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Full Length Research Paper

Lithofacies and paleo depositional environment of the rocks of Nkpuma-Akpatakpa, Izzi, Southeast Nigeria

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A detailed geological investigation of Nkpuma-akpatakpa, Izzi, Southeast Nigeria, done on a map scale of 1: 25,000, showed its lithofacies as brown shales, dark-grey shales, mudstones, siltstones and limestones. These lithofacies have been organized into two main lithostratigraphic units namely, brown shales (Unit A) and dark-grey shales (unit B). The brown colour of shales (unit A) suggests high content of ferric oxide due to intense weathering and low metamorphism caused by volcanism in the area. The dark colour of shale (unit B) suggests deposition in anoxic or reducing environment. Its dark-grey colour and the presence of bivalves suggest deposition in a low energy, marine environment. The abundance of illite which increases with depth indicates deeply buried shale not less than 3,500 m below surface. The presence of shelly limestone indicates shallow, warm, silt-free and clean marine environment. The intact shells of bivalves suggest deposition in a low energy protected shoreline where wave action is limited. Sedimentary structures like fissility and laminations, also suggest deposition in low energy marine setting. Pyroclastic rocks mapped in the area have been interpreted as volcanic tuffs and agglomerates interstratified with the shales.

Key words: Lithofacies, depositional environment, rocks, Nkpuma-akpatakpa, Izzi.

INTRODUCTION

Facies classification is one of the basic practices which define geology as a field of study. Initially, identification of rock facies was a common practice only to surface geological mapping. However, the story has changed in recent times as facies identification has become an integral part of the oil exploration/exploitation.

An understanding of depositional environment is quite important in appreciating the geology of an area. To put together the geologic history of a region, the depositional environments of its sedimentary rocks must be analyzed. By reconstructing depositional environments geologists are able to reconstruct the climates of the past, life forms of the past, and geography of the past, where the mountains, basins, large rivers, and bays of the ocean were. A depositional history of an area enhances the ability to locate energy deposits in the form of coal or oil, each of which originates in a certain type of depositional environment.

Presently, a search for hydrocarbon is incomplete without sequence stratigraphic analysis of core samples from appraisal wells and it involves detailed petrographic and geochemical studies. Several successful attempts of reconstruction of paleodepositional environment and facies have been made by Diessel (1986), Singh et al. (2010a, b, 2011, 2012a, b, c, 2013), on the basis of petro-chemical studies of coal and the associated rock formations.

Facies are a body of rock with specified characteristics (Reading, 1996). It is a distinctive rock unit that forms under certain conditions of sedimentation, reflecting

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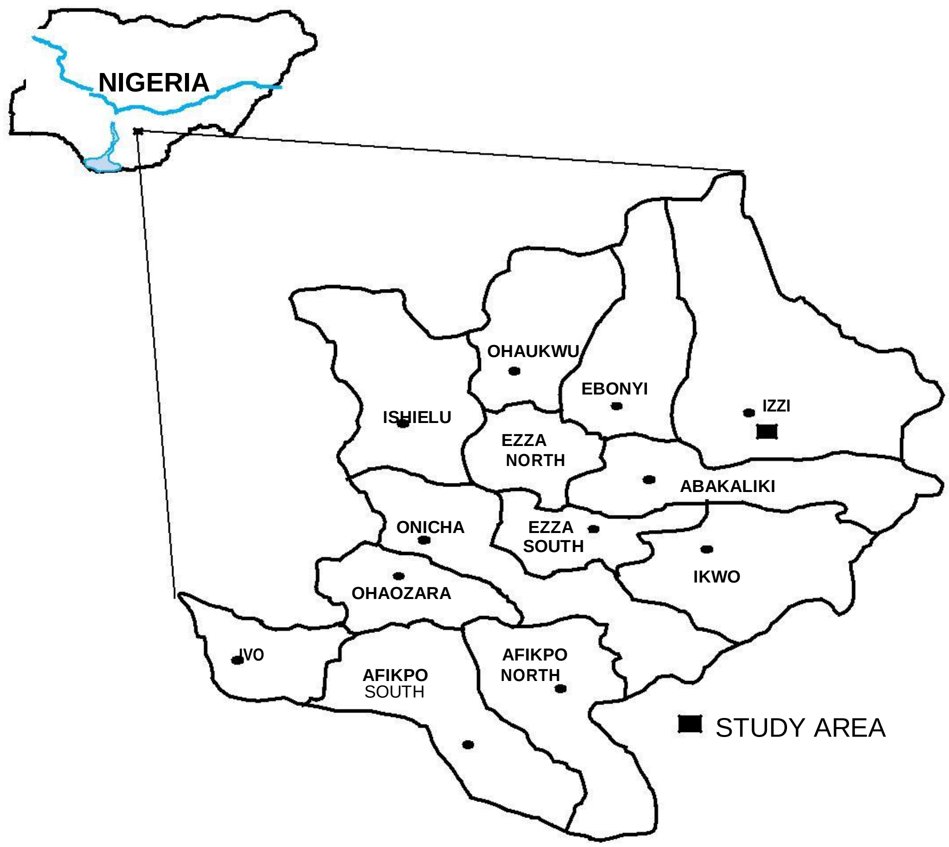

