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Calcareous Nannofossil, Foraminifera Biostratigraphy and Paleoenvironmental Analysis of D1 Well, Offshore Eastern Niger Delta, Nigeria

Owoeye O.O. and Alkali Y.B.
Department of Geology, Federal University of Technology, P. M. B. 65, Minna, Nigeria
Correspondence: femiseunowoeye@yahoo.com

Abstract

Calcareous nannofossil and foraminifera biosratigraphic analysis was carried out on one hundred ditch cutting samples from the D1 well, offshore Niger Delta Basin. The studied interval ranges from 3440 - 9950 feet. The samples were studied for their lithology, calcareous nannofossil and foraminiferal contents with the aim of subdividing the sequence into foraminifera and calcareous nannofossils biozones, determining the age and the paleoenvironment of the strata penetrated by the well. The standard foraminifera and calcareous nannofossil recovery techniques were employed. The lithology of the penetrated sequence is charaterised by the alternating sand and shale sequence of the Agbada Formation at the lower section, while the predominantly sandy upper section of the well corresponds to the Benin Formation. Richly diverse calcareous nannofossils and foraminifera assemblages were recovered. Four foraminifera biozones established in this study are the *Globorotalia tumida/Valvulina flexilis* zone, *Neogloboquadrina dutertrei/Cyclammina minima* zone, *Sphaeroidinella dehiscens/Haplophragmoides narivaensis* zone, *Globorotalia merotumida/plesiotumida/Ammobaculites agglutinans* zone. Two calcareous nannofossils zones established in this study are the *Discoaster* spp. and *Discoaster quinqueramus/Discoaster berggrenii* zones. The age assigned to the studied interval of D1 well ranged from Late Miocene to Early Pliocene based on the recovered assemblages. Outer neritic to Upper bathyal depositional environment is inferred for the entire studied interval of D1 well because of the frequent occurrence of the diagnostic species of the following genera: *Uvigerina, Globocassidulina, Eponides, Bulimina, Pullenia, Oridosalis, Sphaeroidina, Cibicidoides, Gyroidinoides* and deep water arenaceous forms such as *Cyclammina, Kareriella* and *Recurvoides.*

Keywords: Foraminifera, Calcareous Nannofossil, Biostratigraphy, Paleoenvironment, Offshore, Niger Delta.

1.0 Introduction

The Niger Delta oil province over the years has become a key place of interest and research as its importance lies in its hydrocarbon resources and is among the world's most productive oil provinces. Over the years, thousands of wells have been drilled across the delta penetrating the sediments, in which petroleum generation, migration and accumulation have occurred. The studied D1 well is located in the offshore depobelt of the eastern Niger Delta (Figure 1). The concentration of this study is on the calcareous nannofossil and foraminifera biostratigraphy, dating and environment of deposition of D1 well.

Fadiya (2014) stated that some biostratigraphic studies have been carried out in the offshore area of the Niger Delta basin with only few of such works on calcareous nannofossils been documented in the literature due to proprietary reasons. Ogunjobi (1996) discussed the advantages of calcareous nannofossils in the recognition of Marine Flooding Surfaces in the Niger Delta most especially in the Late Miocene to Late Pliocene. He recognized four delta wide flooding surfaces based on the *Discoaster quinqueramus*, *Ceratholithus* species and *Gephyrocapsa* species and *Sphenolithus* species. This was confirmed by Oyebamiji (1997) who also observed the appearance of *Sphenolithus abies* in the Late Miocene of the Niger delta. Fernacci *et al.* (1996, 2000) also published valuable information on calcareous nannofossils biostratigraphy of some wells in the Niger Delta basin.

Ozumba (1999) carried out high resolution

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foraminiferal biostratigraphy of four wells (Kanbo-5, Egbedicreek-1, Angalalli-1 and Opukushi-5) located in the coastal and central swamp of the western Niger Delta. Six foraminiferal zones (Assemblage/Partial range zones) were defined for the middle to late Miocene Niger Delta namely; *Globigerina cf ciperoensis* zone, *Nonion centrosulcatum / Chiloguembelina victoria* zone, *Eponides eshira* zone, *Uvigerina sparsicostata* zone, *Spirosigmoilina oligoceanica* zone, and *Florilus ex. gr. costiferum* zone.

Boboye and Adeleye (2009) dated some sequences in the deep offshore Niger delta Late Miocene, based on the presence of *Eggerella bradyi* and the first downhole occurrence of *Cyclammina cf. minima*. Chukwu (2012) established a planktic *Praeorbulina glomerosa* zone and a benthi *Poritextularia panamensis* zone in Oloibiri- well, Eastern Niger delta.

Okosun *et al.* (2012) revealed that the plankti foraminiferal preservation in the wells from Akata field, onshore south-eastern Niger delt is poor, they identified four planktic zones namely: *Globorotalia continuosa* zone *Globorotalia mayeri* zone, *Praeorbulin glomerosa* and *Globorotalia peripheroroacut* zone. They also identified the followin benthic zones: *Spirosigmoilina oligocaenica* *Uvigerina sparsicostata*, and *Eponide eshira/Brizalina mandorovensis*, an *Poritextularia panamensis*. With these th interval studied was dated Miocene based o foraminiferal assemblage.

