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Biostratigraphy and Depositional Environment of the Pebble Belt Area, Southeastern, Nigeria

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Abstract

The depositional environment of the pebble belt within the Arochukwu – Odoro Ikpe – Ndot Ikpe areas of southeastern Nigeria is the focus of this research. Standard methods as applied in fieldwork, sedimentological, palynological and paleontological analyses has been applied in this research. A Late Maastrichtian – Paleocene age has been assigned to the sediments (lithological units - clay, shale and limestone) which make up part of the lithostratigraphic units in the study area. The assigned age corresponds to Mamu and, Nsukka Formations based on the association of mainly benthic, planktonic and palynomorphstaxa recovered. The foraminifera comprises *Ammobaculites sp, A. amabensis, A. bauchensis, A. numanhensis, A. coprolithiformis, Bulimina sp, Bolivina sp, B. afra, B. explicata, Haplophragmoides sp, H. sahariense, H. saheliense, H. nigeriaense, H. talakaoense, Nonionella insecta, Milliamina pindigensis, M. petila, Valvulineria aegyptica, V. jacksonense Anomalinoides midwayensis, A. unboniferous, Margulina dorsata, Gavelinella guineana, Elphidiella Africana, Planularia nacatochensis, Cibicides harperi, C. succedens, Nonionella cummunis, Fursenkoina wilcoxensis, F. nigeriana, Eponides elevatus, E. Reyment, E. pseudoelevatus, Lenticulina midwayensis, Textularia hocklyensis, T. biafrea, Trachommina sp, T. dutsua, Spiroloculina sp, Spiroplectammina sp, S. semicomplanata, Heterohelix Striata, H. globosa, Siphongeneriniodes sp, S. cretacea, Osangularia sp, Nodosaria sp, Quinqueloculina sp, Saracenaria sp, Morozovella aqua, M. acuta, Globorotalia haynesi, Globotruncana sp, G. linneiana and Reophax minuta.* Palynomorphs recovered include *Cribroperidinuim 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*. The environment of deposition is interpreted as shallow inner neritic to outer neritic, based on the occurrence ostracods, pelecypods and gastropods along with foraminifera. The environment of deposition ranges from raised bog to lagoonal, and overall increase in the abundance of pollen/spores in the study area suggest proximity to the shore line.

Keywords: Pebble belt area; Maastrichtian – Paleocene age; Mamu and Nsukka Formations

Introduction

The pebble belt areas in the southeastern part of Nigeria and consist of pebble beds, sandstone and associated shale/clay beds that has been dated as Eocene – Miocene [1-6]. Studies relating to the pebble belt areas in Akwa Ibom State are regional studies of the Ogwashi-Asaba and Benin Formations, which placed the age of the Ogwashi-Asaba Formation as Oligocene to Miocene, and the Benin Formation as Pliocene to Pleistocene, thus suggesting that these pebble beds have similar ages [1-4]. According to Petters [6], the sand/gravel facies in Akwa Ibom State form part of the Ogwashi-Asaba and Benin Formations. But Amajor [5] assigned a Miocene – Pliocene age to these deposits whereas Inyang [7] placed the age of shale and clay beds below the pebble bed as Campanian to Early Eocene and named it as Nkporo Formation based on taxa identified as *Afrobolivina afra, Morozovella aequa, Anomalinoides midwayensis, A. umboniferous, Cibicides succedens, C. harperi Planorotalites pseudomenardi, Eponides pseudoelevatus, Globigerina velascoensis and G. daubjergensis, Selaginella myosurus, Homotryblium sp, Proxapertites operculatus, Spiniferites sp, Apectodinium parvum, A. Homomorphum and Mauritiides crassiexinous*. According to him, these pebble deposits are stratigraphic equivalents of the top of the Bende-Ameki Formation while the base formed part of the Ogwashi-Asaba Formation because these deposits post-date the shale and clay beds. Okoro and Nwojiji [8] in their work on palynological analysis of Late Cretaceous sediment-fill of the Afikpo Basin, placed the age of the shales croppingout around Asaga Amangwu-Amayi-Nguzu area as Late Campanian-Mid Maastrichtian and suggested that the shale bed

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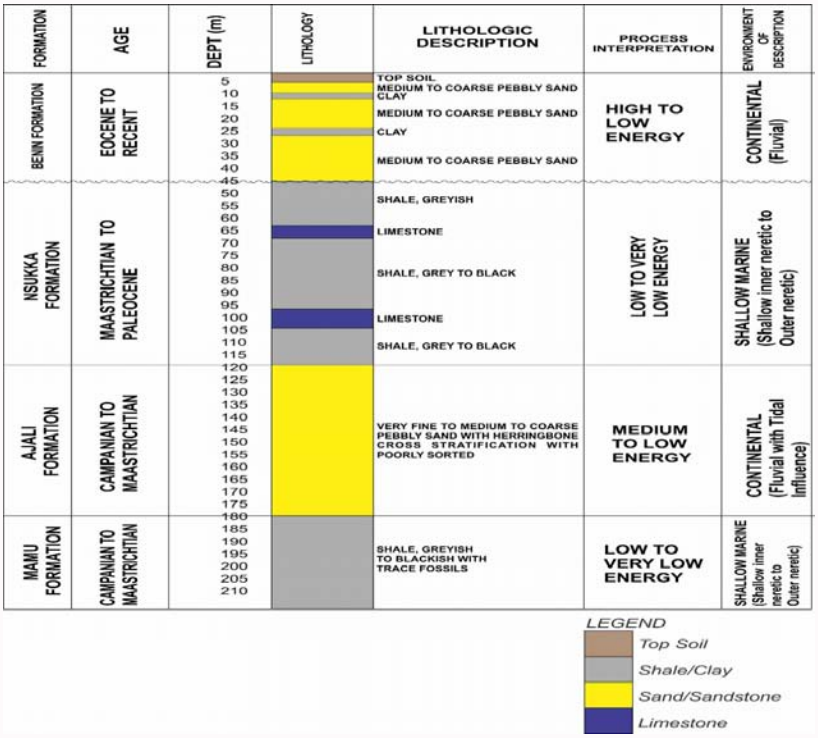

Figure 1: Composite log of the study area showing lithostratigraphic units of the Study area based on correlation of lithologic logs and biostratigraphic data [12].

