

SEDIMENTARY STRUCTURES, STRATIGRAPHY AND PETROGRAPHIC STUDIES OF AKPOHA AREA OF THE AFIKPO BASIN SOUTHEASTERN NIGERIA

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ABSTRACT

Sedimentary structures and petrographic studies of Akpoha area was undertaken in an attempt to understudy and determining its paleoenvironment of deposition. Mainly outcropped are alternating succession of sandstone and shales striking in a NE-SW direction. The sandstone outcrops at Akpoha are highly indurated and occur in ridges within the shale unit. The studied shale outcrops were poorly laminated and low in fossil content. Sedimentary structures identified include: Wavy/ripple lamination, Mud cracks, Parallel lamination and Fissility. The results of the petrographic modal analysis from thin sections studies show the sandstone consists predominantly of quartz (55 - 64%); feldspar (22 - 30%) and rock fragment (1 - 9%). The sandstones were poorly to moderately sorted with angular to sub-angular grain shapes which gives clear indication of high energy and short transport history from provenance.

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1. INTRODUCTION

Field studies of exposed outcrops and structures in a sedimentary environment give the necessary parameters and clues in determining or interpreting past environment of deposition and deformation history of an area. Sedimentary structures as a matter of description are large physical features generally seen, analyzed or described in three dimensions in exposed sedimentary rocks. They are seen mainly on exposed outcrops with the eyes or in large hand specimen rather than through a microscope in the laboratory. Sedimentary structures include features like mud cracks, beddings, ripple marks, fossil tracks and trails. Stratigraphy studies in the other hand describe rock successions and their interpretation in terms of general time scale.

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1. Brief introduction
2. Objectives
3. Methods used
4. Key findings
5. Implications of key findings
6. conclusion

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Akpoha area is characterized by the predominance of sandstones which were visibly exposed. Studies have shown that these sandstones which dotted the length and breadth of the study area belong to the Ezeaku Group which has been identified as a shallow marine sequence (Simpson, 1954 and Reyment, 1965). The sandstones consist of NE-SW trending ridges believed to be of sub tidal origin alternating with marine shale (Banerjee, 1980). Evidence of storm deposition was derived by Amajor (1987) after a detailed study of the Amasiri Sandstone ridges. Ojoh, 1990 reported that the sandstone from Akpoha is of marginal marine origin. Therefore, the aim of this paper is to document

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sedimentary structures, stratigraphy and petrographic studies that unequivocally define the paleoenvironment of deposition.

2. STUDY AREA LOCATION AND GEOLOGICAL SETTING

The study area Akpoha is within Afikpo North Local Government Area of Ebonyi State, in Southeastern Nigeria. Some of the villages in the area include Ibii, Oziza, and Amata. The extent of study or mapped area lies between latitudes $5^{\circ} 55'N$ and $6^{\circ} 00'N$ and longitude $7^{\circ} 55'E$ and $8^{\circ} 00'E$.

The study area is accessible through a network of major roads, minor roads and footpaths that exist within the area. Some of the major roads include Abakaliki – Afikpo road, Amasiri – Afikpo road and Abomege – Ugep road (see Fig. 1).

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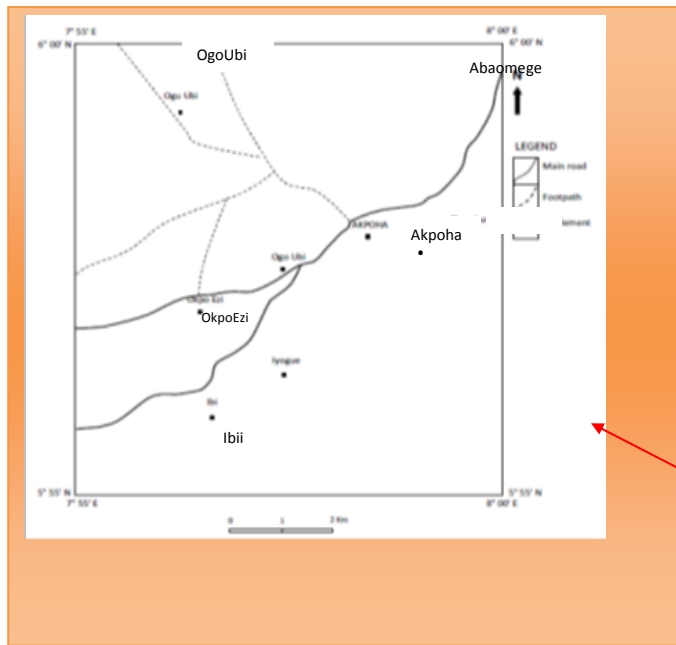


Fig.1 Map of the study area showing accessibility.

