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Late Miocene Foraminiferal and Palynologic Events of Oborduka-1 Well, Deep Offshore, Niger Delta, Nigerian

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Abstract: A biostratigraphic study has been carried out on thirty (30) cutting samples retrieved from Oborduka-1 well. The studied intervals were taken at 60ft, ranging from 10510ft-12310ft depth, to determine the chronology, biozonation and paleoenvironment that characterized the well. The lithostratigraphic description of the cuttings revealed that the bulk of the lithofacies constitutes shaly sandstone and sandy mudstone with intercalations of medium to fine-grained sandstone beds. The well yielded well preserved and fairly rich palynomorphs. The microfossil biozones of *Cyclammina minima* and *Haplophragmoides narivaensis* have been established (N17). A peak abundance surface of foraminifera was identified at 12070ft. A major palynological zone established was P800 with two subzones of P820 and P830. The top of P830 (youngest) is placed at 10510ft and its base at 11710ft which is marked by base occurrence of *Stereisporites* sp. and the P820 (oldest) which has its top marked at 11710ft with its base placed at 12310ft respectively. This zone is correlated with the broad Pan-tropical zone of *Echitricolporites spinosus* based on the index taxa recorded. The fauna and flora recovered suggest late Miocene age, nearshore and/or marginal marine environment. A cycle of transgression/regression was also identified based on the facies assemblage.

Key words: Palynomorphs · Foraminiferal · Zones · Miocene · Facies · Assemblages Paleoenvironment

INTRODUCTION

The Niger Delta petroliferous province located in the southern most part of Nigeria represents the most significant hydrocarbon province in the West African continental margin. The proven ultimate reserve of thirty billion barrels of oil and two hundred and sixty trillion cubic feet of natural gas ranks the Niger Delta as one of the world's major hydrocarbon provinces [1].

Only about two and a half billion barrels of oil from the offshore areas, but of the twenty-six billion barrels recoverable reserve earlier estimated [2]. These could have been due in part to the extensive exploration activity, which concentrates in the onshore areas of the Niger Delta. The Delta is an epicontinental marginal sag basin of the deltaic gravity tectonics type. It occupies an area of about 100,000 sq. km extending for more than 300km offshore and onshore (Fig.1). It comprises regressive wedge of clastic sediments which reaches a maximum thickness of about 12km [2].

The increase in exploration of hydrocarbon in the Niger Delta has made the search of oil and gas increasingly difficult. This is in turn, has made its important to acquire knowledge and expertise, in other to improve geological research and technology to field development and production of this vast hydrocarbon resource in the Niger Delta. Maximum abundance as well as diversity of foraminifera and mangrove palynomorphs coupled with maximum diversity of coastal plant pollen grains enhances the recognition of maximum flooding surfaces and their condensed section, such analysis facilitates better understanding of different facies relationship within sequences. Integrated data which involves the use of palynological and foraminiferal study is applied to provide information on chronostratigaphy, paleobathymetry, eustatic sea-level changes and paleoclimatic trends to aid the paleoecological reconstruction of the Oborduka-1 well in the deep offshore of Niger Delta.

Geologic Setting and Stratigraphy of the Study Area: The study area is part of the Tertiary Niger Delta, which is defined in terms of lithology consists of both marine and non-marine sedimentary rocks.

