FORAMINIFERAL ANALYSIS OF AE-1 WELL, AGBADA FORMATION ONSHORE, WESTERN NIGER DELTA BASIN: IMPLICATION FOR BIOZONATION AND AGE DATING

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(Received 13 July 2020; Revision Accepted 24July 2020)

ABSTRACT

Foraminiferal and sedimentological analysis was carried out using ditch cutting samples from intervals 2700 ft. - 10,185 ft. in AE-1 well. The samples were composited at 60 ft. into ninety four (94) ditch cutting samples. The standard micropaleontological sample procedures to recover the foraminiferal biofacies assemblages was utilized, followed by analysis and interpretation of the obtained results. The sedimentological analysis reveals five lithofacies - sandstone, sandy shale, shaly sand, mudstone and sandy clay which constitute part of the Agbada Formation of the Niger Delta. The foraminiferal fauna recovered from the samples studied comprised of twenty four species grouped into nineteen genera from nineteen families and nineteen subfamilies. A few number of miscellaneous microfossils such as Ostracoda, Holothurioidea and Echinoderm remains were recovered. The total count of foraminiferal defined from this well is four hundred and ninety four (419). The planktic foraminiferal count was two hundred and forty two (242) (57.8 % of the total count) while the benthics foraminiferal count was one hundred and seventy seven (177) (42.2 % of the total count). Among the benthic forms, the calcareous consists of one hundred and forty nine forms (149) (33.4 % of the total benthic count) while the agglutinating benthic forms were thirty seven (37) (8.8 % of the total benthic count). One (1) planktic (Chiloguembelinacubensis) and three (3) benthic (Eponidesberthelotianus, Hanzawaiastratonii and Nonionellaauris) informal foraminiferal zones were established in the well. The age of the AE-1 well sediments has been interpreted to belong to Early Oligocene - Early Miocene in comparison with foraminiferal markers species whose stratigraphic ranges are well established in the Niger Delta and globally. This inferred the presence of the Rupelian - Burdigalian sediments in the Niger Delta.

KEYWORDS: Foraminiferal, Biozone, Age, Rupelian, Burdigalian.

INTRODUCTION

Biozone units are intervals of geological strata demarcated based on their typical fossil taxa found in them. These may be a single taxon or combination of taxa. A sequence of biozones is called biozonation. These fossil taxa characterize the diversity of things living at the time the sediment was laid down, and the changes in fossil faunas function as stratigraphic time lines. With the identification of fossils in a sequence of rock, correlation of rock units with changing lithologies across enormous distances and establishment of time horizons in lithologically even rock units can be attained. The boundary of two different biostratigraphic units is called a biohorizon which can be subsequently divided into sub-biozones.

The main data of biostratigraphic analysis are: the occurrence or nonexistence of a fossil taxon in a geologic horizon; the First Downhole Occurrence (FDO) /Last Appearance Datum (LAD); the First Appearance Datum (FAD)/Last Downhole Occurrence (either local or global). Rock unit categorized by one or more taxa can be differentiated from next rock units with one or more other taxa to form biozone or zone. As submitted by Nichols Gary (2009), biozones must have a type section designated as a stratotype. These stratotypes are named according to the typical taxon (or taxa) that are found in that particular biozone. Foraminiferal are good microfossil that can be utilized in erecting / establishing biozones as they tend to exist even in very small samples and evolve comparatively. Benton and Michael (2009).Several foraminiferal biozonation studies have been carried out with the utilization ofcorces, sidewall and ditch cutting samples in the Tertiary Niger Delta Basin. Various significant biozonation studies carried out include the work of Ifeoluwadun and Saka (2018). They established two informal planktonic foraminiferal zones (Globoquadrina dehiscens and Globigerinoidesrubra).

