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Foraminifera Biostratigraphy of Two Wells in Niger Delta

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Research Article

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Abstract

Biostratigraphic studies of foraminifera were carried out on two exploratory wells drilled in the Eastern Niger Delta to establish the age, biozonation and paleoenvironment of the foraminifera present in the strata penetrated by the wells.

A total of 80 ditch cutting samples retrieved at 60ft intervals from AX-1 and AX-2 Wells at the depth of 3,600ft to 6,000ft and 4,200ft to 6500ft. respectively were subjected to micropaleontological analysis which involves picking and identification of the foraminifera present. The resulting data were loaded into the Stratabug software and interpreted.

The foraminifera recovered and identified from the two wells are made up of both benthic and planktic species. The marker species, whose stratigraphic range are well established were used to describe the biozonation and these includes *Heterostegina sp, Catapsydrax stainforthi, Chiloguembelina victoriana, Orbulina universa/suturalis, Praeorbulina sicana, Buliminella subfusiformis, Nonion centrosulcatum, Catapsydrax dissimilis, Globigerinoides bisphericus and Globigerinoides sicanus.*

Four biozones of foraminifera made up of N8, N7-N8, N6-N7 and N5-N6 were recognised based on the zonation scheme of Grandstein; with their stratigraphic age ranging from early Miocene to middle Miocene. Furthermore, the environment of deposition prevailing in the Formations penetrated by the two wells are predominantly middle neritic with similarity in their ages as observed from the correlation of the biozones from the two wells.

Keywords: Foraminifera; Biozonation; Early Miocene-Middle Miocene; Marker Species; Correlation

Introduction

The two exploratory wells been studied were drilled at the Eastern part of the Niger Delta basin in Nigeria. This basin is regarded as a prolific hydrocarbon basin and as such various studies have been carried out in it ranging from geophysics, basin analysis, sequence stratigraphy, biostratigraphy amongst others. All these studies are geared towards a better understanding of the environment of deposition, ages of Formation in the subsurface and their fossil assemblages.

This study involves using foraminifera biostratigraphic approach in determining the age and biostratigraphy of lithologies penetrated by the exploratory wells under study. And also deducing the environment of deposition of the foraminifera and strata as well as correlation of the 2 exploratory wells using sequence stratigraphy.

Geologic setting of Niger Delta

Niger delta is one of the sedimentary basins in Nigeria. It is a pericratonic basin found at the margin of craton and therefore regarded as open ended basin.

Niger Delta basin is located at the intersection of the Benue Trough and the Atlantic Ocean where a tripled junction developed during the separation of the continents of South America and Africa (Figure 1).

Considering the entire area extent, Niger Delta occupies about 100,000km^2 of which less than 20% is considered to be prospective for oil and natural gas [1]. This area is characterized by high energy wave and tidal deltas.

The stratigraphic framework and detailed Tertiary stratigraphy of the Niger Delta have been based on correlation of palynomorphs and foraminifera zones [2]. Three lithostratigraphic units as shown in Figure 2 were recognized from Paleocene to Recent. These units are the basal Paleocene to Recent Akata Formation representing the pro-delta, the Eocene to Recent paralic Agbada Formation representing the delta-front and the Oligocene to Recent Benin Formation representing the delta-plain.

The 3 units basinward, reflect the overall regression of depositional environments within the Niger Delta clastic wedge. Stratigraphic equivalent units to these three formations are exposed in the southern Nigeria.

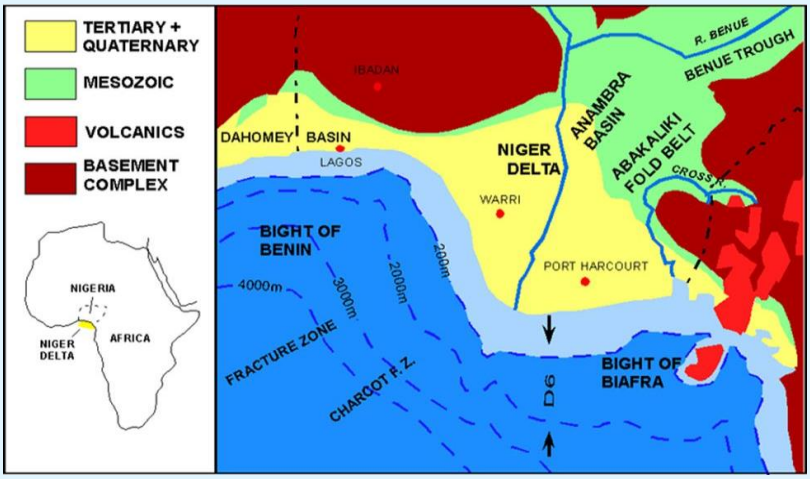

Figure 1: A geologic map showing the location of the Niger Delta (*modified after Doust and Omatsola 1990*) [3].