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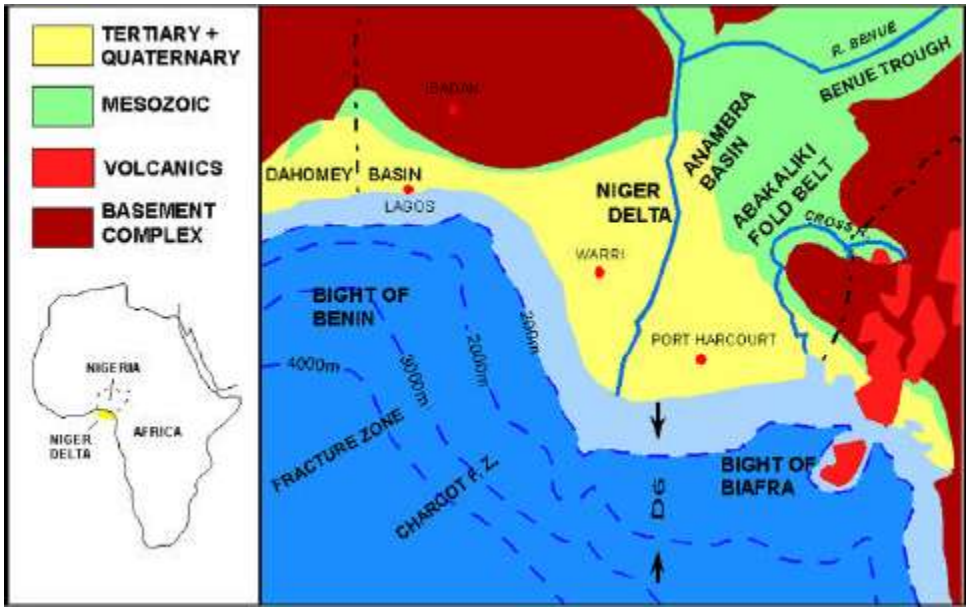


Fig. 1: A geological map showing the location of Nigerian Niger delta Complex

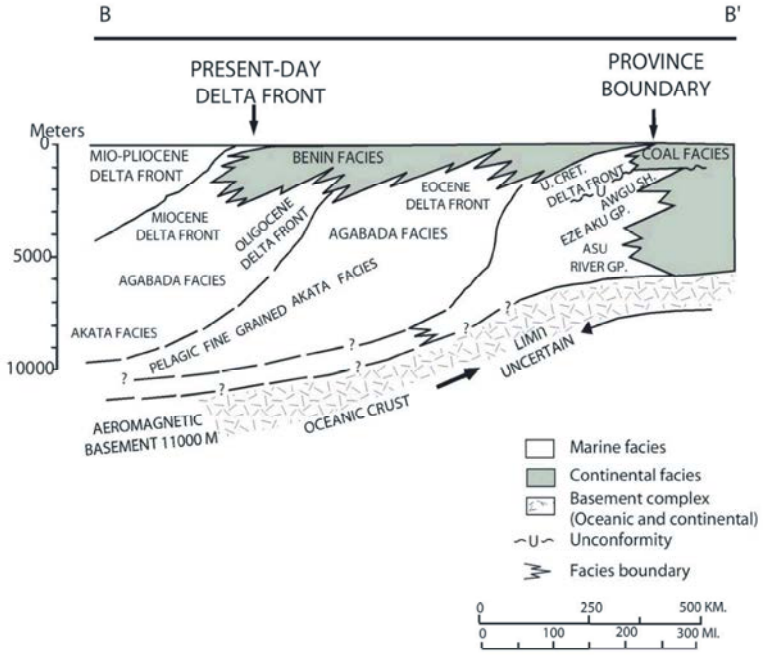


Fig. 2: Southwest-Northeast (B-B') Cross Section through the Niger Delta Region. (modified from Whiteman, 1982)

It is a petroliferous province in the southern part of Nigeria (Fig. 2). Allen studied the recent surface sediments of the Niger Delta and classified the sedimentary bodies recognized as younger suite elder and repositioned break (Regression) these he assigned the age of Pleistocene and Holocene [3,4]. He further observed that the late Quaternary Niger Delta is based on essential concentric facies elements as in many other clastic deltas rather than on radial elements as in the Mississippi bird-foot delta.

Three main subsurface lithostratigraphic units recognized and delineated are Akata, Agbada and Benin formations [5], which are in turn overlain by diverse types of Quaternary deposits. The Akata Formation is dominantly shale of marine origin while the Agbada Formation is a paralic facies of shale and sand. The Benin

Formation is a continental deposit made up of mainly sandstone. The Quaternary deposits consist of either a relatively uniform lithology of sand, silt, sand-silt-clay mixtures with clay and peat increasingly more predominant seaward. The three formations are stratigraphically superimposed in space and time and range from Eocene to Recent in age.

Previous Geological Studies: Premier studies of rocks in the Niger Delta were carried out by some workers at the first quarter of the twentieth century. Parkinson zoned the southern Niger Delta rocks based on their similarities and unconformities [6]. He concluded by proposing an estuarine to fresh water paleoenvironment of deposition for the sediments.