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The study area consists of nearly parallel ridges of sandstone units striking NE-SW with intervening lowland units formed by the shale. Akpoha and its environ lies within the Eastern Flank of the Abakaliki Anticlinorium. The sandstone ridges in the area are about 350ft thick above mean sea level while the shale, where found, lies at an average elevation of 150m above sea level. The relief from map is very high in the south-eastern. The ridges and hill in the areas run from NE – SW along the Abakaliki Anticlinorium. Two major relief patterns are predominant; planes underlain by shales and sandstone ridges which form the topographic height.

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The area under study falls completely within the rain forest belts of Nigeria (see Fig. 2), bounded in the north by the savannah grassland. The area experiences two seasons; the wet (May to October) and dry season (November to April) in each climatic cycle. During the wet season the area experiences torrential down pour in the range of about 250 – 300mm mean annual rainfall. This is coupled with the double rainfall maximal in the months of July and September with average temperature range of about 21^o C to 31^o C as minimum and maximum temperature respectively, while the atmospheric pressure is between 1010 – 1016 milibars. Akpoha enjoys luxuriant vegetation with high forest zone (rain forest) and derived savannah (Fig. 3) belts of southeastern Nigeria. They are dominated by thick grasses, shrubs with abundant palm trees and dense forest as a result of weathered materials which contain nutrients and close water table. This vegetation also follows paths of stream between the escarpments having lowland areas made up of luxuriant grasses and isolated trees, which is referred to as gallery vegetations.

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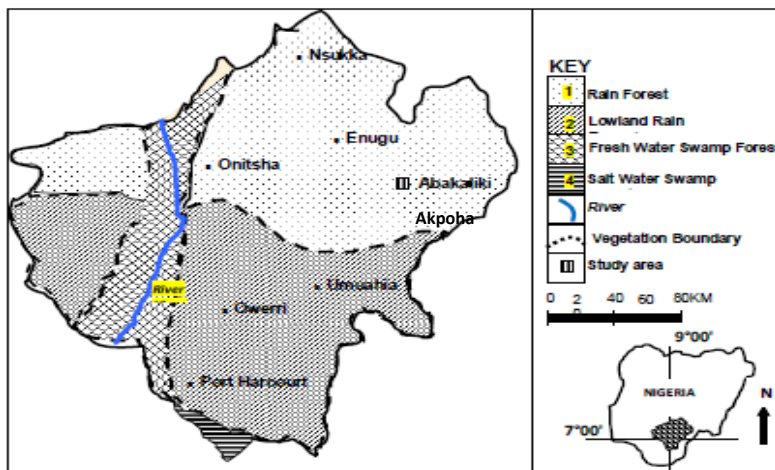


Fig.2 Vegetation of southeastern Nigeria (modified after Igbozuruike 1975)

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Fig. 3. Vegetation type of Akpoha area (derived savannah)

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Sedimentation in the southern Benue Trough, Nigeria began in the early Cretaceous (Murat, 1972; Burke et al., 1972; Olade, 1975; Hoque, 1977; Petters, 1978). The stratigraphy of the southern Benue Trough is summarized in Table 1. The Ogoja Sandstone (Aptian - early Albian) which is the basal Cretaceous sedimentary unit in the southern Benue Trough unconformably overlies the Precambrian Basement Complex (Reyment, 1965; Nwachukwu, 1972; Uzuakpunwa, 1986). It is the basal unit of the Albian Asu River Group and consists of Arkosic sandstone and conglomerates restricted to Ogoja and Ikom areas (Uzuakpunwa, 1986). The group also comprises the Awi Formation, Abakaliki Formation and the Mamfe Formation (Murat, 1972; Whiteman, 1982). The Abakaliki Formation consists dominantly of dark-grey shales (which are baked in some places within the Abakaliki Anticlinorium), lenses of sandstones and sandy limestones, volcanoclastics with subordinate mudstones (Reyment, 1965; Benkheil, 1987). The deposition of Asu River Group sediments was followed with the deposition of Odukpani Formation, Eze-Aku Group and its lateral equivalents and the Awgu Formation all within late Albian - Coniacian. The Odukpani Formation is restricted to the Calabar Flank and consist of dark grey to black calcareous shales which has been

