Foraminiferal Biozonation And Biochronology of Priabonian – Rupelian sediments of the Agbada Formation, Niger Delta

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Abstract-Foraminiferal biostratigraphic analysis was carried out on eighty (80) ditch cutting samples from two wells (well C: 13 samples, interval 2410 -2770m at 30m and well F: 67 samples, interval 2000-3320m at 20metres) located in the Northern Depobelt of the Tertiary Niger Delta. This was achieved based on the use of standard micropaleontological sample procedures and the analysis and interpretation of the foraminiferal biofacies assemblages. A total of eighty four (84) foraminifera species were recovered from the study wells consisting of thirty (30) genera, eighteen (18) families and three (3) suborders with a total foraminifera count of one thousand, eight hundred and seventy two (1872) comprising twenty four (24) planktic and one thousand, eight hundred and forty eight (1848) benthic forms respectively. The planktic and benthic foraminifera recovered from the Agbada Formation are transitional in character between the typical Late Eocene (P16/17) and the Early Oligocene (P18/19) epoch and therefore, indicate the transition between the Priabonian age and the Rupelian age. This interpretation reaffirms the existence of the Late Eocene – Early Oligocene sediments in the Niger Delta.

Index terms: Agbada Formation, Biozone, Biochronology, Foraminifera, Niger Delta, Priabonian, Rupelian, Northern Depobelt.

I. INTRODUCTION

The concept of biozonation is very important in Biostratigraphy (stratigraphy) and it buttress the facts that organisms that are fossilized after death display obvious evolutionary changes through the geologic time that are unique to a particular series/stages as evidenced in stratigraphic record. This therefore makes the fossil assemblages that characterize any geologic age distinct from any other. The basic units of biostratigraphy are the biozone. Biozones (also known as biostratigraphic zone) are bodies of strata that are interpreted based on the fossils found in the rocks. Biostratigraphic units are delineated based on the presence of some diagnostic biostratigraphic feature or attribute (fossil taxa). A biozone can be established based on the following criteria (but are not limited to this): a single taxon, co-occurrence of taxa, on appearance and disappearance of taxon / taxa and relative abundances (Petters, 2016 Personal communication).

In biostratigraphy study, the main goal is to understand the distribution of fossils in the stratigraphic record and attempt to subdivide these strata into units based on the fossil found in them as well as use this information to adequately place the rock units within a certain time spans according to the evidences. Biozone (in the strict sense) are records of events that took place in geologic past and should not be confused with chronostratigraphy.

The concept of biozonation is somewhat straight forward and uncomplicated. The occurrence of a particular fossil species in different geographic localities points to the fact that rocks from these localities were deposited at similar times in the earth history. However, complexities may arise from the following: the training and identification ability of the biostratigrapher, environmental effects, rates of evolution and state of preservation of the fossils. It is a generally practice in biozonation to stack relatively older and

younger biozones together with no attempt made to give absolute ages (in years) for the biozones. Due to this, the concept of biozonation gave bath to a new and more dependable concept called biochronology.

Biochronology attempts to accurately date evolutionary first appearance or extinction of a species using ages calibrated by radiometric methods alone or in relationship with radiometrically calibrated magnetic reversals, stable isotope zones or astronomically tuned events. These dated levels on a global synchronous events are denoted as first appearance datums (FADs) and last appearance datums (LADs) or locally as FO or LO of a species in a particular region. Environmental factors may obstruct the actual ages locally and prevent it corresponding to its actual FAD or LAD.

A. Biostratigraphic studies of the Niger Delta

Intensive foraminiferal biostratigraphic studies of the onshore, shallow and deep offshore areas of the Tertiary Niger Delta have been carried out using ditch cuttings, cores and sidewall sample. Surprisingly, most of the foraminifera biostratigraphic studies are not recorded in literature (unpublished) due to problems associated with exclusive legal right.

Reyment (1959, 1965) attempted the establishment of biozone for the Tertiary sediments of the southern Nigeria based on the identified foraminifera species (*Bolivina spp, Afrobolivinia afra, Afrobolivina bantu, Bolivinia ihuoensis and Bolivina owerri).*

Petters (1979) describe the two (2) distinctive biostratigraphic horizons from the Parabe-1 well using ditch cutting samples. *Globorotalia tumida and Globorotalia fohsi peripheroronda* was used to identify the Pliocene and Early – Middle Miocene age respectively whilst *Globorotalia opima nana* and *Globorotalia opima opima* in association *with Globorotalia siakensis* suggests Late Oligocene age. Petters (1982) carried out a detailed documentation of the benthic foraminiferal species in the Niger Delta as part of the Central West Africa Cretaceous – Tertiary stratigraphy and recognized eleven (11) benthic foraminiferal zones namely *Anomalina plummerae – Trochammina wickendeni* zone, *Planulina beadnelli - Ammoastuta nigeriana* zone, *Neobulimina subregularis – Gabonita lata* zone, *Bolivina afra – Haplophragmoides talokaense* zone, *Anomalinoides bermudezi – Epinodes pseudoelevatus* zone, *Nonion oyae – Uvigerina hourcqi* zone, *Altistoma sclaris – Epistominella pontoni* zone, *Hanzawaia mantaensis – Cibicidoides colombianus* zone, *Nonion ecaudoranum – Epinodes eshira* zone, *Pseudonodosaria paucicostata – Spiroloculina tenuis* zone and *Amphistegina gibbosa – Epistominella vitrea* zone.

Petters (1983) also studied the planktic foraminiferal contents of the Niger Delta as part of the Gulf of Guinea and recognized nine (9) planktic zones namely *Subbotina praecursoria* zone (Late P1), *Morozovella pussila – M. angulata* zone (P3), *planorotalites pseudomenardii* zone (P4), *Morozovella velascoensis – M. subbotinae* zone (P5-P6), *Acarinina pentacamerata* zone (P9), *Globorotalia opima* zone (P21), *Globogerina* ciperoensis – *Globorotalia kugleri* zones (P22-N4), *Praeorbulina glomerosa* zone (N8), *Globorotalia fohsi fohsi – G. fohsi lobata – robusta* zones (N10-11). Petters (1984) identified *Globorotalia officinalis, Globorotalia ouachitaensis, Globorotalia occlusa, Globorotalia angulisuturalis* and *Globorotalia nana* from the Opuama-1 and Opuekeba-1 wells (base of Opuama Shale) belonging to the following zones: *Globorotalia opima, Globorotalia ciperoensis and Globorotalia kugleri* planktic foraminifera zones. Petters (1995) stated that the Akata and Agbada Formations contain abundant foraminifera (such as *Nonion costiferum, Nonion ecuadoranum, Hopkinsina bononiensis, Hopkinsina Magnifica, Bolivina ignara. Bolivina simplex, Bolivina gracilis, Bolivina miocenina, Bolivina scintilla, Bolivina ordinaria, Uvigerina mexicana, etc)* with the open shelf pro-delta environments being usually very densely populated by foraminifera unlike the tidal creeks and estuaries which are inhabited by arenaceous foraminifera.