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four informal benthonic foraminiferal zones (Cyclaminacancellata, Lenticulinainornata, Marginulinaostata/Quinqueluculinamicostata and Heterolepapseudogeriana) from foraminiferal biostratigraphy of Opolo-5 Well, Western Niger Delta, Nigeria. The age of the well varies between Late Miocene-Early Pliocene. Similarly, Ukpung et al., (2017), worked on the foraminiferal biozonation of “well k-27”, located in the Greater Ughelli Depobelt, Niger Delta Basin, South Eastern Nigeria. The results from their analyses showed that the well section produced distinctive benthic foraminiferal markers such as Hopkinsinabononiensis, Spiroplectamminawrightii, Uvigerinellasparsicostata, Lenticulinagrandis and Bolivinaimperatrix which relates to P18-P19, P20/N1, P21/N2 and P22/N3 foraminiferal zones utilized to allocate an Early Oligocene to Late Oligocene and younger ages for the well. Also, four informal foraminiferal zones were recognized - Globigerinaseili/pseudohastigerinabarbadoensis zone (P18-P19), Globigerinamultipapulosa zone (P20/N1), Globorotaliapomerajca zone (P21/N2) and Globigerinaciperoensis zone (P22/N3). Besides, Ajayi and Okosun (2014), worked on the planktic foraminiferal Biostratigraphy in four well (A, B, C and D well). Three planktonic foraminiferal biozones were erected and correlation of the studied sections were established. The investigated well penetrated Late Miocene to Early Pliocene sedimentary sequence. Equally, Okosun et al., (2012), established three informal planktonic and benthic foraminiferal zones from two wells (Akata-2 and Akata-4). Also, one planktonic and benthic informal foraminiferal zone were recognised in the remaining two wells (Akata - 6 and Akata - 7), of the Akata field in the eastern Niger Delta Basin. Correspondingly, Oloto and Promise (2014) worked on the biostratigraphic analysis of core samples from three wells. Two of the wells are from offshore depositional belt and the remaining one well is from the onshore coastal swamp depositional belt in southwestern Niger delta. Based on the First Appearance Datum (FAD) and last Appearance Datum (LAD) of diagnostic faunal makers such as Globorotaliaobesa, Globigerinoidesbispinatus, Globigerinoidesobligatus, Globigerinoidesmammatus, Orbulinauniversa and Orbulinasuturalis, the sediments penetrated by the wells was dated as Early Miocene. Besides, the occurrence of Early-Middle Miocene benthic foraminiferal assemblage such as Bolivinamicoenena, Lenticulinarotulata, Alvolephonagriumcrassum, Bolivinabeyrichi, Saccamminacomplanata and Cyclamminiminima also give credence to the age assigned to the wells. Likewise, Petters (1983) carried out a study on the planktic foraminiferal constituent of the Niger Delta as part of the Gulf of Guinea. Nine planktic foraminiferal zones were recognised which includes: Subbotinapraecursoria zone (Late P1), Morozovellapussilamorozovellaangulata zone (P3), plankorotalitespseudomendosa zone (P4), Morozovellavelascoensis - M. Subbotininae zone (P5-P6), Acaninapentacameratatazone (P9), Globorotaliapomerajca zone (P21), Globigerinaciperoensis – Globorotaliakugleri zones (P22-N4), Praeorbulinaglomerosa zone (N8), Globorotaliafohsifohsi- G. fohsiobata-robusta zones (N10-11). Samples were collected from AE-1 well, located at geographic coordinates of Longitude E5° 33'55".58 and Latitude N6° 18'32".64 in the Greater Ughelli Depobelt of the Niger Delta Basin. Fig.1. This study does not include the systematic description/classification of foraminiferal as proposed by Loeblich and Tappan (1987). However, the study intends to analyse the foraminiferal contents from the sediments and establish the biozonation and determine the age of the penetrated well. It is hoped that information from the findings will add to the already existing literature in the Niger Delta Basin.

Figure 1: Location map showing the study area in the western Niger Delta and simplified bathymetry (after Bakare et al., 2009).
GEOLOGIC SETTING AND LITHOSTRATIGRAPHY OF THE NIGER DELTA BASIN

The Niger Delta is one of the World’s largest Tertiary delta systems and an exceptionally prolific hydrocarbon province. It is situated on the West African continental margin at the apex of the Gulf of Guinea, which formed the site of a triple junction during continental break-up in the Cretaceous. Doust (1990). The current morphology of the Niger Delta is that of a wave-dominated delta, with a smoothly seaward-convex coastline traversed by distributary channels. Doust (1990). From apex to coast the subaerial portion stretches more than 300 km, covering an area of 75,000 km². Below the Gulf of Guinea, two massive lobes extend beyond an additional 250 km into deeper waters. Doust (1990). It is located between Latitudes 3° and 6° N and Longitudes 5° and 8° E respectively in the Gulf of Guinea, on the margin of West Africa. Figure 1.

Doust (1990), posited that the Delta stratigraphic sequence is made up of three gross lithofacies with an upward-coarsening regressive association of Tertiary clastics that is up to 12 km thick. The three key lithostratigraphic units are demarcated in the Niger Delta by several workers: Short and Stauble (1967); Evamy et al., (1978); Doust and Omatsola (1990) among others. The type sections of these Formations have been described by the following authors: Doust and Omatsola (1990); Knox and Omatsola (1989) and Kulke (1995). The oldest subsurface lithostratigraphic unit at the base is the Akata Shales which consist of marine over pressured monotonous marine shale deposited in marine environment. The outcropping units of the Akata Formation is the Imo Shale, Maron (1969); Omatsola and Adegoke (1981) and Salami (1983), which is Paleocene/Eocene to Recent in age. Whiteman (1982), Nwajide (2013), Reijers et al., (1997) and Jev et al., (1993), estimated the thickness to range from 2,000 ft. - 20,000 ft. This is superimposed by the deltaic Agbada Formation consisting of alternations of sandstones, siltstones and claystones of foreshore, upper to lower shoreface source indicating a coarsening upward sequence. The sand percentage increases upwards. The outcropping units of the Agbada Formation are the Ameki Group and Ogwashi-Asaba Formations which is Eocene to Recent in age (Table 1). According to Avbovbo (1978), the thickness ranges from 9,600 ft. - 14,000 ft. (3,000 m - 4,200 m). This is overlaid by alluvial sands of the Benin Formation deposited in continental environment. Shale content increases towards the base of the Formation. This is the youngest of the sequence from Oligocene to Recent. Avbovbo (1978), estimated the Formation thickness to be up to 1,000 ft. Boboye and Fawora (2007), postulated that the Benin Formation is overlain by different types of Quaternary sediments and according to Whiteman (1982), these sediments are deposited on Upper and lower flood plain environments.