assigned late Albian - Cenomanian (Reyment, 1965; Petters, 1982; Nyong and Ramanathan, 1985). However, Murat (1972) and Amajor (1985) attributed Cenomanian stage in the southern Benue Trough to either unconformity or a minor folding phase. Meanwhile, Ojoh (1990) has dated Cenomanian based on the palynological studies of black shales outcropping in Ngbanocha, Nara, Ezillo and Akaeze.

The Ezeaku Group shale facies overlies the Odukpani Formation in the Calabar Flank and unconformably overlies the Asu River Group at both flanks of Abakaliki Anticlinorium. The group consists of thinly laminated, dark grey flaggy shales with sandstones and subordinate limestones rich in pelagic faunas, pelecypods and gastropods (Reyment, 1965; Adeleye, 1975; Petters, 1980). The Eze-Aku Group is conformably overlain by the Awgu Formation in the western flank of Abakaliki Anticlinorium and unconformably underlies the Nkporo Group in the Afikpo Synclinoium with Awgu Formation abruptly missing. This is represented by Santonian angular unconformity in the basin. The Awgu Shale consists of dark and bluish-grey well bedded shales with abundant thin limestone and marl inter-beds (Ofoegbu, 1984, Reyment, 1965).

Table 1: Correlation Chart for Early Cretaceous Tertiary strata in the Southeastern Nigeria (After Nwajide, 1990)

Age		Abakaliki-Anambra Basin	Afikpo Basin
m.y 30	Oligocene	Ogwashi-Asaba Formation	Ogwashi-Asaba Formation
54.9	Eocene	Ameki/Nanka Formation/ Nsugbe Sandstone (Ameki Group)	Ameki Formation
6.5	Palaeocene	Imo Formation Nsukka Formation	Imo Formation Nsukka Formation
73	Maastrichtian	Ajali Formation Mamu Formation	Ajali Formation Mamu Formation
83 87.5	Camparian	Nkporo Oweli Formation/Enugu Shale	Nkporo Shale/ Afikpo Sandstone
	Santonian	Aghani Sandstone/Awgu Shale	Non-deposition/erosion
88.5	Coriacian		Eze Aku Group (incl. Amasiri Sandstone)
	Turonian	Eze Aku Group	
93 100	Cenomanian- Albian	Asu River Group	Asu River Group

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The tectonic episode occurring in the mid-Santonian time deformed the Benue trough which led to folding accompanied by structural inversion (Hoque, 1976) and widespread erosion in the sediment fill of the Benue Trough. The Santonian Orogeny resulted in the uplifting of the

Abakaliki Anticlinorium (Fig. 4) and the subsidence and formation of the Anambra Basin on its western flank and the Afikpo Synclinorium on its south eastern flank (Hoque, 1976).

