Obaje, 1994). Offodile (1976) reported that intrusives in the Lafia-Awe area are restricted to anticlinal structures. In the Middle Benue Trough, the volcanics are mostly confined to the Keana, Awe, Kanje and Jangerigeri areas.

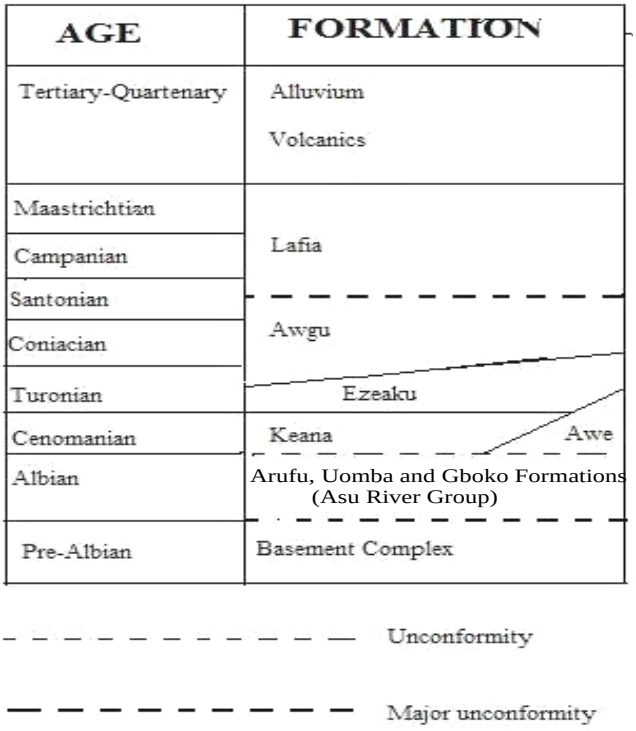


Figure 4: Stratigraphic Succession in the Middle Benue Trough (Offodile, 1976).

METHODS AND MATERIALS

The geological survey of Abuni and its Environs was carried out. For this purpose rock and soil samples were collected from the study area. This was done in stages, which include;

1. Library Research: it involves the review of the geological information of the area and careful planning of the fieldwork and the acquisition of maps and photo-satellite image of the area, as well as, the procurement of equipment to be used.

2. Field Work: it involves detailed of the outcrops (rocks) exposed in the area.

Equipment used for this work included;

(i) Base Map: very important in any fieldwork, used for locating areas to be mapped.

(ii) Compass Clinometer: used for measuring strike directions and dips.

(iii) Field Note Book: used for jotting down features seen in each of the locations.

(iv) Hammer: used for breaking fresh samples of rocks.

(v) Sample Bag: used for collecting samples on the field.

(vi) Camera: used for taking photographs of various geological features.

(vii) Hand lens: used for grain size magnification and textural observations.

(viii) Measuring Tape and Ruler: used for measuring the length, width, as well as, height outcrops and structures.

(ix) Water proof maker: for sample labeling.

(x)Global Positioning System: used for positioning on the field.

STRATIGRAPHY

The stratigraphy of the studied area consists of the Awe Formation, Keana Formation and the Volcanics (Figures 5 and 6).

Awe Formation

The Awe Formation was deposited as passage (transitional) beds during the Late Albian-Early Cenomanian regression. The Awe Formation exposed in the area mapped is about 97m thick

and it consists entirely of flaggy, whitish and medium to coarse grained calcareous sandstones, shales, little limestones and clays. The sandstones became fine grained and more micaceous towards the base with fine current bedding. Its typical sections occur around Abuni and Anuku.

Figure 5: Sandstones of Awe Formation Exposed around Abuni.

Sandstone Unit: The sandstone unit of the Awe Formation covered almost half of the plot (around the basal and middle part of the plot) but in some places been overlain by shales, limestones and clays and also been intruded by the volcanics (Figure 5). This rock unit is fine to medium grained in texture and are well cemented with siliceous materials constituting the bulk of the cement and ranges in color from whitish to grey and brown with reddish and yellowish spots in some areas (Figure 5). The beds of this unit are usually multilayered, highly micaceous, fine current bedded and tabular. The sandstone unit grades into shale in some places as observed around the southeastern part of the plot and giving rise to joints at right angles. This rock unit is generally trending in NE-SW direction with a dip of 20°SE. It ranges in thickness from 30-38m.