Table 1: Stratigraphic column of Niger Delta Basin and other coastal basins in Nigeria according to Omatsola and Adegoke (1981) and Salami (1983).
MATERIALS AND METHODS

Ninety four (94) ditch cutting samples composited at 60 ft. from interval 2700 ft. - 10,185 ft. were provided by the Nigerian Petroleum Development Company (NPDC). Safety requirements were observed in carrying out both the lithostratigraphic and biostratigraphic analyses and caution were taken to prevent contamination of one sample by the other.

Lithostratigraphic analysis was carried out on the samples using reflected binocular microscope and by visual inspection. Physical characteristics such as lithology, texture, colour and sorting, were documented. The presence of calcareous materials in sample was detected with the use of 10 % dilute HCl acid. Biostratigraphic analysis on the other hand adopted the anhydrous sodium carbonate procedure for thorough disintegration of samples as outlined by Brasier (1980). The detailed sample preparation procedures are outlined below:

Logging and Composition of Samples

Labelled samples were laid out sequentially in batches and then composited at 60 ft. interval. Tags and clean plates were arranged for individual sample.

Sample Treatment 1: Drying and Weighing

Composited sample were placed into the sample plates and labelled accordingly and accurately. Labelled samples in plates were secured on hot plate and dried at 80°C. The dried samples were thereafter weighed (10 gm) and set aside for soaking (placed in clean plates).

Sample Treatment 2: Soaking

The samples were treated with one teaspoonful of anhydrous sodium carbonate for thorough disintegration and enough water was added to cover the samples. This was allowed to stand for 24 hours.

Sample Treatment 3: Wet-Sieving and Drying

Samples were cleaned by washing under a running water over a 63 micron sieve mesh. Samples were returned into the aluminium plates and were dried on hot plate inside a fume cupboard. Dried samples were then sieved into different fraction with 20 and 80 mesh sieves. The three fractions (fine, medium and coarse) were packaged in different plastic bag and labelled properly ready for picking.

Picking

During the picking exercise, sieved samples were examined individually in little quantities at a time in a picking tray under reflected binocular microscope (wild Heerbrugg M5 - 81796 model). For accurate examination, the grid lines were followed. Identified foraminiferal and miscellaneous microfossils were picked with picking needle into micropaleontological slide cavity. The several foraminiferal taxa and miscellaneous microfossils were assembled and mounted by the use of a gum. The slides were then covered with micropaleontological cover slips and arranged serially with their depth intervals in a slide tray for safety and future reference.

FORAMINIFERAL IDENTIFICATION

The identification of the various foraminiferal taxa (both planktonic and benthonic forms) was based on comparison with publications on foraminiferal and those formerly defined by Petters (1982), Loeblich and Tappan (1987), and Bolli and Saunders (1985). The statistical data (foraminiferal count) acquired was computerized by means of the Microsoft Excel spread sheet. Area plots of the abundance were made to represent the assemblage count recovered from the well.

FORAMINIFERAL BIOZONATION

The following bioevents are considered important in the foraminiferal biozonation of the well interval. The First Downhole Occurrence/Last Appearance Datum (FDO/LAD) and Last Downhole Occurrences/First Appearance Datum (LD0/FAD) of chronostratigraphically significant planktic/benthic foraminiferal taxa with recognized stratigraphic ranges in the Niger Delta. On the basis of the criteria stated above, the proposed ages and biozones assigned to the interval were established by employing the SPDC Niger Delta faunal zones, Blow (1969); Bolli and Saunders (1985) and Berggren et al., (1995) zonal scheme. The stratotypes were named according to the typical taxon (or taxa) that are found in that particular biozone.

RESULTS AND DISCUSSION

Lithostratigraphy

The marine-paralic sequence (7110 ft. - 10185 ft.) belonging to the Agbada formation. This interval reveals predominantly shale lithology with thin layers of alternating sand, shaly-sand, sandshale and thick shale bed deposited in marginal marine. Delta front to prodelta setting. The shales are grey and light brown, platy to flaggy and moderately hard. The sands are light grey and brown, predominantly medium grained, subrounded to rounded, moderately well to well sorted. Index minerals are dominated by mica flakes and moderate occurrence of ferruginous materials with rarity of glauconite and shell fragment. Some of the sediments within this interval are calcareous while the rest are non-calcareous.

