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Late Eocene—Early Oligocene Foraminiferal Biostratigraphy and Paleoenvironment of Sediments from "Beta- 24 Well" Niger Delta Basin, South Eastern Nigeria

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Abstract:

Foraminiferal and lithological analyses of ditch cutting samples and well logs from depth interval 2008 – 3396 meters in Beta-24 well in the Niger Delta basin of Nigeria was carried out in order to determine the biostratigraphy and paleoenvironment of the sequences penetrated by the well. Standard foraminiferal sample preparation method which involved sample disaggregation and washing through a 63 micron mesh sieve, drying and picking of the foraminifera and accessory fauna were employed. The result showed that the well penetrated the alternating sand and shale sequences of the Agbada Formation. A Late Eocene to Early Oligocene age was assigned to the well section based on the presence of some characteristic Late Eocene to Early Oligocene foraminifera assemblages of the Niger Delta such as Bolivina tenuicostata, Bolivina imperatrix, Bolivina ihuoensis and Globigerina ampliapertura. The P16/17 and P16/17 – P18/19 foraminiferal biozones were erected for the studied interval of the well. The P16/17 foraminiferal biozone was delineated on the basis of the Last Downhole Occurrence (LDO) of Globigerina ampliapertura at 2928m and the First Downhole Occurrence (FDO) of Bolivina ihuoensis at 2768m while the top of the P16/17-P18/19 zone was

tentatively defined at 2248m based on the occurrences of Bolivina tenuicostata and Bolivina imperatrix and the base was placed at 2648m on account of the LDO of Bolivina imperatrix. Paleoenvironmental interpretation based on the foraminiferal assemblages recovered revealed that the lithologic units were deposited within the non-marine through shallow inner neritic, inner neritic, middle neritic to outer neritic environments.

Key words: Foraminifera, Eocene, Oligocene, Neritic, Biostratigraphy, Paleoenvironment, Niger Delta.

1.0. INTRODUCTION

The Niger Delta basin with latitudes 3^0 N - 6^0N and longitudes 5^0E - 8^0E respectively is situated in the Gulf of Guinea along the West Africa margin (Fig. 1). It occupies a total area of 300,000 km^2 (Kulke, 1995), a sediment volume of 500,000 km^3 (Hospers, 1965), and a sediment thickness of over 10 km in its depocentre (Kaplan *et al.,* 1994). It is one of the largest regressive deltas in the world considered as a classical shale tectonic province (Doust & Omatsola, 1990; Wu & Bally, 2000). The progradation of the delta began in the Eocene and prograded southwestward, to the recent time forming depobelts that represent the most active portion of the delta at each stage of development (Doust & Omatsola, 1990). Petroleum exploration has been carried out since the late 1950's, when oil was discovered in commercial quantities by Shell B.P Petroleum Development Company in Oloibiri-1 well located in the eastern Niger Delta. So far several thousand wells have been drilled, which provides good data source for foraminiferal biostratigraphic and paleoenvironmental analysis. Most of the studies carried out by the oil companies operating in the Niger delta have not been documented in the literature for proprietary reasons (Fadiya *et al*., 2014). However, several

foraminiferal biostratigraphic and paleoenvironmental studies have been carried out for wells in the Niger Delta basin (Petters 1979; Okosun *et al*., 2012; Chukwu *et al*., 2012; Adeigbe *et al*., 2013; Fadiya *et al.,* 2014).

