BIOSTRATIGRAPHIC AND PALEOENVIRONMENTAL EVALUATIONS OF TWO WELLS FROM THE ANAMBRA BASIN SE NIGERIA

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ABSTRACT

This paper is focused on some aspect of biostratigraphic study of the Mamu and Enugu Formations, Anambra Basin. It covers biostratratigraphic analysis of two exploratory wells for diagnostic age determination and paleoenvironmental interpretation. Twenty-five and ninety-three ditch cutting samples from Amansiodo and Akukua-2 wells respectively were palynological processed and analyzed for their palynomorphs content. In Amansiodo well, two broad informal palynological zones were identified *Echitriporites trianguliformis* zone (Campanian) and *Longapertites* sp. Zone (Maastrichtian), whereas five informal palynological zones viz; *Proteacidites sigalii* (AI Campanian), *Longapertites* sp. (AII Maaastrichtian), *Proxapertites operculatus* (AIII Paleocene), Auriculopollenites reticulates zone *(*AIV Middle *Eocene)* and *Spinizonocolpites baculatus* (AV Late Eocene) were erected in Akukua-2 well. Foraminiferal analysis shows moderately diverse assemblages of planktonic and benthonic foraminifera with a total of 41 species (30 calcareous and 11 arenaceous). A number of diagnostic biomarkers/ marker species and associated foraminiferal species such as *Ammobaculites coprolithiformis*, *Lenticulinagrandis, Lenticulina pseudomammiligerus, Bolivina afra, Bolivina explicata, Hedbergella holmdelensis,* and *Globotruncanita elevate* were recovered from Akukwa-2 well suggesting predominantly Inner Neritic, deepening to Middle Neritic at some horizons. The *Globotruncanita elevate, Hedbergella holmdalensis-Bolivinia afra* and *Ammobaculites coprolithiformis* foraminifera zones were established for this well and they quite correlate with the palynological zones. Based on the occurrence and distribution of microflora and microfauna species identified in the Akukwa-2 well (640-2384m), a Late Cretaceous (Campanian-Maastrichtian)-Paleogene (Paleocene-Late Eocene) age is identified for the studied section. In the Amansiodo well, poorly diverse assemblages of benthonic foraminifera with a nine arenaceous species such as *Ammobaculites coprolithiformis*, *Ammobaculites amabensis*, *Ammobaculites bauchensis*, *Haplophragmoides sahariense and Haplophragmoides talokaense* were recovered. This assemblage is typical of Campanian - Maastrichtian age. The sediments were predominantly deposited within Coastal Deltaic and deepening to Inner Neritic zones.

1. INTRODUCTION

Stratigraphic biostratigraphic study allows the use of age diagnostic microflora and microforams to date sedimentary sequences and correlate such sequence across wells and basin. Biozones are easily mapped and integrated with other studies to accurately date and correlate intervals of interest especially in hydrocarbon exploration. The dating is based on the First Downhole Occurrence (FDO) or Top occurrence (TO), Last Downhole Occurrence (LDO or Base occurrence (BO), Quantitative Top and Base occurrence (BO) etc. of key microflora.

High Resolution Biostratigraphic study was carried out on two exploration wells Amansiodo and Akukua-2 located in the Anambra Basin SE Nigeria (Fig. 1). The primary objectives of the study include the identification of age diagnostic palynoflora and macrofaunal assemblages found in the ditch cuttings and use their occurrence to corroborate the age and define the paleoenvironment. Ninety-three (93) ditch cutting samples from the wells were palynological processed and analyzed for their palynomorphs content and used to decipher the age of the sediment succession the well penetrated, while Forty (40) ditch cutting samples were analyzed for foraminifera and accessory microfaunas. This study is significant as it develops an informal biostratigraphic framework, thus, establishing the age of deposition of the sediments and also attempts a biostratigraphic correlation between the two wells.

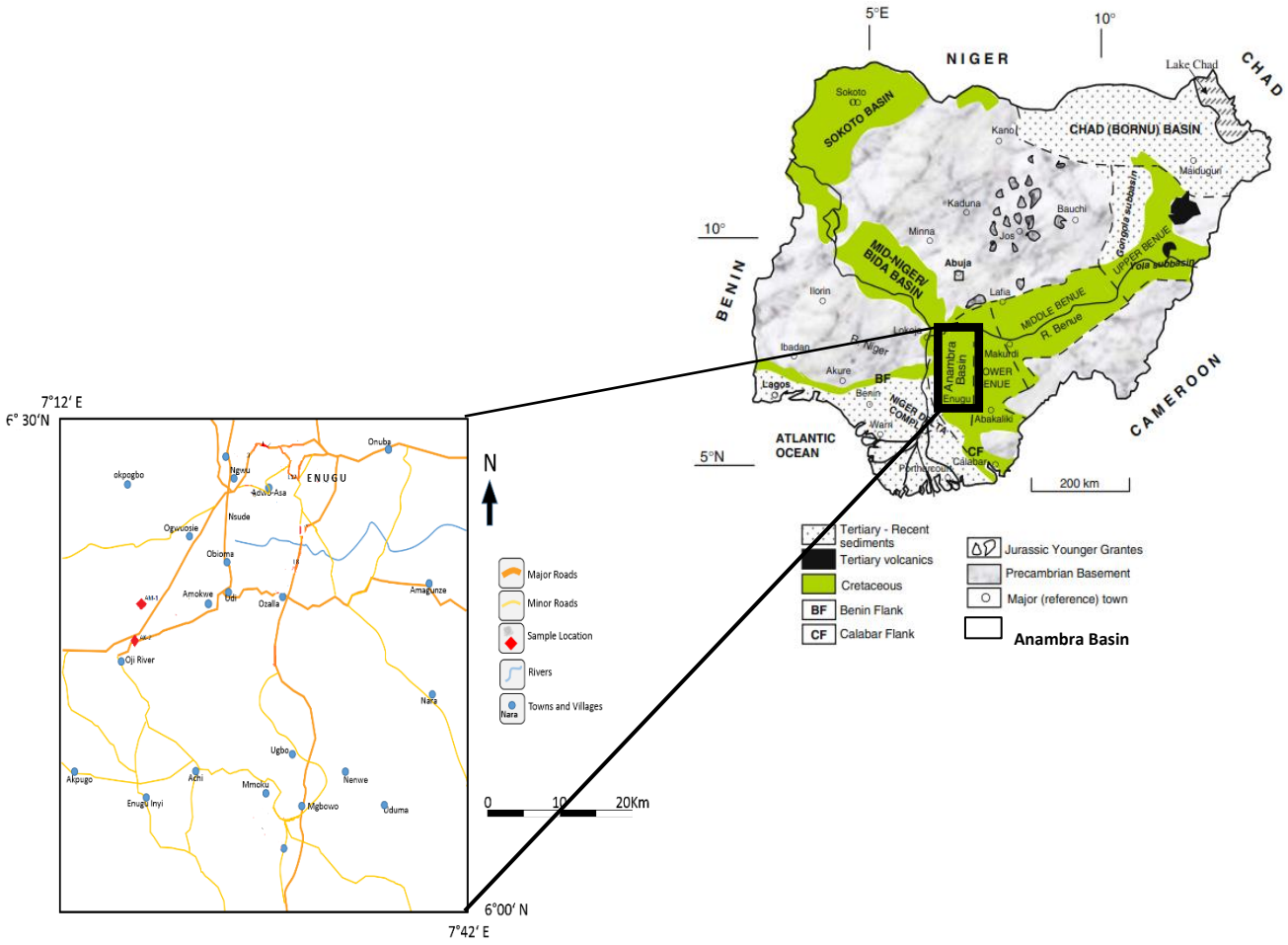


Fig 1: Map showing location of Amansiodo and Akukua-2 exploration wells

1.1 Geology of the study area

The Upper Cretaceous Anambra Basin is a NE-SW trending geosyncline that developed as a result of tectonics of the Lower Cretaceous breakup of the Gondwana continent. It covers an area of about 40,000sq.km. with sediment thickness increasing southwards to a maximum thickness of 12000m in the central part of the Niger Delta (Ononiwu *et al*. 2014). The Anambra basin is bounded on the Northwest by the Benue flank, on the Southeast by the Abakaliki fold belt and Southwestern flank by the Niger Delta hinge line. It is the structural link between the Cretaceous Benue Trough and the Tertiary Niger Delta.

