



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

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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*, *Holothuroidea* and *Echinoderm remains* were recovered. The total count of foraminiferal defined from this well is four hundred and nineteen (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*, *Hanzawiastratonii* 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 of cores, 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 (*Globoquadrinadehiscens* and *Globigerinoidesruber*)

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four informal benthonic foraminiferal zones (*Cyclaminacancellata*, *Lenticulinainornata*, *Marginulinacostata/Quinqueloculinamicrocostata* 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, Ukpong *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 - *Globigerina selli/pseudohastigerinabarbadoensis* zone (P18-P19), *Globigerina ampliapertura* zone (P20/N1), *Globorotaliaopima* zone (P21/N2) and *Globigerina ciperoensis* zone (P22/N3). Besides, Ajayi and Okosun (2014), worked on the planktic foraminiferal Biostratigraphy in four well (A, B, C and D well). Three planktic 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 benthonic foraminiferal zones from two wells (Akata-2 and Akata-4). Also, one planktonic and benthonic 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*, *Globigerinoidesbisphericus*, *Globigerinoidesobliquus*, *Globigerinoidesimmaturus*, *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 *Bolivinamiocenica*, *Lenticulinarotulata*, *Alveolephragmiumcrassium*, *Bolivinabeyrichi*, *Saccamminacomplanata* and *Cyclammina minima* 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), *Morozovellapussila- M. Angulata* zone (P3), *planorotalitespseudomenardii* zone (P4), *Morozovellavelascoensis - M. Subbotinae* zone (P5-P6), *Acarininapentacamerataz* one (P9), *Globorotaliaopima* zone (P21), *Globigerinaciperoensis* - *Globorotaliakugleri* zones (P22-N4), *Praeorbulinaglomerosa* zone (N8), *Globorotaliafohsifohsi- G. fohsilobata- robusta* zones (N10-11).

Samples were collectrd 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.

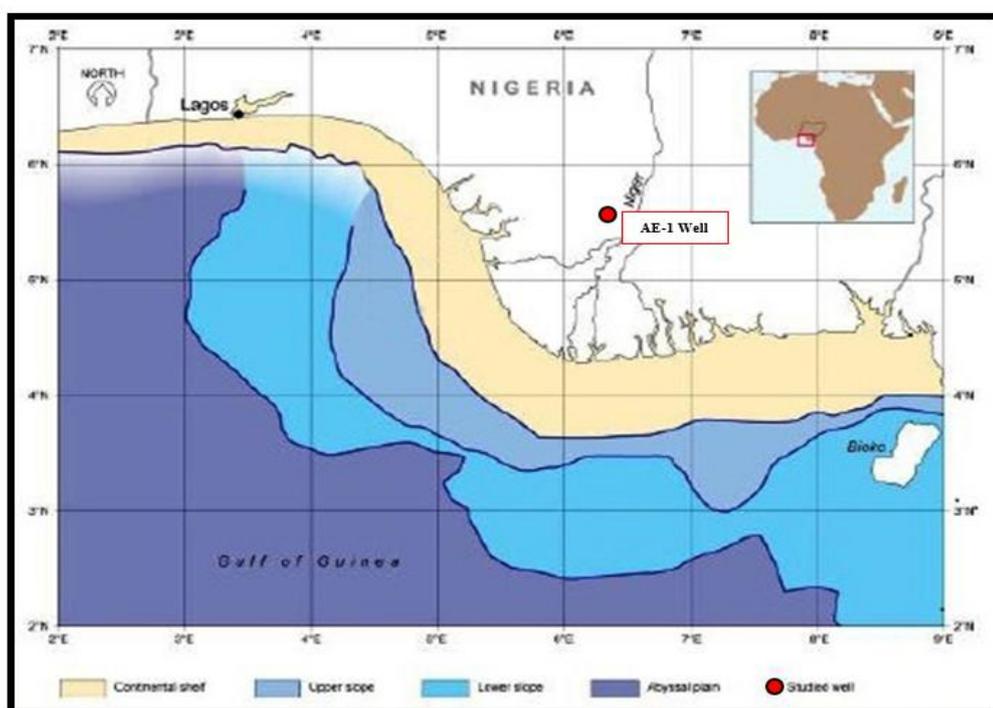


Figure 1: Location map showing the study area in the western Niger Delta and simplified bathymetry (after Bakare *et al.*, 2009).

