

Sedimentology and biostratigraphic studies of a section in Ameki Formation along Umuahia Junction, Bende/Ohafia Road in Abia State, South-Eastern Nigeria

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ABSTRACT: This study investigates the sedimentological and biostratigraphic analyses of a stratigraphic section of the Ameki Formation outcropping at Umuri and Ameki, near Umuahia was carried out with 20 samples collected at regular intervals to determine the age and paleoenvironment of deposition. The samples were analysed using a petrographic and stereo microscope, and the preparation of the samples involved maceration and mounting on microscopic slides. Grain size analysis was carried out using a set of sieves and was visualised in a graphical method from which some simple statistical parameters were derived. The lithology varies from sandstone to shale. The sandstone exhibits cross bedding and bioturbation (evidence of organic activity). Twenty-six foraminiferal species were recovered, with benthonics dominating. The presence of *Heterohelix globulosa*, an index fossil of upper Maastrichtian, suggests that the age of the formation is late Maastrichtian-mid Eocene, and the forms show that they were deposited along the Continental shelf.

Keywords: Biostratigraphic, bioturbation, deposition, paleoenvironment, sedimentological.

INTRODUCTION

The Upper Cretaceous strata in the southeastern Nigerian sedimentary basins are being investigated as prospective targets for stratigraphic and structural traps for possible petroleum development. This consideration has arisen due to the urgent need to increase petroleum reserves to meet increasing demands in Nigeria. The spatial differentiation of the various lithostratigraphic units in the sedimentary basins has not been substantially achieved, but is somewhat tricky as a result of widely spaced outcrops and insufficient subsurface data (Nwajide and Reijers, 1996; Obaje *et al.*, 2004; Onyekuru and Iwuagwu, 2010). Simpson (1954) modified the Cross River and Benue Shale to the Asu River Series and the Ezeaku Shale, which was renamed Ezeaku Group and dated Turonian, and the Awgu-Ndeaboh Shale became known as Awgu Group (including the Agbani Sandstone) and dated Coniacian.

The Awgu Formation constitutes one of the pre-Santonian units in eastern Nigeria. It occupies a narrow strip between the eastern flank of the cuesta between

Enugu and Awgu and the gentle rolling land north of Ndeaboh (Hoque, 1977; Agumanu, 2011). It is a linear NE-SW trending sedimentary deposit composed of the Awgu Shale at the base and overlain by the Agbani Sandstone. The blue-grey shale with some pyrite indicates a marine environment that occasionally attained anoxic levels (Agumanu, 2011).

Diverse works have been acknowledged on the palynological studies of the Niger Delta Basin. Most of the works are majorly on the subsurface sector of the Niger Delta Basin, which include the works of Igbini *et al.* (2021), Asadu and Odumoso (2020), Dairo *et al.* (2019), Chukwuma-Orji *et al.* (2017), Osokpor *et al.* (2015), Soronnandi-Ononiwu *et al.* (2014), and Ige *et al.* (2011). Until now, the inland part of the basin has received little attention (Ikegwuonu *et al.*, 2020) documents the palynomorph assemblage bio-zonations of the up-dip areas of Niger Delta Basin's Paleogene strata covered along the Bende-Umuahia axis, southeastern Nigeria.

They established six familiar palynomorph assemblage zones, named Zones A to F, based on the first and/or the last occurrence of two or more species. Chiaghanam *et al.* (2017) conducted a palynological and paleoenvironmental study of outcrops around the Bende and Umuahia area. Age determination/correlation was attained based on the stratigraphically significant age-diagnostic palynomorph assemblages obtained from the examined samples. They suggested the Paleogene age for the Formations and Deltaic to shallow marine as their environment of deposition. Okeke and Umeji (2016) used palynological information to describe the palynofacies, palaeoecology, palynostratigraphy and sequence stratigraphy of the Paleogene sandy succession along the Onitsha-Awka transect.

The post-Santonian Nkporo Group of southeastern Nigeria comprises the Nkporo Shale, the Owelli/Afikpo Sandstone and the Enugu Shale (Reyment, 1965; Obi *et al.*, 2001; Onuigbo and Okoro, 2014). The position and age of the Owelli Sandstone within the Nkporo Group have been a matter of controversy. Groves (1951), Simpson (1955) and Reyment (1965) previously referred to the sand body "Awgu Sandstone". Reyment (1965) described the Owelli sand body as "the sedimentary rock intervening between the deformed Coniacian-Santonian Awgu Formation and the gently-dipping Campanian-Maastrichtian Enugu Shale in the Awgu area of Anambra Basin". Obi (2001) and Obi *et al.* (2001) described the Owelli Sandstone as intervening between the Nkporo Shale and the Enugu Shale. Akande *et al.* (2011), Odumoso *et al.* (2013), Nwajide (2013), and Onuigbo and Okoro (2014) described the sandstone as being laterally equivalent to the Nkporo Shale and Enugu Shale.

Reyment (1965) assigned the Campanian-Maastrichtian age to the Owelli Sandstone, and this was widely adopted until recently, when mix-ups in the age showed up. Obi (2001), Obi *et al.* (2001) and Nwajide (2013) proposed a Campanian age for the sand body.