Shale Unit: The shale unit of the Awe Formation is found towards the western and southeastern part of the plot (Figure 5). The shale unit in this area is fine grained, loosely cemented, laminated, clayed and fissile and ranges in color from grey to milky with white bands probably limestones. The shale bed frequently overlies the sandstone bed, except in few places where both beds grade into one another. This rock unit is generally trending in NE-SW direction with a dip of 22°SE. It ranges in thickness from 20-25m. The shale weathers into clayey and muddy soils.

Limestone Unit: The limestone unit of the Awe Formation is found towards the western part of the plot and it is found somehow included in the shale as bands of limestones (Figure 5). This rock unit is generally trending in NW-SE direction with a dip of 22°SW. It ranges in thickness from 10-15m.

Sandy Claystone Unit: The sandy claystone unit almost divided the plot into two (Figure 5) and it is the youngest in the Awe Formation of the area mapped. The unit consists of clays with impurities of sands. This rock unit is generally trending in NW-SE direction with a dip of 23°NE. It ranges in thickness from 10-18m.

Keana Formation

The Keana Formation resulted from the Cenomanian regression which deposited fluviodeltaic sediments. The Keana Formation exposed in the area mapped is about 60m thick and it consists entirely of cross-bedded, coarse grained feldspathic sandstones and bands of shale. Its typical sections occur around Angwan Ladi and Kanje area.

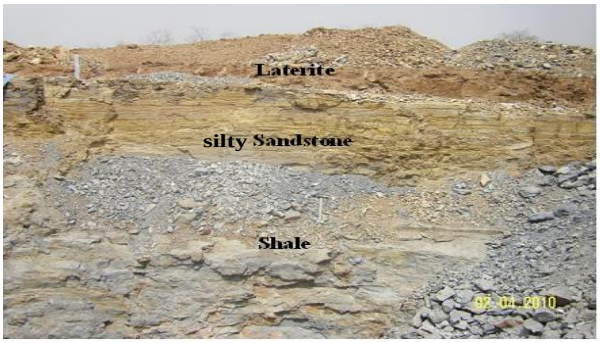


Figure 6: Keana Formation Exposed around the Northern part of the area Mapped.

Silty Sandstone Unit: The silty sandstone unit of the Keana Formation is found towards the northeastern part of the plot (Figure 6). This rock unit consists mainly of thickly bedded, cross bedded, fine to very coarse gritty arkosic sandstones with impurities of sands (Figure 6). This rock unit is fine to medium grained in

texture. This rock unit is generally trending in NE-SW direction with a dip of 25°SE. It ranges in thickness from 30-35m.

Shale Unit: The shale unit of the Keana Formation is found towards northwestern part of the plot (Figure 6). The shale unit in this area is fine grained, laminated and fissile. In some places, the sandstones of the Keana Formation overlie the shale (Figure 6) while the shale also overlies the sandstones and both forming a shale/sandstone sequence of varying thickness. This rock unit is generally trending in NE-SW direction with a dip of 24°SE. It ranges in thickness from 20-22m. The shale weathers into clayey and muddy soils.

Volcanics (Basalts)

Basalt is a mafic, medium grained rock which contains plagioclase feldspar of labradorite composition and pyroxene of augite or titanoaugite composition as essential minerals, and magnetite, titano-magnetite, or ilmenite as accessory minerals where olivine also occurs as an additional mineral. The areas covered by basalts are mostly flat and are found mostly as laterite, there is also the existence of dense and vessicular basalts (fig 7 and 8) with no pillow structures. The thin section analysis shows that the basalts are mainly the fresh olivine type and are generally ferrugenised. The age of the volcanic is ascertained to be Cenozoic (Offodile, 1976; Obaje, 1994). In the area mapped, the volcanics are mostly confined to Abuni (south-west of the plot) and Anuku (south-east of the plot).

Figure 7: Volcanics (Vessicular Basalt) Observed around Abuni.