The Basin contains thick sequence of Campanian marine shales of Nkporo Formation overlain by the Campanian-Maastrichtian Mamu Formation. This is overlain by the Ajali Sandstone Formation. This fluvio-deltaic Sandstone is subsequently overlain by the marine shale of Danian-Paleocene Nsukka and Imo Formation respectively. The Eocene Ameki group (Ameki, Nanka and Nsugbe Formations) overly the Imo shales and constitute the youngest lithostratigraphic units of the Anambra Basin (Table 1)

Table 1: Regional Lithostratigraphic Framework of SE Nigeria (modified from Murat

AGE		ABAKALIKI-ANAMBRA BASIN	AFKPO BASIN
M.Y 30	Oligocene	Ogwashi-Asaba Formation	Ogwashi-Asaba Formation
54.9	Eocene	Ameki/Nanka Formation/ Nsugbe Sandstone(Ameki group)	Ameki Formation
65	Paleocene	Imo Formation Nsukka Formation	Imo Formation Nsukka Formation
73	Maastrichtian	Ajali Formation Mamu Formation	Ajali Formation Mamu Formation
83	Campanian	Npkoro Oweli Formation/Enugu Shale	Npkoro Shale/Afikpo Sandstone
87.5	Santonian	Agbani Sandstone/ Awgu Shale	Non-deposition/Erosion
88.5	Coniacian		Eze Aku Group (include Amasiri Sandstone)
	Turonian	Eze Aku Group	
93	Cenomanian-Albian	Asu River Group	Asu River Group

2 METHODOLOGY

2.1 Palynological Preparation Technique

The Amansido-1 well (616-2287m) is located in the Anambra Basin SE Nigeria and classified in the OPL905 concession block. Ninety-three (93) ditch cutting samples from the well were palynological processed and analyzed for their palynomorphs content and used to decipher the age of the sediment succession the well penetrated

2.2 Micropaleontological preparation techniques

Foraminiferal analysis was carried out using twenty-five (25) ditch cutting samples and the biozonation of the well was based largely on sequence stratigraphic principles with precise age dating of zonal boundaries.

Forty (40) ditch cutting samples were analyzed for foraminifera and accessory microfaunas. The processing follows standard micropaleontological preparation techniques and the biozonation of the wells was based largely on sequence stratigraphic principles with precise age dating of zonal boundaries. A standard weight (30g) of each sample is soaked for four hours in kerosene, followed by water soaking overnight. The disaggregated sample is then washed under a shower of water over a 63-micron mesh sieve. The washed residue is then dried over a hot plate and sieved into three fractions (coarse, medium and fine) prior to picking. All the foraminifera, ostracods, shell fragments and other biota seen are picked and counted. The statistical data obtained is computerized using the Strata Bugs software. Bar plots of the abundance and species diversity are made from which candidate Maximum Flooding Surfaces are selected. Their positions are later confirmed on the log. The complete micropaleontological data is plotted in colour using StrataBugs at a scale of 1:5000. Faunal associations including benthic, planktic, benthic/planktic ratio (normalized) agglutinated/calcareous foraminiferal ratios etc., are plotted.

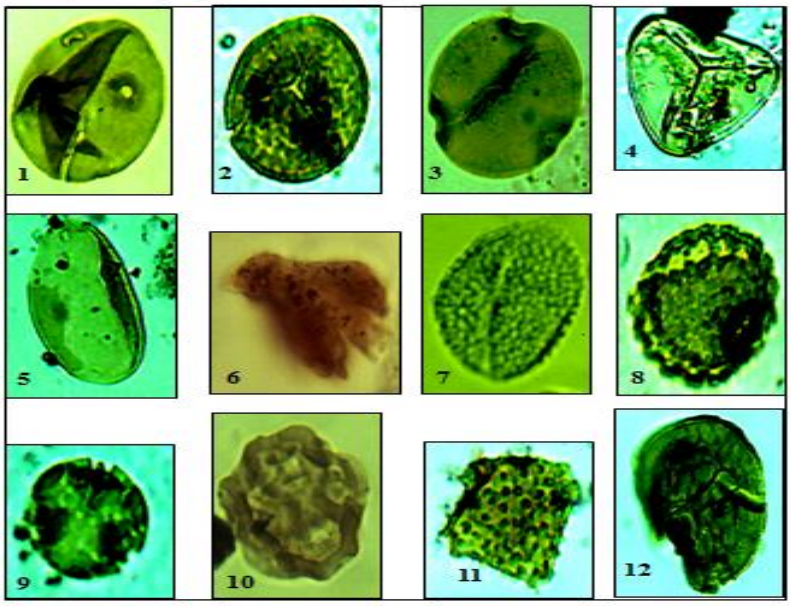
RESULTS DISCUSSIONS

PALYNOLOGICAL BIOSTRATIGRAPHY

2.1 PALYNOLOGICAL BIOSTRATIGRAPHY OF AKUKWA-2 WELL (640-2384M)

Ninety-three (93) ditch cutting samples from the well were palynological processed and analyzed for their palynomorphs content and used to decipher the age of the sediment succession the well penetrated. The palynoflora is quantitatively dominated by continental sporomorphs such as *Echitriporites trianguliformis*, *Longapertites* sp., *Monocolpites marginatus Laevigatosporites* sp., *Retimonocolpites* sp., and *Monocolpites marginatus* amongst others. Fairly abundant and diverse dinoflagellate cysts were recovered such as *Spiniferites* sp., *Cleistosphaeridium* sp., *Selenopemphix* sp., and *Exosphaeridium* sp. amongst others (Plate 1).

