

# Biostratigraphic Study And Paleoenvironmental Reconstruction Of Cores From Offshore (South Western) Niger Delta, Nigeria

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**Abstract:** Biostratigraphic and lithologic analysis were carried out on core samples from three wells of two fields in offshore depositional belt and one onshore well in coastal swamp depositional belt in southwestern Niger delta, namely Bongo-ST-1, Bongo -4, Ngolo and Opukushi-25 respectively. A total of 99 samples are examined 35 samples for Bongo -ST-1, 23 for Bongo -4, 16 for Ngolo and 25 samples for Opukushi -25 well with total thickness of 2421feet, 526feet, 5563feet respectively. Biostratigraphic analyses established Early- Middle Miocene age of Bongo ST -1, Ngolo and Opukushi - 25 wells and Early Miocene for Bongo -4 well based on the First Appearance Datum (FAD) and last Appearance Datum (LAD) of diagnostic faunal and floral makers such as *Globorotalia obesa*, *Globigerinoides bisphericus*, *G. obliquus*, *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*, *Saccamina complanata* and *Cyclamina minima*. Some of the diagnostic flora makers encountered in this study include *Magnastriatites howardii*, *Verrutricolporites retundiporus* *Praedapollis africanus* *Crassorettriletes vanraandshooveni*, *Racconocolpites hians*. *Echiperiporites estalae*, *Pachydermites diedeixi*, *Grimsdalea magnaclavata* and *Echitricolporites spinosus* The depositional environment and paleobathymetric ranges of the four wells are determine and interpreted with the use of depth sensitive benthics, floral and associated accessories such as glauconite, mica, faecal pellets foraminiferal test linings pediatrum and fugal spores within each wells. The paleodepositional environment established marginal marine to shallow marine (littoral-middle neritic) corresponding to onshore to offshore within the continental plain to the continental shelf.

**Index Terms:** Biostratigraphy, offshore, cores, Niger Delta, Paleoenvironment, foraminifera

## (I) INTRODUCTION

The Niger delta is a prolific oil province within the West Africa subcontinent. The Tertiary Niger delta basin is one of the sedimentary basin formed by the rift faulting of the Nigeria precambrian rock. It is large acute sediment wedge of the destructive wave dominated type (Evamy et al; 1978). This delta is important because of its hydrocarbon resources, which started to evolve in Eocene period, and deposition is still on going offshore. The development of the delta depended on the interplay between sediment supply and subsidence. Larger amount of data from several thousands of drilled wells have led to a considerable understanding of the stratigraphy and regional geology of the delta. Information have been published on petroleum, sedimentology (Short and Stauble 1967, Weber, 1971, Weber Daukoru, 1975; Ejedawe, 1981, 1982, Stacher 1994) and biostratigraphic (Adegoke et al; 1971, 1976, Petter, 1972, 1982a, 1983 Seigle et al; 1982, Ojo 1996, Ozumba 1995, 1997, 1999, Adeniran 1997, 1998, Fadiya 1988, Fadiya 1988). Peters (1982a) provided a detailed benthic foraminifera biostratigraphy and described four zones from the late Early Miocene to the Pliocene. Adeniran (1997) defined six zones based on planktic foraminifera from the Oligocene to the Pliocene from the western Niger Delta.

## GEOLOGIC SETTING AND STRATIGRAPHY

The Niger delta in which these wells are located is a prograding depositional complex found within the Cenozoic Formation of the Southern Nigeria. The Niger is bound in the west by the Benin flank; the subsurface continuation of the West Africa shield; in the east by Calabar flank, the subsurface continuation of the Oban massif; to the North by Abakaliki, and the post Abakaliki Anambra basin; and the Atlantic Ocean to the south (Muraat, 1972). The combination effect of subsidence and the deposition has resulted in a succession of transgressive and regressive

sequence and a 250km shoreline advance in the southwest direction in the Niger delta (Oomkens, 1974). The accumulated result of these events is the deposition of between 9,000m to 12000m thick transgressive/regressive depositional sequences, which is very similar to the United State Gulf Coast Tertiary section (Curtis 1970). Short and Stauble (1976) divided the subsurface Niger delta into three stratigraphic units stating from the top to the bottom they are (a) Benin Formation (b) Agbada Formation (c) Akata Formation

## (II) METHODOLOGY AND DATA SOURCE DESCRIPTION

Core samples from three offshore wells and one onshore well from three fields in the South-West Niger Delta namely: Bongo-4, Bongo -ST - 1, Ngolo and Opukushi -25 wells respectively are analyzed. The samples examined comprise a wide variety of lithological types, ranging from fine grain sandstones, sandy shale and shale. Logs for the penetrated wells are not available, so as comparative detailed lithology description is compiled from the relative closely sampled sediments. The first three wells from two fields are located in the offshore depobelt in the southern Niger delta, while the fourth well being Opukushi -25 is located in the coastal swamp depobelt in the Western Niger delta. Samples from the penetrated formations are collected at approximately 5-20 feet interval. So a total of 35 samples are analyzed for Bongo-ST-1, 23 samples are analyzed for Bongo-4, 16 samples for Ngolo and 25 samples for Opukushi - 25 well