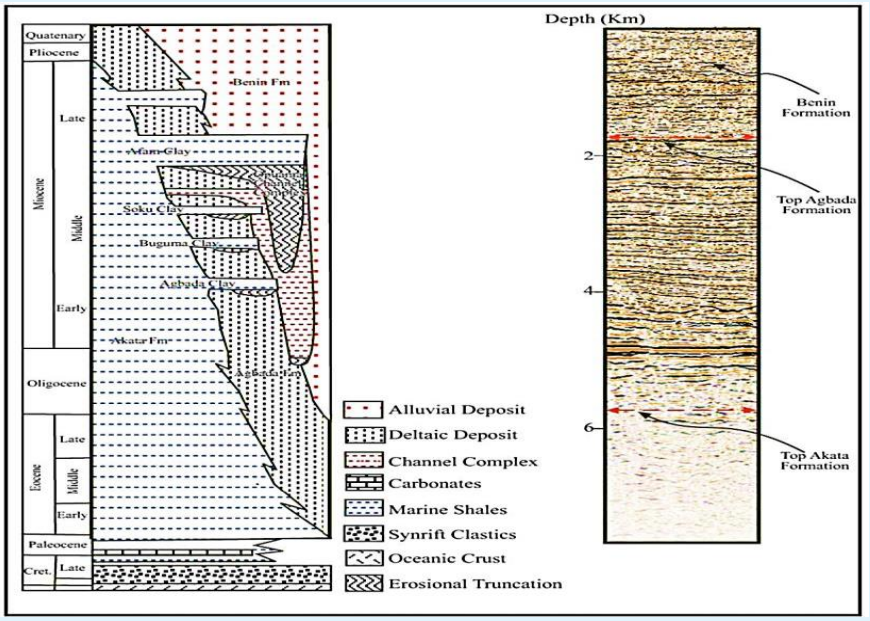

Figure 2: Schematic diagram of Niger Delta regional stratigraphy and variable density seismic display of the main stratigraphic unit with corresponding reflection (*modified from Lawrence, et al. 2002*) [4].

Method of Study

A total of 80 ditch cutting samples collected from 2 exploratory wells were made available for this research. Wherein forty (40) samples were selected from AX-1 and AX-2 wells at 60ft intervals within the depth of (1116m)3600ft to (1860m)6000ft and (1302m)4200ft to (2015m) 6500ft respectively. These samples were subjected to micropaleontological analysis (foraminifera sample processing) and lithological analysis. The sediments encountered from the two wells made of sequences of sand and marine shale units.

Foraminifera Sample Processing

Equipment such as binocular microscope, moistened picking brush (0.00M), slides, cover slips, graded picking tray, and some water were employed in this procedure. In order to pick the foraminifera out of the dried samples, they were scattered on the black graded picking tray after which they were placed on a stage under a well illuminated binocular microscope. The tray was gently moved on the stage while microfossil specimens in it were picked. These specimens were gently removed from the tray and placed into the slides, covered with cover slips and stored for identification. Altogether, 80 ditch cutting samples from the two wells were treated in this manner.

Identification

Foraminifera picked were identified under reflected light binocular microscope with the aid of paleontological textbooks, manuals, monographs and publication dealing with the description of various foraminifera forms.

After the identification, the information from the recovered fossils was inputted into the software called stratabug which generated the foraminifera's distribution and abundance.

Result and Interpretation

The biostratigraphic analysis of AX-1 and AX-2 wells presented below was based on the integration of data derived from the foraminifera identified in the two wells while the biozonation was based largely on sequence stratigraphic principles with precise age dating of the zonal boundaries. The chronostratigraphic scheme adopted follows the usage of Gradstein, et al. (2012) [5] in which case, the First and Last Downhole Occurrences (FDO and LDO) of index foraminifera identified were used in biozonation.

Foraminifera Diversity, Abundance and Assemblage in AX-1 and AX-2 wells

In the two studied sections, the most abundant benthonic foraminifera are *Heterostegina sp* while the least abundant is *Eponides eshira* and in the two wells, the marker species of the planktons are rare.

Richly diverse assemblages of planktonic and benthonic foraminifera with a total of 78 species were recorded in AX-1 well. 76 species (97.4%) are calcareous, while 2 species (2.6%) are arenaceous. Among the calcareous forms, benthics accounted for 61 species (80.3%), while the remaining 15 species (19.7%) are planktics.

