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FORAMINIFERAL BIOSTRATIGRAPHY AND PALEOENVIRONMENTAL STUDY OF THE SEDIMENTS PENETRATED WITHIN THE INTERVAL OF 6030FT. TO 11115FT. OF ASH-3 WELL IN THE GREATER UGHELLI DEPOBELT, NIGER DELTA BASIN

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ABSTRACT

Foraminifera biostratigraphy and paleoenvironmental study was carried out on sediments penetrated by Ash-3 Well in the Greater Ughelli Depobelt, Niger Delta. The aim of this study is to erect a foraminifera zonation and carry out paleoenvironmental study of Ash-3 Well. Seventy (70) ditch cutting samples were subjected to foraminifera slide preparation technique and analysis was carried out with reflected light binocular microscope. Most of the species recorded are calcareous and arenaceous (agglutinated) benthic foraminifera species with planktic generally absent in the well. Four (4) foraminifera genera and twenty six (26) foraminifera species were recovered from the well. Two benthic foraminefera zones were identified: Lower N2- N4 and N4 – N5 Zones of Blow (1969, 1979). The age of the well from 9960ft – 11115ft indicates an Oligocene age based on the recovery of age diagnostic markers such as Spirosplectammina wrightii, Altistoma scalaris, Hopkinsinna bononiensis, Haplophragmoides narivaensis, Spirosigmoilina oligocaenica, Eponides eshira, Lenticulina grandis and Poritextularia panamensis, while the age from depth 6030 ft. - 9945ft. indicates Early Miocene age based on the recovery of age diagnostic markers such as Lenticulina grandis, Florilus costiferum, Lenticulina inornata, Eponides eshira and Poritextularia panamensis. Paleoenvironmental study based on the benthic foraminifera association revealed that the sedimentary sequences were deposited in range of environment from marginal marine environment (littoral Zone) to shallow marine environment (inner neritic zone). The alpha diversity index for Ash-3 Well based on the plot of the amount of benthonic foraminifera species against the number of individual foraminifera ranges from α2 – α5, this therefore indicates that the salinity during the deposition of the sediments of Ash-3 Well was within the hyposaline marshes – hyposaline shelf sea, which implies that the salinity of the water condition during this time was abnormally low salinity.

Keywords: calcareous, arenaceous, agglutinated, hyposaline marshes, hyposaline shelf sea.

INTRODUCTION

The Niger Delta is the largest hydrocarbon producing basin in Nigeria where profound petroleum exploration and exploitation activities have been in progress since the discovery of hydrocarbon in Oloibiri community, Bayelsa State in 1956 (Reijers et al., 1996). The basin is petroliferous in nature which has made the Nigeria economy to be depended on the oil and gas resources. It is situated at the zone where the rifting and separation of Africa and South America was initiated. The basin was formed by failed arm of a triple junction (aulacogen) after rifting ceased in the Mid-Cretaceous (Short and Stauble, 1967).

Foraminifera biostratigraphy as a tool in stratigraphy is used for age determination, correlation and paleoenvironmental analysis. The following workers that have documented their work on the Upper Cretaceous and Tertiary Foraminiferal on ages, paleoecological and paleoenvironmental interpretation in the Nigeria sedimentary basin (Adegoke et al., 1971; Ogbe, 1974; Ayayi and Okosun, 2006; Obaje and Okosun, 2013; Ajayi and Okosun, 2014; Fadiya et al., 2014 and Nwaejije et al., 2017), but there is scanty of information on the biostratigraphy of the Greater Ughelli depobelt.The area of study is located in the Greater Ughelli Depobelt. The well is geographically positioned on latitude 5°30'N and longitude 5°45'E (Figure 1).

