Sequence Stratigraphy and Biostratigraphic Characterization of the System Tracts in the Calabar Flank, Lower Benue Trough, Nigeria

Thomas A. Harry, Clement E. Bassey, Sunday W. Petters

Department of Geology, Akwa Ibom State University, Ikot-Akpaden, Mkpat Enin, AKS
Department of Geology, University of Calabar, Calabar- CRS, Nigeria
Corresponding email: tharry.tom@gmail, thomasharry@aksu.edu.org

Abstract— The sequence stratigraphic approach was employed in this study using outcrops across the Calabar Flank and interpretations done based on vertical relationship of lithofacies, foraminiferal and palynological data. Each outcrop was extensively analyzed in terms of system tracts, maximum flooding surfaces and sequence boundaries. The Awi Formation represents deposition during the low stands of the sea during the Aptian Stage (? 125-110Ma) while Mfamosing Formation comprises a depositional sequence formed during the third-order global sea level cycle with the UZA-1 representing the Mid-Albian Stage (103-96.6 Ma). Two genetic sequences corresponding to the third order cycles UZA-2 (Albian-Early Cenomanian) and UZA-2.5 (Late Cenomanian-Mid-Turonian) were recognized for the Ekenkpon Shales with Maximum Flooding Surfaces (MFS's) delineated at 17.0m, 12.0m and 4.0m, representing the Late-Albian to Cenomanian Stage (?99-97Ma), Late Cenomanian stage (?94.1 – 92.1Ma) and Early to Mid Turonian Stage (?92-91.2Ma) respectively. These depositional sequences were dated using the associated planktic foraminifera. The Regressive parasequences belonging to the Mid-Cenomanian stage (? 94.5-94Ma) were encountered in the course of this work. The New Netim Marl reflected a Highstand and Transgressive System Tract of Coniacian stage, while the Nkporo Shale indicated a Transgressive System Tract (TST) formed during the Campanian-Maastrichtian stage.

Key words— *Biostratigraphy, Calabar Flank, Foraminifera, Lithofacies, Palynology, Parasequence, Sequence Stratigraphy*

1 Introduction

MOST of the foraminiferal and sequence stratigraphic studies in the Calabar Flank have so far been on a local scale, often being restricted to a single outcrop or borehole section. The need for further work to establish, correlate and model the system tracts across the basin inspired the current research work. The research covers sequence stratigraphy and biostratigraphic characterization of system tracts in the Calabar Flank portion of Southern Benue Trough. The aim of the present study was to undertake a detailed foraminiferal, palynologic and lithostratigraphic analysis of Cretaceous outcrops in the Calabar Flank including hitherto unstudied outcrops in order to establish a Sequence Stratigraphic Model for the Flank.

1.1 Geologic Setting

The study area lies between latitudes 4050'N and 5050'N and longitudes 7050'E and 8050'E (Fig. 1) and is situated within the Calabar Flank (fig.1). The term Calabar Flank was first introduced by Murat (1972) as that part of the southern Nigerian sedimentary basin which is bordered by the Precambrian Oban Massif in the north and the Recent Niger Delta in the south. The Afikpo syncline marks the northwestern limit while the Cameroon volcanic ridge bounds it in the east. Tectonically the geologic history of southern Nigeria has been controlled by three major tectonic phases (Murat, 1972). The origin of the Calabar Flank is intimately associated with the development of the Benue Rift System, both events being related to the opening of the South Atlantic and the existence of a RRR triple junction which was active in Early Cretaceous times (Petters 1980; Petters, 1982, Petters et al, 1995) and is part of the Southern Nigeria sedimentary basin trending in a Northwest – Southeast (NW-SE) direction. The attitude of block faults, eustatic changes in the sea level within the adjacent South Atlantic, as well as the geology of the provenance areas, controlled the stratigraphic development of the Flank. (Petters et al, 1995)

1.2 Concept of Sequence Stratigraphy

Van Wagoner et al (1988, 1990) defined sequence stratigraphy as "the study of rock relationships within a chronostratigraphic framework of repetitive, genetically related strata bounded by surfaces of erosion or non-deposition or their correlative conformities" Any unconformity bounded "sequence" can then be divided internally into smaller- scale genetically related units (system tracts) deposited during individual phases of sea- level change (i.e. transgression,high-stand, regression, low-stand). Sequence stratigraphy is a precise methodology that attempts to subdivide sedimentary deposits into unconformity bound units on a variety of scales and explains these stratigraphic units in terms of variations in sediment supply and rate of change in accommodation space which is often associated with relative sea level changes. Traditional stratigraphy defines stratigraphic units in terms of lithostratigraphy within imprecise biostratigraphic boundaries. Sequence stratigraphy defines units that evolve in response to changes in shelfal accommodation

ISSN 2229-5518

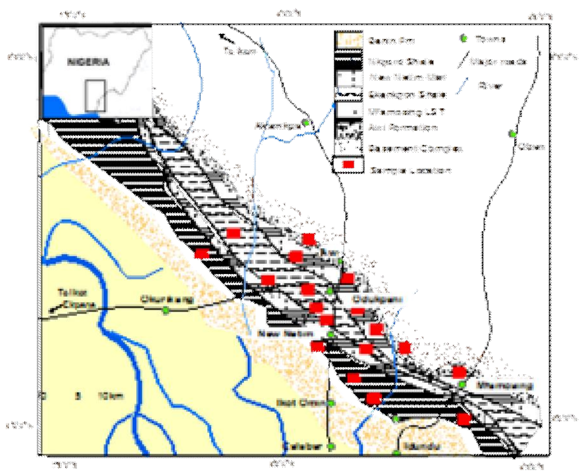


Fig.1 Outline geological map of Calabar flank, Lower Benue Tough – Nigeria

These units are bounded by stratal discontinuity surfaces on seismic profile and geologic cross-section and are specific surfaces between vertical changes in facies stacking patterns on well logs and outcrops (Catuneanu, 2003; 2006). Where the sediments are thick enough, these surfaces can be identified on seismic data and outcrop sections and well logs, and can be dated biostratigraphically. Thus sequence stratigraphic units are time-equivalent rock packages (Reijers and Petters, 1997) caused by lithologic transitions created by abrupt changes in the sediment supply delivered to each locality. Sequence stratigraphic approach is a preferred technique that could lead to a purposeful exploration for hydrocarbon traps especially the stratigraphic ones. (Bassey et al, 2013; Adegbie and Bassey, 2007; Bassey and Ojesina, 1999).The basic units of sequence stratigraphy are Depositional Sequences, Systems Tracts, and Parasequence. This method is a powerful tool in modern stratigraphic studies because it integrates many aspects of Stratigraphy including seismic stratigraphy, lithostratigraphy, cyclostratigraphy, event-stratigraphy and biostratigraphy into a single stratigraphic framework.

2 METHODOLOGY

A total of two hundred and forty samples comprising shale, marls, siltstones and limestone were collected from road cuts, quarry faces and stream valleys within the Calabar Flank. The sampling interval in most of the outcrops was irregular owing to the deep weathering, poor exposure and inaccessibility of parts of some of the sections. The methods employed in this study include; detailed fieldwork, laboratory analysis, and sequence stratigraphic analysis. Lithologic logs from studied sections in the study area were used to delineate the different lithology and establish the parasequence sets, upward-coarsing and fining-upward sequences while the biostratigraphic data derived from microfossil extraction from the samples yielded biofacies information for the paleo-water depths. In addition, fossil abundance and diversity trends, recognized through statistical analyses were used with stratigraphically consistent biochronoevents, global eustatic curve (Haq et al 1988) and lithologs to delineate and date the key surfaces such as the Maximum Flooding Surface (MFS) and Sequence Boundary (SB).The stacking patterns and lithologic analysis aided the delineation of the Low-Stand Systems Tract (LST), Transgressive Systems Tract (TST) and the High-Stand Systems Tract (HST).Graphic charts were generated using the STRATABUGS software and ArcGIS version 10.1.

