

Foraminiferal Assemblage and Palaeoenvironment: A Case Study of Meren 31 Side Tract -2 Well, Offshore Niger Delta

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Abstract
A total of one hundred and thirty seven (137) ditch cutting samples retrieved from a well in shallow offshore western Niger delta were composited to sixty-nine (69) and analyzed to determine the microfossils that characterized and for environmental reconstruction of that portion of the Niger delta. Twenty-two (22) benthonic species aside the indeterminate benthos were found in the interval studied. Prominent 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. The arenaceous forms identified include Ammobaculites spp., Haplophragmoides sp., Alveolophragmium crassum, Cyclammina spp**.** and Poritextularia panamensis. Deep water species identified include Verneuillina sp., Karrerialla spp., and Karreriella siphonella. Two informal benthonic zones were proposed for the interval, which also falls within Agbada Formation. They are Heterolepa Pseudoungeriana Informal Zone (1507 m – 1945 m) and Lenticulina Inornata Informal Zone (2420 m– 2758 m) suggesting the depth range studied to be deposited during Early to middle Miocene. The sediments were deposited within inner to middle neritic environment, inner neritic environment and coastal deltaic environments.
Keywords: Benthonic, Agbada Formation, Heterolepa Pseudoungeriana, Lenticulina Inornata, paleodepth.

INTRODUCTION
Meren 31 side tract -2 well is located in the shallow offshore western Niger Delta (Fig.1) within the Oil Mining Lease (OML)-95 of Chevron Nigeria Limited. The purpose of the study is of two folds; first, to document the foramineferal recoverable in a portion of the western Niger delta; and second, to apply the result in the environmental reconstruction as well as in paleoclimatic and paleodepth studies of Agbada Formation as penetrated by Meren 31 side tract -2 well.

Published information on foraminifera assemblage in the Niger delta remains scanty in spite of the numerous studies that date back to the early exploration efforts that has today made the basin one of the most prolific deltaic hydrocarbon provinces of the world. Prominent among the few publications include Adegoke et al (1976) that gave a detailed account of the ecological, biological, biofacies and lithofacies characteristics of the modern Niger Delta; Ozumba (1995), which identified *Brizalina aenariensis* (Costa), *Globigerinoides ruber* (d'Orbigny) and *Alveolophragmium crassum* (Reuss) as good index species in the Miocene – Pliocene of the Niger Delta; Omoboriowo et al. (2011) who suggests the fossil *Orbulina universa* as the index fossil for Middle Miocene for some strata in the offshore, Niger delta; and Chiaghanam et al. (2011) that used some key species like *Bolivina Mandoroveensis, Cibicorbis Inflata Bolivina Mandoroveensis,* not only for paleoenvironmental indicator but for the determination of key stratigraphic surfaces during early Miocene in the Delta.

In addition, based on the presence of *Eggerella bradyi* and the first downhole occurrence of *Cyclammina cf. minima* some sequences in the deep offshore Niger delta were dated Late Miocene (Boboye and Adeleye, 2009). Even though, Okosun et al. (2012) claimed that the planktic foraminiferal preservation in the wells from Akata field, onshore southeastern Niger delta is poor, they recognised in the field four planktic zones, namely: *Globorotalia continuosa* zone, *Globorotalia mayeri* zone, *Praeorbulina glomerosa* and *Globorotalia peripheroroacuta* zone together with the following benthic zones: *Spirosigmoilina oligocaenica, Uvigerina sparsicostata*, and *Eponides eshira/Brizalina mandorovensis, Brizalina andorovensis*/*Eponides eshira* and *Poritextularia panamensis.* With these the interval studied was dated Miozene based on foraminiferal assemblage. This study therefore attempts to add to information on the micro faunal recoverable from the Niger Delta, Nigeria, which could assist in the ongoing biozonation scheme refinement of the delta.

GEOLOGICAL SETTING
The Niger Delta is situated in the Gulf of Guinea (Fig. 1) and extends throughout the Niger Delta Province as defined by Klett and others (1997). From the Paleocene to the present, the delta has prograded southwestward over the continental edge onto oceanic basement, forming depobelts that represent the most active portion of the delta at each stage of its development (Doust and Omatsola, 1990). These depobelts form one of the largest

regressive deltas in the world with an area of some 300,000 km^2 (Kulke, 1995), a sediment volume of 500,000 km^3 (Hospers, 1965), and a sediment thickness of over 10 km in the basin depocenter (Kaplan and others, 1994). The three major depositional environments typical of most deltaic environments (marine, mixed and continental) are observable in the Niger Delta and are represented by Benin, Agbada and Akata Formations (Short and Stauble, 1967). The Benin Formation extends from the west across whole Niger delta area and southwards beyond the present coastline. It is over 90% sandstone with shale intercalations; coarse grained, gravely, locally fine grained, poorly sorted sub-angular to well rounded and bears lignite streaks and wood fragments (Weber 1971). The underlying Agbada Formation is a sequence of alternation of sandstones and shales. It consists of an upper predominantly sandy unit with minor shale intercalations and a lower shale unit which is thicker than the upper sandy unit. The lowermost lithostratigraphic unit (Akata Formation) is a uniform shale development consisting of dark grey sandy, silty shale with plant remains at the top (Kruit, 1955) and Oomkens, (1967).

