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CHRONOSTRATIGRAPHIC EVALUATION OF THE LATE CRETACEOUS-RECENT SEDIMENTS IN PARTS OF CALABAR FLANK

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ABSTRACT

The stratigraphic and paleontologic analyses of the Late Cretaceous to Recent sediments in parts of the Calabar Flank were carried out using outcrop data. The present study is aimed at a high-resolution biostratigraphic study for relative age dating and correlation of chronostratigraphically significant faunal assemblages. From available results, the co-occurrences of *Hedbergella delrioensis*, *H. planispira*, *Heterohelix moremani* were used to assign a probable Aptian to Albian age for the Awi Formation. The co-occurrences of *Ammobaculites bauchensis*, *Miliammina pindigensis* and *Trochammina wickendeni* was used to assign an Albian age for the Mfamosing limestone. This was supported by occurrence of *Steevesipollenites sp.*, *S. giganteus*, *S. binodosus*, *Ephedripites jansonii*. The co-occurrences of *Heterohelix reussi*, *H. moremani*, *Hedbergella delrioensis*, *H. simplicissima* assigned a Late Turonian – Coniacian age to the New Netim Marl in the area with only *Syncolporites subtilis* as the only identified palynomorphs supporting this age. The age diagnostic planktic assemblage comprising of *Guembelitra harrisi*, *Clavohedbergella simplex*, *Heterohelix reussi*, *H. moremani*, *H. pulchra*, *Whiteinella archaeocretacea* and *Praeglobotruncana inornata* was used to assign a Cenomanian to Early Turonian age to the Ekenkpon Shale. This age is also supported by the co-occurrences of *Steevesipollenites sp.*, *Classopollis sp.*, *C.jardinei*, *Ephedripites multicostatus*, *E. procerus*, *E. strigatus*, *E. subtilis*. The co-occurrences of *Rugoglobigerina rugosa*, *Bolivina afra*, *B. explicata*, *Praebulimina exigua*, *Ammobaculites amabensis*, and *A. coprolithiformis*, confirm a Late Campanian – Maastrichtian for the Nkporo Shales aided by the co-occurrences of *Ctenolophonidites costatus*, *Longapertites marginatus*, *Proteacidites longispinosus*, *Cingulatisporites ornatus*, *Constructipollenites ineffectus*. The Late Miocene to Early Pliocene age interpretation of the Benin Formation sediments encountered in the area is based on the co-occurrences of *Pachydermites diderixi*, *Nymphaepollis clarus*, *Retibrevitricolporites obodoensis*, *Retistephanocolporites gracilis*, *Gemmamonoporites sp* and *Stereisporites sp*.

1.0 INTRODUCTION

The stratigraphic evolution of the various basins and sub-basins of the Southern Nigeria continental margin has been attributed to the differences in their structural and tectonic framework through time. These include both tensional and compressional regimes for the Pre-Santonian basins. The complex stratigraphic nomenclatures and mix-up in the region have been a subject of lively controversies. This problem may be linked to inaccurate basin delineation and other field mapping strategies. Several attempts had been made in the past to correlate various lithologies in the basins with reference to its chronostratigraphic equivalence.

Harmonization of lithostratigraphic nomenclature in line with standard practice is still on-going. The Nigerian Geological Survey Agency is saddled with onerous task of mapping and producing standard geologic maps of the country with all the updated codes, but surprisingly the old lithostratigraphic nomenclatures are still in vogue.

The Calabar Flank is a sedimentary basin bordering southeastern Nigeria continental margin. It is at right angle to the major rift faults of the Benue Trough. It is characterized by crustal block faulting trending in the NW-SE direction (Reijers and Petters, 1987). The evolution of the basin is intimately connected to the breakup of the African and South American plates as has been described by several workers (Grant, 1971; Burke et al, 1972; Olade, 1975).

The sedimentary basin was controlled by vertical movements of faulted blocks notably the Ituk High and the Ikang Trough and by associated transgressions and regressions (Murat, 1972; Nyong, 1995).

The present study is aimed at a high-resolution biostratigraphic study for relative age dating and correlation of chronostratigraphically significant faunal assemblages.

Location of study

The study area is located between Longitude $8^{\circ}15'$ and $8^{\circ}30'E$ and Latitude $5^{\circ}00'$ and $5^{\circ}15'N$. The area is accessible through major highway, Calabar-Ikom, Calabar-Ikang. The study area covers the following towns Odukpani, Mfamosing, Akamkpa, Uwet, Ekenkpon, Oberekai etc. The study area is located between Longitude $8^{\circ}15'E$ and $8^{\circ}30'E$ and Latitude $5^{\circ}00'N$ and $5^{\circ}15'N$. The spatial distribution and accessibility of the study area are presented in Figure 1, which shows the location map of the Calabar Flank and surrounding towns.

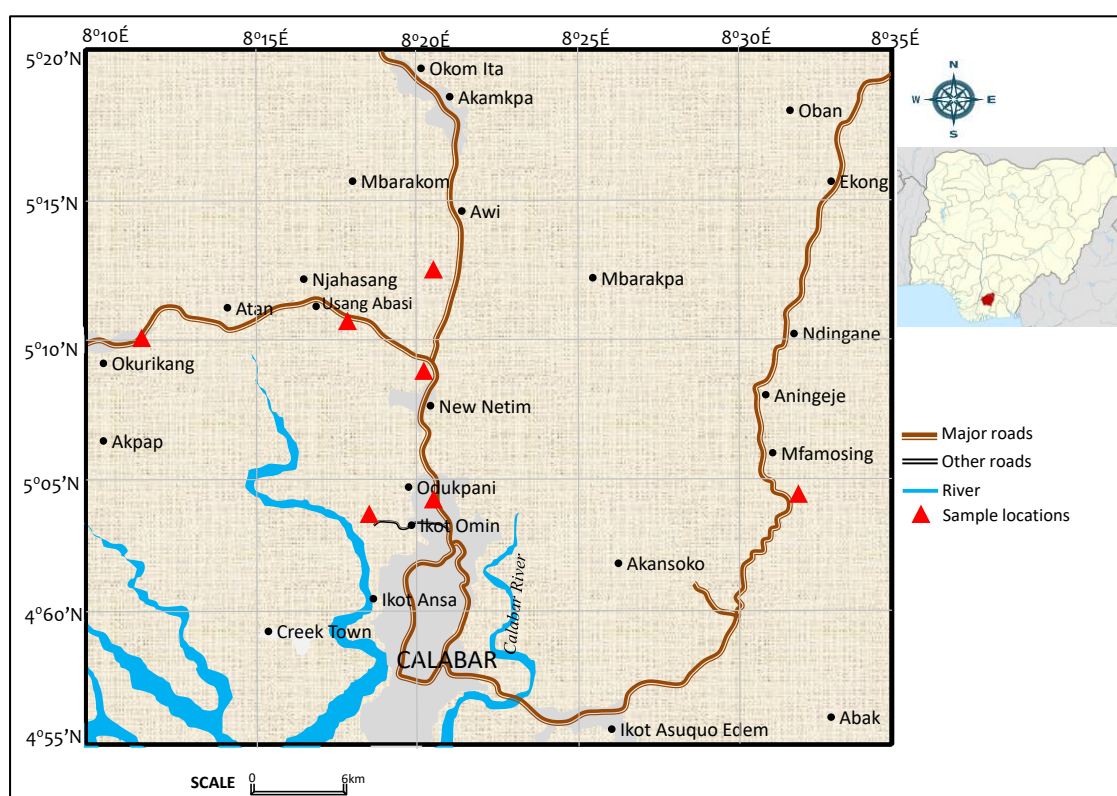


Fig. 1 Location map of the study area

Lithostratigraphic Components of the Calabar Flank

The Awi Formation

Awi formation is the oldest unit in the calabar flank, between Aptian-Albian age and rests unconformably on the Oban massif basement complex of Nigeria. The Awi formation represents deposition during the low stands of the sea during the Aptian Stage (? 125-110Ma)

The formation is about 50m thick and consists dominantly of conglomerate and sandstone units with minor mudstones, shales and some carbonaceous materials in a cyclic fining upward unit. (Nyang 1995, Umeji 2006).

The name Awi formation was proposed by (Adeleye and Fayose, 1978) to be the basal arenaceous part of the Odukpani formation. They delineated a type of section and retained the name Odukpani for the rest of the succession. (Adeleye and Fayose, 1978) described the Awi formation as fluvio-deltaic, partly fossiliferous and consist of cross bedded sandstones, siltstone, mudstone, claystone, conglomerate and shales. (Ramanathan and Kumaran, 1981), described the Awi formation as a fluvial and shallow littoral depositional environment.

The Awi formation is devoid of foraminifera and Ostracod (Petters 2015). This agrees with the study of (Nton, 1999) and is largely due to its environment of deposition (fluvial system). It is however rich in microflora (Odebode, 1982; Ramanathan 1981). A recent study on the Awi formation by (Itan and Inyany, 2015) also pointed out that the Awi formation is lacking fossils.

Mfamosing Formation

As a component of the Asu River Group, the regional extent of the Mfamosing limestone is seen as an arcuate belt hugging the southwestern margin of the exposed part of the Oban massif in the calabar flank. The mfamosing limestone is correlatable with south Atlantic platform carbonates across the Guinea Ridge. Mfamosing Formation comprises a depositional sequence formed during the second-order global sea level cycle representing the Mid-Albian Stage (103-96.6 Ma). Mfamosing facies has been assigned to marginal marine environment resulting from a major marine transgression in the late Albian-Cenomanian. The over 300m thickness of Albian carbonates proved from the subsurface (ituk well), is the thickest carbonate buildup in Nigeria (Petters and Reijers, 1986). In the quarry site and elsewhere, the limestone is highly cavernous. This is attributed to partial dissolution, followed by roof collapsed or later movements along faults. Studies by petters and Reijers(1996), revealed extensive karstification. The limestone body had been built on carbonate platforms on the offshore basement high that rimmed the Oban massif. The Mfamosing Limestone Formation was exhumed during a period of epeirogenic uplift associated with Neogene tectonics along the Cameroon Volcanic Line; subsequently the limestones were subjected to karst weathering. The tectonism produced fracturing and faulting in the limestone, that further enhanced karstification. The best outcrop locations are the Mfamosing Quarry; a locality near Etankpini village with extensive karst developments. Ekwueme (1987) study of the Mfamosing limestones, revealed similar fractures and karsts. Here, dissolution has created gorges, tunnels, and caves, many of them featuring well developed stalagmites and stalactites.