**(a) Foraminiferal Sample Preparation** The samples available from the borehole are broken into pieces in a mortar, about 10 grams put into an enamel plate, mixed with water treated with 2 grams sodium carbonate and finally boiled for 30 minutes on a hot plate at 250°C in order to disintegrate the clay and shale particles and free the

fossils from the matrix. The boiled solution from each plate is in turned decanted into stack of sieves arranged in decreasing order 140 mm coarse (C), 300um medium (M) and 106um fine (F) and wash in a jet of water. Residues from each sieve size are collected in a filter paper tagged with label for each depth and dried at a temperature of 100°C bottled in separate pack for analysis. All recognizable species encountered are generally determined under the microscope. In the identification of the different foraminiferal species, important consideration is given to the recent taxonomic revisions as publish in Bolli et al; (1985) Zacharinsse (1990) etc, especially with respect to planktonic foraminiferal. These changes are made with the aim of changing the numerous errors common in the literature and the systematic description of the main foraminiferal index with respect to time and paleobathymetry. Also analyses of the fossils population are done using the numerical relative abundance method based on the average counts of the genera and species present. Scan of very important forms are done which are presented on the various plates with explanation.

### (b) Sedimentological Samples Description

Sedimentological sample analysis is done by weighing a given amount of sample, which is treated with 10% dilute hydrochloric acid for the presence of calcareous materials. The texture, fissility and sedimentary composition are also examined with the aid of the binocular microscope, the index minerals like glauconite, siderites, iron and carbon are identified where present

## (III) PRESENTATION OF RESULT

### BIOSTRATIGRAPHIC RESULT OF THE STUDIED

**WELLS** Biostratigraphic events are important stratigraphic signature left by the fauna and flora through which important interpretation can be made. Because these events seem to be synchronous in fossil organism and are affected by series of global changes, these events are very important in correlation datum. Alongside the lithology and sedimentological description of the studied formation are the biostratigraphic results. The four wells, Bongo-ST-1, Bogo \_4, Ngolo and opukushi 25 are examined for their fauna and palynomorphs content which yielded rich to fairly rich species. (See plate 1)

**(a) Bongo – st - 1 - well** The sample in this formation yielded a total of 69 different benthic foraminiferal species representing about 74% of the total number of fauna species recovered. Out of this, the calcareous benthic constituted 45 species (65%) while the arenaceous benthic species is 24, which constituted 26% of the benthic assemblage. The planktic foraminiferal species is 32 in number, which represented 24% of the total number of fauna encountered. The percentage distribution of the fauna in this formation is common to fairly rich. From the basal unit between intervals 10669- 8800 feet there is eventually no planktic present and the benthic assemblage present are more of calcareous forms than agglutinated benthics. The calcareous assemblages is constituted *Epistominella vitrea* (Parker, *beyrichi* 1953), *Oolina* species (Hynes 1958), *Fissurina compressa* (D'orbigny, 1839), *Bolivina* (Reuss. 1861) and *Elipsoglandulina* species

(Silvestri, 1907). While the few arenaceous benthic assemblage includes *Saccamina complanata* (Franke), *Valvulina flexilites*. (Cushman and Renz, 1941), *Ammonia beccari* (Linne 1758) and *Milliammina* species (Heron – Allen and Earland, 1930). The calcareous benthic association within this interval include *Quinquenloculina vulgaris* (D'orbigny, 1826), *Lenticulina inomata* (D'orbigny, 1846), *Cibicides lobatulus* (Walker and Jacob, 1798), *Bulimina infla* (Seguenza, 1862) and the arenaceous benthic assemblage include, *Valvulina flexitalis* (Cushman and Renz 1946), *Trochammina* species (Parkar and Jones, 1859), *Ammodiscus glabratus* (Cushman) and *Cyclammina minima* (Leroy, 1939), most of fauna are identified to species, level. This indicates a high degree of the planktic species, but some of the benthic could not be identified to species level probably due to partial damage during the drilling or preparatory phase. However they are identified to genus level. Their quantitative effect on the quality of total interpretation is therefore considered negligible. Species occurrence range from fairly rich to very rich as shown in the biostratigraphic distribution chart The palynomorphs assemblage which comprised pollen, spores dinoflagellate, fungal spore, pediatrum and foraminiferal test lining are of diverse forms.