Palynomorph photomicrographs of Akukwa -2 well (Plate 1)



1. *Monoporites annulatus*. 1024m. X400
2. *Rugulatisporites caperatus*.1006m.X400
3. *Brevicolporites guinetii*. 1954m. X400
4. *Cyathidites* sp. 951m. X400.
5. *Laevigatosporites* sp. 750m. X400
6. *Botryococcus braunii*. 914m. X400.
7. *Arecipites exilimuratus*. 1945m. X400
8. *Tubistephanocolpites cylindricus*. 1244m. X400
9. *Psilatricolporites operculatus*. 1341m. X400
10. *Ctenolophonidites costatus*. 805m. X400
11. *Echitriporites trianguliformis*. 1244m. X400.
12. *Zlivisporites blanensis*. 3960m. X400

2.1.2. Palynological Zones of Akukwa-2 well

Based on the occurrence of marker species and palynoflora associations identified in the study, five (5) informal palynological zones viz; *Proteacidites sigalii* Zone (AI), *Longapertites* sp. Zone (AII), *Proxapertites operculatus* Zone (AIII), Auriculopollenites reticulatus Zone (AIV) and *Spinizonocolpites baculatus* Zone (AV) were erected. These zones are compared with published zones of Evamy *et al*. (1978), Lawal and Moullade (1987), Muller *et al.* (1987) and Salard cheboldaeff (1990). Thus, a Campanian (Late Cretaceous) to Priabonian (Late Eocene) age is established for the studied well section. The palynological details of the Zones are succinctly discussed below and graphically shown in table 2,

(i) *Echitriporites trianguliformis-Proteacidites sigalii* Zone

***Palynological Code:*AI**
Base depth: 2384m.
Top depth: 1116m.
Age: Campanian (Late Cretaceous)

This is the oldest palynostratigraphic unit identified in the well; it is a broad interval with sediment thickness of approximately 1268m. The base of this Zone coincides with the last sample analyzed at 2384m. The top is defined by the Top occurrence of *Monocolpopollenites sphaeroidites* (Pl. 3, Fig. 7) marked at 1116m. Other diagnostic palynomorphs identified in this zone are *Auriculiidites reticulatus, Echitriporites trianguliformis, Proteacidites sigalii Monocolpites marginatus*. Also, dinoflagellate cysts such as *Exochosphaeridium* sp., *Diphyes colligerum, Deflandrea* sp, *and Spiniferites* sp. amongst few others are recorded. This zone relates to the P100 zone of Evamy *et al*. (1978), the *Echitriporites trianguliformis-Scabratriporites annellus* (undifferentiated) Zone of Salard cheboldaeff (1990), *Longapertites* sp. 3 zone of Lawal and Moullade (1987) and the *Auriculiidites reticulatus* Zone of Muller *et al* (1987).

(ii) *Longapertites* sp. zone

***Palynological Code:* AII**

Base depth: 1116m.
Top depth: 1006m.
Age: Maastrichtian (Late Cretaceous)

The Top occurrence of *Monocolpopollenites sphaeroidites* defines the base of this zone; the top coincides with the Cretaceous-Tertiary (K/T) boundary at 1116m. This boundary is also marked by the Top occurrence of *Buttinia Andreevi* (Pl. 3 Fig. 6) and Top occurrence of *Proteacidites dehaani* (Pl. 3 Fig.9) defined at 1006m. Additional palynoflora events that characterizes this zone include; *Buttinia andreevi, Gnetaceaepollenites sp., Spinizonocolpites baculatus, Longapertites sp., Milfordia* sp., *Echitriporites trianguliformis* and *Exochosphaeridium* sp. This zone relates to the P100 zone of Evamy *et al.*, (1978), the *Echitriporites trianguliformis-Scabratriporites annellus* (undifferentiated) zone of Salard cheboldaeff (1990), *Longapertites sp.3–Spinizonocolpites baculatus*(Undifferentiated) zone of Lawal and Moullade (1987) and *Crassitricolporites subprolatus-Proteacidites dehaani* (Undifferentiated) zone of Muller et al (1987).

(iii) *Proxapertites operculatus* zone

***Palynological Code:*AIII**
Base depth: 1006m.
Top depth: 951m.
Age: Paleocene (Danian-Thanentian).

The base of this zone coincides with the Cretaceous-Tertiary (K/T) boundary, as well as the top occurrence of *Buttinia andreevi* and Top occurrence of *Proteacidites dehaani*at 1006m. The top is defined by the Quantitative Top occurrence of *Cyathidites* sp. (Pl. 1 Fig. 4) and the Top occurrence of *Auriculopollenites reticulatus* (Pl.3 Fig. 4) at 951m. The thin zone is also characterized by the occurrence of *Longapertites* sp., *Monocolpites marginatus, Echimonoporites rarispinosus,* and *Proxapertites operculatus*. Sparse presence of *Spiniferites* sp. and *Leoisphaeridia* sp. are also identified. This zone correlates to the P200 zone of Evamy *et al*. (1978), *Spinizonocolpitesbaculatus-Rugotricolporites felix* zone of Muller et al. (1987) and the *Proxapertites operculatus* zone of Salard cheboldaeff (1990). It was penetrated in Lawal and Moullade (1987).

(iv) *Auriculopollenites reticulatus* zone

***Palynological Code*: AIV**
Base depth: 951m.
Top depth: 732m.
Age: Lower (Yrepsian)-Middle (Bartonian) Eocene.

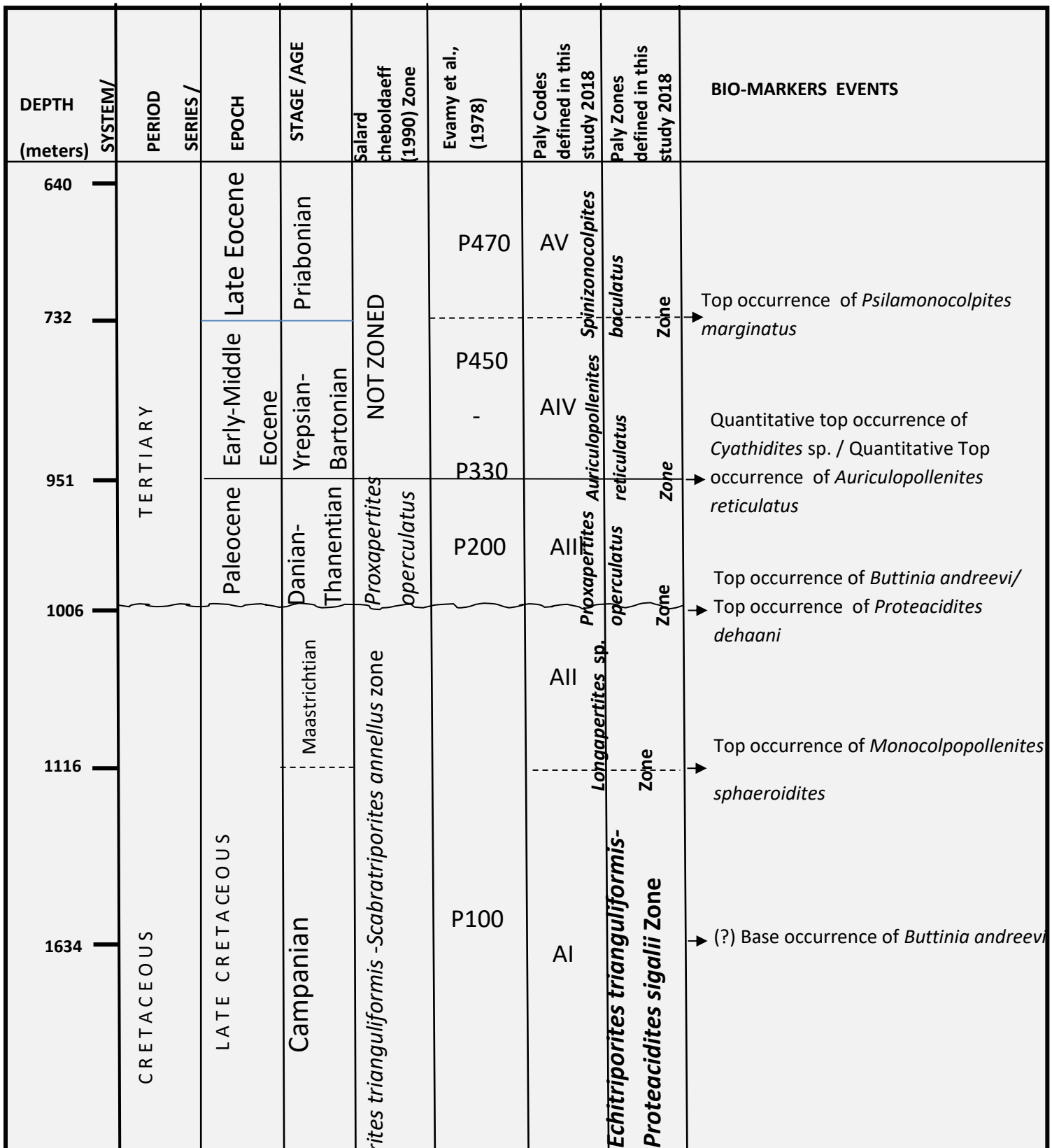
Description: The Quantitative top occurrence of *Cyathidites* sp. and the Quantitative top occurrence of *Auriculopollenites reticulatus* marked the base of this zone. The upper boundary is defined by the Top occurrence of *Psilamonocolpites marginatus*(Pl.3 Fig 5)at 732m. The occurrence of *Echitriporites trianguliformis, Auriculopollenites reticulatus, Mauritidites* sp., *Psiladiporites nnewiensis, Retitricolporites crassireticulatus, Retimonocolpites obaensis,* and fresh water species *Botryococcus braunii* areadditional palynoflora events recorded in this interval. Dinoflagellate cysts such as *Lingulodinium machaerophorum, Cyclonephelium* sp., *Homotryblium pallidum* and *Spiniferites ramosus* are identified. This zone correlates with the P330-P450 (undifferentiated) zone of Evamy *et al*. (1978) and the *Echitriporites trianguliformis* ''A''-*Echiperiporites estelae* zone of Muller *et al.* (1987).