Figure 8: Volcanics (Dense Basalt) Observed around Anuku.

Thin Section analysis of Basalt

Observation of the slide under microscope indicates that the slide is composed of the following minerals;

Olivine: Occurs as subhedral, pale-coloured crystals having high relief in ppl. It is traversed by deep cracks along which there are alterations in ppl. It shows a very high interference colour in xpl.

Hornblende: Occur as tabular, pale-green crystals having a moderate relief in ppl and weakly pleochroic. It shows two cleavages intersecting at 120^0. It is greenish in xpl with an oblique extinction.

Plagioclase Feldspar: Occurs as prismatic, colorless crystals having a low relief in ppl. It is grayish in xpl and shows polysynthetic twinnings.

Accessory Minerals: Occur as an additional mineral and have a low percentage (5%). Examples include Sphene, Garnet, Magnetic minerals e.t.c.

Table 1: Modal Estimation in Percentage (%) of Minerals in Basalt.

S/N	MINERALS	AMOUNT (%)
1	Olivine	40
2	Hornblende	38
3	Plagioclase Feldspar	17
4	Accessory Minerals	5
	Total	100

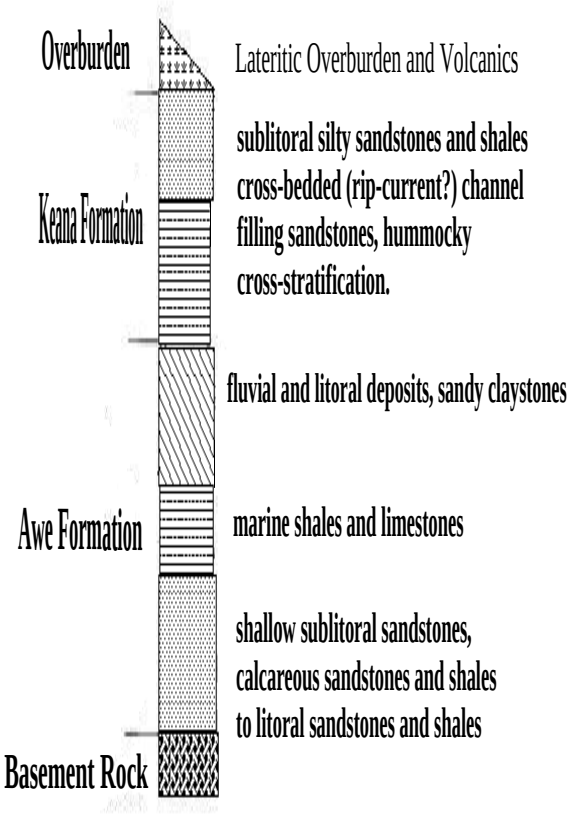
Figure 9: Photomicrogram of Basalt under (ppl).

Figure 10: Photomicrogram of Basalt under (xpl).

Structural Geology

In a broad sense, structural geology can be thought of as the study of the architecture of earth's crust, its deformation features, their mutual relations and origin (Offodile, 1976). Besides, structural geology can be defined as the branch of geology concerned with the shapes, arrangement, relationships of bedrock units and the force that causes them (Benkhelil, 1982). It is noticeable that in the studied area,

some structures were formed at the time of sedimentation while others were formed after sedimentation and it is against this observation that the structures have been sub-divided into syn-sedimentary and post-sedimentary structures.



Scale: 1cm: 10.83m.

Figure 11: Generalized Stratigraphical Succession of the Area Mapped (Abuni and it Environs).

The various structures observed in the field are discussed below:

Syn-Sedimentary Structures: These are structures formed contemporaneous with sedimentation and are produced as a result of changes in the pattern of sedimentation, usually changes in sediment composition, grain size and current direction (Offodile, 1976). The following syn-sedimentary structures were observed;

Bedding: These are structures layering greater than one centimeter and are bounded above and below by bedding planes. They are produced usually by changes in sediment composition or grain size. This type of structure is observed in all the lithologies encountered.

Lamination: These are fine discrete layers of rock that are less than one centimeter in thickness and are usually found in fine grained rocks. This sedimentary structure is typical of shales of the Keana Formation found in the north-western region of the studied area.