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, silstones 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).

Age		Group	Benin Flank (Omatsola and Adegoke, 1981; Salami 1983)	Niger Delta Basin			
				This study			
				Subsurface	Surface Outcrop		
Quaternary			Alluvium	Alluvium	Alluvium		
NEO GENE	Pliocene		Benin Formation	Benin Formation	Benin Formation		
	Miocene						
PALEOGENE	Oligocene	Ameki Group	Ijebu Fm	Upper Agbada Fm	Ogwashi Asaba Fm		
			Ameko Fm Earo Fm Oshosun FM		Lower Agbada Fm	Ameki Formation	
	Eocene		L	Imo Group	Akimbo Fm Ewekoro Fm	Akata Fm	Imo Shale Formation
			M				
			E				
	Paleocene		L	Coal Measures Group	Araromi Shale	Major Unconformity	Major Unconformity
M							
E							
Late Cretaceous	Late Maastrichtian						

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 (LDO/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.) belong to the Agbada formation. This interval reveals predominantly shale lithology with thin layers of alternating sand, shalysand, sandyshale 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, shalysand, sandyshale and sandyclayinterbeds 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, fissile 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 litholog 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

Table 2: Simplified composite litholog of AE-1 well, Western Niger Delta.

Depth (ft.)	Formation	Lithofacies Sequence	Lithology	Lithostratigraphy
15 - 2175	Benin	Continental	d	Predominantly sandstone with thin fissile shale interbeds. The sandstone are fine to medium grained, subangular to subrounded, poorly to well sorted with mica flakes, carbonaceous detritus and considerably ferruginized.
2175 - 2955				
2955 - 3990			d	
3990 - 5100			d	
5100 - 5910			d	
5910 - 7110			d	
7110 - 7830	Agbada	Transitional		Heterogenous succession of alternating sandstone, shalysand, sandyshale and thick bed of shale. The sandstone are fine to medium grained, subrounded, moderately sorted with mainly mica flakes and rarely ferruginized.
7830 - 8880				
8880 - 9360				
9360 - 10185				

LEGEND	Shale	Shalysand	Sandyshale	Sandy clay	Sandstone
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Micropaleontology in AE-1 well.

The microfaunal analysis yielded no data over the upper section (2700 ft. - 7350 ft.) of the well. The paucity/barrenness 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 *Spiroplectamminawrightii*. 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	

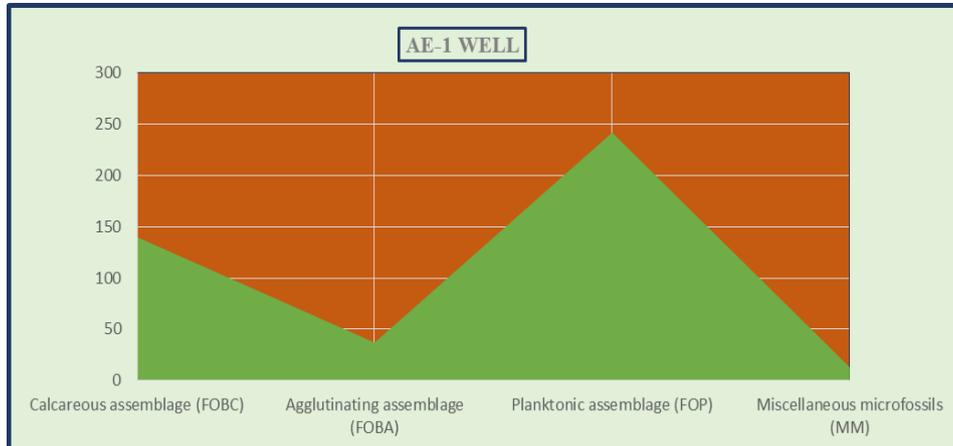


Fig. 2: Area plot showing the different foraminiferal count recovered in AE-1 well.