In AX-2 well, similar assemblages of planktonic and benthonic foraminifera with a total of 68 species were recorded. 65 species (95.6%) are calcareous, while 3 species (4.4%) are arenaceous. Among the calcareous forms, benthics accounted for 70.8% (46 species), while the remaining 19 species (29.2%) are planktics.

The accessory microfauna recorded include Echinoid remains, pelecypods, ostracods, shell fragments and micromolluscs.

Some of the foraminifera identified in these wells include *Globigerinoides sicanus*, *Catapsydrax dissimilis*, *Buliminella subfusiformis*, *Praeorbulina sicana*, *Nonion centrosulcatum*, *Heterostegina sp, Praeorbulina glomerosa*, *Bolivina mandorovensis* and *Turborotalia peripheroacuta* as shown in Figures 3 & 4.

The presence of planktic individuals as well as thick-walled calcareous forms indicates normal marine environment [6]. Also, very wide shelves and enclosed epicontinental seas are characterized by low abundance of planktic forms as evidenced in the 2 wells analysed [7].

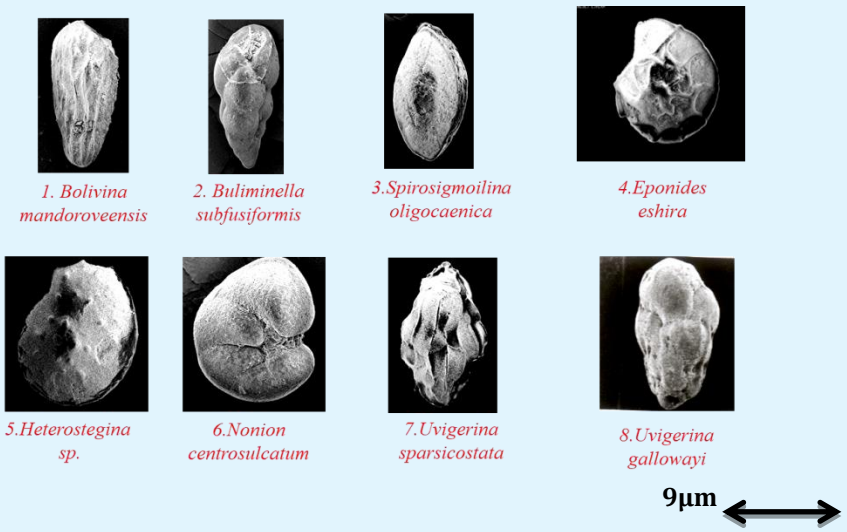

Figure 3: Photomicrographs of some identified bentonic foraminifera species in the two well under Scanning Electron Microscope (**scale bar 9µm**).

1. Bolivina mandoroveensi **de Klaszb & Rerat,** 2. Buliminella subfusiformis **Cushman,** 3. Spirosigmoilina oligocaenica **Cushman,** 4. Eponides eshira **de Klasz & Rerat,** 5. Heterostegina sp. **Papp & Kuper** 6. Nonion centrosulcatum **de Klasz & Rerat,** 7. Uvigerina sparsicostata **Leroy,** 8. Uvigerina gallowayi **Cushman**

Figure 4: Photomicrographs of some identified planktonics foraminifera in the two wells under Scanning Electron Microscope (**scale bar- 9µm**)
1. Turborotalia peripheroacuta **Blow & Banner,** *2. Praeorbulina glomerosa* **Blow,** *3. Catapsydrax dissimilis* **Cushman & Bermudez,** *4.Chiloguembelina Victoriana* **Beckmann.**

Foraminifera Biozonation of AX-1 well

Four (4) foraminifera biozones were recognized in the well based on the critical evaluation of the key bioevents, particularly the First Downhole Occurrences (FDO) and Last Downhole Occurrences (LDO) of chronostratigraphically important foraminifera markers. The index fossils identified include *Turborotalia peripheroacuta, Bolivina Mandroveensis, Praeorbulina*

Glomerosa, Nonion Centrosulcatum, Praeorbulina sicana, Catapsydrax dissimilis and Buliminella subfusiformis. The zonal names used conform to the foraminifera zonation scheme that is used in Niger Delta by the oil industry.

The zones recognized are N8, N7-N8, N6-N7 and N5-N6 as shown in Figures 5 & 6.