Between 1960 and 1965, some more important works were published on the stratigraphy, palaeontology and sedimentary rocks of southern Nigeria. They include Reyment's monographs on the Nigerian Upper Cretaceous and lower tertiary ostracoda (1960, 1963), and a detailed account of the sedimentary rocks of south Nigeria. Short and Stauble (1967), in their study of the geology of the Niger Delta proposed a three-fold lithostratigraphical subdivision of Eocene-Recent (Benin Formation, Agbada Formation and Akata Formation). Okosun (1994) used Ostracods in the study of the stratigraphy of Southern Nigeria. The main focus of this work is a detailed geological mapping of the Obeagu Awgu and its environs, accompanied by granulometric analysis and paleocurrent analysis to interpret the depositional environment within the area.

Thus, this study aims to identify, describe and classify the fossils found in the area of study with the objective of dating the outcrop based on the available fossils and infer

the lithofacies description and environment of deposition.

GEOLOGY OF THE STUDY AREA

The study area initially falls within the Anambra Basin in South-Eastern Nigeria. The Anambra Basin is a Cretaceous Basin which lies within the precincts of the Middle Benue Trough, Nupe Basin, the Abakaliki-Okigwe Anticlinorium and the Niger Delta. It reflects the features of the break-up of the Gondwana supercontinent and the stratigraphy infilling sediments, young southwards from pre-Albian to the Tertiary in the present-day Niger Delta. Sedimentary thickness ranges from 2500 m North-South attaining a maximum thickness of 1200 m in the Central Niger Delta (Nwajide and Reijers, 1996). During the Albian-Santonian, the Anambra Proto Basin was a platform covered by a thin veneer of older sediments. The Santonian orogeny uplifted the Abakaliki-Benue Trough and its environs, resulting in the folding and westward translation, which led to the tectonic inversion and sagging that created the Anambra basin and others (Reyment, 1965; Whiteman, 1982). Consequent to the Santonian deformation, deposition shifted westward from the Abakaliki-Benue rifts into the Anambra basin with the formation of paralic Enugu Formation and Nkporo Formation, the Coal Measures of the Mamu and Nsukka Formations and fluvio-deltaic sandstone. The post-Maastrichtian folding affected all sediments; it was less intense than the Santonian, with the result that sediments in the Benue Trough with older sediments were folded twice (Murat, 1972; Whiteman, 1982; Kogbe, 1976).

Location and accessibility of the study area

Biostratigraphic study of an outcropping unit of the Ameki Formation was investigated along the Umuahia axis due to the paucity of this outcrop elsewhere in the Niger Delta. The area of study is an outcrop about 10 km away from Umuahia junction, along Bende/Ohafia Road in Abia State. It falls within the Ameki Formation in the Niger Delta Basin. It lies approximately at latitude 6°12' and longitude 7°24' in the southeastern part of Nigeria. The outcrops were in two locations: Location 1; Umunri with strike 320° and dip 3°SW, and Location 2, Ameki with strike 346° and dip 3°SW, both in Arochukwu Local Government Area (LGA) in Abia State. It is accessible by roads, foot path and bridges, though scarcity of outcrops and thick vegetation cover sometimes posed accessibility problems (Figure 1).

MATERIAL AND METHODOLOGY

Samples were collected from two exposed outcrops: Umuri (Location 1), which is about 2 km from Ameki (Location 2). These outcrops are predominantly fine to