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., *Nonionellaauris*, *Cancristurgious*, *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 *Spiroplectamminawrightii* 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 *Chiloguembelinacubensis* 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.

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 *Spiroplectamimawrightii* at 9435 ft., the regular occurrences of *Spiroplectamimawrightii* at several depths within this interval and the co-occurrences of *Uvigerina*spp. and FDO of *Lenticulinagrandis* 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*, *Spiroplectamimawrightii*, *Uvigerinellasparsicostata*, *Lenticulinagrandis* 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 chipolensis* / *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*- *Epistominellapontoni* zone of Petters (1982); P18/P19: *Pseudohastigerinamicra*/ *Globigerina ampliapertura* zone of Bolli and Saunders (1985); P18 - P21a: *Chiloguembelinacubensis* - *Pseudohastigerina* spp. - *Gl. angulisuturalis* / *Chiloguembelinacubensis* zone of Berggren *et al.*, (1995); O1 - O4: *Pseudohastigerinanaguwichiensis* - *Globigerina angulisuturalis* / *Chiloguembelinacubensis* zone of Berggren and Pearson (2005) as well as O1 - O4: *P. naguwichiensis* - *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.

Interval 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* - *Globoquadrinadehiscenes Praedehiscens* - *G. Dehiscenesdehiscenes* zone of Berggren (1969); P18 - M1b: (*Ch. Cubensis* - *Pseudohastigerina* spp. - *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).

Intervals 8040 ft. - 8640 ft. encountered the FDO of *Hanzawaiastratonii* 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. *Epistominellapontoni*s 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* / *Praeorbulinasicanas* 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), *Hanzawaiastratonii* zone (Aquitanian - Burdigalian) and *Nonionellaauris* 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.

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 (Chronostratigraphic)	Foraminifera zone Blow (1969)	Planktic Foraminiferal zone Bolli and Saunder (1985)	Foraminiferal zone Berggren <i>et al.</i> , (1995)	Biozonation for this study	Significant Foraminiferal Bioevent
8040 - 8640	Burdigalian	Early Miocene	N5 - N7	N8 and Younger	M1b - M4: (<i>Gt. kugleri</i> / <i>Gq. dehiscens</i> - <i>Catpsyrax dissimilis</i> / <i>Praeorbulina sicana</i>)	<i>Hanzawaia stratonii</i>	FDO / LAD of <i>Valvulineria</i> -1A (<i>Hanzawaia stratonii</i>) @ 8040 ft.
8640 - 8895	Chattian - Aquitanian	Late Oligocene - Early Miocene	P21 - N5	P18/P19 - N8	P18 - M1b: (<i>Ch. Cubensis</i> - <i>Pseudohastigerina</i> spp. - <i>Gt. kugleri</i> / <i>Gq. dehiscens</i>)	<i>Eponides betherlotianus</i>	FDO / LAD of <i>Rotalia</i> 2 (<i>Eponides berthelotianus</i>) @ 8640 ft.
8895 - 10185	Rupelian	Early Oligocene	P18 - P21	P18/P19	P18 - P21a: (<i>Ch. cubensis</i> - <i>Pseudohastigerina</i> spp. - <i>Gl. angulisuturalis</i> / <i>Ch. Cubensis</i>)	<i>Ch. cubensis</i>	FDO / LAD of <i>Guembelina</i> 4 (<i>Chiloguembelina cubensis</i>) @ 8895 ft. and common occurrence of <i>Uvigerina</i> spp.