Figure 1. Map of Ebonyi State indicating the study area.

a particular process or environment. Gressly was the first to use the word in 1838 (Cross and Homewood, 1997). Establishment of sedimentary facies depends on the aspect of the sediment that is under study. If petrological characteristics are understood properly, lithofacies can be established; if paleontological characteristics are understood, biofacies are established. In this work, petrological characteristics of the rocks of Nkpuma-akpatakpa were used to establish lithostratigraphic units and their corresponding lithofacies. The objectives of this work include: i) To map and demarcate the lithologic units underlying the study area; ii) To make a detailed descryption of different rock types encountered; iii) To discuss the map, lithofacies units and interpret their depositional environment.

LOCATION, EXTENT AND ACCESSIBILITY

The study area is situated at about 5 km north of Abakaliki town, precisely in Izzi Local Government Area of Ebonyi State in the southeastern part of Nigeria (Figure 1). It is bounded on the north and south by latitudes 6°20^{1}N & 6°25^{1}N, and on the west and east by longitudes 8°10^{1}E and 8°15^{1}E (Figure 2). It covers an area of about 81 kilometre square (81 km^2). Accessibility to the area is enhanced by roads and footpaths which are common. Major roads leading to the area are the Abakaliki - Onuebonyi - Ogoja road, and the Onuebonyi - Sharon - Iboko road.

Physiography and geology

The study area has predominantly flat topography, with little undulation. The elevations are underlain by pyroclastic rocks (Figure 3). Two major rivers, Olilo and Ewe, drain the study area, along with their tributaries. While the Olilo River drains the northern part, the Ewe River drains the central - southern part of the area. The dominant drainage pattern is dendritic. The area is part of the rainforest vegetation of Nigeria with numerous species of trees, creepers and climbers. Most of the trees retain their green leaves throughout the year.

Geologically, the study area is part of the Abakaliki Formation of the Asu River Group (Reyment, 1965; Agumanu, 1989). It consists of fossiliferous shales, siltstones, limestones and minor fine to coarse-grained