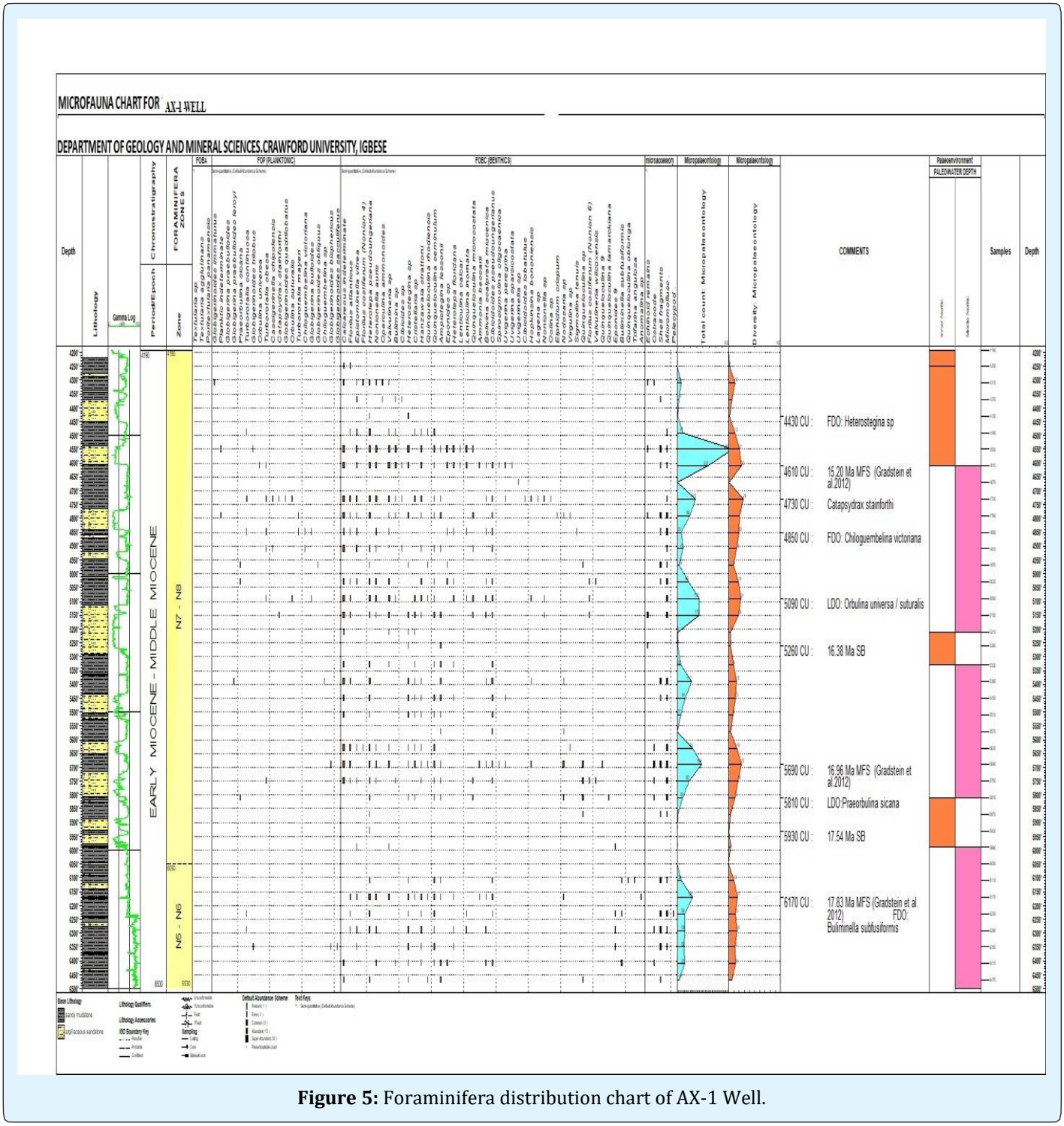

Figure 5: Foraminifera distribution chart of AX-1 Well.