Ekenkpon Formation

The Ekenkpon formation is a thick sequence of black to grey shale unit, the formation is characterized by minor intercalation of marls; calcareous mudstone and oysters beds. This shale unit was deposited during the late Cenomanian-Turonian times, as a result of a regressive sea movement, in a marine environment. Two genetic sequences corresponding to the second order cycles (Albian-Early Cenomanian) and (Late Cenomanian-Mid-Turonian) were recognised for the Ekenkpon Shales. The Eze aku shale is represented by the Ekenkpon shale which is overlain by Awgu shale, which is also represented by New Netim marl. A thick marl unit.

The New Netim Formation

New Netim formation is dominantly made up of thick shale unit, characterized by minor intercalation of marls, calcareous mudstones and oyster beds. A nodular marlstone interbedded with thin beds of shales. New Netim marl unit was deposited during the late Turonian-Coniacian times, as a result of a transgressive sea movement, corresponding to the third order sedimentary cycles in a marine environment.

Nkporo Formation

The formation consists of dark grey to black, fissile, friable and soft shales and mudstones with occasional thin beds of sandy shale, fine grained sandstone and marl with coatings of sulphur. Rare thin bands of shelly limestone are present. (Nwajide, 2013). Campano-Maastrichtian times, in a marine environment.

The stratigraphic relationships and age distribution of the lithostratigraphic units discussed above are summarized in Table 1, which presents a generalized stratigraphic chart of the Calabar Flank (modified after Petters et al., 2010).

Table 1: Stratigraphic chart of the Calabar Flank (Modified after Petters et al., 2010)

AGE	LITHOLOGY		DESCRIPTION
Recent Eocene -	Benin Formation		Loose sands, pebbly and arkosic
Maastrichtian L. Campanian -	Nkporo Shale		Dark grey, very fissile carbonaceous shale with gypsum bands and some calcareous nodules
Santonian	Santonian Deformation		Santonian deformational episode characterized by period of folding of pre-existing rocks and erosion and/or non deposition.
Coniacian	ODUKPANI GROUP	New Netim Marl	Dark grey massive marls intercalating with flaggy, calcareous grey shale with thalassimoides structures
Turonian		Ekenkpon Shale	Grey fissile shale with thin bands of calcareous nodules, limestone and mudstone units. Abundant shell fragments, keeled ammonite, juvenile
Cenomanian		Un-named Shale	Dark gray shale, highly fissile and separated by the upper shale unit by a regressive mudstone
Mid - Albian		Mfamosing Limestone	White to light grey limestone, stromatolitic at the base, with abundant fossils (gastropods, corals, shell fragments)
Neocomian - Aptian	Awi Formation		Reddish brown, coarse to medium grained arkosic sandstone. Pebbly at the base and exhibit fining upward succession in cycles, graded bedding.
Precambrian	Precambrian Basement Complex		Southeastern Basement Complex – Oban Massif composed predominantly of granite gneisses, granites and granodiorites.

2.0 METHODOLOGY

Field Mapping

This involves the following:

Detailed geologic mapping and description of outcrop section. The lithologic relationship in the outcropping profile, the nature of contacts, texture, composition, fossil contents and the sedimentary structure was used to identify the various lithofacies. The attitude of the bed was measured with the aid of Brunton Compass, while steel tape was used for measurement of the vertical thickness of the units.

Collection of rock samples using the geologic hammer, while hand auger was used for loose, unconsolidated sediments. All sample locations was georeferenced to the base map using a (GPS). Photograph of the outcrop and features of interest was taken

Biostratigraphic Analyses

Foraminiferal and palynological analysis are the two biostratigraphical methods that shall be carried out using rock samples.

Details of the procedures for these analyses are presented in the following sub-sections

Foraminiferal Sample Preparation and Analysis

Representative fresh rock samples were prepared following standard procedures: crushing, soaking in distilled water and anhydrous Sodium Trioxocarbonate IV (NaCO_3) to disaggregate thoroughly, then passed/sieved using 53-micron sieve. The washed samples are then dried in an oven at a minimum temperature of 20°C , they were further separated into three (3) fractions namely coarse, medium and fine for easy picking. All three representative size fractions were examined and foraminiferal forms were picked and placed in a gridded picking tray. The picked microfauna are grouped according to genera and species with the aid of picking brush under binocular reflection microscope. The picked fauna are subjected to species identification and abundance and diversity counts. The identification of the foraminiferal taxa was based on comparison with standard manuals such as Adegoke *et al*, 2017, Petters, (1982 and 1983), SHELL foraminiferal photocatalogue for Foraminifera.

Palynological sample preparation and Analysis

Fresh shale and mudstone samples from ditch cuttings and outcrops were used for palynological analysis. The samples are subjected to treatment with dilute hydrochloric acid (HCl) to remove any available carbonate in the sample. Samples are first treated with warm 36% HCl, then cold HCl to remove fluoride gels, then washed with 0.5% HCl. The samples were then transferred into small 15cm^3 centrifuge tubes. The 0.5% HCl was decanted and then Zinc Bromide (with specific gravity of 2.2) was added and properly stirred with a glass rod. After centrifuging, the floating top part consisting of organic material was gently decanted into another tube. The organic material is then thoroughly washed with water. The organic residue is then transferred into a porcelain basin, and concentrated Nitric acid (HNO_3) is gently added. The mixture was warmed for a few minutes and stirred properly with a glass rod, later centrifuged and the Nitric acid decanted, and the residue thoroughly washed with distilled water. Warm potassium hydroxide (KOH) is added to the residues and allowed to stand for about 5 minutes. It was then centrifuged and KOH decanted. The residue was washed for about two to three times with distilled water in order to ensure that all the KOH is washed out. The residue was finally washed twice with alcohol. A biological microscope was used for the analysis, whereby species were identified by comparison using standard manuals e.g the Evamy, *et al* (1978), and Shell Petroleum Development Company (SPDC) Photo Album, etc. The abundance of the diverse palynological groups were recorded accordingly and tallied by numbers.

The Biozonation on the other hand, was achieved by using standard published scheme; Dim *et al*, (2017). This was complemented by the stratigraphic ranges of foraminiferal species / biozonation of Petters, 1982, Evamy *et al*, (1978); Germeraad *et al*, (1968); and Stratcom (2002).

3.0 RESULTS

3.1 Results of Foraminiferal Analysis

Along Calabar-Lagos coastal High way off Odukpani road (Awi Formation)

Five of the six samples in this outcrop location were barren of foraminifera. The moderately high occurrences of *Hedbergella delrioensis*, *H. planispira*, *Heterohelix moremani*, *Trochammina wickendeni*, *Ammobaculites agrestis*, *A. obliquus* and *A. subcretacea* were obtained from the intercalating shale in the lower section of this predominantly sandstone lithofacies (Fig 2).

UNICEM Main gate (Mfamosing Limestone)

The very low occurrences of arenaceous taxa: *Ammobaculites sp*, *A. bauchensis*, *Haplophragmoides sp*, *H. bauchensis*, *Milammina sp*, *M. pindigensis* and *Trochammina wickendeni* constitute the foraminiferal distribution at this outcrop section (Fig 3).

KM 22.8 Calabar – Ikom Highway (Ekenkpon Shale)

The foraminiferal distribution in this outcrop location is composed of planktic species such as *Heterohelix globulosa*, *H. reussi*, *H. moremani*, *H. pulchra*, *Hedbergella delrioensis*, *H. planispira*, *H. crassa*, *H. hoelzli*, *H. portsdownensis*, *H. amabilis*, *Clavihedbergella simplex*, *Praeglobotruncana inornata*, *Whiteinella archaeocretacea*, and *Guembelitra harrisi*; Calcareous benthic species, *Bolivina cretosa*; as well as agglutinated species, *Ammobaculites agrestis* and *A. subcretacea* (Fig 4).

Behind New Shopping Centre at Odukpani Junction (Ekenkpon Shale)

The foraminifera found in the sediments at this location is composed of very low to moderate occurrences of planktic taxa such as; *Heterohelix sp*, *H. reussi*, *H. moremani*, *Hedbergella sp*, *H. delrioensis*, *H. planispira*, *H. sigali*, *H. crassa*, associated with arenaceous benthic taxa: *Haplophragmoides sp*, *Ammotium bornum* and *A. nkalagum* (Fig 5).

Section near CRS Power Plant along Calabar-Itu Highway (New Netim Marl)

The foraminiferal assemblage at this outcrop location; is entirely planktonic and consists of very low to moderately high occurrences of *Heterohelix sp*, *H. reussi*, *H. moremani*, *Hedbergella sp*, *H. delrioensis*, *H. planispira*, *H. sigali*, *H. simplicissima*, *H. crassa*, *H. hoezli*, *Whiteinella sp*, *W. balthica*, *Clavihedbergella sp*, *C. subcretacea*, *Rugoglobigerina macrocephala*, *etc*

Km 20.4 Calabar – Ikom Highway (Nkporo Formation)

The samples from this outcrop location yielded very low to moderately high foraminiferal taxa comprising of planktic species such as *Rugoglobigerina rugosa*, *Hedbergella sp*, *Heterohelix pulchra*, *Archaeoglobigerina cretacea*, *Globotruncana rosetta* and *G. fornicata*; benthic species such as *Planulina sp*, *Gabonita sp*, and *Cibicides harperi* as well as a singular arenaceous taxon; *Ammobaculites sp* (Fig 6).

Km 39 Calabar – Itu Highway (Nkporo Formation)

The samples from this outcrop location yielded very low to moderately high foraminiferal taxa. The occurrences of a singular planktic species, *Rugoglobigerina rugosa*; is associated with the occurrences of calcareous benthic taxa (*Bolivina afra*, *B. explicata* and *Praebulimina exigua*) as well as arenaceous benthic taxa such as *Ammobaculites sp*, *A. amabensis*, *A. coprolithiformis*, *Haplophragmoides sp*, *H. sahariense*, *H. saheliense*, *H. excavata*, *Miliammina sp*, *M. pindigensis*, *M. petila*, *Textulariopsis dukamaijina*, etc (Fig 7).

KM 4 From Tinapa Junction (Benin Formation)

Most of the samples from this location were barren of foraminifera. Only three (3) samples yielded long-ranging undiagnostic arenaceous foraminifera: *Ammobaculites sp* and *Haplophragmoides sp* (Fig 8).