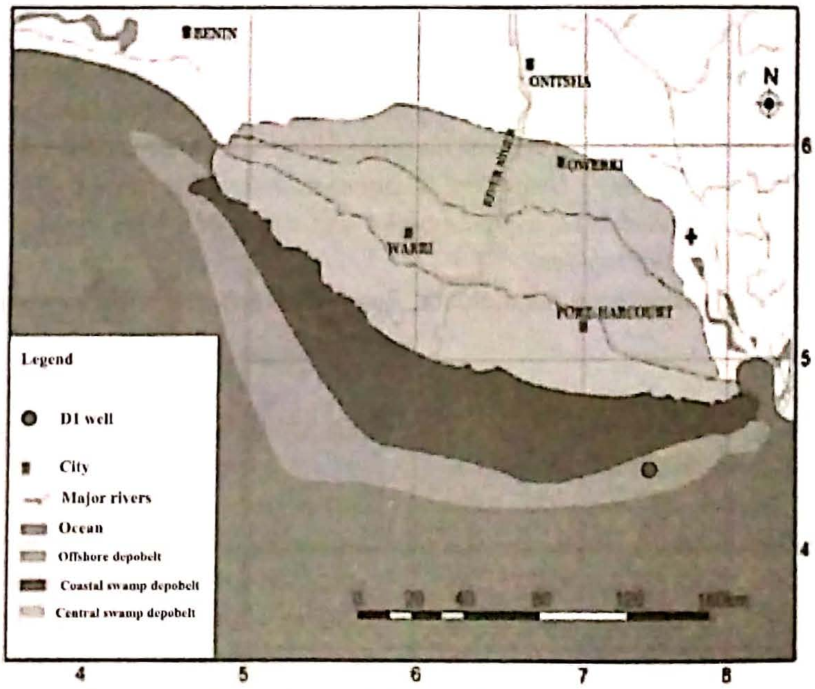

Figure 1: Location of D1 well, Niger Delta

Fadiya (2014) assigned Middle to Late Eocene age to the stratigraphic interval studied from AM-2 well, Niger Delta due to the occurrence of Middle to Late Eocene foraminfera age diagnostic marker species such as *Globigerina eocaena*, *G. bagni*, *G. cryptomphala*, *G. inaequispira*, *Chiloquembelina cubensis*, *C. martini*, *Pseudohastigerina micra*, *P. wilcoxensis*, *Turborotalia cerroazulensis cerroazulensis*, *T. griffinae*, *T. pseudomayeri* and *T. cerroazulensis pomeroli*.

A great challenge to petroleum exploitatio has been the precise biozonation and hig resolution biostratigraphic correlation o hydrocarbon bearing units within a field o basin for the purpose of directing we trajectory. This study presents biostratigraphi analysis which will enable mapping of tim significant surfaces. The aim of this study is t subdivide the studied interval (D1 well) int calcareous nannofossil and foraminifer

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biozones and also deduce it paleoenvironment of deposition.

2.0 Materials and Method

One hundred samples from D1 well have been studied, and the samples within the depth interval of 3440 ft. - 9950 ft. were analysed for foraminiferal and calcareous nannofossils. Some of the materials used during sample preparation and analyses include distil water, kerosene, aluminium foil, liquid detergent, hot plate, 63 micron sieve size, filter paper, sample bags, marker pen for labelling the sample bags, picking brush, picking tray, binocular microscope, slides and cover slides and gum.

The kerosene method of preparing samples for foraminifer's recovery was employed because it is economical and could disaggregate the samples. 30 g of each sample was weighed and crushed to loosen the bounded particles. The samples were soaked using distilled water and kerosene in a beaker over night for complete digestion. Samples were then washed with tap water using 63 micron mesh sieve.

The residues from the washed samples were then dried both on hot plate and in an oven. The samples were packed in well labelled sample bags for picking and observation under the binocular microscope. The prepared samples were placed on a picking tray and viewed under a reflected light binocular microscope for any preserved foraminifera content. The foraminiferal specimens were picked out with either a fine brush or wet toothpick and dropped in the micro paleontological slide cavity. Cover slips were used in covering the slides and arranged serially according to their depths in slide tray for analysis. The picked foraminifera were subjected to identification and abundance or diversity counts. During identification, relevant published manuals were utilized, such as Stainforth *et al.* (1975), Bolli *et al.* (1985), Petters (1982, 1983, and 1995), Okosun and Liebau (1999). The biozonation and age determination of the studied well were carried out using the age diagnostic foraminiferal species.

Twenty eight (28) ditch cutting samples were selected from foraminifera-rich depth intervals (5330 ft. - 9170 ft.) from D1 well which indicate periods of high marine influence in the area penetrated by the well. The samples were processed for calcareous nannofossil recovery using the standard preparation technique of Haq *et al.* (1987). The simple smear slide method was routinely applied to process all the samples. The prepared slides were examined for their calcareous nannofossil content under a high power light microscope in cross-polarized and transmitted lights. Detailed abundance counts of the assemblages were made at x1000 magnification. Identification of species was made by consulting the works of Blow (1969), Backman (1980), Perch-Nielsen (1985), Fernacci *et al.* (1996) and Fadiya (1999).
Lithological description of the ditch cutting samples was carried out to support the interpretation. The ditch cutting samples were studied with a magnifying hand lens for lithologic description and preparation of lithologic log. The roundness, colour, average grain size and sorting of the sand particles was noted. The lithology of the ditch cutting samples was then calibrated and depth matched with corresponding wireline logs.

3.0 Results and Discussion

3.1 Lithostratigraphy of D1 well

Lithostratigraphy and subdivision of the D1 well is presented in Figure 2. The studied depth interval ranges from 3440 ft. - 9950 ft. The formation delineated within this interval is the Agbada Formation (3440 ft. - 9950 ft.). Two (2) lithofacies sequences delineated within the studied interval are the Upper paralic sequence and the Lower paralic sequence.

The Upper paralic sequence (3440 ft. - 6250 ft.) is characterised mainly by thick sands with shale intercalations at the upper section and transcends into shaly sands at the lower section. Sands are generally shaly, medium grained, occasionally coarse-grained. Sands are generally moderately to well sorted.

The Lower paralic sequence (6250 ft. - 9950

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ft.) is characterised by sub-equal proportion of sand and shale sequences. Shale thickness tends to increase down the section. Sands are predominantly fine to medium-grained. Sands are generally well sorted (Figure 2).