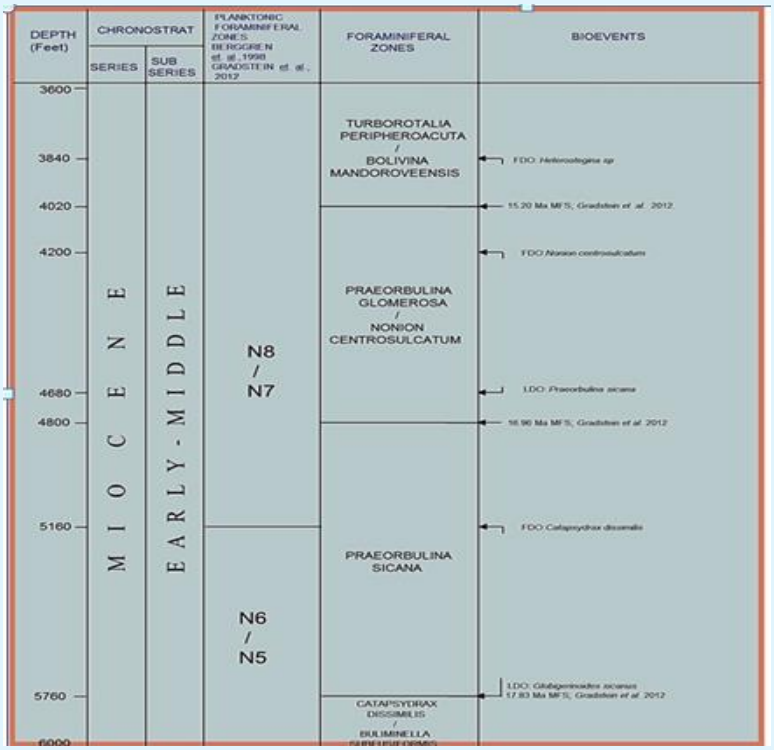

Figure 6: Foraminifera biozones in AX-1 well.

Turborotalia Peripheroacuta/Bolivina Mandoroveensis Zone

Zone: N8
Age: Middle Miocene (***Langhian***) (15.20Ma and younger)
Stratigraphic Interval: (1116m) 3600ft – (1246.2m) 4020 ft.
Diagnosis*:* This is the youngest zone encountered in the well. The zonal top is tentatively placed at (1116m) 3600 feet; the depth of the first sample analysed while the base is placed at the 15.20Ma MFS (Bur5/Lan1MFS) recognized at (1246m) 4020 feet. The zone correlates with the "Upper" N8 planktic foraminifera zone of Berggren, et al. (1995) [8] and Gradstein, et al. (2012) [5]. The age is Middle Miocene (15.20Ma and younger). This zone is characterised by the FDO of *Heterostegina sp* (Figure 4).

Praeorbulina Glomerosa/Nonion Centrosulcatum Zone

Zone: N7-N8
Age: Early Miocene (***Burdigalian***) (16.96Ma-15.20Ma)
Stratigraphic Interval: (1246.2m) 4020ft-(1488m)4800ft.
Diagnosis: The top and base of this zone are marked by the 15.20Ma MFS (Bur5/Lan1 MFS) and 16.96Ma MFS (Bur4 MFS) recognized at (1246.2m) 4020ft and (1488m) 4800ft respectively. The FDO's of the zonal markers, *Heterostegina sp.* and *Nonion centrosulcatum* were recorded at (1190m) 3840ft and (1302m) 4200ft respectively. The zone is correlated with the "Upper N8 – Upper N7" planktic foraminifera Zone of Berggren, et al. (1995) [8] and Gradstein, et al. (2012) [5].

Praeorbulina Sicana Zone

Zone: N6-N7
Age: Early Miocene (***Burdigalian***) (17.83Ma – 16.96Ma)
Stratigraphic Interval: (1488m) 4800ft – (1785.6m) 5760ft.
Diagnosis: The 16.96Ma MFS (Bur4) that marks the top of the zone was recognized at 4800 feet while the base is recognized at (1785.6m) 5760ft The LDO of the zonal marker, *Praeorbulina sicana* was recorded in the well at (1450.8m) 4680ft. The zone correlates with the "**Upper N7 – Upper N8**" Planktic Foraminifera zone of Berggren, et al. (1995) [8] and Hardenbol, et al. (1998) [9]. The age

of this zonal interval is Early Miocene (17.83Ma – 16.96Ma).

Catapsydrax Dissimilis/Buliminella Subfusiformis Zone

Zone: N5-N6
Age: Early Miocene (***Burdigalian***) (17.83Ma and Older)
Stratigraphic Interval: (1785.6m) 5760ft-(1860m)6000ft
Diagnosis: The 17.83Ma MFS (Bur3) that marks the top of the zone was recognized at (1785.6m) 5760ft while the base is tentatively placed at (1860m)6000ft, the depth of the last sample studied. The FDO of the zonal marker *Catapsydrax dissimilis* was recorded in the well at (1599.6m) 5160ft. The LDO of the second marker, *Globigerinoides sicanus* was recorded at (1785.6m) 5760ft. The zone correlates with the "Upper N5" Planktic Foraminifera zone of Berggren, et al. (1995) [8] and Hardenbol, et al. (1998) [9]. The age of this zonal interval is Early Miocene (17.83Ma and Older)

Foraminifera Biozonation of AX-2 well

In this well four (4) biozones comprising of N8, N7-N8, N6-N7 and N5-N6 were recognised (Figures 7 & 8). These zones include:

Turborotalia Peripheroacuta/Bolivina Mandoroveensis Zone

Zone: N8
Age: Middle Miocene (***Langhian)*** (15.20Ma and younger)
Stratigraphic Interval: (1302m) 4200ft. – (1429m) 4610ft.
Diagnosis: This is the youngest zone encountered in the well. The zonal top is tentatively placed at (1302m) 4200ft, the depth of the first sample analyzed, while the base is placed at the 15.20Ma MFS (Bur5/Lan1MFS) recognized at (1429m) 4610ft. The zone correlates with the "Upper" N8 planktic foraminifera Zone of Berggren, et al. (1995) [8] and Gradstein, et al. (2012) [5]. The age is Middle Miocene (15.20Ma and younger). This zone is marked by the FDO of *Heterostegina sp.*

Praeorbulina Glomerosa/Nonion Centrosulcatum Zone

Zone: N7-N8
Age: Early Miocene (***Burdigalian***)
Stratigraphic Interval: (1429m) 4610ft – (1763.9m) 5690 ft.
Diagnosis: The top and base of this zone are marked by the 15.20Ma MFS (Bur5/Lan1 MFS) and 16.96Ma MFS (Bur4 MFS) recognized at (1429m) 4610ft and (1763.9m) 5690ft respectively. The FDO's of the zonal markers, *Heterostegina sp., Catapsydrax stainforthi* and *Chiloguembelina victoriana* were recorded at (1373.3m) 4430ft, (1466.3m) 4730ft and (1503.5m) 4850ft respectively. The LDO of another zonal marker, *Orbulina suturalis,* was recorded at (1577.9m) 5090ft. The zone is correlated with the "Lower N8 – Upper N7" planktic foraminifera Zone of Berggren, et al. (1995) [8] and Gradstein, et al. (2012) [5]. The age is Early Miocene (16.96Ma – 15.20Ma).

Praeorbulina Sicana Zone

Zone: N6-N7
Age: Early Miocene (***Burdigalian***)
Stratigraphic Interval: *(*1763m*)* 5960ft – (1912.7m) 6170ft.
Diagnosis: The 16.96Ma MFS (Bur4) that marks the top of the zone was recognized at (1847.6m) 5960ft while the base is recognized at (1912.7m) 6170ft. The LDO of the zonal marker, *Praeorbulina sicana* was recorded in the well at (1801.1m) 5810ft. The zone correlates with the "Lower N7 – Upper N6" Planktic Foraminifera zone of Berggren, et al. (1995) [8] and Hardenbol, et al. (1998) [9]. The age of this zonal interval is Early Miocene (17.83Ma – 16.96Ma).

Catapsydrax Dissimilis/Buliminella Subfusiformis Zone

Zone: N5-N6
Age: Early Miocene (***Burdigalian***)
Stratigraphic Interval: (1912.7m) 6170ft – (2015m) 6500ft.
Diagnosis: The 17.83Ma MFS (Bur3) that marks the top of the zone was recognized at (1,912.7m) 6170ft while the base is tentatively placed at (2015m)6500ft, the depth of the last sample studied. The FDO of the zonal marker *Buliminella subfusiformis* was recorded in the well at (1912.7m) 6170ft. The zone correlates with the "Upper N5" Planktic Foraminifera zone of Berggren, et al. (1995) [8] and Hardenbol, et al. (1998) [9]. The age of this zonal interval is Early Miocene (17.83Ma and Older).