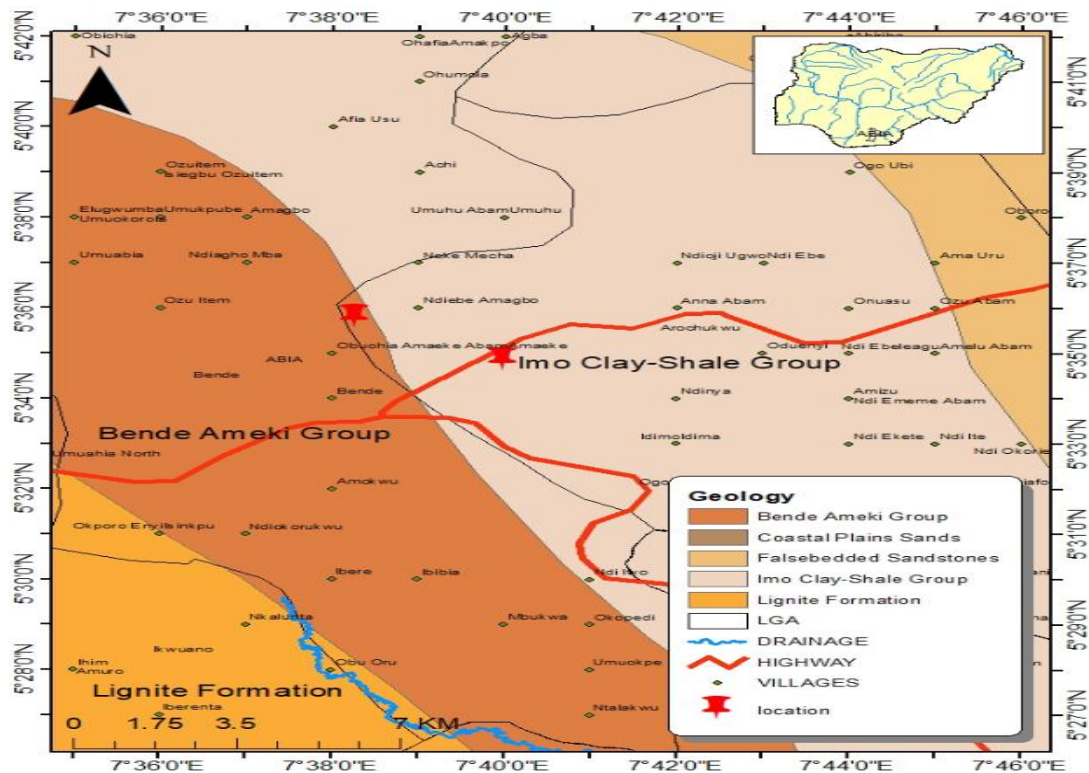


Figure 1. Map showing the location of the study area.

medium sandstone and shale. Instruments used during the field studies include: compass, clinometers, hammer, ruler, sample bags, camera, measuring tapes, writing materials, as well as a field notebook.

Sample collection

The samples were collected from two outcrops of different locations, Umuri and Ameke, in Arochukwu Local Government Area in Abia State. The outcrops are 10 km away from Umuahia junction along the Bende/Ohafia road in Abia State. The procedure employed in the collection of samples was the directed walk method. Hammers and chisels were used for the collection of samples (18 samples) from the outcrop, and enough samples were collected to avoid going back to the outcrop. During the collection of samples, care was taken to avoid the collection of weathered and contaminated outcrop by recent vegetation or by hammers. Also, the sample bag was absolutely clean inside, and samples put into the sample bag were properly labelled, taking note of the sample number, rock unit, horizon above or below, locality and date. All this information was placed on the outside or inside of the sample bag on a card before scaling or using masking tape. Bed thickness and sample point were measured and recorded, and at the same time, relevant dates were also entered into the field notebook and

sketches of the outcrops were taken too.

Sample preparation

In sample preparation, about 5 g of the sample was put into the aluminium pan. water and a teaspoon of anhydrous sodium carbonate were added. The aluminium pan was labelled according to the sample to boil for 3 to 5 minutes, and then stir with a spatula. The sample was allowed to boil until it desegregated and formed a paste. Then, it was sieved using a sieve mesh of 100 μ m and 53 μ m mesh until the water was clean. The sieve was tilted, so the sample could go to the side. Then, the residue was poured into the filter paper and allowed to drain a little before placing it on the hot plate. Allow it to dry for 20-30 minutes. Finally, all size fractions of the washed and dried residue were examined under the microscope for foraminifera. Forms are picked out and placed on the slide. Then, a numerical count form is drawn and identified.

PRESENTATION AND INTERPRETATION

Lithologic data

A total of 20 samples were collected from two locations, Location 1: Umuri in Arochukwu L.G.A, Abia State, with dip

