

# Integrated Biostratigraphic Analysis for part of Deep Offshore, Niger Delta Basin, Nigeria

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## Abstract

Integrated biostratigraphic analysis were carried out on Bobo-3, Doro-1 and Bolia-1X wells deep offshore Niger Delta Basin, Nigeria. Palynological analysis was carried out on 295 ditch cutting samples (Bobo 3 = 82, Doro 1= 109, and Bolia 1X= 104). Foraminiferal and openhole geophysical log data were also provided for the studied interval. The intervals studied are 10700-15600 ft, 8060-16860 ft and 7900-13000 ft in Bobo-3, Doro-1 and Bolia-1X wells respectively belonging to the Agbada Formation. Lithologically, the section varies from alternation of sand and shale units with carbonaceous debris, mica flakes, ferruginised materials and glauconite at some interval as accessory minerals. Biozonation included twelve palynological biozones ( three taxon range biozones in Bobo-3 well, two interval, three taxon range, one non-diagnostic biozones in Doro-1 well and one interval, one diagnostic, three taxon range biozones in Bolia-1X well) and six planktonic foraminiferal biozones ( one taxon range biozone in Bobo-3, one interval, four taxon range biozones in Doro-1 and Bolia-1X wells). The proposed palynological biozones are *Stereisporites* sp. - *Cyperaceaepollis* sp., *Nymphaepollis clarus*- *Gemmamonocolpites* sp., *Multiareolites formosus* - *Retibrevitricolporites obodoensis*, *Belskipollis elegans*, *Crassoretitriteles vanraadshooveni*, *Pachydermites diderixi* and *Magnastriatites howardi* biozones which are correlatable with the pantropical zones. While established foraminiferal zones are *Globorotalia fohsi peripherronda*, *Globigerinoides extremus*-*Globigerinoides humerosa*, *Globorotalia acostaensis acostaensis*, *Globorotalia fohsi peripherronda* and *Catapsydrax stainforthi*. Samples from the section are dated early Miocene to early Pliocene age based on the independent paleontological evidences. The deduced paleoenvironments of the strata penetrated by the well range from outer neritic through bathyal to deep marine.

**Keywords: Palynological, Foraminiferal, Biozonation, Miocene, Deep marine**

## I. Introduction

The study area is located in the deep offshore Niger Delta area, Nigeria (Figure 1). The Niger Delta is situated in the Gulf of Guinea on the west coast of Central Africa. It lies between latitudes 4° and 6° N and longitudes 3° and 9° E in southern Nigeria. The Delta is situated at the intersection of the Benue Trough and the South Atlantic Ocean where a triple junction developed during the separation of South America and Africa in the Late Jurassic (Obaje and Okosun, 2013). This study involves an integrative approach to biostratigraphic study involving palynological, foraminiferal and openhole geophysical log data from Bobo-3, Doro-1 and Bolia-1X wells deep offshore Niger Delta Basin, Nigeria. Despite numerous works on the basin involving sedimentology, hydrocarbon potential, tectonic evolution, among others, biostratigraphic studies and research on the stratigraphic settings of the deep offshore Niger Delta Basin is scanty. Hence

integration of palynological, foraminiferal and open hole geophysical logs was carried out on Bobo-3, Doro-1 and Bolia-1X well in order to highlight the biozones, and depositional environment which would assist exploration of other areas by solving geological problems through correlation.

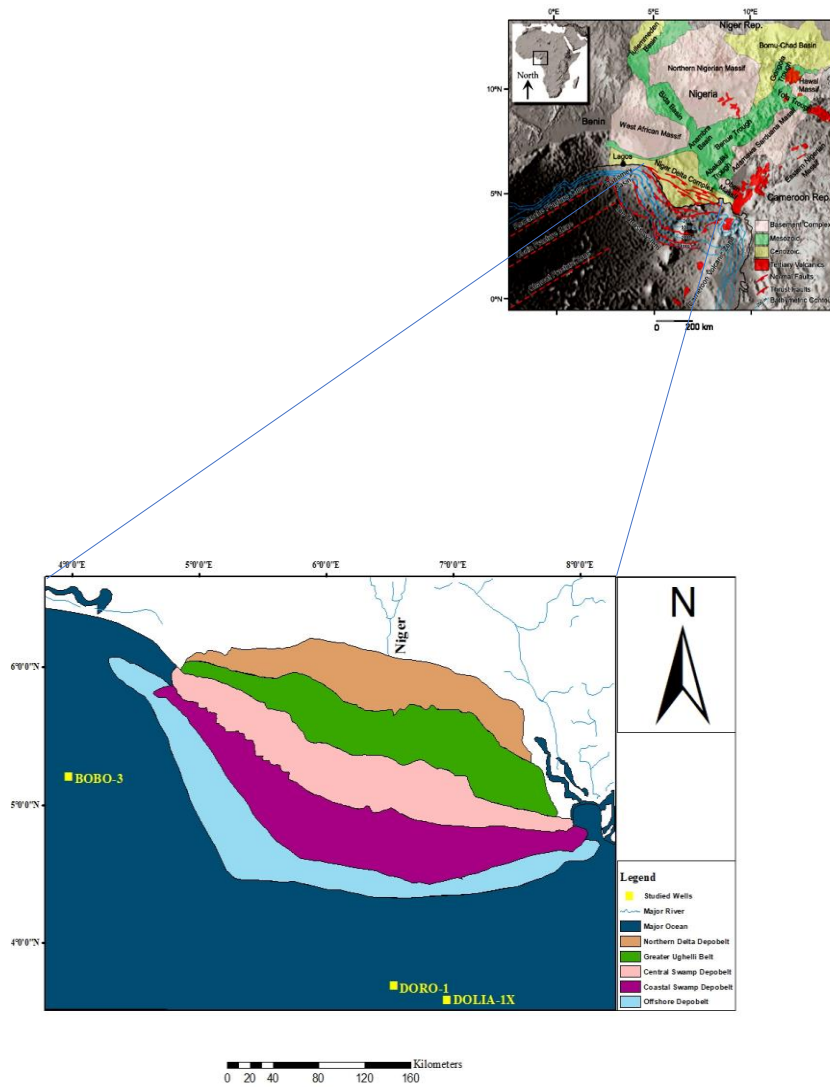


Figure 1: Location of the study area

## II. Geologic Setting and Stratigraphy

The Niger Delta Basin, also referred to as the Niger Delta province, is an extensional rift basin located in the Niger Delta and the Gulf of Guinea on the passive continental margin near the western coast of Nigeria (Tuttle *et al.*, 2015). This basin is very complex, and it carries high economic value as it contains a very productive petroleum system. The Niger Delta Basin is one of the largest subaerial basins in Africa. It has a subaerial area of about 75,000 km<sup>2</sup>, a total area of 300,000 km<sup>2</sup>, and a sediment fill of 500,000 km<sup>3</sup> (Tuttle

*et al.*, 2015). The sediment fill has a depth between 9–12 km. It is composed of several different geologic formations that indicate how this basin could have formed, as well as the regional and large scale tectonics of the area (Fatoke, 2010). The Niger Delta Basin is an extensional basin surrounded by many other basins in the area that all formed from similar processes and lies in the south westernmost part of a larger tectonic structure, the Benue Trough. The other side of the basin is bounded by the Cameroon Volcanic Line and the transform passive continental margin (Fatoke, 2010).

The Niger Delta Basin was formed by a failed rift junction during the separation of the South American plate and the African plate, as the South Atlantic began to open. Rifting in this basin started in the late Jurassic and ended in the mid Cretaceous. As rifting continued, several faults formed many of them thrust faults. Also at this time syn-rift sands and then shales were deposited in the late Cretaceous. This indicates that the shoreline regressed during this time.

The Niger Delta stratigraphic sequence comprises an upward-coarsening regressive association of Tertiary clastics up to 12 km thick (Weber and Daukoru, 1975; Evamy *et al.*, 1978). It is informally divided into three gross lithofacies: (i) marine claystones and shales of unknown thickness at the base; (ii) alternation of sandstones, siltstones and claystones, in which the sand percentage increases upwards; (iii) alluvial sands, at the top (Doust, 1990). Three lithostratigraphic units have been recognised in the subsurface (Short and Stauble, 1967) which are the basal and oldest Akata Formation that compose primarily of dark shale with occasional sand and considered the hydrocarbon producing unit. The middle Agbada Formation considered the main petroleum bearing unit and consisting of interbedded sandstone and shale. Lastly, is the topmost Benin Formation which consist of continental sand (Short and Stauble, 1967) (Figure 2). These formations were deposited in environments which are marine, transitional and continental respectively; forming a thick, progradational passive-margin wedge (Esan, 2002).

Three major depositional cycles have been identified within Tertiary Niger Delta deposits (Short and Stauble, 1967; Doust and Omatsola, 1990). The first two, involving mainly marine deposition, began with a middle Cretaceous marine incursion and ended in a major Paleocene marine transgression. The second of these two cycles, starting in late Paleocene to Eocene time, reflects the progradation of a “true” delta, with an arcuate, wave- and tide-dominated coastline. These sediments range in age from Eocene in the north to Quaternary in the south (Doust and Omatsola, 1990). Deposits of the last depositional cycle have been divided into a series of six depobelts (Doust and Omatsola, 1990; also called depocenters or megasequences) separated by major synsedimentary fault zones (Figure 1). These depobelts formed when paths of sediment supply were restricted by patterns of structural deformation, focusing sediment accumulation into restricted areas on the delta. Such depobelts changed position over time as local accommodation was filled and the locus of deposition shifted basinward (Doust and Omatsola, 1990).

