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Foraminiferal Biostratigraphy and Depositional Environment of Oloibiri-1 Well, Eastern Niger Delta, Nigeria

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Abstract

Foraminiferal biostratigraphy has been undertaken from the ditch cutting samples of Oloibiri-1 well located in the eastern Niger Delta. Oloibiri-1 well is composed of shale and mudstone/siltstone with intervals of sand/sandstone. Oloibiri-1 well which contains both planktic and benthic foraminifera, penetrated strata of Miocene age, and have been subdivided into biostratigraphic zones. The planktic zone established for the well is *Praeorbulina glomerosa* Zone. The benthic zone established is a taxon range zone of *Poritextularia panamensis*. Other sections of the well were barren or have sparse foraminifera content. Littoral-deltaic to marine environments of deposition have been inferred on the bases of the occurrence of environmentally restricted benthic foraminifera taxa, some which belong to the following genera *Quinqueloculina, Hopkinsina, Spiroplectamina, Lenticulina, Heterolepa, Alveolophragmium* and *Textularia.*

Keywords: foraminifera, biostratigraphy, depositional environment, eastern Niger delta, Nigeria

1. Introduction

Oloibiri-1 well is among the first exploratory wells drilled in the Eastern Niger Delta in the 1950s (precisely 1956) by Shell B.P Petroleum Development Company. Oloibiri-1 well is located around latitude $4^0$658'N and longitude $6^0$26'E (Figure 1). Exploratory activities in the Niger Delta provided accessibility to the sub-surface formations that characterize the basin. Thousands of wells have been drilled across the delta penetrating the sediments, where in petroleum generation, migration and accumulation have been found. The relatively large amount of data obtained from the wells has led to considerable understanding of the regional geology and stratigraphy (Adeniran, 1997). The work of Short and Stauble (1967), Avbovbo (1978) and Frankl and Cordry (1967) discussed the subsurface distribution of stratigraphic units in the Niger Delta. They recognized three main formations (Benin, Agbada and Akata) within the Niger delta complex. The oldest formations (Paleocene-Eocene) in the Niger delta form an arcuate exposure belt along the delta frame. These are the Paleocene Imo Shale (fossiliferous blue-grey shales with thin sandstones, marls and limestones, and locally thick near shore sandstones), the Eocene Ameki Formation (fossiliferous calcareous clays, coastal sandstones), the late Eocene-Early Oligocene lignitic clays and sandstones of the Ogwashi-Asaba Formation and the Miocene-Recent Benin Formation (coastal plain sands). These formations are highly diachronous and expanded into the subsurface where they have been assigned different formation names: The Akata, Agbada and Benin formations are interfingering facies equivalents representing pro-delta, delta-front and delta-top environment respectively. Unconformities, large clay fills of ancient submarine canyons and deep-sea fans occur in the eastern and western delta. These were formed mainly during early Oligocene and Tertiary lowstands of sea – level (Burke, 1972, Reijers et al., 1996). Short and Stauble (1967) defined the contact between the Agbada and Benin formations at the highest shale bearing a marine fauna (foraminifera) in the Agbada Formation. However, the contact is more practically defined at the base of the massive sandstones typical of the Benin Formation and generally corresponds to the base of freshwater-bearing strata (Bustin, 1988). Benin Formation lacks marine or brackish water microfauna (Short & Stauble, 1967). Fayose (1970) studied the biostratigraphy of Afowo-1 well in the Dahomey Basin from which he proposed ten biostratigraphic units, most of which are Cretaceous to Palaeogene in age. The last 3 units contain Neogene forms. Peters (1979b) described three stratigraphic zones in Parable-1 well using: *Globorotalia opima nana* and *Globorotalia opima opima* to define Late Oligocene, *Globorotalia foshi peripheronda* was used to define early middle Miocene and Pliocene. Adeniran (1997) defined six zones based on planktic foraminifera from Oligocene to Pliocene from the Western Niger Delta. Okosun and Liebau (1999) presented qualitative benthic and planktic foraminiferal biostratigraphy and zonation of five wells (Obirikom-1, Ebegoro-1, Afam-1, Kolocreek-1 and Akata-1 wells) from the Eastern Niger delta. Ozumba and Amajor (1999) carried out a high resolution foraminiferal biostratigraphy of four wells (Kanbo-5, Egbedicreek-1, Angalalli-1 and Opukushi-5) located in the coastal and central swamp in the western Niger Delta. They defined six foraminiferal zones (Assemblage/Partial range zones) 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. The focus of the present work is on the planktic and benthic foraminiferal biostratigraphy and depositional environment of Oloibiri -1 well (Figure 1) from eastern Niger Delta.