The continental sequence (15 ft. - 7110 ft.) belong to the Benin Formation consist predominantly of sand bed with intercalations of thin mudstone, shaly-sand, sandshale and sandclayinterbeds deposited in continental setting. This agrees with the submission of Esan (2002) that the Benin Formation consists of fluvialite sands with clay and shale/mudstone interbeds. The shales are light grey, grey, light brown and brown, fissioned and moderately hard. Lithologically, the sands are light grey, grey, light brown and brown, fine - medium grained, subangular to subrounded, mostly subrounded, poorly to moderately well sorted. Index minerals and accessories are dominated by mica flakes, carbonaceous detritus, moderately ferruginized materials. Most of the sediments within this interval are non-calcareous while few are calcareous. In over-all, the litholg shows a general coarsening upward sequence where the upper part of the well has a higher sandstone percentage than the lower part. This infers the advanced seaward development of the Niger delta through geological time. Table 2
Micropaleontology in AE-1 well.
The microfaunal analysis yielded no data over the upper section (2700 ft. - 7350 ft.) of the well. The paucity/barreness of foraminiferal species recorded in this section of the studied intervals is probably due to predominantly sandy lithology, rapid and high energy environment of which are inappropriate for the preservation of foraminiferal species. Rare/consistent occurrence of foraminiferal was recorded within interval 7350 ft. - 8895 ft. with low diversity. Common occurrence of *Globigerinoides* spp. was recorded at the 8895 ft. Interval 8895 ft. - 10,185 ft. was characterized by rare/common planktonic foraminiferal with low diversity and random occurrence of calcareous benthic foraminiferal. The agglutinated benthonic foraminiferal was dominated by *Spiroplectammina wrightii*. Besides, a few number of miscellaneous microfossil such as *Ostracoda*, *Holothuroidea* and *Echinoderm remains* were present. The poor preservation of the morphology of the planktonic foraminiferal species affected the identification of specie to generic level. They were thus treated as indeterminate. The foraminiferal fauna separated from the studied ninety four (94) samples comprise of a total of twenty four (24) species grouped into nineteen (19) genera from nineteen (19) families and nineteen subfamilies. Also a few number of miscellaneous microfossil such as *Ostracoda*, *Holothuroidea* and *Echinoderm remains* were recovered. The total count of foraminiferal defined from this well is four hundred and nineteen (419). The planktic foraminiferal constituted two hundred and forty two (242) counts (57.8 % of the total count) while the benthics consists of one hundred and seventy seven (177) counts (making 42.2 % of the total count) respectively. Among the benthic forms, the calcareous consists of one hundred and forty (140) forms (33.4 % of the total benthic count) while the agglutinating benthic forms make up thirty seven (37) forms (8.8 % of the total benthic count) respectively. Table 3 shows the different foraminiferal count while fig. 2 shows the area plot of the different foraminiferal count recovered in AE-1 well.
Table 3: Shows the different foraminiferal count recovered in AE-1 well.

| Types of foraminiferal | Calcareous assemblage (FOBC) | Agglutinating assemblage (FOBA) | Planktonic assemblage (FOP) | Miscellaneous microfossils (MM) |
|------------------------|------------------------------|-------------------------------|----------------------------|-------------------------------|
| Foram count            | 140                          | 37                            | 242                        | 13                            |
| % value                | 33.4                         | 8.8                           | 57.8                       | 1426                          |

Fig. 2: Area plot showing the different foraminiferal count recovered in AE-1 well.

**Benthonic foraminiferal in AE-1 Well**

The benthonic foraminiferal species is made up of diverse foraminiferal species which are fairly preserved. The diversity is moderate with very poor to poor frequency. Twenty benthonic foraminiferal species belonging to sixteen (16) genera, sixteen families and sixteen subfamilies. Given this, the calcareous benthonic forms constitute seventeen (17) taxa outlined into fourteen (14) genera, fourteen families and fourteen subfamilies whereas the agglutinating benthic forms constitute three taxa delineated into two genera, two families and two subfamilies. The calcareous benthonic forms were dominated by calcareous indeterminate followed by the species of *Uvigerina* spp., *Nonionella auris*, *Cancristurgius*, *Eponides* spp., *Uvigerinella* spp., *Epistonellapontoni*. The remaining species were rare and in many instances single occurrences. The agglutinating benthonic foraminiferal were dominated by species of *Spiroplectammina wrightii* and *Ammobaculites* spp. while Arenaceous indeterminate have a single occurrence and *Textularia* spp. occurred twice. The benthics consists of one hundred and seventy seven (177) forms (making, up 42.2 % of the total count. Among the benthic forms, the calcareous consists of one hundred and forty (140) forms (33.4 % of the total benthic count) while the agglutinated benthic forms make up thirty seven (37) numbers (8.8 % of the total benthic count.

**Planktonic foraminiferal in AE-1 Well**

Four planktonic foraminiferal species belonging to three (3) genera, three (3) families and three (3) subfamilies were identified. Species diversity was low with very poor frequency. The planktonic foraminiferal assemblages found in the well were poorly preserved. The exceptionally abundant species is the planktonic indeterminate. Others include *Globigerinoides* spp. and*Globigerina* spp. with *Chilougembelinacubensis* and *Globorotalia* spp. The planktic foraminiferal constituted two hundred and forty two (242) (57.8 %) of the total count. Few number of miscellaneous microfossil such as *Ostracoda*, *Holothuroidea* and *Echinoderm remains* were also recovered from the well. Fig. 3 shows the foraminiferal abundance and diversity pattern, important foraminiferal events and paleo water depth established in AE-1 well.