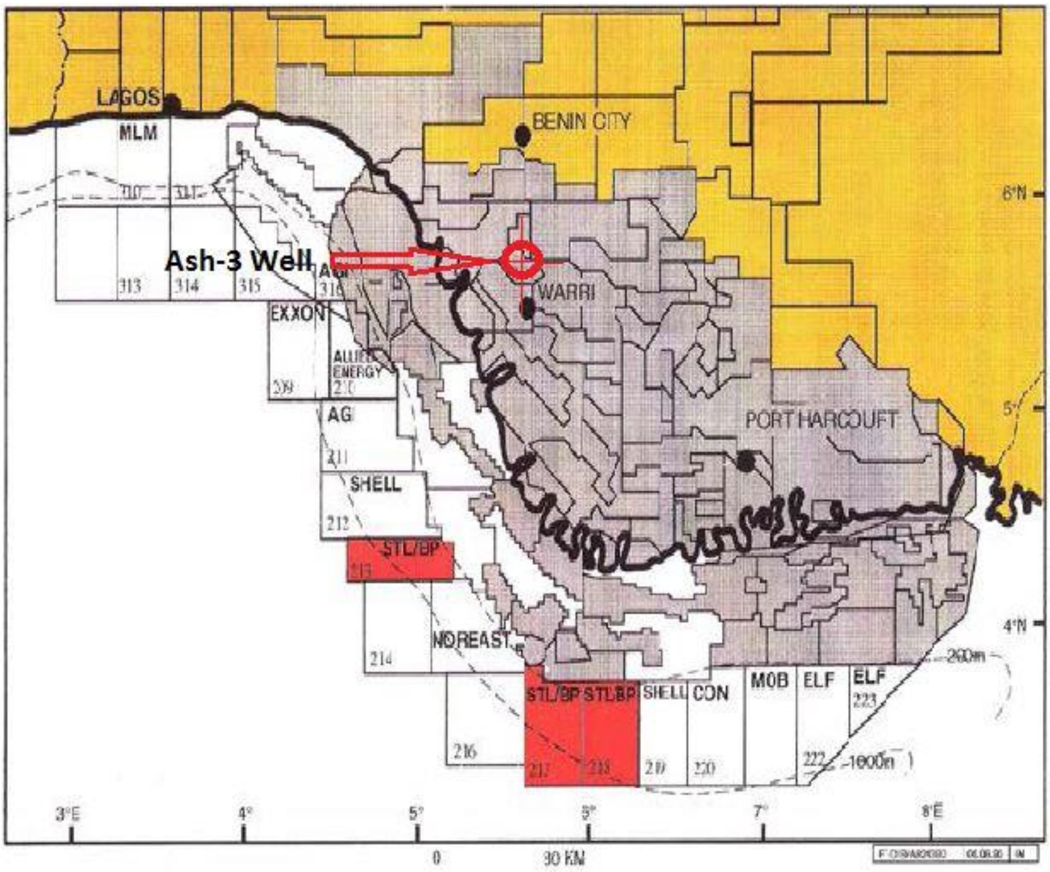

Figure 1: Location map of Study Area (Lucas et al., 2016)

MATERIALS AND METHOD

Seventy (70) ditch cutting samples from Ash-3 Well between the intervals of 6030 feet to 11430 feet were taken from the shaly and sandy shale intervals of interest for foraminifera slides preparation.

Materials:

Slides, microscope, digital camera, sieves, picking trays, needles, brushes and hot plates.

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Procedures for Foraminifera Slide Preparation:

Labeling and Weighing: About 25g of each collected samples were weighed, packaged and labeled accordingly indicating the well name, sample type and depth.

Soaking: The samples were soaked with kerosene for about six (6) hours after which the samples were decanted. Water was later added to the labeled samples and allowed to stay/ soak overnight.

Wet sieving and Drying: Samples were washed through 270 mesh sieve with 53 micron (µm) aperture under running tap water with a shower head. Washed samples were dried on hot plate at about 50°C for about 30 minutes.

Dry sieving and Bottling: A set of micro sieves (coarse, medium and fine) were stacked on each other and the dried residue for each sample was allowed to run through them and sieved manually. The respective fraction of each of the residue was collected and put inside a labeled bottle.