Massive Bedding: This can be described as beds appearing to lack internal structure, this type of beds are formed either by very rapid depositions from suspensions or by deposition from highly concentrated sediment dispersed. This type of structure is observed around the northern part of the plot mapped.

Graded Bedding: These are layers in which there is a gradual, abrupt or stepwise vertical and or lateral change in the grain size distribution thereby causing a sorting effect with the 'coarsest' materials at the base and the finest material at the top, observed within the Awe Formation.

Mud Cracks: These are vertical to sub-vertical shrinkage cracks which are formed from the construction of cohesive muddy sediments. Muds formed from the weathering of shale are found covering the floors of many rivers as well as streams in the studied area. In the dry season when these sediments lose pore water, they contract forming spindle shaped cracks as observed around Abuni, Anuku and very close to Angwan Ladi along the road to Kanje.

Figure 12: Mud Cracks.

Cross Bedding: This is the characteristics bedding structure produced by the migration of bed forms with inclined depositional surface. It could also be seen as a series of inclined bedding planes having some relationship to the direction of current flow, the angle of rest of the sediment are the rate of supply of sediment, hence the often used "current bedding" they consist of inclined dipping beds, bounded by sub horizontal surfaces and this type of structure is typical of sandstones of the Keana Formation which are cross bedded and are found in the northern part of the plot.

Post-sedimentary Structures

These are formed as a result of the deformation of pre-existing sedimentary rocks. They are usually formed at the end of sedimentation. The post-sedimentary structures encountered during the field mapping exercise were formed as a result of deformational forces which acted upon the rocks. The following post-sedimentary structures were observed;

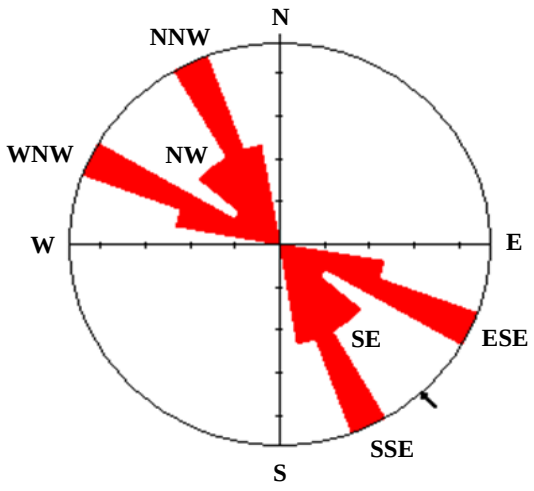
Folds: The term fold refers to a flexure in a rock causing an originally planar geological surface to be curved or angular. This phenomenon usually causes originally horizontal beds to dip at a certain angle. If the flexure, takes form of an arch it is called an anticline but if the flexure is in the form of the basin, it is called a syncline. The Keana Anticline is the main fold element that dominates the geology of the entire Middle Benue Trough.

Joints: The term joint refers to a fracture in a rock in which there is no observable relative movement. It could also be seen as a fracture which is nearly normal to the bedding and along which there is no relative displacement. Joints were observed on Awe Formation and the orientations of the joints vary within the sandstones from NNW -SSE, WNW-ESE and NW-SE directions.

Figure 13: Joint Observed on Awe Formation.

Table 2: Measurements of Joints Orientation on Sandstones.

S/N	Joints Orientation (°)	No. of Occurrences
1	313	1
2	298	1
3	341	1
4	333	1
5	290	2
6	315	1
7	346	1
8	330	1
9	310	1
10	345	1
11	339	1
12	300	1
13	327	1
14	335	1
15	295	1
16	339	1



Number of Data Plotted = 16
Dorminant Trend = NNW-SSE and WNW-ESE

Figure 14: Rose Plot of Joints Orientation within Sandstones.

Some minerals and materials found within the area may be economical if they could be mined at profit. Out of the economic minerals and materials are;

Limestone: This is one of the most important economic raw materials found in the Benue Trough. Its occurrence is wide spread starting from the lower area around Makurdi to the upper parts. The limestones occur principally in the Albian-Turonian Formation and are of fairly good quality. Little outcrop of Limestone was mapped on the field within the Awe Formation around the Abuni-Anuku Junction. Nearly all limestone deposits in the country are used for the manufacture of cement.