3 RESULTS

3.1 Sequence Stratigraphic interpretation of Awi outcrop section.

The Awi Formation is the basal unit in the Calabar Flank. Sequence stratigraphic interpretations (Table 1) were based on the lithofacies and stacking pattern. The section comprises a fining upward fluvial sequence, mostly an alternation of fine to medium grained sandstones with light grey to black micaceous shale and mudstone. The sandstones are conglomeritic at the base. The sedimentation is aggradational, typical of basin floor fans. It represents the Lowstand of sea level preceding the initial sea level rise in the Mid-Albian. The paucity of foraminifera is also a confirmation of the lowstand levels of the sea during the Aptian. (Sharon et al 2015)

TABLE 1:

Sequence stratigraphic summary of Awi Formation

Location (m)	Systems Tract	Key Surfaces
1-4m	LST	SB(112.4Ma)

.

3.2 Sequence Stratigraphic interpretation of Mfamosing Limestone section

The stacking pattern of sediments indicates a fining upward sequence. Systems tract delineated in this study include the Highstand, Lowstand and Transgressive Systems Tracts corresponding 30-35m, 20-25m and 5-15m depth respectively. The Sequence stratigraphic summary of the analyzed section of the outcrop is presented in Table 2.

Mfamosing Limestone indicates the presence of agglutinating forams in higher numbers than the planktics foraminifera.TST ratio for Mfamosing Limestone Formation for Planktic and Agglutinating forams is 1:4 i.e. Planktics (20%), arenaceous benthics (80%).Also present was a good number of Gastropod spp. and shell fragments. The HST facies did not yield much forams for any significant analysis.

TABLE 2:

Sequence stratigraphic summary of Mfamosing Limestone

Location (m)	Systems Tract	Key Surfaces
5.0 -15.0	TST	
20.0 – 25.0	LST	SB (101 Ma)
30.0 – 35.0	HST	

.

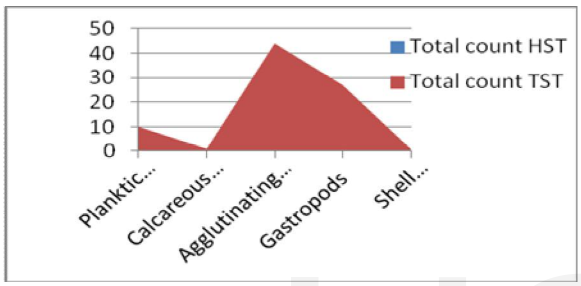


Fig. 2: Chart illustrating the total abundance of microfossils within the identified system tracts of mfamosing LST

TABLE 3:

Sequence stratigraphic summary of Ekenkpon Shales

Depth (m)	Systems Tract	Key Surfaces
1.0 – 3.0	HST	_
3	_	MFS (94.75Ma)
3.0 – 5.0	TST	_
5.0 – 5.5	LST	SB (93.99Ma)
5.5 – 8.0	HST	_
8	_	MFS (93.09Ma)
8.0 – 14.0	TST	_
14	LST	SB (92.36Ma)
14.0 – 16.0	HST	_
16	_	MFS (91.19Ma)
16.0 – 18.0	TST	_

.

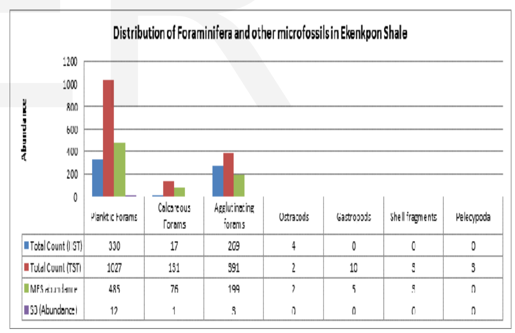


Fig. 2: Distribution of foraminifera and other microfossils in Ekenkpon

3.3 Sequence Stratigraphic interpretation of Ekenkpon Shales

The integration of foraminiferal / biofacies, observed sedimentologic and paleobathymetric data sets (see the distribution chart) facilitated the interpretation of sequence stratigraphic development within the analyzed section of the outcrop. The approach of Wornardt et al (1999) was followed in attempting the interpretation of this section of the outcrop. The Maximum Flooding Surfaces (MFS) have been delineated at 16.0m, 8.0m and 6.0m and dated 91.19Ma 93.09Ma and 94.75Ma respectively. These candidate surfaces have been dated and correlated to the third order cycles chart of Haq et al., (1998). The Maximum Flooding Surfaces were delineated on the basis of high foraminiferal abundance and diversity. Sequence boundary (SB) candidates, on the other hand, were observed at 5.0m and 14.0m and were coevally dated 93.99Ma and 92.36Ma. This Maximum Regressive Surfaces (MRS) was recognized based on the faunal minima and shallowing of paleo-water depths (Table 3). Two genetic sequence developments have been recognized for this section following the approach of Cateneneau, (2006).

3.4 Biostratigraphic Characterization of Ekenkpon Shales

From the analysis carried out, the Transgressive System Tract (TST) of the Ekenkpon Formation recorded higher abundances of Planktonic, Calcareous and agglutinating foraminifera when compared with the Highstand System Tract (HST). Specifically the ratio obtained for foraminiferal abundances for the TST and HST disaggregated by foraminiferal types are as shown in the Table 3.

TABLE 3

Biostratigraphic characterization of Ekenkpon Shales

	TST abundance	HST abundance	Ratio	%
Planktics	1082	330	3:01	77
Benthics	131	17	8:01	89
Agglutinating /Forams	395	269	$1^{1/2}$:1	59

3.5 Sequence stratigraphic interpretation of New Netim Marl

Sequence stratigraphic analysis based on inferred sea level changes shows that the marl is an aggradational sequence stratigraphic unit with continuous fluctuation in sea level between shallow and deep marine environment during the Coniacian transgression in the South Atlantic. The New Netim Marl sequence shows several lithofacies changes. It shows a general succession of Nodular Marl units, Marl inter-bedded with highly weathered brownish mudstones and highly laminated grey shale units (Fig. 5). The dark colour of the shale may suggest bottom anoxia perhaps due to dense stratification and poor circulation of oxygen (Essien and Bassey, 2012). Shales in the upper and lower horizons are highly weathered but are easily distinguished from the Marls by its wavy and laminated structures. About 70% planktics, 10% arenaceous benthics and 10% ostracods/shell fragment were recovered from the studied sections of New Netim Marl.(Table 4)

TABLE 4

Sequence stratigraphic summary of New Netim Marl section

	TST abundance	HST abundance	Ratio	%
Planktics	1082	330	3:01	77
Benthics	131	17	8:01	89
Agglutinating /Forams	395	269	$1^{1/2}$:1	59

The overall shallowing upward sequence is associated with stacks of progradational sediments pattern indicative of a typical regression. The peak of this regressive phase (MRS) was delineated at 3.0m based on the faunal minima (fig. 4) at this depth. The observed Sequence Boundary (SB) is dated 88.5Ma by correlation to the third order cycle chart of Hardenbol et al., (1998).

3.6 Sequence stratigraphic interpretation of Nkporo section

The lower part of the Nkporo Shale, exposed in the Calabar Flank yielded a rich foraminiferal assemblage composed mainly of planktics. The topmost part of the Nkporo Shale in the Calabar Flank at kilometer 19 on the Calabar-Odukpani road yielded an entirely benthic assemblage with dominance of *Ammobaculites* and rare occurrence of *Bolivina spp* Cushman, *Trochammina taylorana* Cushman and *Miliammina onyeamaensis* Petters. The sequence stratigraphic interpretation of the Nkporo outcrop section was attempted. Table 5 shows the stratigraphic summary of the analyzed section.