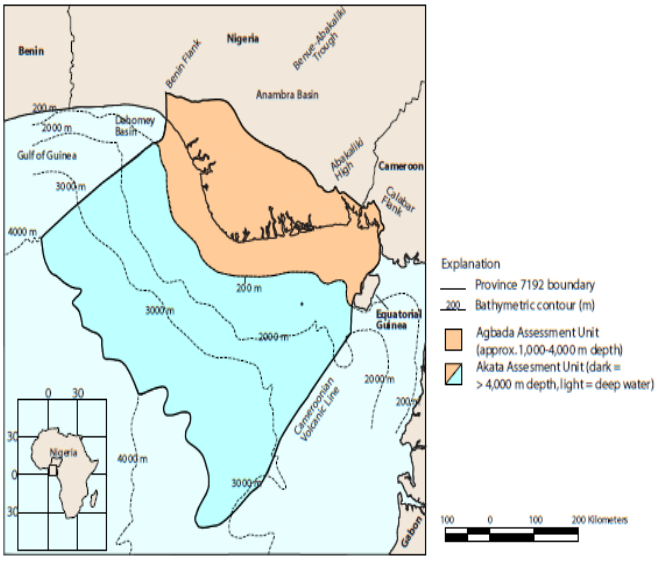

Figure 1: Map showing the location of the Niger Delta, Province outline, bounding structural features; The Agbada Unit overlies the Akata Unit where the two overlap (Tutlle *et al*., 1999).

Petters (1979) identified two biostratigraphic zones in Parable-1 well, Niger delta: the lower zone *Globorotalia opima nana* and *Globorotalia opima opima* dated Oligocene and the upper zone *Globorotalia foshi peripheronda* dated early middle Miocene to Pliocene. Fadiya *et al.* (2014) established four benthonic foraminferal assemblage zones -*Altistoma tenuis*, *Eponides africana*, *Uvigerina peregrina/Lenticulina grandis* and *Bolivina ihuoensis/Hopkinsina hourqi* zones which corresponded to the P12, P13/P14, P15, P16 and younger planktic foraminiferal zones and assigned a Middle – Late Eocene age for the sediments deposited in the Inner to Middle Neritic paleoenvironments of well AM-2, Niger Delta. Okosun *et al.* (2012) established three planktic foraminiferal zones viz;

Globorotalia continuosa, *Globorotalia obesa/Globorotalia mayeri,* and *Globorotalia peripheroacuta* zones and three benthic foraminiferal zones viz; *Spirosigmoilina oligocaenica, Uvigerina sparsicostata*, and *Eponides eshira/Brizalina mandorovensis* zones dated Miocene age. They also inferred a littoral to outer neritic environments of deposition for sediments from Akata field, Eastern Niger Delta. Similarly, Obaje & Okosun (2013) using well sediments from XY-1 Field, Offshore Western Niger Delta identified two benthonic foraminiferal zones of *Spirosigmoilina oligoceanica* and *Florilus* ex. gr. *N. costiferum* and dated them Middle to Late Miocene age. Fajemila (2012) established five foraminiferal zones from two wells in the offshore western Niger Delta. These foraminiferal zones are: *Globorotalia acostaensis/Uvigerina subperegrina* zone, *Globorotalia merotumida/plesiotumida/Ammobaculites agglutinans* zone, *Globoquadrina dehiscens/Haplophragmoides narivaensis* zone, *Globorotalia tumida/Cyclammina minima* zone and *Globigerina nepenthes/Haplophragmoides compressa* zone dated Early-Pliocene to Late Miocene age with the paleobathymetry ranging from Inner Neritic to Upper bathyal environments. Okosun & Chukwuma-Orji (2016) in their work on the calcareous benthic foraminifera biostratigraphy and paleoenvironment of deposition of KK-1 well, offshore western Niger Delta, established the interval range zones of: *Eponides eshira – Valvulineria* sp, *Eponides berthelotianus – Epistominella vitrea, Planullaria auris - Buliminella multicamerate, Anomallinoides midwayensis – Lagena laevis* and *Uvigerina farinosa – Pullenia eocenica* dated Middle –Late Eocene to Middle Miocene. Outer neritic to bathyal paleodepositional environment was inferred for the sediments.