D1 Well

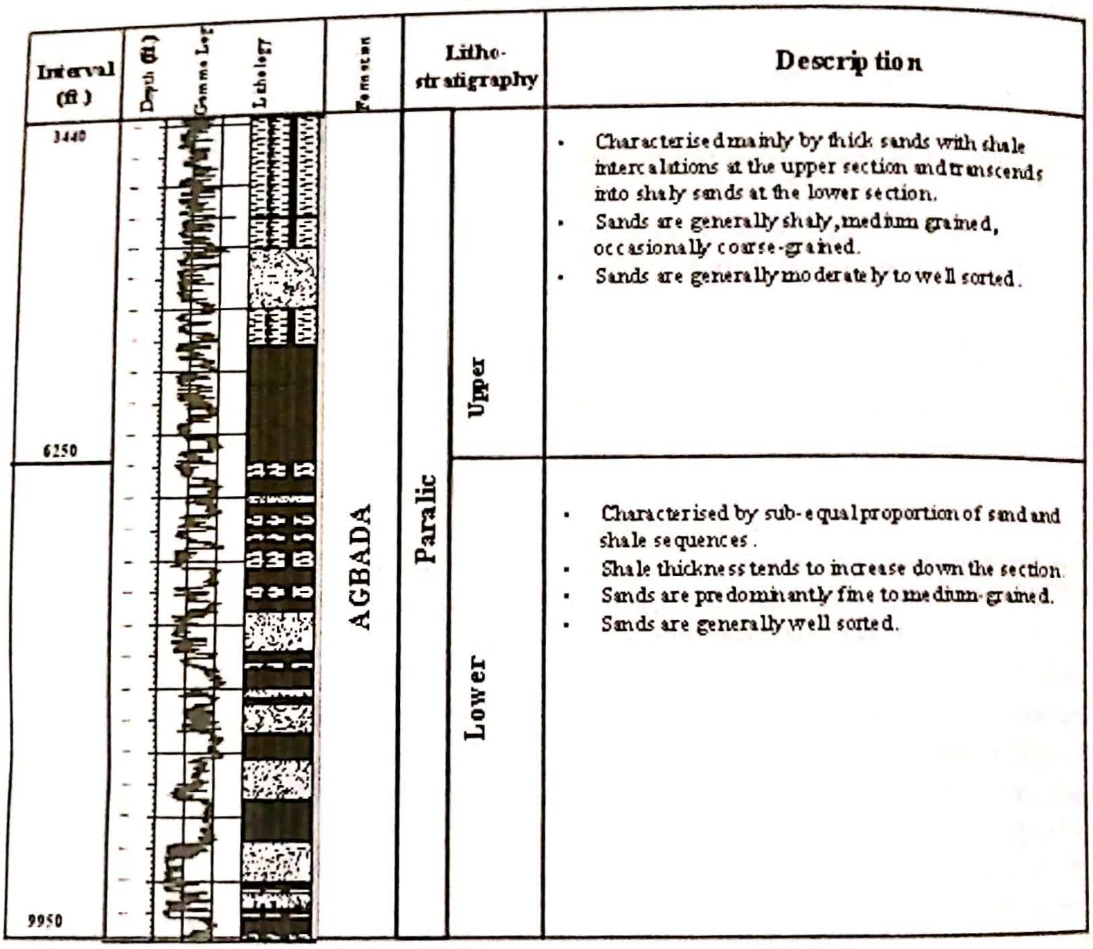

Figure 2: Lithostratigraphic description and subdivision of D1 well

3.2 Biostratigraphy of D1 Well

The results of the foraminifera and calcareous nannofossil analysis of the studied interval are presented in the foraminifera distribution chart, calcareous nannofossils distribution chart, foraminifera and calcareous nannofossils synthesis chart of D1 well (Figures 3, 4, 5, 6 and 7). A lithologic log was prepared by integrating lithologic description data with the available well log data which include gamma ray and resistivity logs. Some photomicrographs of the recovered foraminifera and calcareous nannofossils species are presented in Plates 1 and 2.

3.2.1 Foraminifera Biostratigraphy of D1 Well

Foraminiferal analysis of D1 well presented below was carried out using One hundred (100) ditch cutting samples and the biozonation of the well was based largely on sequence stratigraphic principles with precise age dating of zonal boundaries.

The statistical data obtained was computerized using the StrataBugs software. Bar plots of the abundance and species diversity were made, from which candidate Maximum Flooding Surfaces (MFS) were selected. Their positions were later confirmed on the log. The complete micropaleontological data is plotted in colour using StrataBugs at a scale of 1:5000. Faunal associations including benthic, planktic, benthic/planktic ratio (normalised) agglutinated/calcareous foraminiferal ratios etc., are plotted in Figure 3. The ditch cutting samples were analysed at 30 ft. intervals for foraminifera and richly diverse

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assemblages of planktonic and benthonic foraminifera species with a total of 93 species recorded. 70 species (75%) are calcareous, while 23 (25%) are arenaceous. Among the calcareous forms, benthics accounted for 66% (46 species), while the remaining 24 species (34%) are planktics. The foraminiferal distribution chart and the plots of the peaks of species diversity and population abundance are presented in Figure 3, while the zones are shown in Figure 4.

A good number of diagnostic marker species such as *Cyclammina minima, Karreriella bradyi, Haplophragmoides narivaensis, Valvulina flexilis, Neogloboquadrina dutertrei, Sphaeroidinella dehiscens, Globorotalia plesiotumida/merotumida, Globigerinoides bulloideus, Turborotalia acostaensis, Globorotalia tumida tumida* and *Globigerinoides extremus* were recovered from D1 well. This assemblage is typical of N16 - N19 foraminiferal zones of Berggren *et al.* (1998) of the Late Miocene – Early Pliocene age and permitted the zonal subdivision of the well section based on the zonation scheme of Berggren *et al.* (1998) and Gradstein *et al.* (2012).

Four (4) foraminifera zones are recognized in D1 well namely: *Globorotalia tumida/Valvulina flexilis* zone, *Neogloboquadrina dutertrei/Cyclammina minima* zone, *Sphaeroidinella dehiscens/ Haplophragmoides narivaensis* zone and *Globorotalia mero/plesiotumida/Ammobaculites agglutinans* zone, based on the critical evaluation of the key bioevents, particularly the First Downhole Occurrence (FDO) and Last Downhole Occurrence (LDO) of chronostratigraphically important foraminifera markers. Characteristic benthic markers such as *Cyclammina minima, Karreriella bradyi* and *Haplophragmoides narivaensis*, whose LAD's / FDO's mark Late Miocene ages confirm the age of the well.

Zone: *Globorotalia tumida/Valvulina flexilis* zone

Stratigraphic Interval: 3440-4430 feet.