TABLE 5

Sequence stratigraphic summary of Nkporo Section

Depth (m)	Systems Tract	Key Surfaces
1.0 – 4.0	TST	_

Interval:1.0 – 3.0m
System Tract: Transgressive
The predominantly shale deposits encountered in this interval were deposited in Inner to Middle Neritic paleo water depths and are associated with overall retrogradational sediment pattern.

Fig. 3: Regressive Parasequences in Bedded Mudstone (Mid-Cenomanian)

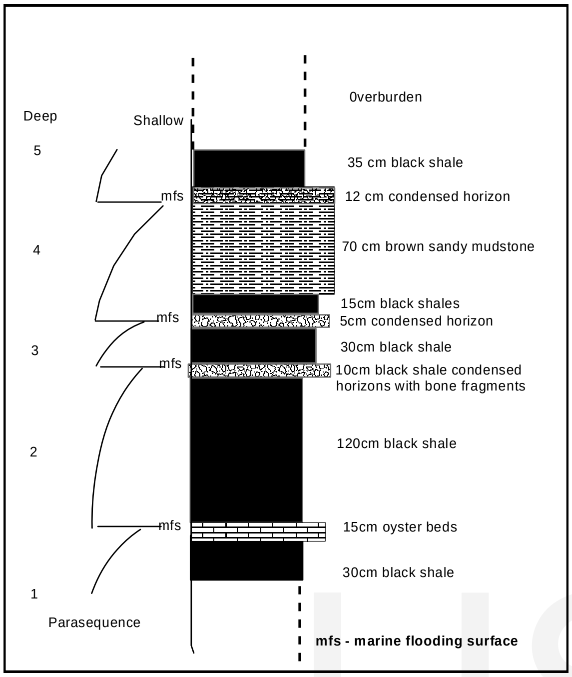


Fig. 4: Lithostragraphic section showing regressive parasequences (mudstones within the Ekenkpon Shale)

Fig. 5: Section of New Netim Marl with thin Laminations of shale (at Mfamosing) Lithostragraphic section showing regressive Parasequences (mudstones within the Ekenkpon Shale)

4 DISCUSSION

Two genetic sequences were recognized for the Ekenkpon Shale with Maximum Flooding Surfaces (MFS's) delineated at 17.0m, 12.0m and 4.0m and dated 91.19Ma 93.09Ma and 94.75Ma respectively. These candidate surfaces have been dated and correlated to the third order cycles chart of Hardenbol et al., (1998). The Maximum Flooding Surfaces were delineated on the basis of high foraminiferal abundance and diversity. Sequence boundary (SB) candidates on the other hand were observed at 6.0m and 15.0m and were coevally dated 93.99Ma and 92.36Ma. This Maximum Regressive Surfaces (MRS) were recognized based on the faunal minima and shallowing of paleo-water depths.

The outcrop sections studied were quite fossiliferous and exhibit many diverse benthic and planktic foraminiferal fauna which provided the basis for the biostratigraphic characterization of the system tracts in the Calabar Flank.

The TSTs of Ekenkpon Shales constitute 77% planktics, 89% Calcareous and 59% agglutinated forams while HST sections accounted for the remaining percentages for Planktics, Calcareous benthics and agglutinated forms respectively. However, 67% of total ostracods recovered were from the section interpreted as HST.

The Cenomanian Ekenkpon Formation has a dominance of planktic over the benthic forms. This does not necessarily suggest a very deep marine environment of deposition. The presence in addition, of arenaceous benthic forms such as Trochammina sp. together with the planktonic species of the suborder Hedbergella suggest rather a protected, occasionally open shallow marine depositional environment. The Ekenkpon Shales shows general paucity of arenaceous species at some depths and a dominance of Heterohelix and Hedbergella fauna, probably due to shallow water and restricted paleoecologic conditions.

The abundance of mollusks shells, gastropod remains and high ratios of arenaceous taxa in the Mfamosing formation suggests an uplifted platform less than 70m of water depth. The Campanian-Maastrichtian Nkporo Shales forms the topmost part of the Cretaceous sediments and contains diverse species of benthic foraminifera, including abundant shallow marine genera of Buliminella, and Globigerinelloides and which reveal a shallow marine depositional setup. Also, the absence of porcelaneous species indicates non-existence of continental or parallic conditions during the deposition of Nkporo Shales. Two main cycles of marine transgressions can be delineated in this study. During the Late Cenomanian and Turonian, This observation coincides reasonably with global sea level curve of Haq et al (1998) for the Cretaceous period.

5 CONCLUSION

The need for further work to establish, correlate and model the system tracts across the Calabar Flank basin inspired this research work. So the application of several approaches including field work, Lithologic logs, Laboratory analysis, diversity/abundance plots, sequence stratigraphic analyses helped to facilitate a better understanding of the sequence stratigraphy and paleoecology of the Calabar Flank.

Two genetic sequences were recognized for the Ekenkpon Shale with Maximum Flooding Surfaces (MFS's) delineated at 17.0m, 12.0m and 4.0m and dated 91.19Ma 93.09Ma and 94.75Ma respectively. Also, a Highstand, Lowstand and Transgressive System Tracts corresponding to 30-35m, 20-25m and 5-15m depth respectively were delineated for the Mfa-

ISSN 2229-5518

mosing limestone while a Highstand and Transgressive Systems Tract were identified for the New Netim marl. Evidence from Nkporo Formation indicated a Transgressive Systems Tract (TST). Two main cycles of marine transgressions was established in this study between the Late Albian to Early Cenomanian and Late Cenomanian to Mid-Turonian. This observation coincides reasonably with global sea level curve of Haq et al (1998) for the Cretaceous period. Paleoenvironments for studied sections ranged from fluvial to proximal offshore.

6 APPENDICES

6.1 DESCRIPTION OF LITHOLOGY, PALEONTOLOGY, PRIMARY SEDIMENTARY STRUCTURES, MICROFACIES AND ENVIRONMENTS OF DEPOSITION OF THE STUDIED LITHOLOGIC UNITS.

Age	Formation	Structures	Paleontology
Campanian-Maastrichtian	Nkporo Shale	Plant remains, burrows and parallel laminations.	Ammonites, and foraminifera.
Coniancian	New Netim Marl	Nodules, parallel laminations, irregular-massive beddings, mud cracks, root moulds, burrow and bioturbations.	Algae, foraminifera, and ammonites.
Late Cenomanian-Turonian	Ekenkpon Shale	Fissile, parallel laminations, parallel-massive beddings, burrows, and bioturbations.	Low diversity fauna dominated by dwarfed bivalves, and gastropods.

Age	Formation	Diagenetic Features	Lithology	Lithofacies/Microfacies	Environment of Deposition
Campanian-Maastrichtian	Nkporo Shale	Nodules, and concretions	Dark grey, carbonaceous, gypsiferous, friable shale with nodules.	Dark grey, carbonaceous friable shale.	Highly variable environments ranging from shallow open
Coniancian	New Netim Marl	Pelleted and clotted micrite matrix, fenestrate, desiccation vugs,	Dark grey- grey, massive bedded, laminated, poorly sorted, nodular, pelleted,	Laminated-bioturbated lime mudstone/micrite, nodular-massive marl.	Shallow marine shelf, lagoon to tidal flats.
Late Cenomanian-Turonian	Ekenkpon Shale	Limestone beds with pleated and clothe micrite envelope, isopachous, fringing cements, and neomorphic	Light grey- black, bioturbated, burrowed, poorly sorted, pelleted, skeletal, micritic limestone/wackstone and shale.	Whole fossils, 'Oyster' shell bed, bioturbated peloidal limestone interbeds, skeletal mudstone, dark flagger shale.	Shallow restricted marine shelf, lagoon and tidal flats, and open platform shelf lagoon with circulation.