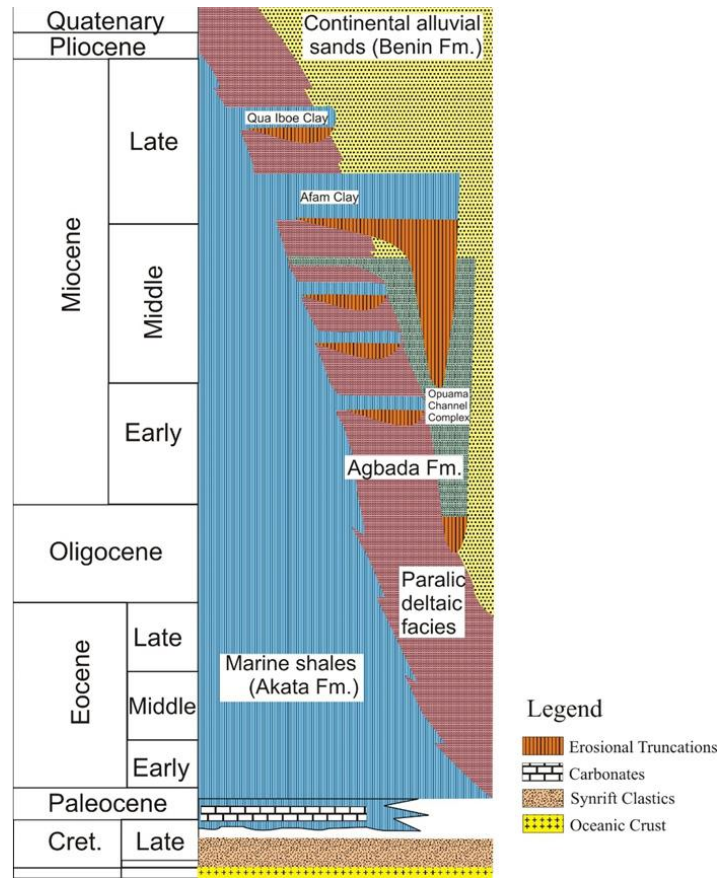


Figure 2: Lithostratigraphic column of the Niger Delta (Lawrence *et al.*, 2002)

### III. Methods of Study

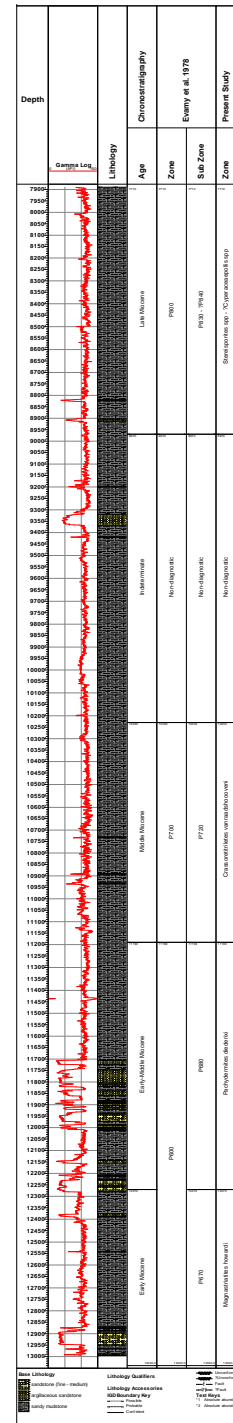
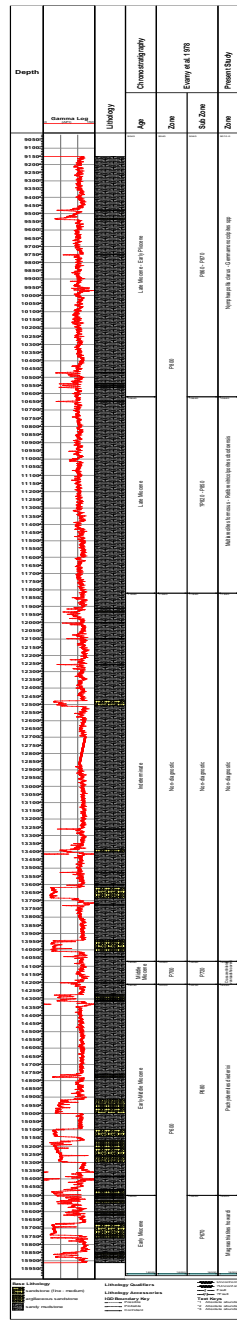
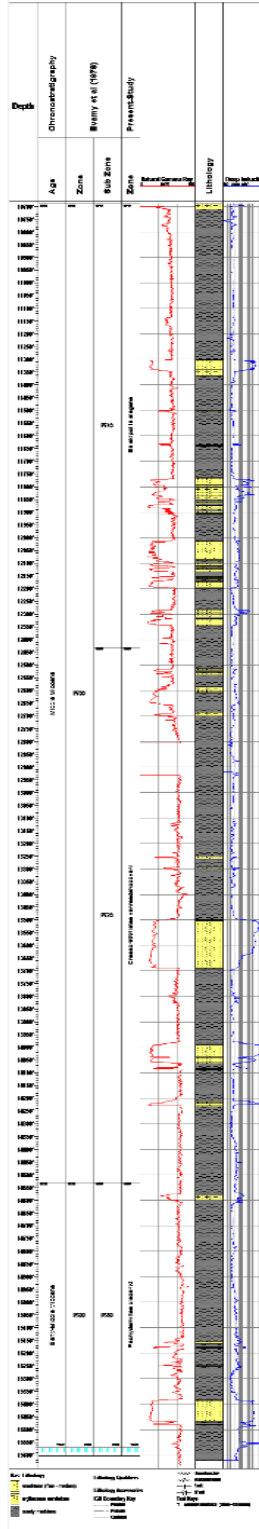
Two hundred and ninety five (295) ditch cutting samples (Bobo 3 = eighty two (82), Doro 1= one hundred and nine (109), and Bolia 1X= one hundred and four (104)) composited at 60 ft interval provided by SNEPCO were utilized for this study. The intervals studied are 10700-15600 ft, 8060-16860 ft and 7900-13000 ft in Bobo-3, Doro-1 and Bolia-1X respectively. Foraminiferal and openhole geophysical log data were also provided for the studied intervals. Palynological processing follows the standard acid preparatory method and is as follows:

Twenty grammes (20g) of each sample was treated with 10% HCl under a fume cupboard for the complete removal of carbonates that may be present in the samples. This was followed by complete neutralisation with distilled water before the next procedure. Then 40% HF was added to the sample which was placed on a shaker for 24 hours to speed up the reaction rate, to ensure a complete dissolution of the silicates that may be present in the samples and for the particles to settle down. Thereafter, the HF was carefully decanted, then followed by complete neutralisation with distilled water in order to remove fluoro-silicate compounds usually formed from the reaction with HF. Sieving and separation was performed using Brason Sonifier 250. Brason Sonifier is an electric device used with the aid of 5 micron sieve to filter away the remaining inorganic matter (silicates, clay, and mud) and heavy minerals to recover organic matters. It operates in a sonic vibration to filter out inorganic matter and heavy minerals. The treatment of samples with HCl and HF is referred to as demineralisation. The sieved residue was given controlled oxidation using

concentrated nitric acid (HNO<sub>3</sub>) for palynomorph slides. However, the oxidation process is omitted for palynodebris slide in order not to bleach the palynodebris. The level of oxidation required by each sample was closely monitored under a palynological microscope. This oxidation process is known as maceration. Staining with safranin O is done for palynodebris slides in order to enhance the clarity of dinoflagellate cyst. The prepared slides were studied under transmitted binocular microscope. Identification and analysis were attempted for as many forms as possible with the help of publication from different authors.

#### **IV. Lithologic Interpretation**

The lithology of the studied wells (Bobo-3, Doro-1 and Bolia-1X) consists of alternating shale and sandstone units. The shale is mostly grey to brownish grey in colour, platy to fissile in appearance. The sandstones are white to very light grey, coarse to fine grained, angular to subangular to rounded, and moderately to well sorted in texture. The accessories include ferruginous materials, mica flakes, and carbonaceous detritus. This observation suggested that the studied wells penetrated the Agbada Formation of the Niger Delta basin. These characteristics were also found in the work of Ukpong and Anyanwu, 2018, where it was interpreted that Agbada Formation as consisting of sandstone and shale alternations. The sandstones are light grey to smoky white, fine to coarse grained, moderately to well sorted, sub angular to subrounded, carbonaceous while the shale units are dark grey, subfissile to fissile, mostly hard to moderately hard, slightly calcareous and micaceous. This also agrees with the work of Reijers et al. (1997) that the Agbada Formation of the Niger Delta is composed of an alternation of sands and shales of equal proportion in the lower units as well as sands and minor shales in the upper units. This is also in line with the work of Short and Stauble (1967), which opined that the Agbada Formation is characterized by the alternation of sandstone and sand bodies with shale layers. The sandstone and shale alternations observed in the Agbada Formation of the Niger Delta are probably due to differential subsidence, sediment supply variations, as well as the transgression and regression episodes which caused a shift in the sediment depositional axis within the delta (Short & Stauble, 1967).



Well Bobo-3

Well Doro-1

Well Bolia-1X

Figure 3: Lithologic logs of the Wells Bobo-3, Doro-1 and Bolia-1X

**V. Results and Discussion**

## **Biostratigraphic Interpretation**

The analysis of samples used for these studies revealed a diverse miospore assemblage, but only well-established species with known stratigraphic ranges (Figures 4,5 and 6 ) are utilized in deducing the geologic age, zones and subzones. The recovered forms were placed under their phytoecological groups proposed by Poumot (1989). The occurrences of age diagnostic palynomorphs such as *Verrutricolporites rotundiporus*, *Pachydermites diderixi*, *Cassoretitriteles vanraadshooveni*, *Magnastriatites howardii*, *Racemonocolpites hians*, *Praedapollis flexibilis*, *Multiareolites formosus*, and *Zonocostites ramonae* at some intervals of the studied wells suggest Early to Middle Miocene.