Age: Early Pliocene

Diagnosis: This is the topmost zone identified in the studied section of the well. The zonal top is tentatively placed at 3440 ft, the depth of the first sample analyzed, while the base is placed at the observed FDO of *Cyclammina minima* recorded at 4430 feet which marks the top of the next zone. The interval is characterized by the LDO of *Globorotalia tumida*, FDO of *Valvulina flexilis* and occurrence of associated forms such as *Globigerina bulloides, Globigerina praebulloides, Globigerinoides extremus, Globigerinoides immaturus, Globigerinoides sacculiferus, Globoquadrina altispira, Globorotalia plesiotumida/ merotumida, Globorotalia scitula, Globorotalia tumida tumida, Turborotalia acostaensis, Globorotalia scitula gigantea* and *Globorotalia scitula praescitula*. The zone is correlated with the Lower N19 and Upper N18 foraminifera zone of Berggren *et al.* (1998) and Gradstein *et al.* (2012). The age is Early Pliocene.

Zone: *Neogloboquadrina dutertrei / Cyclammina minima* zone

Stratigraphic Interval: 4430-6980 feet.

Age: Late Miocene

Diagnosis: The top of this zone is placed at the observed FDO of the zonal marker *Cyclammina minima* recorded at 4430 ft. while the base is marked by the FDO of *Haplophragmoides narivaensis* recorded at 6980 feet. The other zonal markers in this zone are *Neogloboquadrina dutertrei and Karreriella bradyi.* The associated species in this zone include *Globigerina bulloides, Globigerinoides bolli, Globigerinoides immaturus, Globorotalia plesiotumida/ merotumida, Globorotalia scitula, Turborotalia acostaensis* and *Orbulina universa*. The 5.47Ma MFS; Gradstein *et al.* (2012) recognized at 5390 ft. occur within this zone. The zone correlates with the Upper N18 foraminifera zone of Berggren *et al.* (1998) and Gradstein *et al.* (2012). The age for this zonal interval is **Late Miocene**.

Zone: *Sphaeroidinella dehiscens / Haplophragmoides narivaensis* zone

Stratigraphic Interval: 6980-9410 feet

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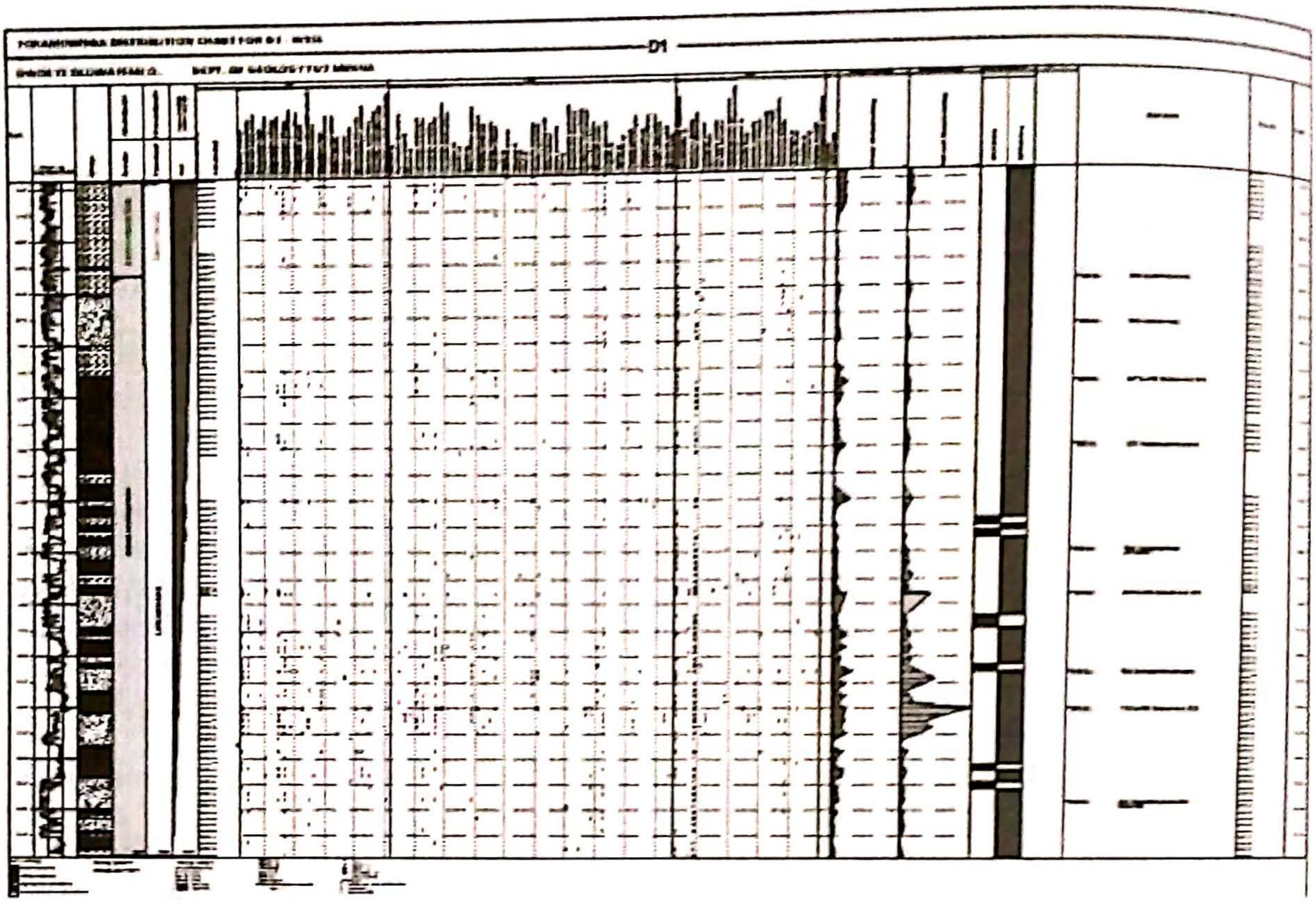

Figure 3: Foraminiferal distribution chart of D1 well.