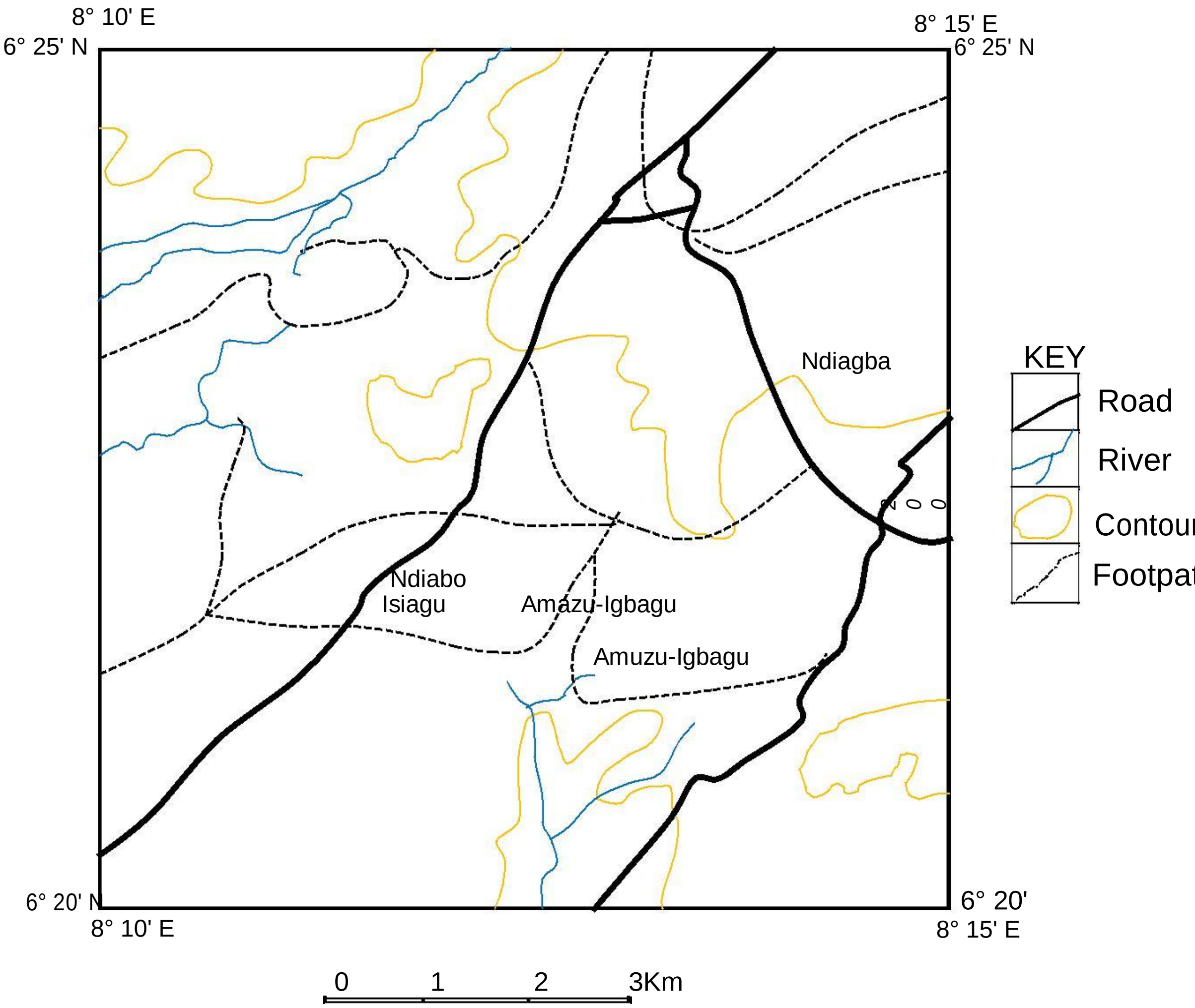

Figure 2. Topographic map of the study area.

Figure 3. The pyroclastic rocks underlying the Ezzaegu areas.

Table 1a. Lithostratigraphic units and their lithofacies.

Age	Group	Formation	Lithostratigraphic units	Lithofacies
Middle Albian	Asu River	Abakaliki	Dark-grey shales (unit B)	- Mudstone - Limestone - Shales
			Brown shales (unit A)	- Mudstone - Siltstone - Shales

Table 1b. Interpretation of depositional environment using features of the shales and fossil content (Modified from Obasi et al., 2011).