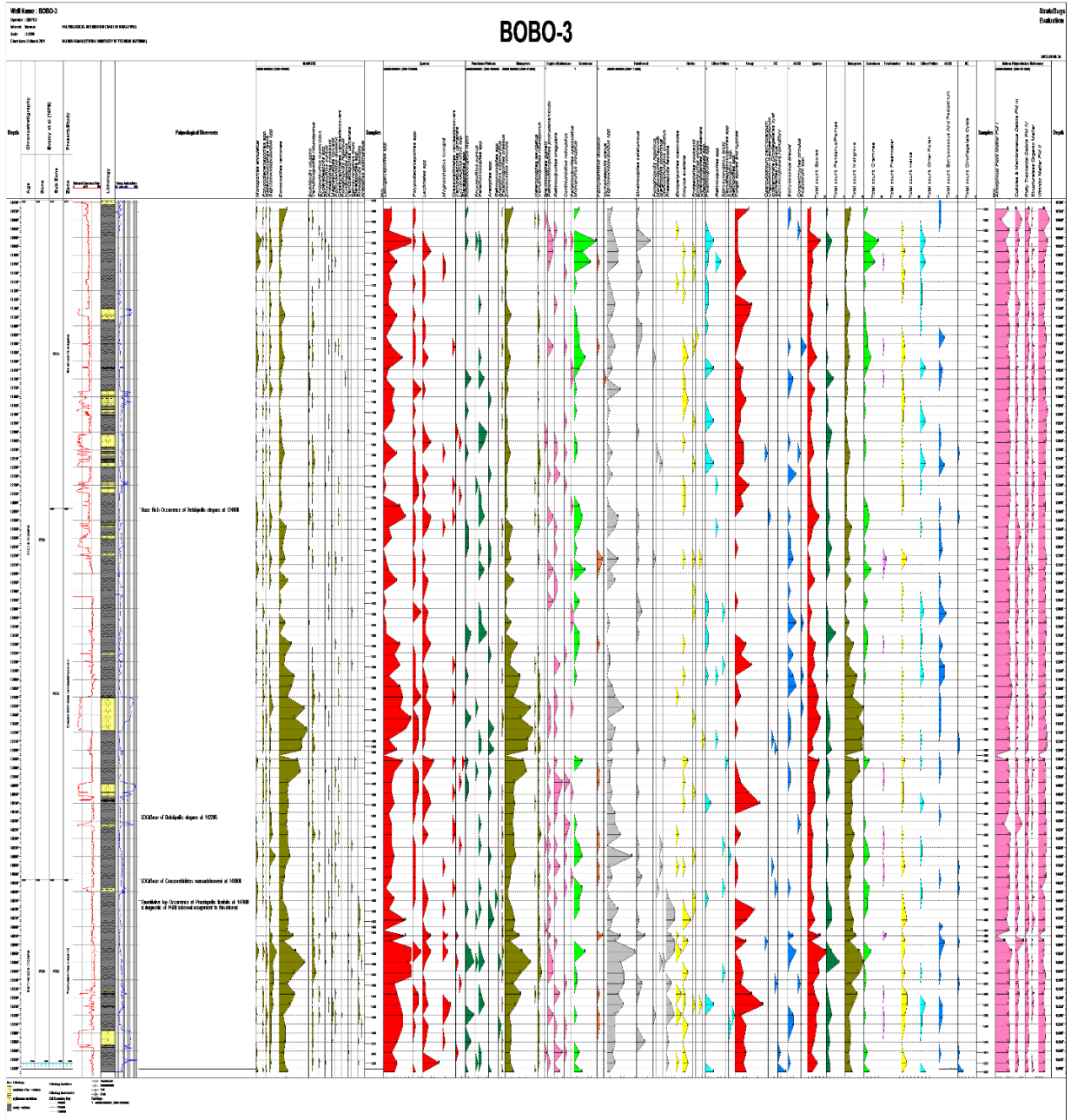


Figure 4: Palynological distribution of well Bobo-3





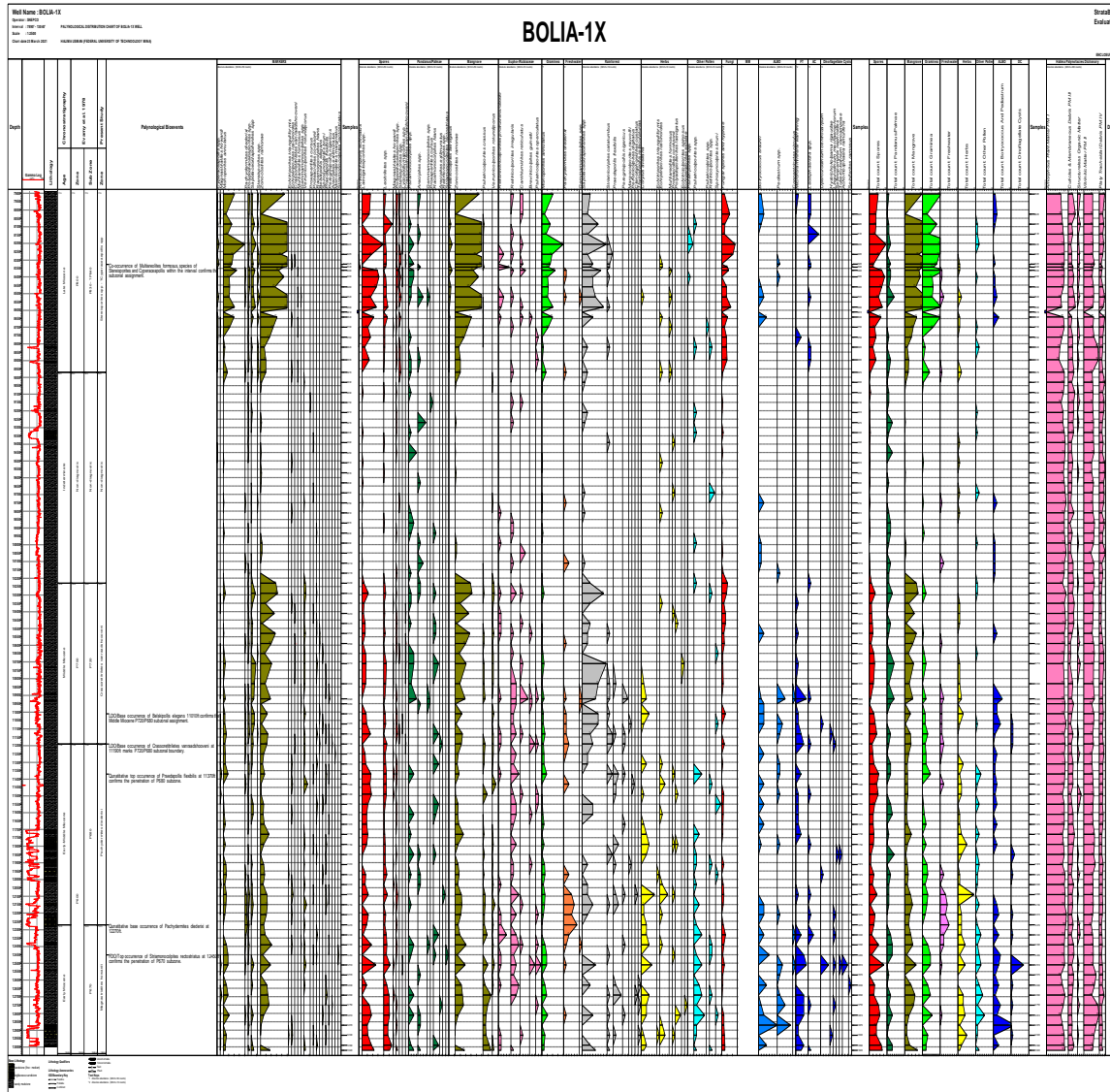


Figure 6: Palynological distribution of well Bolia-1X

Zonation and age determination of the three wells (Bobo-3, Bolia-1X and Doro-1) sections were based on First and Last Downhole Occurrences (FDO and LDO) of chronostratigraphically important or index miospore species, abundance distribution of index species together with miofloral assemblage. Chronostratigraphic Schemes of Evamy *et al.*, (1978), Legoux (1978) and Germeraad *et al.* (1968) were used. The classical zonation of Germeraad, *et al.* (1968) has been found to be not utilizable in this study, because of the broad nature of the pantropical *Echitricolporites spinosus* and *Magnastriatites howardi* zone (Figure 7). Neither the alphanumeric zones proposed by Evamy *et al.*, (1978) nor that by Legoux (1978) have plausible criteria for defining the boundaries in the studied sequence. However, the alphanumeric codes of these authors were given a formal name using the names of species that marked the subzonal boundaries in the studied wells.

The recognized sections in the analyzed interval are given below while the identified forms are presented in Plate I

DEPTH (FT.)	AGE	GERMERAAD ET AL. (1968) ZONE	LEGOUX (1978) ZONE	ZONE	SUBZONE	EVAMY ET AL. (1978)	PREENT STUDY	BIOEVENTS
10740	Middle Miocene	Echitricolporites spinosus	F - E3	P700	P740		Belskipollis elegans zone	Base Rich Occurrence of <i>Belskipollis elegans</i> at 12480ft.
12480								
14220	?Early Middle Miocene	Magnastriates howardi	E2 - 1	P600	P680		Crassorettriletes vanraadshooveni zone	LDO of <i>Belskipollis elegans</i> at 14220ft.
14580								LDO of <i>Crassorettriletes vanraadshooveni</i> at 14580ft.
14700								Quantitative top Occurrence of <i>Praedapollis flexibilis</i> at 14700ft is diagnostic of P680 subzonal assignment to this interval.
15620							<i>Pachydermites diderixsis</i> zone	

Figure 7: Palynological biozonation of well Bobo-3

The descriptions of the recognized subdivisions are given below:

***Belskipollis elegans* zone – taxon range zone**

**Stratigraphic Interval: 10740–12480 ft**

**Description:** Subzonal top is tentatively placed at 10740ft, top of the analyzed section while base rich occurrence of *Belskipollis elegans* at 12480ft defines the subzonal lower boundary.

**Diagnosis:** Moderately rich abundance and fairly diverse of miospores characterize this interval. *Zonocostites ramonae*, *Monoporites annulatus*, fungal spore/hyphae, species of *Psilamonocolpites*, *Sapotaceoidaepollenites*, *Laevigatosporites*, *Polypodiaceiosporites* and *Leotritiletes* dominated the microfloral assemblage of this interval. Sparse to common recoveries of *Racemonocolpites hians*, *Verrutricolporites rotundiporus* and *Belskipollis elegans* are other diagnostic feature of this zone.

**Age:** The zone is dated Middle Miocene because taxa such as *Verrutricolporites rotundiporus* and *Racemonocolpites hians* are diagnostic of Middle Miocene (Morley, 1997).

**Remark:** This is equivalent to P700 zone and P740 subzone of Evamy *et al.* (1978)

***Crassoretitriletes vanraadshooveni* zone – taxon range zone**

**Stratigraphic Interval: 12480-14580 ft**

**Description:** Base rich occurrence of *Belskipollis elegans* at 12480ft defines subzonal top while Last Downhole Occurrence (LDO)/base occurrence of *Crassoretitriletes vanraadshooveni* at 14580ft marks the subzonal lower boundary.

**Diagnosis:** *Zonocostites ramonae* and *Laevigatosporites* spp were abundant while *Monoporites annulatus*, fungal spore/hyphae, species of *Sapotaceoidaepollenites*, *Psilamonocolpites*, *Polypodiaceiosporites* and *Leoitriletes* were appreciable or fair within the interval.

**Age:** First Downhole/Top Occurrence of *Spirosyncolpites bruni* at 13020ft and Last Downhole/Base Occurrence of *Belskipollis elegans* at 14220ft confirm penetration of Middle Miocene.

**Remark:** This is equivalent to P700 zone and P720 subzone of Evamy *et al.* (1978)

***Pachydermites diderixi* zone- taxon range zone**

**Stratigraphic Interval: 14580–15620ft**

**Description:** Base occurrence of *Crassiretitriletes vanraadshoveni* defines the subzonal upper boundary at 14580ft while the subzonal lower boundary is tentatively placed at 15620ft, depth of last analyzed sample.

**Diagnosis:** Appreciable recoveries of miospore were recorded within this interval. The earlier mentioned miospores in the overlying subzone still dominated the microfloral assemblage. *Zonocostites ramonae*, fungal spore/hyphae, species of *Sapotaceoidaepollenites* and *Laevigatosporites* dominated the microfloral assemblage of this interval. Slight improvement in the recoveries of *Racemonocolpites hians*, *Magnastriatites howardi* and *Echiperiporites icacinoides* are diagnostic of the interval.

**Age:** Quantitative top occurrence of *Praedapollis flexibilis* at 14700ft confirms the penetration of this zone and dated Early-Middle Miocene.