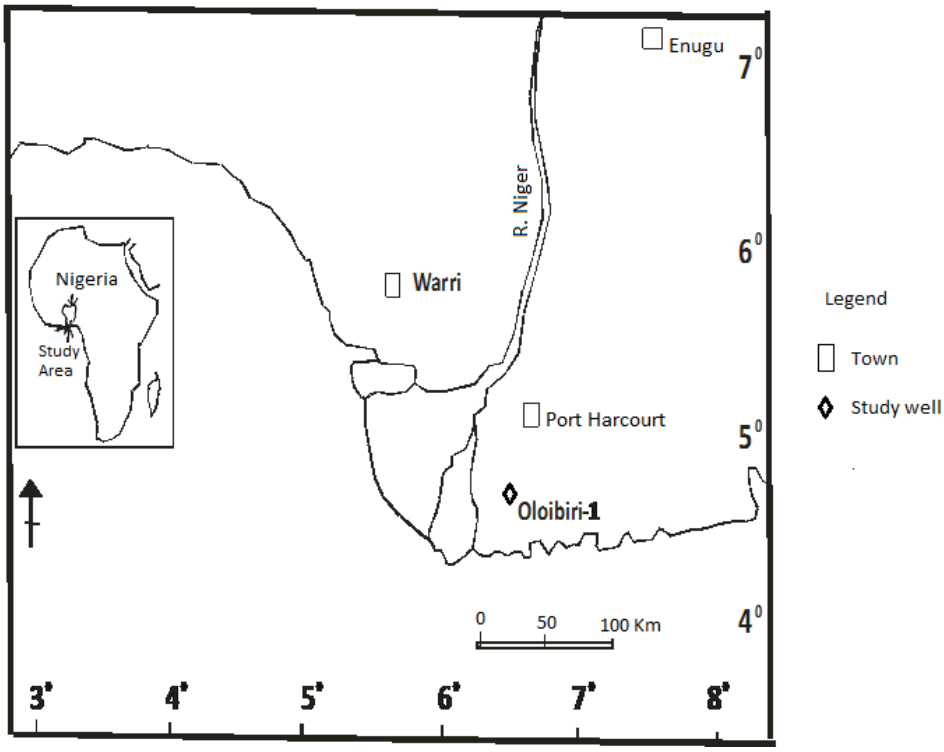

Figure 1. Location map of Oloibiri -1 well in the Niger Delta

2. Stratigraphy of Tertiary Niger Delta

The Tertiary stratigraphy of the Niger delta has been described and defined by Short and Stauble (1967), who recognized three formations. In ascending order, these formations are; the Akata, Agbada and Benin Formations (Figure 2). The stratigraphic succession is an overall coarsening-upward sequence more than 12 km thick.

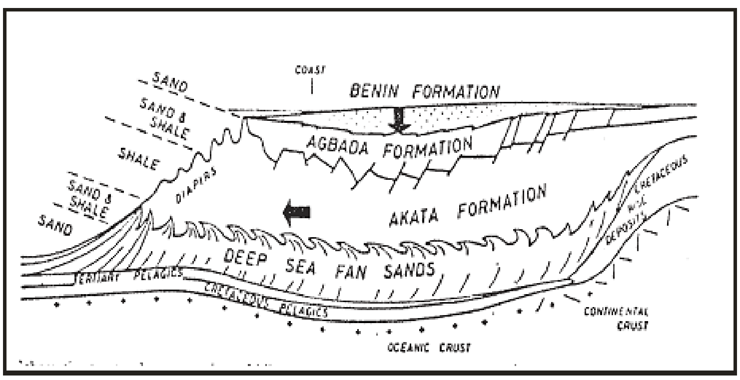

Figure 2. Schematic structural cross section of Niger Delta (After Bustin, 1988)