S/N	Features present	Depositional environment
1	Dark grey colour of shales	Anoxic, reducing environment such as in stagnant water columns.
2	Dark-grey Shales with pelecypod fossils	Low energy marine environment.
3	Shelly limestone	Shallow, well oxygenated, warm, silt free & clean marine environment.
4	Intact fossil shells	Low energy, protected shoreline where wave action is limited.
5.	Thick shelled *inoceramus species*	Shallow marine environment .

sandstones (Agumanu, 1989). They are associated with saline seepages, lead-zinc mineralization, basic intrusions and pyroclastics. These sediments were deformed during the Santonian tectonic phase producing numerous gentle folds. The anticlines of these folds are transected by northwesterly and northerly trending tensional faults and fractures (Olade, 1976). The folds, coupled with the identification of the igneous rocks such as andesites in the Abakaliki area led some workers to propose a compressional (subduction) rather than an extensional tectonic setting for the area (Farrington, 1952; Burke et al., 1971; Benkhelil, 1986). The thickness of the sediments varies from one point to another (Kogbe, 1976). However, no detailed geologic investigation has been done locally within the study area, hence, the need for the present study.

RESEARCH METHODOLOGY

The present work involves review of earlier literatures, field mapping and laboratory analysis. Compass and traversing method was adopted for the field mapping, which covered both rainy and dry seasons. In each location, samples were collected, described and numbered.

RESULTS AND DISCUSSION

Delineation of lithostratigraphic units

The rocks encountered in the study area are shales, siltstones, pyroclastics limestones, mudstones and pyroclastics. These lithofacies have been organized into two Lithostratigraphic units namely; "The brown shales" and 'the dark-grey shales" (Table 1a, b), while the pyroclastics are discussed separately as evidence of igneous activity in the area.

The brown shales (Units A)

This unit is older than the unit B and underlies. It occupies the central part of the study area (Figure 4). Outcrops are common along the river banks, channels and road cut in Ohagulode, Obeagu-Ikenyi and some parts of Amuzu-Igbeagu villages. Lithofacies were studied in the outcrops alone. Rock type is dominantly brown shales interbedded with mudstone and siltsone. The shale is generally grey to reddish brown in color, often with dark patches (carbonaceous stains) (Figure 5). It is indurated and severely jointed (Figure 6). Often, the joints break the shales into splintery blocks. They are composed of clay minerals and are micaceous along with the presence of some pyrites.

The induration of the shales can be attributed to baking effect due to volcanic activity in the area as evidenced by the presence of pyroclastic rocks interbedded with this shale unit (Figure 7).

The siltstone lithofacies of this unit is greyish-brown in colour, unconsolidated and fragile, often with mudstones and carbonaceous laminations. Its study on hand specimen indicates that it contains quartz, feldspars and muscovites.