Biostratigraphic analysis of a well is very important for the stratigraphic sub-division of the sequences penetrated by the well into units which can be correlated through biozonaion

and dating. Paleoenvironmental interpretation on the other hand is crucial for the reconstruction of the depositional history of the sediments. This study is aimed at determining the foraminiferal biostratigraphy and paleoenvironments of deposition for sediments of Beta-24 well in the Niger Delta basin.

2.0. LITHOSTRATIGRAPHIC FRAMEWORK

The lithostratigraphy of the Tertiary Niger Delta Basin have been described and classified in several literatures (*e.g*. Short & Stauble, 1967; Avbobvo, 1978; Evamy *et al*., 1978; Doust & Omatola, 1990; Reijers, *et al.,* 1997; Tutlle *et al*., 1999; Corredor *et al.,* 2005). The Tertiary Niger Delta is classified into three formations of progradational depositional environments. The marine shales of the Akata Formation is at the base of the delta with thickness ranging from 2000 m (6600 ft) at the most remote part to 7000 m (23,000 ft) thick beneath the continental shelf (Doust & Omatsola, 1990). The Formation is composed of thick shale sequences which could represent potential source rocks, turbidite sand representing potential reservoirs in deep water, and minor amounts of clay and silt (Tutlle *et al*., 1999). The Akata Formation ranged from Paleocene to Recent (Stacher, 1995). Relatively, little is known about this Formation because it has not been extensively penetrated in the Niger Delta (Tutlle *et al*., 1999). The overlying Agbada Formation is believed to be the major petroleum-bearing unit of the Niger Delta basin with the deposition of sediments beginning in the Eocene and continuing through the Recent in the nearshore shelf setting of the Niger Delta (Reijers *et al*., 1996). This Formation consists of paralic siliciclastics of more than 3500 m (11,500 ft) thick, representing the actual deltaic portion of the basin (Corredor *et al.,* 2005). The Agbada Formation is overlain by the Benin Formation which is composed of late Eocene to

Recent continental deposits, including alluvial and upper coastal-plain sands of up to 2000 m (6600 ft) thick (Avbovbo, 1978). Figure 2 is a stratigraphic column showing the three formations of the Niger Delta.

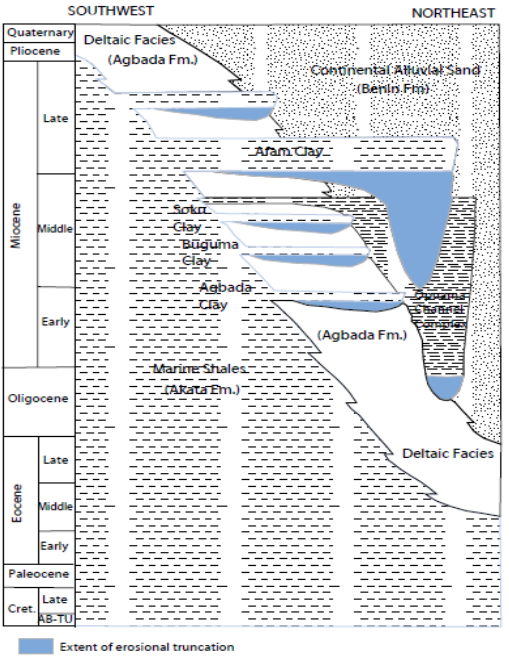

Figure 2: Stratigraphic column showing the three formations of the Niger Delta (After Tutlle *et al*., 1999).

3.0. MATERIALS AND METHODS

Ditch cuttings samples retrieved from interval 2008m - 3396m of Beta-24 well, northern depobelt of the Niger Delta basin were used for this study. The location of the well is approximately shown in Figure 3. For the foraminiferal analysis, twenty (20) grams of each sample was soaked overnight with anhydrous sodium carbonate and water in a sample preparation bowl. Disaggregated samples were wet-sieved through a clean 63µ sieve under a gentle jet of water from the tap. All materials residues trapped in the sieve were collected and dried in an