Age: Late Miocene

Diagnosis: The zonal marker, *Haplophragmoides narivaensis* whose FDO marks the top of the zone was recorded at 6980 feet while the base is marked by the LDO of *Globorotalia mero/plesiotumida* recorded at 9410 feet which marks the top of the next zone. The other zonal marker in this zone is *Sphaeroidinella dehiscens.* The associated species in this zone include *Globigerina bulloides, Globigerina praebulloides, Globigerinoides obliquus, Globigerinoides quadrilobatus, Globorotalia mero/plesiotumida, Globorotalia scitula, Turborotalia acostaensis, Globorotalia scitula gigantea* and *Globorotalia acostaensis trochoidea.* The 5.99Ma MFS; Gradstein *et al.* (2012) recognized at 7395 feet occur within this zone. The zone correlates with the Upper N17 - LowerN17 foraminifera zone of Berggren *et al.* (1998) and Gradstein *et al.* (2012). The age is Late Miocene.

Zone: *Globorotalia mero/plesiotumida / Ammobaculites agglutinans* zone

Stratigraphic Interval*:* 9410 ft. - 9950 ft.

Age: Late Miocene

Diagnosis: The LDO of the zonal marker *Globorotalia mero/plesiotumida* recorded at 9410 ft. marks the top of this zone. *Ammobaculities agglutinans*, another zonal maker whose FDO, marks the top of the zone was not recorded in the well. The base of the zone is tentatively placed at 9950 feet, the depth of the last sample for the studied section of the well. The associated species in this zone include *Globigerina bulloides, Globigerina praebulloides, Globigerinoides obliquus, Globigerinoides quadrilobatus* and *Globorotalia acostaensis trochoidea*. The zone correlates with the "Upper" N16 Planktic Foraminifera zone of Berggren *et al.* (1998) and Gradstein *et al.* (2012). The age for this zonal interval is Late Miocene.

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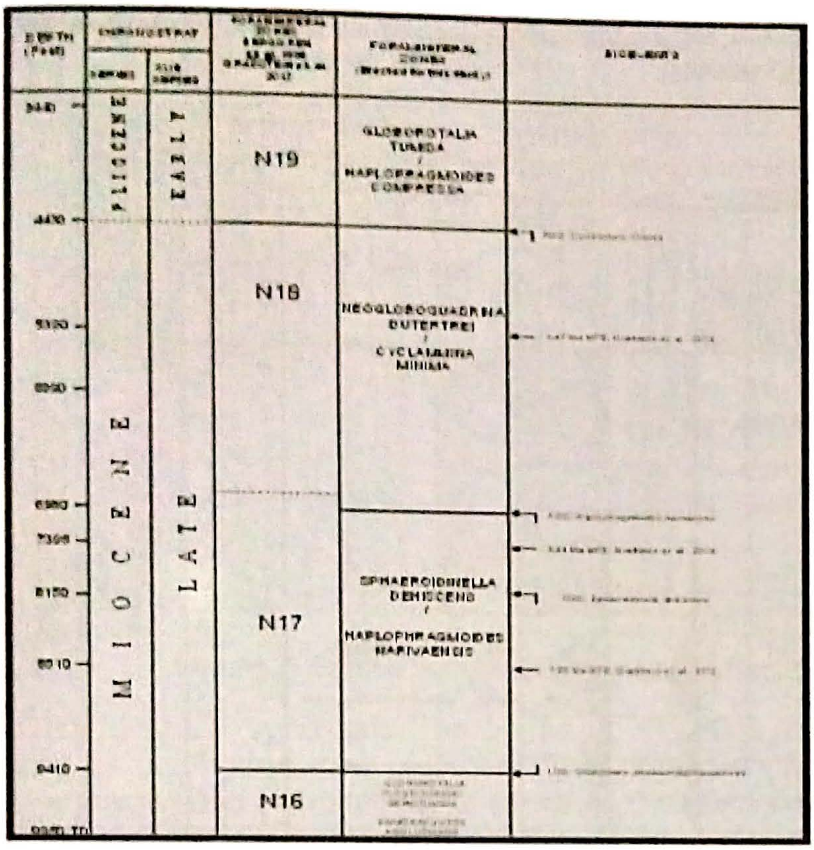

Figure 4: Foraminiferal zones recognised in D1 well.

3.2.2 Calcareous Nannofossil Biostratigraphy of D1 well

A total of twenty-eight samples were analysed for calcareous nannofossils. Calcareous nannofossils are studied under a transmitting light microscope in polarised light. For this, a binocular microscope was used with work being done at 1250x magnification with immersion oil. Then standard counts of 12 traverses were carried out followed by an extensive search of the slide for rare marker fossils. This method was standardised for each slide in the well. The D1 well is moderately rich and diverse in calcareous nannofossils. A total of fifteen nannofossil species were recovered. The biozonation and age dating of the wells was based largely on calcareous nannofossils assemblages, abundance and diversity.

The assemblage comprises mainly of *Discoaster quinqueramus, Discoaster pentaradiatus, Discoaster brouweri, Discoaster beggrenii, Pontosphera japonica, Pontosphera multipora, Coccolithus pelagicus, Sphenolithus moriformis, Reticulofenestra haqii, Helicosphera cateri*.

The chronostratigraphic scheme adopted follows the usage of the worldwide zonation schemes of Martini (1971), Okada & Bukry (1980) and Gradstein *et al.* (2012). Considerable effort was made to identify and define zonal tops with the First Down-hole Occurrence (FDO's), Last Down-hole Occurrence (LDO's) of diagnostic marker species, abundance, and species diversity peak as these form the most reliable events.

The highest nannofossil peaks were dated using important marker species such as *Discoaster quinqueramus* and *Discoaster berggrenii*. The stratigraphic distribution of the recorded species along with the significant datum, suggested Maximum Flooding Surfaces, Nannofossil zones and age interpretations. The result of this analysis is ~~been~~ presented in the nannofossils distribution chart and the summary of biozones shown in Figure 5 and 6.