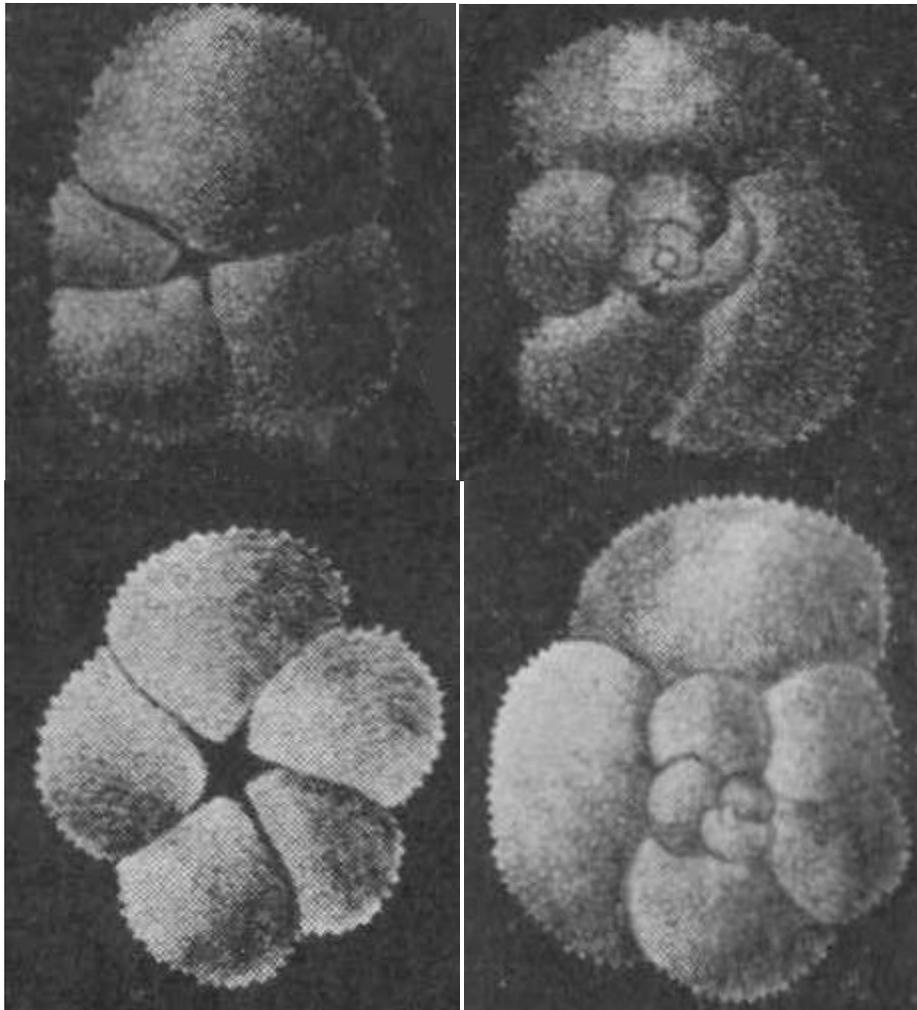
**(b) BONGO – WELL** The foraminiferal assemblage in this well is made up of diverse and fairly rich to occasionally rich foraminifera species. Faunal presentation is fairly good through the sequence as displayed on the Biostratigraphic distribution chart. A total of 45 different benthic foraminiferal species are identified, the benthic species make up about 79% of the total foraminifera population The arenaceous benthics constituted more than 23% while the calcareous species in this assemblage constituted more than 78% in term of diversity but over 94% in term of abundance. However, the pattern of occurrence of fauna throughout the well is definitely suggestive of paleoecological control and therefore, to be used with extreme caution in the paleoenvironmental interpretation of the well. The planktonic foraminiferal species are of diverse nature in the sequence as shown on the distribution chart. A total of 12 species are identified which constituted about 21% of the total foraminiferal assemblage. 10 out of this number are identified to species level which is an indicative of high degree of preservation of the planktic species during the period of deposition and low level of damage by the drill bits in the course of well drilling. The basal units of this well which is between 8776 – 8700 feet, there is 100% calcareous benthic occurrence with no planktic encountered. The next overly unit in the interval of 8515-8435 feet, no planktic encountered. The percentage occurrences of the benthic are 100%, about 80% calcareous and 20% arenaceous. The calcareous benthic assemblages encountered in this section include *Heterolepa pseudoungerianus* (Cushman, 1932) *Bolivina miocenica* (Macfadyen, 1930) *Epistominella vitrea* (D, orbigny, 1846) *Lenticulina inorata* (D orbigny, 1846) and *Uvigerina species* (Dorbigny, 1846). Also the arenaceous benthic association recorded in this interval include *Ammonia beccani* (linne, 1839), *Eggerella scabra* (Williamson, 1856) and *Haplophragmoides* species (Cushman, 1910). The inception of planktic species in this well is recorded at interval 8345 – 8340 feet. The

percentage occurrence of planktic species at the inception point is 3% which drastically increased to 50% in the next level, while total benthic species occurrence is 97% has decreased to 50% in the overlying interval. Within the next sequence which is between the interval depths of 8320 – 8300 feet the total benthic association increased to 100% with eventually no planktic species occurrence.