MATERIALS AND METHODS

One hundred and thirty seven ditch cutting samples (137) covering a depth range of 1507 m - 2758 m were subjected to simple sedimentological study using Olympus stereoscopic binocular microscope for observation. All the 137 samples were further composited to 69 for micropalaeontogic involving boiling in water to which hydrogen peroxide (H_2O_2) has been added and washing through 63µm and 125µm sieves until each was free of clay. The clean residues +and counted using Olympus stereoscopic binocular microscope. Distribution of foraminifera species was calculated and environment of deposition inferred using Shannon function (H) of diversity and equitability (E):

$$(H) = (-\sum_{i=1}^{s} Pi \, Ln \, Pi)$$

in which ‘s’ is the number of species in a sample and P_i is the proportion of the i^{th} species in that sample. Equitability was calculated using

$$E = e^{H}/S.$$

RESULTS

Sedimentology

The absence of wireline logs prevented electrofacies and consequently detailed paleo-environmental interpretation of the studied section of Meren-31 well. However, integration of sedimentological and micropaleontological data as well as the general knowledge of the Niger delta suggest that the studied section of Meren-31 well is broadly the transitional paralic lithofacies (Agbada Formation) sequence. The Akata formation was presumed not penetrated at all because of its well known overpressured nature. The sequences studied are predominantly composed of sands with interbedded shale units. The upper part is more sandy than the lower part, which consist of thin sand beds that could not be properly captured because of the sampling depth (18 m) interval, hence the predominantly shale sequences displayed at the lower part in column 2 of figure 2.

Biostratigraphy

The foraminiferal contents (Figure 2) of Meren-31 could be described as rare to common; only few samples yielded an abundant assemblage. In all, twenty-two (22) benthonic species aside indeterminate benthos were recovered. No planktonic foraminiferal was found. Both calcareous and arenaceous forms were identified but the benthonic species were more diverse. The calcareous species include *Lenticulina inornata, Quinqueloculina microcostata, Quinqueloculina Lamarckiana, Heterolepa floridana, Heterolepa pseudoungeriana, Marginulina costata, Cibicides spp., Amphicoryna scalaris caudata, Lagena spp., Lagena striata* etc. The arenaceous forms identified include *Ammobaculites spp., Haplophragmoides sp., Alveolophragmium crassum, Cyclammina spp.*, *Poritextularia panamensis, Verneuillina sp., Karrerialla spp.,* and *Karreriella siphonella.* The total abundance and diversity (Table 1) as well as the range and depth at which these forms occur are shown on the biostratigraphic distribution chart in Figure 2. The results of the calculated Shannon function of diversity and equitability from where the paleoenvironment of the sequences penetrated by the well was inferred is shown in Table 2

Systematic Micropaleontology

Systematic micropaleontology of the foraminiferal taxa encountered in the well is given below following the procedure of Loeblich and Tappan (1964), Phleger and Parker (1951), and Cushman (1939,). All the figured specimens are kept in the Museum of the Federal University of Technology, Akure, Nigeria.
Phylum: PROTOZOA
Class: RHIZOPODA (Von Siebold, 1845)
Order: FORAMINIFERIDA Erchwald, (1830)
Super family: NODOSARIACEA (Ehrenberg, 1836)

Family: LAGENIIDAE (Cushman, 1923)
Genus: *Lagena* (Walker and Jacob, 1789)
Legena striata (Walker and Jacob, 1789) Plate : 1. Fig. p
Description: Test subangular and unilocular; ornamentation consisting of few prominent primary costae running from the aperture to the apical and of the test; aperture small and rounded.
Dimension: 45.7µm x 49.1 µm
Locations: 2475-2493 m and 2621-2640 m
Remarks: Fairly well preserved. Rare in distribution.
Age: Miocene to Recent.
Genus: *Lenticulina inornata* (Linne, 1758) Plate 1, Fig. e, f, and g.
Description: Test relatively small, free planispiral, lenticular and biumbonate; small; aperture radial at peripheral angle.
Dimension: 60.7 µm x 55.1 µm
Locations: 1597-1945 m and 2402-2758 m
Remarks: Majority are well preserved.
Age: Eocene to Recent

Genus: MARGINULINA (d' Orbigny, 1826)
Marginulina costata Plate 1, fig. l
Description: Test subcylindrical, somewhat compressed; earliest portion closed coiled; final chambers inflated; aperture broken.
Dimension: 45.7µm x 49.1 µm
Locations: 1579-1609 m
Age: Miocene to Recent