One of the earliest foraminiferal studies in the region was carried out and identified species *Miliolina, Tuncatilina, Textularia, Bolivina, Globigerina, Lenticulina* and *Buliminina.* He proposed a shallow water environment for them.

Today vast research on the Niger Delta is facilitated due to its prolific hydrocarbon potential which has enhanced understanding on its biostratigraphy, sedimentology, geochemistry and paleoenvironment.

Van Hoeken-Klinkenbers carried out palynological studies on boreholes samples in the western part of the Niger Delta and concluded that Paleogene age in some part of the Niger Delta exhibits poor palynomorphs preservation [7]. Bandy and Arnal postulated criteria for establishing Cenozoic zones of modern tropical climate based on planktonic foraminiferal abundance and diversity [8]. Wade demonstrated a continuous temperature-climate optimum for the development of *Globigerina bulloides* and tropical climate for the development of *Globorotalia foshi* and concluded that Tertiary faunal provinces were distributed asymmetrically about the equator probably by major ocean currents like in the present day condition [9]. Mid-Tertiary stratigraphic ambiguities were designated by Drooger into Chattian, Aquitanian and Burdigalian stages type localities which correspond to three successive time intervals highly embraced today [10].

Sowunmi and Kogbe reported that angiosperm palynomorphs are predominant in the Niger Delta Post-Eocene sediments with no records of gymnosperms. They concluded that dicotyledonous pollen grains form about 50% of the total number of palynomorphs while monocotyledonous pollens and pteridophytes spores form about 12.5% and 10% respectively. Index fossil pollens in the Niger Delta sediments are reported by many workers [11-13]. Germeraad *et al*. reported that the fossil pollens of Rhizopora type are absent from Pre-Miocene sediments in Nigeria with earliest occurrence in early Miocene [14]. Boboye and Adeleye identified four condensed sections for the foraminiferal assemblages and four zones for the calcareous nannofossil in the Niger Delta which was correlated to the NN13, NN11, NN10 and NN9 of Global Cycle Chart [15-19]. Other workers with diverse reports on biostratigraphy of this basin include Ogbe, Ozumber, Salard-Chaboldaeff and Dejax, Salami amongt others.

Methodology: Thirty ditch samples at 60ft intervals retrieved from Oborduka-1 well were analyzed for foraminifera and palynomorph constituents. The well penetrated a total depth of 1800ft. The lithological description was done using a hand lens and a binocular microscope.

Sample Preparation for Foraminifera (Microfossils) Analysis: Twenty grammes (20g) of each samples was weighed using an electronic balance. Indurated samples were disaggregated by crushing in a mortar. 10% concentrated hydrogen peroxide (H_2O_2), anhydrous sodium carbonate ($NaCO_3$), sieve (63 microns), glass funnel, filter paper, oven, slides, Leitz-Wetzler binocular microscope. All samples were in turn subjected to standard foraminiferal treatment for foraminiferal recovery which consists of the following steps:

- Each sample was soaked in a sufficient quantity of 10% concentrated hydrogen peroxide (H_2O_2) and about two teaspoonful of anhydrous sodium carbonate ($NaCO_3$) were added to disperse mud and free the microfauna, while the hydrogen peroxide facilitates the reaction (catalyst).
- The mixture was then boiled until it smeared and then allowed to cool.
- Each boiled sample was wet-seived under a gentle jet of tap water using 63 microns.
- The residue retained on the sieve was flushed carefully into filter paper bearing the depth and the well name placed on a glass funnel.
- The filter paper and residue were carefully removed from the funnel wrapped and placed in an oven to dry at a temperature of about 80°C.
- Each washed and dried samples was dry-sieved through a set of mesh size consisting of three grades sieve; 30 and 60 (apertures 500 and 251 microns respectively) to facilitate the picking process.

Foraminifera and other microfauna were picked with the aid of a wet, well-trimmed picking brush under Leitz-Wetzler binocular microscope. The picked microfauna were carefully transferred into slides and identified.