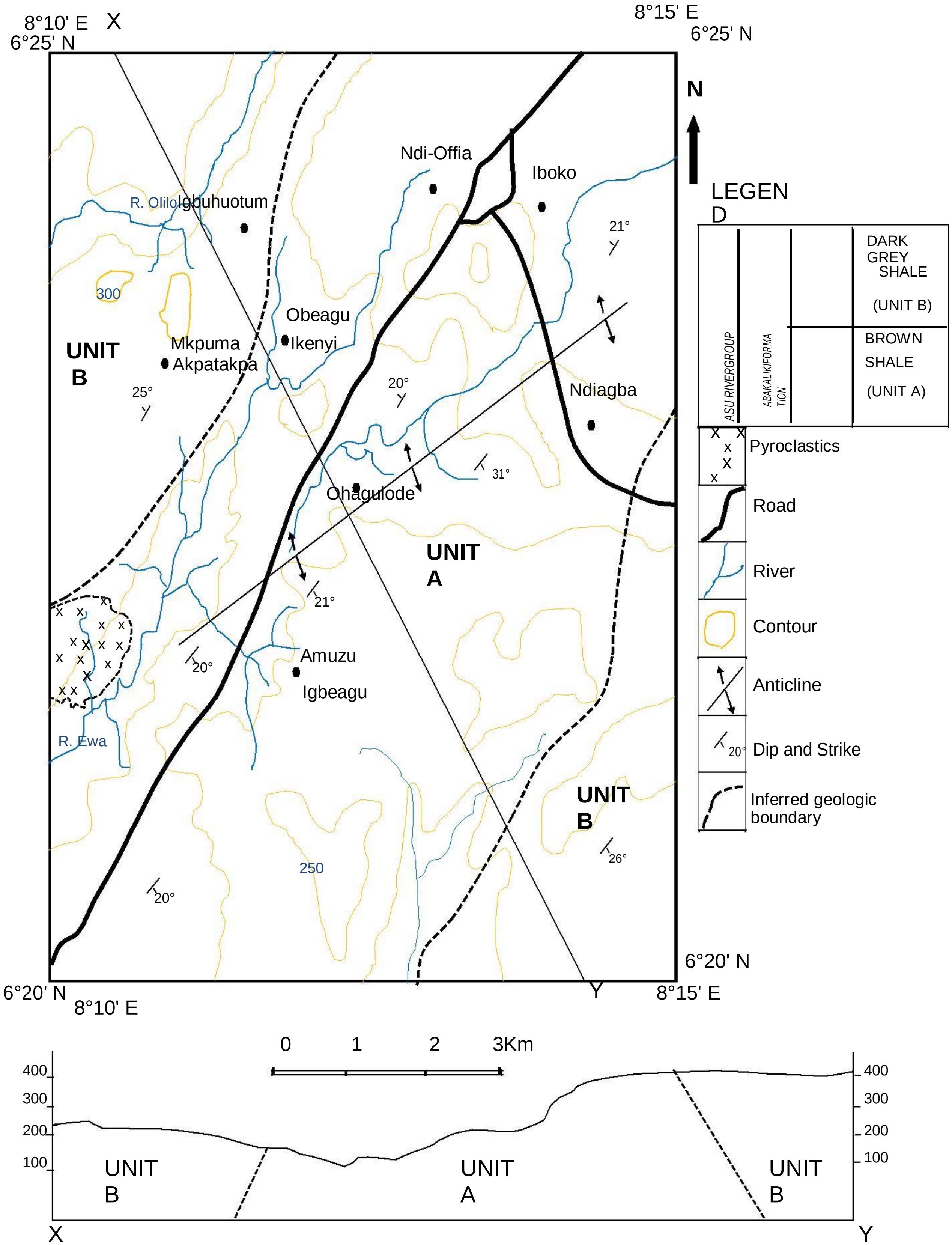

Figure 4. Geologic map of the study area.

Figure 5. Field occurrence of the brown shales at Obeagu - Ikenyi.

Figure 6. The joints in the brown shale unit.

The dark-grey shales (Unit B)

This unit consists predominantly of shales, which are dark-grey to black in colour and finely laminated, interbedded with limestones and mudstones. Outcrops are common in river channels at Ikenyi, Mkpuma-akpatakpa and west of Igbuhuotum. It occupies the northwest and northeastern parts of the study area (Figure 8). The dark-grey shales are hard, fissile and laminated. They are rich in clay mineral suites. Agumanu (1989) identified illite, kaolinite, chlorite and some smectites as the main minerals in the Abakaliki Shales. The illite and chlorite minerals increase with depth of burial. This could be due to diagenetic conversion of kaolinite to illite and chlorite at depth (Donuyer de Segonzac et al., 1967). Fissility could be brought about

Figure 7. The pyroclastic rocks interbedded with the shales at Ezzaegu. The yellow line shows sharp contact between the pyroclastic and shale.

Figure 8. Field occurrence of the dark-grey shales at Nkpuma-akpatakpa.

by parallel arrangement of micaceous minerals, organic matter content or diagenesis. However, fissility occurring in this shale is brought about by the mechanical arrangement of clay and micaceous minerals during diagenesis. Lamination as observed in the dark-grey shales is diagenetic in origin. They occurred as a result of the diagenetic cementation of organic matter contained in the rock.