Genus: AMPHICORYNA (Schlumberger, 1881)
Amphicoryna scalaris caudata (Silvestri, 1906). Plate: 1. Fig r
Description: Test free, elongate, rectilinear, consisting of about five chambers; wall calcareous and finely perforate; surface ornamented with longitudinal costae; aperture terminal.
Dimension: 45.7µm x 49.1 µm
Locations: 1542-1561 m and 1615-1634 m
Age: Miocene.
Super family: CASSIDULINACEA (d'Orbigny, 1839)
Family: NONIONDAE (Schultze, 1854)
Genus: *Florilus* (De Montfort, 1808)
Florilus costiferus (Cushman, 1926). Plate: 1 fig. o
Description: Test free, planispiral, involute, peripheral margin rounded; umbilical region slightly depressed; wall calcareous and finely perforate; aperture narrow and interiomarginal.
Dimension: 46.5µm x 42.6 µm
Locations: 2475-2658 m
Remarks: Recovered only in certain depth in the well.
Age: Miocene
Genus: *Heterolepa* (Franzenau, 1876)
Heterolepa pseudogeriana (Franzenau, 1884). Plate: 1 fig. a & b.
Description: Test free, trochospiral, unequally biconvex or planoconvex, periphery bluntly angled, flat to slightly convex ,evolute spiral side; wall calcareous; thick and lamella; coarsely and regularly perforate.
Dimension: 62.5µm x 60.1 µm
Locations: 1579-1945 m and 2420- 2758 m
Age: Miocene to Recent
Super family: ROTALIACEA (Ehrenberg, 1839)
Family: BOLIVINITIDAE (Cushman, 1927)
Genus: BOLIVINA (D'Orbnigny, 1839)
Bolivina scalptrata miocenica. Plate: 1 fig. k.
Description: Test elongate, somewhat compressed, chambers low, biserially arranged throughout, wall calcareous, perforate; aperture large, U-shaped and not supported by neck.
Dimension: 43.6µm x 41.5µm
Locations: 2438-2694 m
Remarks: Occurred rarely in the well.
Age: Miocene.

Family: LITUOLIDAE (de Blainville, 1825)
Sub Family: CYCLAMMINANAE (Marie, 1941)
Genus: *Alveolophragmium* (Stchedrina, 1936)
Alveolophragmium crassum (Stchedrina, 1936). Plate: fig c & d.
Desription: Test trochoid, medium to coarsely arenaceous with shell material on the wall surface, chambers-globular, inflated, about seven visible in the last whorl, sutures distinct, straight and lobulate, aperture cresentic shaped, broadly interiomarginal.
Dimension: 44.7µm x 47.1 µm
Locations: 2438-2713 m
Remarks: Recovered at certain depth, well preserved and rare.
Age: Miocene to Recent
Super family: MILIOLACEA (Ehrenberg, 1839)
Family: MILIOLIDAE (Ehrenberg, 1839)
Genus: QUINQUELOCULINA (D' orbigny, 1826)
Quinqueloculina lamarckiana (D' orbigny 1839). Plate: 1 fig. j
Description: Test elliptical, somewhat triangular, chambers angled, slightly convex, earlier chambers strongly overlapping, aperture oval, unidentate, tooth elongate and single.
Dimension: 62.3 µm x 65.1 µm
Locations: 1579-1597 m
Remarks: Recovered in lower part of the well. Poorly preserved.
Age: Oligocene to Recent

Paleoecology.

Table 3 shows the mode of life, substrate, mode of feeding, salinity, paleo-temperature and paleodepth of some key forms as shown in the work of Murrays (1991).

DISCUSSION

Paleodepths and Paleotemperature

In the upper part (Fig.2) of Meren-31st-2 well, the occurrence of *Heterolepa pseudoungeriana, Heterolepa floridana, Bolivina scalprata miocenica., Marginulina costata* etc. suggest warm, temperate – tropical environments and shallow depths (Murray, 1991). *Amphycoryna scalaris caudata* needs approximately 15°C of temperature for reproduction and depths of 0 – 50m (Murray, 1991). This area may probably belong to the inner shelf (Murray, 1991) or inner neritic at 1561 - 1743 m and inner neritic – middle neritic environments (Murray, 1973) at 1725 – 1890 m because of this foraminifera association and occurrence of arenaceous *Ammobaculites spp*.

The occurrence of some temperate – cold arenaceous species of *Haplophragmoides sp*., and *Alveolophragmium crassum* (Figure 2 and Table 2) coupled with a change in temperature and salinity (Murray, 1991) at depths 2219 – 2438 m could be associated to deepening (shelf – bathyal environment). Murray (1991) reported that the genera *Alveolophragmium* thrive better at temperatures of about 10°C and depths between 20 – 700 m. A mid shelf environment is therefore proposed for interval 2438 – 2512 m, due to abundant occurrence of *Alveolophragmium crassum.*

The lower parts of Meren-31st-2 well, from 2512 m to the last sample, 2758 m, are dominated by deeper depth arenaceous species with affinities for cold temperature. Some of the species that are indicative of cold temperature within this zone, includes *Karreriella siphonella*, which thrives at temperatures below 10°C and dwells in outer shelf/outer neritic to bathyal environments (Murray, 1991), so also Reophax spp., prefer a cold – temperate environment.

In this (lower) region of Meren-31 st-2 well (deeper than 2658 m) ocean depths probably exceed 100 m and may also be an outer shelf environment or beyond. The genera, *Verneuilina spp* are mostly found at depths greater than (>) 100 m (Murray, 1991) and even the occurrence of deep water species *Poritextularia panamensis* in this region further gives credence to this.