Sample Preparation for Palynomorphs Analysis:

Step 1: Hydrofluoric acid (HF) are gently applied into each samples and properly stirred for digestion to stay overnight.

Step 2: Carbonates are removed with the aid of hot 10% HCl solution. The digested samples are gently poured into the beakers with 10% Hcl solution and heat for about 25 to 30 minutes. The samples are decanted at an interval of 1 hour each for three times. This is done through the Branson Sonifer, with the aid of 5micron sieve to filter away the inorganic matter. (After sieving the retrieved organic matter are stained with Safranin solution (Reddish colour substance). This will aid easy identification of dinocyst that are almost totally transparent).

Step 3: The recovered organic matters are uniformly spotted on arranged cover slips with use of hand pipette and then allow drying for mounting. Loctite impruv is used for permanent mounting of the slides; it's allowed to dry under natural condition for about 5minutes.

RESULTS AND DISCUSSIONS

Lithostratigraphic Description: The lithostratigraphic log showed that the major constituent of the lithofacies to be sandy mudstone, sandstone and shaly sandstone. They are from grey to dark grey in colour. The sandstone range from medium to fine-grained. The grains are angular to rounded and poorly sorted to well sorted. The accessory minerals present in profusion include ferruginous material, mica flakes and some shell fragments. The stereo binocular microscope was used to describe the cutting samples (Fig. 3).