The Niger Delta lithostratigraphic units are strongly diachronous .The age of the Akata Formation ranges from Paleocene in the proximal parts of the delta to Recent in the distal offshore; the oldest deposits of the Agbada Formation are of Eocene age in the north and are presently being deposited in the nearshore shelf domain, while the Benin Formation first occurs in Oligocene times in the northern delta sector (Reijers et al. 1996). Along the northern perimeter of the Niger Delta, where the proximal parts of these lithostratigraphic units are exposed and partly grade into the lithofacies of the Anambra basin, the same formations have been termed Imo Shale (Akata), Ameki (Agbada) and Ogwashi-Asaba (upper Agbada facies).

Ancient and persistent submarine canyons are common in the eastern (Afam channel) and western (Opuama channel) parts of the Niger delta succession. They are locally incised more than 1,000 m deep and contains a polyphased fill of deep marine clays, lowstand fans and shallow estuarine clastics which correspond to various successions of lowstand (deep marine deposits) to transgressive (wave and tide-dominated deposits) systems tracts formed during Oligocene to Pliocene times.

3. Materials and Methods

A total of 307 ditch cutting samples from Oloibiri-1 well were collected from Nigerian Geological Survey Agency (NGSA) Kaduna. The sampled depth interval studied in Oloibiri-1 well ranges from 20-12000 feet.

Other materials used include 63 micron sieve, hot plates, weighing balance, binocular microscope, slides and cover slides, water, gum, sample envelopes, liquid soap, a set of 3 stacked sieves, toothpick, picking tray, hydrogen peroxide, oven, beakers, and hand lens.

Twenty grammes of each sample were processed for their foraminiferal content using the standard preparation techniques. The weighed samples were placed in 500ml pyrex beaker and were oven dried for about 30 minutes at 108^{o}C. Three percent (3%) hydrogen peroxide solution was then added (with the volume of solution being three times that of the sample being processed), and gently agitated, and was allowed to soak for 24 hours at room temperature. It was occasionally stirred and kept covered with aluminium foil to prevent contamination. The solutions containing samples were heated on a hot plate to boil for 15-20 minutes, stirring frequently and taking care that the solutions did not boil over. The solution was allowed too cool and then, the samples were washed over 63 micron sieve size with liquid soap and water to remove the clay fractions. The liquid soap serves as a cleaning agent in oil based drilling mud ditch cuttings.

The washed residues were dried over hot plate and then sieved into coarse, medium and fine fractions, using a set of 3 stacked sieves. Each fraction was examined under binocular microscope. All the foraminifera, ostracodes, shell fragments and other microfossils observed were picked with the aid of picking needle/tooth pick, counted, placed in foraminifer's slides and covered with cover slide for safety and future reference. The slides were properly labelled with well name and sample depth.

Foraminifera identification was made to genus and species levels where possible using the taxonomic scheme of Leoblich and Tappan (1964) and other relevant foraminiferal literature e.g. (Fayose, 1970), (Murray, 1991), (Okosun & Liebau, 1999), (Petters, 1979a, 1979b, 1982), and (Postuma, 1971).

4. Results and Discussion

The result is presented in the distribution chart of Oloibiri- 1 well (Figure 3). A lithologic log was prepared by integrating lithologic description data with the available SP and resistivity log. The samples of the well consist of shale, mudstone and sandstone. The shale and mudstones are mostly grey to dark grey or black. The sandstones ranges from coarse to fine grained, angular through subangular to rounded, and poor to well sorted. Index accessory minerals observed include ferruginous materials, pyrite, glauconite and mica. Carbonaceous matter and shell fragments were also recorded from different depth intervals. The stratigraphic intervals studied in Oloibiri-1 well has been characterized or subdivided into biostratigraphic zones based on their foraminiferal contents (planktics and benthics).