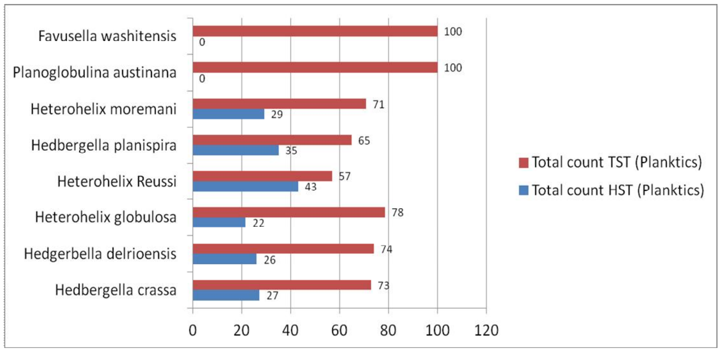
Age	Formation	Structures	Paleontology
Early-Mid Cenomanian	Ekenkpon Shales (Regressive parasequence)	Ventricular-flaser beddings, joints, folds, wavy laminations, plant remain, and mud cracks.	Ammonites, gastropods, and pelecypods
Middle Albian	Mfamosing Limestone.	Massive beds, algal mounds, burrows and bioturbations, boring, algal laminations.	Low diversity fauna dominated by coralline algae, stromatolites, stromatoporoids, gastropods, bivalves & ammonites.
Early Cretaceous	Awi Sandstone	Parallel-ripple laminations, folds, parallel-cross bedding, discontinuous-lenticular beddings, fluvial	Pelecypods, and coal beds.

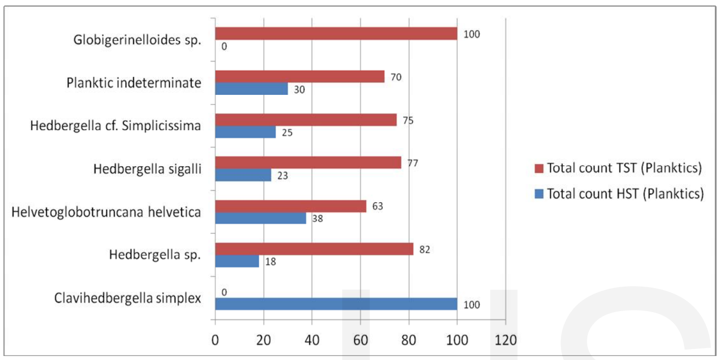
Age	Formation	Structures	Paleontology
Early-Mid Cenomanian	Ekenkpon Shales (Regressive parasequence)	Ventricular-flaser beddings, joints, folds, wavy laminations, plant remain, and mud cracks.	Ammonites, gastropods, and pelecypods
Middle Albian	Mfamosing Limestone.	Massive beds, algal mounds, burrows and bioturbations, boring, algal laminations.	Low diversity fauna dominated by coralline algae, stromatolites, stromatoporoids, gastropods, bivalves & ammonites.
Early Cretaceous	Awi Sandstone	Parallel-ripple laminations, folds, parallel-cross bedding, discontinuous-lenticular beddings, fluvial	Pelecypods, and coal beds.

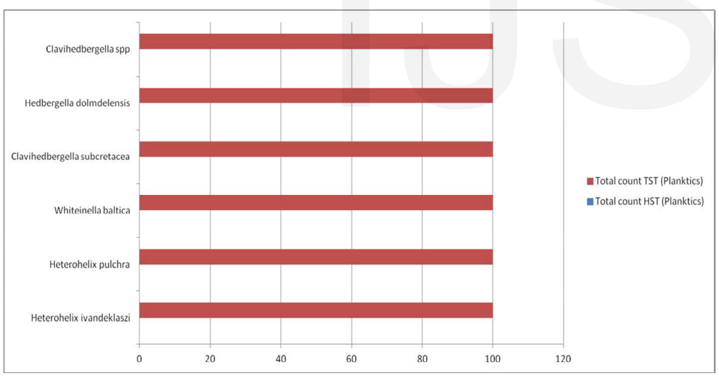
Age	Formation	Diagenetic Features	Lithology	Lithofacies/Microfacies	Environment of Deposition
Early-Mid Cenomanian	Ekenkpon Shales (Regressive parasequence)	Nodules, and concretions.	Light grey-pale plastic shale, lenticular- flaser bedded, clayey-silty shales with	Light grey-pale, plastic shale.	Regressive tidal flats.
Middle Albian	Mfamosing Limestone.	Pelleted and clotted micrite matrix, meniscus cement, fenestrate, isopachous cement, desiccation vugs, neomorphic spars.	Grey-dark grey, massive, micritic, pelleted, skeletal, bioturbated, stromatolitic limestone with siliclastic admixtures.	Pure lime mudstone, laminated-bioturbated micrite, skeletal packstone, algal stromatolite boundstone.	Variable environment ranging from platform reef or patch reef through open platform shelf, lagoon to tidal flats.
Early Cretaceous	Awi Sandstone	Ironstone nodules and concretions, sutured and fractured quartz grains and quartz overgrowth.	Grey-brownish, coarse-fine. Poorly sorted, angular-sub-rounded, arkosic conglomerates, sandstones, siltstones, mudstones, shales and coal.	Conglomerate- pebbly sandstone, cross bedded sandstones- siltstone, siltstone-mudstone-shale-coal.	Wide range of fluvial-deltaic environments.

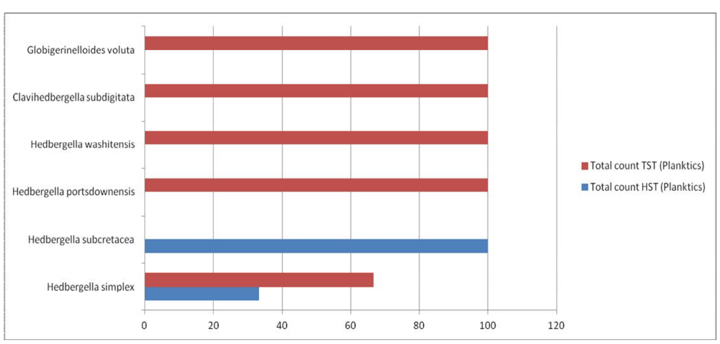
ISSN 2229-5518

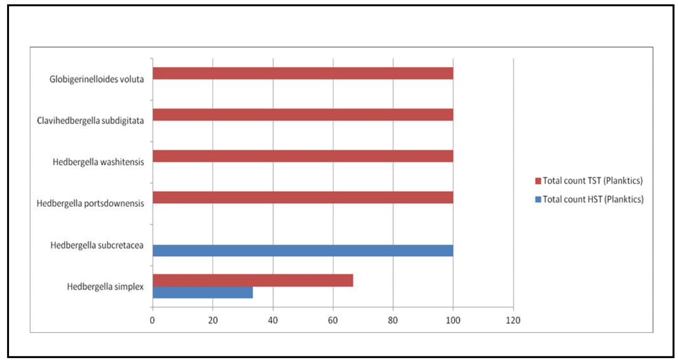
6.2 PERCENT DISTRIBUTION OF FORAMINIFERA WITHIN THE SYSTEM TRACTS (TST,HST) OF EKENKPON SHALE