Mode of life and mode of feeding

The mode of life and mode of feeding of some living benthonic foraminiferal have been studied by Murray (1973, 1991). Benthic foraminiferal biofacies generally trend parallel to the shore and slope, and reflect the influence of changing substrate, water clarity, turbulence, sedimentation rate, seasonality, temperature, food availability, and dissolved oxygen with increasing depth and distance from the shoreline. The same physical processes and environmental variability responsible for the distribution of modern assemblages were likewise responsible for controlling ancient depth-dependent and distance-from-shore-dependent assemblages (Leckie and Olson, 2003). Since the present is the key to the past, both feeding habits and mode of lives of some benthonic foraminiferals recovered from the studied were deduced following the works of Murray (1973, 1991).

The upper part of the well (1524 – 1945 m) is dominated by *Heterolepa pseudoungeriana, Cibicides spp. Bolivina scalprata miocenica., Heterolepa floridana;Lagena spp.,* e.t.c., which are all epifaunal, clinging/ and free; passive suspension feeders and/ or detrivores with hard or muddy sediments substrate (table 3 and fig 2). Most of these species are floaters or shallow water dwellers. Their subtrates are strong enough to prevent them from being washed away by water current and consequently making feeding easy for them. Deep water arenaceous species are rare within this interval probably due to fact that their mode of life and mode of feeding are not favoured by the prevailing water conditions at this depth interval.

No calcareous species occurred at the middle portion of the well (1945- 2402 m), (fig 2). Infact *Alveolophragmium crassum, Karreriella spp.,* and *Ammobaculites spp*. are the arenaceous species found within this interval. They are basically epifaunal or free living; detritivore with sand, silt, muddy sediment substrates (Table 3). Their mode of life, feeding habit as well as their substrate types have made them adaptable to the relatively harsh water condition at this interval.

The lower part of the well is characterized by the dominance of arenaceous species which include *Alveolophragmium crassum, Karreriella spp., Ammobaculites spp.,* and *Haplophragmoides sp.* Thsese species are basically epifaunal / infaunal or free; detritivore with sand, silt, muddy sediment substrates (Table 3 and Fig. 2). Co-occuring at this interval are calcareous species like *Quinqueloculina lamarckiana, Quinqueloculina vulgaris, Quinqueloculina microcostata, Heterolepa pseudoungeriana, Heterolepa floridana,* e.t.c., majority of which are epifaunal, free or clinging. They are herbivore with plant or sediment substrate (Table 3). The mode of life and mode of feeding as well as substrates of both arenaceous and calcerous species retrieved at this interval within the well are so designed to adapt to water conditions at deeper depth or water bottom.

Informal Benthonic Foraminiferal Zonation Of Meren 31st-2

Using benthonic forams for bioevents in the area of study created some difficulties. However, the abundance and diversity (Table 2) of the benthics suggests three condensed sections (Fig. 2). But based on the stratigraphical ranges of benthonic foraminifera species identified in this well, two informal benthonic zones have been suggested. They are *Heterolepa pseudoungeriana* informal zone (1507 m – 1945 m) and *Lenticulina inornata* zone informal (2420– 2758 m)

Heterolepa pseudoungeriana informal zone (1507 – 1945 m). This zone is entirely dated as Early Miocene. The base of this zone is defined by the last down-hole occurrence (LAD) of *Heterolepa pseudogeriana and Lenticulina inornata* .The top of the zone is defined by the first downhole occurrence (FDO) of *Marginulina costata, Quinqueloculina lamarckiana, Cibicides spp., Lenticulina inornata, and Amphycoryna scalaris caudata* and quantitative occurrence of *Heterolepa pseudoungeriana.*

The *Heterolepa pseudoungeriana* zone is characterized by the restricted occurrence of *Heterolepa floridana* and complimented by the abundant occurrence of *Lenticulina inornata* and *Marginulina costata*.

Lenticulina inornata informal zone (2420– 2758 m).This zone spans through the Middle Miocene age. The base of the zone is defined by the quantitative base occurrence of *Lenticulina inornata* and the last appearance datum (LAD) of *Bolivina scalaris caudata*. The top of the zone is marked by the remarkable constant presence of *Heterolepa pseudoungeriana* at depths shallower than 2438 m, reduction in the dominance of *Lenticulina inornata* from 100% at 2420 m and 2694 m to almost 0% at 2731 m. Other associated benthonic species that helped in defining this zone are *Lagena striata, Lagena spp, Heterolepa flodina, Ammobaculites spp, Alveolophragmium crassum, Poritextularia panamensis.* and *Heterolepa pseudoungeriana*. This zone contains the highest agglutinated benthonic assemblage.

Inferred Environments of Deposition

Three different values measured for diversity are shown in Table 2. These measurements and their relation to information theory have been explained by a number of authors (e.g., Buzas and Gibson, 1969). Using the measurement for environmental delineation, Murray (1991) concluded that H(S) values less than (<) 0.60 indicate brackish waters while values greater than (>) 2.1 indicate normal marine environments. In this study (Table 1) the number of species studied ranges from one (1) to fourteen (14), the spread of Shannon – Weaver function (Information theory, H) is also low ranging from 0 – 0.87 with equitability values ranging from 0.11 – 1.00 (1.00 being the maximum value for equitability).. At 2658 m, the highest H(S) value of 0.87 was recorded and from this depth to about 1551 m, H(S) decreases to 0.12 except at 2676 m where it became zero. From 1524 m to about 1689 m, H(S) was relatively low; in fact less than (<) 0.6. For this reason, brackish water environment was suggested for this (interval. (Murray, 1991).