A total of 24 taxa including eight planktic, seven calcareous benthic, and nine arenaceous benthic foraminiferal species were identified from the studied samples of Oloibiri-1 well (GSN. BH. NO. 1316). Also a good number of accessories like ostracodes, shell fragments and micromolluscs were recovered from the studied samples of the well. The results of this analysis are contained in the foraminifera biostratigraphic chart of Oloibiri-1 well (Figure 3). Diagrams of some recovered foraminifera are shown on plates 1 and 2.

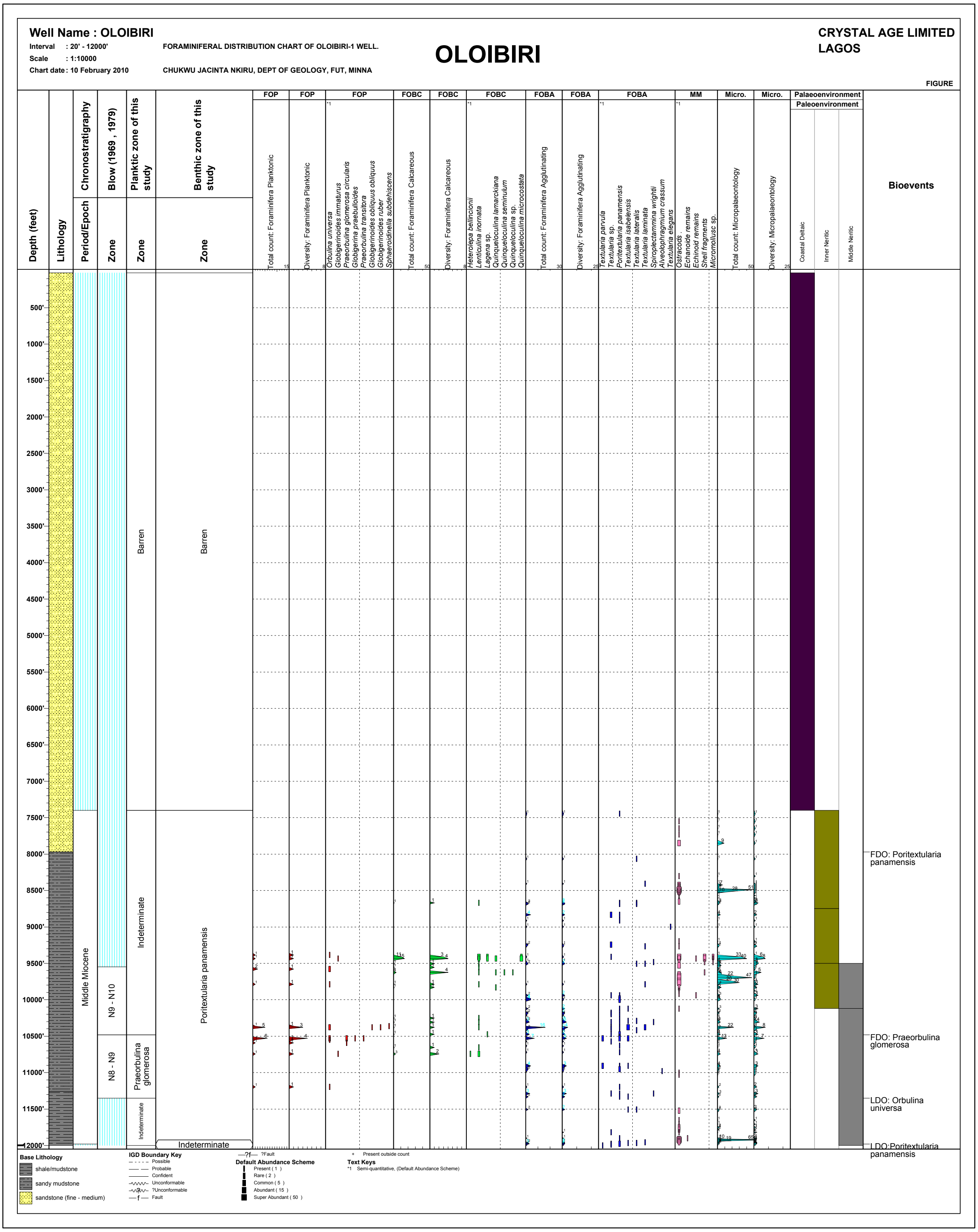

Figure 3. Foraminiferal distribution chart of Oloibiri – 1 well

4.1 Planktic Foraminifera Zone

The planktic foraminiferal preservation in the well is poor. Some stratigraphically important taxa (index planktic forms) were not identifiable to generic/species levels. Therefore, they are placed in the planktic indeterminate group. However, within the recognized planktic foraminiferal species, one concurrent ranges zone was recognized. The zone is the *Preaorbulina glomerosa* Zone. Above this zone is an Indeterminate Zone. This is because the available index planktic species in this zone occurred also in the *Preaorbulina glomerosa* Zone and therefore could not be used to establish another zone. Above the Indeterminate Zone is the barren zone because there was no foraminiferal recovery in the zone.

Zonal Characteristic of *Preaorbulina glomerosa* Zone:

Stratigraphic interval: 11350 – 10480 ft

The zone is characterized/defined by the FDO (First Downhole Occurrence) of *Preaorbulina glomerosa* at the top and LDO (Last Downhole Occurrence) of *Orbulina universa* at the base. Other planktics occurring within the zone are *Globigerinoides immaturus, Globigerina praebulloides, Sphaeroidinella subdehiscens, Globigerinoides ruber and Globigerinoides obliqus obliqus.* The zone is equivalent to the N8-N9 zone of Blow (1969 & 1979).

Age: Base of middle Miocene.