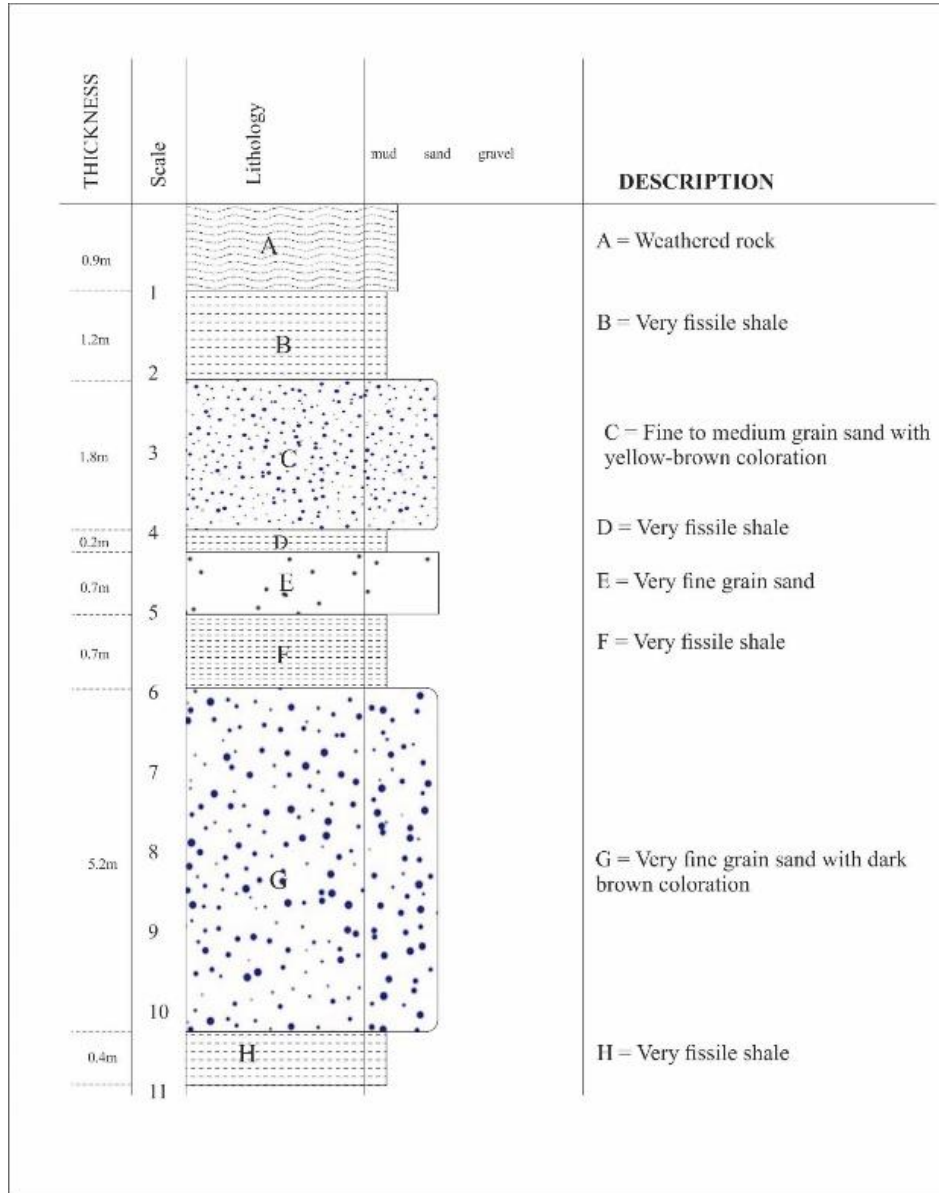


Figure 2. Composite stratigraphic section of location 1 (Scale 2 cm).

3°SW and strike-320°. Location 2: Amaeke in Arochukwu L.G.A, Abia State, with dip 3° SW and strike 346°.

Lithologic Description

Location 1

The sample in the location was collected from three points: A, B, and C. It consists mainly of sandstones and shale, and the composite log of the three points was taken, thereby dividing the sample collected into 12, labelled A-L. From the composite log, the bed labelled D has trough cross bedding, and it is fine to medium-grain (Figure 2).

The labelled bed E has cross bedding with bioturbation on it, while Samples F, G, H, and I have cross bedding (Figure 2). Bioturbation was observed within the sandstone beds, the beds dip 3° southwest, and the sandstone beds are almost horizontal. The thickness of these beds is about 8m and is poorly fossiliferous (Plates 1 and 2).

Location 2

The sample from this location is barren, as no fossils were found. The barren nature of the sample obtained could have been due to some reason, probably due to the absence of oxygen, which may have caused the death of

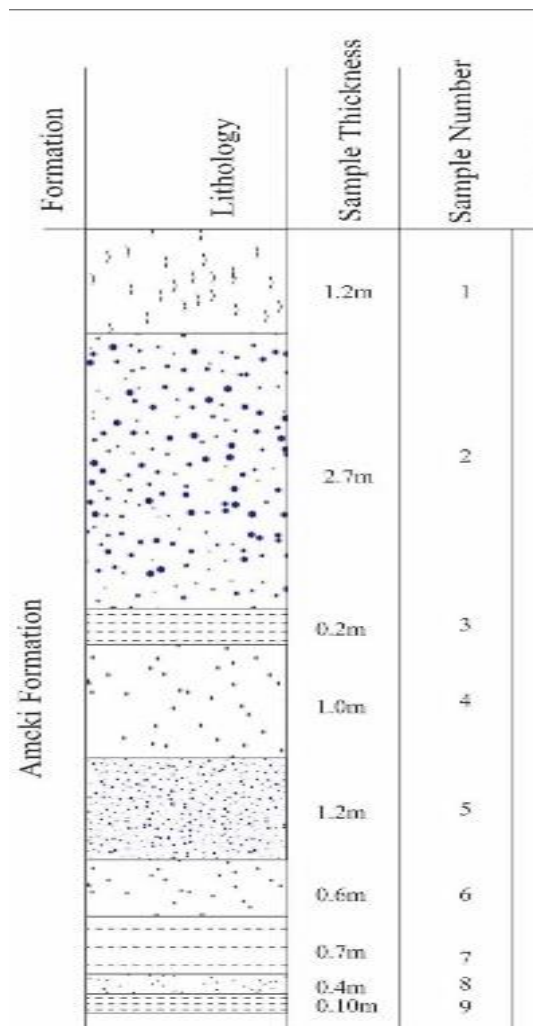


Figure 3. Composite graphic stratigraphic section of Location 2 (Scale 2 cm).

the organisms at the time, thereby making the environment unconducive for organisms to dwell in. On the other hand, they could have been washed/eroded away before the consolidation of the sediments (Figures 3 and 4).

Biostratigraphic description

Sample 1: Sample 1 is sandstone, of course, grain quartz. It contains 85% quartz and 15% muscovite. It has a high percentage of quartz, which is coarse-grained and not favourable to the preservation of fossils.

Sample 2: Sample 2 is mainly shale fragments, indicating a marine environment, while the presence of muscovite indicates that the provenance is far. The fossils identified include: *Nonion Qyaa* (Jur-Rec) and *Quinqueloclena hauerina d'orbigny* (upper Oligocene). They are both benthonic forms and are mostly favoured in the middle Neritic zones because of rapid burial.