Thus from the foraminiferal perspective, the age could not be determined

3.2 Results of Palynological Analysis

Along Calabar-Lagos coastal High way off Odukpani road (Awi Formation)

The very low to low occurrences of an indeterminate pollen species is associated with spores (*Laevigatosporites sp*, *Verrucosisporites sp* and *V. farvus*) and fungi (*Fungal spore* and *Fusiformisporites sp*) constitute the palynofloral suite at this outcrop location (Fig 2).

UNICEM Main gate (Mfamosing Limestone)

The samples from this location yielded very low to moderately high abundance of palynoflora of various categories; pollens (*Ephedripites sp*, *Longapertites sp*, *Multiporopollenites polygonalis*, *Retitricolporites sp*, etc); Spores (*Leiotriletes sp*, *Lycopodiumsporites sp*, *Circacosisporites sp*, *Converrucosisporites proxigranulatus*, etc); Fungal spore; Dinocyst (*Dinocyst indet.sp* and *Lingulodinium sp*) as well as Foraminiferal lining (Fig 3).

KM 22.8 Calabar – Ikom Highway (Ekenkpon Shale)

The samples from this location yielded low to high abundance of palynoflora of various categories; pollens (*Ephedripites sp*, *Syncolporites sp*, *Monocolpopollenites sphaeroidites*, *Psilastephanocolpites sp*, etc); spores (*Foveotriletes margaritae*, *Leiotriletes sp*, etc); Dinoflagellate cysts (*Selenopemphix sp*, *Cribroperidinium sp*, *Lingulodinium sp*, *Spiniferites sp*, *Apectodinium sp*, *Andalusiella sp*, *Hystrichokolpoma sp*, etc) and foraminiferal test lining (Fig 4)

Behind New Shopping Centre at Odukpani Junction (Ekenkpon Shale)

The samples from this location yielded low to high abundance of palynoflora of various categories; pollens (*Ephedripites* sp, *Multiporopollenites* sp, *M. polygonalis*, *Monocolpopollenites sphaeroidites*, etc); spores (*Circatrisporites* sp, *Leiotriletes* sp, *Cycadosporites granulatus*, etc); Fungal spore, Dinoflagellate cysts (*Cribroperidinium* sp, *Lingulodinium* sp and *Dinoflagellate indeterminate* sp) as well as Foraminiferal test lining (Fig 5).

Section near CRS Power Plant along Calabar-Itu Highway (New Netim Marl)

The samples from this location yielded low to high abundance of palynoflora of various categories; pollens (*Ephedripites* sp); Spores (*Leiotriletes* sp, *L. adriennis*, *Circatrisporites* sp); Fungal spores, Dinoflagellate cysts (*Selenopemphix* sp, *Cribroperidinium* sp, *Spiniferites* sp and *Homotryblium* sp); as well as Foraminiferal test lining.

Km 20.8 Calabar – Ikom Highway (Nkporo-Benin Formation contact)

The samples from this location yielded low to high abundance of palynoflora of various categories of pollens (*Psilatricolpites* sp, *Ephedripites* sp, *Proteacidites miniporatus*, *Monocolpopollenites sphaeroidites*, *Retitricolporites* sp, *Azolla cretacea*, *Syndemicolpites typicus*, *Cyathidites minor*, *Cycadopites granulatus*, *Proxapertites* sp, etc); Spores: (*Foveotriletes margaritae*, *Leiotriletes* sp, *L. adriennis*, *Lycopodiumsporites* sp, *Rugulatisporites* sp, *R. caperatus*, *Laevigatsporites ovatus*, etc); Fungi (*Fusififormisporites* sp and *Multicellites* sp); Freshwater algae (*Concentricytes circulus*); Dinoflagellates (*Leujeunecysta* sp, *Selenopemphix* sp, *Cribroperidinium* sp, *C. tenuitabulatum*, *Spiniferites* sp, *Operculodinium* sp, *Andalusiella* sp, *Paleocystodinium* sp, *Andalusiella* sp, *A. polymorpha*, etc); Foraminiferal test lining; Acritarchs (*Acritarch* sp and *Leiosphaeridia* sp) (Fig 6);

Km 39 Calabar – Itu Highway (Nkporo Formation)

The samples from this location yielded low to very high abundance of palynoflora of various categories of pollens (*Monocolpites* sp, *Syncolporites* sp, *Longapertites* sp, *Proteacidites miniporatus*, *Retitricolporites annulatus*, *Tripoporopollenites brutus*, *Retitricolpites punctatus*, and *Longapertites rotulatus*, etc); Spores (*Foveotriletes margaritae*, *Leiotriletes* sp, *L. adriennis*, *Gleichenioidites senonicus*, *Lycopodiumsporites* sp, and *L. adriennnis*, etc); Dinoflagellate cysts (*Selenopemphix* sp, *Cribroperidinium* sp, *Spiniferites* sp, *Apectodinium* sp, *Dinogymnium acuminatum*, *D. cooksoniae*, *D. auclaensis*, *Paleocystodinium* sp, and *Senegalinium bicavatum*, etc); foraminiferal test lining and Fungal spores (Fig 7)

KM 4 From Tinapa Junction (Benin Formation)

The samples from this location yielded low to very high abundance of palynoflora of various categories of pollens (*Alchornea cordifolia*, *Elaeis guineensis*, *Monoporites annulatus*, *Psilatricolporites crassus*, *Retitricolporites irregularis*, *Striatricolporites catatumbus*, etc); Spores (*Selaginella myosurus*, *Verrucatosporites alienus*, *V. tenellis*, *Laevigatsporites discordatus*, etc); Fungal spores, Freshwater Algae (*Concentricytes circulus* and *Botryococcus brauni*); Dinoflagellate cysts (*Leujeunecysta* sp, *Selenopemphix* sp, *Cribroperidinium* sp, and an indeterminate Dinoflagellate sp) as well as Foraminiferal test lining (Fig 8)

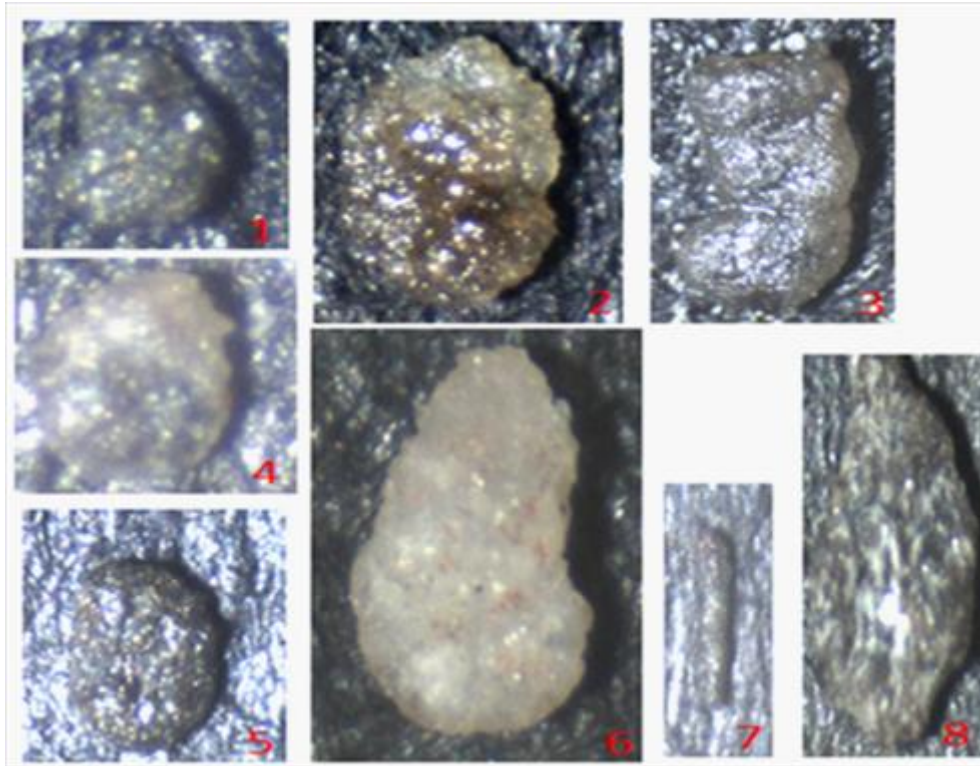


Plate I. Photo micrographs of some diagnostic forms of the benthic foraminifera recovered from the sediments studied: 1. *Ammotiumnwalium* (Petters, 1979f) Side view ($\times 500$), 2. *Ammotiumnkalagum* (Petters, 1979f) Side view ($\times 400$), 3. *Ammobaculitescoprolithiformis* (Schwager, 1868) Side view ($\times 350$), 4. *Haplophragmoides bauchensis* (Petters, 1979f) Spiral view ($\times 350$), 5. *Ammobaculites* sp. (Cushman, 1910) Side view ($\times 500$), 6. *Ammobaculitesbenuensis* (Petters, 1979f) Side view ($\times 300$), 7. *Reophax* sp. (De Monfort, 1808) Side view ($\times 600$), 8. *Ammobaculitesjessensis* (1979f) Side view ($\times 300$).