oven at 50°C. The dried residues were sieved through coarse, medium and fine size fractions to allow for the picking of the foraminifera and other microfauna accessories. The foraminfera and microfauna contents were then picked carefully out of the residue with the aid a binocular microscope and transferred into slides for identification. The identification of foraminifera was made to genus and species levels where possible using the taxonomic scheme of Leoblich & Tappan (1964), Petters (1982) and other relevant foraminiferal literature like (Fayose, 1970), (Petters, 1979), (Postuma, 1971), (Murray, 1991) and (Okosun & Liebau, 1999). Lithologic description was achieved through description of the ditch cuttings under a binocular microscope. The lithology (sand and shale) were carefully described and the accessory minerals noted for paleoenvironmental interpretation. The foraminiferal and lithologic data was imputed into Strata- Bugs (Biostratigraphy Data Management software) to prepare the stratigraphic chart. The gamer ray and resistivity logs provided for the study when interpreted and integrated complemented greatly to the lithologic descriptions of the sedimentary units.

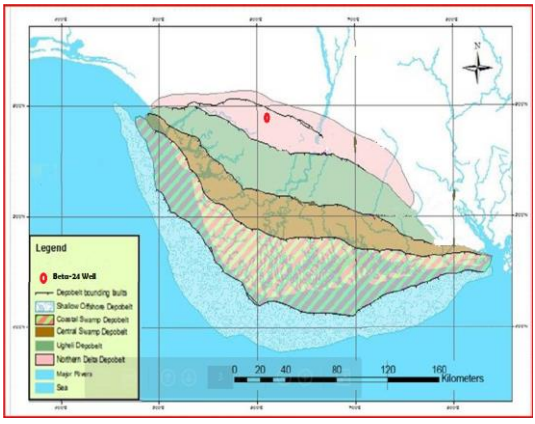

Figure 3: Map of Niger Delta depobelts showing the approximate location of the study well (modified after Okosun & Osterloff 2014).

4.0. RESULTS AND DISCUSSION

4.1. Results

The lithostratigraphic interpretation of the section of the studied section of the well (2008m - 3396m) comprises mainly of alternations of sandstone and shale (Fig 4). The sandstones are mostly light grey to smoky white, coarse to fine grained occasionally containing large crystal grains. They are moderately to well sorted, sub angular to subrounded, carbonaceous and slightly ferruginised, occasionally containing traces of glauconite and coaly materials. The shales are dark grey, subfissile to fissile, hard to moderately hard, sometimes calcareous and micromicaceous.

The foraminifera recovered from the sediments of Beta-24 well were poorly preserved, making their identification and description difficult. However, a total of forty one (41) foraminiferal species were identified. Thirty five (85.4%) were calcareous benthic foraminifera species, two (4.88%) were arenaceous benthics while four (9.76%) of the species were planktics. The accessory microfauna assemblages recovered are: Ostracodes, gastropod and shell fragments. Figures 4 show the foraminiferal distribution and stratigraphic chart of the studied section of the well. The upper interval (2008 – 2248 m) was totally barren of foraminifera. However, the underlying interval (2248 – 2968 m) was characterized by high diversity and abundance of calcareous benthic foraminiferal species. Interval 2968-3396m was dominated by single occurrence of foraminiferal species. Biostratigraphic analysis of the well section was made possible by using the First and Last downhole occurrence (FAD and LAD) of chronostratigraphically significant foraminiferal species. This involved the use of foraminiferal species whose stratigraphic ranges are well established in the Niger Delta and worldwide as well as the stratigraphically important planktic and benthic foraminifera

species which have been extensively utilized and established in the Niger Delta (Bolli & Saunders, 1985; Petters, 1982; Petters, 1979; Blow 1979; Fayose, 1970; Ukpong *et al*., 2017).