**(c) NGOLO WELL** In this well, an interval of 10141 - 11029 feet, having a thickness of 888 feet is analysed. These wells consist of diverse faunal assemblage but poor to occasionally fairly rich species as displayed on the distribution chart (Appendix 3). Faunal preservation is moderate throughout the studied formation. A total of 33 different benthic foraminiferal species are identified which make up both arenaceous benthic 50%, of the 33 benthic species encountered, only about 50% could be identified to species level, which amounted to less than 42% of the total assemblage. A total of 6 planktic species are identified to level. The frequency of occurrence is very sporadic. No sample is analysed for interval 10196 – 10144 feet because it was not cored. The uppermost part of this well, which is at depth 10141 feet recorded about 100% pollen and spores occurrence with no other palynomorphs present. Some of the arenaceous benthic species encountered in the well include *Haplophragmoides compressa* (Leroy, 1939), *Reophax species* (De monfort 1808), *Trochammina species* (parker & Jones 1859), *Saccammina complanata* (franke) *Cyclammina Minima* (Leroy, 1939) *Velvulina fleilis* (Cushman & Renz, 1941) *Ammonia beccari* (linne, 1756). Also the calcareous benthic assemblage present in this well include *Lenticulina inomata* (D'orbigny, 1846), *Heterolapa pseudoungerianus* (Cushman, 1932), *florilus atlanticus* (Cushman), *Bolivina miocenica* (Macfadyen, 1930), *Hoeglundina elegans* (d'orbigny, 1826) and *Hanzawaia stratonii* (Applin). The planktic species assemblage encountered include *Globigerinoides obliquus* (boli, 1957), *Gloigerinoides bisphericus* (Todd, 1954) and *Globorotalia obese* (Bolli, 1957)

**(d) OPUKUSHI- 25 WELL** The foraminiferal assemblage in the Opukushi- 25 well is made up of poor to scanty fauna occurrence as shown in the distribution chart. Faunal preservation is poor throughout the studied interval. A total of 20 different benthic species are identified which constituted about 83% of the number of foraminifera encountered. Out of this number, the calcareous benthic contributed 13 (65%) while the arenaceous benthic constituted 7(35%). The basal unit of this well which is at depth 12349 feet recorded 33% occurrence of the planktic species assemblage and 67% benthic species occurrence of this number (67%), 75% of it is recorded as calcareous benthics and 25% arenaceous. The Palynomorphs assemblages in this formation are as well found to be very sporadic in occurrence which comprised pollen and spores most of which are identified to species level. Dinoflagellates and fungal spores also have sporadic occurrences as shown in the distribution chart. The percentage occurrence of palynomorphs in this well indicate between the interval of 12349-12274 feet, the pollen and spores as having 100% occurrence, while no dinoflagellates or miscellaneous particles are present. The next overlying unit, which is in the depth range of 12288-12132feet is barren but interval

12180 feet recorded 100% spores occurrence. Within the interval of 12042-11808 feet, the percentage occurrence of pollen and spores increase and decrease up the sequence with more spores is about 70% while that of pollen is about 30%. No dinoflagellates or accessories are encountered here. The upper most part of this well which is between the depths of 11789-11786feet, the percentage occurrence of pollen and spore decreased to about 25% while there is 33% occurrence of dinoflagellate at 11789 feet. This is the only depth in which the dinoflagellate occurred in this well. Some of pollen and spores encountered in this well include *Monoporites annulatus* (Van Der Hamman, 1954), *Pachydermites diderixi* (Germead, Hopping & Muller, 1968), and *Laevigatosporites ovatus* (Wilson & Webner 1946) and *Cyathidites australis* (Couper 1953) the only dinoflagellate present is *Apectodinium homomorpha* (Lentin & Williams, 1977)



**Plate 1:** Showing some of the forms of foraminifera encountered in the study

## AGE DETERMINATION OF THE STUDIED WELL

Age determination in the southwestern Niger delta has been carried out using combined benthics, planktics and Palynomorphs index species. However the benthics and palynomorphs index species. However the benthic forms are found to be tied to the paleoenvironment rather than the biostratigraphy. Siege et al; (1983) developed planktic and benthic foraminiferal zones for this area of the Niger delta. This compared very well with Blow (1969, 1979) zonation. The associated Planktic foraminiferal, paleoenvironment and palynological age for the various lithostratigraphic units are identified. The benthic foraminiferal zones have varying geochronological duration. Some zones span over several age or epoch while others are short ranging and have very useful stratigraphic application. Marine transgressions and regressions controlled sedimentation in these areas. Consequently, the benthic foraminiferal zones reflect the duration of each marine cycle. Since organisms, which live in shallow unstable shelf environments are susceptible to rapid extinction each marine transgression, therefore, tend to establish its own biozones. Specific age determinations are based on Stratigraphic First Appearance Datum. (FAD) and last Appearance Datum (LAD) of fauna and flora index marker fossils and their suite of benthics, planktics and palynomorphs assemblages where applicable. A detailed description of the paleontological and palynological subzones for the Niger delta by Evamy et al; (1978) are presented below.