(v) <u>*Spinizonocolpites baculatus* zone</u>

***Palynological Code*: AV**
Base depth: 732m.
Top depth: 640m.
Age: Priabonian (Late Eocene)

The base of this zone is marked by the top occurrence of *Psilamonocolpites marginatus*, while the top coincides with the first sample analyzed at 640m. *Cupanieidites* sp., *Echitriporites trianguliformis, Grimsdalea* sp., *Longapertites* sp., *Retimonocolpites obaensis, Spinizonocolpites baculatus, Laevigatosporites* sp. and *Acrostichum aureum* are identified in this zone. This zone relates to the P470 zone of Evamy *et al*. (1978) and the *Echiperiporitesestelae* zone of Muller *et al*., (1987).

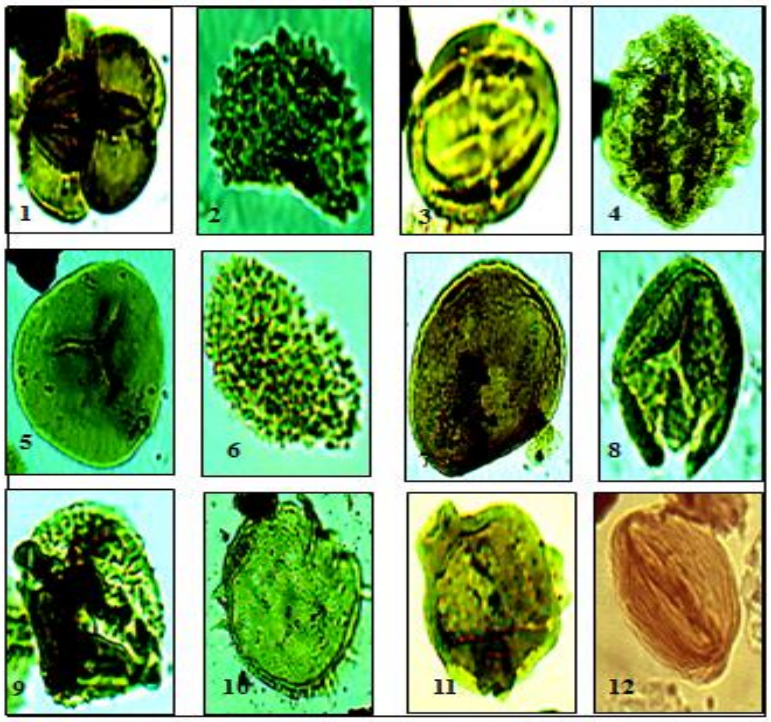
Table 2: Palynological Zones identified in the Akukwa-2 well (640 –2384m.).



2.2 PALYNOLOGICAL BIOSTRATIGRAPHY OF AMANSIDO-1 WELL (616-2287M)

Palynological processing, analysis and interpretation were carried out on twenty-five (25) ditch cutting samples to decipher the age of deposition. Moderately abundant and diverse palynomorphs were recovered from the samples (Plate 2).

Palynomorph Photomicrographs for Amansido-1 well (Plate 1)



1. *Adenantherites simplex*. 850m. X400.
2. *Verrucatosporites usmensis*. 759m. X400
3. *Sapotaceoidaepollenites* sp. 759m. X400
4. *Peregrinipollis nigericus*. 884m. X400.
5. *Acrostichum aureum*. 616m. X400
6. *Racemonocolpites hians*. 1852m. X400.
7. *Verrucatosporites* sp. 759m. X400.
8. *Polypodiaceoisporites* sp. 616m. X400.
9. *Polypodiaceoisporites* sp. 884m. X400.
10. *Spinizonocolpites echinatus*. 759m. X400.
11. *Retibrevitricolporites ibadanensis*. 1509m. X400.
12. *Striatricolpites (Striatopollis) catatumbus*. 850m. X400.

2.2.2: Palynological Zones of the Amansido-1 well

Two (2) broad informal palynological zones were identified and briefly described below. The palynomorph distribution is graphically presented as enclosure 4 while its stratigraphic summary is graphically shown as table 4:

(i) *Echitriporites trianguliformis* zone

***Palynological Code:*AI**
Base depth: 2287m
Top depth: 1399m
Age: Campanian

This is the oldest zone defined in the studied interval. The top is marked by the quantitative base occurrence of *Monocolpites marginatus (Pl. 4 Fig. 6)* at 1399m, while the base coincides with the last sample analyzed. Other palynoflora occurrence that characterizes the interval includes; *Proxapertites cursus, Echitriporites trianguliformis, Monocolpites sp., Psilatricolporites onitshaensis, Retitricolpites bendeensis, Polypodiaceoisporites sp., Longapertites* sp. and fresh water algae *Botryococcusbraunii*. The zone is correlated to the *Echitriporites trianguliformis-Scabratriporites annellus* combined zone of Salard cheboldaeff (1990), *Longapertites* sp.3zone of Lawal and Moullade (1987) and the *Auriculiidites reticulatus* zone of Muller *et al*., (1987).