outcropping around Asaga is Nkporo Shale based on the following 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*. According to Agagu et al [9] and Reyment [2] the Nkporo Shale in both Anambra and Afikpo Basin have yielded the following dominantly benthonic foraminifera *Bolivina explicata, Afrobolivina afra, Bulimina fang, B. prolix, Gabolinella elongata, Gavelinella sp*, and *Praebulimina banta*. Rare planktonic foraminifera such as *Globotruncana sp*, *Rugoglobigerina rugosa* and *Globigerina sp* have also been identified which may represent the upper part of the formation. The results of the current biostratigraphic analysis suggest a different age for the shale cropping out at Asaga, as the shale is laterally continuous from Arochukwu area (with lenses of limestone) to Odoro Ikpe area where it is uncomformably overlain by the Benin Formation. According to Ekwere et al [10], limestones around Obotme area commonly occur in two bands of unequal thickness and occasionally as boulders approximately 3km from Asaga – Amangwu. These basal limestone beds are bioclastic and highly fossiliferous containing gastropods and bivalves. The other variety of the limestone is shaly with lots of allochems closely associated with Paleocene shales and minor sandstone uncomformably overlying older Cretaceous strata. The associated shales contain Paleocene benthonic calcareous foraminifera, which are dominant and comprise Anomalinoides midwayensis, *A. umboniferous*, and *Elphidiella africana*. Planktonic foraminifer is rare and consists of *Morozovella aequa* and *M. acuta*. According to Etuk [11], the association of *Anomalinoides umboniferous*, *Cibicides succedens*, *Gavelinella guineana*, *Ammobaculites sp*, *Lenticulina sp*, *Maginulina costata* and *Dentalina sp* (benthonic forms) are supportive of a Late Paleocene whereas *Morozovella angulata* is the only planktonic form associated with the shales around Obotme in addition to the limestone lenses which he also dated as Paleocene. The results of this research have a contrary age based on foraminifera and palynoflora identified in the study area. The geology, sedimentology, stratigraphy and structural geology of the study area has been extensively discussed by Ideozu [12], Ideozu and Ikoro [13], Ideozu and Amararu [14], Ideozu and Solomon [15] and Ideozu and Akatakpo [16].

Materials and Methods

Materials

Materials for this research has been sampled during fieldwork in the study area. Forty-six representative samples of shales, limestones, and clays wereanalyzed for their microfossil content.

Sample preparation for foraminifera

The simple washing soda method was used in preparing for foraminiferal analysis; this method is useful for loose sediments [17]. Two spoonful of sodium bicarbonate was added to the crushed samples in water in aluminum pans and allowed to boil. The resulting liquid was allowed to simmer until the rock showed no further sign of breaking down. The samples were washed through sieve mesh of 300, 200 and 53 with a gentle jet of water. Each prepared sample labelled A, B and C scanned on a picking tray, picked onto Franke slides and analyzed using a Zeiss binocular paleontological microscope.

Sample preparation for palynomorphs

- Representative samples were selected for palynological analysis. The following order of analysis was adopted after Armstrong and Brassier [17].

- Each sample was treated with 10% HCL to remove free calcium carbonate in the sediment; this was carried out to avoid exine corrosion and oxidation.

		Aritdalsiilsp	Aquilapollenites sp	Auriculiides reticulates	Buttinia andrewsEarly	Congabitsporites cornatus	Constructipolenites ineffectus	Clavodoporiidites costatus	Echinoporites triangulformis	Faecotriletes minegattae	Longapertites marginatus	Longapertites marginatus	Longapertites sp	Longapertites varnectedlong	Nigrodumsporites adrienis	Mauritidiesx crassibaculatus	Mauritidiesx crassiexinous	Proxapertites cursus	Proxapertites operculatus	Regulatisporites capcatus	Retidiportites magdalenensis	Retimonocolpites sp	Spiniferonocolpites tasculatus	Spiniferonocolpites echinatus
Pliocene	Late																							
	Mid																							
	Early																							
Miocene	Late																							
	Mid																							
	Early																							
Oligocene	Late																							
	Mid																							
	Early																							
Eocene	Late																							
	Mid																							
	Early																							
Paleocene	Late																							
	Mid																							
	Early																							
Maastrichtian	Late																							
	Mid																							
	Early																							
Campanian	Late																							
	Mid																							
	Early																							

Figure 2: Diagnostic Palynomorphs/Stratigraphic useful taxa and their age ranges for the study area (Ideozu, 2014).

- The suspension was neutralized with KOH to deflocculate and remove humic colloid. Thereafter, hydrofluoric acid treatment was used to remove siliceous materials and acetolysis treatment was used to remove cellulose.

- Nitric acid was used for oxidation in addition to removing lignin. Finally, the samples were washed and sieved to clear the microfossils by clogged debris.

Results and Discussion

Results

Fieldwork: Fieldwork, generated data used in the establishing stratigraphic relationships of the sedimentary units and sedimentary sequence in the study area and to make a comparison with the regional stratigraphy of the Lower Benue Trough (Figure 1).

Biostratigraphy: Biostratigraphic analyses, generated data for relative age determination of the sediments under study to appropriately place the sediments within the regional geology of the Lower Benue Trough, in addition to interpreting the environment of deposition (Figures 2,3 and Plates 1,2). No attempt was made at description of the forms identified because many workers have already described these forms in their works [6,18,19].

Biofacies description:

Location 1: (Odoro Ikpe)

Thickness (m): Biofacies Description

0.90: Clay, greyish to whitish, composed of angular to sub-angular quartz 75%, pyrite 3%, glauconite 2%, coal fragments 10%, muscovite flakes 9: the palynomorphs recovered are not age diagnostic and include *Leiotriletes Adreinnis, Aquilapollenites Sp*, and dinoflagellate cysts (probably reworked).

0.22: Clay, whitish, composed of angular to sub-angular quartz 75%, pyrite 5%, glauconite 3%, rootlet 1%, coal fragments 3%, and muscovite flakes 3% and barren.

0.10: Clay, brownish and structureless, barren of palynomorphs but the following forams were recovered *Bolivina midwayensis, Bolivina sp, Cibicides harperi* and *gastropods*. Based on the forams recovered this bed is dated Late Maastrichtian to Paleocene and the environment of deposition is inner neritic.