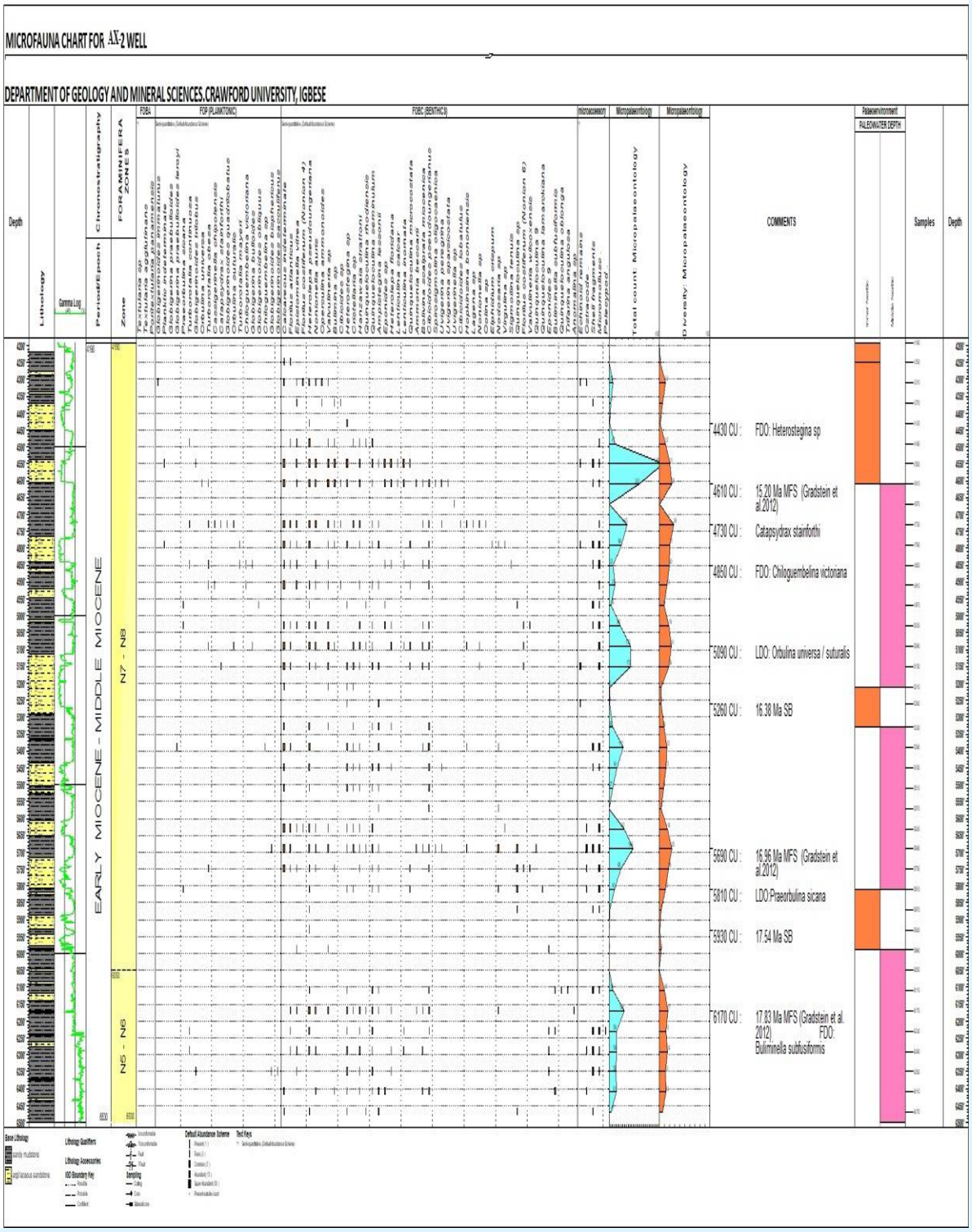

Figure 7: Foraminifera distribution chart of AX-2 well.

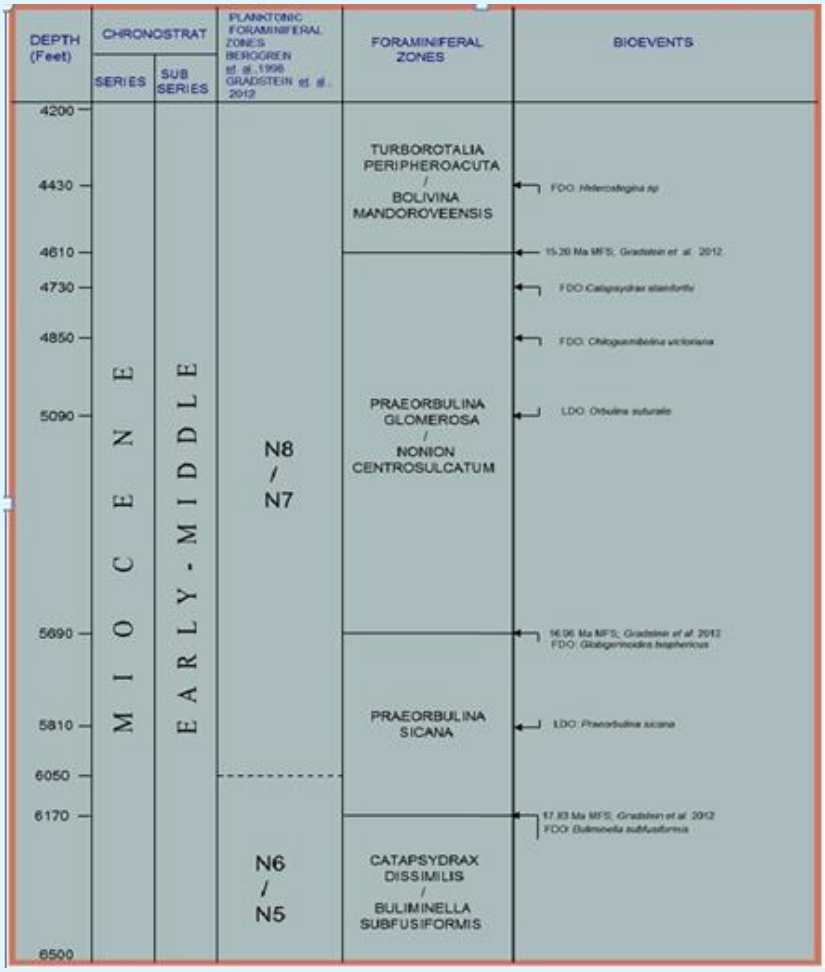

Figure 8: Foraminifera biozones in AX-2 well.