Sample 3: Sample 3 is sandstone that contains 80% of quartz, 18% of muscovite and 2% of fossils. Fossils identified include: *Cibicides sinistralis* (Lower Miocene) and *Heterohelix globulosa* (upper Maastrichtian), which occur mainly in the Cretaceous beds. *Heterohelix globulosa* is a characteristic of planktonic forams, and *Cibicides sinistralis* is a benthonic forams. It is inferred that the environment of deposition open shelf environment (continental slope) and the bathyal zone because of their coexistence. Note, plankton are deep marine environment, ranging from bathyal to abyssal (Figures 3 and 4).

Sample 4: This sample is made up of shale fragments of 50%, 40% of quartz, 6% of muscovite and 4% of fossils. Forms identified include: *Nonion Oyaa* (Jur-Rec) and *Epistominella minula* (Eocene). They are both benthonic forms.

Sample 5: Sample 5 is sandstone of fine-grained quartz. It

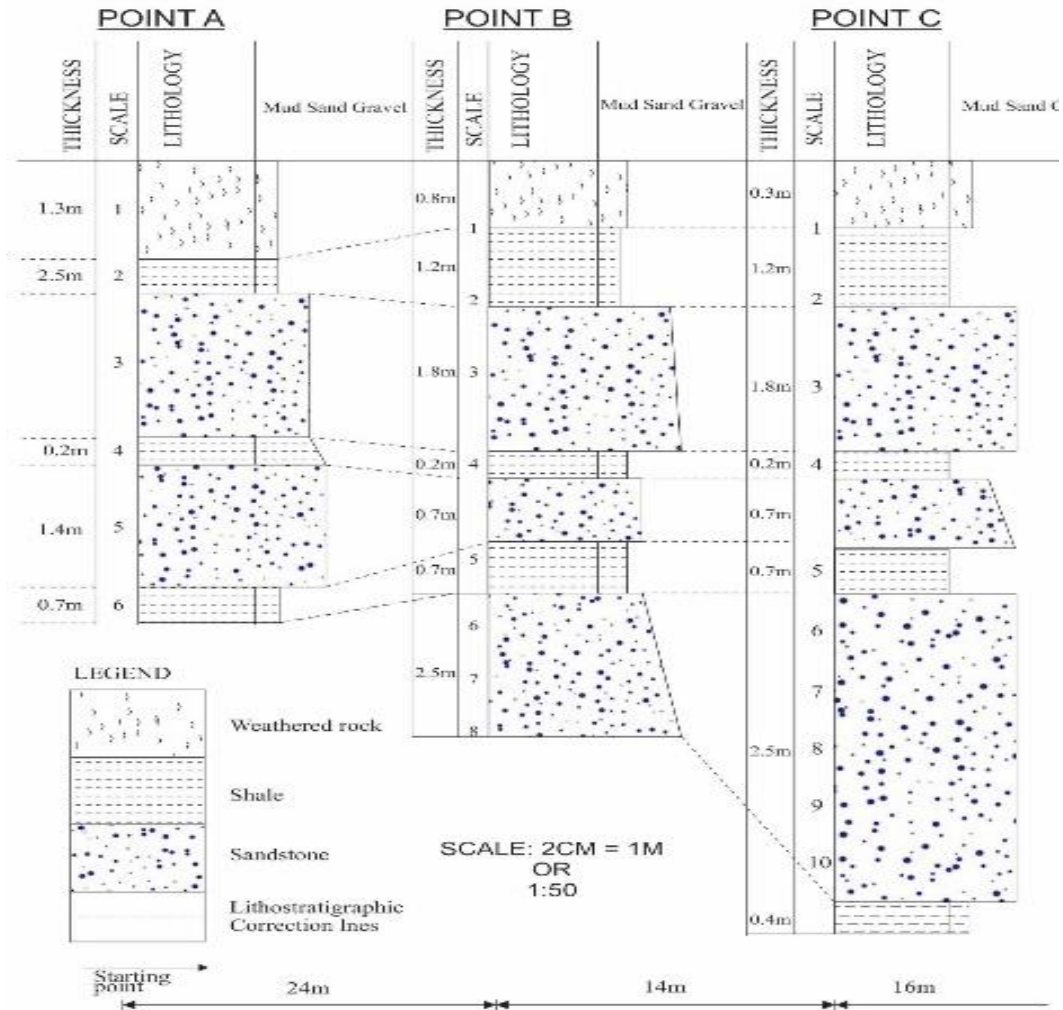


Figure 4. Correlation of points A, B, and C of the study area.

has 86% of quartz, 10% of muscovite, and 4% of fossil content. The fossil that was found included: *Bolivina ihuensis* (Jur-Rec) and *Eponides reymenti* Fayose (Palaeocene). They have few chambers and range from the Danian to the middle Palaeocene. They are also benthic forams (Figure 5).

Sample 6: This sample is made of shale fragments of 52%, 35% of quartz, 4% of muscovite and 6% of fossil. Forams identified include: *Nonion Obducum*, (Jur-Rec) *Qinqueloculria seminuluni* lower Miocene in age and *Bolivina ihuoensis* (cret-rec), both are benthic forams.