2.40: Shale and massive fractured, dark gray to greenish. The following palynomorphs were recovered from this bed, *Caryapollenites sp, Psilatricolporites sp, Leiotriletes adriennis* and *Psilatriporites sp* in addition the following forams were recovered these are *Bolivina crassicostata, Cibicides sp, Anomalinoides midwayensis, Cibicides harperi, Morozovella quetra* and *gastropods*. This bed is dated Late Maastrichtian to Paleocene and the environment of deposition is middle neritic.

3.40: Shale, greyish. The following palynomorphs were recovered from this bed-Psilatricolporitessp and Caryapollenites sp both of which are not age diagnostic. They may have been reworked. In addition, the following forams were recovered- *Bolivina crassicostata*, *Cibicides harperi*, *Eponides elevatus*, *Orthokarstenia clavata*, *Morozovella coniconstruncata*, *M. aequa*, *Planulina nacatochensis* and *gastropods*. Based on these forms this bed is dated Late Maastrichtian to Paleocene. The environment of deposition is upper bathyal.

0.91: Shale, dark gray to brownish and sandy. No palynomorphs was recovered from this bed. The forams recovered provide the only means to date this bed. The forams recovered include the following. *Cibicides harperi*, *Bolivina midwayensis*, *Morozovella sp*, *M. aequa*, *M. pseudobulloides*, ostracods and gastropods. Based on the forams listed above, this bed is dated Late Maastrichtian to Paleocene.

Location 2: (Obotme)

1.83: Fine to very fine-grained sandstone, weathered and clayey.

0.91: Shale, fissile, gray to black, ostracods and gastropod are rare, composed of sub-angular to rounded quartz grains 50%, rock fragments 15%, fecal pellets 7%, coal fragments 10%, muscovite flakes 5%, pyrite 5%, rootlets 5%, and fossil 3%. This bed is fossiliferous; *palynomorphs* recovered include *Cribroperidinuim sp*, *Gliecheniidites Senonicus*, *Leiotriletes sp, Reticolpites sp, Longapertites sp L. reticulatus, Aderiantherites sp, Selenopemphix sp, Proxapertites Operculatus, Spiniferites sp, Mauritidites crassibaculatus, M. crassiexinous, Hystrichololpama sp, Syncolporites Ituensis, Polycolpites clavatus, Echimonocolpites bituitus, Polypodiites sp, foram linings and dinocyst indeterminate. Forams recovered include Quinculoculina sp, Nodosaria sp, Saracenaria sp, Planulina nacatochensis, Lenticulina midwayensis, Cibicides succedens* [20], *C. harperi* [21], *Anomalinoides unboniferous and A. midwayensis in addition to Gavelinella guineana [19], Valvulineria aegyptica, Morozovella aequa, M. acuta, Eponides*

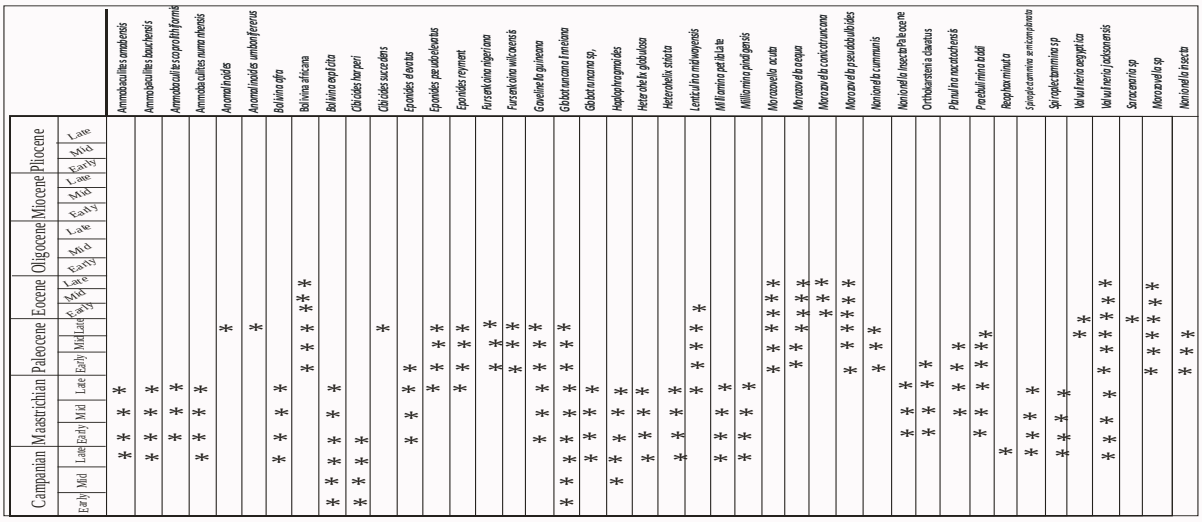

Figure 3: Diagnostic Foraminifera/Stratigraphic useful taxa and their age ranges for the study area [12].

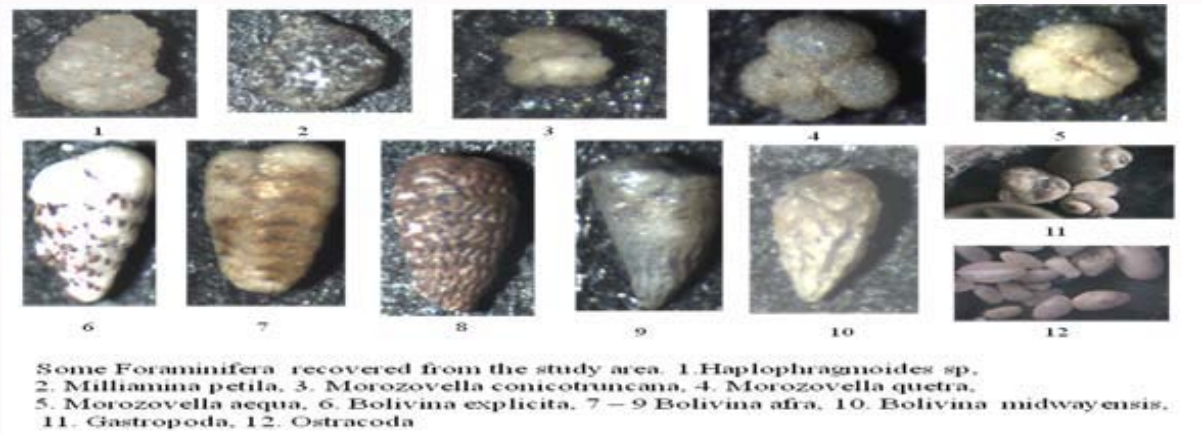

Plate 1: Some Foraminifera recovered from the study Area.

elevatus. The association of Proxapertites operculatus, Mauritidites crassibaculatus, and *M. crassiexinous,* and *the association of Lenticulina midwayensis, Cibicides succedens [20], C. harperi, Planulina nacatochensis Anomalinoides unboniferous,* and *A. midwayensis in addition to Gavelinella guineana [19], Valvulineria aegyptica [22], Morozovella aequa, M. acuta and Eponides elevatus* date this bed as Late Maastrichtian to Paleocene. The benthics predominate and the environment of deposition is middle neritic.