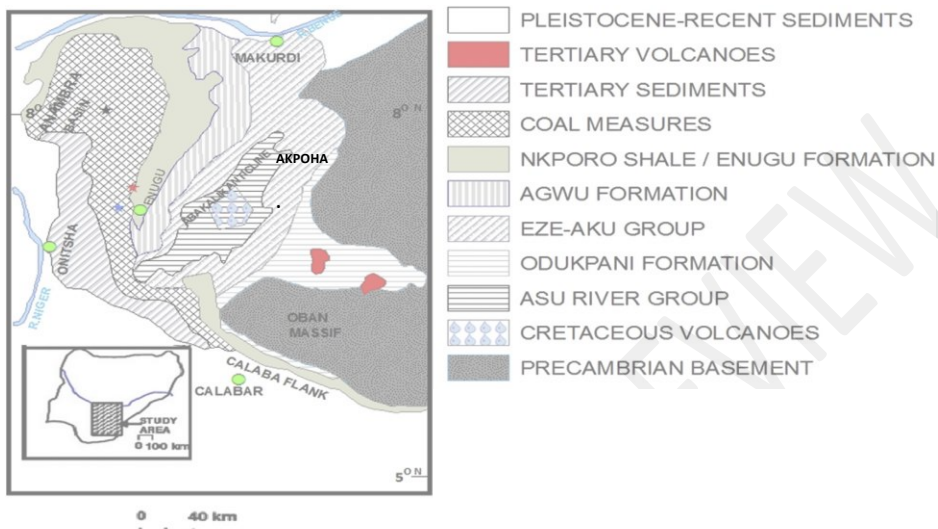


Fig. 4 Geological Map of Southern Benue Trough (Modified from Ojo et al., 2009).

Campanian - Maastrichtian transgression resulted in deposition of marine sediments. Over 2000 metres of sediments deposited in the Afikpo Sub-Basin and Anambra Basin were eroded from uplifted Abakaliki Anticlinorium (Hoque, 1976). Thus the Anambra Basin and Afikpo Syncline (Fig. 5) became the major depocentres for the Campanian - Maastrichtian sediments (Murat, 1972). The Nkporo Group, Mamu Formation, Ajali Sandstone and Nsukka Formation were deposited in these basins.

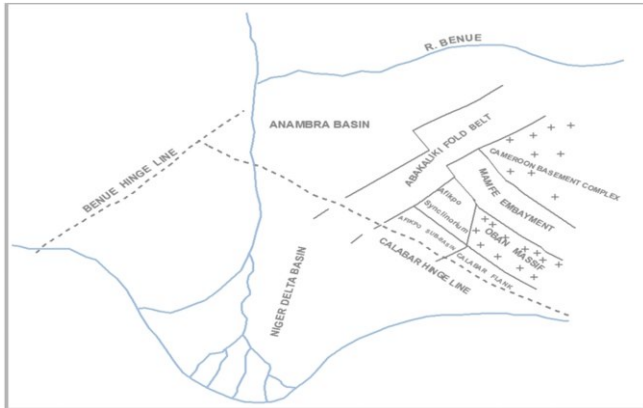


Fig.5 Tectonic Elements map of the Southern Benue Trough (Modified after Murat, 1972).

The Ezeaku Group is believed to represent typical shallow water deposit, consisting mainly of hard grey to black shales and siltstones. Facies changes to sandstones and sandy shales are common. The thickness of this Formation varies and locally may be up to 100 m thick and passes laterally into sandstone ridges at Amasiri sandstone, limestone, calcareous sandstone, and sandy limestone. Murat (1972) was of the view that the Ezeaku Shale shows deposits of marine condition in a tectonically controlled basin (the Abakaliki Trough). He believed that sandstone deposits mark a period of regression, while the shale deposits indicate a period of transgression. On the basis of the predominance of shale from Aba-Omege towards Abakiliki, Nwachukwu (1975) concluded that deep-sea conditions terminated at Aba-Omege from where a shallow marine condition commenced. He also believed that a distant metamorphic basement had contributed to the sediments in the Ezeaku Shale because he found metamorphic minerals in the sandstone units, in addition to conclusions he drew from heavy mineral analysis.

The Ezeaku Group was deposited in the Turonian transgressive phase but in a shallow marine environment. The lithologies include shale, sandstones, and calcareous sandstones. The fossils in this Formation include vascocerastids, pelecypods, gastropods, echinoids, fish teeth, decapod, and plant fragments (Reyment, 1965). The predominantly Albian-Cenomanian marine depositional cycle was terminated by a phase of folding (Nwachukwu, 1975; Olade, 1978), which affected the Asu River Group in the area. The second transgressive-regressive phase of deposition in Turonian to Santonian was terminated again by a phase of folding and faulting in the early Santonian times, which affected all the sediments deposited before the tectonism and this produced the Afikpo syncline.