**Remark:** This is equivalent to P600 zone and P680 subzone of Evamy *et al.* (1978).

DEPTH (FT.)	AGE	GERMERAAD ET AL. (1968) ZONE	LEGOUX (1978) ZONE	EVAMY ET AL. (1978)		PRESENT STUDY	BIOEVENTS
				ZONE	SUBZONE		
9040	Early Pliocene - Late Miocene	Echitricolporites spinosus	H - J2	P800	P860 - P870	Nymphaepollis clarus Gemmamonocolpites spp zones	Quantitative base occurrence of <i>Nymphaepollis clarus</i> at 10640ft, marks Late Miocene P860/P850 subzonal boundary.
9700							
10640	Late Miocene				P820 - P850	Retistephanocolpites formosus Echitricolporites subobovatus zones	
11840	Indeterminate	Echitricolporites spinosus	Non-diagnostic	Non-diagnostic	Non-diagnostic	Non-diagnostic	Base/LDO Occurrence of <i>Crassoretitriletes vanraadshooveni</i> at 14090ft defines the P720/P680 subzonal boundary. Quantitative top occurrence of <i>Praedapollis flexibilis</i> at 14330ft confirms the P680 subzonal assignment to the interval.
14090							
14230	Early - Middle Miocene	Magnastriatites howardi	E2 - I	P600	P680	Pachydermites diederixi zone	Quantitative base occurrence of <i>Pachydermites diederixi</i> at 15520ft defines the Early Miocene P680/P670 subzonal boundary. FDO/Top occurrence of <i>Striamonocolpites rectostriatus</i> at 15640ft supports the P670 subzonal assignment to the interval.
14330							
15520	Early Miocene	Magnastriatites howardi	E2 - I	P600	P670	Pachydermites diederixi zone	FDO/Top occurrence of <i>Striamonocolpites rectostriatus</i> at 15640ft supports the P670 subzonal assignment to the interval.
15640							
15940							

\* *Crassoretitriletes vanraadshooveni* zone  
 \*\* *Magnastriatites howardi* zone

Figure 8: Palynological biozonation of well Doro-1

The descriptions of the recognized subdivisions are given below:

***Nymphaepollis clarus- Gemmamonocolpites spp zone – Interval zone***

**Stratigraphic Interval: 9040–10640ft**

**Description:** Top of this composite subzone is tentatively placed at 9040ft, top of the analyzed section while quantitative base occurrence of *Nymphaepollis clarus* at 10640ft defined the interval lower boundary.

**Diagnosis:** High abundance and high diversity of miospores still dominated by *Zonocostites ramonae*, *Monopoorites annulatus*, fungal spores/hyphae, species of *Sapotaceoidaepollenites* and *Laevigatosporites* were observed within the interval. Rare to common occurrences of *Multiareolites formosus*, *Crassoretitriletes vanraadshooveni*, *Retistephanocolpites gracilis*, species of *Gemmamonocolpites*, *Cyperaceapollis* and *Stereisporites* are other significant features of the interval.

**Age:** Quantitative base occurrence of *Nymphaepollis clarus* at 10640 ft and species of *Gemmamonocolpites* confirm Late Miocene – Early Pliocene.

**Remark:** This zone is equivalent to P800 zone and P860 – P870 subzones of Evamy et al., (1978).

***Multiareolites formosus* - *Retibrevitricolporites obodoensis* zone – interval zone**

**Stratigraphic Interval: 10640-11840 ft**

**Description:** Top of this composite subzone is defined by quantitative base occurrence of *Nymphaepollis clarus* at 10640ft while the lower boundary is tentatively placed at 11840 ft, the top of the non-diagnostic subzone.

**Diagnosis:** The miospores recovered were similar to that recovered within the overlying interval. However, unlike the overlying interval, the miospores were abundant but moderately diverse.

**Age:** The zone is dated Late Miocene because of the appreciable occurrence of diagnostic features of this age such as *Multiareolites formosus*, *Pachydermites diderixi*, species of *Cyperaceapollis* and *Stereisporites*.

**Remark:** This zone is equivalent to P800 zone and P820 – P850 subzones of Evamy *et al.*, (1978).

**Non-diagnostic zone**

**Stratigraphic Interval: 11840-14090ft**

**Description:** Top of this interval is tentatively placed at 11840ft, the top of the non-diagnostic subzone while the lower boundary is tentatively placed at 14090ft, the base of the non-diagnostic subzone.

**Diagnosis:** The interval is characterized by low abundance and low diverse long ranging and non-age diagnostic miospores. This made both age determination and zonal/subzonal delineation of the interval difficult. Miospores present include *Verrutricolporites rotundiporus*, *Echiperiporites icacinoides*, *Proteacidites cocksonii*, species of *Cyperaceapollis* and *Stereisporites*.

**Age:** Indeterminate

***Crassoretitriletes vanraadshooveni* – taxon range zone**

**Stratigraphic Interval: 14090-14230 ft**

**Description:** The base of the non-diagnostic subzone tentatively placed at 14090ft marked the subzonal top while Last Downhole/Base Occurrence (LDO) of *Crassoretitriletes vanraadshooveni* at 14230ft defined the interval lower boundary.

**Diagnosis:** Slight increase in the recoveries of miospores such as *Zonocostites ramonae*, *Monoporites annulatus*, *Corylus avelana*, *Echiperiporites icacinoides*, *Proteacidites cocksonii*, fungal spores/hyphae, species of *Laevigatosporites*, *Sapotaceoidapollenites* and *Psilamonocolpites* characterize the interval. Thinness of this subzone may be as a result of fault/unconformity suspected at 14162ft (based on foraminifera data).

**Age:** The zone is dated Middle Miocene because of the quantitative base occurrence of *Crassoretitriletes vanraadshooveni*.

**Remark:** This zone is equivalent to P700 zone and P720 subzones of Evamy *et al.* (1978).

***Pachydermites diderixi* zone – taxon range zone**

**Stratigraphic Interval: 14230-15520 ft**

**Description:** Base occurrence of *Crassiretiritetes vanraadshoveni* defines the subzonal upper boundary at 14230ft while the subzonal lower boundary is marked by quantitative base occurrence of *Pachydermites diderixi* at 15520ft.

**Diagnosis:** Slight increase in the recoveries of miospore were recorded within the upper part (14230-14830ft). The interval is dominated by *Zonocostites ramonae*, *Monoporites annulatus*, Fungal spores/hyphae and *Laevigatoosporites* spp while the lower part (14830-15520ft) recorded decrease in miospores recovery.

**Age:**The zone is dated Early-Middle Miocene because of the quantitative top occurrence of *Praedapollis flexibilis* at 14330ft.

**Remark:** This zone is equivalent to P600 zone and P680 subzones of Evamy *et al.*, (1978).

***Magnastriatites howardi* zone – taxon range zone**

**Stratigraphic Interval: 15520-15940ft**

**Description:** Quantitative base occurrence of *Pachydermites diderixi* at 15520ft defines the subzonal upper boundary while the subzonal lower boundary is tentatively placed at 15940ft, depth of last sample analyzed.

**Diagnosis:** Moderate abundance and low diversity of miospores characterize this interval. Most of the earlier mentioned miospores in the overlying intervals still dominated the microfloral assemblage of the interval. Low percentage recovery of *Verrutricolporites rotundiporus* when compared with the overlying *Pachydermites diderixi* zone, fair abundance of *Monoporites annulatus* and top occurrence of *Striamonocolpites rectostriatus* at 15640ft are other important features of the subzone.

**Age :** The zone is dated Early Miocene and correlated to P600 zone and P670 subzone of Evamy *et al.*, (1978).

DEPTH (FT.)	AGE		GERMERAAD ET AL. (1968) ZONE	LEGOUX (1978) ZONE	EVAMY ET AL. (1978)		PRESENT STUDY	BIOEVENTS
	AGE	GERMERAAD ET AL. (1968) ZONE			ZONE	SUBZONE		
7710	Late Miocene	Echitricolporites spinosus	H - J1	P800	P830 - ?P840	Stereisporites spp - Cyperaceapollis spp zone		Co-occurrence of <i>Multiareolites formosus</i> , species of <i>Stereisporites</i> and <i>Cyperaceapollis</i> within the interval confirms the subzonal assignment.
8970	Indeterminate							
10230	Middle Miocene	E3	P700	P720	Crassoretitriletes vanraadshooveni zone		<ul style="list-style-type: none"> <li>← FDO/Top occurrence of <i>Spirosyncolpites bruni</i> at 10650ft confirms the penetration of Middle Miocene subzone P720 at the depth.</li> <li>← LDO/Base occurrence of <i>Belskipollis elegans</i> 11010ft confirms the Middle Miocene P720/P680 subzonal assignment.</li> <li>← LDO/Base occurrence of <i>Crassoretitriletes vanraadshooveni</i> at 11190ft marks P720/P680 subzonal boundary.</li> <li>← Quantitative top occurrence of <i>Praedapollis flexibilis</i> at 11370ft confirms the penetration of P680 subzone.</li> <li>← Quantitative base occurrence of <i>Pachydermites diederixi</i> at 12270ft.</li> <li>← FDO/Top occurrence of <i>Striamonocolpites rectostriatus</i> at 12450ft confirms the penetration of P670 subzone.</li> </ul>	
10650								
11100	Early - Middle Miocene	Magnastriates howardi	E2 - I	P600	Pachydermites diederixi zone			
11190								
11370								
12270	Early Miocene	Magnastriates howardi zone			Magnastriates howardi zone			
12450								
13020								

Figure 9: Palynological biozonation of well Bolia-1X

The descriptions of the recognized subdivisions are given below:

***Stereisporites* spp - *Cyperaceapollis* spp zone – interval zone**

**Stratigraphic Interval: 7710–8970ft**

**Description:** Top of the combined subzone is tentatively placed at 7710ft, top of the analyzed section while the base is tentatively placed at 8970ft, the top of the non-diagnostic subzone.

**Diagnosis:** High abundant recovery of miospores dominated by *Zonocostites ramonae*, *Monoporites annulatus*, Fungi spores/and hyphae, species of *Laevigatosporites* and *Sapotaceoidapollenites* characterize the interval. Scattered to rare occurrences of *Crassoretitriletes vanraadshooveni*, *Pachydermites diederixi*, *Echiperiporites icacinoides* and *Gemmamonocolpites* spp also characterize the interval.

**Age:** The co-occurrence of *Multiareolites formosus*, species of *Cyperaceapollis* and *Stereisporites* and the absence of *Nymphaepollis clarus* confirm the subzonal assignment and dated Late Miocene.

**Remark:** This is equivalent to P800 zone and P830-P840 subzone of Evamy *et al.* (1978)



### **Non- diagnostic zone**

#### **Stratigraphic Interval: 8970-10230ft**

**Description:** Top of this non-diagnostic subzone is tentatively placed at 8970ft while the subzonal base is defined at 10230ft.

**Diagnosis:** The interval is characterized by low abundance and low diverse long ranging and non-age diagnostic miospores. This made both age determination and zonal/subzonal delineation of the interval difficult. Miospores present include *Verrutricolporites rotundiporus*, *Echiperiporites icacinoides* *Proteacidites cocksonii*, species of *Cyperaceapollis* and *Stereisporites*.

**Age:** Indeterminate

#### ***Crassoretitriletes vanraadshooveni* zone – taxon range zone**

#### **Stratigraphic Interval: 10230-11190ft**

**Description:** Subzonal top is placed tentatively at 10230ft, the base of the non- diagnostic zone while the subzonal lower limit is defined at 11190ft by Last Downhole/Base Occurrence (LDO) of *Crassoretitriletes vanraadshooveni*.

**Diagnosis:** *Zonocostites ramonae*, *Monoporites annulatus*, *Retitricolporites irregularis*, species of *Laevigatosporites* and *Sapotaceoidapollenites* still dominated the microfloral assemblage of the interval.

**Age:** First Downhole/Top Occurrence of *Spirosyncolpites bruni* at 10650ft and Last Downhole/Base Occurrence (LDO) of *Belskipollis elegans* at 11010ft are important diagnostic features recorded and dated the interval Middle Miocene.