0.76m: Shale, gray to brownish, calcareous, and composed of angular to rounded quartz grains 30%, rock fragments 25%, fecal pellets 5%, rootlets 2%, coal fragments 20%, pyrite 10%, and glauconite 6%, fossil 2%. The fossils recovered are age diagnostic: the forams recovered include *Cibicides Succedens*, *C. harperi*, *Planularia nacatochensis*, *Anomalinoides Unboniferous*, *A. midwayensis*, Lenticulina Midwayensis, Valvulineria aegyptica [22], *Eponides elevatus*, *Nodosaria sp*, *Saracenaria sp*, and *Morozovella aequa*. The benthics predominate in this bed in addition; are abundant shell fragments pelecypods, ostracods and gastropods. The palynomorphs recovered are pollen and spores and dinoflagellates. The assemblages include, *Lejuenecysta sp*, *Mauritidites crassiexinous*, *Spiniferites sp*, *Lingolodinium sp* others include foram linings and dinoflagellate cyst indeterminate. The following associations of both forams and palynomorphs such as *Cibicides succedens*, *Anomalinoides unboniferous*, *A. midwayensis*, *Lenticulina midwayensis*, *Eponides elevatus*, and *Morozovella aequa* and *Mauritidites crassiexinous* date this bed as Late Maastrichtian to Paleocene. The environment of deposition is middle neritic.

0.12m: Shale, fissile, gray to black, composed of angular to sub-angular quartz 25%, gastropods 1 %, rock fragments 23%, fecal pellets 3%, rootlets 5%, coal fragments 5%, muscovite flakes 5%, pyrite 20%, glauconite 3% and fossil 4%. The palynomorphs recovered include *Apectodinium sp*, *A. quiquelatum, A. homomorphum, Monocolpopollenites sphaeroidites, Mauritidites crassibaculatus, M. crassiexinous,Operculodinium sp, Polysphaeridium sp, Proxapertites operculatus, P. cursus, Selenopemphix sp, Foveotriletes margaritae, Spiniferites sp, Polypodiites sp, Hystrichololpama sp, Adenantherites sp, Syncolporites sp, Syncolporites marginatus, Leiotriletes adreinnis, Ifecysta pachyderma, Triporopollenites bitutus, Proteacidites miniporatus, Susessiod sp, Retitricolporites crassireticulatus, Echimonocolpites rarispinous, Retitricoporites annulatus, Nematosphaeridium sp, Homotryblium sp, Retidiporites magdalenensis, Longapertites marginatus*, in addition to foram linings and dinocyst indeterminate. The only forams recovered are *A. umboniferous*. This bed is dated Late Maastrichtian - Paleocene based

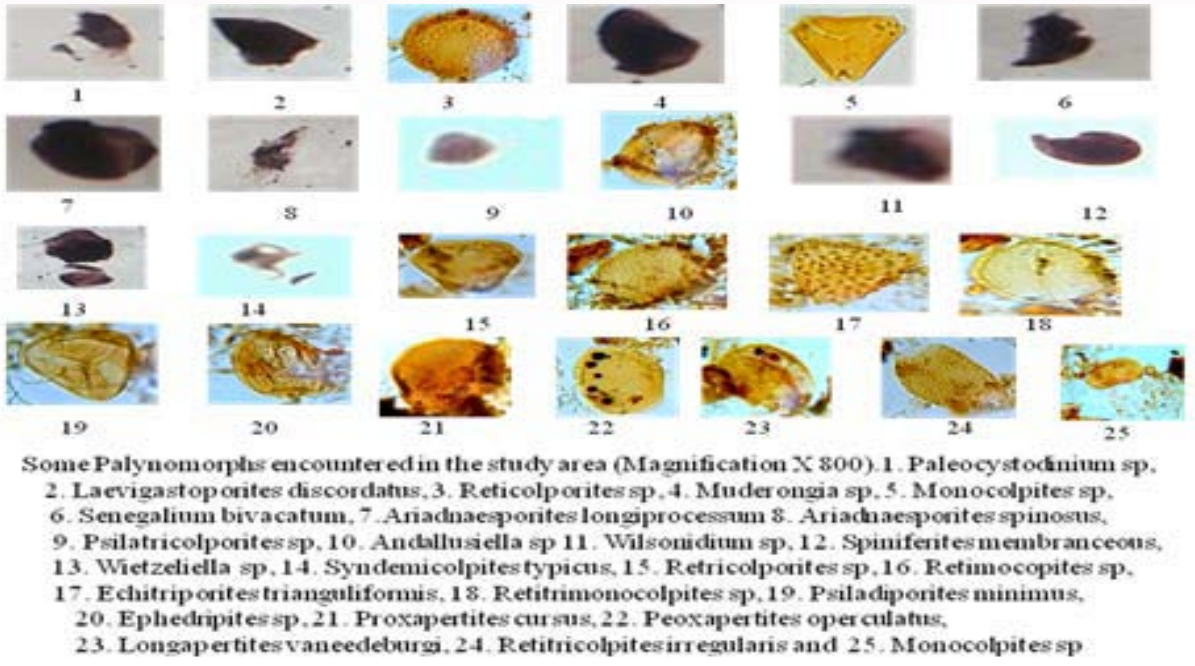

Plate 2: Some palynomorphs recovered from the study Area.

on the association of palynomorphs *Mauritidites crassibaculatus*, *M. crassiexinous*, Proxapertites operculatus, and P. cursus in addition to *A. umboniferous*. The environment of deposition is shallow inner neritic.