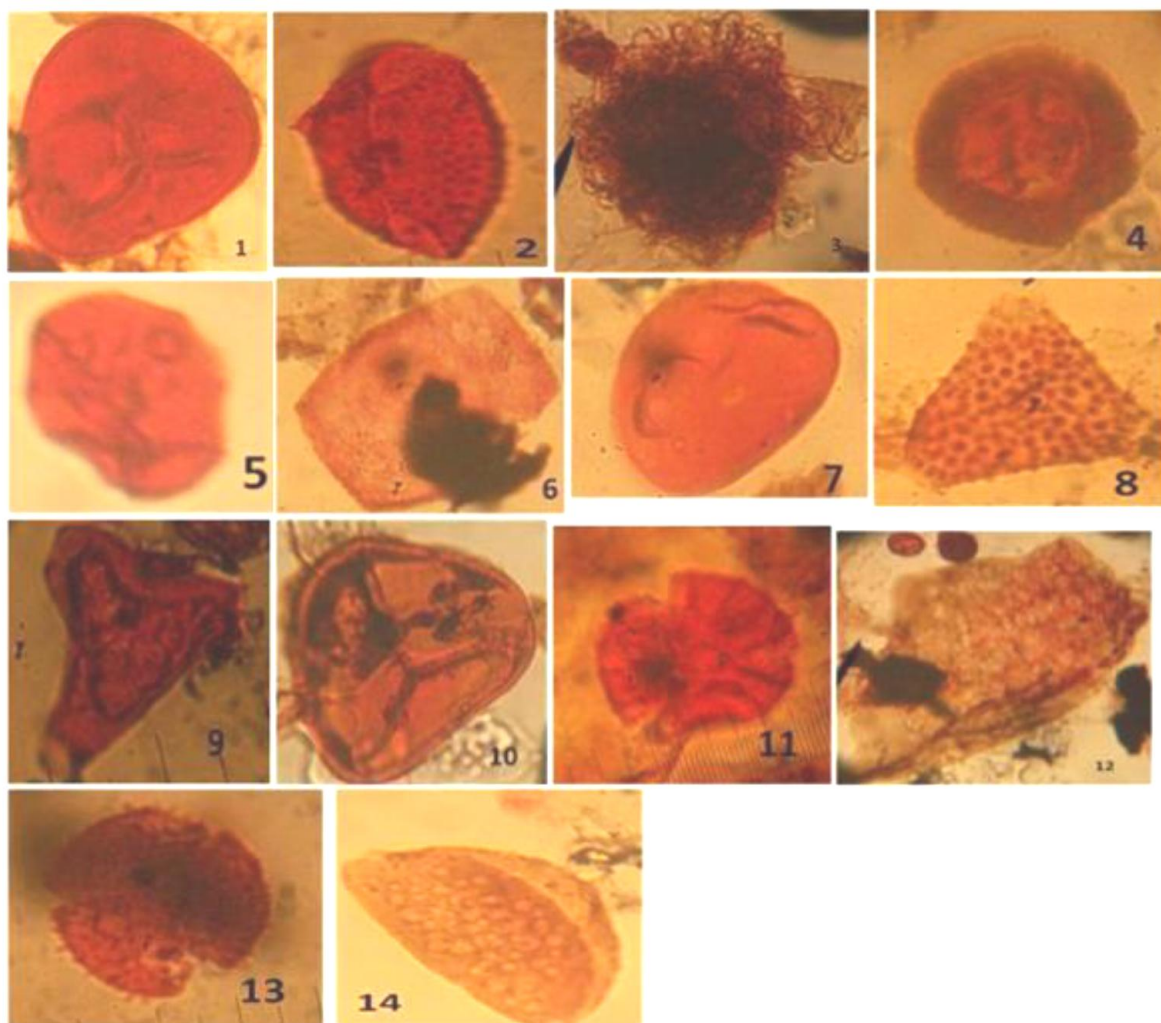


Plate II. Photomicrographs of some identified palynomorphs

1. *Leiotriletes maxoides*
2. *Echimonocolpites major*
3. *Araidnaesporites nigeriensis*
4. *Cingulatisporites ornatus*
5. *Monoporites annulatus*
6. *Retidiporites magdalenensis*
7. *Laevigatosporites ovatus*
8. *Echitriporites trianguliformis*
9. *Proteacidites miniporatus*
10. *Cyathidites australis*
11. *Retistephanocolpites williamsi*
12. *Longapertites vaneedenburgi*
13. *Echitricolporites maristellae*
14. *Longapertites marginatus*

Outcrop Section: Off Calabar-Ikom Highway along the new Cal-Lagos coastal highway

INTEGRATED BIOSTRATIGRAPHY OF AWI FORMATION

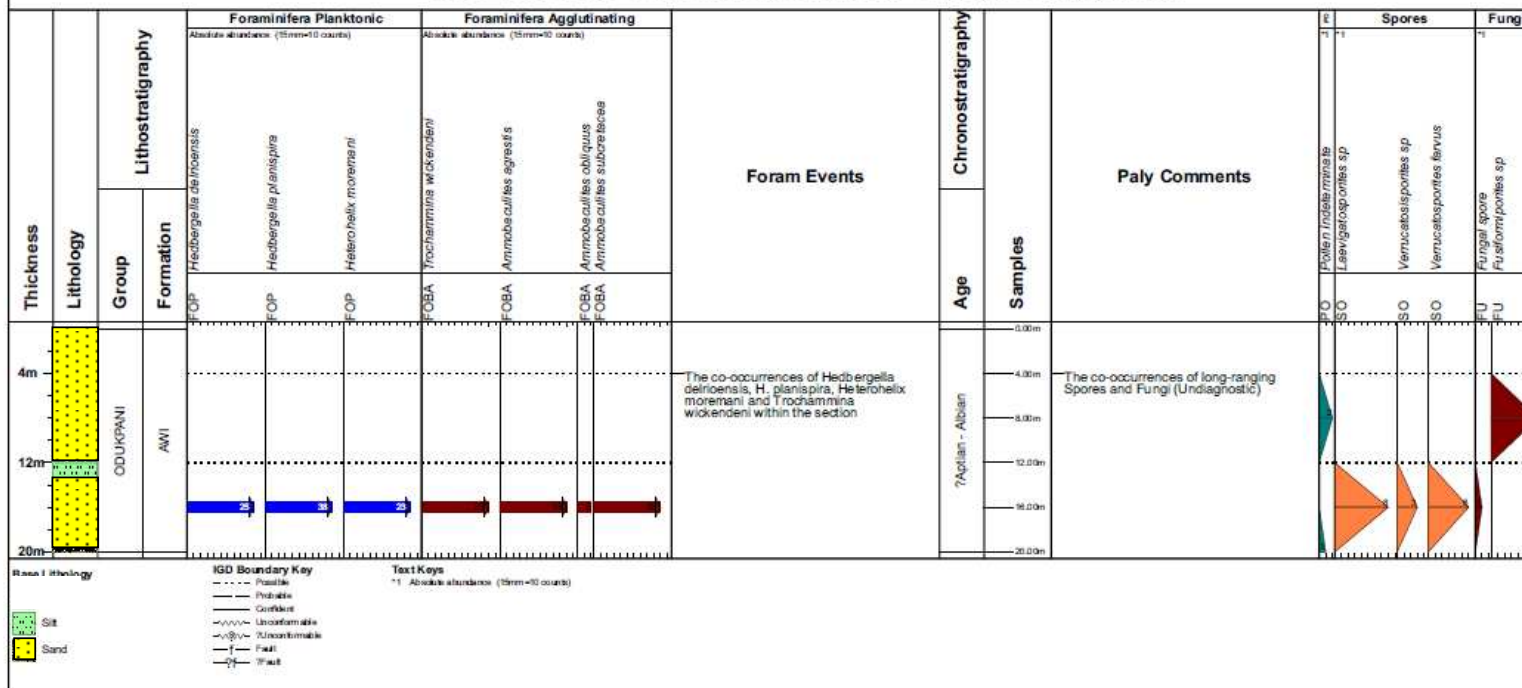


Fig. 2 Integrated biostratigraphic chart of Awi Formation along the new Calabar-Lagos coastal highway

Section: Mfamosing Limestone at Unicem
Main gate

INTEGRATED BIOSTRATIGRAPHY OF MFAMOSING LIMESTONE

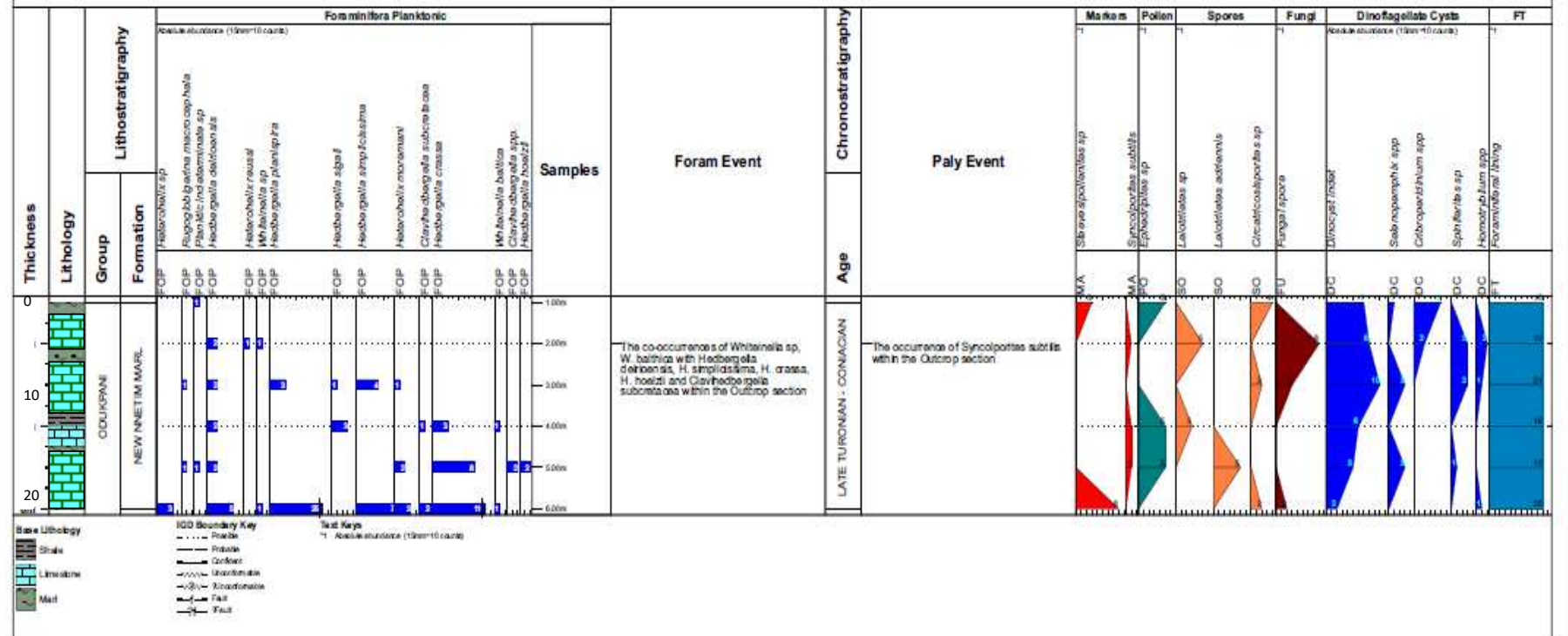


Fig. 3 Integrated biostratigraphic chart of Mfamosing Limestone at UNICEM maingate