Nannofossil zones of D1 well

Interval: 5330 – 6860 feet
Zone: ?NN12
Age: Late Miocene
Diagnosis: This interval is NN12 zone of Martini, 1971 based on superpositioning and it is characterized by few diagnostic calcareous nannofossils. There are records of *Discoaster spp., Discoaster brouweri, Reticulofenestra minuta, Reticulofenestra hagii, Helicosphaera multipora.*

Interval: 6860 – 9170 feet
Zone: NN11
Age: Late Miocene
Diagnosis: This interval is fairly rich in calcareous nannofossils. The FDO of *Discoaster quinqueramus* at 7100 ft. marks the top of this NN11 zone of Martini (1971). The base of the zone is tentatively placed at 9170 ft. the depth of the last

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sample for the studied interval. The highest peak at 7395 feet is dated 5.99 Ma MFS (Gradstein *et al.*, 2012) condensed section.

The presence of *Discoaster berggrenii* at 8390 ft. marks the 7.72 Ma MFS (Gradstein *et al.*, 2012).

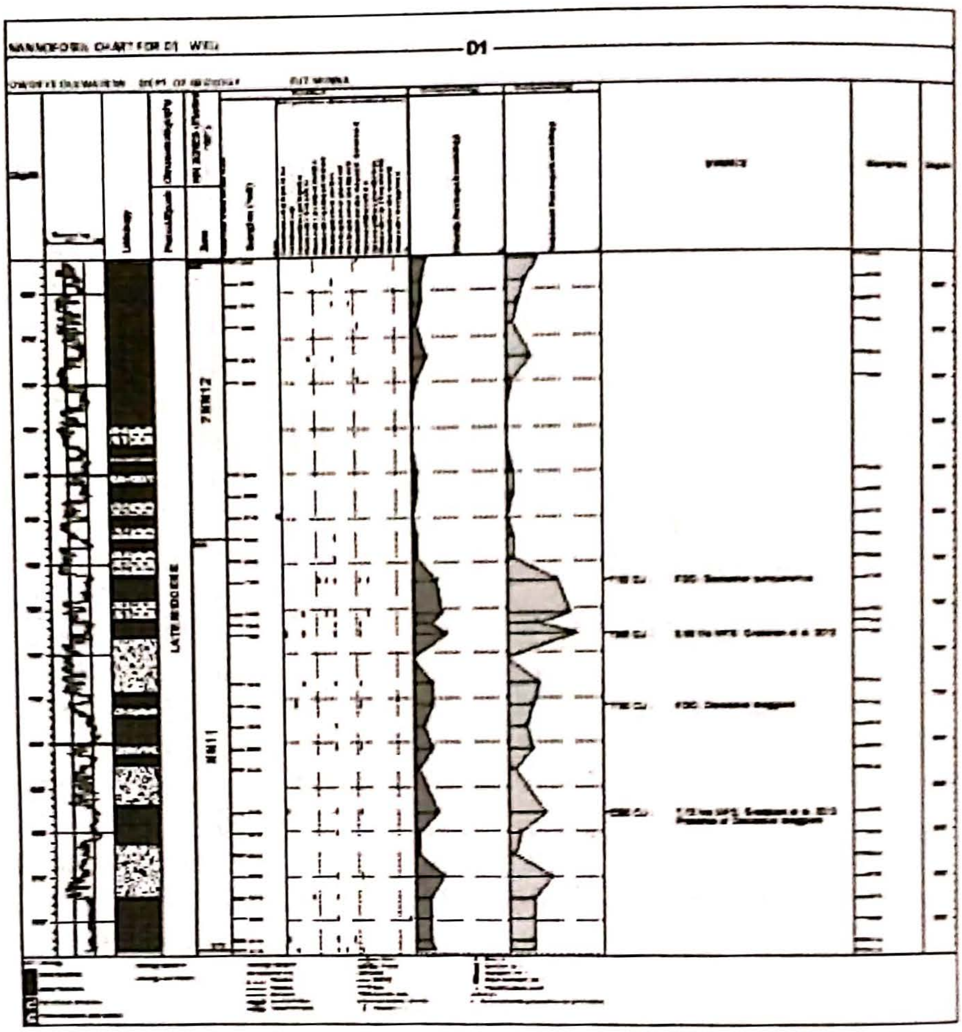

Figure 5: Calcareous nannofossil distribution chart of D1 well.

DEPTH (FEET)	DOWNHOLE OCCURRENCE OF CALCAREOUS NANNOFOSSILS	AGE (Ma) Gradstein et Al. 2012	NP ZONES (MARTINI, 1971)	INFERED RELATIVE AGES
5330	FIRST SAMPLE ANALYSED		7NN12	LATE MIOCENE
6860				
7100	FDO of Discoaster quinqueramus		NN11	
7395	Maximum Flooding Surface	5.99		
7790	FDO of Discoaster berggrenii			
8390	Maximum Flooding Surface, Presence of Discoaster berggrenii	7.72		
9170 TD				

Figure 6: Calcareous nannofossil zones recognised in D1 well.

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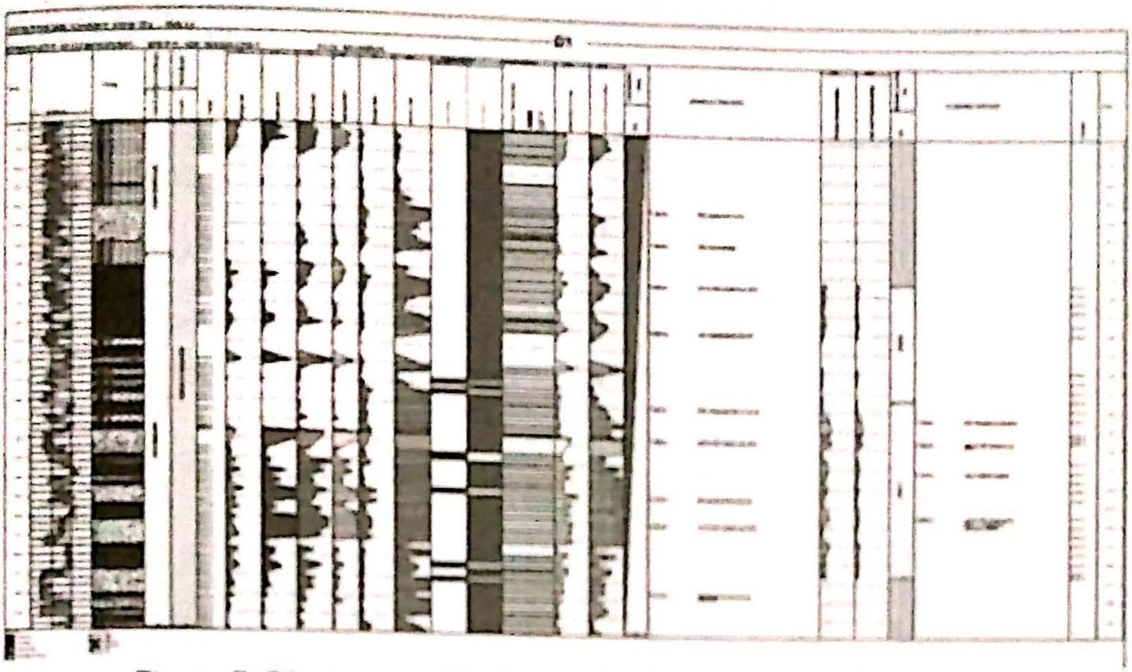