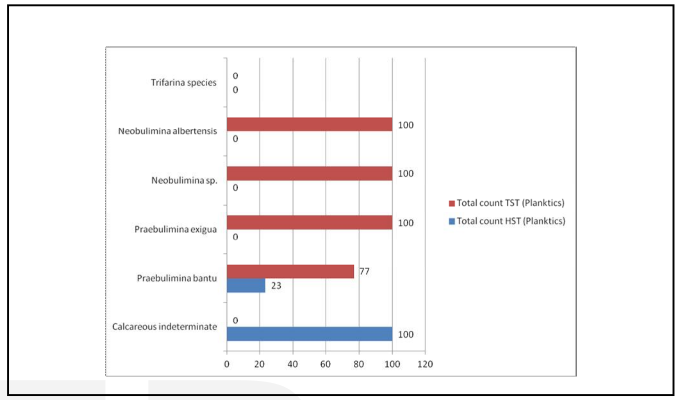




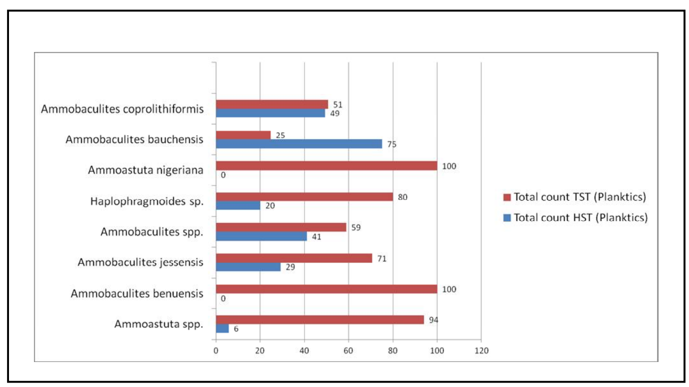


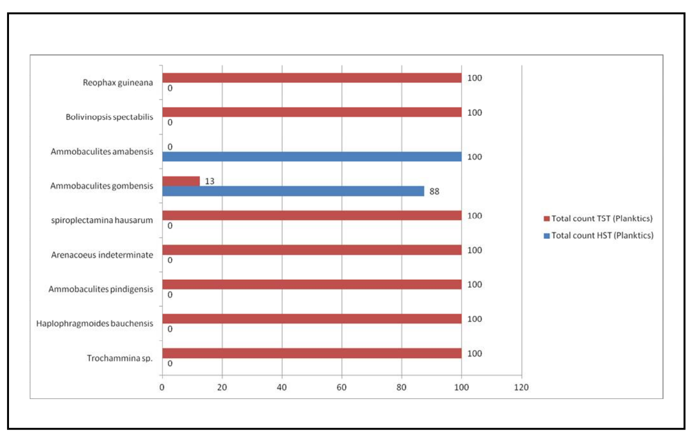






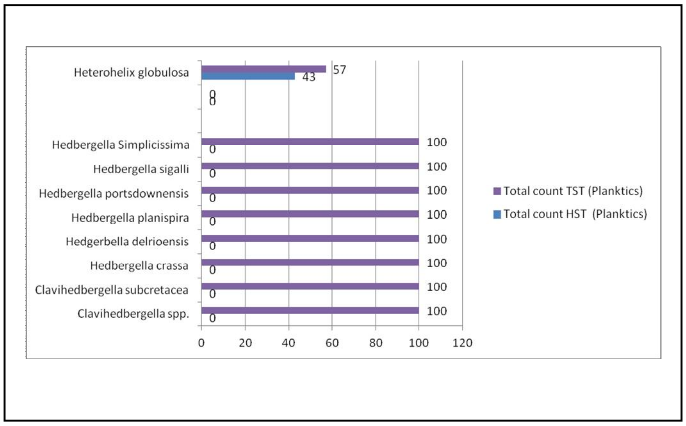
6.3 PERCENT DISTRIBUTION OF ARENACEOUS FORAMINIFERA WITHIN THE SYSTEM TRACTS (TST,HST) OF EKENKPON SHALE

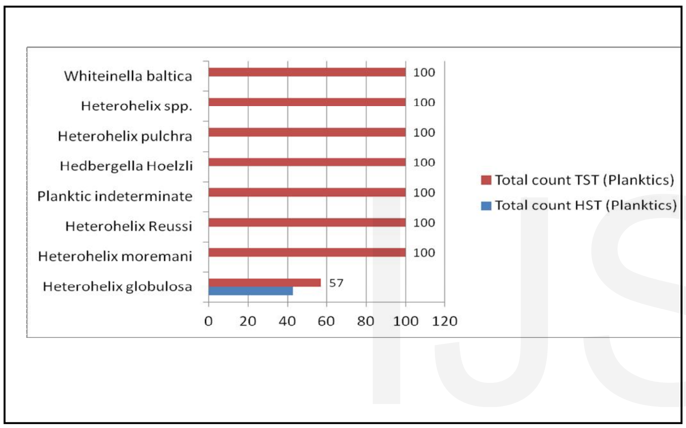


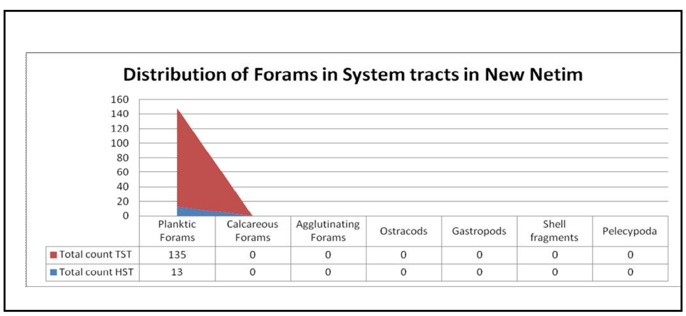


ISSN 2229-5518

6.4 PERCENT DISTRIBUTION OF PLANKTICS WITHIN THE SYSTEM TRACTS (TST,HST) OF NEW NETIM MARL

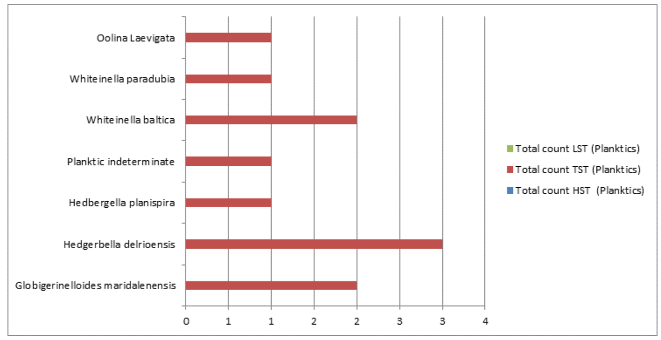


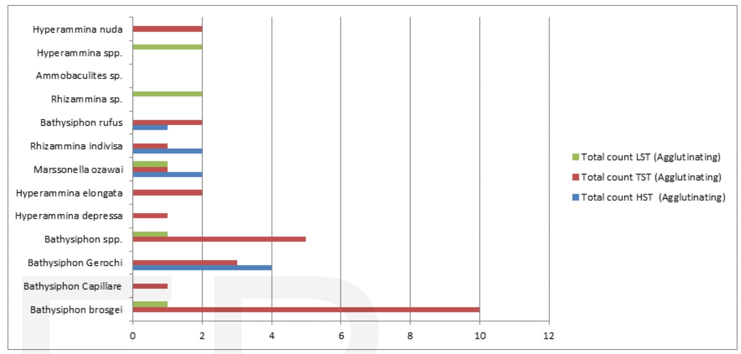


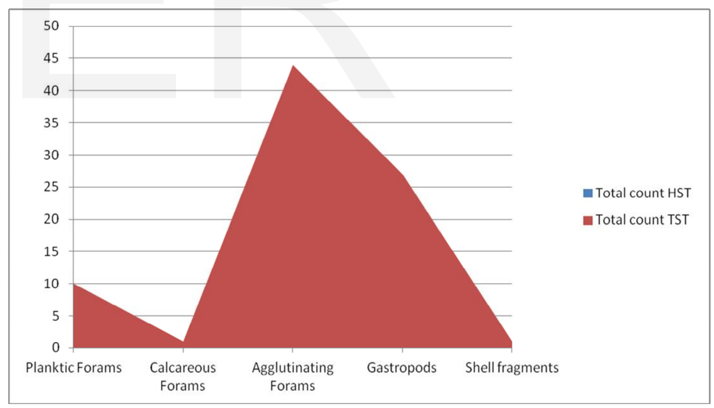


	Planktic Forams	Calcareous Forams	Agglutinating Forams	Ostracods	Gastropods	Shell fragments	Pelecypoda
Total count TST	135	0	0	0	0	0	0
Total count HST	13	0	0	0	0	0	0