Section: Ekenkpon Shale at km 22.8 Calabar-Itu Highway

INTEGRATED BIOSTRATIGRAPHY OF EKENKPON SHALE FORMATION

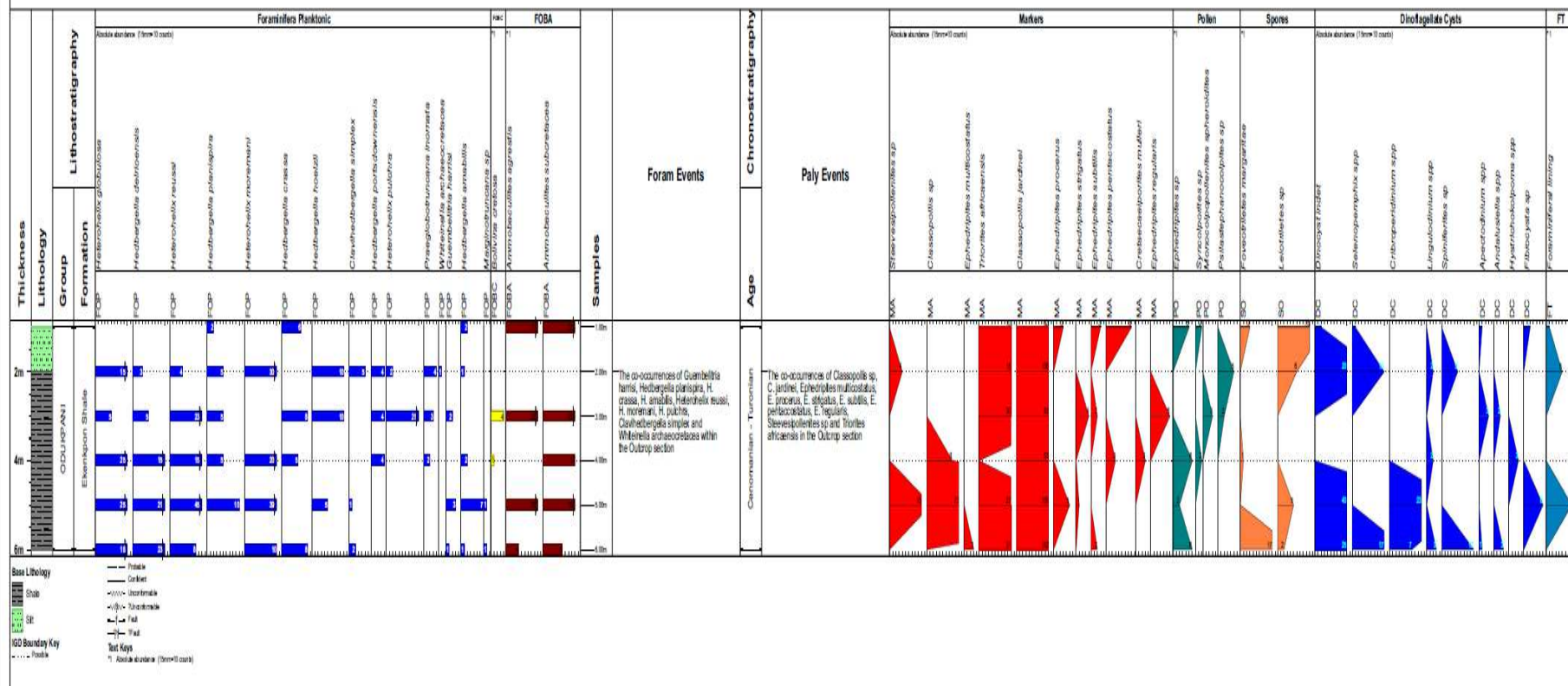


Fig. 4 Integrated biostratigraphic chart of Ekenkpon Shale at km 22.8 Calabar-Itu highway

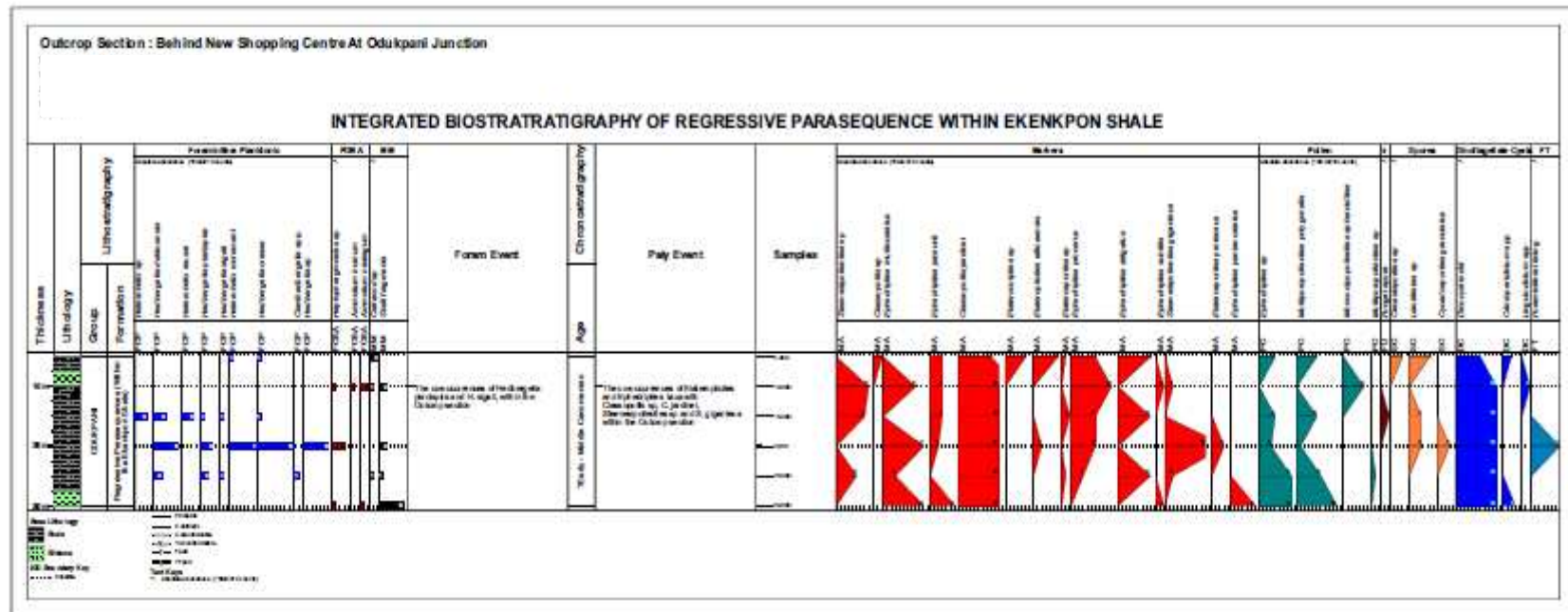


Fig. 5 Integrated biostratigraphic chart of Ekenkpon Shale at behind shopping mall at Odukpani junction

INTEGRATED BIOSTRATIGRAPHY OF NKPORO SHALE



Section: Nkporo Formation at km 39 Calabar-Itu Highway

INTEGRATED BIOSTRATIGRAPHY OF THE NKPORO SHALE

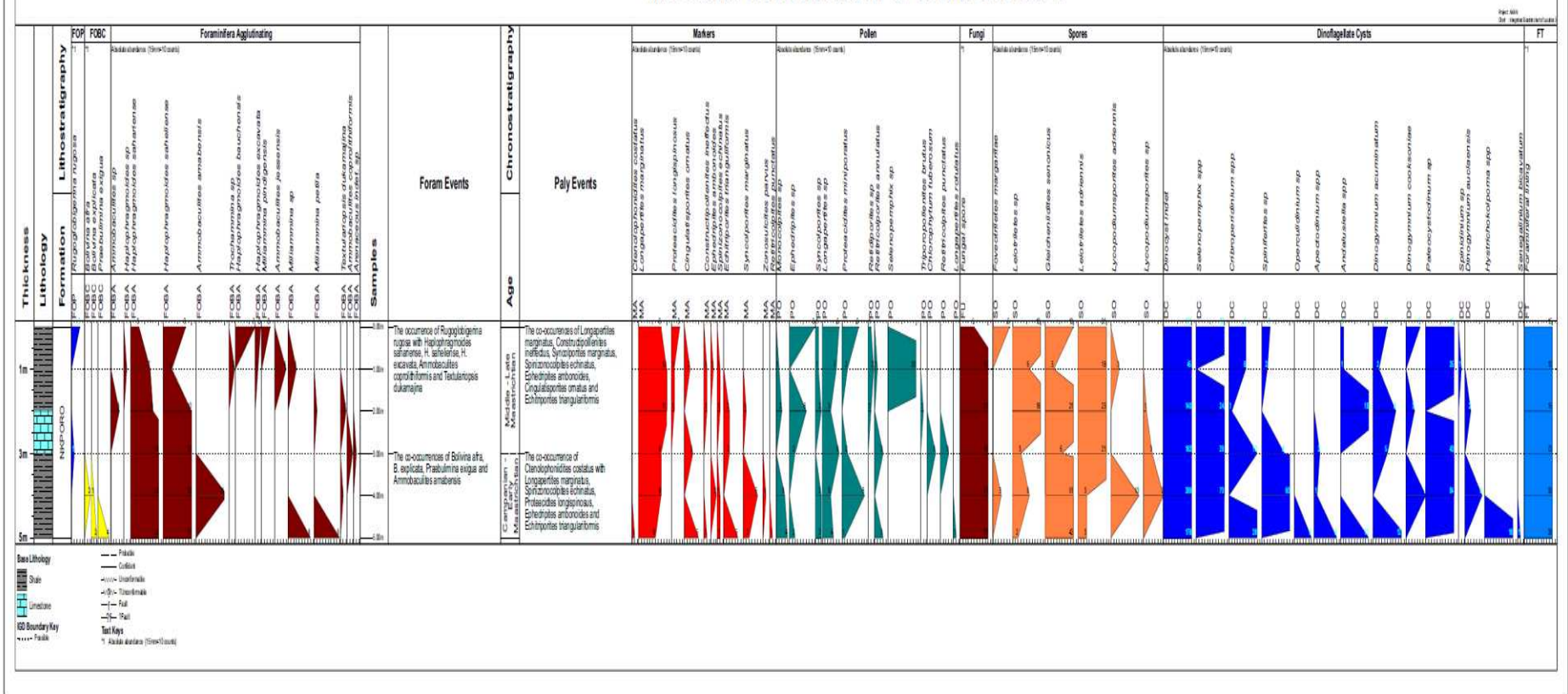


Fig. 7 Integrated biostratigraphic chart of Nkporo Shale at km 39 Calabar-Itu highway