Figure 7: Biostratigraphic Synthesis Chart produced for D1 well.

A biostratigraphic synthesis chart was produced for the studied interval (Figure 7). This chart represents the summary of all the analysis carried out in this study as it aim is to integrate all findings from the foraminiferal and calcareous nannofossil analysis.

4.0 Paleoenvironment

Inference on the paleodepositional environment of the studied well was based on the biofacies information interpreted from the qualitative and quantitative evaluation of the benthic foraminiferal assemblages and integration of the lithologic description of the section. The parameter considered in the interpretation of the paleoenvironment is the presence/absence of environmental diagnostic marker species (Phleger 1960 and Murray 1991).

The depositional environment of D1 well is predominantly Upper Bathyal, shallowing to Outer Neritic at some horizons. Details of the paleoenvironments and the associated taxa are presented below on interval basis:

i. **Stratigraphic Interval**: 3440-5270 feet

Common occurrence of deep water foraminifera such as *Cibicidoides pseudoungerianus*, *Cibicidoides pachyderma*, *Uvigerina proboscidea*, *Alveolophragmium subglobosum*, *Cyclammina minima*, *Eggerella bradyi*, *Trochammina proteus*, *Recurvoides deformis* and *Valvulina flexilis* confirm an environment of deposition that is predominantly Upper Bathyal (Phleger, 1960 and Bandy, 1967; Stanley and Adegoke 1972).

ii. **Stratigraphic Interval**: 5270-7395 feet.

The abundant record of Upper Bathyal foraminifera such as *Cibicidoides pachyderma*, *Cibicidoides pseudoungerianus*, *Globocassidulina subglobosa*, *Gyroidinoides girardanus*, *Heterolepa bellincioni*, *Hoeglundina elegans*, *Planulina wuellerstorfi*, *Uvigerina proboscidea*, *Alveolophragmium subglobosum*, *Eggerella bradyi*, *Trochammina proteus* and *Recurvoides deformis* confirm an environment of deposition that is predominantly Upper Bathyal, shallowing to Outer Neritic at some horizons (Phleger, 1960 and Bandy, 1967).

iii. **Stratigraphic Interval**: 7395-9950 feet.

The abundant record of Upper Bathyal foraminifera such as *Bulimina marginata*, *Anomalinoides alazanensis*, *Cibicidoides incrassatus*, *Cibicidoides pachyderma*,

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Cibicidoides pseudoungerianus, Globocassidulina subglobosa, Gyroidinoides neosoldanii, Heterolepa bellincioni, Heterolepa dertonensis, Hoeglundina elegans, Planulina wuellerstorfi, Uvigerina proboscidea, Sigmoilopsis schlumbergeri, Sphaeroidina bulloides, Alveolophragmium subglobosum, Eggerella bradyi, Trochammina proteus and *Recurvoides deformis* confirm an environment of deposition that is predominantly Upper Bathyal, shallowing to Outer Neritic at some horizons (Phleger, 1960 and Bandy, 1967). Photomicrographs of some of the foraminifera species recovered from D1 well are shown in Plate I and calcareous nannofossils species recovered from the studied interval are also shown in Plate 2.

5.0 Conclusion

One hundred (100) ditch cutting samples from D1 well within the depth interval of 3440 - 9950 ft. yielded richly diverse assemblages of planktonic and benthonic foraminifera species and twenty-eight (28) ditch cutting samples selected from foraminifera-rich depth intervals from D1 well which were also analysed yielded moderately rich and diverse assemblages of calcareous nannofossils species. The foraminifera biozones established in this study are the *Globorotalia tumida/ Valvulina flexilis* zone, *Neogloboquadrina dutertrei/Cyclammina minima* zone, *Sphaeroidinella dehiscens/Haplophragmoides narivaensis* zone, *Globorotalia mero /plesiotumida/ Ammobaculites agglutinans* zone. These zones correspond to the Upper N16 - Lower N19 zones of Berggren *et al.* (1998) and Gradstein *et al.* (2012). Calcareous nannofossil biostratigraphic analysis was also carried out in D1 well, and the *Discoaster* spp. and *Discoaster quinqueramus / Discoaster berggrenii* zones were established. These zones correspond to the NN12 and NN11 zones of Martini (1971). The age assigned to the studied interval of D1 well ranged from Late Miocene to Early Pliocene.

The age assigned to the stratigraphic surfaces delineated within the studied interval (5.47 Ma - 8.5 Ma) established the fact that the well is located in the ofshore depobelt of the Niger Delta Basin.

Outer neritic to bathyal depositional environment is inferred for the entire studied interval of D1 well because of the frequent occurrence of the diagnostic species of the following genera: *Uvigerna, Globocassidulina, Eponides, Bulimina, Pullenia, Oridosalis, Sphaeroidina, Cibicidoides, Gyroidinoides* and deep water arenaceous forms such as *Cyclammina, Kareriella* and *Recurvoides* known to inhabit outer neritic to bathyal environment. Based on the lithologic, foraminiferal and paleoenvironmental analysis, it is inferred that the intervals penetrated by the well corresponds to Benin Formation and Agbada Formation, and they are of Late Miocene to Early Pliocene age.