The standard planktic foraminiferal zonation scheme of Blow (1969, 1979) was used to erect biozones for Beta-24 well based on the stated criteria. The well section penetrated the late Eocene to early Oligocene age which corresponds to P16/17 and P16/17-P18/19 foraminiferal biozones of Blow (1979). The P16/17 biozone was defined on bases of the LDO of *Globigerina ampliapertura* at 2928m and the FDO of *Bolivina ihuoensis* at 2768m while the P16/17-P18/19 zone was tentatively defined at 2248m on the bases of the occurrences of *Bolivina tenuicostata and Bolivina imperatrix* which had their base at 2648m (LDO of *Bolivina imperatrix)* (Fig. 4).

The quantitative and qualitative evaluation of the benthonic foraminiferal species, planktonic/benthonic foraminifera ratio, presence/absence of ostracode, lithologic description of the ditch cuttings and gamma ray log response as well as integration of biofacies to banthymetric ranges (Harris, 1981; Culver, 1988; Petters, 1995) was used for paleoenvironmental interpretation. The Paleodepositional environment of the well ranged from non-marine through shallow inner neritic, inner neritic, middle neritic and outer neritic environments (Fig. 4).

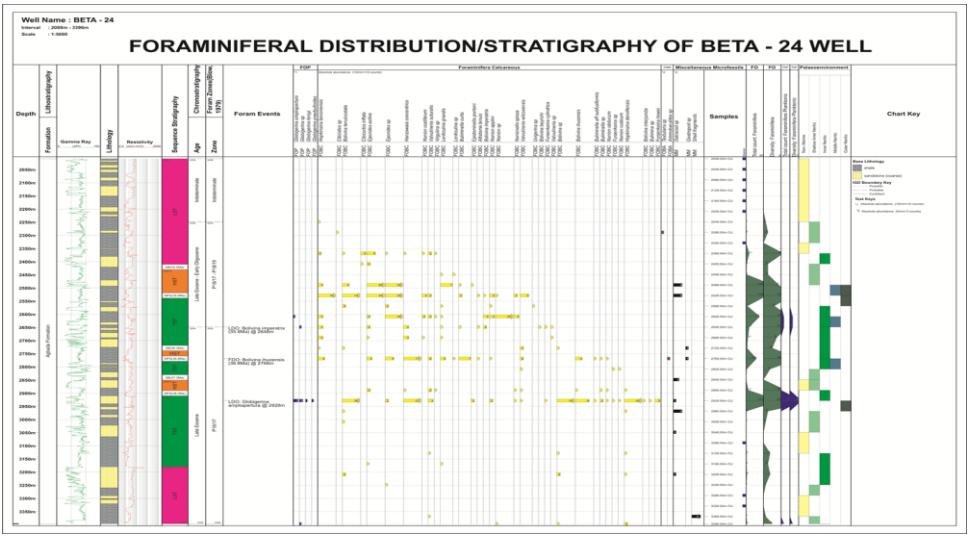

Figure 4: Foraminiferal Distribution and Stratigraphic Chart of "Beta- 24 Well"

4.2 Discussion

4.2.1 Lithostratigraphy

The lithologic log of the well (Fig 4) shows alternation of sandstone and shale sequence. The sandstone sections are mostly light grey to smoky white, coarse to fine grained with few large crystals, moderately to well sorted and sub angular to subrounded. The shales are dark grey, subfissile to fissile, hard to moderately hard, sometimes calcareous and micromicaceous. These characteristics define the Agbada Formation (Short & Stauble, 1967; Reijers *et al*., 1997; Corredor *et al.,* 2005) and as such "Beta-24 well" penetrated the paralic sequences of the Agbada Formation. Reijers *et al*. (1997) described the Agbada Formation as comprising mostly of sands and minor shales in the upper section, and an alternation of sands and shales of equal proportions at lower levels. Short & Staublee (1967) described the Agbada Formation, stating that it is characterized by the alternation of sandstone and sand units with shale layers. The sandstone is fine to coarse grained and

predominantly unconsolidated. The alternations of sandstone and shale in the Agbada Formation has been reported to be as a result of differential subsidence, variation in the sediment supply, and shifts of the delta depositional points resulting to local transgressions and regressions (Short & Stauble,1967).