(ii) *Longapertites* sp. zone

***Palynological Code*: AII**
Base depth: 1399m
Top depth: 616m
Age: Maastrichtian

*T*he upper margin of this zone is higher than the first sample analyzed and as such was not identified at 616m. The lower margin of is marked by the quantitative base occurrence of *Monocolpites marginatus*at 1399m. In addition, the occurrence of *Proteacidites sigalii, Longapertites vaneendenburgi, Longapertites marginatus, Longapertites microfoveolatus, Buttinia andreevi, Tubistephanocolpites cylindricus, Echitriporites trianguliformis, Scabratriporites annellus, Retidiporites magdalenensis, Ephedripites* sp. and *Spinizonocolpites echinatus* are recorded. Dinoflagellate cysts such as *Selenopemphix* sp., Spiniferites sp., *Leoisphaeridia* sp. and *Lingulodinium machaerophorum* were also identified. The zone is largely correlated to the *Echitriporites trianguliformis-Scabratriporites annellus* combined zones of Salard cheboldaeff (1990), *Longapertites* sp.3- *Spinizonocolpites baculatus* combines zones of Lawal and Moullade (1987) and the *Crassitricolporites subprolatus-Proteacidites dehaani* (Undifferentiated) zone of Muller *et al*., (1987).

Table 4: Palynological Zones identified in the Amansido-1 well (616 – 2287m.).

DEPTH (meters)	SYSTEM/PERIOD	SERIES / EPOCH	STAGE /AGE Lawal & Moullade	(1987) Zone Salard cheboldaeff (1990) Zone	Paly Code defined in this study 2018	Paly Zones defined in this study 2018	BIO-MARKERS EVENTS
616	CRETACEOUS	LATE CRETACEOUS	MAASTRICHTIAN	*Longapertites* sp.3 – *Spinizonocolpites baculatus* Zone	AII	***Longapertites* sp. Zone**	Occurrence of *Proteacidites sigalii* / Occurrence of *Longapertites vaneendenburgi* / Occurrence of *Scabratriporites annellus*
759							
1378							
1399			CAMPANIAN	*Echitriporites trianguliformis* – *Scabratriporites annellus* Zone	AI	***Echitriporites trianguliformis* Zone**	Quantitative base occurrence of *Monocolpites marginatus*.
1772							(?) Base occurrence of *Echitriporites trianguliformis.*
2287							

A sketch diagram of correlation between Akukwa-2 and Amansido-1 wells is shown in Fig. 2. The Akukwa-2 well (640-2384m) and Amansido-1(616-2287m) wells both penetrated Campanian and Maastrichtian sediments of majorly the Mamu and Enugu Formation. These zones are discussed in details below;

I. **Campanian age-*Echitriporites trianguliformis* zone**

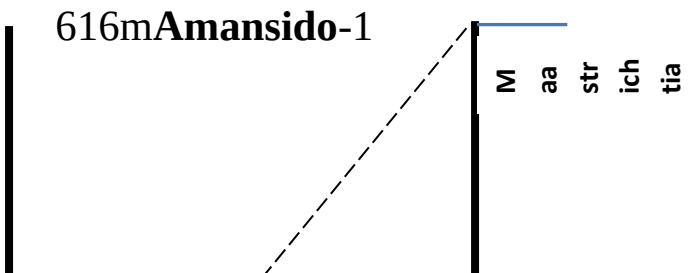
In the Akukwa -2 well, the Campanian sediments constitute the oldest interval, ranging 1116-2384m and is about 1268m thick. The Campanian age of the Amansido-1 well also make up the oldest sediments in the well ranging from 1399-2287m and is 888m thick. The palynoflora assemblages are generally similar and diagnostic for the Campanian age in both wells and as such can be correlated.

II. Maastrichtian age- *Longapertites* sp. Zone

The age is bonded at the upper margin by the K/T boundary at 1006m in the Akukwa -2 well. It ranges from 1006-1116m and about 106m thick. However, in the Amansido-1 well, the upper margin coincides with first samples analyzed at 616m. It ranges from 616-1399m and is about 783m thick. This well is further north in the Anambra Basin as against the Akukwa-1 well which is further south towards the Niger Delta Basin. This probably accounts for the Tertiary sediments encountered in the Akukwa-2 well. The palynoflora assemblages in both wells are generally similar and diagnostic of the Maastrichtian age and as such can be correlated.

III. Danian-Priabonian- *Proxapertites operculatus-Spinizonocolpites baculatus* Zone

Amansido-1 well did not penetrate Tertiary sediments while the upper section of Akukwa -2 well (640-1006m) approximately 366m thickness of Tertiary (Paleocene-Late Eocene) sediments were penetrated.



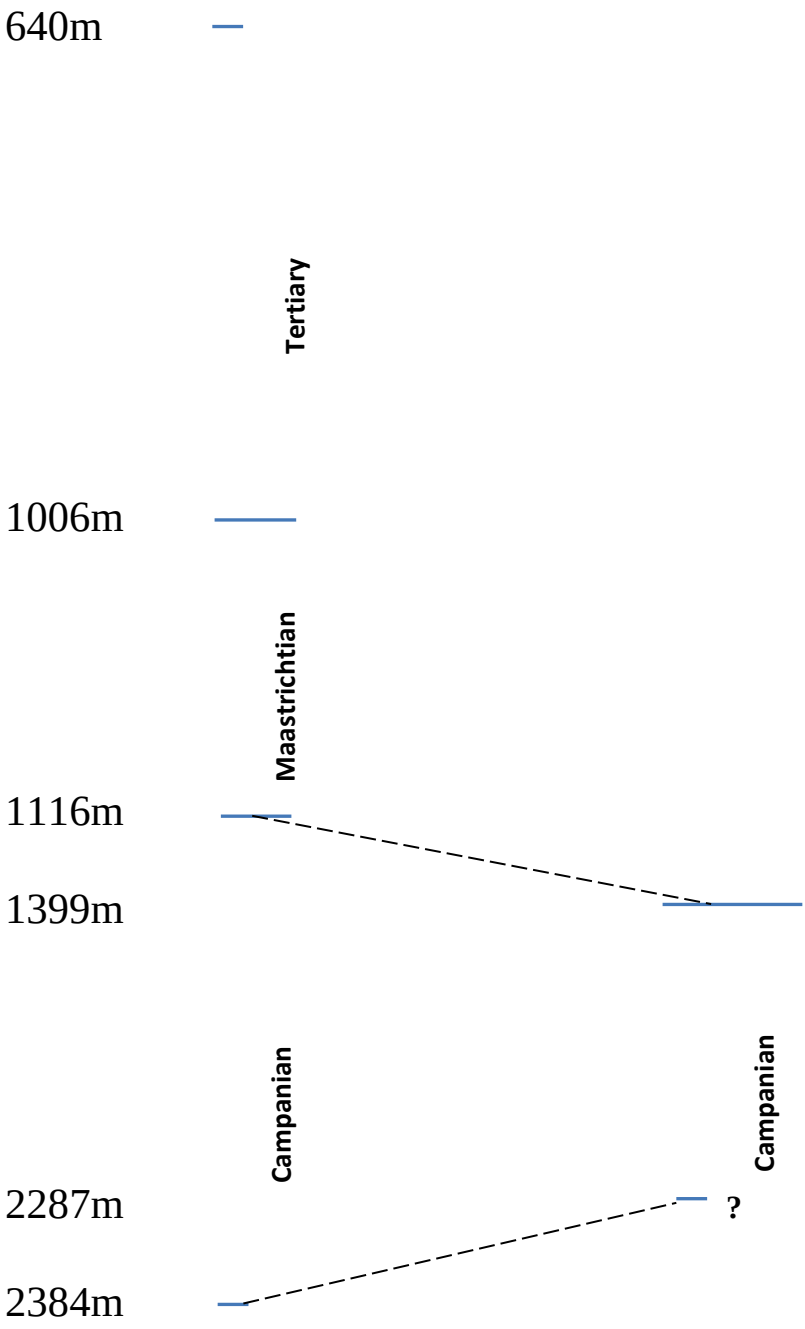


Figure 2: Sketch diagram of correlation between Akukwa-2 and Amansido-1 wells.