Chiaghanam *et al.,* (2011) worked on Miocene sediments and encountered three sequences. These include: Bolivian 25a (*Bolivina mandoroveensis*), *Bolivina spp., Uvigerina* spp., Textularia-3 (*Spiroplectammina wrightii*), T*extularia spp.,* Planktonic-Spp, *Glogiberinaoides spp., Globigeria spp.and* Ostracoda as the dominant species in sequence I. The dominant species within sequence II are *Globigerina spp*, Nonion-3(*Pseudonoion atlanticum*), Uvigerina-5(*Uvigerina sparsicostata*), *Valvulineria*-1 (*Hanzawaia strattoni*) and Ostracoda. The dominant species identified within sequences III are Bolivina 25(*Brazilina interjuncta*), Bolivina 26(*Bolivina beyrichi*), Cassidolina-3(*Cassidulina norcrossi*), Eponides 12(*Cibicorbis inflata*), *Globigerina*- Spp, Globigerinoides-1(*Globigerinoides immaturus*), Ostracoda and Uvigerina-5(*Uvigeria sparsicostata).* Adegoke (2012) identified some transgressive markers such as *Eponides* (13.8Ma and Older*), Globigerinoides subquadratus/Uvigerina sparsicosta* (12.5 - 13.8Ma), *Globorotalia mayeri/Spirosigmoilina oligocaenia* (12.5 – 10.5Ma) *and Uvigerina subperegrina* (10.5 - 8.2Ma) in the Niger Delta. Fajemila (2012) on the other hand identified five (5) foraminiferal zones in two wells from the offshore western Niger Delta. These include *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. Okosun *et al,* (2012) carried out foraminiferal biostratigraphy of the Akata Field (

Akata-2, 4, 6 and 7 wells) located in the eastern Niger Delta. Three (3) planktic foraminiferal zones *(Globorotalia continuosa, Globorotalia obesa/Globorotalia mayeri, and Globorotalia peripheroacut)* and three (3) benthic zones *(Spirosigmoilina oligocaenica, Uvigerina sparsicostata*, and *Eponides eshira/Brizalina mandorovensis)* were established in both well Akata-2 and 4. One planktic foraminiferal zone (*Praeorbulina glomerosa)* and two benthic foraminiferal zones (*Brizalina mandorovensis*/*Eponides eshira* and *Poritextularia panamensis)* were proposed for wells Akata-6 and 7.

Obiosio (2013) encountered a rich *Bolivina* assemblage (*Bolivina ottaensis, Bolivina ihuoensis, Bolivina imperatrix, Bolivina simplex, Bolivina striatella, Bolivina ignara, Bolivina foliacea, Bolivina inconspicua etc)* during the study of the onshore Tonjor-1 well in the Niger Delta. He identified eighteen foraminifera species and assigned Late Eocene age based on the index planktonic foraminifera. Obiosio (2013) used the *Bolivinids* presence to correlate with global Early Eocene transgression and utilized the morphologic features (strong costae and larger test) to suggest a well oxygenated slope to bathyal environment for the penetrated sediments. Peter and Adewale (2014), working on the shallow offshore western Niger Delta identified twenty-two (22) benthonic species among them are the following calcareous species: *Lenticulina inornata, Quinqueloculina microcostata, Quinqueloculina lamarckiana, Heterolepa floridana, Heterolepa pseudoungeriana, Marginulina costata, Cibicides spp., Amphicoryna scalaris caudata, Lagena spp., and Lagena striata.* Two informal benthonic zones were proposed for the interval, which also fell within the Agbada Formation. They are *Heterolepa Pseudoungeriana* Informal Zone and *Lenticulina inornata* Informal Zone

Ajayi and Okosun (2014) carried out a study on four (4) wells located in the deep-offshore area of the Niger Delta. Forty two (42) planktic foraminifera species were recorded and three (3) planktic zones were established (*Globorotalia margaritae margaritae* subzone : N18, *Globigerinoides obliquus extremus – Sphaeroidinellopsis seminulina* zone : N17, and *Globorotalia acostaensis* zone : N16).

Oloto and Promise (2014) also carried out a biostratigraphic analysis on core samples from three wells (two (2) wells from offshore depositional belt and one (1) well from the onshore coastal swamp depositional belt) in southwestern Niger delta and dated the sediments penetrated by the wells as Early Miocene based on the First Appearance Datum (FAD) and last Appearance Datum (LAD) of diagnostic faunal makers such as *Globorotalia obesa, Globigerinoides bisphericus, Globigerinoides obliguus, Globigerinoides immaturus, Orbulina universa* and *Orbulina suturalis* and their suite of Early-Middle Miocene benthic foraminiferal assemblage which include *Bolivina miocenia, Lenticulina rotulata, Alveolephragmium crassium, Bolivina beyrichi, Saccammina complanata* and *Cyclammina minima.*

Ukpong *et al.,* (2017) carried out a biostratigraphic study of Well K-27 in the Niger Delta and identified four foraminiferal zones viz: *Globigerina selli/pseudohastigerina barbadoensis zone* (P18-P19), *Globigerina ampliapertura zone* (P20/N1), *Globorotalia opima opima zone* (P21/N2) and *Globigerina ciperoensis ciperoensis* zone (P22/N3).

B. Location of study well

The study wells (wells C and F) are located in the Northern Delta depobelt of the Niger Delta which forms a segment of the Niger Delta petroleum province of Nigeria (figure. 1).