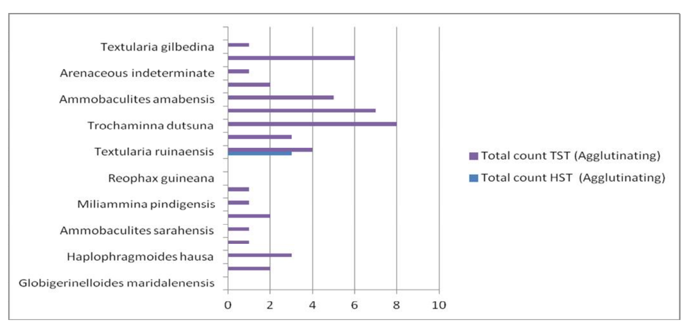
6.5 PERCENT DISTRIBUTION OF PLANKTICS AND BENTHICS WITHIN THE SYSTEM TRACTS (TST, HST) OF MFAMOSING LIMESTONE

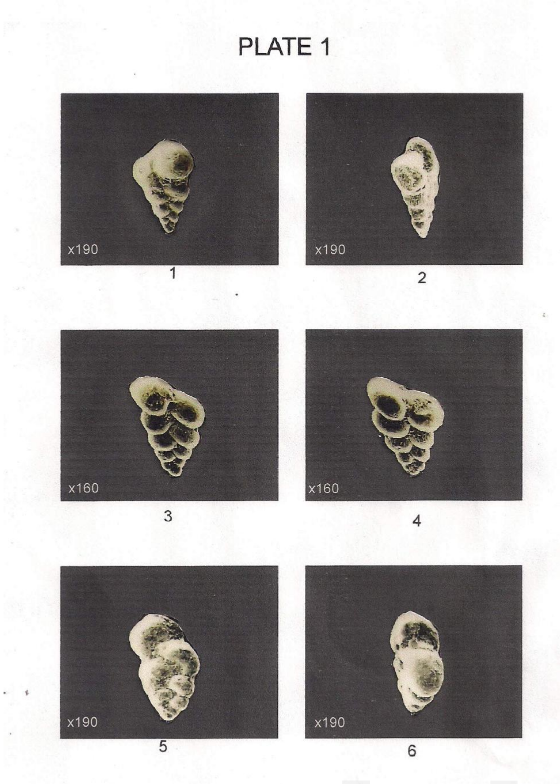






6.6 PERCENT DISTRIBUTION OF ARENACEOUS FORAMS WITHIN THE SYSTEM TRACTS (TST, HST) OF NKPORO SHALE.





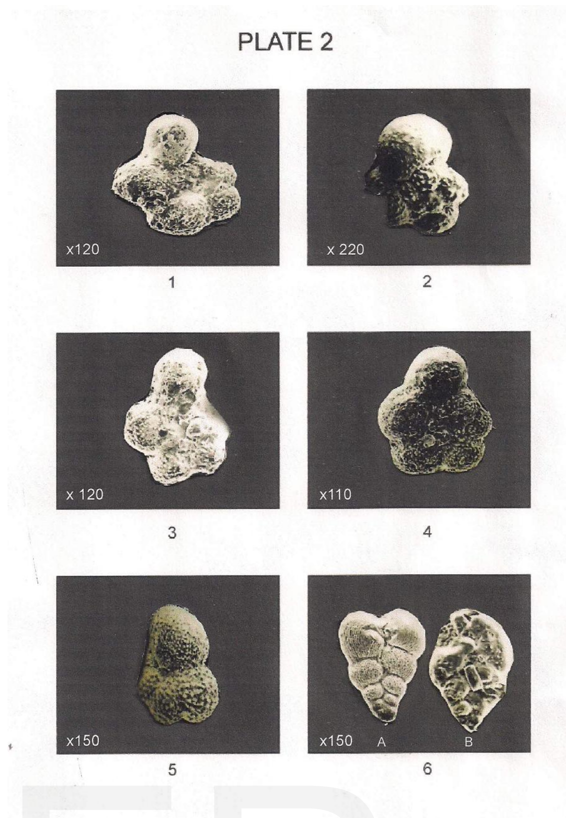


PLATE 1

1-2

Heterohelix reussi (Cushman)

1. *Side view x 190 Ekenkpon Shales beds(3m,6m, 8m,16m) from top of Ekenkpon Formation*
2. *Apertural view x 190*
   Dark grey shales

3-4

Heterohelix moremani (Cushman)

3 & 4 – Side view x 160 (Both)

Ekenkpon Shales bed (3m, 6, 12m, 14m) from top of Ekenkpon Formation

Dark grey shale

5-6

Heterohelix Globulosa

5- Side View x 190. Ekenkpon Shales bed.6: Apertural view x 190 (2m, 4m,6m,8m,12m, 16m) from the top of Ekenkpon Shales Formation

Dark grey shale

PLATE 2

1.

Clavihedbergella subcretacea(Tappan)

Umbilical view x 190. Ekenkpon Shales bed (2m,4m,8m,12m,16m) from the top of Ekenkpon Shales Formation

Dark grey shale.

2.

Whiteinella Spp.

Spiral view x 220. 9m from the top of Ekenkpon Formation (very rare)

3.

Clavihedbergella Simplex (Morrow)

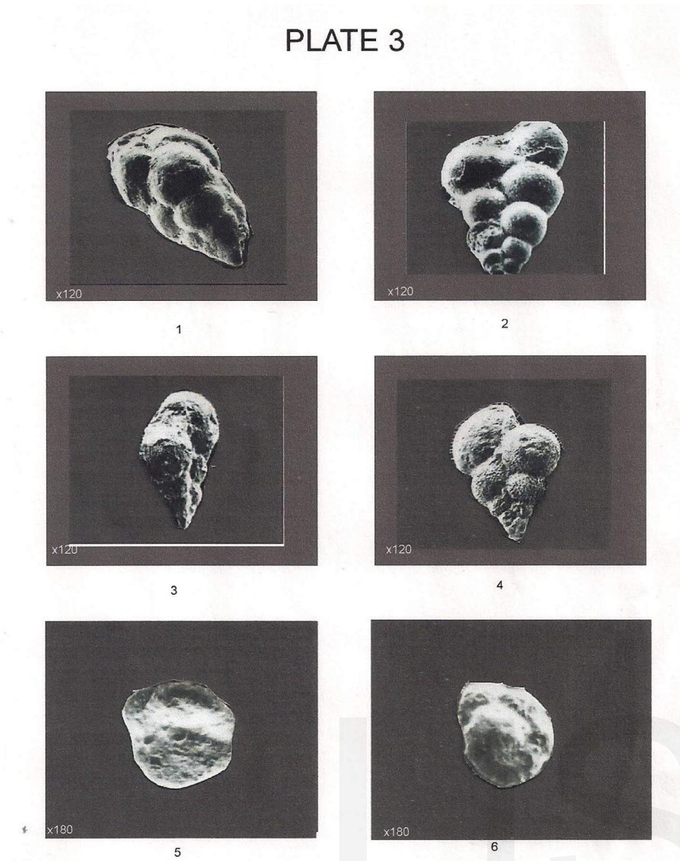
Umbilical view x 120. Ekenkpon shale. 9m from the top of Ekenkpon Formation

4.