Picking: Each fraction was spread on a gridded foraminifera tray of 4.5 by 6.0cm and moved along definite traverses to pick observed foraminifera under a reflected light binocular microscope. The forms were picked and placed in the cavity of appropriately labeled slide.

Splitting: This is the sorting and grouping of fossils according to their morphological similarity. Different species were grouped together with the help of a moistened fine brush and stocked in 10s, 20s, and 50s depending on the richness of the intervals. They were placed on the slide and glued with tragacanth gum.

Analysis: Identification of foraminiferal was carried out using published references of Fayose (1970), Blow (1979) and Bolli and Saunders (1985) and foraminifera album considering the test composition, chamber arrangements, sutures, apertures, habits and ornamentation.

RESULTS AND DISCUSSION

Lithologic Description of Formations in Ash-3 Well

The depth of this well is from 15fts to 11430ft. This well consists of five lithofacies types namely: sandstone, clayey sandstone, shaly sandstone, sandy shale and shale. The grain sizes vary from shale to boulder. The well consists of two formations namely: the Agbada and Benin Formation (Figure 2).

Benin Formation

This formation occurs within the interval of 15ft to 6015ft. It consists mainly whitish to yellowish sandstones with clayey sandstone at the top (30ft to 225ft). The grain varies from very fine to boulder, angular to well-rounded and poorly sorted to very well sorted. Minerals found within this zone include iron oxide, mica, pyrite and carbonate. Coal is presence within the formation ranges from 5 to 80%. Thin laminae of shale are found occasional within this zone.

Agbada Formation

This formation occurs within the interval of 6030ft to11430ft. This zone consists of alternation of sand and shale with mainly shaly sandstone at the top and sandy shale at the base. The shale is mainly greyish in colour, fine grained and fissile, which is an indicative of quiet and an anoxic condition and the sand varies from very fine to very coarse. The minerals found within this zone include iron oxide, mica, pyrite and clay. Wood fragments and rootlets also occur in this formation.