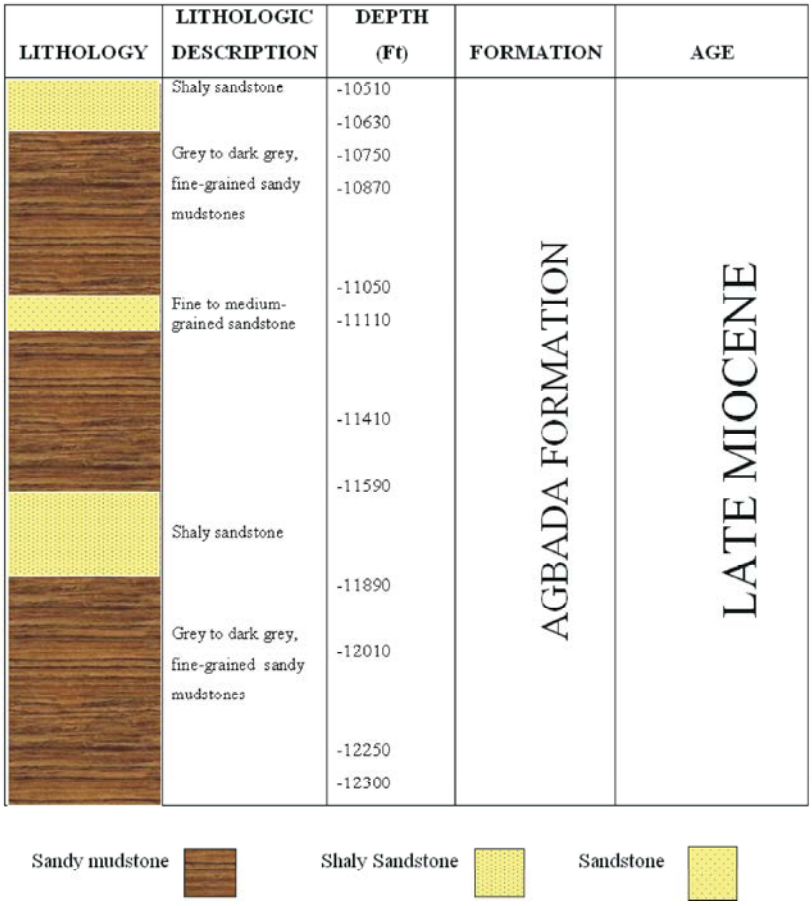


Fig. 3: Lithostratigraphy of Oborduka-1 well

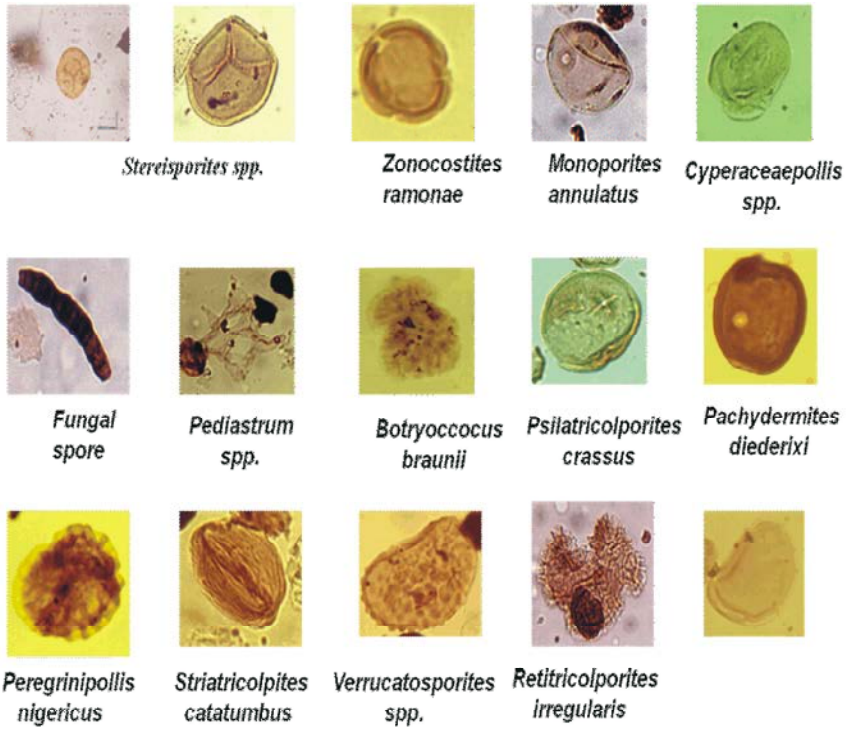


Plate 1: Some of the palynomorphs recorded within the Oborduka-1 well.

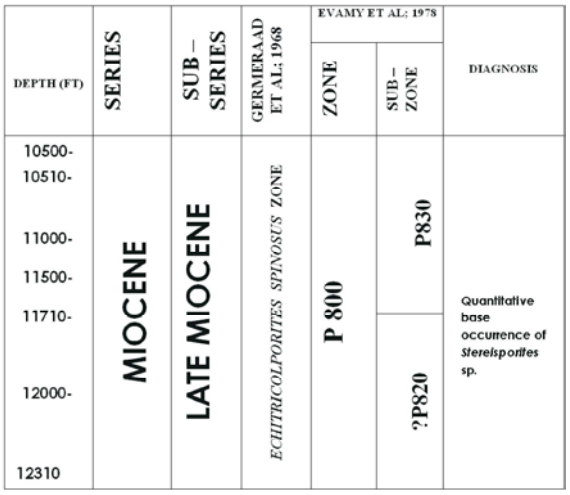


Fig. 4: Palynological zones established for the well.

Palynostratigraphy: A total number of thirty-five (35) palynomorph species were recorded. Moderate numbers of land derived palynomorphs such as *Zonocostites ramonae, Monoporites annulatus, Sapotaceoidaepollenites* sp., *Retibrevitricolporites protudens, Striatricolpites catatumbus, Verrucatosporites* sp., *Laevigatosporites* sp. and *Polypodiaceiosporites* sp. were recovered. Few freshwater algae *Botryococcus braunii* and *Pediastrum* sp. were recorded within some intervals in the well. *Dinoflagellate cysts* were not recovered (Plate 1).

The Oborduka-1 well sequence falls within the broad Pan-tropical *Echitricolporites spinosus* Zone of Germeraad *et al*. and the P800 Zone of Evamy *et al*. [14, 20]. The P800 Zone has been sub-divided into P830 and P820 Subzones respectively (Fig. 4).

Zone: P800
Sub-zone: P830

This is the first and the youngest sub-zone recognized within the studied section. The top of this sub-zone is placed at 10510ft. The base is placed at 11710ft which is defined by the high frequencies occurrence of *Stereisporites* sp. This thick interval is characterized by the regular records of *Stereisporites* sp., *Cyperaceapollis* sp. and the consistent records of *Monoporites annulatus*. This subzone is dated Late Miocene.