Sample 7: This sample is sandstone of fine-grained quartz, with 85% of quartz, 10% of muscovite in age and *Eponides reymenti* fayose, Palaeocene in age. Both are also benthonic forams.

Sample 8: This sample consists of 55% shale fragment, 40% quartz, 2% muscovite and 3% fossil content. The

forms identified in sample include *Epistominella minula* Eocene in age and *Qirqueloculira seminuluni* lower Miocene in age, and are benthic in nature.

The samples in the study were also collected at three points, A, B, and C, and grouped into 8 labelled A-H. It is composed of sandstones and shale. The shale is very fissile, while the sandstone ranges from very fine to fine sandstone. The colour of shale ranges from grey to light brown. It consists of rapidly alternating sandstone and shale (Figure 5). The location is highly fossiliferous with forams; the following forams were observed and noted: *Epistominella minula* (Eocene), *Biovlivina Ihuonsis* Cret-Rec, *Nonion oyea* (Jur-Rec), *Nonion Obducum* (Jur-Rec), *Eponides reymenti* Fayose (Paleocene), *Qirqueloculira semnului* (Lower Miocene), *Heterohelix globulosa* (Upper Maastrechtian), *Qinqueloculine Hauerina* d'orbigny (Jur-Rec), and *ibicids sinistralis* (lower Miocene). The thickness of the beds in this location is about 10.5 m (See Plates 1 and 2).

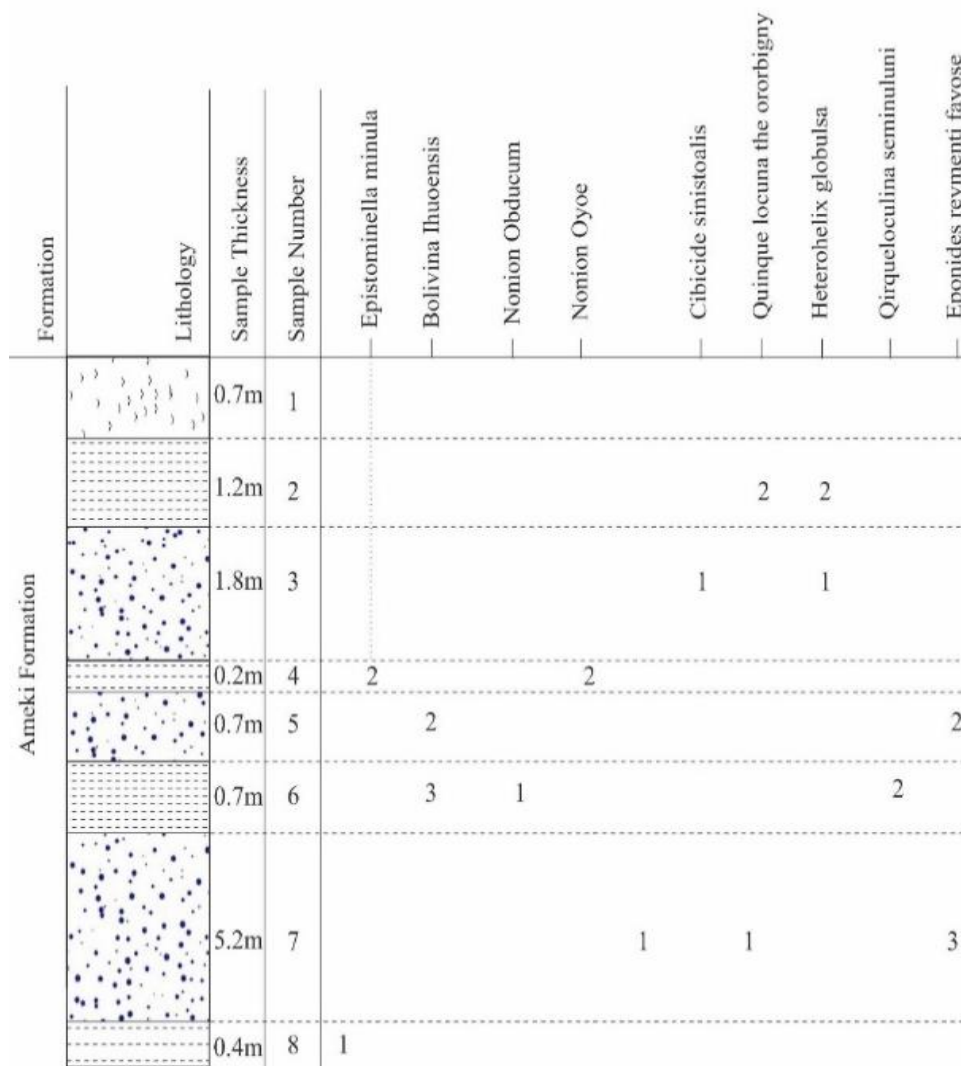


Figure 5. Distribution chart of palynomorph counts within the study area.