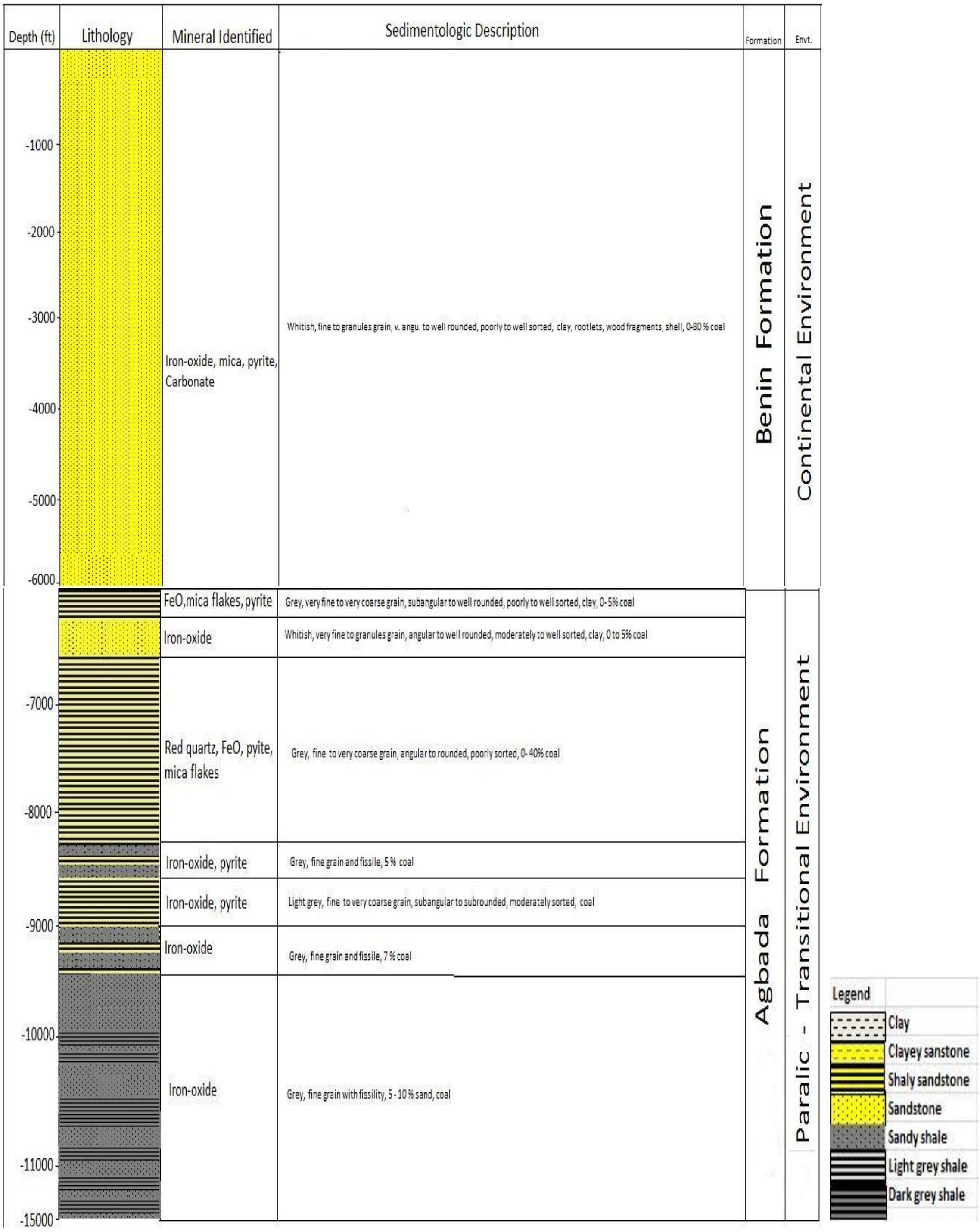

Figure 2: Lithologic log showing the Formations of Ash-3 Well

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Quantitative Count

Foraminifera assemblages over these intervals are generally poor with some barren intervals. Most of the species recorded are calcareous and arenaceous (agglutinated) benthic foraminifera species with planktic foraminifera generally absent in the well. Seventeen (17) out of twenty six (26) foraminifera species recovered are calcareous benthics while arenaceous (agglutinated) benthics accounted for the remaining nine (9) species. This group of foraminifera has a calcareous wall that is either perforate or imperforate. They account close to seventy (70%) of the recovered foraminifera species.

The calcareous species recorded include: *Heterolepa pseudoungeriana, Florilus costiferum, Calcareous indeterminate, Florilus atlanticus, Lenticulina inornata, Lenticulina grandis, Eponides esaira, Hanzawaia concentrica, Valvulineria sp., Nonion sp., Cristellaria sp., Altistonia scalaris, Altistonia sp., Hopkinsina bononiensis, Spirosigmoilina oligocaenica, Bolivina dertonensis and Nonionella turgidus*.

The arenaceous (agglutinated) benthics foraminifera account for about (30%) of the total foraminifera species with low diversity. Their test is made up of foreign materials mainly sand grains, sponge spicules and mica flakes. The arenaceous (agglutinated) recorded are: *Poritextularia panamensis, Eggerella scabra, Arenaceous indeterminate, Reophax sp., Spiroplectammina wrightii, Haplophragmoides sp., Bathysiphon sp., Alveolophragmium crassum* and *Haplophragmoides narivaensis*.

Foraminifera Zonation and Age for Ash-3 Well

The foraminifera zonation for Ash-3 Well was guided by the work of Blow (1969, 1979), Bolli and Saunders (1985). The benthic foraminifera species whose stratigraphic distribution has been well known in the Niger Delta and has been calibrated with planktic foraminifera species were used to assign age and biozonation. Important foraminifera bio-events considered include: First Downhole Occurrence (FDO) of chronostratigraphically significant planktic/benthic foraminifera marker species, the Last Downhole Occurrence (LDO) of chronostratigraphically significant planktic/benthic foraminifera marker species, foraminifera abundance and diversity peaks.