4.2.2 Age and Biozonation of "Beta-24 Well"

The section of the well analyzed is characterized by some important foraminiferal markers like *Bolivina tenuicostata, Eponides eshira, Hanzawaia concentrica, Hopkinsina bononiensis, Nonion costiferum, Valvulineria suturalis, Lenticulina grandis, Epistominella pontoni, Bolivina imperatrix, V. wilcoxensis, Bolivina ihuoensis, Nonion obducum, N. rusticum, Hopkinsina danvillensis* and associated sparse occurrences of planktonic taxa such as *Globigerina ampliapertura, G. praebulloides and G. leroyi* (Fig. 4). This foraminiferal assemblage is typical of the P16/17 and P16/17 – P18/19 planktonic foraminiferal Zones (Blow, 1979) of Late Eocene to Early Oligocene age. The presence of some characteristic Late Eocene to Early Oligocene foraminifera species of the Niger Delta such as *Bolivina tenuicostata, Bolivina. imperatrix, Bolivina ihuoensis* and *Globigerina ampliapertura* confirms this age assignment. However, the paucity of forms in the upper section of the well makes the age at this interval (2008m – 2248m) indeterminate (Fig. 4).

Foraminiferal analysis shows that "Beta-24 well" (2008m – 3396m) penetrated Late Eocene to Early Oligocene sediments which corresponds to the P16/17 and P16/17 – P18/19 foraminiferal Zones of Blow, (1979). Table 1 shows foraminiferal biozonation of the study well.

Foram Zone: P16/17
Interval: 2648 – 3396m
Age: Late Eocene

Key Foram Event:
FDO of *Bolivina ihuoensis* at 2768m
LDO of *Globigerina ampliapertura* at 2928m

The occurrences of *Bolivina tenuicostata, Bolivina imperatrix, Eponides eshira, Hanzawaia concentrica, Lenticulina grandis, Valvulineria suturalis, V. wilcoxensis, Bolivina ihuoensis, Nonion obducum, N. rusticum, Hopkinsina danvillensis,* etc. and associated sparse planktonic taxa such as *Globigerina ampliapertura, Globigerina praebulloides and Globigerina leroyi* were used to define this foram zone.

Table 1: Foraminiferal Biozonation of "Beta-24 Well"

Interval(m)	Foram Zone	Age	Bio-Event
2008 - 2248	Indeterminate	Indeterminate	Indeterminate
2248 - 2648	P16/17 – P18/19	Late Eocene – Early Oligocene	Last Down hole Occurrence (LDO) of *Bolivina imperatrix* at 2648m
2648 - 3396	P16/17	Late Eocene	First Downhole Occurrence (FDO) of *Bolivina ihuoensis* at 2768m Last Downhole Occurnce (LDO) of *Globigerina ampliapertura* at 2928m

The Top of this Zone is tentatively defined and it coincides with the base of the overlying zone at 2648m. Other defining bio-events within this bio-zone include the FDO of *Bolivina ihuoensis* at 2768m as well as the LDO of *Globigerina ampliapertura* at 2928m. These bio-events all occur in the P16/17 (Late Eocene). The LDO of *Globigerina ampliapertura* was identified in this zone and this foram event was used by Bolli & Saunders (1985) to define this zone. Thus, "Beta– 24 well" was probably not older than the Late Eocene.

Foram Zone: P16/17 – P18/19
Interval: 2248m – 2648m
Age: Late Eocene – Early Oligocene
Key Foram Event:
LDO of *Bolivina imperatrix* at 2648m

The assemblage consisting of *Hopkinsina bononiensis, Bolivina tenuicostata, Eponides eshira, Hanzawaia concentrica, Nonion costiferum, Valvulineria suturalis, Lenticulina grandis, Epistominella pontoni and Bolivina imperatrix* characterize this foraminifera Zone. These taxa straddle the Late Eocene – Early Oligocene age interval (Fig.4; Table. 1).