From 2621 m to 2749 m H(S) values increase from between 0 and 0.87 with equitability ranging from 0.11, this depth interval probably range from brackish to fresh environment. Following Murray's proposition, normal marine environment could not be suggested for any depth interval because H(S) greater than (>) 2.1 was not recorded.

The values information function and equitability were slightly constant from 1780 m to 1798 m, with H(S) values between 0 and 0.32 and equitability with values a greater than zero or equal to 0.45.

From the above argument, it could be deduced that there probably exist similar environments or environmental conditions between 1597 – 1615 m and 1780 – 1798 m and 1862 – 2283 m. And according to Murray (1991), lesser values are typical of the most stressed areas.

On the basis of foraminiferal assemblage present, the intervals studied in the well have been delineated into three environments of deposition. These are from base to top:

(1) Inner to Middle Neritic environment;
(2) Inner Neritic Environment;
(3) Coastal Deltaic environment.

Inner Neritic Environment

This environment is recognized in the well at the depth of 1561 – 1945 m and 2402 – 2694 m. These intervals are essentially intercalation of shale and sand. The environment is characterized by the abundance of *Lenticulina inornata,* which suggests inner to middle neritic, *Heterolepa pseudoungeriana, Heterolepa floridana, Quinqueloculina microcostata* which also suggest fluviomarine to inner neritic while the presence of *Quinqueloculina lamarckiana* and *Florilus sp* suggests nearshore to inner neritic influence. Other foraminiferal assemblages within this environment are *Ammobaculites strathearnensis, Verneuilina spp sp* and *Alveolophragmium crassum.* These are also found in the inner neritic environment (Murray, 1973).

Due to the dominance of inner neritic influence of majority of the species, the inner nerritic environment has been inferred for these intervals. This probably has some middle neritic effect.

Inner to Middle Neritic Environment

Depths of 1579 – 1652 m and 2420 – 2694 m in Meren 31 st-2 have been assigned to Inner to Middle Neritic environment. The lithologies of these intervals were dominantly of shale with minor intercalation of sand. The shale is grey to dark grey, carbonaceous and pyritic.

The intervals are dominated by inner to Middle Neritic microfauna such as Florilus atlanticus, Lenticulina inornata, Heterolepa pseudoungeriana, Quinqueloculina microcostata Quinqueloculina lamarckiana, Karreriella spp, Karreiella siphonella etc. Murray (1973) has used the assemblage species of Haplophragmoides spp, Lagena, Ammobaculites spp., all of which are present within these intervals and some of the above to infer Inner neritic to outer-neritic bathymetric environment.

Coastal Deltaic Environment

The environment is deduced at intervals 1524 – 1542 m and 1963 – 2384 m in the studied well following the lithology of the environment dominantly of sand with some thin shale intercalations. The shale is light grey to grey and the sand is light-brown to white, subrounded to rounded and contains glauconite. The rare occurrence of foraminiferal assemblages coupled with the absence of foraminiferal inner linning and dinoflagellate cysts enable the delineation of this environment (Muller, 1968).

6. 0 CONCLUSIONS

The predominance of sands with interbedded shale units in the studied sequences as revealed by sedimentological analysis integrated with foraminiferal data as well as the general knowledge of the Niger delta suggest that the studied section of Meren-31 well is broadly the transitional paralic lithofacies of Agbada Formation.

Benthonic foraminiferal species showed signs of good preservation and were free from selective dissolution. It is therefore possible that the sediments must have been deposited above the Calcium Compensation depth (CCD).

The spread of Shannon – Weaver function (Information theory, H) is also low ranging from 0 – 0.87 with equitability values ranging from 0.11 – 1.00, suggesting brackish to fresh water environment (open marine) of deposition for the section studied.

The presence of *Lenticulina inornata, Heterolepa pseudoungeriana, Heterolepa floridana, Quinqueloculina microcostata, Quinqueloculina lamarckiana* and *Florilus* together with sedimentological paramerters are indicative of Inner Neritic, Inner to Middle Neritic and Coastal Deltaic environments of deposition.

Paleodepth did not exceed 700 m whereas paleotemperature ranges between 10^0C - 15^0C as indicated by abundant occurrence of *Alveolophragmium crassum, Karreriella siphonella*, and *Amphycoryna scalaris caudata*

Shallow water dwellers or floaters such as by *Heterolepa pseudoungeriana, Cibicides spp. Bolivina* *scalprata miocenica., Heterolepa floridana;Lagena spp*., e. t. c, dominates the upper part of the well (1524 – 1945 m) whereas *Alveolophragmium crassum, Karreriella spp., Ammobaculites spp.,* and *Haplophragmoides sp* which are all bottom dwellers are the_dominate species identified at lower part of Well.This indicates that foraminiferal assemblages present in the studied interval of the well show good adaptability to the prevailing water conditions in their environment.

Two informal benthonic zones could be inferred for the interval studied: *Heterolepa Pseudoungeriana* Informal Zone (1507 m – 1945 m) and *Lenticulina Inornata* Informal Zone (2420 m – 2758 m), which put the age at Early to middle Miocene

Acknowledgements.
Many thanks to the Department of Applied Geology of the Federal University of Technology, Akure, Nigeria for permitting the use of the samples provided by Chevron Nig. Limited for research purposes. Dr. Fadiya facilitated the use of Crystal Age limited laboratory for the analysis. These are all appreciated.