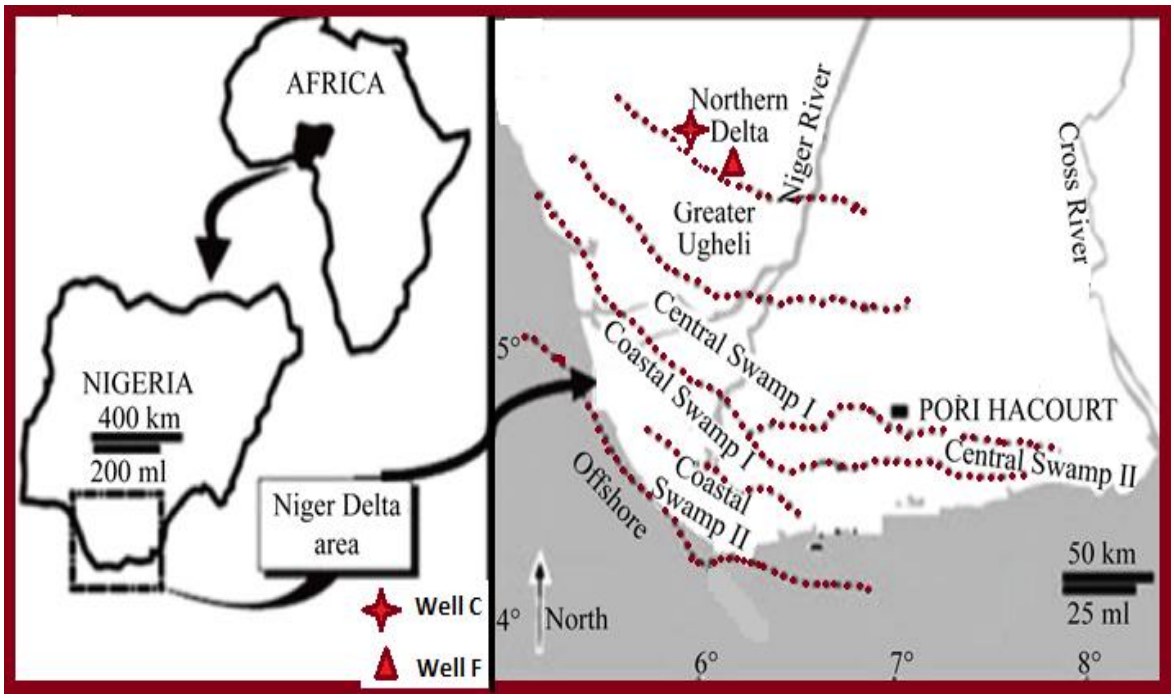

Figure 1: Map of the Niger Delta showing the depobelts and location of the study wells (C and F)

C. Regional setting

The Niger Delta Basin is a prolific hydrocarbon provinces that contains enormous hydrocarbon both on the onshore, shallow and deep offshore areas and it is located between Latitudes 3° and 6° N and Longitudes 5° and 8° E respectively in the Gulf of Guinea, on the margin of West Africa (figure 2). The segment that characterizes the onshore of the Niger Delta Province is defined by the geology of southern Nigeria and southwestern Cameroon. The northern boundary and the northeastern boundary is characterized by the Benin Flank trending east-northeast hinge line south of the West Africa basement massif and outcrops of Cretaceous age on the Abakaliki High and Calabar Flank demarcating the adjacent Precambrian respectively (Tuttle *et al*, 1999). The offshore boundary to the east of the Niger Delta province is characterized by the Cameroon volcanic line, the western boundary is defined by the easternmost transform-fault which forms the Dahomey basin and the 4000-meter bathymetric contour and two kilometer (2km) sediment thickness contour or in areas characterized by sediment piles greater than two kilometers to the south and southwest (Tuttle *et al*, 1999).

The Niger Delta is described by Doust and Omatsola (1990) as one of the largest deltaic systems in the world. The formation of the Niger Delta basin began in the Early Cretaceous; it was developed at the triple junction between South Atlantic, Gulf of Guinea Margin and Benue Trough (Burke, 1972). The Niger Delta deltaic system is known to prograded over an area of three hundred kilometers (300 km) since the Late Eocene (Short and Stauble, 1967; Burke, 1972; Evamy *et al*., 1978; Whiteman, 1982; Stacher, 1995). The development of the Niger Delta continues from Late Eocene till the Holocene, building out on African continental margin and its associated oceanic crust.