**Remark:** This zone is equivalent to P700 zone and P720 subzone of Evamy *et al.* (1978).

#### ***Pachydermites diderixi* zone – taxon range zone**

#### **Stratigraphic Interval: 11190-12270 ft**

**Description:** Last Downhole/Base Occurrence (LDO) of *Crassoretitriletes vanraadshooveni* at 11190ft defined the subzonal upper boundary while quantitative base occurrence of *Pachydermites diderixi* at 12270ft marked the subzonal lower limit.

**Diagnosis:** Sparse to moderately rich recoveries of miospores such as *Zonocostites ramonae*, *Corylus avellana*, *Echiperiporites icacinoides*, Fungi spores/and hyphae, species of *Laevigatosporites*, *Polypodiaceoisporites*, *Leoitriletes*, and *Sapotaceoidapollenites* characterize the interval.

**Age:** Quantitative top occurrence of *Praedapollis flexibilis* at 11370ft confirms Early – Middle Miocene.

**Remark:** This zone is equivalent to P600 zone and P680 subzone of Evamy *et al.* (1978).

***Magnastriatites howardi* zone – taxon range zone**

**Stratigraphic Interval: 12270-13020ft**

**Description:** Subzonal top is marked by quantitative base occurrence of *Pachydermites diderixi* at 12270ft while the base is tentatively placed at 13020ft, depth of last sample studied.

**Diagnosis:** *Zonocostites ramonae*, *Monoporites annulatus*, *Corylus avellana*, *Psilatricolporites crassus*, *Retitricolporites irregularis*, Fungi spores/and hyphae, species of *Laevigatosporites*, *Leotriletes* and *Psilatricolporites* are dominant miospores which characterize the palynofloral assemblage of the interval.

**Age:** First Downhole/Top Occurrence (FDO) of *Striamonocolpites rectostriatus* at 12450ft is diagnostic of the Early Miocene.

**Remark:** This zone is equivalent to P600 zone and P670 subzone of Evamy *et al.* (1978).

## **Foraminiferal Biostratigraphy**

### **Planktic Foraminiferal Biozonation of Bobo-3, Bolia-1X and Doro-1 Wells**

The following bioevents are significant in the zonal delineations of the studied well intervals:

- First and Last Downhole Occurrences (FDO and LDO) of chronostratigraphically important planktic and benthic foraminiferal species.
- Foraminiferal abundance and diversity peaks when datable with foraminiferal marker species whose stratigraphic ranges are well established in the Niger Delta and worldwide.

The planktic foraminiferal zones recognized in this study are based on the revised Cenozoic geochronologic and Chronostratigraphic Schemes of Berggren *et al.* (1995) and Blow (1969, 1979). The foraminifera stratigraphic distribution charts are shown as Enclosures 2A, 2B and 2C while the summary of foraminifera biozonation of Bobo-3, Bolia-1X and Doro-1 wells are presented in Tables 2.2a-c.

### **Foraminiferal Biozonation and Description of Recognized Stratigraphic Subdivisions of Bobo-3 Well**

One hundred and sixty-three (163) analyzed samples from well section 10740– 15620ft of Bobo-3 well were used for foraminifera interpretation. Most of the samples were at 30ft intervals while few of the samples came at various intervals.

The foraminifera recovered were generally low to moderate both in abundance and diversity with many barren intervals especially at the upper part of the studied section (10770-10920ft, 11010-11370ft, 11640-11670ft, 11730-11970ft, 12000-12180ft and 12210-12330ft). However, abundant foraminifera were recovered within intervals 12600-12900ft, 13230-13350ft and 14880-14940ft. Sixty-seven (67) foraminiferal species were recovered. Nineteen (28%) of these were planktics, eighteen (27%) were calcareous benthics while the remaining thirty (45%) species were arenaceous benthic species. Echinoid remains, scaphods and shell fragments were the associated microfossils recovered.

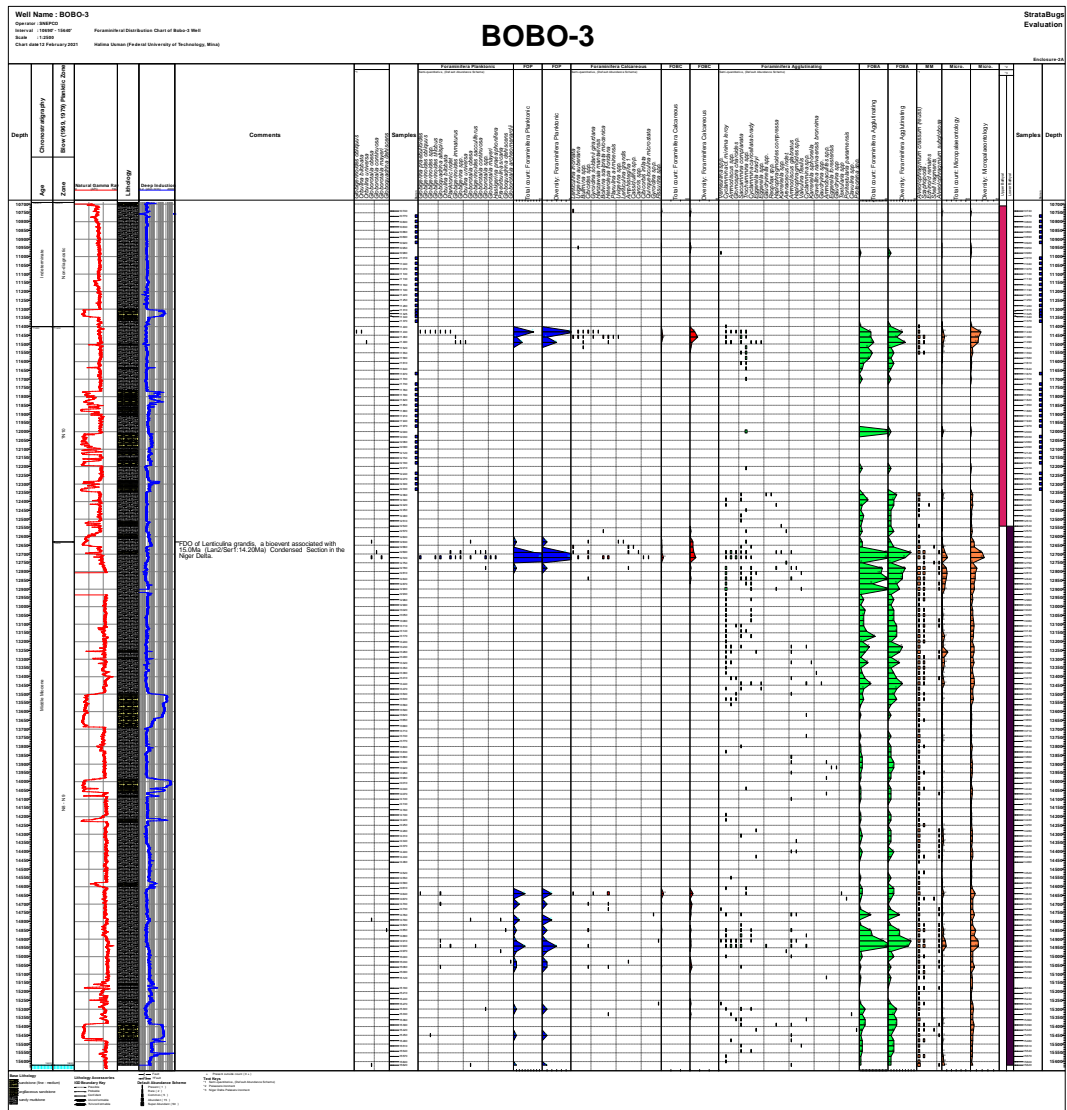


Figure 10: Foraminiferal distribution chart of well Bobo-3

The planktic foraminiferal zones recognized in this study are summarized in figure 4.8 and briefly described below.

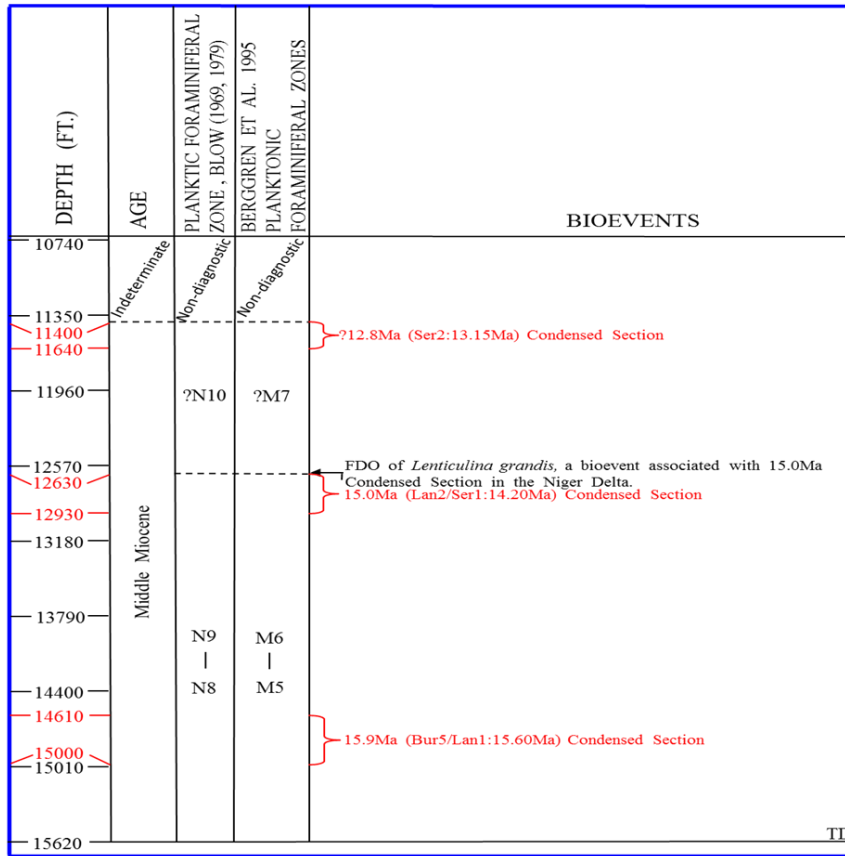


Figure 11: Foraminiferal biozonation of well Bobo-3

**Stratigraphic Interval: 10740-11400ft**

**Planktic foraminifera Zone: Non-diagnostic**

**Description:** Top of the zone is tentatively placed at 10740ft, top of the analyzed section while the base is placed at 11400ft, the base of the Non-diagnostic zone. The interval is barren of planktic foraminifera.

**Age:** Indeterminate

***Globorotalia fohsi fohsi* zone - taxon range zone**

**Stratigraphic Interval: 11400-12630ft**

**Planktic foraminifera Zone: N10 (M7)**

**Age: Middle Miocene**

**Description:** Top of the zone is placed at the top of the non-diagnostic zone while the base is approximated at 12630ft, the First Downhole Occurrence (FDO) of *Lenticulina grandis*.