Fig. 3 shows the foraminiferal abundance and diversity pattern, important foraminiferal events and paleo water depth established in AE-1 well.
FORAMINIFERAL ANALYSIS OF AE-1 WELL, AGBADA FORMATION ONSHORE, WESTERN NIGER DELTA BASIN:

Figure 3: Shows the foraminiferal abundance, diversity pattern, important foraminiferal events and paleo water depth established in AE-1 well.

| DISTRIBUTION OF FORAMINIFERAL IN AE-1 WELL | Miscellaneaous | FOP (Total Count) | FOP (Species Richness) | FOBC (Total Count) | FOBC (Species Richness) | FOBA (Total Count) | FOBA (Species Richness) |
|--------------------------------------------|--------------|------------------|-----------------------|------------------|----------------------------|------------------|----------------------------|
| Age                                        |              |                  |                       |                  |                            |                  |                            |
| 15-7275                                    |              |                  |                       |                  |                            |                  |                            |
| Undiagnostic                               |              |                  |                       |                  |                            |                  |                            |
| 7350                                       |              |                  |                       |                  |                            |                  |                            |
| 7425                                       |              |                  |                       |                  |                            |                  |                            |
| 7485                                       |              |                  |                       |                  |                            |                  |                            |
| 7650                                       |              |                  |                       |                  |                            |                  |                            |
| 7660                                       |              |                  |                       |                  |                            |                  |                            |
| 7755                                       |              |                  |                       |                  |                            |                  |                            |
| 7830                                       |              |                  |                       |                  |                            |                  |                            |
| 7905                                       |              |                  |                       |                  |                            |                  |                            |
| 7980                                       |              |                  |                       |                  |                            |                  |                            |
| 8040                                       |              |                  |                       |                  |                            |                  |                            |
| 8130                                       |              |                  |                       |                  |                            |                  |                            |
| 8205                                       |              |                  |                       |                  |                            |                  |                            |
| 8305                                       |              |                  |                       |                  |                            |                  |                            |
| 8355                                       |              |                  |                       |                  |                            |                  |                            |
| 8400                                       |              |                  |                       |                  |                            |                  |                            |
| 8480                                       |              |                  |                       |                  |                            |                  |                            |
| 8540                                       |              |                  |                       |                  |                            |                  |                            |
| 8640                                       |              |                  |                       |                  |                            |                  |                            |
| 8715                                       |              |                  |                       |                  |                            |                  |                            |
| Chattian - Aquitanian                       |              |                  |                       |                  |                            |                  |                            |
| 8820                                       |              |                  |                       |                  |                            |                  |                            |
| 8905                                       |              |                  |                       |                  |                            |                  |                            |
| 8970                                       |              |                  |                       |                  |                            |                  |                            |
| 9045                                       |              |                  |                       |                  |                            |                  |                            |
| 9125                                       |              |                  |                       |                  |                            |                  |                            |
| 9195                                       |              |                  |                       |                  |                            |                  |                            |
| 9270                                       |              |                  |                       |                  |                            |                  |                            |
| 9345                                       |              |                  |                       |                  |                            |                  |                            |
| 9415                                       |              |                  |                       |                  |                            |                  |                            |
| 9525                                       |              |                  |                       |                  |                            |                  |                            |
| 9600                                       |              |                  |                       |                  |                            |                  |                            |
| 9705                                       |              |                  |                       |                  |                            |                  |                            |
| 9800                                       |              |                  |                       |                  |                            |                  |                            |
| 9900                                       |              |                  |                       |                  |                            |                  |                            |
| 9995                                       |              |                  |                       |                  |                            |                  |                            |
| 10095                                      |              |                  |                       |                  |                            |                  |                            |
| 10115                                      |              |                  |                       |                  |                            |                  |                            |
| 10185                                      |              |                  |                       |                  |                            |                  |                            |

| Paleo Water Depth                          |              |                  |                       |                  |                            |                  |                            |
| Important Foraminiferal Events              |              |                  |                       |                  |                            |                  |                            |
| FDO Hanzawaia strattonii                   |              |                  |                       |                  |                            |                  |                            |
| FDO Eponides berthelotianus                |              |                  |                       |                  |                            |                  |                            |
| FDO Chiloguembelina cubensis               |              |                  |                       |                  |                            |                  |                            |
Age determination of AE-1 well

The age of this well was determined by using foraminiferal marker species whose stratigraphic ranges are well established in the Niger Delta and correlating with zonal scheme demarcated by Blow (1969); Bolli and Saunders (1985) and Berggren et al., (1995). The age of the well has been interpreted to belong to Early Oligocene - Early Miocene.