0.24m: Limestone lenses, bioclastic with abundant shell fragments, bivalves, ostracods and gastropods. The palynomorphs recovered include *Longapertites sp, Monocolpopollenites sphaeroidites, Leiotriletes adreinnis, Psiladiporites nnewiensis, Hystrichololpama sp, Lingolodinium sp, and M. crassiexinous, in addition to foram linings and dinocyst indeterminate. Foraminifera recovered include Planulina nacatochensis, Lenticulina midwayensis, Cibicides succedens, C. harperi, Anomalinoides unboniferous, and A. midwayensis, Elphidiella Africana [22], Gavelinella guineana, Valvulineria aegyptica* [22], and Eponides elevatus in addition to coral reef fragments. The only age diagnostic palynomorphs is *M. Crassiexinous* (Paleocene). The associations of the following forams, *Lenticulina midwayensis, Cibicides succedens, Anomalinoides unboniferous,* and *A. midwayensis, Elphidiella africana, Gavelinella guineana*, date this bed as Late Maastrichtian - Paleocene. The environment of deposition ranges from inner neritic to outer neritic.

0.90m: Shale, fissile, gray to dark gray, ostracods are common. The forams recovered include *Planulina nacatochensis, Bulimina sp, Nonionella cummunis, Cibicides succedens, C. harperi, Anomalinoides unboniferous*, and *A. midwayensis*. The palynomorphs recovered include *Longapertites sp, Longapertites reticulatus, Longapertites marginatus, Selenopemphix sp, Gliecheniidites senonicus, Leiotriletes adrennis, Spiniferites sp, Milfordia jardinei, Ctenolopheniidites costatus, Psiladiporites nnewiensis, Monocolpopollenites sphaeroidites, Retidiporites sp, Polycolpites pocoki, Cordosphaeridinium sp, Andalusiella sp, Paleocystodium sp, Triporopollenites bitutus, Adenantherites sp, Apectodinium sp, Longapertites marginatus, Syncolporites marginatus, Monocolpites sp, Mauritidites crassibaculatus, M. crassiexinous, Operculodinium sp,* and *Proxapertites operculatus*. In addition to foram linings, fungal spores and dinocyst indeterminate identified. This bed is dated Late Maastrichtian - Paleocene based on the association of the following *palynomorphs and forams Nonionella cummunis, Cibicides succedens, Anomalinoides Unboniferous, A. midwayensis, Mauritidites crassibaculatus, M. crassiexinous, Apectodinium sp*, and *Proxapertites operculatus.* The environment of deposition is outer neritic.

22.4m: Shale, fissile, greyish and highly ferruginised, composed of sub-angular to rounded Quartz 30%, rock fragments 7%, and coal fragments 12%, and rootlets 1%, pyrites 45 % and muscovite flakes 5%. No forams recovered (barren). Palynomorphs recovered are not age diagnostic, they include: *Selaginella myosurus, Leiotriletes adrennis, Laevigatosporites discordatus, Syncolporites sp*, fungal spores and dinocyst indeterminate. Based on stratigraphic position this bed is dated Late Maastrichtian-Paleocene.

2.1m: Limestone lenses, bioclastic with abundant bivalves, gastropods, ostracods and shell fragments. Whitish to greyish towards the base. Forams recovered include *Karerriela sp, C. harperi, Anomalinoides unboniferous*, and *A. midwayensis, Lenticulina midwayensis, Quinculoculina sp, Planulina nacatochensis*, and *Eponides elevatus*. The palynomorphs recovered are not age diagnostic and include *Monocolpites sp, Ephedripites sp, Lejuenecysta sp, Leiotriletes adrennis, Retitricolporites sp, Longapertites marginatus*, and *Lejuenecysta fallax*, in addition to foram linings and dinocyst indeterminate. This bed is dated Late Maastrichtian to Paleocene based on the following associations of forams: *Anomalinoides unboniferous*, and *A. midwayensis, Lenticulina midwayensis, Quinculoculina sp, Planulina nacatochensis*, and *Eponides elevatus*. The environment of deposition is interpreted as Shallow Inner Neritic. The benthics predominate.

0.10m: Shale, fissile, gray to black, calcareous, with abundant gastropods and bivalves. This shale bed is composed of angular to sub-angular quartz 56%, fecal pellets 3%, pyrites 20%, muscovite flakes 2%, coal fragments 17%, and fossils 2%. The following palynomorphs were

recovered: *Gliecheniidites senonicus, Laevigatosporites discordatus, Adenantherites sp, Leiotriletes sp, Ctenolopheniidites costatus, Selenopemphix sp, Syncolporites sp, Retidiporites magdalenensis, Syncolporites Marginatus, Polycolpites Clavatus, Polycolpites pocoki, Spiniferites hyalosoinous, Retitricolporites sp, Longapertites reticulatus, Echitriporites trianguliformis* [23], *Retidiporites sp, Retimonocolporites pluribaculatus, Monocolpopollenites sphaeroidites, Spiniferites sp, Polypodiites sp, Lygodiumsporites adrennis [24], Apectodinium sp, M. crassiexinous, Triporollenites sp Proxapertites operculatus ,and Monocolpites sp*, in addition to fungal spores and dinocyst indeterminate. The foraminifera recovered include Nonionella Insecta, Fursenkoina wilcoxensis, Fursenkoina nigeriana, in addition to bivalves and gastropods. This bed is dated Late Maastrichtian – Paleocene based on the association of the following forams and *palynomorphs: Nonionella Insecta, Fursenkoina wilcoxensis, Fursenkoina nigeriana, Mauritidites crassibaculatus, Triporollenites sp, M. crassiexinous, Proxapertites operculatus* and *Spiniferites hyalosoinous*. The environment of deposition is inner neritic.

4.60m: Ajali Formation (non-fossiliferous).