2.3: FORAMINIFERA BIOSTRATIGRAPHY

2.3.1 FORAMINIFERA BIOSTRATIGRAPHY OF AKUKWA-2 WELL

Moderately diverse assemblages of planktonic and benthonic foraminifera with a total of 41 species were recorded. 30 species (73.2%) are calcareous, while 11 (26.8%) are arenaceous. Among the calcareous forms, benthics accounted for 70% (21 species), while the remaining 9 species (30%) are planktics. The foraminiferal distribution chart is presented as Enclosure 2, while the zones and the plots of the peaks of species diversity and population abundance are shown in table 3. The highlights are graphically presented in Figure 3. A number of diagnostic biomarkers/ marker species and associated foraminiferal species such as *Ammobaculites coprolithiformis*, *Lenticulina grandis, Lenticulina pseudomammiligerus, Bolivina afra, Bolivina explicata, Hedbergella holmdelensis,* and *Globotruncanita elevate* were recovered from Akukwa-2 well.

Three (3) foraminifera "zones" are recognized in Akukwa-2 well, based on the critical evaluation of the key bio-events, particularly the First Downhole Occurrence (FDO) and Last Downhole Occurrence (LDO) of chronostratigraphically important foraminifera markers.

(i) Indeterminate Zone.

Stratigraphic Interval: 640 - 933m.

This is the first zone in the studied section of the well. The zonal top is placed at 640m, the depth of the first sample while the base is defined by the 57.97 Ma MFS; Hardenbol *et al.* 1998, at 933m. The interval is characterized by occurrence of *Lenticulinagrandis, Cibicorbisinflata, Hanzawaiastrattonii, Praeglobobuliminaovata* and *Alveolophragmiumcrassum*.

(ii) *Ammobaculites coprolithiformis* Zone

Stratigraphic Interval: 933- 1006m.

The top of this zone is defined by the 57.97 Ma MFS; Hardenbol *et al*. 1998 at 933m while the based is by the unconformity recognized at 1006m. The FDO of the zonal marker, *Ammobaculites coprolithiformis* was recorded at 969m.The zone correlates with the "P2" Planktic Foraminifera zone of Berggren *et al*. (1998) and Gradstein *et al*. (2004). The age for this zonal interval is Late Paleocene.

(iii) *Hedbergellaholmdelensis / Bolivinaafra* Zone

Stratigraphic Interval: 1006-1244m

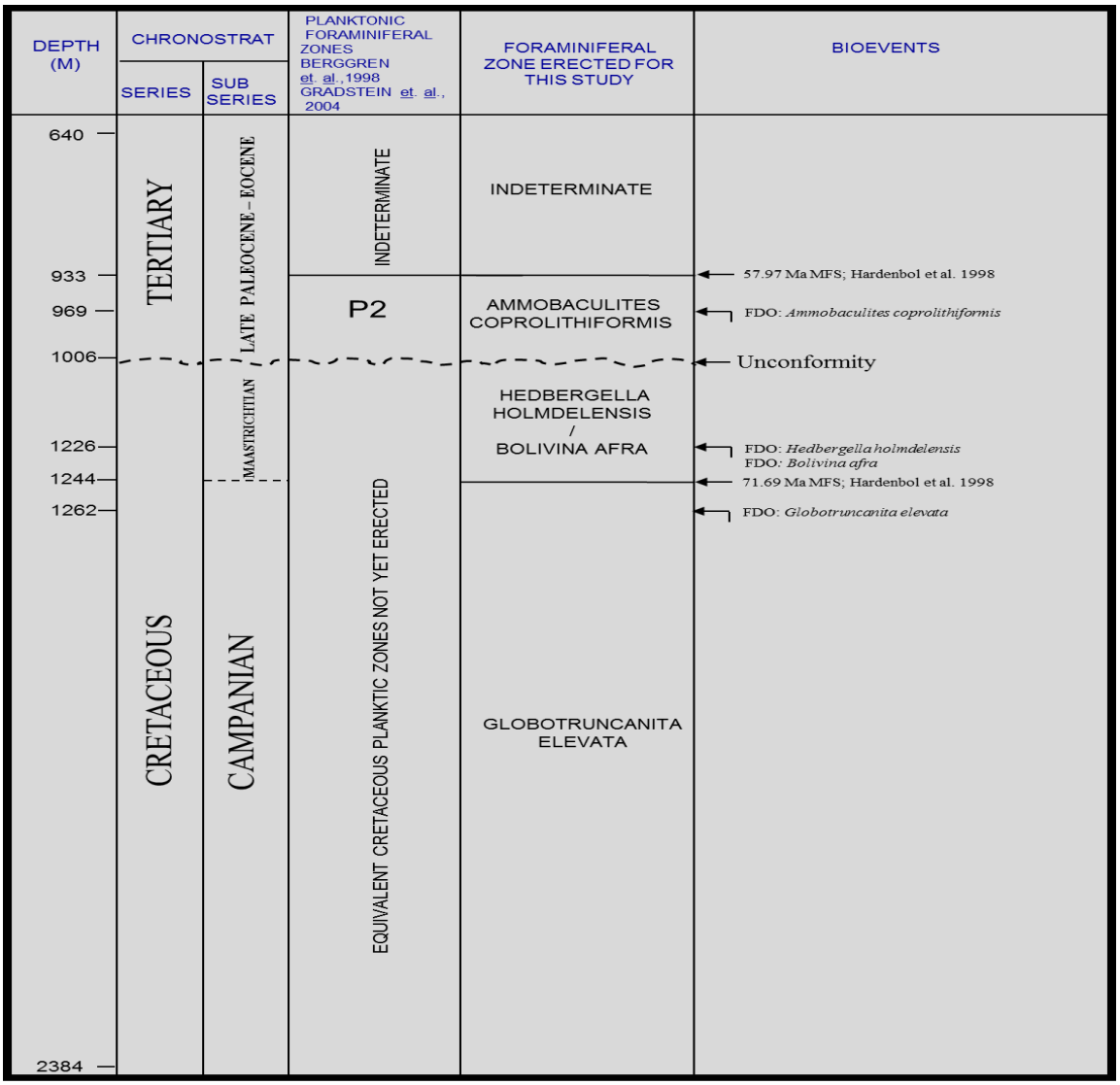
The top of the zone is defined by the unconformity recognized at 1006m, while the base is defined by the 71.69 Ma MFS; Hardenbol et al. (1998) recognized at 1244m. The FDO of the zonal markers, *Hedbergella holmdelensis* and *Bolivina afra* was recorded at 1226m. The associated species in this zone include *Heterohelixnarrovaensis, Pseudotextularia elegans, Globotruncanella havanensis, Ammobaculites amabensis* and *Ammobaculites coprolithiformis.* The age for this zonal interval is Maastrichtian.