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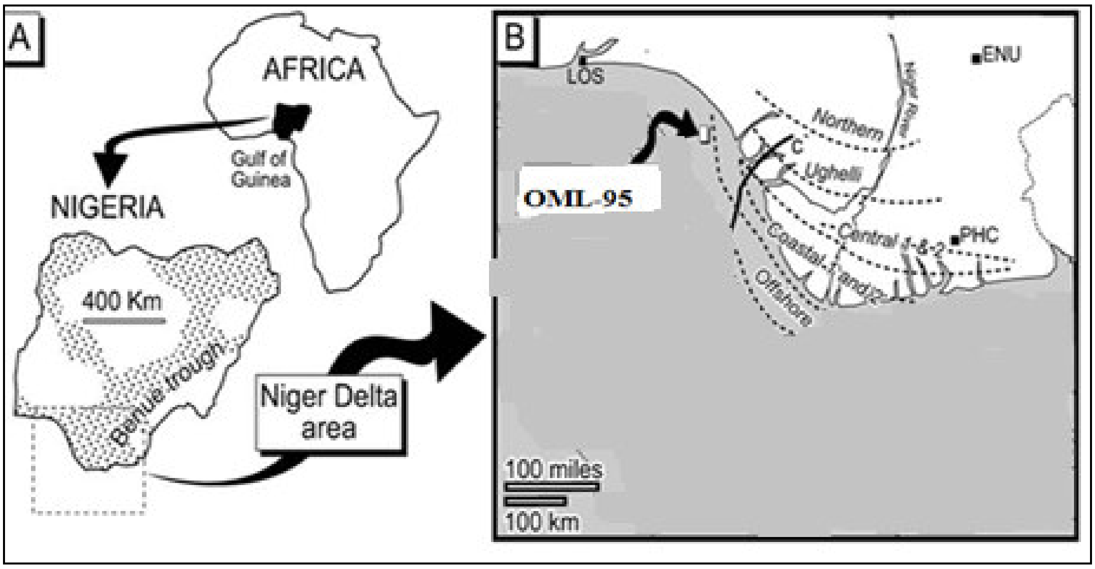

Figure 1: (A) Location of Niger Delta in Africa. (B) Location of Meren field along the western corner of Niger Delta.(modified from Short and Stauble 1967).