Clay: Clay occurrence is found in the Maastrichtian Lafia Formation. Mostly in Lafia area of Nasarawa State. Other known occurrence is in the Keana-Awe Formation. During the field mapping, clays were detected in the Awe Formation although sandy just before Angwan Ladi when going from Abuni to Kanje junction and it almost divided the portion into two. Clays are used in pottery, earthware, China cooking ware, building bricks, vases, plumbing fixtures, tiles, porcelain wares, ornaments and it is also used in making refractory wires.

Lead-Zinc-Copper Sulphides: The mineralization zone extends from the south east in a narrow belt to Zurak in the North east. Farrington (1952) and Mc Connell (1949) the mineralization in the area is hydrothermal in origin, mud deposited under mesothermal condition. The occurrence of lead-zinc-copper sulphides in the Benue Trough has attracted a lot of attention. Some important occurrence are also found in the Asu River Group (Arufu), Akwana and Zuruk. Smaller occurrence is also found in the Muri-Gwana Hills. The mineralization in the Akwana and Arufu is hosted in Silicified limestone sequence and also belong to the Asu River Group. Though Lead-Zinc-Copper Sulphides was not detected in the plot but there are some artesenal miners mining Lead-Zinc deposits just a few km away from the plot which indicates that if detailed exploration is carried out, the plot might also be rich in this deposit. The geochemical analysis result gotten indicates the probability of this mineralization in some areas within the plot though the extent of the anomaly is not known, as only the soils were analyzed.

Laterites: Laterites are products of the weathering of the rocks present in the area mapped. Laterites are used for concrete production, brick making, feeder road construction and surfacing. Laterites are confined to the Anuku area within the plot mapped (Plate 5.1) and they are formed as a result of the alteration processes of the basalt.

Sands and Gravels: These are found along the stream and river channels most especially along the channels and river beds of the Atatakoro River and Ambaja River and their tributaries. Sands when mixed with cement are used for flooring and plastering of houses. Gravels, when mixed with sands and cement, form aggregate which is used for construction of bridges, dams and culverts. The sands and gravels along the channels of the Atatakoro River and Ambaja River and their tributaries are extensively mined by the people of the area and it is used for building and construction purposes.

Basaltic Rocks: Basaltic rocks are mined for constructional purposes, though geologically, it is not advisable to use this type of rock material for constructional purposes because they have high density and due to their mineralogical composition which is mafic, can weather easily. Instead of Basaltic rocks, Granites should be used for construction, structural and building purposes. Ogezi (2008) is of the opinion that basaltic rocks have the essential elements needed by plants, therefore it should be crushed and process in form of fertilizers for agricultural purposes.

Shale: Shale acts as natural antibiotics and balm due to the presence of yellowish sulphuric beds. Shales have also found their use in agriculture where they serve as fertilizers.

CONCLUSION

The study area covered Abuni and its environs in Awe Local Government area of Nasarawa State. The area is part of the Middle Benue Trough of Nigeria and the area is composed of the Late Albian-Cenomanian Awe and Keana Formations (consisting essentially of sandstones with intercalations of bands of shales and clays) and Cenozoic volcanics. Structures observed on the field include bedding, lamination, massive bedding, graded bedding, mud cracks, cross bedding, folds and joints. The major structural trends are oriented in NE-SW, NNW-SSE, WNW-ESE and NW-SE directions. The mineral suites identified from the thin section of the volcanic include hornblende, plagioclase feldspar, olivine and accessories minerals which include opaque minerals and are believed to be iron oxides due to the high concentration of iron in the area. The Sandstones are also made up essentially of quartz so they are quartz arenites. Similarity observed in most of the sedimentary rocks of the study area suggest that the sedimentary rocks were deposited under almost similar geological processes but not at the same time while the dissimilarity observed in the volcanics is due to the fact that they are relatively the youngest as they can be seen to intrude the Late Albian-Cenomanian Awe and Keana Formations.

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