DISCUSSION

Biostratigraphy

A total of 20 samples were collected from two locations, 1 and 2. In Location 1, a total of 12 samples were analysed and fossils were identified, but in Location 2, a total of 5 samples were analysed and the lithology is composed of sand and shale (Figures 2 and 3). The sandstone ranges from very fine to fine-grained grain, and the shale is very fissile with colour ranging from grey to light brown. This location is highly fossiliferous, and a total of 29 forams were identified, these include the following and their ages in paranthesis; *Epistominella minula* (Eocene), *Cibicides sinistralis* (Lower Miocene), *Bolivina ihuoensis* (Cret-Rec), *Quinqueloculina hauerina d'orbigny* (Jurassic-Rec), *Nonion oboducm* (Jur-Rec), *Heterohelix globulosa* (Upper Maastrichtian), *Nonion oyea* (Jur-rec), *Quinqueloculina*

seminuluni (Lower Miocene), and *Eponides reymenti Fayose* (Palaeocene). The forams identified are mostly Benthonic (*Quinqueloculina hauerina d'orbigny*, *Nonion obducum*, *Quinqueloculina seminuluni* only in Sample 3 were planktonic foraminifera (*Heterohelix globulosa*) identified, inferring Bathyal zone and a continental slope environment.

Based on the lithofacies of average grain sizes (Quartz grain of 50%, Shale fragment of 40%, muscovite 6% and fossil content of 4%). In the entire outcrop of location 2, the colour ranges from grey to brown, the fissile nature of the shale and the biofacies of the above-named fossils, it is clear that the paleoenvironment is of a middle outer neritic shallow marine environment. The inferred deposited environment is a continental shelf.

Okoro and Nwojiji (2010) in their work on palynological analysis of Late Cretaceous sediment-fill of the Afikpo Sub-Basin, placed the age of the shale cropping out

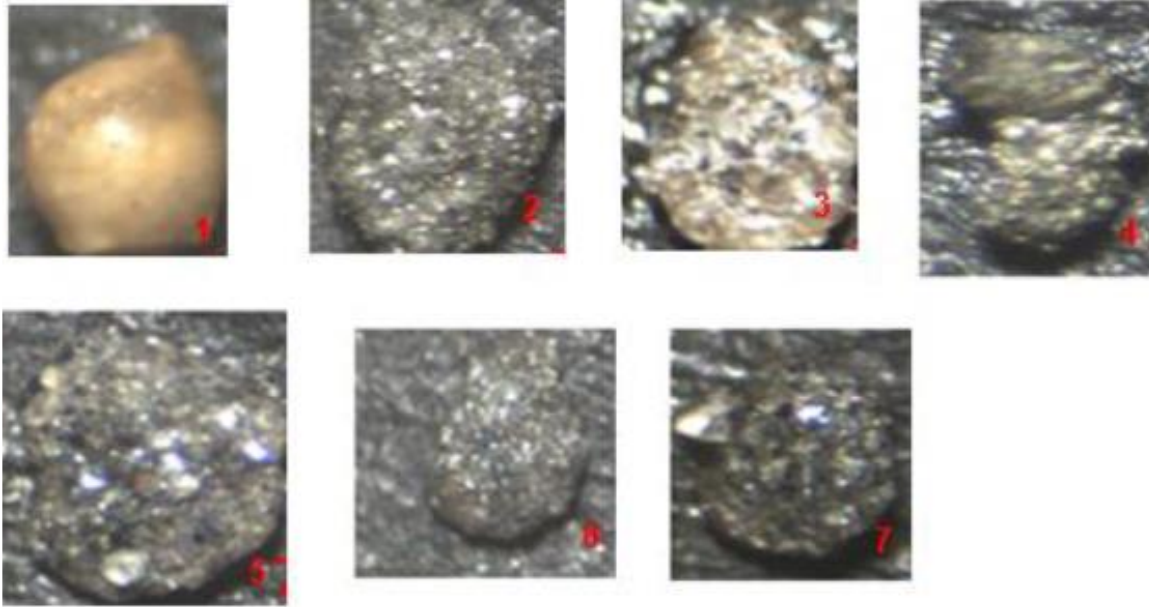


Plate 1. 1. *Nodosaria* sp (Magnification: x40); 2. *Milliammina* sp (Magnification: x40,); 3. *Ammobaculites* sp (Magnification: x40, 4. *Reophax* sp (Magnification: x40,); 5. *Haplophragmoides* cf *excavates* (Magnification: x40,); 6. *Ammobaculites* sp (Magnification: x60,); 7. *Haplophragmoides* sp (Magnification: x60).

around Asaga Amangwu-Amayi-Nguzu area as Late Campanian-Mid Maastrichtian and suggested that the shale bed outcropping around Asaga is Nkporo Shale based on taxa they identified as *Andallussiella polymorpha*, *Coronifera tubulosa*, *Senegalinium bivacatum*, *Longapertites marginatus*, *Monocolpites marginatus*, *Proxapertites cursus*, *P. operculatus*, *Mauritides crassibaculatus*, *Constructipollenites ineffectus* and *Syncolporites marginatus*.