Sub-zone: P820

This is the oldest and the last subzone identified within the studied section of the well. The top of the subzone is marked by the high frequencies occurrence of

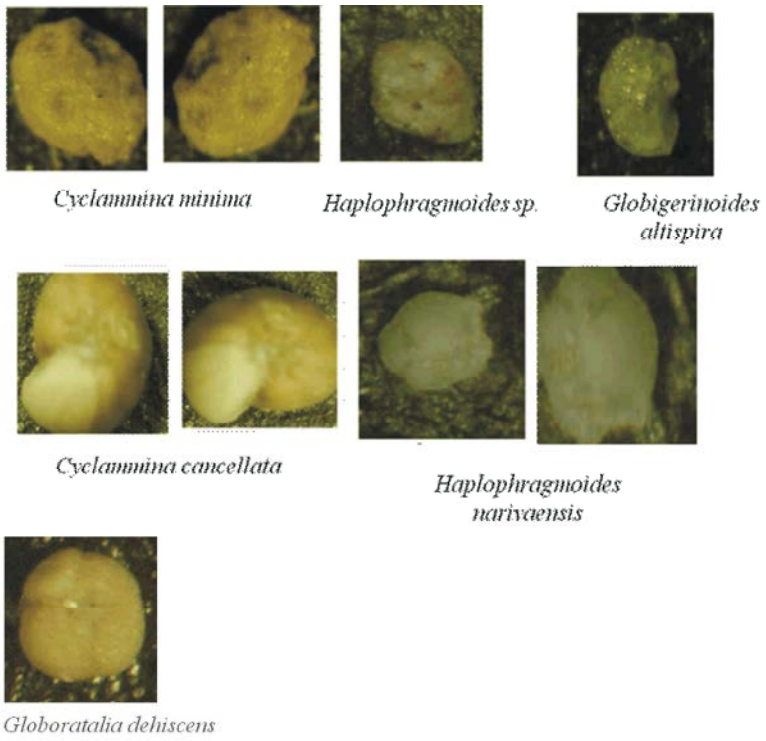
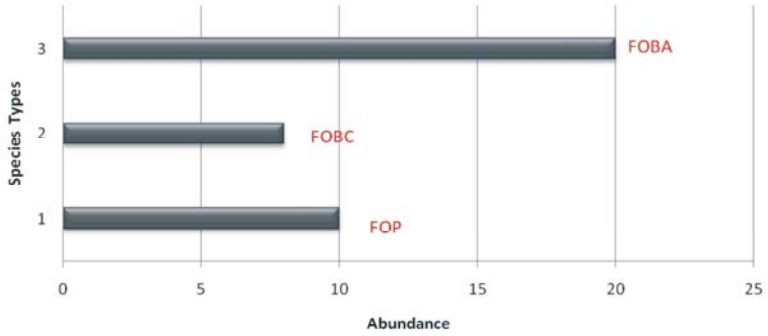


Plate 2: Some foraminiferal forms recorded within the Oborduka-1 well.



FOBA-AGGLUTINATE; FOBC-CALCAREOUS; FOP-PLANKTONIC

Fig. 5: A Chart showing foraminifera types Abundance

Stereisporites sp. at 11710ft, while the base is placed at 12310ft. This interval is characterized by the abundant occurrence of *Sapotaceoidaepollenites* sp., *Zonocostites ramonae* and *Racemonocolpites hians.*

Micropaleontology: A total number of seventy seven (77) fauna were recovered. The preservation of foraminifera microfossils within the study interval is poor which could be due to dilution of flora and fauna by large terrigenous influxes which disrupts the sequential occurrence of species leading to scarcity of planktic foraminiferal specie. Foraminiferal abundance and diversity were recorded at diverse depth of the well (Plate 2). Foraminiferal species recorded include planktonic foraminifera such as *Sphaerodinella dehiscens, Globigerinoides altispira, Globigerinoides sacculiferus* and benthic foraminifera *such as Lenticulina inomata, Haplophragmoides* sp., *Cyclammina cancellata, Valvulina flexilis, Trochamina globigeriniformis, Bathysiphon* sp. Some shell fragments were also encountered (Fig. 5). A foraminiferal biozone of N17 was established with the occurrences of *Cyclammina minima* and *Haplophragmoides narivaensis* of Late Miocene age [21, 22] (Fig. 6).