Well Name: Bongo-ST-1  
 Age: Early-Middle Miocene  
 Interval: 8248-10669 feet  
 Thickness: 2421feet  
 Formation: Agbada

The First appearance datum of *Globigerinoides bisphericus* (Todd, 1954) an Early-Miocene in age, at 8785 feet which last appearance datum at 8248 feet. Also the first appearance datum of *Globigerinoides obliquus* (Bolli, 1957) and *Orbulina universa* (Jorbigny, 1839) Middle Miocene in age at 8775 feet, *Globorotalia obesa* (Bolli, 1957), which could not be traced beyond the point which corresponds with the inception point of and last appearance datum of *Globigerinoides obliquus* is at 8248 feet but *Orbulina universa* could not be traced beyond the depth of 8775 feet. Also the first quantitative base appearance of *Globorotalia menardii* 'A' (Bolli, 1970) at 8766b ft, *Orbulina suturalis* (Bonnimann, 1951). *Magnestriatites Howardii* (Germerad, Hopping & Muller, 1968) Early Miocene at 10660 feet and extinction point at 8800 feet. This interval is within the *Magnestriatites howardii* zone established in this study which corresponds to p.620-p.770 of the Niger delta palynological subzone. The presence of *Verrucolporites rotundiporus* (Gonzalez Guzman 1967) at 8766feet and *Praedapollis africanus* at 8761 feet both of which have single occurrence within this interval of the well support the existence of the P620-P770 subzone here and defined the age of this well as Early-Middle Miocene. The depths 8766 feet also correspond with the First appearance datum of planktic Foraminiferal index markers encountered in this well which are of Early-Middle Miocene of age, hence this interval is of stratigraphic importance.

Well Name: Bongo-4  
 Age: Early Miocene  
 Interval: 8250-8776feet  
 Thickness: 826 feet  
 Formation: Agbada

The first appearance datum (FAD) of *Globigerinoides altiapertura* (Bolli, 1957), Early Middle Miocene at 8265 feet which has its last appearance datum (LAD) at 8250feet defines the zone for this well under study. Also the presence of *Globigerinoides bisphericus* (Todd, 1954) which inception point is 8260 feet and extinction point is 8255feet support the age of this interval as Early Miocene. This interval corresponds to N5-N6 subzone of (Blow, 1969). Also the presence of *Globigerinoides immaturus* (Leroy) and *Globigerinoides trilobus* (Reuss, 1890) which first appearance datum (FAD) is at the depth of 8250 feet. This LAD at 8250feet mark the inception point of *Globigerinoides obliquus* (Bolli, 1957) which single occurrence could not be traced beyond that point which probably suggest the upper part of the well as Middle Miocene age. The suite of Early Miocene benthic Foraminiferal markers encountered within this interval includes *Lagena sulcata* (Walker & Jacob, 1798). *Lenticulina inonata* (D'orbigny, 1846) *Eggerella scabra* (Williamson, 1858) and *Bolivina miocenica* (Macfadyen 1930) From Palynological results for this well, the occurrences of diagnostic markers are very sporadic. However, the interval is defined by the First appearance datum of *Crassoretitrites varrandshooveni* (Muller et al; 1968) at 8340feet and *Racemonocolpites hians* (Gonzalez Guzman, 1967) at 8283 feet. These flora help define a zone for the interval. The zone defined as *Crassoretitrites varrandshooveni* which corresponds to P650-P670 subzone is assigned Early Miocene age following the approach of Evamy et al; Most of the forms encountered here are long ranging and reworked Fossils of Oligocene and older Forms.

Well Name: Ngolo  
 Age: Early-Middle Miocene  
 Interval: 10141-11029 feet  
 Thickness: 888 feet  
 Formation: Agbada