3.10m: Shale, gray to dark gray, finely laminated, massive, hard, when split breaks along conchoidal fractures, trace fossils and fecal pellets are rare. This bed is composed of sub-angular to rounded quartz grains 60%, rock fragments 10%, pyrites 10%, coal fragments 3%, muscovite flakes 10% and fossils 3%. The following forams were recovered, Haplophragmoides saheliense, H. excavate [18], *Lagena semiornata, Textularia laevis, Spiroloculina badness, Heterohelix striata, Siphongeneriniodes sp, Globorotalia haynesi, Planularia toddae, Globorotruncana linneiana, Bulimina trigonalis, Lenticulina midwayensis,* and *Cibicides succedens*. The palynomorphs recovered include *Proxapertites operculatus, Psiladiporites nnewiensis, Retricolporites crassireticulatus, Mauritidites crassiexinous, Syncolporites sp, Syncolporites marginatus, Wietzeiela sp, Milfordia Jardinei, Retidiporites magdalenensis, Homotryblium sp, Spiniferites bifurcates, Fybrocysta sp, Lingolodinium sp, Longapertites sp, Longapertites marginatus, Apectodinium sp, Ephedriporites sp, Lygodiumsporites adrennis, Foveotriletes margaritae, Nematosphaeridium sp, Retidiporites adegokei, Homotryblium constructum, Laevigatosporites discordatus*, and *Rugulatisporites caperatus*. Based on the forams and palynomorphs assemblages as *Haplophragmoides Saheliense, H. excavata, Globorotalia hayensi, Globotruncana linneriana* and *Heterohelix striata* are planktonic forms which are age diagnostic. *Lagena semiornata, Textularia laevis, Spiroloculina badenesis, Siphongenerimodes sp, Haplophragmoides excavata* (Petters, 1979), Planularia toddae, Lenticulina midwayensis, Cibicides succedens and Bulimina trigonalis are benthonic forms; *Proxapertites operculatus, Retricolporitescrass ireticulatus, Mauritiditescrassiexinous and Retidiporites Adegoke. Homotryblium constructum* is a reworked form. This bed is dated Late Maastrichtian which indicate environment of deposition to be shallow Inner to Inner Neritic? This corresponds to Mamu Formation.

0.91m: Shale, gray to dark gray, finely laminated, massive, hard, when split breaks along conchoidal fractures, trace fossils and fecal pellets are rare. This bed is composed of 50% angular to sub-angular quartz grains, 35% rock fragments, 5% pyrite, 3%coal fragments, 3% mica flakes and 3% fossil. The following forams were recovered *Haplophragmoides sahariense, H. saheliense, H. Excavata, Ammobaculities amabensis, A. bauchensis, A. numanhensis, Milliamina pindigensis*, and *M. petila. The following palynomorphs were recovered, Cribroperidinuim sp, Spiniferites sp, Spiniferites membraceous, Gliecheniidites senonicus, Hystrichololpama sp, Selenopemphix sp, Monocolpites sp, Polypodiites sp, Lejuenecysta sp, Lejuenecysta globosa*. This bed is dated Late Maastrichtian and the environment of deposition shallow inner neritic. This bed corresponds to Mamu Formation.

Location 3: Akama-Arochukwu

2.20: Shale, brownish to gray. The following forams were recovered *Ammobaculities amabensis, Anomalinoides midwayensis, Textularia hocklyensis, T. biafrae* [18], *Miliammina petila, Reophax minuta, Haplophragmoides sahariense* [18], *H. saheliense* [18], *H. talakaoense* [19], *Bolivina sp, B. afra [2], Trachommina sp, Osangularia sp, and Planulina nacatochensis. In addition, ostracods and shell fragments were identified. This bed is dated Late Maastrichtian* and the environment of deposition is middle neritic.

0.30: Shale, gray to black. The following forms of foraminifera were recovered *Ammobaculities Amabensis, Haplophragmoides nigeriense* [18], *H. talakaoense, Trachommina dutsuna, H. sahariense, Textularia hocklyensis, Bolivina sp* and *Gavelinella guineana* [19]. This bed is dated Late Maastrichtian to Paleocene and the environment of deposition is middle neritic based on foraminifera assemblage. The palynomorph assemblage include *Andalusiella sp, Ariadnaesporites sp, A. spinosus, Auriculiidites reticulatus, Cerodinium speciosum, Cicatricosisporites sp, Cingulatisporites ornatus, Constructipollenites ineffectus, Cribroperdinium sp, Cycadopites sp, Echimoncolpites rarispinosus, Echitriporites trianguliformis, Gleicheniidites senonicus, Hexaporotricolpites emelianova, Leiotriletes sp, L. adriennis, Lejeunecysta fallax, Lejeunecysta sp, Longapertites sp, L. marginatus, L. microfovelatus, L. reticulatus, Lycopodiumsporites sp, Marcrotyloma brevicaule, Monocolpites sp, Monocolpollenites sphaeridites, Paleocystodinium sp, Proxapertites operculatus, Psiladiporites nnewiensis, Retimonocolpites pluribaculatus, Selenopemphix sp, Senectotetradites varireticulatus, Spinizonocolpites echinatus, S. baculatus, Syncolporites poricostatus, Syndemicolpites sp, Tubistephanocolpites cylindricus, Verrucosisporites obscurilaesuratus and Zonosulcites parvus*. This assemblage is dated Late Maastrichtian – Paleocene [25,26] based the palynomorph assemblage.

22.50: Shale, dark gray to black and fossiliferous. Forms recovered include *Ammobaculities sp, A. Amabensis [18], A. coprolithiformis, Anomalinoides midwayensis, Haplophragmoides sp, H. nigeriense, H. talakaoense, H. sahariense, Trachommina sp, T. dutsuna, Bolivina sp, B. afra [2], Planulina nacatochensis, Textularia hocklyensis, T. biafrae [18], Gavelinella guineana [19], Spiroplectammina sp, S. semicomplanata, Heterohelix globulosa* [27], *Globotruncana sp, Bulimina sp, Cibicides harperi, Eponides reyment, E. pseudoelevatus, Valvulineria jacksonensis, Nonionella cummunis* in addition to shell fragments and coral fragments. This bed is dated Late Maastrichtian to Paleocene based on the foraminiferal assemblage and the environment of deposition is shallow inner to outer neritic. The palynomorphs recovered include *Andalusiella sp, Ariadnaesporites sp, A. longiprocessum, A. spinosus, Asplenium sp, Bacutriporites orluensis, Buttinia andreevi, Calamuspollenites pertusus, Cerodinium speciosum, Chlorophytum tuberosum, Cingulatisporites ornatus, Constructipollenites ineffectus, Cribroperidinium sp, Crototricolpites densus, Ctenoloponidites costatus, Cycapodites sp, Deflandrea sp, D. dentaculata, Dynogymnuim acumulatum, Echitriporites trianguliformis [23], Ephedripites*