**Diagnosis:** The interval is barren of planktic foraminifera. Few foraminifera present were benthic species. Moderate abundances and diversities of foraminifera recovered within interval 11400-11640ft are thought to present 12.8Ma Condensed Section of Haq *et al.*, (1988). This is equivalent to Ser2: 13.15Ma Condensed Section of Hardenbol *et al.*, (1998). It is based on superposition. The Condensed Section lying above is positively dated 15.0Ma Condensed Section of Haq *et al.* (1988) which is equivalent to Lan2/Ser1:14.20Ma Condensed Section of Hardenbol *et al.* (1998).

***Globorotalia fohsi peripherronda - Praeorbulina glomerosa zone - interval zone***

**Stratigraphic Interval: 12630-15620ft,**

**Planktic foraminifera Zone: N9-N8 (M6-M5)**

**Age: Middle Miocene**

**Diagnosis:** Top of this zone is approximated at 12630ft, the First Downhole Occurrence (FDO) of *Lenticulina grandis* which is a bioevent associated with 15.0Ma Condensed section of Haq *et al.* (1988) in the Niger Delta. The base is placed at the total depth, 15620ft. Planktics recovered include *Globorotalia continua*, *Globorotalia obesa*, *Globorotalia mayeri*, *Globigerinoides trilobus* and *Globigerina praebulloides*.

Moderately abundant and fairly diverse foraminifera species recovered within intervals 12630-12900ft and 14610-14940ft are thought to represent 15.0Ma and 15.9Ma Condensed Sections of Haq *et al.* (1988) respectively. These are equivalent to Lan2/Ser1:14.20Ma and Bur5/Lan1:15.60Ma Condensed Sections of Hardenbol *et al.* (1998).

**Remarks:** *Globorotalia fohsi peripherronda - Praeorbulina glomerosa* zones (N9- N8 ) (M6-M5) is combined due to poor stratigraphic record of *Orbulina universa*, the *Globorotalia fohsi peripherronda - Praeorbulina glomerosa* zone (N9- N8) (M6/M5) boundary marker species.

### **Foraminiferal Biozonation and Description of Recognized Stratigraphic Subdivisions of Doro-1 Well**

Two hundred and eight (208) analyzed samples from the well section 9040–15940ft of Doro-1 well were used for foraminifera interpretation. Most of the samples were at 30ft and 60ft intervals while few of the samples came at various intervals.

One hundred and eighty-eight (188) foraminiferal species were recovered. Forty-nine (26%) of these were planktics, eighty-nine (47%) were calcareous benthics while the remaining fifty (27%) were arenaceous benthics.

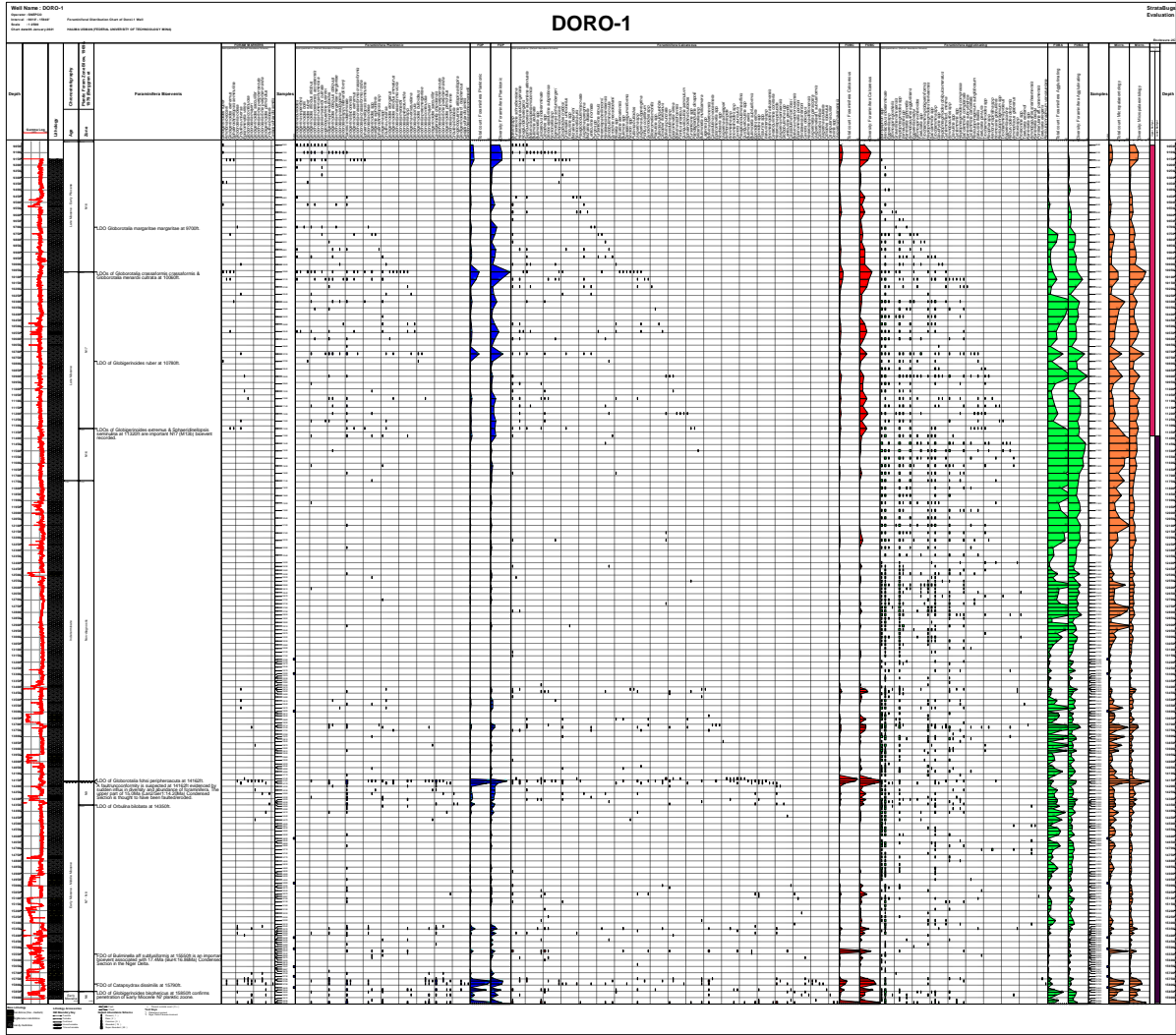


Figure 11: Foraminiferal distribution chart of well Doro-1

The planktic foraminiferal zones recognized in this study are summarized in figure 4.12 and briefly described below.

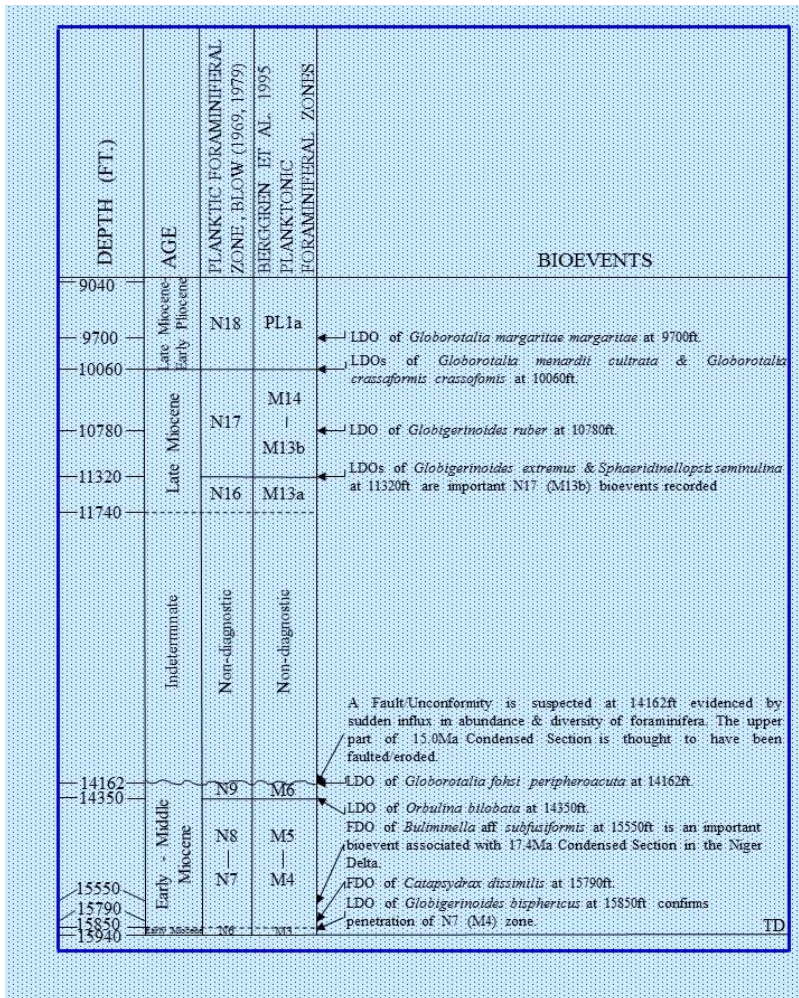


Figure 11: Foraminiferal biozonation of well Doro 1

***Globorotalia margaritae margaritae* zone – taxon range zone**

**Stratigraphic Interval: 9040-10060ft**

**Planktic foraminifera Zone: N18 (PL1a)**

**Age: Early Pliocene - Late Miocene**

**Diagnosis:** The top of the zone is placed tentatively at 9040ft, top of the studied section while the base is defined by the Last Downhole Occurrence (LDO) of *Globorotalia crassaformis crassaformis* at 10060ft. The interval is characterized by low to moderate planktics except within interval 10000- 10060ft, where abundant planktics were recovered. *Globorotalis crassaformis ronda*, *Globigerinoides ruber*, *Globorotalia margaritae margaritae*, *Globigerinoides extremus* and *Globigerinoides bollii* were among the planktics recorded.

Last Downhole Occurrences (LDOs) of *Globorotalia margaritae margaritae* at 9700ft and *Globorotalia menardii cultrata* at 10060ft are important *Globorotalia margaritae margaritae* (N18) (PL1a) bioevents present.

**Remarks:** *Globoorotalia crassaformis crassaformis* recorded at 10720ft and *Globigerinoides ruber* at 10780ft are considered caved.

***Globigerinoides extremus*/G. *humerosa* zone – taxon range zone**

**Stratigraphic Interval: 10060-11320ft**

**Planktic foraminifera Zone: N17 (M13b – M14)**

**Age: Late Miocene**

**Diagnosis:** The top of the zone is defined by the Last Downhole Occurrence (LDO) of *Globoorotalia crassaformis crassaformis* at 10060ft while the base is placed at 11320ft, the Last Downhole Occurrence (LDO) of *Globigerinoides extremus*. Low to moderate abundance and low diverse planktonics characterize the interval. Planktics present include *Globoorotalia acostaensis acostaensis*, *Globigerinoides trilobus trilobus*, *Globigerina praebulloides* and *Globigerina bulloides*.

Last Downhole Occurrence (LDO) of *Spheroidinellopsis seminulina* at 11320ft is an important *Globigerinoides extremus*/G. *humerosa* (N17) (M13b) bioevent recorded. This confirms both zonal delineation and age assignment to the interval.