3. MATERIALS AND METHODS

Field investigations involved geological mapping. The aim was to delineate and correlate various rock units in the study area, measure their geographic positions and elevations as well as establish sample locations. Field mapping was carried out with the aid of Afikpo Northeast topographic map (Sheet No. 313 of the Nigerian Geological Survey Agency, with scale of 1:100,000), Brunton compass, measuring tape, geological hammer and Global positioning system device (GPS-Garmin Model). Focus was, however, placed on the geological and geographic distribution of the Amasiri Sandstone in Akpoha town. The sampled rocks used for petrographic analyses were fresh and unweathered.

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. RESULTS AND INTERPRETATIONS

4.1 Findings from Field Mapping

The geology of Akpoha and environs (Fig.6) consists of alternating succession of sandstone and shales striking in a NE-SW direction (see Fig.7). The northern part of the study area is generally lowland, rising to some 30m above sea level. The high ridges are underlain by the Amasiri Sandstones in Okpo-Ezi (about 120m high), Ibi and Akpoha areas (about 75m high). The sandstone ridges have been subjected to prolonged and intense weathering producing huge craggy blocks of boulders and rock falls. The sedimentary rocks exposed are Cenomanian - Turonian in age and belong to the Amasiri Sandstone of the Ezeaku Group.

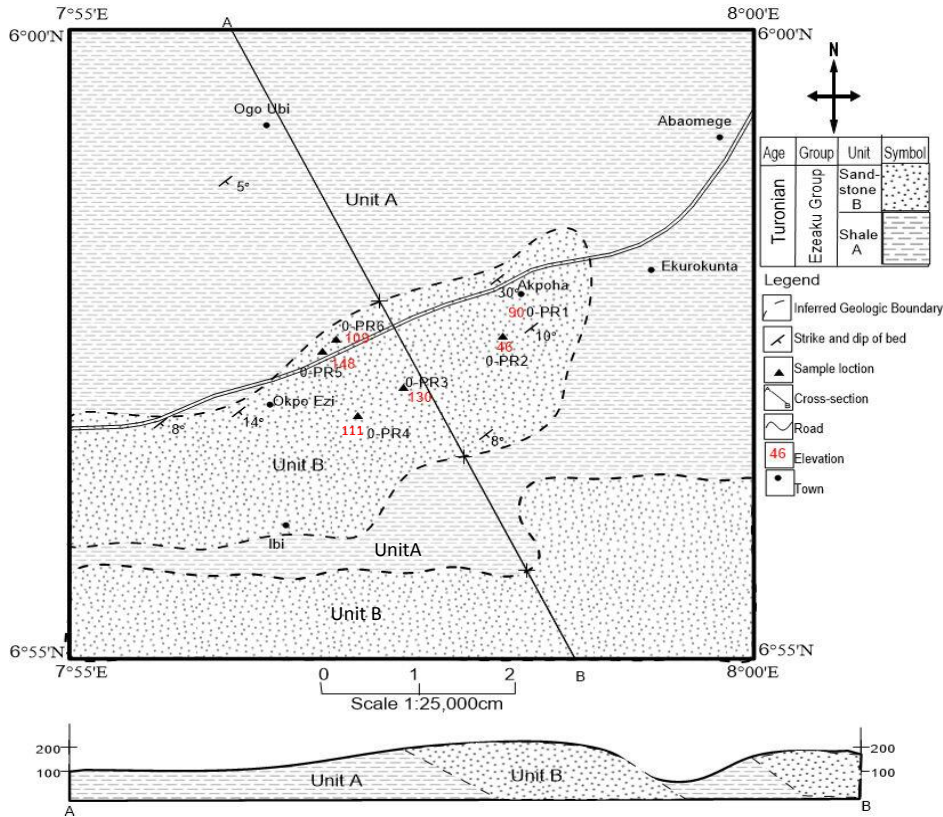


Fig. 6 Geological map of Akpoha area.

There is rapid alternation of sandstone and shales in the Ezeaku Group. The units were delineated based on their structure, Sedimentological characteristics and stratigraphic position. The lithofacies that constitute the local geology of the study area include sandstones, dark to grey shale and brown-flaggy shale (see Fig.7).