Intervals 8895 ft. - 10185 ft. recovered the FDO of Chiloguembelinacubensis. This specie is an important index marker for F7200 - F7800a / Early Oligocene of SPDC's Niger Delta faunal zonal scheme. The influx of Spiroplectaminamwrigthii at 9435 ft., the regular occurrences of Spiroplectaminamwrigthii at several depths within this interval and the co-occurrences of Uvigerinaspp. and FDO of Lenticulinaigrandis at 9345 ft. among the foraminiferal assemblages within this intervals is indicative of the Early Oligocene. According to Petters (1982), the index foraminiferal taxa such as Hopkinsinabononiensis, Spiroplectaminamwrigthii, Uvigerinellasparisicostata, Lenticulinaigrandis and Bolivinaimperatix. Hopkinsinabononiensis are an Early Oligocene - Miocene forms. Also, Petters (1982), submitted that Uvigerina spp. is of Paleocene - Oligocene form. This interval relates to the Cassigerinella chiplolenis / Hastigerinamica - Globorotaliaopimaopima zone of Bolli (1966); P18 - P21 zone of Blow (1969); Globigerina tapuniensis - Globorotalia (Turborotalia) opimaopima zone of Berggren (1969); P18 - N2 zone of Blow (1979); Allistomasclaris- Epistominellapontoni zone of Petters (1982); P18/P19: Pseudohastigerinamica/ Globigerina ampliaperturazone of Bolli and Saunders (1985); P18 - P21a: Chiloguembelinacubensis – Pseudohastigerina spp. - Gl. angulisuturalis / Chiloguembelinacubensis zone of Berggren et al., (1995); O1 - O4: Pseudohastigerinanaguewchiensis - Globigerina angulisuturalis / Chiloguembelinacubensis zone of Berggren and Pearson (2005) as well as O1 - O4: P. naguewichiensis - G. angulisuturalis / C. cubensis zone of Wade et al., (2011).

The boundary between Oligocene / Miocene was demarcated based on the common occurrence of Globigerinoides spp. at depth 8640 ft. This corresponds to earlier researchers such as Banner and Blow (1965). They established the Oligocene / Miocene boundary at the first occurrence (FO) of the genus Globigerinoides. This opinion was acknowledged by other numerous researchers. For example, Bolli (1966) and Bolli and Premoli - Silva (1973), recognised the Oligocene / Miocene boundary based on the Globigerinoides datum. From the preceding works and owing to the non-recovery of Gr. kugleri, the common occurrence of Globigerinoides spp. at depth 8640 ft. was use as a marker for the Oligocene / Miocene boundary in this study.

Intervals 8640 ft. - 8895 ft. encountered the FDO of Eponidesberthelotianus which is a marker specie for F7800a - F7800c / Late Oligocene (Chattian) - Early Miocene (Aquitanian) and is equivalent to P21 - N5 zone of Blow (1969): Globorotalia (Turborotalia) opimaopima – Globocadrinadethesicese Praedehiscences - G. Dehiscedesdehiscenciese zone of Berggren (1969);P18 - M1b: (Ch. Cubensis – Pseudohastigerina spp. - Gt. Kugleri / Qq. Dehiscens) zone of Berggren et al., (1995); P18/P19 - N8 of Bolli and Saunders (1985) and O4 - M2: G. angulisuturalis / C. cubensis - G. binaensis zone of Wade et al., (2011).

Intervals 8040 ft. - 8640 ft. encountered the FDO of Hanzawaiastratoni which was used to identify Early Miocene F7800c (Aquitanian) - F9300 (Burdigalian) in the studied well. The co-occurrence of Epistominellapontoni among the foraminiferal assemblages within intervals are indicative of the Miocene age. Epistominellapontonis is an Oligocene - Miocene form. Petters (1995).This zone is equivalent to N5 - N7 zone of Blow (1969); N8 and younger of Bolli and Saunders, (1985) and M1b - M4: Gt. kugleri / Gq. dehiscens- Catpsydraxdissimilis / Praeorbulinasicas zone of Berggren et al.,(1995). The age of the interval between 7350 ft. - 8040 ft. is indeterminate due to absence of marker specie. Table 4.

Biozonation

The use of different foraminiferal species to define the different zones demarcated, was established on the occurrences of age diagnostic planktics taxa with additional related benthic assemblages. The fairly rich stratigraphic distribution of foraminiferal in the study well, permits the recognition of four informal foraminiferal zones - Chiloguembelinacubensis zone (Rupelian), Eponidesberthelotianus zone (Chattian - Aquitanian), Hanzawaiastratoni zone (Aquitanian - Burdigalian) and Nonionellaularris zone (undiagnostic). The criteria used to delineate the biozones are based on the First down hole occurrence (FDO) / Last Appearance Datum (LAD) of marker species presented in the interval in which they are recognized. This is done to prevent the effect of caving-in/admixture of samples associated with ditch cutting sample. The established zone characterizes a time stratigraphic unit. The top of an underlying zone corresponds to the lower portion of the overlying zone. The biozones have been discussed from the base (oldest) to the top (youngest). Table 4.
**FORAMINIFERAL ANALYSIS OF AE-1 WELL, AGBADA FORMATION ONSHORE, WESTERN NIGER DELTA BASIN:**