Section: Benin Formation at km 4 from Tinapa junction

INTEGRATED BIOSTRATIGRAPHY OF COASTAL PLAIN SANDS (Benin Formation) IN THE CALABAR FLANK AREA

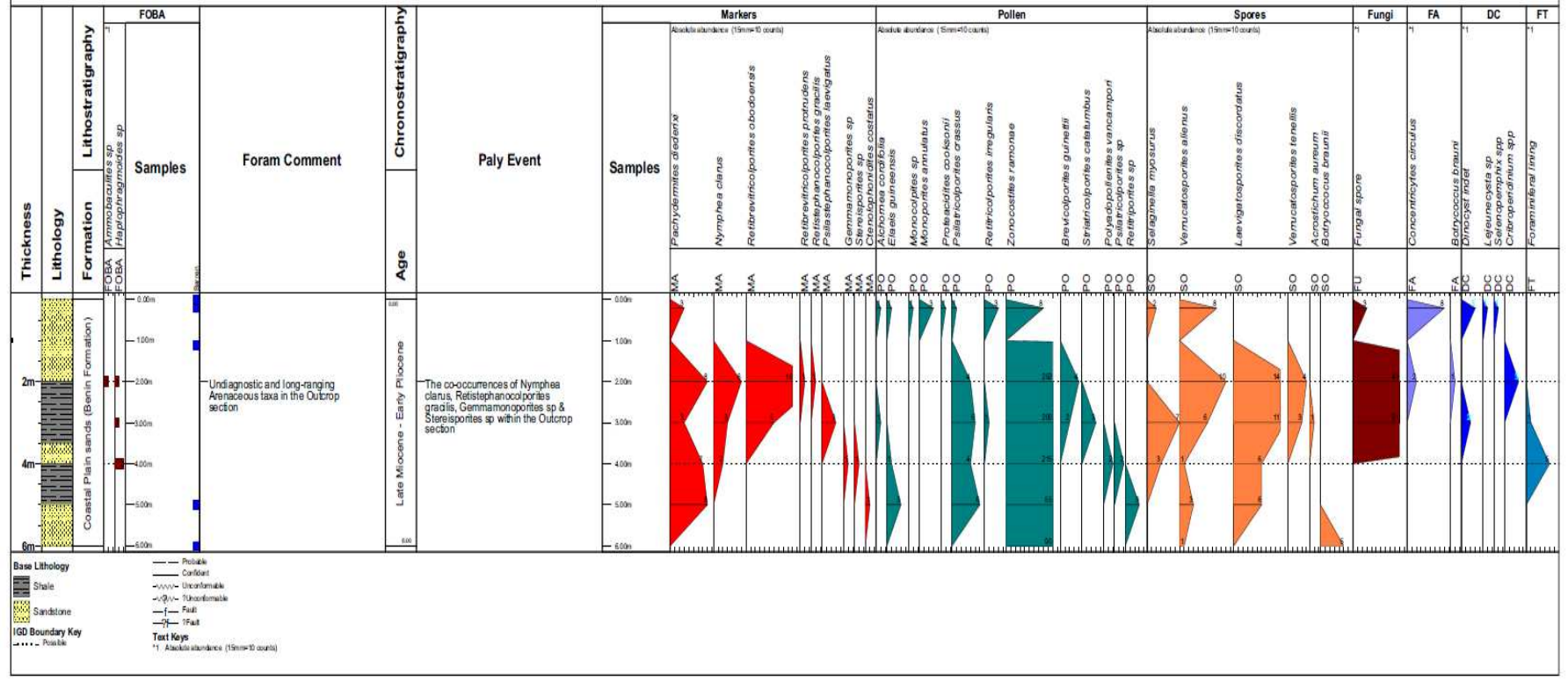


Fig. 8 Integrated biostratigraphic chart of Benin Formation at km 4 from Tinapa junction

Representative photomicrographs of the identified foraminifera and palynomorphs used for biostratigraphic interpretation are presented in Plate I and Plate II, respectively. Plate I shows diagnostic benthic foraminiferal taxa, while Plate II illustrates key palynomorph species identified in the study.

4.0 DISCUSSION

Chronostratigraphy

The integrated interpretation of foraminiferal and palynological data, as presented in Figures 2–8, forms the basis for the chronostratigraphic framework discussed below.

Awi Formation

Biostratigraphic age assessment was based on selected key stratigraphic marker species of palynomorphs recovered from the examined samples.

The co-occurrences of *Hedbergella delrioensis* (Aptian – Coniacian), *H. planispira* (Aptian- Cenomanian), *Heterohelix moremani* (Albian – Turonian) were used to assign a probable Aptian to Albian age (Petters, 1983) to the sediments of the Awi Formation. Also, the occurrences of agglutinated taxa: *Trochammina wickendeni* (Albian), *Ammobaculites agrestis* and *A. subcretacea* (Albian – Turonian) and *A. obliquus* (Albian – Cenomanian) support this age assignment.

Petters, et al, 2010, may have assigned a probable Aptian to Albian age to this Formation based on its stratigraphic position; as the bio-criteria for their interpretation are not stated.

The very low to low occurrences of an indeterminate pollen species is associated with spores (*Laevigatosporites sp*, *Verrucosisporites sp* and *V. farvus*) and fungi (*Fungal spore* and *Fusiformisporites sp*) constitute the palynofloral suite at this outcrop location.

These sporomorphs are long-ranging and non-diagnostic, and thus precluded the age determination of the sediments encountered in this outcrop location. However, a probable Aptian – Albian age has been assigned based on foraminiferal evidence and the stratigraphic position of the Awi Formation

Mfamosing Limestone

The co-occurrences of *Ammobaculites bauchensis*, *Miliammina pindigensis* and *Trochammina wickendeni* has been used to assign an Albian age to the sediments encountered at this outcrop location. *Trochammina wickendeni* is restricted to the Albian (Petters, 1982) although Iwobi, 1991 recorded it in the Cenomanian. The age discrepancy may have arisen probably because they may be two or more variants that have age significance. Also its close morphological affinity with *T. taylorana* which is dated Cenomanian (Petters, 1982, and Iwobi, 1991) may account for this mix up. *Miliammina pindigensis* is one of species encountered in the type section of the Gboko Formation, which was dated Middle Albian by virtue of its stratigraphic position. Both limestone bodies (Mfamosing and Gboko) are lateral equivalents and this may have been responsible for the adoption of a Middle Albian age for the Mfamosing Limestone (Petters, et al, 2010).

The co-occurrences of *Steevesipollenites* sp, *S. giganteus*, *S. binodosus*, *Ephedripites jansonii*, *E. procerus*, *Classopollis jardinei* and *Elateroplicites africaensis* have been used to distinguish and define the Middle Albian age for this outcrop section. The absence of species of *Elateropollenites* lends credence to an age not older than Middle Albian (Herngreen, et al, 1996). The presence of *Circacosisporites* sp at the upper section of the outcrop location could probably be reworked.

New Netim Marl

The co-occurrences of *Heterohelix reussi*, *H. moremani*, *Hedbergella delrioensis*, *H. simplicissima*, *H. crassa*, *H. hoelzi*, *Whiteinella baltica*, and *Clavihedbergella subcretacea* have been used to assign a Late Turonian – Coniacian age to the sediments encountered at this location (Petters, 1980, 1983 and Iwobi, 1991).

The absence of *Whiteinella archaeocretacea* in this outcrop section is considered as an indication of the penetration of Late Turonian and younger sediments. This planktic species was used as an index fossil for the penetration of Early Turonian sediments (Van Hinte, 1974, Robaszynski, et al, 1982 and Iwobi, 1991).

Heterohelix reussi ranges from Turonian to Campanian while *H. moremani* is Albian to Turonian and both are recorded as being common to very abundant in the Nkalagu Formation (Petters, 1980 and 1983). The *Hedbergellids* in this assemblage; *H. delrioensis* (Aptian – Coniacian), *H. simplicissima* (Albian – Coniacian), *H. crassa* (Turonian – Early Santonian) and *H. hoelzi* (Late Turonian – Coniacian) have been used as components for dating the Late Turonian to Coniacian sediments in parts of the Nkalagu and Awgu Formations in the Southern Benue Trough. *Whiteinella baltica* which occurs in the Ogugu section of the Awgu has been dated Coniacian – Early Santonian, while *Clavihedbergella subcretacea* is dated Albian – Coniacian (Petters, 1977, 1980, 1983 and Iwobi, 1991).

The paucity of marker species in mapped unit precluded a proper dating of the sediments using palynomorphs. However, the rare occurrence of *Syncolporites subtilis* is an indication of the penetration of Coniacian age (Jardine and Margloire, 1965).

Ekenkpon Shale

The age diagnostic planktic assemblage (*Guembelitria harrisi*, *Clavihedbergella simplex*, *Heterohelix reussi*, *H. moremani*, *H. pulchra*, *Whiteinella archaeocretacea* and *Praeglobotruncana inornata*) in this outcrop section points to a Cenomanian to Early Turonian age.

The presence of these benthic taxa; *Bolivina cretosa* (Turonian – Coniacian), *Ammobaculites agrestis* and *A. subcretacea* (Cenomanian – Turonian) lend credence to this interpretation (Petters, 1980, Nyong and Ramanathan, 1985).