FDO = First Downhole Occurrence

LAD = Last Appearance Datum

Characteristic of *Chiloguembelinacubensis* 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 *Chiloguembelinacubensis* at 8895 ft. influx of *Spiroplectamimawrightii* 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 (*Chiloguembelinacubensis*). The planktic foraminiferal assemblage in this zone is more common, but less diversified. It is dominated by the indeterminate planktic 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 include *Cancris* 1 (*Cancristurgios*), *Uvigerinella* 5 (*Uvigerinellasparsicosta*), *Cristellaria* 13 (*Lenticulinagrandis*), *Bolivina* 27 (*Bolivinadertonensis*), *Eponides* spp., *Heminwayina* spp., *Rotalia* 1A (*Ammonia baccarii*), *Anomalina* 8 (*Nonionellaauris*), *Rotalia* spp., *Eponides* 12 (*Cibicorbisinflata*), *Valvulineria* 19 (*Hanzawaiastratonii*), *Uvigerina* spp. and regular occurrences of calcareous indeterminate. The FOBA was dominated by *Textularia* 3 (*Spiroplectamimawrightii*). Others include *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-Epistominellapontoni* zone of Petters (1982); P18/P19 / *Pseudohastigerinamicra* / *Globigerina ampliapertura* zone of Bolli and Saunders (1985); P18 - P21a: *Chiloguembelinacubensis* - *Pseudohastigerina* spp. - *Gl. angulisuturalis* / *Chiloguembelinacubensis* zone of Berggren *et al.*, (1995); O1 - O4: *Pseudohastigerinanaguwichiensis* - *Globigerina angulisuturalis* / *Chiloguembelinacubensis* zone of Berggren and Pearson (2005) as well as O1 - O4: *P.naguwichiensis* - *G. angulisuturalis* / *C. cubensis* zone of Wade *et al.*, (2011). Two marker shale (*Uvigerinella* 5 and *Textularia* 3) based on *Uvigerinellasparsicosta*, *Lenticulinagrandis* and *Spiroplectamimawrightii* 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 *Chiloguembelinacubensis*. 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., *Globigerinoides* spp. and planktic indeterminate. The FOBA recovered is *Spiroplectamminawrightii*. The age relates with P21 - N5 zone of Blow (1969); *Globorotalia (Turborotalia) opimaopima* – *Globoquadrinadehiscens Praedeheiscens* - *G. Dehiscensdehiscens* zone of Berggren (1969); P18 - M1b: *Ch. Cubensis* - *Pseudohastigerina* spp. - *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).

Characteristic of *Hanzawiastratonii* zone

Interval: 8040 ft. - 8640 ft.

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

Age: Early Miocene (Burdigalian)

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

Description: The top is delineated by the FDO of *Hanzawiastratonii* at depth of 8040 ft. while its base is placed at 8640 ft. and defined by the FDO of *Rotalia2 (Eponidesberthelotianus)*. The FOBC recovered within this zone include *Eponides12 (Cibicorbis inflata)*, *Uvigerinella* spp., *Epistominellapontoni*, *Uvigerina* spp., *Rotalia* spp., *Nonionellaauris*, *Valvulineria* spp., *Hanzawiastratonii* and calcareous indeterminate. The FOBA recovered includes *Spiroplectamminawrightii* 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* / *Praeorbulinasicanas* zone of Berggren et al., (1995).

Characteristic of *Nonionellaauris* zone

Interval: 7350 ft. - 8040 ft.

Equivalent planktic foraminiferal zone: Undiagnostic

Age: Indeterminate

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

Interval: 2700 ft. - 7350 ft.

Foraminiferal zone: Undiagnostic

Age: Indeterminate

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 (*Chiloguembelinacubensis*) and three benthic (*Eponidesberthelotianus*, *Hanzawiastratonii* 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.

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