Environment of Deposition of Foraminifera Identified In AX-1 and AX-2 Wells

Benthic foraminifera are most useful for paleoenvironment studies and their distribution is restricted by basin configuration.

The environment of deposition of the studied sections of AX-1and AX-2 wells presented below is based on the integration of the textural characteristics of the ditch cutting samples studied with wireline log and the qualitative evaluation of the bathymetric ranges of selected environmentally significant benthic foraminifera. The depositional environment of the section is predominantly Middle Neritic, shallowing to Inner Neritic at some horizons.

Foraminifera Distributions at Intervals

The foraminifera recorded within the Turborotalia peripheroacuta/Bolivina mandoroveensis interval for the two wells include Lenticulina grandis, Bolivina mandoroveensis, Bolivina beyrichi, Bolivina miocenica, Hopkinsina bononiensis, Hopkinsina semiornata, spirosigmoilina oligocaenica, Cibicidoides pseudoungerianus, Praeglobobulimina ovata, Eponides iojimaensis, Uvigerina gallowayi, Heterolepa floridana and Heterolepa pseudoungeriana. These are suggestive of the Middle Neritic environment [10,11].

While the ones that fall within the interval of Praeorbulina glomerosa/Nonion centrosulcatum include Epistominella vitrea, Florilus costiferum, Nonionella auris, Bolivina miocenica, Bolivina mandoroveensis, Hopkinsina bononiensis, Hopkinsina semiornata, Cibicidoides

pseudoungerianus, Uvigerina peregrina, Uvigerina sparsicostata, Heterolepa floridana and Heterolepa pseudoungeriana. These are suggestive of the Middle Neritic environment [10,11].

Also, other Foraminiferas within the Praeorbulina sicana zone include Amphistegina lessonii, Bolivina miocenica, Nonionella auris, Epistominella vitrea, Hanzawaia strattonii, Bolivina mandoroveensis, Hopkinsina bononiensis, Hopkinsina semiornata, Cibicidoides pseudoungerianus, Heterolepa pseudoungeriana, Eponides eshira, Heterolepa floridana and Heterostegina sp which further confirms a low energy environment of deposition predominantly Middle Neritic while shallowing to Inner Neritic at some horizons [10-12].

Middle Neritic environment was also infered by the presence of species such as *Epistominella vitrea, Florilus costiferum, Nonionella auris, Cibicidoides pseudoungerianus, Uvigerina peregrina, Heterolepa floridana* and *Heterolepa pseudoungeriana* within the *Catapsydrax dissimilis/Buliminella subfusiformis Zone* [10-15].

Conclusion

Eighty (80) ditch cutting samples from two wells; AX-1 and AX-2 wells, drilled in the offshore of Niger delta, from (1116m) 3600ft-(1860m)6000ft and (1302m)4200ft-(2015m)6500ft respectively were subjected to biostratigraphic studies and lithological analyses to reveal the biozonation, age and the paleoenvironment of the foraminifera and the formations penetrated by the wells.

The ditch cutting samples were subjected to laboratory studies and the abundance, distribution and the diversity of the foraminifera identified were inputted into the software known as Stratabug.

A total of 224 foraminifera were recovered in the two wells and they are made up of both the planktonic and benthonic foraminifera with micro accessories such as ostracods and pelecypods.

Four (4) foraminifera biozones were established N8, N7-N8, N6-N7 and N5-N6 made up of *Turborotalia peripheroacuta/Bolivina mandoroveensis* zone, *Praeorbulina glomerosa/Nonion centrosulcatum* zone, *Praeorbulina sicana* zone *and Catapsydrax dissimilis/Buliminella subfusiformis* zone using Gradstein, et al. (2012) [5] scheme. Thus, the age of the formations penetrated by the two wells range from early to middle Miocene.

Also, from the foraminifera species identified, their paleoecology was determined; and this revealed the paleoenvironment that ranges from Inner Neritic to Middle Neritic. Furthermore, the alternation of varying horizons of sand, shale and mudstone typify various ecological episodes that led to their deposition.

In conclusion, the age of the lithologies encountered ranges from early Miocene to middle Miocene with the foraminifera encountered revealing an environment of deposition that ranges from Inner Neritic to Middle Neritic marine environment.

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