Agglutinated taxa (*Reophax*, *Textularia* and *Haplophragmoides*) usually represent a range of environments from marginal marine to bathyal depths, but their co-occurrence and dominance in low diversity suggest marginal marine conditions (Gebhardt, 2004a). With increasing paleo-water depth, calcareous taxa (*Eponides* sp and *Bolivina* sp.) are the more prominent components. *Dentalina* and *Lenticulina* are generally found on the shelf, while *Ammotium* is a genus characteristic of a variety of brackish marginal marine environments. Gebhardt (2004b) has also interpreted slightly higher diversity fauna of *Ammobaculites* sp, *Ammotium* sp and *Reophax* sp as representing a brackish or lagoon environment.

Palynological analysis

The studied sections yielded poor to fair diversity assemblages of palynomorphs as seen in the study area and making the interpretation indeterminate for some of the samples.

An overall increase in the abundance of pollen/spores

in the study area suggests proximity to the shore (Edet, 1992). The Nsukka Formation, based on correlation and the results of the biostratigraphic analyses, correlates the Arochukwu area to Odoro Ikpe, where it is overlain by Benin Formation. This age is in agreement with earlier works in this region by Simpson (1954). Palynomorphs recovered comprise *Cribroperidinium* sp, *Gliecheniidites senonicus*, *Proxapertites operculatus*, *Spiniferites* sp, *Mauritidites crassibaculatus*, *M. crassiexinous*, *Leiotriletes adreinnis*, *Milfordia jardinei*, *Apectodinium* sp, *Longapertites marginatus*, *Syncolporites marginatus*, *Monocolpites* sp, *Retidiporites magdalenensis* and *Monocolpopollenites Sphaeroidites* which interprets the shale as Nsukka Formation (Edet, 1992; Ojo and Akande, 2006; Oboh-Ikunebe *et al.*, 2005; Umeji, 2005; Asadu and Lucas, 2006; Ogala *et al.*, 2006). The environment of deposition ranges from raised bog to lagoonal (Umeji, 2005).

Ameki Formation

The representative shale and sandstone samples from Locations 3, 6, 9 and 10, in this Formation bear moderate to fair terrigenous sporomorphs. The terrigenous species include spores such as, *Laevigatosporites discordatus*, *Verrucatosporites usmensis*, *Leiotriletes adreinnis*, *Cyathidites minor* and *Acristichum aureum*. Pollen grains are *Proxapertites operculatus*, *Retistephanocolpites williamsi*, *Longapertites marginatus*, *Mauritidites crassiexinous*, *Monocolpites marginatus*, *Retitricolporites* sp., *Psilatricolporites* sp., *Zonocostites ramona*,

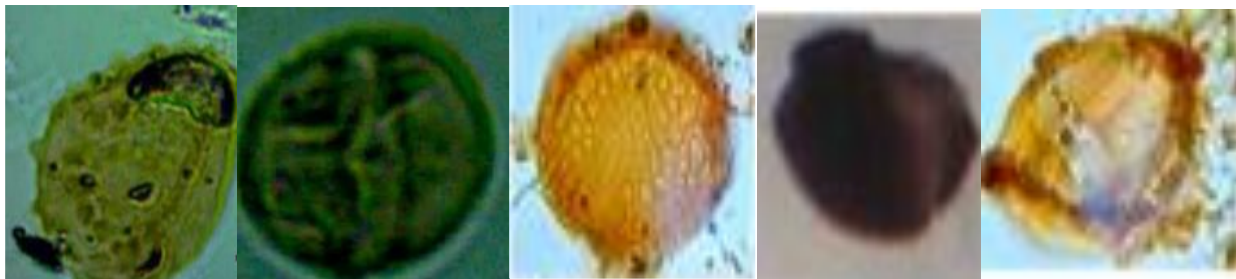


Plate 2. *Verrucatosporites usmensis* 2. *Zonocostites ramonae* 3. *Reticolporites* sp, 4 *Ariadnasporites longiprocessum* 5 *Andallusiella* sp.

Tricolpopollenites hian and *Calamuspollenites petsus*. Marine species include *Leiosphaerida* sp., *Operculodinium centrocarpum*, *Pterospermella* sp., and *Selenopemphix nephroides*. The silty and clayey sands samples yielded very poor to zero palynomorph counts.

But the palynoecological groupings of the recovered palynomorph taxa indicate that the mangrove taxa have the highest representation of the total recovery, followed by freshwater and rainforest swamps taxa in the well. Montane and savanna taxa have the lowest representation. Some authors (Adojoh *et al.*, 2015; Olayiwola and Bamford, 2016; Chukwuma-Orji *et al.*, 2017).

Conclusion

The study area is about 10 km from Umuahia junction along Bende/Ohafia road in Arochukuwu L.G.A in Abia State. Two outcrops were studied and analysed for forams in approximately 8 m and 11.2 m of exposed sediments. The samples are mainly shales and sandstone exhibit cross bedding and bioturbation. The following benthonic forms were identified: *Epistominella cminulai*, *Cibicides sinistraliks*, *Bolivina ihoensis*, *Qirqueloculine hauerina d'orbingny*, *Nonion obducum*, *Noinon oyea*, *Qirqueloculina seminuluni* and *Eponides reymeti* Fayose. While planktonic foram is *Heterohelix globulosa*. Based on the foraminifera data and lithologic description, the environment of deposition inferred is continental shelf, and the paleoenvironment is middle to outer neritic.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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