Hedbergella Crassa

Umbilical view x 110. Lower Ekenkpon Shales from top of road cut km 25, Calabar-Itu road. Dark grey shale

ISSN 2229-5518



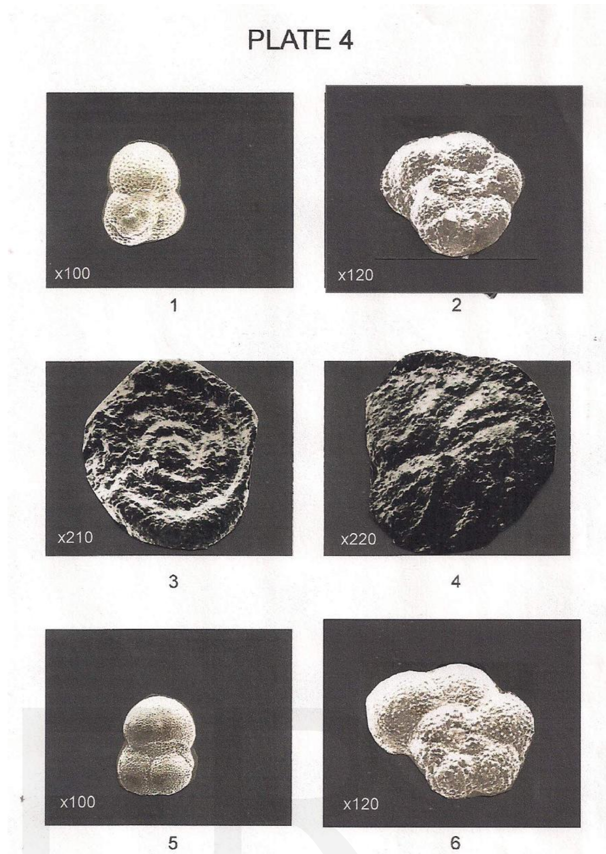


PLATE 3

1.

Praebulimina Exigua (Cushman and Parker)- 1935

1- Side view x 120. Nkporo Shales bed. 20km north of Calabar-Odukpani road.

2.

Heterohelix reussi (Cushman,1938)

Side view x 120. Ekenkpon Formation. Dark Grey Shale

5,6

Planulina beadnelli (Said and Barakat)

(1957) x 120

PLATE 4

1 & 5

Globigerinoides sp. (1,5) x 100

Mfamosing Limestones Formation

2.

Hedbergella portsdownwensis (Williams- Mitchell, 1948)

Spiral vie x 100, Ekenkpon Formation. 0.1km north of Calabar-Ikom-Itu road. Dark Grey Shale

3.

Ammodiscus spp. (D'Orbigny, 1839)

x 210. Nkporo shale West bank of Cross River- Ikot Okpora, Topmost Shale Unit

4.

Ammobaculites agrestis (Cushman and Applin, 1947)

Middle section of Ekenkpon Shales. Calabar- Ikom Junction

5.

Hedbergella delrionsis (Carsey)

Umbiical view x 150. Middle of Ekenkpon Formation. Km 28 Calabar-Itu express way

6A

Heterohelix navarronnensis- Loeblich

Side view x 150. Nkporo Shales

6B.

Heterohelix Pulchra

Side view x 150. Ekenkpon Shales- 2m, 8m,16m from top of Ekenkpon Formation (Dark grey shale)

PLATE ONE

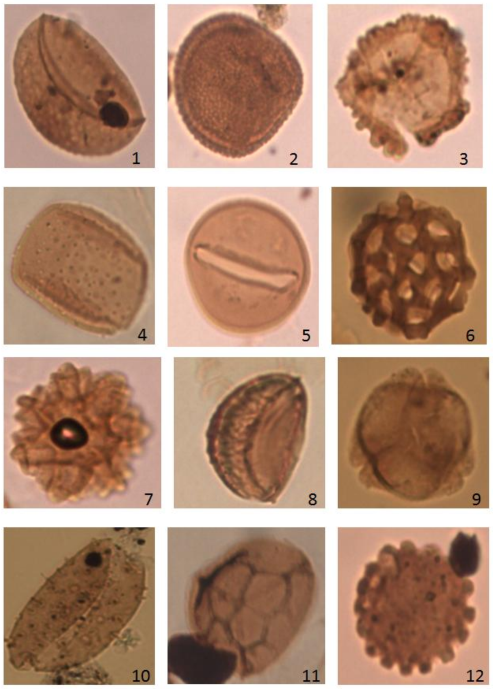


PLATE TWO

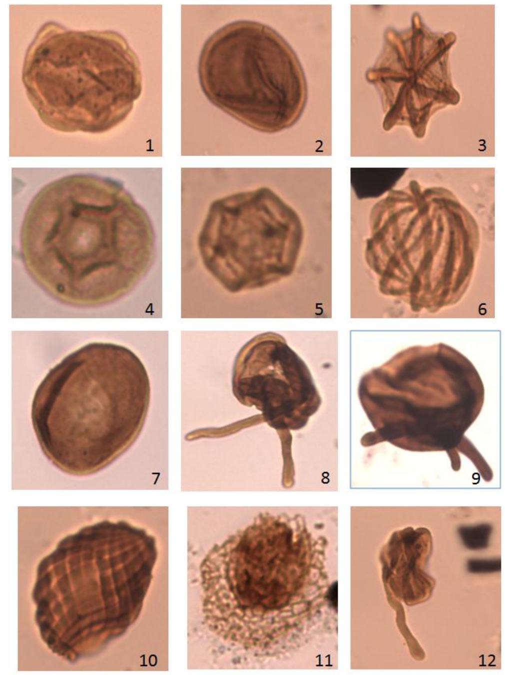


PLATE 1

1. *Ephedripites ambonoides*
2. *Foveotriletes margaritae*
3. *Cingulatisporites ornatus*
4. *Retidiporites miniporatus*
5. *Monocolpites marginatus*
6. *Buttinia andreevii*
7. *Ctenolophonidites costatus*
8. *Ephedripites spp*
9. *Syncolporites marginatus*
10. *Mauritidites crassibaculatus*
11. *Zlivisporis blanensis*
12. *Tubistephanocolpites cylindricus*

PLATE TWO

1 Galeacornea causea
2 Classopollis jardinei

3&6 Ephedripites subtilis
4. Cretacaeiporites mulleri
5. Cretacaeiporites polygonalis
7. Classopollis classoides
8&12. Elatroplicites africaensis
9. Elaterosporites klaszi
10. Ephedripites jansonii
11. Afropllis jardinus