(iv) *Globotruncanitaelevata* Zone

Stratigraphic Interval: 1244-2384m

The top of the zone is defined by the 71.69 Ma MFS; Hardenbol *et al*. (1998) recognized at 1244m, while the base is tentatively placed at 2384m, the depth of the last sample. The FDO of the zonal marker, *Globotruncanitaelevata* was recorded at 1262m. The associated species in this zone include *Pseudotextularia elegans, Ammotiumnkalagum, Ammotiumnwalium, Ammobaculites amabensis, Bolivinaexplicata, Praebulimina longa,* and *Ammobaculites coprolithiformis.* The age for this zonal interval is Campanian.

Table 3: Foram zones of the Akukwa-2 well (640-2384m)


DEPTH (M)
CHRONOSTRAT
SERIES
SUB SERIES
PLANKTONIC FORAMINIFERAL ZONES BERGGREN et. al.,1998 GRADSTEIN et. al., 2004
FORAMINIFERAL ZONE ERECTED FOR THIS STUDY
BIOEVENTS
640
933
969
1006
1226
1244
1262
2384
TERTIARY
CRETACEOUS
LATE PALEOCENE – EOCENE
MAASTRICHTIAN
CAMPANIAN
INDETERMINATE
P2
EQUIVALENT CRETACEOUS PLANKTIC ZONES NOT YET ERECTED
INDETERMINATE
AMMOBACULITES COPROLITHIFORMIS
HEDBERGELLA HOLMDELENSIS / BOLIVINA AFRA
GLOBOTRUNCANITA ELEVATA
57.97 Ma MFS; Hardenbol et al. 1998
FDO: Ammobaculites coprolithiformis
Unconformity
FDO: Hedbergella holmdelensis
FDO: Bolivina afra
71.69 Ma MFS; Hardenbol et al. 1998
FDO: Globotruncanita elevata

2.4.1 FORAMINIFERA BIOSTRATIGRAPHY OF AMANSIDO-1 Well

Poorly diverse assemblages of benthonic foraminifera with a total of nine (9) arenaceous species were recorded. The foraminiferal distribution chart is presented as Enclosure 5 and the highlights are graphically presented in Table 5 below. Foraminiferal species such as *Ammobaculites coprolithiformis, Ammobaculites amabensis, Ammobaculites bauchensis, Haplophragmoides sahariense and Haplophragmoides talokaense* were recovered from well Amansiodo-1. This assemblage is typical of Campanian - Maastrichtian age.

One (1) foraminifera "zone" was recognized in Amansiodo-1 Well based on the critical evaluation of the key bioevents, particularly the First Downhole Occurrence (FDO) of chronostratigraphically important foraminifera marker, *Ammobaculites coprolithiformis* whose FDO's mark Late Maastrichtian age. The zones are correlated with the standard planktic foraminiferal zones of Berggren *et al*. (1998); the Global Sequence Chart of Hardenbol *et al*. (1998) and the chronostratigraphic scheme of Wornardt (2002). The zonal names used in this report conformto the Cretaceous Biochronostratigraphy of Hardenbol *et al.* (1998).

(i) *Barren*.

*Stratigraphic Interval:*2287-1109m.

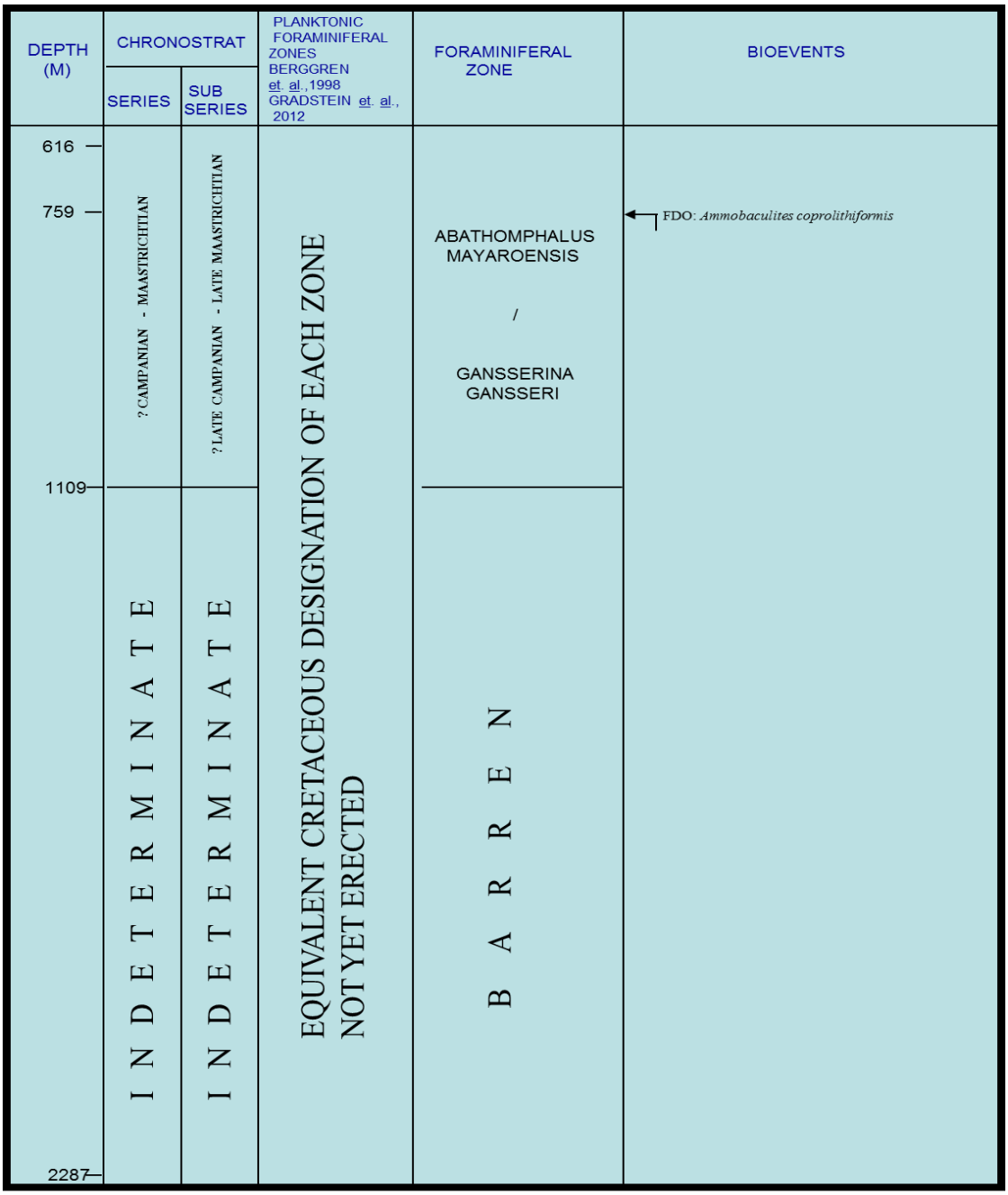
This is the first zone identified in the studied section of the well. The zoneis barren of foraminifera species and it is therefore indeterminable.