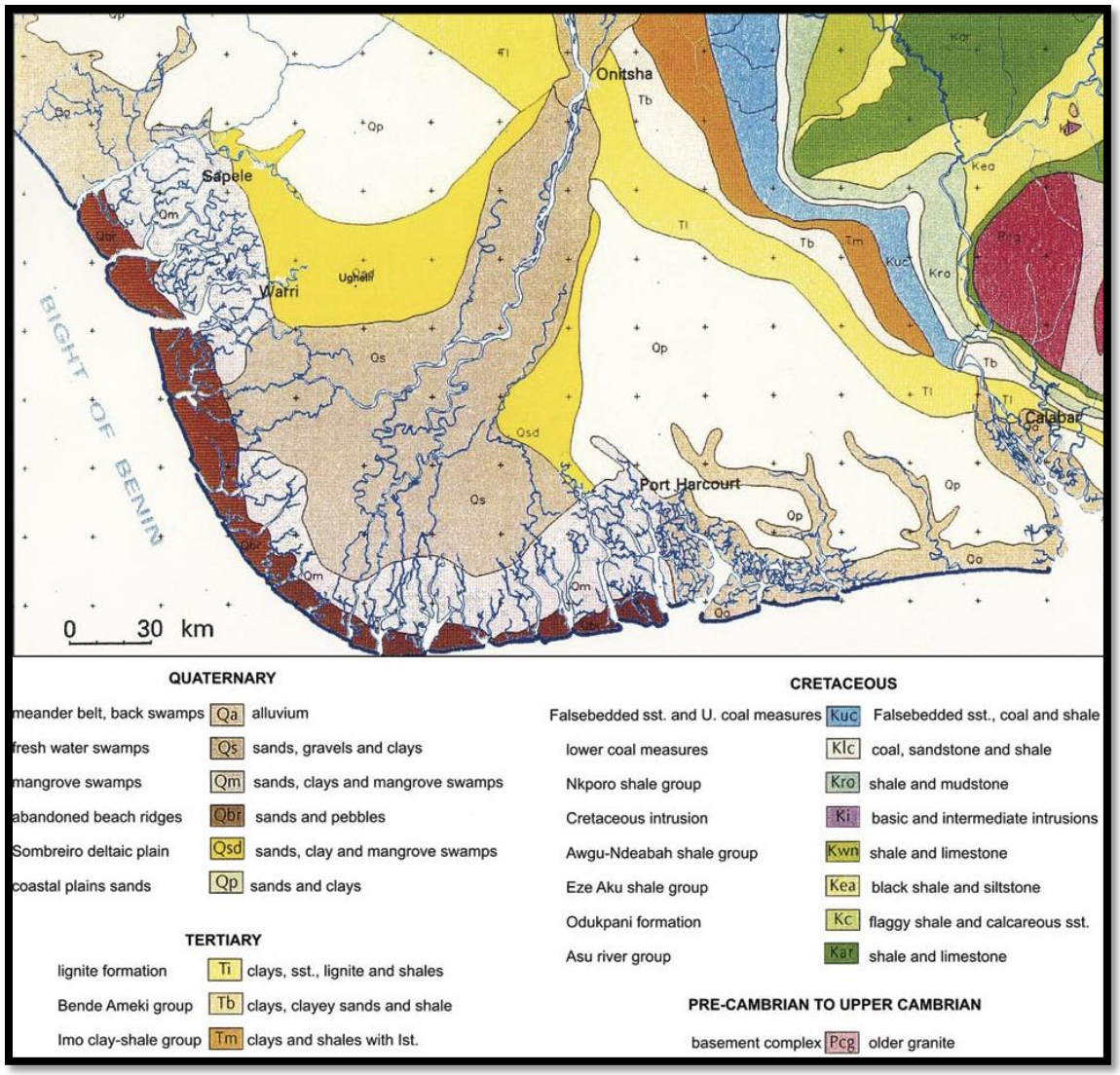

Figure 2. Geologic map of the Niger Delta (Reijers, 2011)

D. Lithostratigraphy of the Niger Delta

Three (3) main vertically stacked lithologic units are known and defined in the Niger Delta by various workers (Doust and Omatsola, 1990; Weber, 1971; Weber & Daukoru, 1975; Evamy *et al*., 1978; Ejedawe, 1981; Knox & Omatsola, 1987) and they correspond to the three-fold lithostratigraphic subdivision proposed by Short and Stauble (1967) for the subdivision of the Niger Delta (figure 3) viz:

I. Akata Formation (indicating marine environment)
II. Agbada Formation (indicating transitional environment) and
III. Benin Formation (indicating continental environment)

The Akata- Agbada – Benin Formations can be distinguished based on their sand-shale ratio. The type sections of these formations have been described by the following authors: Short and Stauble (1965), Avbovbo (1978), Evamy *et al*., (1978), Whiteman (1982), Doust and Omatsola (1990), Knox and Omatsola (1989) and Kulke (1995). These formations represent the major depositional environments of a regressive megasequence (Doust and Omatsola 1990) and strongly point to a deltaic environments characterized by fluvio-marine (wave and tide) interplay. These formations are currently overlain by varied sediments of younger ages. Boboye and

Fawora (2007) pointed out that the Benin Formation is overlain by diverse types of Quaternary deposits. Weber and Daukoru, (1975) defined the diverse nature of the overlying sediments based on the interaction between marine, fluvio-marine and fluvial processes and their deposition on littoral and deltaic plain environments.

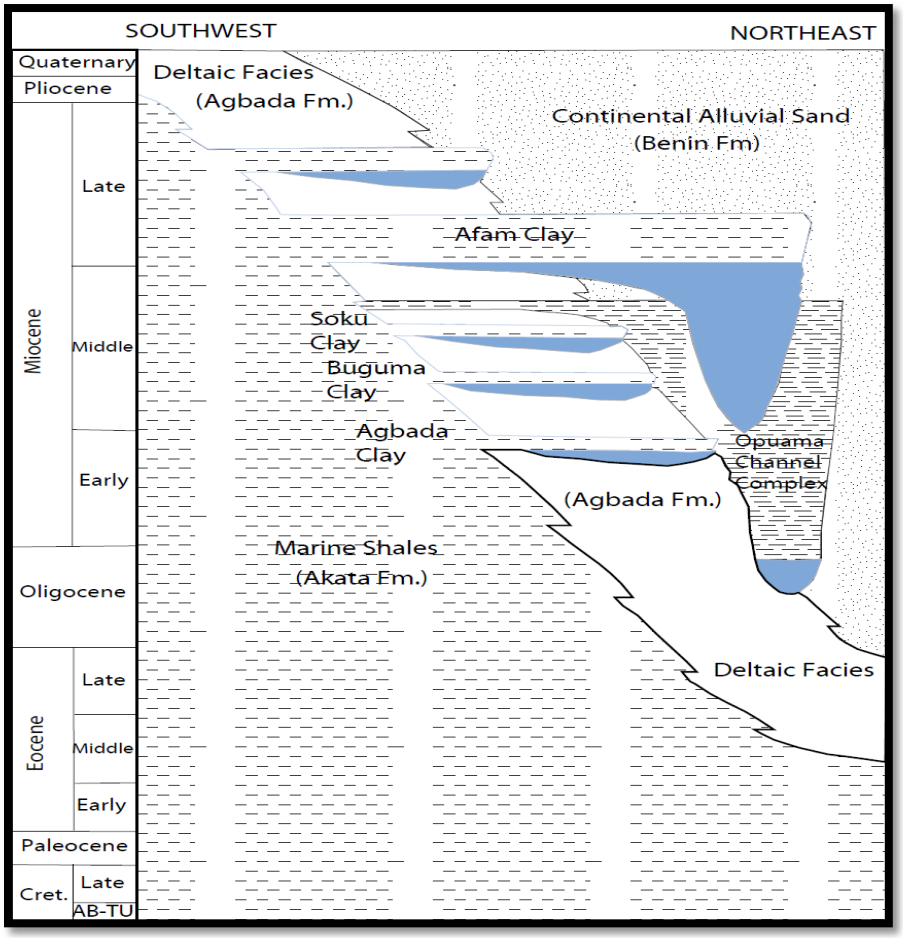

Figure 3. Stratigraphic column showing the three (3) formations that makes up the Niger Delta. Modified from Shannon and Naylor (1989) and Doust and Omatsola (1990).

II. MATERIALS AND METHODS

A. Materials

Ditch cutting samples from the study wells (well C and well F) were obtained. A total of eighty (80) ditch cutting samples were used for this study. Well C ranges from depth 2800m – 2410m consisting of thirteen (13) samples at 30metres interval whilst well F ranges from depth 2000m – 3320m consisting of sixty seven (67) samples.

B. Micropaleontological sample processing

One of the standard approaches for the foraminifera sample processing method was applied in this study. The anhydrous sodium carbonate procedure outlined by Brasier (1980) and Armstrong and Brasier (2005) was utilized in the preparation of samples from wells C and F. The sample preparation is in three (3) phases: soaking, wet sieving and drying of residues. The residues obtained after the extraction of foraminifera from the prepared samples were properly stored in well labeled sample bags for lithologic/sedimentologic analysis. Identification of the foraminifera extracted from the samples was done by comparing picked forms with previously published forms.