costaliferous, Ephedriporites ambonoides, Filtrotriletes nigeriense, Foveotriletes margaritae, Gabonisporis bacaricamuus, Gleicheniidites senonicus, Hexaporotidapites emelianova, Homotryblium sp, Hystrichokolpama sp, Leiotriletes sp, L. adriennis, Lejeunecysta sp, Lentina sp, Longapertites sp, L. marginatus, L. microfoveolatus, L. vanendeenburgi, Lycopodiumsporites sp, Lygodiniumsporites adriennis, Mauritidites crassibaculatus, M. crassiexinous, Milfordia jardenei, Monocolpites sp, M. marginatus, M. sphaeriodites, Paleocystodinium sp, Polypodiidites sp, Proteacidites miniporatus, P. dehaani, P. longispinosus, Proxapertites operculatus, Psilatricolpites sp, P. nnwiensis, Reticolpites sp, Retidiporites sp, R. magdalenensis, Retimonocolpites irregularis, R. pluribaculatus, Selaginella myrosus, Selenopemphix sp, Senectotetradites varireticulatus, Senegalium bivacatum, Spiniferites sp, S. membranceous, Spinizonocolpites sp, S. adananteus, S. baculatus, S. echinatus, S. tenutabulatum, Striamonocolpites undostriatus, *Syncolporites sp, S. marginatus, Syndemicolpites sp, S. pertusus, S. typicus, Triporopollenites bituitus, Tubistephanocolpites cylindricus, Verrucosisporites obscurilaesuratus and Zonosulcites sp*. This assemblage is dated Late Maastrichtian – Paleocene [25,26].

0.60: Clay, reddish and highly fossiliferous. Forms recovered include *Eponides pseudoelevatus, Heterohelix globulosa [27], Gavelinella guineana, Anomalinoides midwayensis, Haplophragmoides sp, Anomalinoides midwayensiS, Haplophragmoides talakaoense, Bolivina afra [2], Siphogeneroides cretacea, Textularia sagttida, Globotruncana linneiana, Millammina petila* and *Dentalina sp*. In addition to coral fragments and pelecypods were also recovered. This bed is dated Late Maastrichtian - Paleocene and the environment of deposition is middle to outer neritic. No age diagnostic palynomorphs was recovered.

Location 4: Amanangwu-Arochukwu

0.91: Very fine to fine grained, lateritic.

3.66: Pebbly ironstone and sandstone fragment angular to sub-round in a clayey matrix. The clay yielded no palynomorphs but yielded the following foraminiferal species *Haplophragmoides talakaoense, Textularia hocklyensis* and *Bolivina explicata*. This bed is dated Late Maastrichtian based on the forams recovered and the environment of deposition is middle neritic.

2.63: Clay, lateritic with reddish to whitish patches. The clay yielded no palynomorphs but yielded the following forams *Bolivina* explicate [28], *Haplophragmoides hausa, Cibicides sp, Praebulimina laddi* and *Textularia talakaoense*. This bed is dated Late Maastrichtian based on the recovered forams and the environment of deposition is middle neritic.

2.31: Shale, gray to blackish and highly fossiliferous. The following palynomorphs were recovered *Muderongia sp, Ariadnaesporities longiprocessum, Wetzeliella sp, Deflandrae sp, Senegalinium bivacatum, Odontochina sp, Asplenium sp, Ariadnaesporities spinosus, Andalusiella sp, Syndemicolpities typicus, Wilsoniduim sp and Laevigatosporities sp. The foraminiferal biota includes Bolivina explicata, Haplophragmoides sp, H. talakaoense, H. saharience and Trochammina sp*. This bed is dated Late Maastrichtian – Paleocene based on the diagnostic palynomorphs and forams such as *Wetzeliella sp, Senegalinium bivacatum, Syndemicolpites typicus, and diagnostic foraminifera* such as *Bolivina explicata*, Afro bolivina afra, H. talakaoense and H. sahariense. The environment of deposition is upper bathyal.

0.91: Shale, reddish and highly fossiliferous. No palynomorphs recovered, this bed has abundant forams that include *Bolivina explicata, Afro bolivina afra, Haplophragmoides sp* and *H. talakaoense*.

12.2: Very fine to fine grained whitish sands with pinkish to reddish stains.

Discussion

Biostratigraphy

The clays and shales around Odoro Ikpe area have yielded no age diagnostic palynomorphs as only reworked forms were observed and has been interpreted as the Benin Formation because continental sediments may not contain fossils [3]. The shales below the Benin Formation have yielded age diagnostic foraminifera (planktonics and benthonics) - Bolivina species such as *Bolivina explicata, B. midwayensis and Morozovella species such as Morozovella aequa, M. conicotruncana, M. pseudobulloides, Planulina nacatochensis, Cibicides harperi, Eponides elevatusand Orthokarstenia clavata* has been observed.Based on the association of these forams the clays and shales are dated as Late Maastrichtian – Paleocene which correspond to the Nsukka Formation [18,29]. The implication of this age suggested for the Odoro Ikpe area is that the Benin Formation (comprising pebbly sandy and conglomeratic beds which have yielded no age diagnostic foraminifera and palynoflora), is younger than the Nsukka Formation and lies unconformably on older Cretaceous sediments (the Nsukka, Ajali and Mamu Formations). This agrees with conclusions reached that the pebbly sand and conglomeratic beds may not yield fossils because they may be continental in origin [3]. Inyang [7] placed the age of shale and clay beds below the pebble beds as Campanian to Early Eocene based on taxa he identified and referred to the clays and shales as Nkporo Shales. He concluded that these deposits post-date the shale and clay beds. In addition, the pebble beds contained no diagnostic fossil which is like the conclusion reached in this work. The only difference is in assigning the proper formational name based on the paleontological and palynological evidence. Based on this work, the identified forms fall within Nsukka Formation and places the shales and clays below the pebble beds as Late Maastrichtian to Paleocene (Nsukka Formation) based on the taxa identified such as *Bolivina explicata, B. midwayensis, B. crassicostata, B. africana, Morozovella aequa, M. conicotruncana, M. pseudobulloides, Planulina nacatochensis, Cibicides harperi, Eponides elevatus and Orthokarstenia clavata*. The conclusion reached in dating the beds around the Odoro Ikpe area are based on Petters [18] and Bassey [29], who in their work dated a similar association of benthonic and planktonic foraminifera in sediments they analyzed which include such forms as *Bolivina afra, Morozovella aequa, Anomalinoides midwayensis, A. umboniferous, Cibicides succedens, C. harperi, Eponides elevatus, E. pseudoelevatus and Orthokarstenia clavata as Nsukka Formation*. The clays, shales and limestone from the Obotme area have yielded age diagnostic foraminifera and palynomorphs. The shales comprise a lower bed and an upper bed interbedded by a limestone and a sandstone bed. The lower shale bed (4.00m) is dated as Maastrichtian based on the association of benthonic and planktonic forms, which corresponds to Mamu Formation [18,19,29]. The upper shale bed (28.00m) is intercalated by limestone; the age of these beds is dated as Late Maastrichtian – Paleocene based on benthonic foraminifera identified [18,19,29]. The palynomorph taxa around the Obotme area consist of pollens, spores, dinoflagellates, foram linings and fungal spores dated as Maastrichtian – Paleocene which corresponds to Nsukka