The stratigraphic distribution chart shows the distribution of palynomorph and foraminifera in the studied well. (Fig. 7). The assemblage follows the zoning

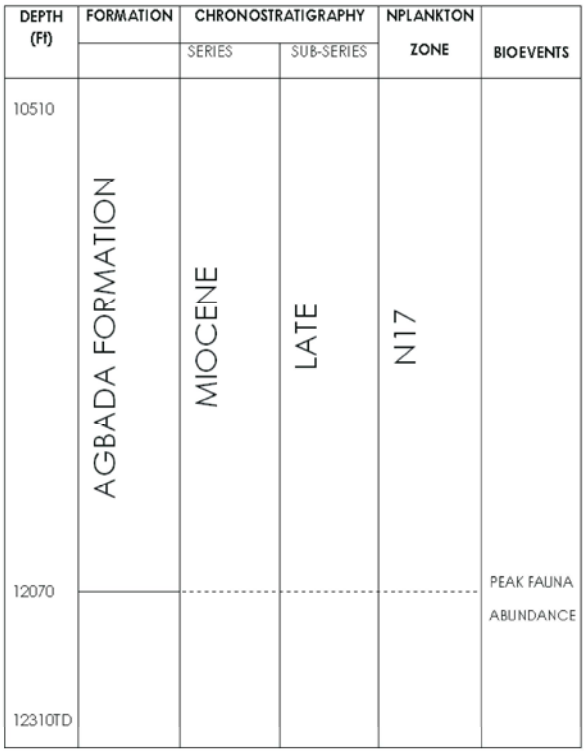


Fig. 6: Biozonation of the foraminifera distribution within the well

scheme according to Blow N17 which is marked by *Haplophragmoides narivaensis* and *Cyclammina minima* indicating late Miocene age [21, 22]. The peak abundance of fauna was recognized around 12070ft interval.

Paleoenvironment: The depositional environments identified were based on recorded fauna and flora assemblages. From the upper part of the well (10510ft-11110ft), fauna such as *Sphaerodinella dehiscens, Haplophragmoides* sp., *Globigerinoides sacculiferus, Cyclammina cancellata* and *Trochamina proteus* were recorded suggesting an inner neritic. From the base of 11050ft-11110ft to the top of 11410ft-11470ft, outer neritic environment is suggested based on the occurrence of *Cyclammina minima, Bathysiphon* sp, *Valvulina flexilis, Trochamina proteus* and *Lenticulina inornata*. Inner neritic foraminifera were again encountered at 11530ft-11590ft, followed by other forms such as the arenaceous indeterminate of Coastal deltaic environment (11770ft-11890ft).

Moderate numbers of land-derived palynomorphs were recorded such as *Monoporites annulatus, Zonocostites ramonae, Retibrevitricolporites protudens, Retitricolporites irregularis, Sapotaceoidaepollenites* sp., *Striatricolpites catatumbus*