III. RESULTS AND DISCUSSION

Foraminiferal analysis was carried out on eighty (80) samples obtained from the two wells (wells C and F). The foraminifera forms recovered include planktic and benthic foraminifera (calcareous benthic and arenaceous benthic foraminifera). Some foraminifera forms are long ranging in terms of stratigraphic occurrence while others have restricted stratigraphic occurrence with regional – cosmopolitan distribution. Foraminifera distribution charts of the wells C and F are presented in figures 4 and 5. The total count of picked foraminifera prior to description was four thousand and twenty two (4022) specimens but due to poor preservation most of the recovered foraminifera could not be described. A total count of one thousand, eight hundred and seventy two (1872) foraminifera specimens were described from the two wells (wells C and F). Also recovered were seventy two (72) ostracods, two (2) pelecypods and one (1) gastropod which were collectively classified as miscellaneous. Figure 4 and 5 shows the foraminiferal chart for wells C and F.

Foraminifera analysis of well C reveals a moderate – high abundance and diversity throughout the entire well section between 2410 – 2560m and 2590 – 2770m except for a barren interval (2560 – 2590m) towards the mid-section of the well. Foraminifera analysis of well F revealed relatively high foraminiferal abundance and diversity throughout the entire well except for some barren intervals within the upper section of the well (2020-2260m) and some intervals (2000-2020m, 2320-2340m, 2400-2420m, 2900-2920m, 3260-3280m) characterized by poor foraminifera recovery. The foraminifera species described from well C consists of twenty seven (27) species from seventeen (17) genera, thirteen (13) families and three (3) suborders while the foraminifera species described from well F consists of seventy nine (79) species from thirty (30) genera, eighteen (18) families and three (3) suborders. The total species recovered from both wells (wells C and F) is eighty two (82) from thirty (30) genera, eighteen (18) families and three (3) suborders.

The total count of foraminifera described from well F is one thousand, seven hundred and seventeen (1717) comprising twenty three (23) planktics (making 1.34percent of the total count) and one thousand, six hundred and ninety four (1694) benthics (making 98.66percent of the total count). The benthic forms comprises of one thousand, six hundred and fifty six (1656) calcerous benthic forms (making 96.44percent of the total benthic count) and thirty eight (38) arenaceous benthic forms (making 2.21percent of the total benthic count). One hundred and fifty five (155) foraminifera counts was obtained from well C, comprising of one (1) planktic (making 0.61percent of the total count) and one hundred and fifty four (154) benthics count (making 99.39percent of the total count). The benthic count comprises of one hundred and forty seven (147) calcerous benthic forms (making 94.84percent of the total benthic count) and seven (7) arenaceous benthic forms (making 4.513percent of the total benthic count).(Figure 6 shows the percent of the total foraminifera counts for wells C and F respectively).