The stratigraphic interval above this zone is assumed to be equivalent to N9/N10 of Blow (1969, 1979) because of its stratigraphic position above the positively assigned zone (*Preaorbulina glomerosa* Zone). The age is also assumed to be middle Miocene for the same reason.

This stratigraphic interval (Indeterminate Zone) is from 10480-7400 ft. Above this stratigraphic interval (Indeterminate Zone) is a Barren Zone, from 3437ft – 20 ft. Furthermore, the stratigraphic interval below the *Praeorbulina glomerosa* Zone is barren of planktic foraminifera, but could be assumed to be the top of early Miocene because of its stratigraphic position below the positively assigned zone of *Praeorbulina glomerosa.*

4.2 Benthic Foraminifera Zones

The benthic foraminiferal assemblages found in the studied well are moderately well preserved. The poorly preserved are placed under benthic indeterminate group. Owing to the absence of index benthic species, a taxon/range zone of *Poritextularia panamensis* is established.

Zonal Characteristics of *Poritextularia panamensis* Zone

Stratigraphic interval: 11980-7400 ft

This is a taxon range zone characterized by the first and last downhole occurrences of *Poritextularia panamensis.* Other benthics associated with it include: *Lenticula inornata, Quinqueloculina microstata, Quinqueloculina seminulum, Textularia laminata, Textularia soldani, Heterolapa bellincionii* and many others. Age: Miocene.

5. Depositional Environment

5.1 Coastal Deltaic (Marginal-marine) Environment

The marginal-marine setting lies along the boundary between the continental and marine depositional realms. These are environments with non to rare recovery of foraminifera because of the unfavourable conditions of rapid sedimentation, temperature and salinity variations and coarse size fractions of sediments. Examples of this type of environment include the deltas, tidal flats, estuaries, lagoons and all marginal marine environments where conditions are subjected to great diurnal and seasonal changes; hence they are highly stressed environments for organisms.