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Fig.7 Sandstone ridge trending NE-SW&Shale outcrop at Amata village

4.2 Stratigraphy

4.2.1 Unit A– Shale (Ogo-Ubi)

This unit comprises mainly shales in the study area. It consists predominantly of grey shale which covers large extent of the northern part of the mapped area. They are poorly laminated and low in fossil content. The shale formed the low-lying part of the Ezeaku Group. The shale around Amata-Elu is black, fissile, laminated and underlies the sandstone. Weathered part of the shale show high fissility and are brownish/yellowish-red in colour. Along the Ebonyi River, the dark grey and fissile shales of unit A are weathered with reddish brown in colour while the shale found around Amata-Enu are fissile and yellow to reddish in colour. The dip of the shale varies from 5° to 15° , while the general strike is NE-SW direction.

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4.2.2 Unit B-Sandstone (Akpoha)

The sandstone outcrops at Akpoha, Okpo-Ezi and Ibi are highly indurated and occur in ridges within the shale unit. The maximum height of the beds is 75m with thickness that ranged from 90cm to 200cm. The sandstone consists of abundant quartz and feldspar. The dip of the sandstone ranges between 8° and 30° in the southeast direction and strike in the northeast – southwest direction. The sandstones vary in grain size from medium to coarse and are moderately sorted. The outcrops are mostly in boulders. The sedimentary structures in the sandstones include cross beds/cross laminations, parallel lamination/bedding, ripple/wavy beds, ripple cross laminations and burrows.

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4.3 Petrographic Modal Analysis

The results of the petrographic modal analysis are summarized in Table 2. Photomicrograph of the studied thin sections is presented in Plate 1, 2, 3, 4 and 5. The sandstone consists predominantly of quartz (55 - 64%); feldspar (22 - 30%) and rock fragment (1 – 9%).

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Table 2. Results of petrographic modal analyses on the samples of the Akpoha Sandstone.

Sample code	Major Constituents				
	Quartz (%)	Feldspar (%)	Calcite (%)	RF (%)	Total (%)
O-PR 1	63	23	5	9	100
O-PR 2	60	25	10	5	100
O-PR 3	55	28	10	7	100
O-PR 4	60	30	9	1	100
O-PR 5	64	22	8	6	100
O-PR 6	60	25	11	4	100
<i>Minimum</i>	55	22	5	1	
<i>Maximum</i>	64	30	11	9	
<i>Mean</i>	60.33	25.5	8.83	5.33	

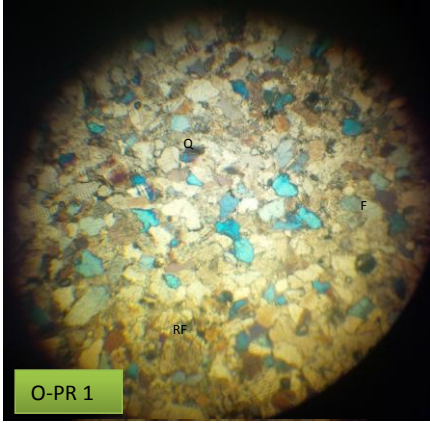


Plate 1. Concave -Convex contact with few line contacts. Monocrystalline quartz, angular to subangular in form, moderately sorted.

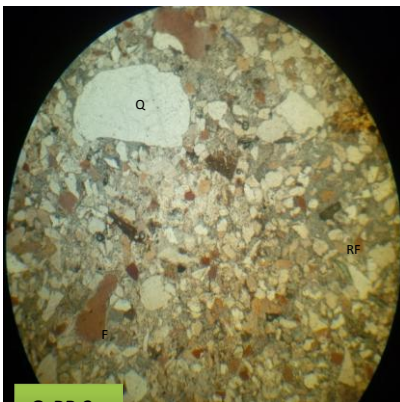


Plate 2. Convex to line contact, monocrystalline quartz, angular to subangular grain, moderately sorted

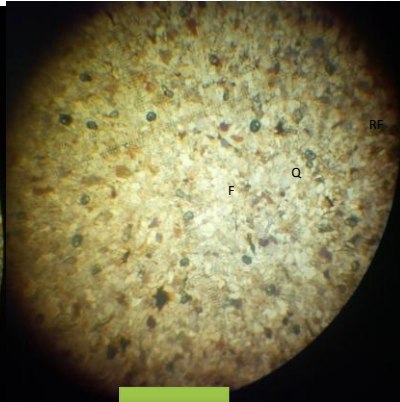


Plate 3. Line contact, monocrystalline quartz, fine grained rounded to subangular, well sorted.