Furthermore, the co-occurrences of *Heterohelix planispira* and *H. sigali* in the sediments at the outcrop section at Odukpani junction confers a Cenomanian age on them. *Heterohelix planispira* ranges from Aptian – Cenomanian

while *H. sigali* is Albian – Cenomanian (Petters, 1983). Both planktic foraminiferal taxa have been variously used by several authors (Petters, 1980, 1983, and Iwobi, 1991) to define Cenomanian age. The absence of *Rotalipora balernaensis* is a probable inference of the penetration of the ?Early to Middle Cenomanian age. Previous reports of this planktic taxon were from Latest Albian – Late Cenomanian (Bandy, 1967, Loeblich and Tappan, 1961, Ramanathan and Rao, 1982 and 1984). Iwobi, 1991 used the co-occurrence of this species and *Globigerinelloides caseyi* to recognize the Cenomanian stage in the lower part of the Nkalagu Formation

The co-occurrences of *Steevesipollenites* sp, *Classopollis* sp, *C.jardinei*, *Ephedripites multicostatus*, *E. procerus*, *E. strigatus*, *E. subtilis*, *E. pentacostatus*, *E. regularis*, *Triorites africaensis* and *Cretaecaeiporites mulleri* constitute the distinctive assemblage used to assign a Cenomanian to Early Turonian age to the sediments. The presence of *Triorites africaensis* in this assemblage confers an age not older than Cenomanian to the sediments. At the Odukpani junction section, the co-occurrences of *Steevesipollenites* sp, *S. giganteus*, *Classopollis* sp, *C. jardinei*, *Ephedripites multicostatus*, *E. jansonii*, *E. procerus*, *E. strigatus*, *E. subtilis*, *E. pentacostatus*, *Elaterocolpites* sp, *Elateroplicites africaensis*, *Elaterosporites* sp, and *E. protensus*, have been used to infer a Cenomanian age for this outcrop section. However, the co-occurrence of this elaterate plexus alongside a pteridophytic spore (*Circacosisporites* sp) affirms a Cenomanian age (Njoh, et al, 2015, Ukpogon and Ekhalialu, 2018). These authors used the co-occurrence of species of the Elaterate group and Pteridophyte spores to assign Cenomanian age to sediments from sections of the Mamfe Basin and the Calabar Flank respectively.

Nkporo Shale

The co-occurrences of *Rugoglobigerina rugosa*, *Bolivina afra*, *B. explicata*, *Praebulimina exigua*, *Ammobaculites amabensis*, and *A. coprolithiformis*, confirm the Late Campanian. Petters, (1982) and (1983) assigned a Late Campanian – Maastrichtian range for these species. The other species that make up this assemblage; (*Haplophragmoides sahariense*, *H. saheliense*, *H. excavata*, *Miliammina petila*, *Textulariopsis dukamaijina*) are Middle to Late Maastrichtian (Petters, 1982). The last occurrence of *Rugoglobigerina rugosa* in the section has been used to infer a probable Late Campanian – Early Maastrichtian / Middle – Late Maastrichtian boundary. This planktic species ranges from Middle – Late Maastrichtian (Petters, 1983).

Thus, the sediments of Nkporo shale at this location are assigned a Late Campanian to Late Maastrichtian age.

The co-occurrences of *Ctenolophonidites costatus*, *Longapertites marginatus*, *Proteacidites longispinosus*, *Cingulatisporites ornatus*, *Constructipollenites ineffectus*, *Spinizonocolpites echinatus*, *Echtriporites trianguliformis*, *Syncolporites marginatus*, etc; have been used to assign a Late Campanian to Late Maastrichtian age to the sediments of the Nkporo Shale (Jardine and Margloire, 1965, Edet and Nyong, 1994, Umeji, 2005, Umeji and Nwajide, 2007).

The occurrences of the Dinoflagellate cyst genus; *Dinogymnium* (*D. acuminatum*, *D. cooksoniae* and *D. auclaensis*) is distinctive and confirms the penetration of the Maastrichtian (Drugg, 1967). The occurrence of *D. acuminatum* further refines the age to Late Maastrichtian (Umeji and Nwajide, 2007).

Benin Formation

The Late Miocene to Early Pliocene age interpretation of the sediments encountered in this location is based on the co-occurrences of *Pachydermites diderixi*, *Nymphaeapollis clarus*, *Retribrevitricolporites obodoensis*, *Retistephanocolporites gracilis*, *Gemmamonoporites* sp and *Stereisporites* sp. This palynofloral assemblage defines the P860 zone of Evamy et al, 1978 and the NNDP 10 – NNDP 08 (pro parte) zone of STRATCOM, 2000.

Thus, evidence from palynology indicates a Late Miocene to Early Pliocene age for the Coastal Plain sands (Benin Formation) at this outcrop location.

A summary of the chronostratigraphic range chart of selected key-age diagnostic foraminiferas and palynomorphs in the study area is shown in fig 9 while the stratigraphic summary of the cretaceous-recent sedimentary successions in the calabar flank is shown in Table 2.

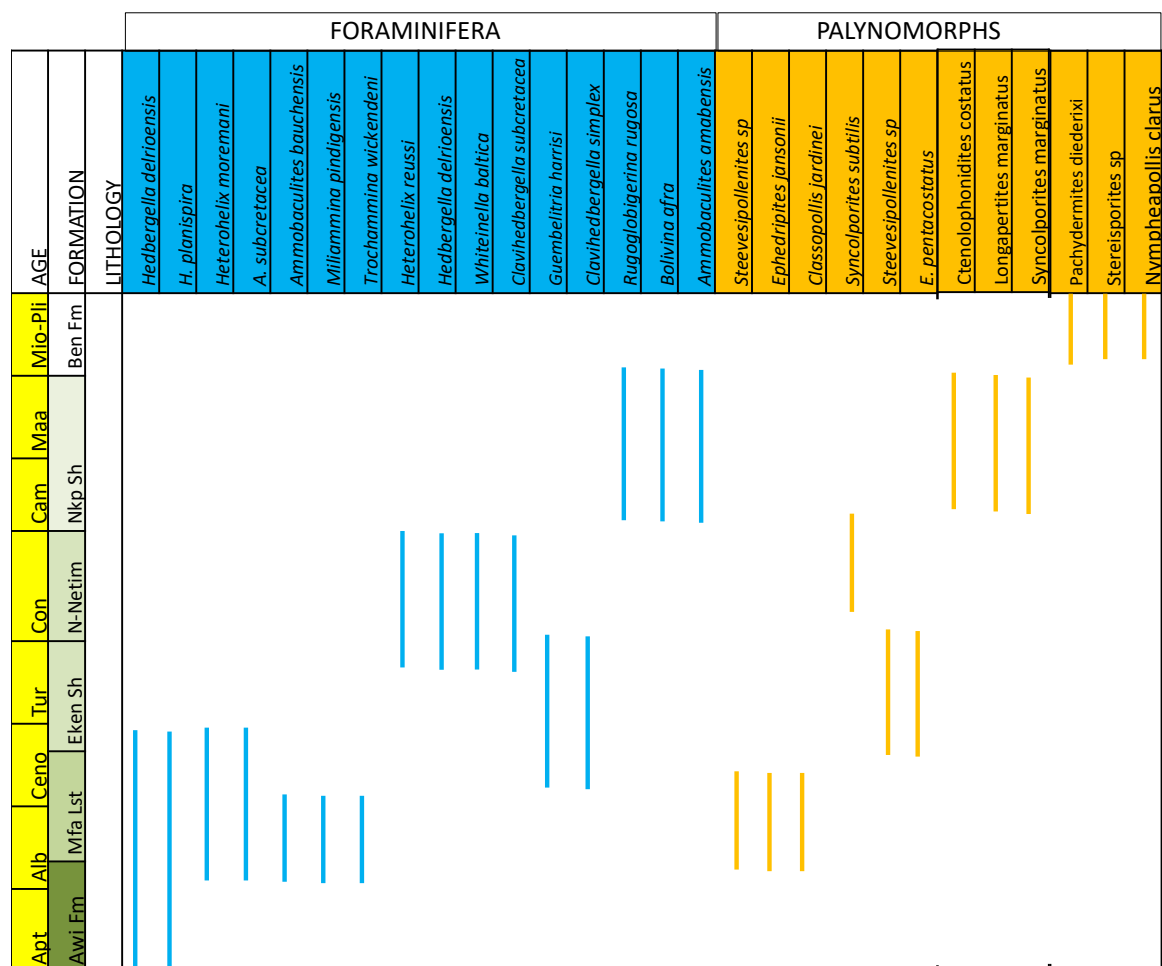


Fig. 9 Chronostratigraphic range chart of selected key-age diagnostic foraminiferas and palynomorphs in the study area

Table 2. Stratigraphic summary of the cretaceous-recent sedimentary successions in the calabar flank

Lithostrat Unit	Age	Paleoenvironmnet
Coastal Plain Sands	Late Miocene-Early Pliocene	Non-Marine to shallow neritic
Nkporo-Benin Formation	Late Maastritchian-Danian	Outer neritic to Upper Bathyal
Nkporo Shale	Late Campanian-Late Maastritchian	Middle-Outer neritic
New Netim Marl	Late Turonian-Coniacian	Middle neritic
Ekenkpon Shale	Cenomanian-Turonian	Middle-Outer neritic
Mfamosing Limestone	Middle Albian	Shallow neritic
Awi Formation	?Aptian-Albian	Non-marine-Inner neritic

CONCLUSION

Biostratigraphic data from outcrops of sedimentary sequences in the Calabar Flank have been used to refine the late Cretaceous to Recent (Aptian to Pliocene) according to international best practices; thus enhancing its calibration to existing global chronostratigraphic schemes. The study dated the sediments using index biostratigraphic markers and evaluated the paleoenvironment of deposition. This will enhance the understanding of the stratigraphy and the exploration and exploitation of the hydrocarbon resources of the Basin.

Author Contributions

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Review and Editing: Essien, A.G., and Enyioko, N.D.

Oversight: Ikoro, D.O., Onyekuru, S.O., and Essien, A.G.

Declarations

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Ethics, Consent to Participate, and Consent to Publish declarations: not applicable.