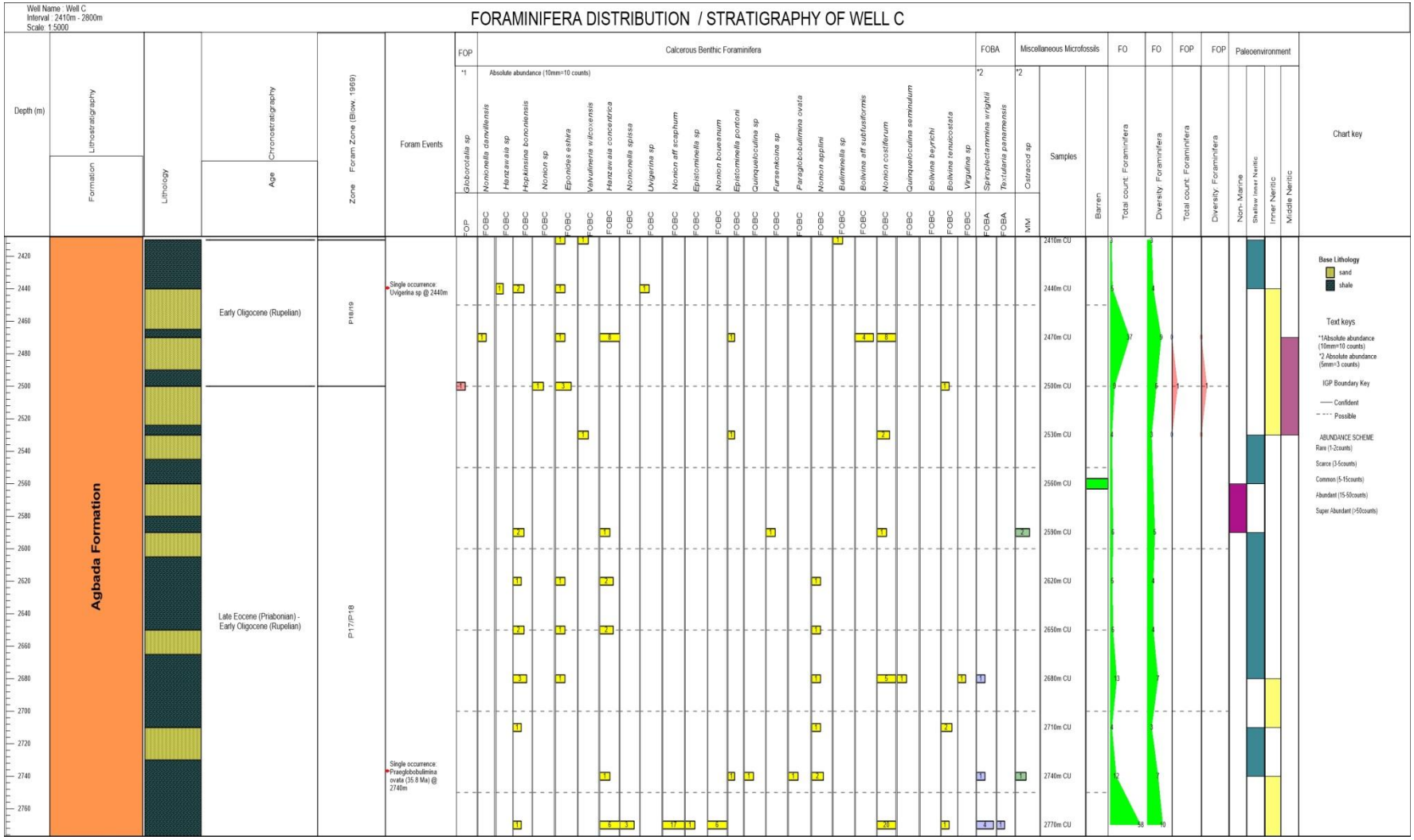

Figure 4. Foraminiferal chart of well C

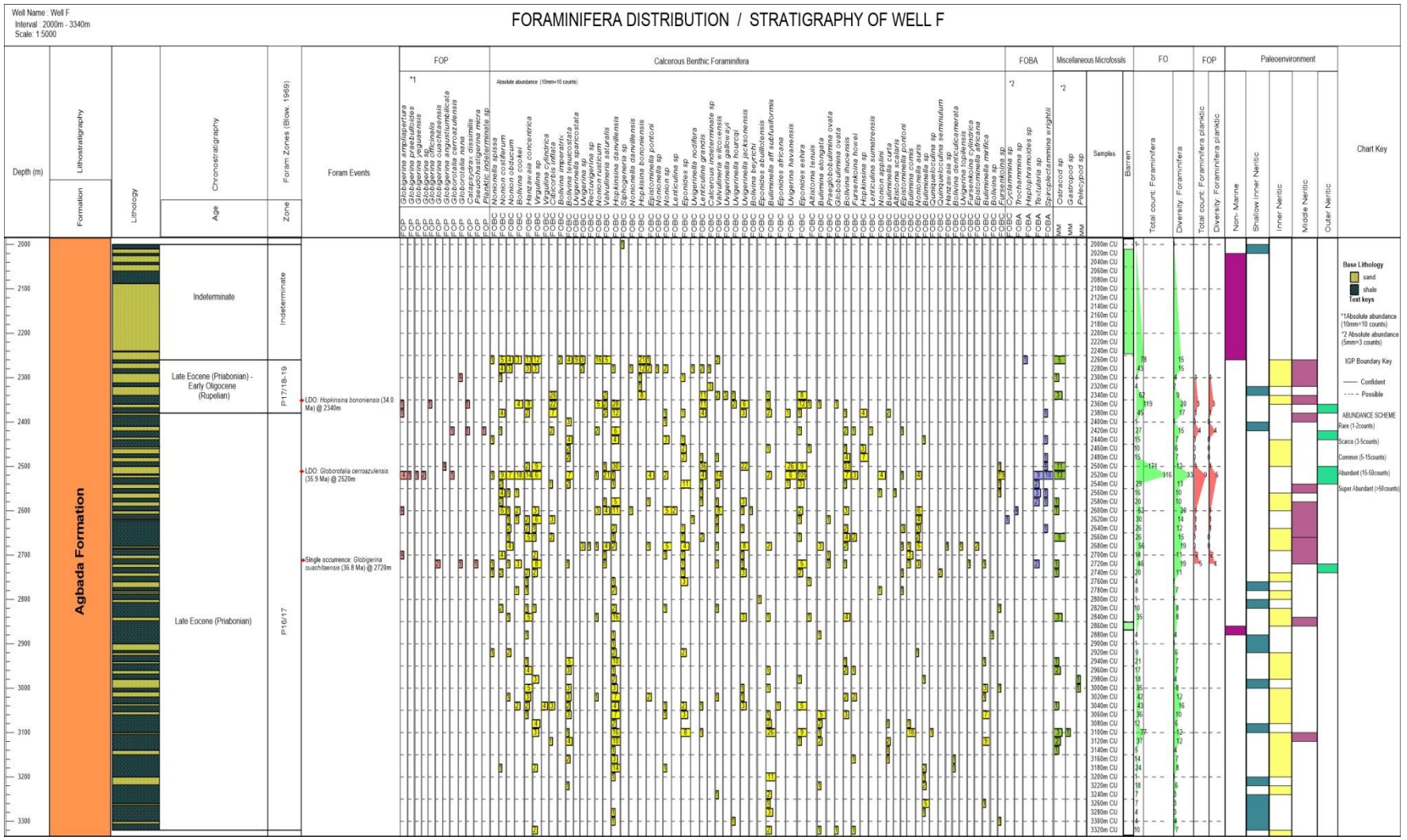

Figure 5. Foraminiferal chart of well F

The alphanumerical designation of Blow (1969) and its equivalent in Bolli and Saunders (1985) and Petters (1982) were adopted for this study. The use different foraminifera species to designate different zones was based on the occurrences of age diagnostic planktics taxa and other associated benthic assemblages.

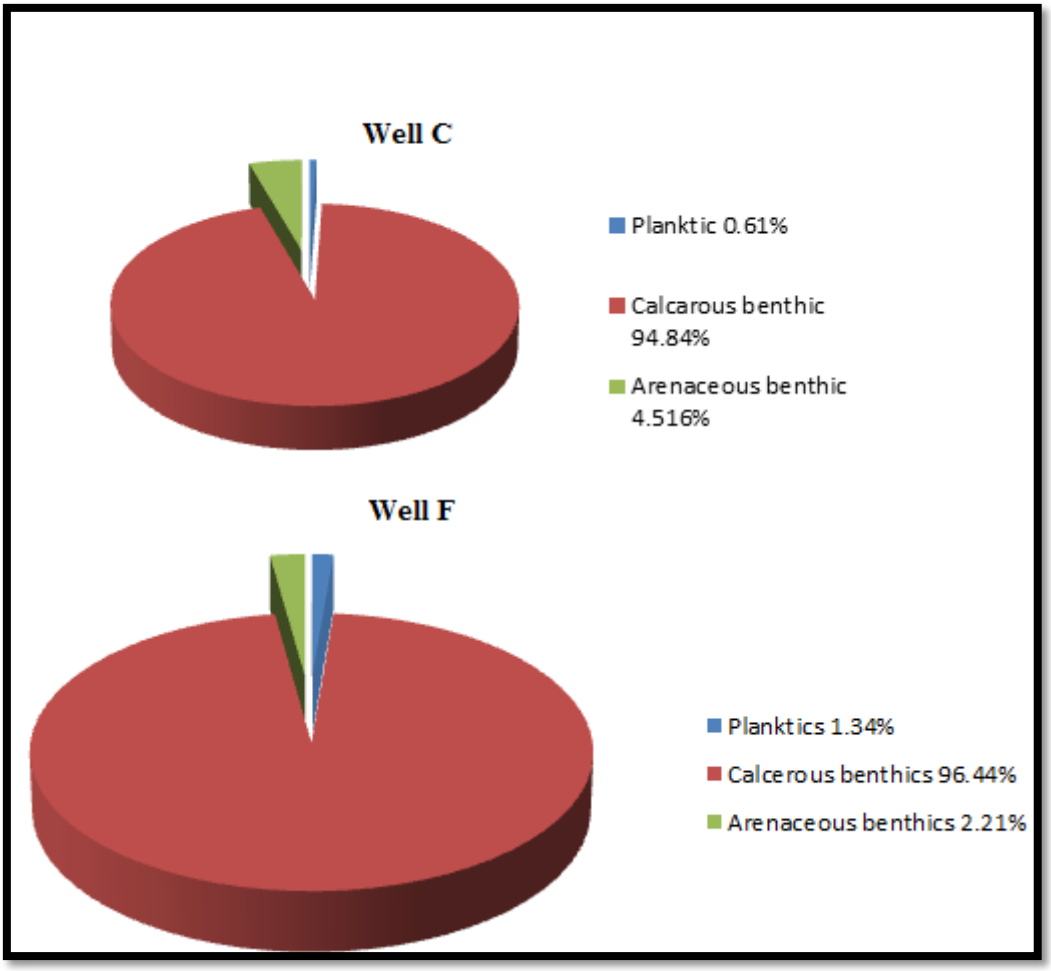

Figure 6. Pie chart showing the percent of foraminifera counts in wells C and F

A. Foraminifera biostratigraphy of Well C

Interval: 2410-2500m

Foram zone: P18 / 19 (*Pseudohastigerina micra* / *Globigerina ampliapertura* zone)