and Mamu Formations [26,30,31-35,]. Benthonic and planktonic foraminiferal species identified from shale and limestone samples around Arochukwu area and include *Haplophragmoides telokaense, Haplopharagmoides sahariense, Ammobaculites amabensis, Ammobaculites coprolithiformis, Cubicides harperi, Planulina nacatochensis, Anomalinoides midwayensis, Bolivina afra, Heterohelix globulosa, H. striata, Hedbegella monomouthesis, Globorotrunca sp, G. linneriana, Morozovella aequa, M. conicotruncana* and *Globigerina fringa*. The shale units from Akama, Amuvi and Asaga are dated Late Maastrichtian to Paleocene which correspond to the Nsukka Formation while the shale unit from Ututu area is dated as Maastrichtian which correspond to the Mamu Formation based on the palynomorph assemblage identified [19]. Both foraminifera and palynological assemblages demonstrate agreement in age and complement each other in dating of the formations under study as they all fall within the Maastrichtian to Paleocene. Based on the results and interpretation of biostratigraphic analysis, fieldwork and correlation, there is lateral continuity of lithostratigraphic units from the Arochukwu section (Cretaceous sediments) to the Odoro Ikpe area where it is uncomformably overlain by the Benin Formation (younger Tertiary sediments) defining an unconformity and a Cretaceous – Tertiary (K –T) boundary? The results of the current biostratigraphic analyses did not indicate the presence of the Imo Shale, Ameki and Ogwashi – Asaba Formations in the study area.

According to [36], the planktonic foraminifera by convention are used for age dating whereas the benthonic foraminifera are used for paleoenvironmental interpretation. The benthonic forams do not only provide a basis for stratigraphic correlation of already established relative ages of lithostratigraphic units in other parts of Nigeria but also serves as indirect link to worldwide chronostratigraphy. Some benthonic genera identified include Ammobaculites, Textularia, Haplophragmoides, Osangularia, Reophax, and Trachommina. Ammobaculites is an infaunal deposit feeder that lives in muddy sediments with brackish to normal – marine salinities; marsh to bathyal environment and is tolerant of low oxygen levels. Textularia species inhabit normal marine environment ranging from lagoon to bathyal and live epitaurally on land substrates, muddy silts, and sand. Trochammina settles as an infaunal or epitaural deposits and plant feeder in a wide range of environment and water depth. It is also tolerant of low oxygen level. Reophax is mainly a marine genus; it has also been reported from brackish lagoons and estuaries. Osangularia species live in modern oceans from outer neritic to bathyal environment with normal marine salinities and prefer muddy sediments. The results show that the benthonic foraminifera predominate in all samples analyzed except for few samples that are barren.

Summary

A Late Maastrichtian – Paleocene age is assigned to the sediments (clay, shale and limestone units) which make up part of the lithostratigraphic units in the study area (Figures 2 and 3). The assigned age corresponds to Mamu and, Nsukka Formations based on the association of mainly benthic and few planktonic taxa such as the following foraminifera *Ammobaculites sp, A. amabensis, A. bauchensis, A. numanhensis, A. coprolithiformis, Bulimina sp, Bolivina sp, B. afra* [2], *B. explicata, Haplophragmoides sp, H. sahariense, H. saheliense, H. nigeriaense , H. talakaoense, Nonionella insecta, Milliamina pindigensis* [18], *M. petila, Valvulineria aegyptica* [22] *V. jacksonense Anomalinoides midwayensis, A. unboniferous, Margulina dorsata, Gavelinella guineana* [19], *Elphidiella Africana [22], Planularia nacatochensis* [28], *Cibicides harperi* [21], *C. succedens* [20], *Morozovella aqua, M. acuta, Nonionella cummunis, Fursenkoina wilcoxensis, F. nigeriana, Eponides elevatus, E. Reyment* [37], *E. pseudoelevatus, Lenticulina midwayensis, Textularia hocklyensis, T. biafrea* [19], *Trachommina sp, T. dutsua, Spiroloculina sp, Spiroplectammina sp, S. semicomplanata, Heterohelix Striata, H. globose* [27], *Siphongeneriniodes sp, S. cretacea, Osangularia sp, Nodosaria sp, Quinqueloculina sp, Saracenaria sp, Globorotalia haynesi, Globotruncana sp, G. linneiana and Reophax minuta* [18,19]. *And palynomorphs recovered such as Cribroperidinuim 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* [26,30,31,33-35,38]. The environment of deposition is interpreted as shallow inner neritic to outer neritic, based on the occurrence ostracods, pelecypods and gastropods along with foraminifera. The environment of deposition ranges from raised bog to lagoonal [26] based on the palynological analyses carried out. An overall increase in the abundance of pollen/spores in the study area suggest proximity to the shore line. According to [11] the limestone at Obotme area occurs as an intercalation within the Imo Shale, current study interprets the shale as Nsukka Formation based on both foraminifer and palynomorphs identified and places the limestone within the Nsukka Formation thus the limestone around Obotme area is an intercalation within the Nsukka Formation. The Nsukka Formation based on correlation and the results of the biostratigraphic analyses (current study) was traced from Arochukwu area to Odoro Ikpe where it is overlain by Benin Formation. This age agrees with earlier works in this region by Simpson [1], Reyment [2], Kogbe [3], Avbovbo [4], Petters [6], Amajor [5] and Inyang [7]. The absence of the Imo Shale may represent a hiatus or an erosional surface in the study area.

Conclusion

A Late Maastrichtian – Paleocene age is assigned to the sediments (clay, shale and limestone units) which make up part of the lithostratigraphic units in the study area. The assigned age corresponds to Mamu and, Nsukka Formations based on the association of mainly benthic and few planktonic taxa.

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