Lithologically, this environment is characterized by fine to coarse-grained subangular to subrounded poorly sorted sands interbedded with thin mudstone and clays. Accessory minerals recorded in this environment include abundant ferrugineous materials, few mica flakes and pyrite. Carbonaceous detritus are also abundant with few shell fragments.

Intermittent to nearly constant subaerial exposure characterized some environments of this setting while some others are continuously covered by shallow water, Bogs (1995).

Microfaunal species that characterized these environments include *Triloculina sp, Ammobaculites, Saccamina, Eggerlla, Haplophragmoides Quinqueloculina lamarckcina* and gastropod shells, Murray (1991) and Phleger (1960). Planktic forms are also rare or entirely absent.

The interval inferred to be deltaic - marine environment from the study ranges from 7400 -20 ft. This inference is based on the following reasons:

a. From 7400 – 20 ft in Oloibiri-1 well are completely barren of microfauna.
b. And are characterized by fine to medium through coarse grained sand.

5.2 Inner Neritic Environment

This is a subdivision of marine environment that lies within 0-40 m on the continental shelf. Inner neritic is subdivided into inner inner neritic (0-20 m) and deeper inner neritic (20-40 m). The inner inner neritic is usually characterized by coarse-grained, clean sand containing abundant rounded shell fragments. A few species usually dominate the benthic faunas. Tests are small and weakly ornamented. Agglutinated species with simple wall structure are common foraminifera in this subenvironment (Boersma, 1978).

Only a few pelagic (planktic) species, usually the genus *Globigerina* may be present. The deep inner neritic contains fine to medium-grained sand, silt clay with common glauconite, mollusks and echinoid remains. There is a change in the structure of foraminifera. The numbers of specimens per species increases with a concomitant decrease in the dominance by one or a few species. The planktic species become more numerous, Boersma (1978). There is an increase in the agglutinated types but still with simple interiors. Common taxa are *Textularia* sp*, Nonion* sp*, Amphistegina lessoni, Elphidium* sp, *Ammonia beccarii* and miliolids.

In this study, the stratigraphic interval that corresponds with the above description lies from 9500-7400 ft. This inference is based on the following criteria:

a. The indicator fauna found here are the miliolids e.g *Quinqueloculina microstata, Quinqueloculina seminulum, Quinqueloculina* sp *and Quinqueloculina lamarckiana* in association with*, Lenticulina inornata, Cibcorbis inflata, Poritextularia panamensis, and other Textularia* sp.
b. The population count of the benthic forms within these intervals is higher than that of the planktic forms. The average planktic/benthic ratio is low. The diversity is low. This is based on simple species diversity.
c. The lithology of the intervals is composed of fine to medium grained sand, silt and mudstone.

5.3 Inner-Middle Neritic Environment

The environment of deposition here fluctuated from inner neritic to middle neritic environments. Benthics occurring within this environment include *Textularia* sp*, Ammonia beccarii,* miliolids*, Lenticulina* sp*, Eponides* sp and nodosariids. Lithologically, it is composed of fine to medium grained sand, clays silts and some shale intervals. There is an increase in the number of planktic species and few ostracodes.

Depth interval of the studied well that is inferred to be belonging to this environment is from 10,150 ft – 9500 ft.

The criteria for this inference are based on the following:

a. The occurrence of the typical forms from inner, middle and outer neritic environments like *Heterolepa bellinocionii, Poritextularia panamensis, Spiroplectamina wrightii, Lenticulina inornata, Quinqueloculina* sp *and Textularia* sp.
b. There is an increase in the population of the planktics and increase in species diversity. Also the planktic/benthic ratio is increased.
c. The lithology is composed of mudstone, sandy mud, silts, clays and sands.

5.4 Middle Neritic Environment

This environment lies between 40 - 100 m in the marine environment within the continental shelf (Boersma, 1978). Lithologically, is composed of clays, silts, shale and poorly sorted sands, large and robust species that are often highly ornamented are present. Species dominance is low and the number of species (diversity) is high. The planktic types constitute from 15-30% of the total fauna, (Boersma, 1978). Common taxa are *Bolivina* sp*, Lenticulina* sp*, Uvigerina peregrina, Eponides* sp, Nodosariids *and Cibicide* sp. This environment is recognized in Oloibiri-1 well from 12,000 – 10,150 ft.