***Globoorotalia acostaensis acostaensis* zone - taxon range zone**

**Stratigraphic Interval: 11320-11740ft**

**Planktic foraminifera Zone: N16 (M13a)**

**Age: Late Miocene**

**Diagnosis:** Top of the zone is defined by the Last Downhole Occurrence (LDO) of *Globigerinoides extremus* at 11320ft while the base is placed tentatively at 11740ft, the top of the non-diagnostic zone. Low abundance and low diverse planktonics characterize this zone. *Globigerinoides trilobus trilobus*, planktic indeterminate species and *Globigerina* spp. were the only planktonics recovered. The *Globoorotalia acostaensis acostaensis* zone (N16) (M13a) is based on stratigraphic position as the zone lies directly below a positively defined *Globigerinoides extremus*/G. *humerosa* (N17) (M14-M13b) zone.

**Stratigraphic Interval: 11740-14162ft**

**Planktic foraminifera Zone: Non-diagnostic**

**Age: Indeterminate**

**Diagnosis:** Zonal top (11740ft) is placed at the base of N16 (M13a) zone while the zonal base is defined at the unconformity/fault surface at 14162ft.



The interval is characterized by low abundance and low diverse long ranging and non-age diagnostic planktics. This made both zonal delineation and age determination of the interval difficult. Planktics present include planktic indeterminate species, *Globigerina praebulloides*, *Globigerinoides obliquus obliquus* and *Globorotalia mayeri*. There is an abrupt increase in abundances and diversities of foraminifera at 14162ft. This is thought to have been as a result of an unconformity.

***Globorotalia fohsi peripherronda* zone – taxon range zone**

**Stratigraphic Interval: 14162-14350ft**

**Planktic foraminifera Zone: N9 (M6)**

**Age: Middle Miocene**

**Diagnosis:** The top of N9 (M6) zone is placed at 14162ft, the unconformity/fault surface while the zonal base is defined by the *Orbulina* datum, here represented by Last Downhole Occurrence (LDO) of *Orbulina bilobata* at 14350ft. The interval is characterized by moderate to abundant and moderately diverse planktics. Planktics recorded include *Globorotalia mayeri*, *Globorotalia obesa*, *Globorotalia continuosa*, *Globigerinoides obliquus* and *Cassigerinella chipolensis*. The co-occurrence of these Middle Miocene forms confirms penetration of Middle Miocene at that interval.

Last Downhole Occurrence (LDO) of *Globorotalia fohsi peripherronda* at 14162ft is an important *Globorotalia fohsi peripherronda* (N9) (M6) bioevent recorded.

The unconformity delineated at 14162ft is thought to have eroded the upper part of *Globorotalia fohsi peripherronda* N9 (M6) zone and invariably the upper part of Lan2/Ser1:14.20Ma Condensed Section of Hadenbol *et al.* (1998) which is equivalent to 15.0Ma Condensed Section of Haq *et al.* (1988). The delineation of unconformity/fault at 14162ft is further confirmed by the thinness of *Globorotalia fohsi peripherronda* N9 (M6) zone.

***Praeorbulina glomerosa - Globigerinatella insueta* zone – interval zone**

**Stratigraphic Interval: 14350-15850ft**

**Planktic foraminifera Zone: N8-N7 (M5-M4)**

**Age: Middle - Early Miocene**

**Diagnosis:** The top of the combined N8-N7 (M5-M4) zones is defined at 14350ft, the Last Downhole Occurrence (LDO) of *Orbulina bilobata* while the base is approximated at 15850ft, the Last Downhole Occurrence (LDO) of *Globigerinoides bisphericus*.

The upper part of the interval (14350-15760ft) is characterized by low abundance and low diverse planktics while moderate to abundant planktics characterize the lower part (15760-15850ft) of the

interval. Planktics recorded include *Globigerinoides trilobus trilobus*, *Globorotalia obesa*, *Cassigerinella chipolensis*, *Globorotalia fohsi peripheroronda*, species of *Globigerina* and *Globorotalia*. First Downhole Occurrence (FDO) of *Catapsydrax dissimilis* at 15790ft is an important *Globigerinatella insueta* (N7) (M4) bioevent recorded. This confirms both zone and age assignment to the interval. Increases in abundances and diversities of foraminifera recorded within interval 15756-15850ft are thought to represent Bur4:16.86Ma Condensed Section of Hadenbol *et al.* (1998). This is equivalent to 17.4Ma Condensed Section of Haq *et al.* (1988).

**Remarks:** Last Downhole Occurrence (LDO) of *Globigerinoides bisphericus* was used to approximate *Globigerinatella insueta* - *Catapsydrax stainforthi* (N7-N6) (M4-M3) boundary instead of Last Downhole Occurrence (LDO) of *Catapsydrax dissimilis*, the *Globigerinatella insueta* - *Catapsydrax stainforthi* (N7-N6) (M4-M3) boundary marker because the base of *Globigerinoides bisphericus* which still occurs within *Globigerinatella insueta* (N7) (M4) zone was recorded below the LDO of *Catapsydrax dissimilis* at 15790ft showing that *Globigerinatella insueta* (N7) (M4) zone still penetrated at 15850ft.

#### ***Catapsydrax stainforthi* zone – taxon range zone**

**Stratigraphic Interval: 15850-15940ft**

**Planktic foraminifera Zone: N6 (M3)**

**Age: Early Miocene**

**Diagnosis:** The top of the zone is approximated at 15850ft, the Last Downhole Occurrence (LDO) of *Globigerinoides bisphericus* while the base is placed at 15940ft, the depth of the last sample studied.

Moderate to abundant planktics characterize this zone. *Globorotalia mayeri*, *Globorotalia obesa*, *Globorotalia continuosa*, *Globigerinoides trilobus trilobus* and *Globigerina venezuelana* were among the planktics recovered.

**Remarks:** The recoveries of *Globorotalia continuosa* and *Globorotalia obesa* whose Last Downhole Occurrences (LDOs) are at *Catapsydrax stainforthi* (N6) (M3) and *Catapsydrax dissimilis* (N5) (M2) zones respectively at last sample studied (15940ft) show penetration of *Catapsydrax stainforthi* (N6) (M3) at total depth and that *Catapsydrax dissimilis* (N5) (M2) was not penetrated at total depth.

#### **Foraminiferal Biozonation and Description of Recognized Stratigraphic Subdivisions of Bolia-1x Well**

One hundred and sixty (160) analyzed samples from the well section 7710–13020ft of Bolia-1X well were used for foraminifera interpretation. Most of the samples were at 30ft intervals while few of the samples came at various intervals.

Foraminifera recovered were generally low to moderate both in abundance and diversity. However, abundant foraminifera were recovered within intervals 8310- 8490ft, 9600-9630ft, 9990-10080ft, 10440-10620ft, 11280-11310ft, 11520-11760ft and 12600-12870ft. One hundred and twenty-seven (127) foraminifera species were recovered. Twenty-nine (23%) of these were planktonics, fifty-seven (45%) were calcareous benthonics while the remaining forty-one (32%) were arenaceous benthonics. Associated microfauna present were shell fragments, pelecypod and gastropods.

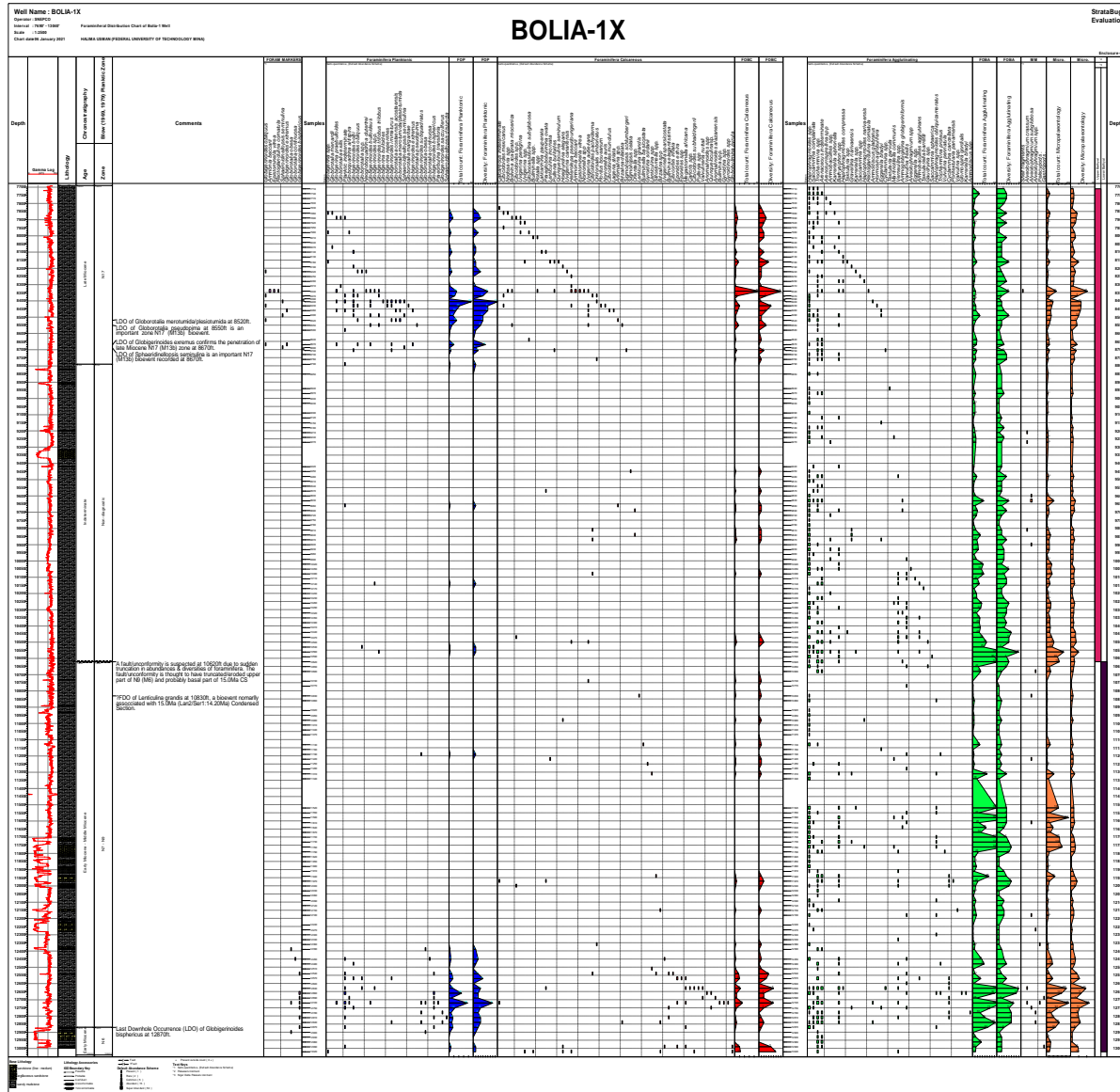


Figure 12: Foraminiferal distribution chart of Bolia-1X

The planktic foraminiferal zones recognized in this study are summarized in Figure 13 and briefly described below.