Age: Early Oligocene (Rupelian)

Key microzone events: The co-occurrence of *Hopkinsina bononensis, Hanzawaia concentrica, Valvulineria wilcoxensis, Epistominella pontoni, Bolivina tenuicostata* and *Uvigerina sp.*

Single occurrence of *Uvigerina sp*

FDO / LAD of *Hopkinsina bononiensis* at 2440m.

The age diagnostic foraminifera assemblage in this interval is characterized by *Epistominella pontoni, Nonionella spissa, Nonion applini Nonion costiferum, Eponides eshira, Hopkinsina bononensis, Hanzawaia concentrica, Valvulineria wilcoxensis,*

Epistominella pontoni, Bolivina tenuicostata and *Uvigerina sp*. All these foraminifera assemblages are suggestive of the Early Oligocene. *Epistominella pontoni* is an Oligocene –Miocene form (Petters, 1995). Petters (1982) reported *Nonionella spissa* and *Nonion applini* as Middle Oligocene – Early Miocene index forms while *Nonion costiferum* was reported as an Oligocene – Pliocene form. Petters (1982) also reported *Eponides eshira* as a Middle Oligocene – Middle Miocene form in the Niger Delta. *Uvigerina sp* is also indicative of Paleocene – Oligocene (Petters, 1982). Brouwer *et al. (*1977) used *Hopkinsina bononiensis* to mark the Early Oligocene. The occurrence of *Hopkinsina bononiensis* and *Uvigerina spp. at* 2410m and 2470m respectively is an indication of an age not younger than Oligocene (table 1). This interval corresponds to the P18 zone of Blow (1969) and *Pseudohastigerina micra* / *Globigerina ampliapertura* zone of Bolli and Saunders (1985) as well as the *Altistoma sclaris – Epistominella pontoni* zone of Petters (1982).

Interval: 2500-2800m

Foram zone: P17/18 zone (*Globorotalia cerroazulensis / Pseudohastigerina micra* zone)

Age: Late Eocene (Priabonian) - Early Oligocene (Rupelian)

Key microzone events: Single occurrence of *Globorotalia sp* at 2500m and *Praeglobolulimina ovata* at 2740m

The age diagnostic foraminifera assemblages in this interval include *Globorotalia sp, Nonion sp, Nonion costiferum, Valvulineria wilcoxensis, Bolivina tenuicostata, Eponides eshira, Praeglobobulimina ovata, Epistominella pontoni, Hanzawaia concentrica* and *Nonion applini.* Petters (1982) used a similar assemblage to assign this age. The single occurrence of *Globorotalia sp* at 2500m and the FDO/LAD of *Praeglobolulimina ovata* at 2740m supports the assigned age (table 1).

Nathan (1977) used *Globorotalia sp* to assign an Early Eocene age to the coastal strip between Buttress Point and Ship Creek, South Westland while Bolli *et al.,* (1994) used *Praeglobobulimina ovata* as a marker for the Early Eocene Lizard Springs Formation of Trinidad. Clendenen *et al.*(1990) also used *Praeglobobulimina ovata* to assign Eocene age to the Albatross sequence in Sitkinak Island.

This interval (2500–2800m) corresponds to the P17/18 zones of Blow (1969) and *Globorotalia cerroazulensis - Pseudohastigerina micra* zone of Bolli and Saunders, (1985) as well as the *Nonion oyae – Uvigerina hourqi* /*Altistoma* sclaris – *Epistominella pontoni* zone of Petters (1982).

B. Foraminifera biostratigraphy of Well F

Interval: 2000 – 2260m

Foram Zone: Undiagnostic

Age: Indeterminate

This interval is barren of foraminifera except for the single occurrence of *Siphogenerina spp.* at 2000m. Thus the age of this interval could not be determined. However, it is not younger than Oligocene. Petters (1995) recovered one specimen of *Siphogenerina senni* that is similar to *Siphogenerina sp* from the Parabe-1 and dated it Oligocene.

TABLE 1: **Foraminiferal microbiozonation of well C**

Interval (m)	Foram zone (Blow, 1969)	Foram zone (Bolli and Saunders, 1985)	Age	Remarks
2410-2500	P18	*Cassigerinella chipolensis / Pseudohastigerina micra* zone	Early Oligocene (Rupelian)	Occurrences of *Hopkinsina bononensis* infer an age not older than Oligocene in the Niger Delta. The co-occurrence of *Hopkinsina bononensis*, *Hanzawaia concentrica*, *Valvulineria wilcoxensis*, *Epistominella pontoni*, *Bolivina tenuicostata* Single occurrence: *Uvigerina spp.* at 2440m. FDO / LAD: *Hopkinsina bononiensis* at 2440m
2500-2800	P17/18	*Globorotalia cerroazulensis / Pseudohastigerina micra* zone	Late Eocene (Priabonian) – Early Oligocene (Rupelian)	Single occurrence: *Globorotalia spp.* at 2500m and *Praeglobolulimina ovata* at 2740m

Interval: 2260 – 2380m

Foram Zone: P17/ P18-19 (*Globorotalia cerroazulensis / Pseudohastigerina micra - Globigerina ampliapertura* zone)

Age: Late Eocene (Priabonian) - Early Oligocene (Rupelian)

Key microzone events:LDO/FAD of *Hopkinsina bononiensis* at 2340m

FDO/LAD of *Globigerina ampliapertura* at 2360m.