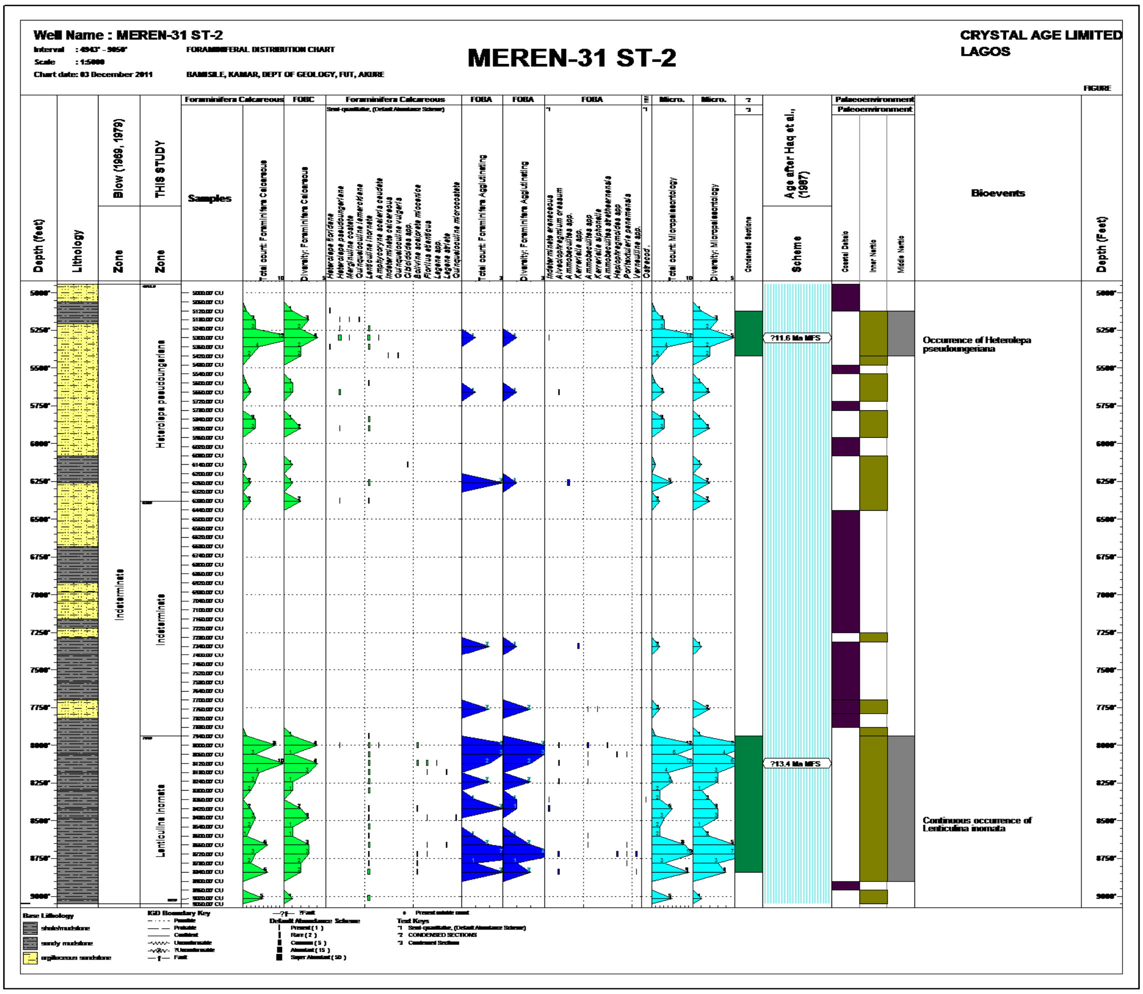

Figure 2: Meren-31 st-2 foraminiferal distribution chart.

PLATE 1: FORAMINIFERAL ASSEMBLAGES OF MEREN 31, WELL.

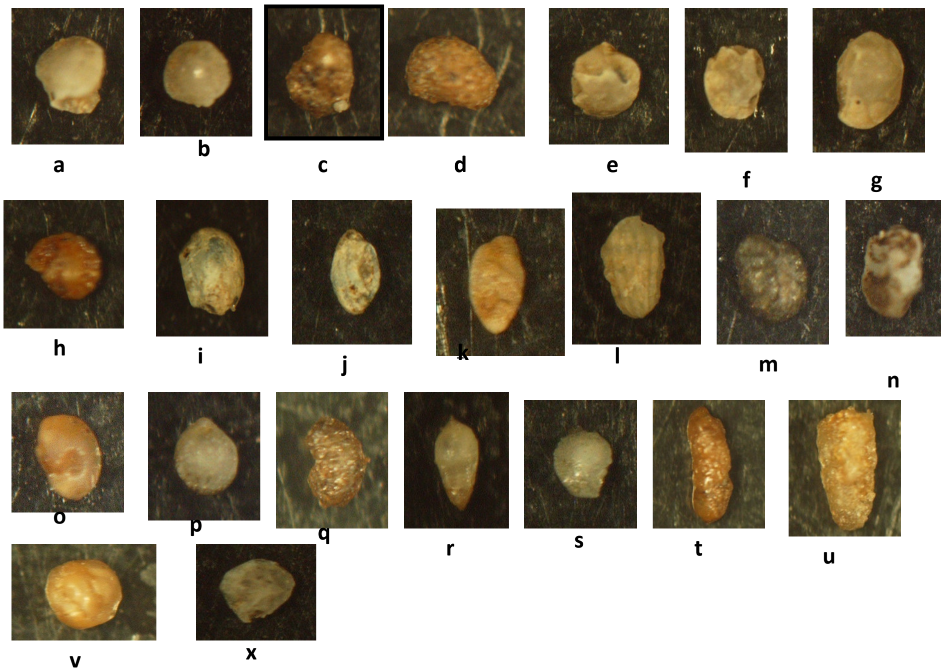

Plate 1.
Fig. a and b: *Heterolepa pseudogeriana* (Franzenau, 1884). 62.5µm x 60.1 µm
Fig. c and d*:* *Alveolophragmium crassum* (Stchedrina, 1936). 44.7µm x 47.1 µm
Fig. e, f and g*:* *Lenticulina inornata* (Linne, 1758). 60.7 µm x 55.1 µm
Fig. h: *Cibicidiodes* _(Franzenau, 1884).
Fig. i: *Quinqueloculina vulgaris* (D' orbigny 1839).

Fig. j:_*Quinqueloculina lamarckiana* (D' orbigny 1839). 62.3 µm x 65.1 µm
Fig. k: _*Bolivina scalptrata miocenica*_(D'Orbnigny, 1839). 43.6µm x 41.5µm
Fig. l: *Marginulina costata*_(d' Orbigny, 1826). 45.7µm x 49.1 µm
Fig. m: *Amphicoryna scalaris spp*_(Silvestri, 1906).
Fig. n: *Poritextularia panamensis*_(Linne, 1758).
Fig. o*:* *Florilus costiferus* (Cushman, 1926). 46.5µm x 42.6 µm
Fig. p*:* *Legena striata* (Walker and Jacob, 1789). 45.7µm x 49.1 µm
Fig. q: *Ammobaculites strathenaisis* (d' Orbigny, 1826)
Fig. r*:* *Amphicoryna scalaris caudata* (Silvestri, 1906). 45.7µm x 49.1 µm
Fig. s:_*Heterolepa floridana* (Franzenau, 1884).
Fig. t*:* *Karreriella siphonella* (Cushman, 1926).
Fig. u*:* *Karreriella spp*_(Cushman, 1926).
Fig. v:_*Quinqueloculina microcostata*_(D' orbigny 1839).
Fig. w: *Verneuilina spp* (Linne, 1758).

Table 1: Benthonic compositions of Meren 31st-2 well.