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REFERENCES

- Akpan E.B (1985). Ichnology of the Cenomanian-Turonian of the Calabar Flank, S.E. Nigeria. *Geol. en Mijnbouw*. 64:365-372.
- Akpan E.B (1992). *Peruviella dolium* (Roemer) and the age of the Mfamosing Limestone, SE Nigeria. *J. Min. Geol.* 28:191-196.
- Asukwo, E.I., Inyang, D.O., Umana,U.S., Akpan, E.B., Udinmwun, E (2017). “Palynostratigraphy of Lemna Road Transect of Benin Formation, Calabar Flank, Nigeria”. *Asian Journal of Physical and Chemical Sciences* 1 (1):1-10. <https://doi.org/10.9734/AJOPACS/2016/30942>.
- Bassey E.C (1991). Cretaceous foraminiferal biostratigraphy of the subsurface of the Calabar Flank. Ph.D. Dissertation University of Calabar, Calabar, Nigeria.
- Berggren, W. A., D. V. Kent, C. Swisher, and M.-P. Aubry, (1995), A revised Cenozoic geochronology and chronostratigraphy, in W. A. Berggren, D. V. Kent, M.-P. Aubry, and J. Hardenbol, eds., *Geochronology, Time Scales, and Global Stratigraphic Correlation: Society for Sedimentary Geology (SEPM) Special Publication 54*, p. 127–208.
- Edet JJ, Nyong EE (1993). Depositional environments, sea level history and paleobiogeography of the Late Campanian - Maastrichtian on the Calabar Flank, SE Nigeria. *Paleogeogr. Paleoclim. Paleoecol.* 102:161-175.
- Edet, J. J. (1992): Palynostratigraphy of Late Cretaceous (Late Campanian – Early Maastrichtian) Sections in the Anambra Basin, Nigeria. *Revista Espanola de Micropaleontologia*, Vol. XXIV, no. 2, pp.3 – 18
- Edet, J. J. and Nyong, E. E. (1994): Palynostratigraphy of Nkporo Shale exposures (Late Campanian – Maastrichtian) on the Calabar Flank, SE Nigeria. *Review of Paleobotany and Palynology*, 80, pp.131 – 147, Elsevier Science B. V., Amsterdam.

- Herngreen, G.F.W., Kedves, M., Rovnina, L.V., and Smirnova, S.B. (1996): Cretaceous Palynofloral provinces: A Review, in: Jasonius, J. and McGregor, D.C. (eds), *Palynology: Principles and Applications*. AASP Foundation, vol.3 p1157 -1188
- Hine, Robert. (2019) "Biostratigraphy." Oxford Reference: Dictionary of Biology, 8th ed., Oxford University Press, 2019.
- Iwobi, O. C. (1991): Foraminiferal Ages in the Southern Benue Trough, *NAPE Bull*, vol (6), No. 1, p39-47.
- Jardine, S. and Margloire, L. (1965): *Palynologie et Stratigraphie du Cretace des Bassins du Senegal et de Cote d'Ivoire*. Mem. B. R. G. M. 32. Coll. Int. Micropal: p187-222.
- Kumaran, K. P. N. and Ramanathan, R. M. (1986). An Upper Cretaceous Assemblage from Nkporo Shale of Calabar Flank. *Journal of the Paleontological Society of India*, 31, p 9-15.
- Mello, M.R., Koutsoukos, E.A.M., Hart, M.B., Brassel, S.C., Maxwell, J.R., (1989). Late Cretaceous anoxic events in the Brazilian continental margin. *Org. Geochem.* 14 (5), 529-542.
- Mello, M.R., Mohriak, W.U., Koutsoukos, E.A.M., Figueira, J.C.A., (1991). Brazilian and west African oils. Generation, migration, accumulation and correlation. In: *Proceedings of the 13th World Petroleum Congress*. John Wiley & Sons, New York, pp. 153-164.
- Mello, M.R., Telnaes, N., Gaglianone, P.C., Chicarelli, M., Brassell, S.C., Maxwell, J.R., (1988b). Organic geochemical characterisation of depositional paleoenvironments of source rocks and oils on Brazilian marginal basins. In: *Mattavelli, L., Novelli, L. (Eds.), Advances in Organic Geochemistry 1987*. Pergamon Press, pp. 31-45.
- Murat R.C (1972). Stratigraphy and paleogeography of the Cretaceous and Lower Tertiary in Southern Nigeria. In: *Dassauvage, T. F. J. and Whiteman, A. J. (Eds.), Africa Geology*, Ibadan 1970. Geol. Dept. Univ. Ibadan, Nigeria. pp. 251-266.
- Njoh O.A (2008). Upper Cretaceous foraminiferal biostratigraphic correlations: Douala and Rio Del Rey Basins. (S.W. Cameroon) and the Calabar Flank (S.E. Nigeria). PhD Dissertation. University of Calabar, Calabar, Nigeria.
- Njoh O.A, Nkeme U.U, Petters S.W (2009). Lower Tertiary foraminiferal from subsurface sediments in the Calabar Flank, southeastern Nigeria. *Int. J. Appl. Sci.* 4(1):35-42.
- Nwajide C. S., (2013). *Geology of Nigeria Sedimentary Basins*; Published by CSS Bookshops Limited, Lagos Nigeria.

- Nyong, F. E. and Ramanathan, R. M, (1985). A record of oxygen deficient Paleoenvironments in the Cretaceous of the Calabar flanks, S. F. Nigeria Journal of African Earth Sciences, Vol.3(4), pp 455 – 460.
- Pessagno E.A (1967). Upper Cretaceous planktonic foraminifera from the western Gulf Coastal Plain. Paleontol. Am. 5(37):245- 445.
- Peters, K.E., (1986). Guidelines for evaluation petroleum source rocks using programmed pyrolysis. AAPG Bull. 70, 318-329.
- Peters, K.E., Moldowan, J.M., 1993. The Biomarker Guide: Interpreting Molecular Fossils in Petroleum and Ancient Sediments. Prentice Hall International, London.
- Petters S.W (1980). Biostratigraphy of the Upper Cretaceous foraminifera of the Benue Trough, Nigeria. J. Foram. Res. 10(3):191-204.
- Petters S.W (1981). Caves and Lower Karsts near Calabar, Nigeria. Nigerian Field Soc. Bull. 46:9-20.
- Petters S.W, Zaborski P.M.P, Essien N.U, Nwokocha K.D, Inyang D.O (2010). Geological excursion guidebook to the Cretaceous of the Calabar Flank, Southeast Nigeria. Nigerian Mining and Geosciences Society 46th Annual Conference "Calabar 2010". Shamber Grafitech Studio. 28p.
- Petters S.W. and T.J.A Reijers (1987). Cretaceous carbonates on the Calabar Flank,”. In : G. Matheis and H. Schandelmesser(Editors), Current Research in African Earth Sciences. Balkema, Rotterdam, 155-158.
- Petters, S. W. (1978): Stratigraphic Evolution of the Benue Trough and its Implications for the Upper Cretaceous Paleogeography of West Africa, Jour. Geol. Vol. 86, p311-322.
- Petters, S. W. (1978): Stratigraphic Evolution of the Benue Trough and its Implications for the Upper Cretaceous Paleogeography of West Africa, *Jour. Geol.* Vol. 86, p311-322.
- Petters, S. W. (1980): Biostratigraphy of Upper Cretaceous Foraminifera of the Benue Trough, Jour. Foram. Res. Vol 10 (3), p191-204.
- Petters, S. W. (1982): Central West Africa Cretaceous – Tertiary benthic foraminifera and Stratigraphy, Paleontographica, 1 – 104.
- Petters, S. W. (1982): Central West African Cretaceous - Tertiary Benthic Foraminifera and Stratigraphy.
- Petters, S. W. (1983): Gulf of Guinea Planktonic Foraminiferal Biochronology and Geological History of the South Atlantic. Jour. Foram. Res., vol.13, no. 1, p32 – 59.
- Petters, S. W. and Ekweozor, C. M (1982). Origin of Mid-Cretaceous black shales in the Benue Trough, Nigeria. Paleogeography, Paleoclimatology, Paleoecology, 40, 311-314.

- Petters, S. W.(1983): Gulf of Guinea Planktonic Foraminiferal Biochronology and Geological History of the South Atlantic. *Jour.Foram.Res.*, vol.13, no. 1, p32 – 59.
- Petters, S.W., (1982). Central west African cretaceous e tertiary benthic foraminifera and stratigraphy. *Palaeontographic Abt. A* 179, 1-104.
- Petters, S.W., Nyong E.E., Akpan, E.B, and Essien N.U., (1995). Lithostratigraphic revision of the Calabar Flank, South Eastern Nigeria,” *Proceedings of the 31st Annual conference of the Nigeria mining and geosciences society*.
- Petters, W.W., Nyong, E.E., Akpan, E.B., Essien, N.W., (1995). Lithostratigraphic revisionfor the Calabar Flank S. E. Nigeria. In: *Proc. of the 31st Ann. Conf. of N.M.G.S., Calabar*
- Ramanathan, Rm. and Rao, V. R. (1982): Lower Cretaceous Foraminifera from the subsurface sediments of the “Kalakkudi Embayment” Cauvery Basin, India. *Bull. of Oil Nat. Gas Commission*, vol. 19 (1), p1-44.
- Stratigraphic Committee of the Niger Delta Biostratigraphic Sub – committee (2000): *Palynological Taxonomy Project Cenozoic Niger Delta* Adeleye, D.R., Fayose, E.A., 1978. Stratigraphy of the type section of Awi Formation, Odukpani area, southeastern Nigeria. *Nig. Tour. Min. Geol.* 15, 35-37.
- Ukpong A. J., Olivier N., and Ushundebe M. A. (2007). Foraminiferal biostratigraphy of the upper part of the Type-section of Ekenkpon Formation, Calabar Flank, South-Eastern, Nigeria. *International Journal of Natural and Applied Sciences (IJNAS)*. 3 (1), 22-28.
- Ukpong A.J, Njoh O.A, Ushundebe,M.A (2008). Foraminiferal biostratigraphy of the upper part of the Type- section of Ekenkpon Formation, Calabar Flank, South-eastern Nigeria. *Int. J. Nat. Appl. Sci.* 3(1,2):28-34.
- Ukpong, A. J. and Ekhalialu, O. M (2015). Integrated biostratigraphic study of well Etankpini 005 (ET005) based on foraminiferal and palynological analysis, Calabar Flank; South Eastern Nigeria. *International journal of scientific and engineering research*, 6(3), 1129-1141. Petters, S. W., (1982). Central West African Cretaceous-tertiary benthic foraminifera and stratigraphy. *Palaeontographica*, 179,1-104
- Umeji, O. P. (2005): Palynological study of the Okaba coal mine section in the Anambra Basin, southeastern Nigeria. *Jour. Min. Geol.*, 41 (2), p193-203.
- Umeji, O. P. and Nwajide, C. S. (2007): Age control and designation of the standard stratotype of Nsukka Formation of Anambra Basin, southeastern Nigeria. *Jour. Min. Geol.* Vol.43 (2), p147-166
- Umeji, O.P. (2007): Late Albian to Campanian Palynostratigraphy of Southeastern Nigeria Sedimentary Basins, Unpublished Ph.D. thesis, University of Nigeria, Nsukka, Nigeria. 232p.