Single occurence of *Globigerina officinalis* at 2360m

The age diagnostic foraminifera assemblage in this interval is made up of *Nonion obducum, Nonion rusticum, Hanzawaia concentrica, Hopkinsina bononiensis, Bolivina imperatrix, Bolivina tenuicostata, Bolivina ihuoensis, Lenticulina grandis, Uvigerina jacksonensis, Uvigerina havenensis, Uvigerina hourcqi, Valvulineria wilcoxensis, Valvulinea suturalis, Globorotalia cerrozulensis, Globorotalia nana, Globorotalia officinalis, Catapsydrax dissimilis and Globigerina ampliapertura.* The recovered foraminifera assemblages suggest Late Eocene – Early Oligocene ages (Petters, 1982, 1983). Petters (1983) reported *Globigerina officinalis* as an index form for middle Eocene - Oligocene in the Niger Delta. The single occurrence of *Catapsydrax dissimilis* further gave credence to the age of this unit (Boersma, 1978). This foraminifera assemblage represents a section of the Eocene/Oligocene transition. The single occurrence of *Globorotalia nana* at 2300m is an indication of an age not younger than Oligocene. The FDO/LAD of this taxon occurs in the Oligocene (Blow, 1969). The FDO/LAD of *Bolivina imperatrix* and *Bolivina ihuoensis* at 2260m and 2380m respectively supports this age. The co-occurrences of *Bolivina ihuoensis, Uvigerina jacksonensis, Uvigerina havanensis* and *Uvigerina hourcqi* at 2380m are indicative of the penetration of the Late Eocene in the Niger Delta (Petters, 1982).This interval corresponds to the P17/P18-19 zones of Blow (1969) and *Globorotalia cerroazulensis / Pseudohastigerina micra - Globigerina ampliapertura* zone of Bolli and Saunders (1985) as well as *Nonion oyae – Uvigerina hourqi /Altistoma* sclaris – *Epistominella pontoni* zone of Petters (1982)(table 2).

Interval: 2380 – 3320m

Foram Zone: P16-17 (*Globorotalia cerroazulensis* zone)

Age: Late Eocene (Priabonian)

Key microzone events: LDO/FAD of *Globorotalia cerroazulensis* at 2520m.

Single occurence of *Globigerina ouachitaensis* at 2720m

Single occurrence of *Pseudohastigerina micra* at 2720m

LDO of *Globigerina ampliapertura* at 2720m.

The age diagnostic foraminifera assemblage in this interval is made up of *Bolivina ihuoensis, Bolivina denticulocamerata, Epinodes eshira, Uvigerina jacksonensis, Uvigerina havanensis, Uvigerina hourcqi, Epistominella minuta, Hopkinsina mirifica, Hopkinsina danvillensis, Eponides eshira, Fursenkoina howei, Fursenkoina cylindrical, Buliminellita mirifica, Nonion obducum, Nonion rusticum, Globorotalia cerroazulensis, Globigerina ampliapertura, Catapsydrax dissimilis, Globigerina ouachitaensis, Globorotalia nana, Pseudohastigerina micra* and *Globigerina yeguaensis.* This foraminiferal assemblage constitutes a typical component of the Late Eocene age in the Niger delta (Petters, 1982; 1983).

Petters (1982) pointed out that *Uvigerina jacksonensis* has been reported from Eocene strata in many parts of the world. Petters (1983) reported scarcity of *Globorotalia cerroazulensis* and *Pseudohastigerina micra* in the Niger Delta. The occurrence of *Globorotalia cerroazulensis* as well as the increase in counts of *Globigerina ampliapertura* is indicative of the penetration of the P16/17 foram zone (Blow, 1969). The single occurrence of *Globigerina ouachitaensis* and *Pseudohastigerina micra* at 2720m further supports the assigned age (Petters, 1983)(table 4).

McGowran (2008) recorded *Globorotalia cerroazulensis* as an index form for the Eocene. Samanta (1969) and Poore and Brabb (1977) used a similar assemblage in dating the Eocene succession of the Kopili Formation and Butano Sandstone respectively. All these give credence to the assigned age of Eocene. Bolli (1957) used *Globigerina yeguaensis* to

date the Middle – Early Eocene in the Navet Formation, Southern Trinidad. *Globigerina yeguaensis* was first described from the subsurface sediments of Yegua Formation (Middle Eocene), Texas and is widely distributed in sediments of Middle and Upper Eocene age. Berggren (1960) extended the lower limit of the age range to the Lower Eocene.

This interval (2380 -3320m) corresponds to the P16/17 zones of Blow (1969) and *Globorotalia cerroazulensis* of Bolli and Saunders (1985) as well as *Nonion oyae – Uvigerina hourqi* zone of Petters (1982)

IV.SUMMARY AND CONCLUSION

The paper provides information on the foraminifera from the Late Eocene (Priabonian) – Early Oligocene (Rupelian) boundary which appears to be one of the most important breaks within the Cenozoic. Continuous sequences at the Eocene - Oligocene transition were rarely described in the literature except for the terminal Eocene events. This study provides a fairly/complete record as well as continuous sequences through the Eocene-Oligocene boundary as recovered in neritic facies contrary to most records that are from the deep ocean environments.

Foraminiferal biostratigraphic analysis of sediments penetrated by well C and F revealed similar ages of Late Eocene – Early Oligocene. The sediments of well C is of Late Eocene (Priabonian age) - Early Oligocene (Rupelian age) and consist of two (2) foram zones: P17/18 (*Globorotalia cerroazulensis / Pseudohastigerina micra* zone) and P18 (*Pseudohastigerina micra* zone). The sediments of well F is also of Late Eocene (Priabonian age) - Early Oligocene (Rupelian age) and consist of four (4) foram zone: P16 -17 / P18-19 (*Globorotalia cerroazulensis / Pseudohastigerina micra - Globigerina ampliapertura* zone).

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TABLE 2.Foraminiferal microbiozonation of well F

Interval (m)	Foram zone (Blow, 1969)	Foram zone (Bolli and Saunders, 1985)	Age	Remarks
2000-2260	Undiagnostic	Undiagnostic	Indeterminate but not younger than Oligocene	Predominantly barren
2260-2380	P17/P18-19	*Globorotalia cerroazulensis / Pseudohastigerina micra* - *Globigerina ampliapertura* zone)	Late Eocene (*Priabonian*) – Early Oligocene (Rupelian)	Single occurrence of *Globigerina officinalis* at 2360m. FDO/LAD of *Globigerina ampliapertura* at 2360m. LDO of *Hopkinsina bononiensis* at 2340m
2380-3320	P16/P17	*Globorotalia Cerroazulensis* zone	Late Eocene (Priabonian)	LDO/FAD: *Globorotalia cerroazulensis* at 2520m. LDO of *Globigerina ampliapertura* at 2720m. Single occurrence of *Globigerina ouachitaensis* and *Pseudohastigerina micra* at 2720m

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