The Top of the Zone in this study is tentatively defined at 2248m; where there is an occurrence of a foraminiferal taxon: the occurrences of *Bolivina tenuicostata and Bolivina. imperatrix* in the upper section of this interval are possible indications of the penetration of the Oligocene (P18/19); as both taxa are not younger than the Oligocene in the Niger Delta (Stratigraphic Committee of the Niger Delta (StratCom), 2002). The Base of the Zone on the other hand, is defined at 2648m where the LDO of *Bolivina imperatrix* was observed. This bio-event occurs within the P16/17 foraminiferal zone of Blow (1979). This foraminiferal zone is considered a composite P16/17 – P18/19 as no foraminiferal bio-event could be used to demarcate their boundary (Late Eocene/Early Oligocene boundary) in the well section.

Foram Zone: Indeterminate
Interval: 2008m – 2248m
Age: Indeterminate
Key Foram Event:
Indeterminate
This interval is completely barren of foraminifera and as such the age could not be determined (Fig.4).

4.2.3 Paleodepositional Environment

Non Marine Environment

This environment is recognized in Beta-24 well at intervals 3368m-3288m, 3128m-3048m, 2888m-2848m, 2368m-2328m and 2248m-2008m (Fig. 4). The lithology of these environments is characterized by fine to medium/coarse grained sandstone and shale. These intervals contain shale units with materials of continental origin. The occurrences of mostly coarse grained sands, ferruginised materials and carbonaceous particle in this environment may be an indication of sediment deposition in a high energy environment with oxidizing conditions probably in a near shore setting. The absence of fauna in the upper interval (2248m-2008m) and the occurrence of few benthic foraminifera in some of the intervals also indicates coastal deltaic (Marginal-Marine) setting (Okosun *et al*., 2012). Serrated log motif on the gamma ray log at these intervals could also be an indication of sediment deposition in a fluvial flood plain environment.

Shallow inner neritic environment

The shallow inner neritic environment was recognized in the study well at intervals 3396m - 3368m, 3288m - 3248m, 3048m - 3008m, 2888m - 2808m, 2488m - 2408m and 2328m - 2248m (Fig. 4). This environment is characterized by fine to medium through coarsed sand and thin shale beds which is an indication of deposition in a progradational environment probably high energy environment (near shore setting). This environment is characterized by some shallow water benthonic foraminifera species like *Textularia sp*., *Eponides eshira*, *Eponides* sp., *Cibicorbis inflata*, *Bolivina tenuicostata* and shale fragments (Fig. 4). Boersma (1978) postulated that the shallow inner neritic environment is characterized by low species diversity and abundance of foraminifera, with few agglutinated forms.

Inner Neritic

The subdivision of the marine environment between 0 – 30m on the continental shelf is known as inner neritic environment (Allen, 1965). This environment is usually characterized by coarse-grained, clean sand containing shell fragments, few species of benthonic foraminifera with small tests, weak ornamentation and agglutinated species with simple wall structure (Boersma, 1978). This environment was recognized in the study well at intervals: 3248m – 3128m, 2928m – 2888m, 2808m – 2568m, 2408m -2368m (Fig. 4). This was based on the presence of diagnostic inner neritic benthic foraminifera as well as low species abundance and diversity of both planktonic and benthonic foraminifera. The benthonic foraminifera which suggestet inner neritic environmental settings for this interval are: *Lenticulina grandis, Cibicubis inflata, Eponides eshira*, *Eponides sp.*, *Ammobaculites sp., Fursenkoina cylindrica, Fursenkoina* sp. and *Fursenkoina howei.* This is in line with Petters (1995) who used benthic foraminifera species of *Eponides eshira*, *Eponides* sp., *Epistominella vitrea*, *Fursenkoina punctata* to indicate fluvio marine to middle neritic species. On the other hand, Okosun *et al.* (2012) used the occurrence of *Lenticulina grandis*, *Lenticulina inomata* to indicate inner neritic environment of deposition. Lithology of this environment comprised essentially intercalation of fine to coarse grained sand and shale.