**Table 4:** The age and biozones established in AE-1 well. Correlated with zonal scheme demarcated by Blow (1969); Bolli and Saunders (1985) and Berggren et al., (1995).

| Depth interval (ft.) | Age  | Epoch (Chronostratigraphy) | Foraminiferal zone Blow (1969) | Foraminiferal zone Berggren et al., (1995) | Significant Foraminiferal Bioevent | Biozation for this study |
|----------------------|------|-----------------------------|-------------------------------|---------------------------------------------|-----------------------------------|--------------------------|
| 8040 - 8640          | Burdigalian Early Miocene | N5 - N7                        | N8 and Younger                  | Mlb - M4: (Gt. kugleri / Gq. dehiscens – *Catapsydrax dissimilis* / Praeorbula sicanus) | *Hanzawaia stratonii*          | FDO / LAD of Valvulinera -1A @ 8040 ft. |
| 8640 - 8895          | Chattian - Aquitanian Late Oligocene - Early Miocene | P21 - N5                        | P18/P19 - N8                    | P18 – Mlb: (Ch. Cabensis - Pseudohastigerina spp. – Gt. kugleri / Gq. dehiscens) | *Eponides berthelotianus*        | FDO / LAD of Rotalia 2 (Eponides berthelotianus) @ 8640 ft. |
| 8895 - 10185         | Rupelian Early Oligocene | P18 - P21                       | P18/P19                        | P18 - P21ac: (Ch. cabensis - Pseudohastigerina spp. - Gt. angulisuturalis / Ch. Cabensis) | *Ch. cabensis*                  | FDO / LAD of Guembelina 4 (Chiloguemblinacubensis) @ 8895 ft. and common occurrence of *Uvigerina* spp. |

FDO = First Downhole Occurrence  
LAD = Last Appearance Datum

Characteristic of Chiloguemblinacubensis zone  
Interval: 8895 ft. - 10,185 ft.  
Equivalent planktic foraminiferal zone: P18/P19 zone of Bolli and Saunder (1985).  
Age: Early Oligocene (Rupelian)  
Key Foraminiferal bioevents: FDO / LAD of Chiloguemblinacubensis at 8895 ft. influx of *Spiroplectaminawrightii* at 9435 ft., FDO of *Lenticulinagrandis* at 9345 ft. and common occurrence of *Uvigerina* spp.  
Description: This is the oldest zone encountered in this well. The base of zone was not seen in the studied well while the zonal top is placed at 8895 ft. and defined by the FDO of Guembelina 4 (*Chiloguemblinacubensis*).  
The planktonic foraminiferal assemblage in this zone is more common, but less diversified. It is dominated by the indeterminate planktonic foraminiferal species. Also recovered among the FOP is the *Globigerina* spp. The FOBC of this zone are moderately diversified with rare to common occurrences. They includes *Cancris 1* (Cancriniturgiuous), *Uvigerinella 5* (Uvigerinellasparsicosta), *Cristellaria13* (*Lenticulinagrandis*), *Bolivina27* (*Bolivinadentonensis*), *Eponides* spp., *Heminwayina* spp., *Rotalia1A* (*Ammonia baccarii*), *Anomalina 8* (*Nonionellaauris*), *Rotalia* spp., *Eponides 12* (*Cibicorbinflata*), *Valvulinera 19* (*Hanzawaiastatronii*), *Uvigerina* spp. and regular occurrences of calcareous indeterminate. The FOBA was dominated by *Textularia 3* (*Spiroplectaminawrightii*). Others includes *Textularia* spp. and *Ammobaculites* spp. Rare miscellaneous microfossil form - *Ostracoda*, *Holothuroidea* and *Echinoid remains*. This interval relates to the *Cassigerinelachipolensis* / *Hastigerinamicra* - *Globorotaliaopimaopima* zone of Bolli (1966); P18 – P21 zone of Blow (1969); *Globigerina tapuniensis* - *Globorotalia* (*Turborotalia*) *opimaopima* zone of Berggren (1969); P18 - N2 zone of Blow (1979); *Altistomasclaris* - *Epistominellaaptoni* zone of Petters (1982); P18/P19 / *Pseudohastigerinamicra* / *Globigerina ampliapertura* zone of Bolli and Saunders (1985); P18 - P21a: *Chiloguemblinacubensis* – *Pseudohastigerina* spp. - *Gt. angulisuturalis* / *Chiloguemblinacubensis* zone of Berggren et al., (1995); O1 - O4: *Pseudohastigerinanaguexwichiensis* - *Globigerina angulisuturalis* / *Chiloguemblinacubensis* zone of Berggren and Pearson (2005) as well as O1 - O4: *P.naguewichiensis* - *G. angulisuturalis* / *C. cubensis* zone of Wade et al., (2011). Two marker shale (*Uvigerinellasparsicosta*, *Lenticulinagrandis* and *Spiroplectaminawrightii*) defined the zone.