The limestone lithofacies of this unit is dark-brown to yellow-brown in colour, and appears very light possibly due to weathering. Its outcrop was studied at Amuzu-Igbeagu where it interbedded with the dark-grey shales. It contains some bivalves and gastropods fossils. Identified bivalves are *Inoceramus* species and *Glycemeris* species. The fossil shells are intact, though few are broken.

The Ezzaegu pyroclastics

Igneous activity in the study area is represented by the occurrence of pyroclastic rocks in the southwestern part of the map (Figure 4). It crops out as elongate and domical body along the core of the anticline found in the area, forming part of the Abakaliki Anticlinorium. The structural relationship suggests they may be stratigraphically contemporaneous with the surrounding shales (Figure 7). Uzuakpunwa (1974) suggested that the pyroclastic rocks are older than the shales. However, field relationship in the study area does not support this. The shales have a depositional contact with the pyro-clastics (Figure 7) which suggests that they are inter-stratified. Furthermore, they trend northeast -southwest alongside the surrounding shales. They are about 10 m thick, with its dominant lithologies as altered mafic agglomerates and tuffs. The agglomerates are composed of angular to sub-angular fragments (Olade, 1979). The tuffs are similar to the agglomerates in composition but are relatively finer grained. They are light to dark-grey in colour. They are calcitic as evidenced by their reaction to acid solution and also confirmed in thin section. The presence of pyroxenes and needles of plagioclases suggest a basaltic composition for the pyroclastics. It is a typical representation of the "Abakaliki Pyroclastics" (Okezie, 1965).

Burke et al. (1971) consider this pyroclastics as andesitic lavas and tuffs, while Olade (1975) considered the rock as altered basalts and tuffs with spilitic affinity. Olade (1978) believes that they are dominantly lapili tuffs and lapili stones of basaltic composition. Offoegbu and Amajor (1987) considered its primary mineralogy to comprise pyroxene which has been mostly replaced by chlorite and calcic-plagioclase that has been recrystallized and altered to albite, carbonate and epidote. Orajaka and Umenwaliri (1989) discussed the presence of zeolite minerals (Clinoptilolite and mordenite) and calcite in these rocks as evidence of diagenetic alteration.

Interpretation of depositional environment

The reddish brown colour of the brown shales indicate high content of ferric oxide (Fe^{3+}) which is due to high degree of weathering and low grade metamorphism associated with the volcanic activity in the area (Obiora and Charan, 2011). The dark colour of the dark-grey shales suggests deposition in an anoxic, reducing environment, such as in stagnant water columns (Zangerl and Richardson, 1963).

The dark-grey colour and the presence of bivalves suggest deposition in a low energy, marine environment. The abundance of illite which increases with depth indicates a deeply buried shale not less than 3,500 m below surface. The presence of shelly limestone indicate shallow, warm, well oxygenated, silt-free and clean marine environment. The intact shells suggest deposition in a low energy protected shoreline where wave action is limited. The presence of thick shelled *Inoceramus* species suggests deposition in a shallow marine environment (Obasi et al., 2011). The above interpretations are summarized in Table 1.

Correlation with a named formation

Owing to the worldwide distribution of the *Inoceramus* species in the Cretaceous period, the age of the lithologic unit in the map area has been considered as Cretaceous period. The lithologic and paleontologic characteristics of the lithostratigraphic units described above indicate similarity with the Abakaliki shales of the Asu River Group sediments (Reyment, 1965; Agumanu, 1989). They are therefore correlated to the Abakaliki shales of the Asu River Group.

Conclusion

The lithofacies and paleo-environment of the rocks of Nkpuma-Akpatakpa was determined based on their petrological characteristics and fossil content. The lithofacies identified are shales, which are dark grey and brown, siltstones, mudstones and limestones. The paleo-environment of the rocks has been interpreted as low energy shallow marine environment.

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