The First appearance datum (FAD), which represents the inception point of *Globigerinoides bisphericus* (Todd, 1954) an Early Miocene index marker at 11005 feet and its last appearance datum at 10991 feet. Also the FAD or inception point of *Globorotalia obesa* (Bolli, 1957) Middle Miocene marker at 10995feet and extinction point at 10985feet defined this interval as Early-Middle Miocene of age. The *Globigerinoides bisphericus* zone established for this well in this study is based on its stratigraphic Position of occurrence. This presence of *Globigerinoides obliquus* (Bolli, 1957) and the suite of benthic foraminiferal assemblage which include *Cyclammina minima* (Leroy, 1939), *Eggerella scabra* (Williamson, 1858), *Bolivina miocenica* (Macfadyen, 1930) *Saccamina complanata* (Franke) and *Bolivina Isitroensis*. (Cushman) within this interval of the well support the existence of this zone here From Palynological data, the *Echitricolporites spinosus* (Germerad, Hopping & Muller 1968) zone is established

for this well based on the occurrence of *Verrutricolporites rotundiporus* (van Dder Hammen & Wijmstra, 1914) *Pachydermites diederixi* and *Grisdalea magnaclavata* (Germeraad, Hopping & Muller, 1968) in the Stratigraphic Sequence. The first appearance datum of *Grimsdalea magnaclavata* (Germeraad, Hopping & Muler, 1968) and *Racemonocolpites hians* (Gonzalez, Guzman, 1957) at 11024 feet and 11029 feet respectively and last appearance datum at the depth of 10985 feet and 10208 feet respectively defined this interval as Early-Middle Miocene age. Also the presence of *Verrutricolporites rotundiporus* (Van Der Hammen & Wijmstra, 1914) and *Pachydermites diederixi* (Germeraad, Hopping & Muller 1968) at 1020 feet and 10985 feet respectively support the existence of Early-Middle Middle age for this well. The established zone corresponds to P680-P770 of the Niger delta Palynological subzone. The subzone P680-P770 is assigned Early - Middle Miocene age following the approach of Evamy et al: (1968).

<b>Well Name:</b>	<b>Opukushi- 25</b>
Age:	Early-Middle Miocene
Well Interval:	11786-12349feet
Thickness:	563feet
Formation:	Agbada

The First appearance datum (FAD) of *Globorotalia obesa* (Bolli, 1957) at 12349 feet which last quantitative base appearance occurred at 11834 feet defines this well interval as Early- Middle Miocene age. Also the presence of *Globigerinoides trilobus* (Reuss, 1850) *Globigerinoides obliquus* (Bolli, 1957) and the suite of Early- Middle Miocene benthic foraminiferal markers which include *Textularia merandii* (Parker, 1952), *Lenticulina rotulata* (Lamarck, 1804), *Saccamina minima* (Leory, 1939) within this interval further support a Early- Middle Miocene age for the analysed section. The zone for the analysed section is established as *Globorotalia obesa* zone based on the stratigraphic position of *Globorotalia obesa* in the sequence. This zone corresponds to N5-N15 of Blow, (1969). From palynological data, the frequency of occurrence of the index markers is very sporadic, most of which has single occurrence. However the First appearance datum of *Pachydermites diederixi* Germeraad, Hopping & Muller 1968), *Crassoretitriteles resraadshooveni* (Muller et al 1968) and *Racemonocolpites hians* (Gonzalez Gzman, 1967) at 12132 feet, 12037 feet and 12349 feet respectively established this natural as Early - Middle Miocene age also the presence of *Echitricolporites mirousis* (Gfermeraad et al;), *Grimsdalea magnaclavata* (Germerad Hopping & Muller 1968) and *magstraitities howardii* (Germarad, Hopping & Muller, 1968) within this interval Further support a Early-Middle Miocene age for the analysed section. The stratigraphic position of *Echitricolporites Spinousus* in the analysed in the analysed sequence helps establish *Echitricolporites spinousus* zone for this well. This zone corresponds to P560-P780 subzone of the Niger delta Palynological zonation Scheme (fig.12). The P680-P780 is assigned Early- Middle Miocene by Evamy et al; (1978) and is similarly adopted here.