Characteristic of Eponidesberthelotianus zone  
Interval: 8640 ft. - 8895 ft.  
Equivalent planktic foraminiferal zone: P18/P19 - N8 zone of Bolli and Saunder (1985).  
Age: Late Oligocene - Early Miocene (Chattian - Aquitanian)  
Key Foraminiferal bioevents: FDO / LAD of Eponidesberthelotianus and common occurrence of *Globigerinoides* spp. at 8640 ft.  
Description: The top is demarcated by the FDO of Eponidesberthelotianus and common occurrence of *Globigerinoides* spp. at depth 8640 ft. while its base is placed at 8895 ft. defined by the FDO of *Chiloguemblinacubensis*. The zone is generally low in
foraminiferal species. Characterized by FOBC taxa such as Nonionellaauris, Uvigerina spp., Cancris spp. and calcareous indeterminate. The FOP recovered are Globigerina spp., Globigerinoïdes spp. and planktic indeterminate. The FOBA recovered is Spiroplectamminowrightii. The age relates with P21 - N5 zone of Blow (1969); Globorotalia (Turborotalia) opimaopima – Globoquadradehrhisces Praedehiscens - G. Dehiscensedeshrhisces zone of Berggren (1969); P18 - M1b: Ch. Cubensis - Pseudohastigerinasp. - Gt. Kugleri / Gq. Dehiscens zone of Berggren et al. (1995); P18/P19 - N8 of Bolli and Saunders (1985) and O4 - M2: G. angulisuturalis / C. cubensis - G. binaiensis zone of Wade et al. (2011).

Characteristics of Hanzawaiaastratonozone

Interval: 8040 ft. - 8640 ft.

Equivalent planktic foraminiferal zone: N8 and younger zone of Bolli and Saund (1985).

Age: Early Miocene (Burdigalian)

Key Foraminiferal bioevents: FDO / LAD of Hanzawaiaastratoni at 8040 ft. and the co-occurrence of Epistominellapontoni.

Description: The top is delineated by the FDO of Hanzawaiaastratoni at depth of 8040 ft. while its base is placed at 8640 ft. and defined by the FDO of Rotalita2 (Eponidesberthelotianus). The FOBC recovered within this zone includes Eponides12 (Cibicorbis inflate), Uvigerinella spp., Epistominellapontoni, Uvigerina spp., Rotalia spp., Nonionellaauris, Valvulineria spp., Hanzawaiaastratoni and calcareous indeterminate. The FOBA recovered includes Spiroplectamminowrightii and arenaceous indeterminate. The FOP recovered are Globorotalia spp. and the regular occurrences of planktic indeterminate. This zone is equivalent to N5 - N7 zone of Blow (1969); N8 and younger of Bolli and Saunders, (1985) and M1b - M4: Gt. kugleri / Gq. dehiscens-Catpsydraxdissimilis / Praerorbulinascanas zone of Berggren et al., (1995).

Characteristics of Nonionellaauris zone

Interval: 7350 ft. - 8040 ft.

Equivalent planktic foraminiferal zone: Undiagnostic

Age: Undeterminate

Description: The top is positioned at 7350 ft. while the lower portion is located at 8040 ft. and is defined by the FDO of Hanzawaiaastratoni. The FOP species recovered here include- Globigerina spp., Globigerinoïdes spp. and planktonic indeterminate. The FOBC recovered within this include Uvigerinasp., Nonionellaauris, Calcareous indeterminate, Valvulineria spp., Rotalia spp. and Hanzawaiaastratoni. Absence of FOBA within this zone. Miscellaneous microfossil was - Holothuroid. The age could not be defined due to absence of index foraminiferal marker specie.

Interval: 2700 ft. - 7350 ft.

Foraminiferal zone: Undiagnostic

Age: Undeterminate

This interval is totally barren of foraminiferal species possibly due to predominantly sandy lithology, rapid deposition and high energy environment of deposition typical of shallow water depositional environment of the sediments over this interval. These conditions are unsuitable for the preservation of foraminiferal species. Thus, the age of this interval could not be determined.

CONCLUSION

This study reveals the sedimentological buildup of the well, consisting of five lithofacies. The foraminiferal fauna recovered from the well consist of twenty four (24) species with a few number of miscellaneous microfossil such as Ostracoda, Holothuroidea and Echinoderm remains. The total count of foraminiferal defined from this well is four hundred and nineteen (419). The planktic foraminiferal constituted 57.8 % while the benthics consists of 42.2 % respectively. One planktic (Chilhoweigenbackensis) and three benthic (Eponidesberthelotianus, Hanzawaiaastratoni and Nonionellaauris) informal foraminiferal zones were established in the well. Significant marker species recovered from the well revealed similar ages of Early Oligocene - Early Miocene and are in comparison with foraminiferal markers species whose stratigraphic ranges are well established in the Niger Delta and worldwide.

ACKNOWLEDGEMENT

The authors are grateful to the Management of Nigerian Petroleum Development Company (NPDC) for donating the ditch cutting samples and providing other data for this research work. Sincere gratitude goes to Professor E.A Okosun of Department of Geology, Federal University of Technology, Minna, Niger State, Nigeria, for his wise counsel, suggestions and for providing necessary materials that have led to an improved final product.

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