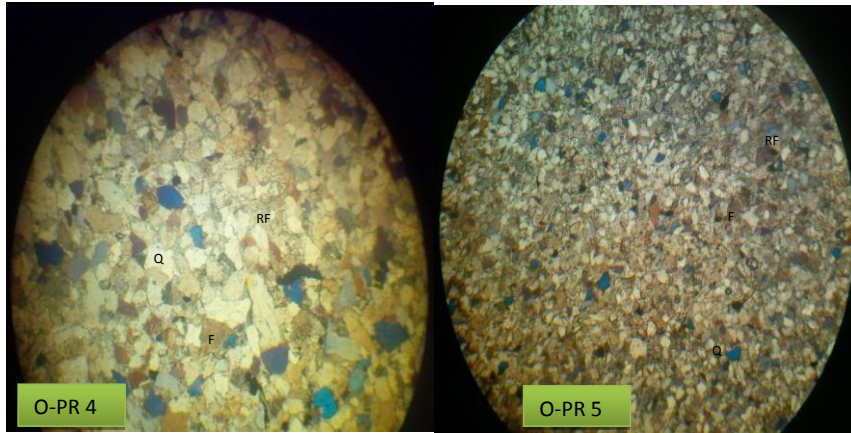


Plate4.Concave-convex contact, monocrystalline quartz, angular to subangular, coarse grained, moderately sorted

Plate5.Line contact, monocrystalline quartz, rounded to subangular, fine grained, well sorted

4.4 Structural Geology

4.4.1 Sedimentary Structures

Sedimentary structures broadly include all the structural features which are formed in sedimentary rocks as a result of the various processes leading to their depositions and subsequent consolidation (PettiJohn, 1975). An understanding of these structures is important to the geologist in the field because they can be used to determine the processes involved in the deposition of sedimentary rocks, the environment and conditions of deposition, as well as the directions of the paleocurrents under which the sediment was deposited (PettiJohn, 1975). The most common sedimentary structures observed in the mapped rocks are the primary or syngenetic structures. The structures include stratifications, ripple marks, laminations, cross beddings, fissility and mudcracks. The biogenic structures observed in the study area include bioturbations and burrows (see Fig.8). Some of the structures are described as thus;

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Fig. 8 Burrows observed behind G.T.C Akpoha

4.4.1.1 Fissility

Fissility is a product of weathering; it is one of the properties of rocks such as shale to split along plane of weakness into thin sheets (Tucker, 2001). Fissility was observed in the shale along Ebonyi River Bank, near Amata-Enu.

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4.4.1.2 Mud cracks

Mud cracks also known as desiccation cracks. They are sedimentary structures formed as muddy sediment dries and contracts. The cracks develop on the mud surface due to the effect of intermediate exposure and covering by water like flood plain. They are common in shallow water environment. The structures result from shrinkage due to loss of water during dry season and may be in-filled with sand, silt or organic matter. This structure was observed along the river bank of the Ebonyi River.

4.4.1.3 Laminations

Lamination is a fine layer of rock with thickness of less than 1.00cm (Fig.9). Laminations are normally smaller and less pronounced than bedding layering. It consists of small differences in the

type of sediment that occur through the rock. They are caused by cyclic changes in the supply of sediment. These changes can occur in grain size, clay percentage, microfossil content, organic matter content or mineral content. Laminations can occur as parallel lamination or as cross lamination.

Parallel lamination; The outcrops behind G.T.C Akpoha are characterized by parallel laminations (see Fig. 9). This may be defined by distinct planar and continuous laminae as evident in the outcrop. The parallel laminations suggest that this lithofacies was deposited in moderate energy deep marine environment (Stow, 1985). The environment was dominated by bottom current reworking with transition from lower flow to upper flow regime (Shanmugun, 2006). The texture and the planar cross stratifications suggest deposition in shallow shoreface environment dominated by storm events (Shanmugun, 2006).