DEPTH (M)	TOTAL BENTHICS	DIVERSITY
1542- 1561	1	1
1561 -1579	3	3
1579 -1597	3	2
1597 -1615	14	5
1615– 1634	4	2
1634 – 1652	2	2
1652-1707	1	1
1707– 1743	3	2
1707 -1780	3	1
1780– 1798	2	1
1798 – 1871	1	1
1871-1908	5	2
1908- 1944	1	1
1944– 2237	2	1
2237 – 2365	2	2
2365 – 2420	1	1
2420 – 2457	12	7
2457– 2474	6	4
2474 – 2493	12	6
2493 – 2511	4	3
2511- 2530	5	3
2530-2566	*2*	2
2566-2585	*5*	3
2585-2603	*3*	3
2603-2621	*2*	1
2621-2631	*2*	2
2631-2658	*8*	5
2658-2676	10	7
2676-2694	3	3
2694-2713	9	4
2713-2758	5	1

Table 2: Distribution of foraminifera species. Shannon function of diversity (H) = (–) in which 's' is the number of species in a sample and Pi is the proportion of the ith species in that sample. Equitability is /S.

DEPTH(ft)	No OF SPECIES IN SAMPLE	SHANNON FUNCTION (H)	EQUITABILITY	REMARKS
1561	1	0	1	Brackish
1579	3	1.1	1	Fresh water
1597	3	0.32	0.46	Brackish
1615	14	0.33	0.1	Brackish
1634	4	0.17	0.23	Brackish
1652	2	0	0.5	Brackish
1707	1	0	1	Brackish
1725	2	0.72	1	Fresh water
1780	3	0.30	0.45	Brackish
1798	3	0.32	0.46	Brackish
1908	2	0.72	1	Fresh water
1945	2	0	1	Brackish
2420	1	0	1	Brackish
2438	12	0.47	0.11	Brackish
2457	6	0.08	0.18	Brackish
2475	6	0.56	0.15	Brackish
2493	4	0.18	0.3	Brackish
2512	5	0.12	0.23	Brackish
2530	2	0.72	1	Fresh water
2548	1	0	1	Brackish
2566	5	0.11	0.22	Brackish
2585	3	0	1	Brackish
2603	2	0.72	1	Fresh water
2621	2	0	1	Brackish
2640	8	0.45	0.11	Brackish
2658	10	0.87	0.24	Fresh water
2676	3	0	1	Brackish
2694	9	0.74	0.23	Fresh water
2749	5	0.12	0.23	Brackish

TABLE 3: ECOLOGICAL DATAOF SOME FORAMINIFERAL SPECIES FROM MEREN 31, WELL.

FORAMINIFERAL SPECIES	MODE OF LIFE	SUBSTRATE	MODE OF FEEDING	SALINITY	TEMPERATURE	DEPTH
	Using Murrays (1991) model		Using Pileous (1964) model			
Alveolophramium crassum	Epifaunal,free	sand	Detritivore	Marine	$10^{o}{}_{c}$	20-700m
Ammobaculites spp.	Infaunal free	Muddy sediment	Detritivore	Brackish-marine	Temperate-tropical	0-180m
Amphicoryna scalar cudata	Epifaunal clinging	Phytal, Carbonate sediment	Herbivore, symbiont	Marine	$18\text{-}26^{0}{}_{c}$	0-50m
Ammobaculites strathearmensis	Infaunal free	Muddy sediment	Detritivore	Brackish-marine	Temperate-tropical	0-180m
Bolivina scalprata miocenica	Infaunal-epifaunal free	Muddy sediment	Detritivore	Marine	Cold to warm	0-400m
Cibicides spp.	Epifaunal attached	Hard substrates	Passive suspension feeder	Marine	Cold	0 to> 2000m
Haplophragmoides sp.	Infaunal free	Mud-sand	Detritivore	Marine	Temperate Cold	0-4000m
Heterolepa floridana	Epifaunal clinging	Hard substrates	Passive suspension feeder	Marine	Temperate Cold	0-4000m
Heterolepa pseudoungeriana	Epifaunal clinging	Hard substrates	Passive suspension feeder	Marine	Temperate Cold	0-4000m
Karreriella spp	Epifaunal free	Mud,silt	Detritivore	Marine	$<10^{0}{}_{C}$	0-4000m
Karreriella siphonella	Epifaunal free	Mud,silt	Detritivore	Marine	$<10^{0}{}_{C}$	0-4000m
Lagena spp	Infaunal free	Sand	Detritivore	Marine	$<15^{0}c$	0-400m
Lagena striata	Infaunal free	Sand	Detritivore	Marine	$<15^{0}c$	0-4000m
Lenticulina inornata	Epifaunal free	Mud	Detritivore	Hypersalin e	Cold	180-4000m
Lenticulina sp.	Epifaunal free	Mud	Detritivore	Hypersalin e	Cold	180-4000m
Quinqueloculina lamarckiana	Epifaunal Free or clinging	Plants or sediment	Herbivore	Marine-hypersalin e	Cold-warm	Hypersaline Lagoon
Quinqueloculina vulgaris	Epifaunal Free or Clinging	Plants or sediment	Herbivore	Marine-hypersalin e	Cold-warm	Hypersaline Lagoon
Quinqueloculina microcostata	Epifaunal Free or clinging	Plants or sediment	Herbivore	Marine-hypersalin e	Cold-warm	Hypersaline Lagoon