(ii) *Abathomphalusmayaroensis / Globotruncanagansseri* Zone

*Stratigraphic Interval:*1109-616m.

The top of this zone is placed at 616 m, the depth of the first sample while the based is placed at 1109 m. The species recovered in this zone include *Ammobaculites coprolithiformis, Ammobaculites amabensis, Ammobaculites bauchensis, Haplophragmoides sahariense and Haplophragmoides talokaense.* The age for this zonal interval is Late Cretaceous (Campanian-Maastrichtian).

Fig 5:Foram zones in the Amansido-1 well (616-2287m)



5. ENVIRONMENT OF DEPOSITION

The depositional environments penetrated by the studied sections were principally arrived at using the palynoflora assemblages recovered in the wells. Microfauna assemblages are also integrated where they have been recorded. The wells are discussed below.

5.1 AMANSIDO-1 WELL (616-2287M)

Three broad depositional environments were suggested in the Amansido-1 well (616-22877m) viz:

616-1109m: Inner Neritic Environment

This interval contains most of the dinoflagellate cysts recovered in the well which include, *Leoisphaeridia* sp., *Thalassiphora sp., Phelodinium* sp., *Lingulodinium machaerophorum, Selenopemphix*sp., *Spiniferites sp.* and foraminifera wall lining. In addition, records of *Ammobaculites coprolithiformis*, *Ammobaculites amabensis*, *Ammobaculites bauchensis*, *Haplophragmoides sahariense* and *Haplophragmoides talokaense*were identified within this interval which corroborates the predominantly Inner Neritic environment of deposition. This assemblage is in association with abundant *Echitriporites trianguliformis, Monocolpites* sp., *Longapertites* sp., *Monocolpollenites sphaeroidites, Psilamonocolpites marginatus, Constructipollenites ineffectus, Retidiporites magdalenensis, Cyathidites* sp., *Verrucatosporites* sp. and *Verrucatosporites usmensis.*

1300-1564m: Lacustrine-Channel to Coastal Swamp Environment

Palynoflora include moderate records of *Polypodiaceoisporites* sp., *Laevigatosporites* sp., *Inaperturopollenites* sp., *Monocolpites* sp., *Psilamonocolpites marginatus, Retimonocolpites obaensis* and *Cyathidites* sp. co-occurring with rare records of *Leoisphaeridia* sp. Fresh water algae *Botryococcusbraunii*is also identified suggesting channel deposits. This interval is barren of microfauna species.

1564-2284m: Channel Environment

This interval shows significant reduction in palynomorphs with sparse occurrence of acritarch *Leoisphaeridia* sp. sporomorphs such as *Psilatricolporites crassus, Sapotaceoidaepollenites* sp., *Retitricolporites irregularis, Echitriporites trianguliformis, Verrucatosporites* sp. and fresh water element *Botryococcusbraunii*.This interval is barren of microfauna species.

5.2 AKUKWA-2 WELL (640-2384)

The palynomorphs recovered from the Akukwa-2 well suggest the following environment of deposition;

640-896m: Fluvio-marine

This interval is characterized by relative low records of terrestrial palynomorphs such as *Laevigatosporites* sp., *Spinizonocolpites baculatus, Cyathidites minor, Monocolpites marginatus, Longapertites* sp. *Retimonocolpites obaensis*and *Constructipollenites ineffectus* in association with dinoflagellate cysts such as *Cyclonephelium*sp., *Spiniferites* sp., *Exochosphaeridium sp.*and *Leoisphaeridia* sp.Also records of microfauna such as *Bolivinascalpratamiocenica, Hopkinsinasemiornata, Lagenastriata, Lenticulinagrandis, Alveolophragmiumcrassum, Ammobaculites coprolithiformis* and species of *Haplophragmoides*were identifiedwithin the 823-1006m interval.

896-1207m: Coastal swamp- Inner Neritic

This interval show an increase in land derived (terrestrial) species which are largely dominated by smooth trilete spore (?*Acrostichum aureum*), *Proxapertites cursus, Auriculopollenites reticulatus, Auriculiidites reticulatus, Inaperturopollenites sp., Longapertites sp., Monocolpites marginatus, Retimonocolpites sp., Cingulatisporites ornatus, Cyathidites minor, Monosulcites sp. and fresh water species Botryococcus braunii* and *Pediastrum.* This is in association with dinoflagellate cysts such as *Achomosphaera* sp., *Exochosphaeridium* sp., *Leoisphaeridia*sp., *Oligosphaeridium complex, Paleocystodinium* sp., *Operculodinium severini and Senegalinium* sp.In addition, *Bolivinascalpratamiocenica, Hopkinsinasemiornata, Lagenastriata, Lenticulinagrandis, Alveolophragmiumcrassum, Ammobaculites coprolithiformis* and species of *Haplophragmoides*were identified within the interval 823-1006m

1207-1908m: Inner Marine

Marine index species such as Cleistosphaeridium sp., Cometodinium sp., Cordosphaeridium sp., Coronifera oceanica, Coronifera sp., Cribroperidinium sp., Diphyes colligerum, Florentina sp., foraminifera wall lining, Leoisphaeridia sp., Impagidinium sp., Selenopemphix sp., Spiniferites sp., Senegalinium sp., Aeoligera sp. and Operculodinium centrocarpum were identified within this interval and depicts marine environment of deposition. This assemblage co-occurs with palynomorphs such as Constructipollenites ineffectus, Echitriporites trianguliformis,

Ilexipollenites sp., Inaperturopollenites sp., Longapertites marginatusand Longapertites vaneendenburgi amongst others.The interval 1006-2018m contain foraminifera species such as*Bolivinaafra, Bolivinaexplicata, Praebuliminaladdi, Praebuliminalata, Praebuliminarobusta, Praebulimina longa, Praebuliminaexigua, Ammobaculites coprolithiformis, Ammotiumnkalagum, Ammotiunnwalium, Ammobaculites amabensis, Ammobaculites bauchensis, Haplophragmoides talokaense and species of Verneuilina*and *Ammobaculites* which furtherconfirm anenvironment of deposition that is predominantly Inner Neritic (Stanley &Adegoke 1972).

1908-2384m: Channel-Coastal Swamp environment

The admixture of predominantly terrestrial palynomorphs and the generally low records of marine dinoflagellate cysts as compared to the abundance in the overlying interval with presence of fresh water algae such as *Botryococcus braunii* and *Pediastrum* sp. suggest deposition of sediments in transitional environment (Coastal swamp/deltaic) with influence of channel deposits depicted by the presence of fresh water elements.

6. **CONCLUSION**

Results on the biostratigraphic and paleoenvironmental evaluations of two wells from the Anambra basin SE Nigeria lead to the following conclusions;

- Five (5) palynological zones were erected within the Akukwa-2 well while two (2) palynological zones were erected in Amansiodo-1 well
- Three (3) foramnifera zones were identified in Akukwa-2 well while Two (2) foraminifera zones were identified in Amansiodo-1 well.
- For Akukwa-2 well, a Late Cretaceous (Campanian-Maastrichtian)-Paleogene (Paleocene-Late Eocene) age is identified for the studied section
- Akukwa-2 well suggesting predominantly Inner Neritic, deepening to Middle Neritic at some horizons.
- Amansiodo-1 well is typical of Campanian - Maastrichtian age. The sediments were predominantly deposited within Coastal Deltaic and deepening to Inner Neritic zones.