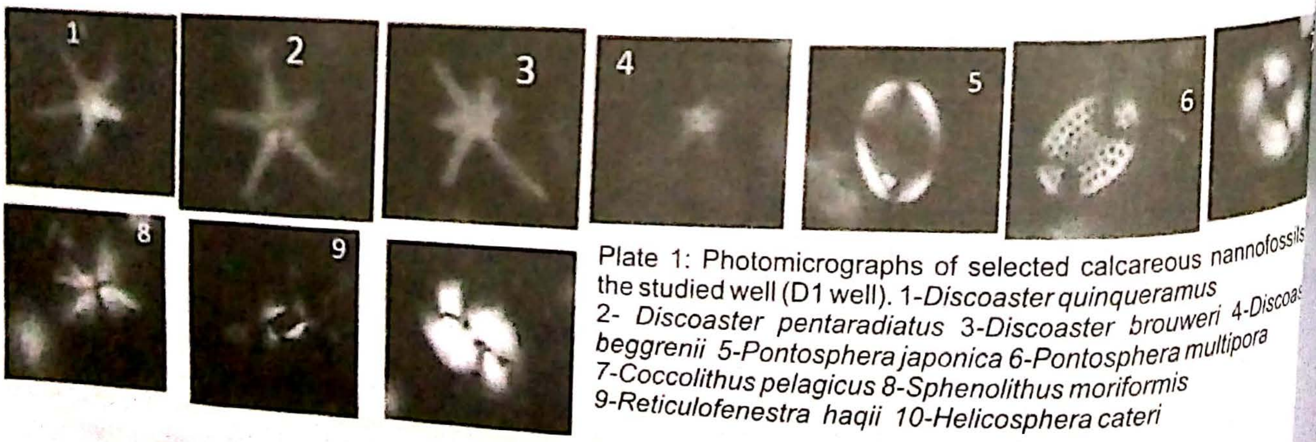

Plate 1: Photomicrographs of selected calcareous nannofossils the studied well (D1 well). 1-*Discoaster quinqueramus* 2- *Discoaster pentaradiatus* 3-*Discoaster brouweri* 4-*Discoaster beggrenii* 5-*Pontosphera japonica* 6-*Pontosphera multipora* 7-*Coccolithus pelagicus* 8-*Sphenolithus moriformis* 9-*Reticulofenestra haqii* 10-*Helicosphera cateri*

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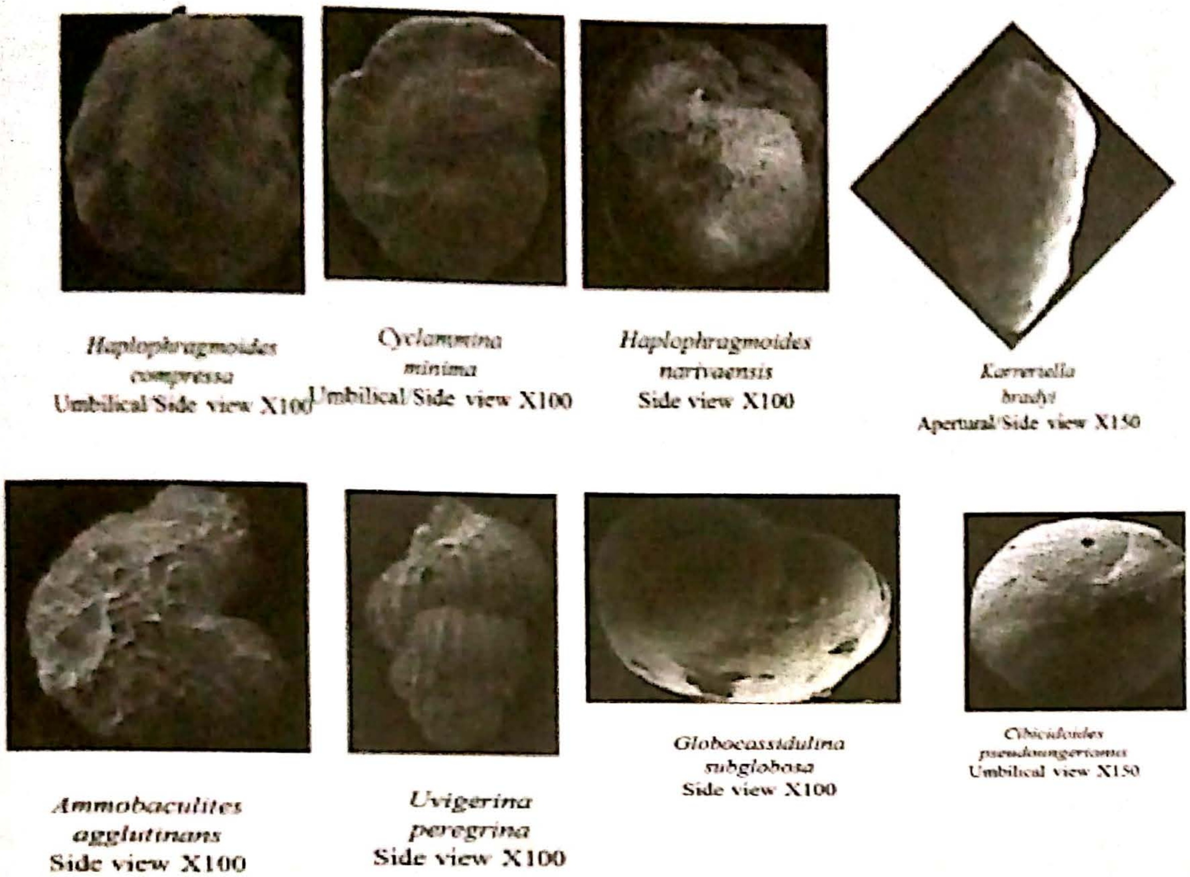

Plates 2: Photomicrographs of selected foraminifera species within the studied wells.

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