Middle Neritic

This environment lies between 30 – 100m along the continental shelf (Allen, 1965). The environment comprised essentially of shale, poorly sorted sands, and abundant glauconite. The environment is characterized by high diversity and abundance of foraminifera (Boersma, 1978). This environment was recognized in the study well at intervals:: 2808m-2768m, 2648m-2608m and 2528m-2488 (Fig. 4) based on the occurrence

of indicator faunas like *Hopkinsina bononiensis, Lenticulina grandis, Nonion costiferum, Nonion sp., Eponides sp*., *Eponides eshira* and *Lenticulina inomata* which are important indicators of the middle neritic environment (Petters 1995). Petters (1995) also pointed out that presence of *Eponides eshira*, *Eponides sp*. and *Hanzawaia concentrica* are possible indicators of middle neritic environment as they are often not found beyond this zone. *Hopkinsina bononiensis*, *Lenticulina inomata Uvigerina sparsicostata, Eponides* sp. and *Hopkinsina bononiensis* have been used to infer middle neritic environment in the Niger Delta (Okosun *et al*., 2012; Chukwu *et al*., 2012).

Outer neritic

The outer neritic environment which extends from 100m– 200m within the continental shelf area of the marine environment (Allen, 1965) are usually comprised of peculiar and abundance foraminiferal species of long geologic ranges especially planktics. This environment occurred at intervals 2968m-2928m and 2528m-2488m in Beta 24 Well (Fig. 4) and was characterized by high abundance of foraminifera species, ostracodes and deep water benthic foraminiferas such as *Uvigerina* sp., *Lenticulina grandis*, abundance of *Eponides eshira, Eponides* sp. *Hopkinsina bononiensis*, *Hopkinsina danvillensis, Bolivina tenuicostata and Bolivina sp.* This inference is in line with the position of Petters, (1995). The planktonic foraminiferal compositions were *Globigerina sp. G. ampliapertura, G. praebulloides and G. leroyi.*

5.0. CONCLUSION

The lithologic units retrieved from "Beta-24 Well" (2008m – 3396 m), northern depobelt of the Niger Delta confirms the penetration of the Agbada Formation. The Agbada Formation is predominantly composed of alternating sand and shale

sequence. Foraminiferal recovery of both planktic and benthic assemblage enabled the subdivision of the well section into the P16/17 and P16/17 – P18/19 planktonic foraminiferal zones of Blow (1979) which is found within the Late Eocene to Early Oligocene age. The presence of some characteristic Late Eocene to Early Oligocene foraminiferal assemblages of the Niger Delta such as *Bolivina tenuicostata, Bolivina imperatrix, Bolivina ihuoensis and Globigerina ampliapertura* confirms this age assignment. However, the paucity of forms in the upper section of the well makes the age at this interval (2008 – 2248m) indeterminate. The P16/17 foraminiferal biozone was delineated on the basis of LDO of *Globigerina ampliapertura* at 2928m and the FDO of *Bolivina ihuoensis* at 2768m while the P16/17-P18/19 zone was tentatively defined at 2248m on the account of the co-occurrences of *Bolivina tenuicostata and Bolivina imperatrix* with the base of the zone placed at 2648m in line with the LDO of *Bolivina imperatrix*. Paleoenvironmental interpretation was based on the quantitative and qualitative evaluation of the benthonic foraminiferal species, planktonic/benthonic foraminifera ratio, presence/absence of ostracode, description of the ditch cuttings and gamma ray log response as well as integration of biofacies to banthymetric ranges. Results revealed that the sequences penetrated by the well were deposited in a wide range of environment from the non-marine setting to the outer neritic environments.

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