ISSN 2229-5518

PLATE THREE

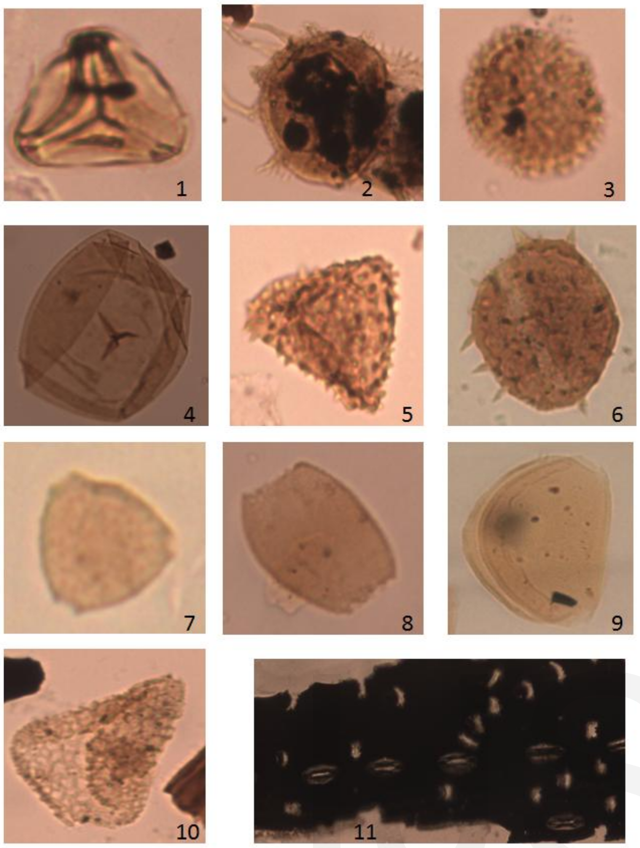


PLATE FOUR

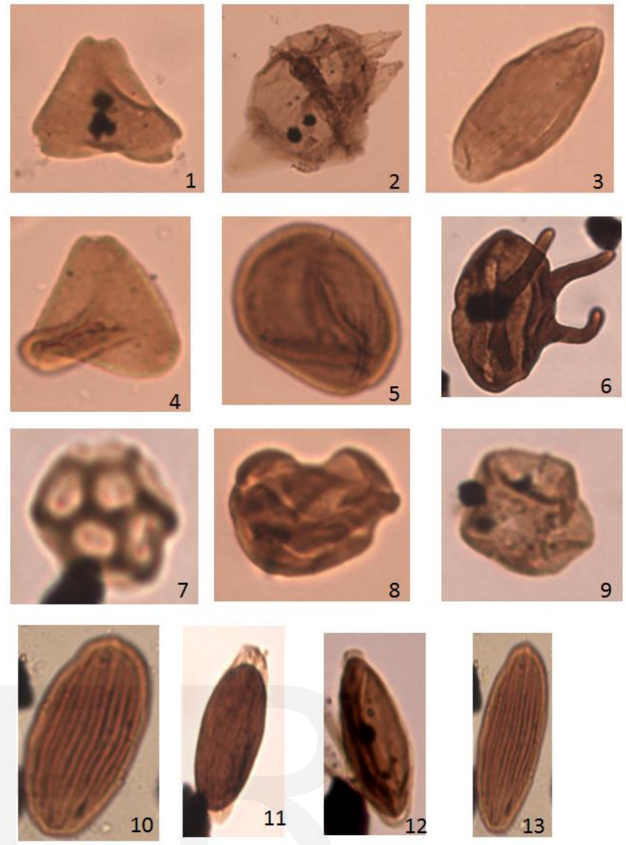


PLATE THREE

1. *Gleichenidites senonicus*
2. *Ariadnaesporites longiprocessum*
3. *Constructipollenites ineffectus*
4. *Acritarch (Leoisphaeridia spp)*
5. *Echitriporites trianguliformis*
6. *Mauritidites crassiexinus*
7. *Proteacidites longispinosus*
8. *Retidiporites magdalenensis*
9. *Longapertites marginatus*
10. *Syndemicolpites typicus*
11. *Charred gramineae cutticle*

PLATE FOUR

1 *1 &4. Triorites africaensis*

2 *Senegalinium bicavatum*

3. Steevesipollenites giganteus

5. Classopollis major

6. Elaterosporites klaszi

7. Cretacaeiporites polygonalis

8. Galeacornea causea

9. Multiporopollenites spp

10. Ephedripites multicostatus

11 &12. Steevesipollenites binodosus

13. Ephedripites spp

References

Adegbie A.T. and Bassey, C.E (2007): Cretaceous foraminiferal biostratigraphy and paleoecology of Ikono-1 well, Calabar Flank, Southeastern Nigeria. Journal of Mining and Geology. Vol 43(1) 2007 pg. 31-41.

Bassey, C.E., Harry, T.A and Ibidapo, A.S (2013): Sequence stratigraphic study of UNIBR field in the northern delta depobelt of Niger Delta, Nigeria. Journal of Environment and earth science. pg. 44-45.

Bassey, C.E and Ojesina, A.O (1999): Sequence Stratigraphic interpretation of E-block in Western offshore Niger Delta, Nigeria. Global Journal of Pure and Applied Sciences, Vol. 5 No. 2, 227-23

Catuneanu, O. (2003): Sequence Stratigraphy of Clastic systems. Geological Association of Canada, Short course notes; Vol. 16, p. 248.

Catuneanu, O. (2006). Principles of sequence stratigraphy. First Edition. Armsterdam p.34-208

Essien, N.U. and Bassey, E.D (2012). Lithostratigraphy, microfacies succession, sequence stratigraphy and depositional environment of the New Netim Formation, Calabar Flank, South Eastern Nigeria. International journal of basic and applied sciences. IJPAS-IJENS Vol. 12 No. 04

Haq B. U. , Hardenbol, J. and Vail, P.R. (1988). Mesozoic and Cenozoic Chronostratigraphy and eustatic cycles, in: Wilgus, et al., (eds.), Sea-level Change: An Integrated approach. SEPM special publication 42, pp 71-108.

Murat, R. C., 1972. Stratigraphy and paleogeography of Cretaceous and Lower Tertiary in southern Nigeria. In African Geology, Proc. Conf: on African Geology. University Press Ibadan, pp. 251- 266.

Nyong, E. E. and Ramanathan, R. M. (1985): A record of oxygen deficient palaeoenvironments in the Cretaceous of the Calabar Flank, S. E. Nigeria. Jour. Afr. Earth. Sc. 3(4): 455-460.

Petters, S. W. (1980): Biostratigraphy of the Upper Cretaceous foraminifera of the Benue Trough, Nigeria. Jour. Foram. Res. 10(3): 191-204.

Petters, S. W. (1982): Central West African – Tertiary benthic foraminifera and stratigraphy. Palaeontographica Abt. A bd. 179 Lfg 1-3: 1-104.

Petters S.W, Nyong E.E., Akpan E.B and Essien N.U. (1995): Lithostratigraphic revision of the Calabar Flank, South East Nigeria. Proceedings of the 31st Annual Conference of the Nigerian Mining and Geosciences Society, Calabar.

Reijers, T.J.A. and Petters, S. W. (1997): Depositional environments and diagenesis of Albian carbonates in the Calabar Flank, S. E. Nigeria. Jour. Petrol. Geol. 10(3): 283-294.

Sharon J.H, Brian T.H, Martin. A, Kenneth G.M (2015): Evolution and Phylogeny of Mid-Cretaceous (Albian- Coniacian) biserial Planktonic foraminifera. Journal of foraminiferal research, V45, P. 42-81. Doi: 10.2113 / gsjfor 45.1.42

Van Wagoner JC, Mitchum RM , Campion KM, Rahmanian VD.1990. Siliciclastic Sequence Stratigraphy in Well Logs, Cores, and Out-crop. v: Concepts for High-Resolution Correlation of Facies.Assoc.Petrol.Geol. Methods in Exploration Series, No.Z55pp.

Van Wagoner J C, Posamentier HW, Mitchum RM Jr,Vail PR,Sarg JF, et al.1988.An overview of the fundamentals of Sequence stratigraphy and key definitions. See Wilgus et al 1988, pp.39-4

Wornardt W., Jory P., Marcel B., (1999), Seismic stratigraphic analysis of the Doula Basin, Cameroun Jour, of Afri. erth. Sc V45, P. 42-81.