Fig.9 Parallel lamination at G.T.C Akpoha

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Wavy/ripple lamination; these features were eminent in the outcrop behind G.T.C Akpoha. They are irregular/wavy and ripple laminations (see Fig.10). These ripples are very low amplitude ripples. There is a vertical distribution grading from plane parallel lamination which occurs in parallel bedded sandstone lithofacies to wavy to ripple drift laminations. The wavy/ripple lamination is interpreted to have been deposited in a low energy deep marine environment (Walker, 1984 and Stow, 1985). The depositional process is dominated by traction and bottom current reworking in the lower flow regime. The ripple-laminated/bedded sandstone represents traction deposits, and thin rippled divisions are interpreted to be products of short-lived traction processes (Bouma, 1962 and Bouma, et al. 2000).



Fig.10 Wavy/ ripple lamination at G.T.C Akpoha

5. DISCUSSION

5.1 Deductions from structural and petrographic analysis

The percentage of feldspar in the sediments from the results obtained from petrographic modal analysis suggest relatively close provenance possibly the Oban Massif of the southeastern Nigeria basement complex which conforms to the views of Odigi and Amajor (2008). Results show that rock samples selected from different locations are medium to coarse grained, leucocratic (light coloured) and consists of angular to sub-angular, anhedral grain with calcite as the cementing materials (5 - 11%). The poor to moderate sorting as well as the angular to sub-angular shapes of the mineral grains give clear indication of high energy and short transport history from provenance. Moreover, the parent materials of the sandstones are igneous and metamorphic rocks exposed to erosion by the orogenic uplift, eroded and transported into the sedimentary basin. The quartzo-feldspathic sandstones are poor in lithic fragments (Dickson and Suczek, 1979).

The presence of quartz with sub-angular to sub-rounded grains and weathered feldspar imply significant mechanical and chemical weathering in the provenance. The compositional sub maturity of these sandstones may be due to short distance in transportation, relatively low source area relief and relatively close provenance under humid climatic condition. In general, the Ezeaku Group was deposited in shallow marine environment. This view is strongly supported by the predominance of sandstone, copious presence of bioturbations (fig.8) and burrows and calcite cement. All these indicate deposition in a shallow marine environment during transgressive/regression episodes. The

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rapid alternations of sandstone and shale units support the view on depositions in transgressive and regressive conditions.

The abundance and well preserved sedimentary structures in Akpoha and environs is an indication of prolong calmness of tectonic/orogenic activities in the area. The fissility observed in shale outcrops and the high induration of the Akpoha sandstones was as a result of compaction from overburden pressure before uplift and exposure. The Mud cracks were due to the effect of intermediate exposure and covering by flood plain. They are common in shallow water environment which corroborates deposition in a shallow marine environment during transgressive/regression episodes.

The occurrences of laminations (parallel) suggest lithofacies were deposited in moderate energy and deep marine environment (Stow, 1985). The environment was dominated by bottom current reworking with transition from lower flow to upper flow regime (Shanmugun, 2006). If that's the case, it suggests the sandstones were products of different regressive and transgressive episodes. The occurrence of irregular/wavy and ripple laminations (Fig.10) with very low amplitude is interpreted to have been deposited in a low energy deep marine environment (Walker, 1984 and Stow, 1985) dominated by traction and bottom current reworking in a lower flow regime.

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6. CONCLUSION

The study area falls within the Lower Benue Trough, Southeast Nigeria. The area of study covers an area of about 86 square kilometres. This study revealed the followings:

1. Akpoha and its environs are underlain by one major lithological unit, the Amasiri Sandstone of the Ezeaku Group, comprising shale and sandstones.
2. The sandstones were products of different regressive and transgressive episodes
3. The sediments were deposited under fluctuating energy levels. The sandstones in the study area are calcareous, bioturbated and burrowed with a wide distribution of medium - coarse grain size.
4. The sediments were deposited during a transgressive and regressive cycle of the Cenomanian - Turonian stage.
5. The rocks strike northeast-southwest with a southeastern dip direction. The petrographic studies gives evidence that the sedimentary materials were derived from proximal basement granites, most probably the Oban Massif, hence a nearby provenance.

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