The Criteria for recognition are:

a. The presence of indicator fauna like *Lenticulina inornata, Hopkinsina danvillensis, Alveolophragmium crassum, Hopkinsina bonomensis, and Poritextularia panamenmsis, Heterolepa bellincionii, Spiroplectamina wrightii.*
b. Increase in the number of planktic specimens. The average planktic/benthic ratio is about 22%. The simple species diversity is also increased, ranging from 0-13 species
c. The lithology is composed of shale, mudstone and silt.

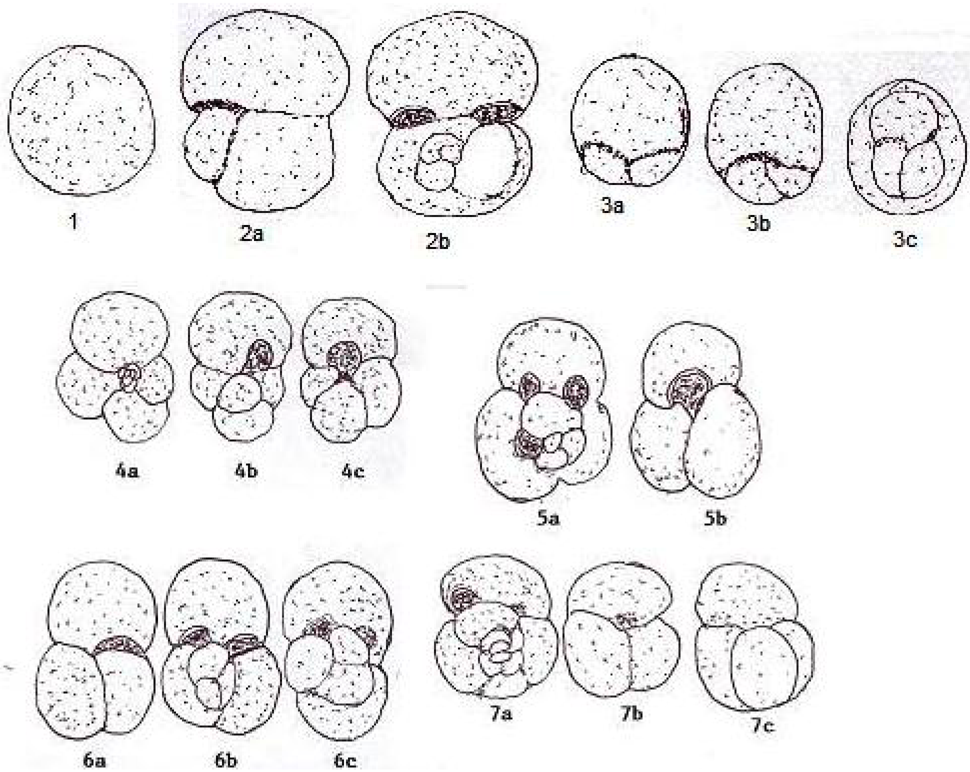

Plate 1. Planktic foraminifera

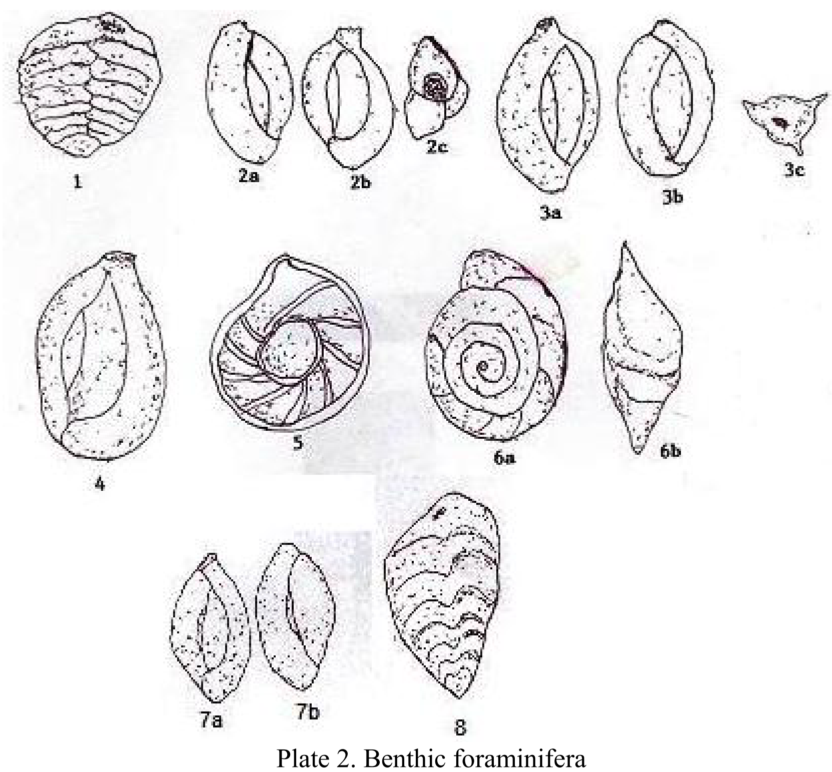

Plate 2. Benthic foraminifera

Explanation of Plate I

1. *Orbulina universa* (d'Orbigny), X60.
2. *Praeorbulina transitoria* (Blow) X100 (a) side view (b) spiral view

3. *Praeorbulina glomerosa* (Blow) X100 (A) side view (b) umbilical view (c) Spiral view
4. *Globigerina praebulloides* (Blow), X70, (a) spiral view (b) side view (c) umbilical view
5. *Globigerinoides ruber* (d'Orbigny), X70, (a) dossal view (b) ventral view
6. *Globi gerinoides immaturus* (Le Roy), X100 (a) dorsal view (b) side view (c) umbilical view
7. *Globigerinoides obliquus* (Bolli), X60 (a) spiral view (b) side view (c) Umbilical view

Explanation of Plate II:

1. *Poritextularia panamensis* (Cushman) X70
2. *Quinqueloculina microstate* (Natland) X65 (a) dorsal view (b) ventral view (c) apertural view
3. *Quinqueloculina lamarckiana* (d'Orbigny) X45 (A) ventral view (b) dorsal view (c) apertual view
4. *Quinqueloculina seminulum* (Linne) X100
5. *Lenticulina inornata* (Linne) X50
6. *Heterolepa pseudeoungeriana* (Franzenau) X70