## (IV) DISCUSSION AND CONCLUSION

This report represent the results of the sedimentological, biostratigraphic (paleontological and palynological) and paleoenvironmental history of Bongo – ST – 1, Bongo – 4, Ngolo and Opukushi – 25 wells from onshore/offshore Southwestern Niger Delta, Nigeria. Some selected core samples are examined for lithologic, fauna, flora and auxilliary microfossils. Biostratigraphic analyses are carried out at approximately 5 – 20 feet interval, especially within litho-sections that are likely to generate microfossils. The interval examined are Bongo ST – 1 well (8948 – 10669feet), Bongo – 4 well (8250 – 8776feet), Ngolo well (10141 – 11029feet) and opukushi – 25 well (11786 – 12349feet). A total of 9 core samples are examined in this study. 35 sample for Bongo – ST – well, 23 for Bongo – 4 well, 16 for Ngolo and 25 samples for opukushi – 25 well. The paleodepositional environments of these wells vary in marginal marine (littoral), from back shore-foreshore of the continental plain to shallow marine (middle neritic) from proximal offshore to distal offshore of within the continental shelf. Paleobathymetric studies based on depth sensitive benthic foraminifera show the well sections as having the above paleoenvironments. Paleontological and palynological zonation used in this study is based on the first occurrence of two or more species in a stratigraphic sequence and this compared with that of Blow, 1969. Also palynostratigraphic scheme applied to the wells sections are largely based on the data of Germeraad, Hopping and Muller (1968) and the already existing Niger delta biozonation scheme. From the Biostratigraphic results, the following numbers of species and genera are encountered in the various wells in this study (Table 18). In Bongo – ST – 1 well, 22 planktonic species, 67 benthic species, which constitute 6 genera and 45 genera respectively. Also 19 pollen grains species, 7 spores species, 4 dinoflagellate species, which constitutes 16 genera, 6 genera and 4 genera respectively are encountered. In Bongo – 4 well, 12 planktic species, 45 benthic species, which constitutes 5 genera and 33 genera respectively. The flora present constitute 12 pollen grains species, 6 spores species and 6 dinoflagellate species, this make up 11 genera pollen grains, 5 spores genera and 5 dinoflagellaate genera respectively. In Ngolo well 7 planktic species, 33 benthic, species, which belong to 4 planktic genera and 23 benthic genera respectively. The flora present are 15 pollen grains, 8 sores species and 5 dinoflagellate species making up 15 genera, 8 genera and 5 genera respectively. In Opukushi – 25 well, 4 planktic species, 20 benthic species, which belong to 2 planktic genera and 16 benthic genera. Also 7 pollen grains species, 7 spores species and 1 dinoflagellate species belonging to 6 pollen grains genera, 6 spores genera and 1 dinoflagellate genera are encountered. Paleontological analysis established early – Middle Miocene age for the well section Bongo – ST – 1 well (8248 – 10669feet) based on the First Appearance Datum (FAD) and Last Appearance Datum (LAD) of *Globigerinoides bisphericus* (Todd, 1954) Early Miocene *Globigerinoides obliquus* (Bolli, 1957) Middle Miocene to Pliocene and *Globrotalia menardii* 'A' (Bolli, 1970) Middle Miocene. Within this interval are single occurrence of the following planktic species *Orbulina sutularis* (Bonnimann, 1951) Middle Miocene, *Globorotalia obesa* (Bolli, 1951) Early-Middle Miocene. The suite of Early-Middle, Miocene benthic

foraminifera assemblage encountered within this section includes *Cyclammina minima* (Leroy, 1939), *Lenticulina inornata* (D'orbigny, 1846), *Bolivina beyrichi* (Reuss, 1851), *Lagena semistriata* (D'orbigny, 1839), *Eggerella scabra* (Williamson, 1858) and *Amphicorya scabaris* (Batsch, 1791). These last forms supports the Early-Middle age for this interval. This interval is within the *Globigerinoides bisphericus* and *Globigerinoides obliquus* zone established in this study based on their occurrence in the stratigraphic sequence. This interval also corresponds to N7 – N15 (Banner & Blow, 195), (Blow, 1969) and F9300 – F9600 subzone of the Niger delta biozone (Evamy et al, 1978) and in Bongo – 4 well (8250 – 8776feet), paleontological analysis established Early Miocene age based on the First Appearance Datum (FAD), Last Appearance Datum (LAD), Inception and Extinction point respectively of *Globigerinoides altiapertura* (Bolli, 1957) Early Miocene, and *Globigerinoides bisphericus* (Todd, 1954) Early Miocene. Also present within this interval are *Globigerinoides immaturus* (Leroy, 1939) Miocene and *Globigerinoides trilobus* (Reuss, 1850), Early Miocene to recent. The suite of Early Miocene benthic foraminifera maker encountered within this interval include *Lagena sulcata* (Walker & Jacob, 1798) *Lenticulina inornata* (D'orbigny, 1846), *Eggerella scabra* (Williams, 1858) and *Bolivina miocenica* (Macfadyen). This interval is within the *Globigerinoides altiapertura* zone defined in this study by its position in the stratigraphic sequence. This *Globigerinoides altiapertura* zone here correspond with N5 – N6 (Blow, 1969) and foram zone F9300 subzone of the Niger delta biozone (Evamy, et. al; 1978). In Ngolo well, paleontological analysis established Early-Middle Miocene age for this formation (1041 – 1102feet) based on the FAD (Inception point) and LAD (Extinction point) of *Globigerinoides bisphericus* (Todd, 1954) Early Miocene, and *Globorotalia obesa* (Bolli, 1957) Middle Miocene *Globigerinoides bisphericus* zone is established for this well in this study based on its stratigraphic position of occurrence. This zone corresponds to N7 – N15 (Banner & Blow, 1965) and Blow, (1969) and F9300 – F9500 subzone of the Niger delta biozone (Evamy, et. al., 1978). The presence of *Globigerinoides obliquus* (Bolli, 1957), Middle Miocene and the suite of Early-Middle Miocene benthic foraminiferal assemblage with the defined interval include *Cyclammina minima*, (Leroy, 1939), *Eggerella scabra* (Williamson, 1958) *saccamina complanata* (Franke), *Bolivina isdroensis* (Cushman) and *Bolivina miocenica* (Macfadyen, 1930) which support the existence of this zone. In Opukushi – 25 well, paleontological analysis established Early – Middle Miocene age for the interval examined (11786 – 12349feet) based on the FAD and LAD of *Globorotalia obesa* (Bolli, 1957) Early-Middle Miocene and *Globigerinoides trilobus* (Reuss, 1850) and the suite of Early – Middle Miocene benthic foraminiferal markers which include *Textularia earlandi* (Parker, 1953, *Lenticulina rotulata* (Lamarck, 1804), *Saccamina complanata* (Franke), *Bolivina miocenica* and *Cyclammina minima* (Leroy, 1939) within this interval further support a Early-Middle Miocene age for the analyzed section. *Globorotalia obesa* zone is established for this interval based on its stratigraphic position in the sequence. This established zone corresponds to N5 – N15 (Banner & Blow, 1965, Blow 1969) and F9300 – F9600 subzone of the Niger delta