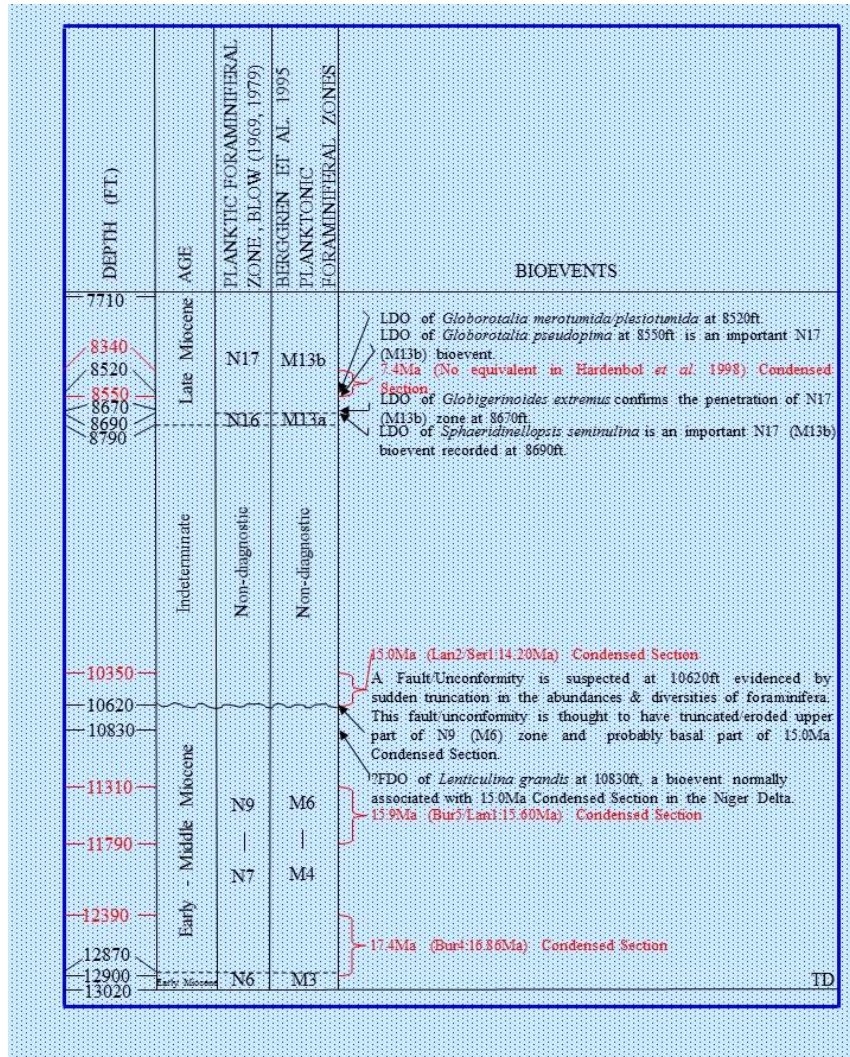


Figure 13: Foraminiferal biozonation of well Bolia-1X

***Globigerinoides extremus-G. humerosa* zone – interval zone**

**Stratigraphic Interval: 7710-8690ft**

**Planktic foraminifera Zone: N17 (M13b)**

**Age: Late Miocene**

**Diagnosis:** Top of the zone is tentatively placed at 7710ft, top of the analyzed section while the base is defined by the Last Downhole Occurrence (LDO) of *Sphaeroidinellopsis seminulina* at 8690ft. The interval is characterized by low to moderate abundance but low diverse planktics. Planktics recorded include *Neogloboquadrina dutertrei*, *Globorotalia pseudopima*, *Globorotalia acostaensis acostaensis*, *Globigerinoides bolli* and *Globigerina nepenthes*.

Last Downhole Occurrences (LDOs) of *Globorotalia merotumida/plesiotumida* (8520ft), *Globorotalia pseudopima* (8550ft) and *Globigerinoides extremus* (8670ft) are important Late Miocene *Globigerinoides extremus*-*G. humerosa* zone (N17) (M13b) bioevents recorded. These confirmed both the zonal and age assignments to the interval. Increases in abundances and diversities of foraminifera recorded within interval 8340-8550ft are thought to represent 7.4Ma Condensed Section of Haq *et al.* (1988). This Condensed Section do not have equivalent in Hardenbol *et al.* (1998) scheme.

**Remarks:** Last Downhole Occurrence (LDO) of *Globigerinoides extremus* is normally used to delineate *Globigerinoides extremus*-*G. humerosa* zone (N17) (M13b)/ *Globorotalia acostaensis acostaensis* (N16) (M13a) zonal boundary, but LDO of *Spheroidinellopsis seminulina* which is in N17 (M13b) was delineated at 8690ft slightly below it, showing that the interval is still within N17 (M13b) zone at depth 8690ft.

***Globorotalia acostaensis acostaensis* zone – taxon range zone**

**Stratigraphic Interval: 8690-8790ft**

**Planktic foraminifera Zone: N16 (M13a)**

**Age: Late Miocene**

**Diagnosis:** Top of the interval is defined by the Last Downhole Occurrence (LDO) of *Spheroidinellopsis seminulina* at 8690ft while the base is tentatively placed at 8790ft, the top of the non-diagnostic zone. The interval is characterized by low abundance and low diverse planktics. Planktics indeterminate species was the only planktic recovered.

**Remarks:** Age and zonal assignments to the interval is based on superposition as it lies below a positively identified and well dated *Globigerinoides extremus*/*G. humerosa* (N17) (M13b) zone.

**Stratigraphic Interval: 8790-10620ft**

**Planktic foraminifera Zone: Non-diagnostic**

**Age: Indeterminate**

**Diagnosis:** Top of the non-diagnostic zone is placed at the base of N16 (M13a) zone while the base is approximated at the depth of the suspected fault/unconformity at 10620ft. The interval is characterized by long-ranging and non-age diagnostic planktics which made both zonal and age assignment to the interval difficult. *Globigerinoides trilobus trilobus*, planktic indeterminate species, species of *Globorotalia* and *Globigerinoides* were the only planktics recovered. There is a sudden drop in the abundances and diversities of foraminifera at 10620ft. This is thought to have been caused by either a fault or unconformity. This fault/unconformity is thought to have cut off or eroded the upper parts of N9 (M6) zone and part of 15.0Ma Condensed Section.

***Globorotalia fohsi peripherronda - Globigerinatella insueta* zone – interval zone**

**Stratigraphic Interval: 10620-12870ft**

**Planktic foraminifera Zone: N9-N7 (M6-M4)**

**Age: Middle - Early Miocene**

### **Diagnosis:**

Top of the combined *Globorotalia fohsi peripherronda* - *Globigerinatella insueta* zone (N9-N7) (M6-M4) is approximated at 10620ft, the unconformity/fault surface while the base is placed at the Last Downhole Occurrence (LDO) of *Globigerinoides bisphericus* at 12870ft. The upper part of the interval (10620-12450ft) is characterized by dearth of planktics with *Globigerinoides subquadratus* being the only planktonics recovered within the interval. However, the lower part of the interval (12450-12870ft) is characterized by low to moderately abundant but low diverse planktics. Planktics recovered include *Globoquadrina altispira*, *Globigerinoides bollii*, *Globigerinoides bulloides*, *Globorotalia obesa*, *Globorotalia continuosa*, *Praeorbulina transitoria* and *Globigerinoides sacculiferus*. Increase in abundances and diversities of foraminifera recovered within intervals 11520-11790ft and 12510-12870ft are thought to represent 15.0Ma and 15.9Ma Condensed Sections of Haq *et al.* (1988) respectively. These are equivalent to Lan2/Ser1:14.20Ma and Bur5/Lan1:15.60Ma Condensed Sections of Hardenbol *et al.* (1998).

**Remarks:** *Globorotalia fohsi peripherronda* - *Globigerinatella insueta* zone (N9-N7) (M6-M4) are combined due to non-recoveries of *Orbulina suturalis* and *Praeorbulina sicana*, the *Globorotalia fohsi peripherronda* - *Praeorbulina glomerosa* zone (N9-N8) (M6-M5) and *Praeorbulina glomerosa* - *Globigerinatella insueta* (N8-N7) (M5-M4) boundary marker species.

### ***Catapsydrax stainforthi* zone – taxon range zone**

**Stratigraphic Interval: 12870-13020ft**

**Planktic foraminifera Zone: N6 (M3)**

**Age: Early Miocene**

**Diagnosis:** Top of the zone is approximated at 12870ft, the Last Downhole Occurrence (LDO) of *Globigerinoides bisphericus* while the base is placed at 13020ft, depth of last sample studied. Low abundance and low diverse planktics characterize this interval. *Globorotalia obesa*, planktonic indeterminate species and *Globigerina* spp were the only planktics recovered.

## **VI. Summary and Conclusion**

Palynological and foraminifera investigation of wells Bobo-3, Doro-1 and Bolia-1X in the deep offshore of Niger Delta Basin has resulted in the interpretation of the chronology, biostratigraphy and environment of deposition of the studied interval. This investigation gave three (3) palynological zones P800, P700 and P600 of Evamy *et al.* (1978) subdivided into Early, Middle, and Late Miocene. The P800 zone recognized was in two (Bolia-1X and Doro-1) wells. This zone was further assigned to combined *Stereisporites* spp - *Cyperaceapollis* spp zone – interval zone (P830-P840) subzones in Bolia-1X while combined *Nymphaepollis clarus*- *Gemmamonocolpites* spp zone – Interval zone (P860-P870) and *Multiareolites formosus* - *Retibrevitricolporites obodoensis* zone – interval zone (P820-P850) were delineated in Doro-1 well. P700 zone was further subdivided into *Belskipollis elegans* zone – taxon range zone (P740) and *Crassoretitriletes vanraadshooveni* zone – taxon range zone (P720) in Bobo-3, but only *Crassoretitriletes*

*vanraadshooveni* zone – taxon range zone (P720) subzone of P700 zone was delineated in Bolia-1X and Doro-1 wells. A non-diagnostic subzone was delineated overlying the *Crassoretitriletes vanraadshooveni* zone – taxon range zone (P720) subzone in Bolia-1X and Doro-1 wells. P600 zone was recognized in the three wells with only *Pachydermites diderixi* (P680) subzone delineated in Bobo-3 while Bolia-1X and Doro-1 wells penetrated *Pachydermites diderixi* (P680) and *Magnastriatites howardi* (P670) subzones.

Established foraminiferal zones are *Globorotalia fohsi peripherronda*, *Globigerinoides extremus-Globigerinoides humerosa*, *Globorotalia acostaensis acostaensis*, *Globorotalia fohsi peripherronda* and *Catapsydrax stainforthi*. Scraps of pyrites deposited within the shales at some depths suggest that the sediments were deposited in a reducing (anaerobic or anoxic) environment. The presence of some benthonic foraminifera like *Cibicides spp*, *Anomalinoides spp*, *Ammodiscus spp*, *Karrieriella spp*, *Martinotiella spp*, *Kareriella siphonella*, *Haplophragmoides compressa*, *Valvulina flexilis*, *Gravelinella narivaensis*, *Eggerella ex gr forestensis*, *Haplophragmoides* indicates an open marine environment (outer neritic-bathyal), also dominance of planktonic foraminifera down the well indicates deeper water depth.

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