7. *Quinqueloculina lamarckiana* (d'Orbigny) X64 (a) side view (b) opposite side view
8. *Textularia laminata* (Cushman) X70

6. Conclusion

This study was carried out on ditch cutting samples of Oloibiri-1 well. The studied depth interval ranges from 20-12,000 ft. The Lithology is composed of grey shale and mudstone/siltstone beds with intercalation of sand/sandstone beds. The topmost parts of the sequence in the well are mainly sands.Foraminiferal biostratigraphic characteristics of the well have been analysed. There was poor foraminiferal recovery from the well. However, a planktic foraminiferal zone was established and it is the *Praeorbulina glomerosa* Zones which corresponds to N8-N9 zone of Blow (1969, 1979). The benthic foraminiferal zone established is the *Poritextularia panamensis* Zone which is a taxon range zone.

The observed foramniferal assemblages especially the benthics together with other accessory microfauna indicated that the sediments of the well were deposited in a lithoral (beach) – deltaic to marine (inner neritic, inner to middle neritic and middle neritic) environments.

Based on the lithologic, foraminiferal and paleoenvironmental analysis of Oloibir-1 well, it is inferred that the intervals penetrated by the well correspond to Benin and Agbada formations, and they are of Miocene age.The alternation of sands and shales/mudstones within the sequence provides the combination of source, reservoir and cap rocks essential for hydrocarbon generation, accumulation and trapping.

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