Miocene (Evamy et. al., 1978). Palynological analysis also established the following age for the intervals under study. Bongo – ST – 1 well 8248 – 10669feet is assigned Early-Miocene age based on FAD and LAD of *Zonocostites ramonae* (Oligocene-Middle Miocene), and all pectinities *howardii* (Germaeraad, Hopping & Muller, 1968) Oligocene – Early Miocene, defined an early – Middle Miocene age for the examined section of this well. To the presence of *Verrutricolporites rotundiporus* (Gonzalez Guzman, 1967) Early – Middle Miocene and *Praedapollis africanus* (Boltenhagen & Guzman, 1967) Early – Middle Miocene which have single occurrence within this interval of the support the assigned early- Middle Miocene age: *Magnestriatites howardii* zone is established in this study for the well interval. This zone correspond with P620 – P770 subzone (Germaeraad, Hopping & Muller, 1968. Bongo – 4 well, is defined as Early Miocene age (8250 – 8776 feet). This age is determined based on the FAD and LAD of *Crassoretitrites varriaadshooveni* (Muller et al., 1968) Early-Middle Miocene and *Racemonocolpites hians* (Gonzalex Guzman 1967) Late Eocene-Middle Miocene. The zone assigned to this interval is *cassoretitrites vanraadshooveni* zone which correspond with P650 – P670 subzone of the Niger delta biozone. Most of forms encountered here are long ranging and worked from older formations. The interval analyzed for Ngolo well (10141 – 11029feet) has been established palynologically as Early – Middle Miocene age based on FAD and LAD of *Grimsdalea ragnaclavata* (Germaeraad, Hopping & Muller, 1968) Early-Middle Miocene and *pacemonocolpites hians* (Gonzalez Guzman, 1957) Late Oligocene – Middle Miocene. The presence of *Echiperiporites estalae* (Van Der Hammen et Wymstra, 1964) Late Eocene – Early Miocene to Middle Miocene and *Verrutricolporites rotundiporis* (Van Der Hamman & Wymstra, 1964) support the existence of the Early-Middle Miocene age for this well. The *Echitricolporites spinosus* zone is established for this well based on the occurrence of *Verrutricolporites rotundiporus*. *Pachydermites diderixi* and *Ginsdalea magnaclavata* in the stratigraphic sequence (Germaeraad, Hopping & Muller, 1968). The established zone corresponds to P680 – P770 subzone of the Niger delta biozone (Evamy et al., 1978). For Opukushi – 25 well, the interval (11786 – 12349feet) has been established from palynological results as Early-Middle Miocene of age based on the single occurrence of *Crassoretitrites vanrandshooveni* (muller et al., 1968) Early-Middle Miocene: Also the presence of *Echitricolporites spinosus* (Germaeraad, Hoping & Muller 1968) Middle Miocene, *Grimsdalea magnaclavara* (Early-Middle Miocene), *Magnestriatites howardii* (Germaeraad, Hopping & Muller, 1968) Oligocene – Early Miocene within this interval further support an Early-Middle Miocene age for this well. The stratigraphic position of *Echitricolporites spinosus* in the analyzed sequence help established the zone for the well, which corresponds to P680 – P780 subzone of the Niger delta biozone. The subdivision of the four wells (Bongo – ST 1, Bongo – 4, Ngolo and Opukushi – 25) shows the correlation of the four wells based on their Biostratigraphic results. The wells are correlatable, as the well from the offshore depobelt Bongo – ST – 1, Bongo – 4 Ngolo are Early – Middle Miocene, Early Miocene Early-Middle Miocene respectively. Opukushi – 25 well from onshore located in coastal swamp depobelt is also Early-

Middle Miocene of age. The correlation is largely based on their faunal and flora species count and percentage distribution of planktic and benthic foraminifera in the studied wells

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