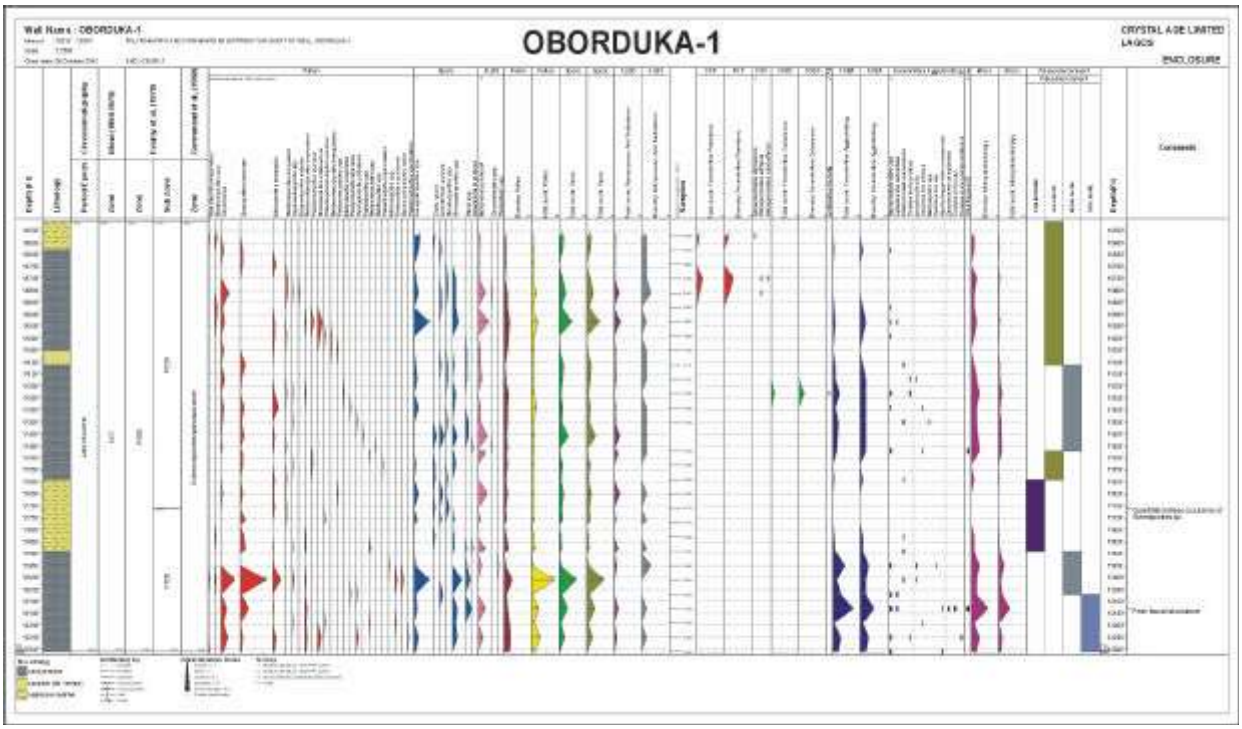


Fig. 7: Biostratigraphic distribution chart of Oborduka-1 well

and the Pteridophyte spores. Ubiquitous occurrence of freshwater algae *Botryococcus braunii* and *Pediastrum* sp. were also encountered at some intervals within the studied section. Dinoflagellate cysts were not recovered. This assemblage suggests a nearshore environment (Fig. 5).

This transition from inner neritic to coastal deltaic environment suggests a period of transgression due to eustatic sea level rise. The change in the environment as revealed by the foraminiferal forms encountered progressed into middle neritic. Inner neritic forms were not part of this transition which continues into an outer neritic environment.

CONCLUSIONS

The age, zonation and environment of deposition of the studied well have been determined. Sedimentological studies showed that the well penetrated major sedimentary formation in Niger Delta (Agbada Formation) which comprise of sandstone, shaly sandstone and sandy mudstone. Diagnostic microflora and microfauna has been used for the age and zone determination.

Moderate numbers of land derived palynomorphs were recovered of which few freshwater algae were recorded within some intervals in the well. The assemblage zone of P800 was established with two Sub-zones of P820 and P830 respectively, which has its boundary at 11710 ft [20]. The zone also correlates with the broad Pan-tropical *Echitricolporites spinosus* Zone [14] and it is dated late Miocene. The foraminifera assemblages in the study interval are poorly preserved which could be as a result of terrigenous sediment influx at the deltaic milieu. A foraminifera biozone of N17 was established with the occurrences of *Cyclammina minima* and *Haplophragmoides narivaensis* of Late Miocene age [21, 22]. This corroborated the established P800 Assemblage Zone.

The paleoenvironment suggested a transition from the inner neritic (topmost interval (10510ft to 11110ft) to middle neritic (11110ft to 11470ft). However, there was a period of transgression due to climatically controlled eustatic sea level changes where the inner neritic forms started emerging (around the base of 11470ft which extends down to 11590ft). This progresses to a Coastal-Deltaic environment (from the base of 11590ft to 11890ft) after which a regression is observed, signified by the occurrence of middle neritic forms (from the base of 11590ft to 11890 ft), then the outer neritic forms (from the base of 11890ft to 12310ft). A near-shore environment of deposition is suggested based on the assemblages encountered within the study well.

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