The result of the analysis indicates that the entire analyzed section (6030 – 11290ft) was deposited during the Early Oligocene to Early Miocene epoch which straddle within the Lower N2- N4 and N4 – N5 Zones of Blow (1969, 1979) (Table 1).

Stratigraphic Interval: 11115ft – 9960ft
Zone: Lower: N2-N4
Age: Early to Late Oligocene

The upper boundary of this zone is defined by the FDO of *Hanzawaia concentrica* at 9960ft. The lower limit is placed at the LDO of *Spiroplectammina wrightii* at depth (11115ft). The interval is also characterized by the co-occurrences of the following foraminifera species viz: *Bolivina dertonensis, Nonion sp., Altistoma scalaris, Hopkinsinna bononiensis, Haplophragmoides narivaensis, Spirosigmoilina oligocaenica*, *Eponides eshira, Lenticulina grandis* and *Poritextularia panamensis*. The above foraminifera assemblage confirms the Early to late Oligocene age for this interval (11115ft - 9960ft).

Stratigraphic Interval: 9960ft – 9585ft
Zone: N4 - N5
Age: Early Miocene

The lower limit of this zone is defined by the FDO of *Hanzawaia concentrica* at

9960ft, while the upper limit is placed at the FDO of *Florilus costiferum.* The First Downhole Occurrence of *Hanzawaia concentrica* at 9960ft which suggests Early Miocene at this depth. The co-occurrences of the following foraminifera assemblages viz *Lenticulina grandis, Florilus costiferum, Lenticulina inornata, Eponides eshira, Poritextularia panamensis, Heterolepa pseudoungeriana* and *Florilus atlanticus* in this zone are consistent with the Early Miocene age.

Stratigraphic Interval: 9585ft - 6030ft
Zone: Indeterminate
Age: Indeterminate

The lower limit of this zone is defined by the co-occurrence of *Heterolepa pseudoungeriana* and *florilus costiferum,* while the upper limit is placed at the top of analyzed interval (first sample analyzed). This interval is barren of foraminifera species.

Table 1: Foraminifera Biozonation and Age for #3 Well

	Calcareous foram							Agglu. Foram				
Depth (ft.)	*Florilus costiferum (Nonion 6)*	*Florilus atlanticus*	*Eponides esaira*	*Hanzawaia concentrica*	*Nonion sp.*	*Hopkinsina bononiensis*	*Nonionella turgidus*	*Spiroplectammina wrightii*	*Haplophragmoides narivaensis*	N/P ZONES BLOW (1969/ 79)	Foaraminifara events	AGE
6030												
6225												
6795												
7005												
7140												
8100												
8280												
8535												
8650												
8955												
9285												
9585	1									N4 - N5	FDO *Florilus costiferum (Nonion 6)*	EARLY MIOCENE
9660												
9675												
9690												
9705												
9735	1	1										
9765	1											
9810												
9825	4											
9885												
9900			1									
9915												
9930												
9945	1											
9960	1			1						LOWER N2-N4	FDO *Hanzawaia concentrica*	OLIGOCENE
9975												
9990												
10005	1	1										
10020												
10035												
10050	1	1						1				
10065												
10095												
10125	1	1										
10140												
10155	1		1									
10260	1	1	1		1							
10275	2	2										
10290												
10305												
10515												
10530												
10545												
10560												
10575												
10590												
10620												
10635												
10665												
10680												
10695		2			1							
10755	1	7										
10770	17											
10785												
10800		2										
10815		1						1				
10860	1	2										
10875		2										
10890		–										
10905	1											
10920												
10935												
10950		1										
10965		1										
10980		1						1				
11010												
11115	11	7				5		1			LDO *Spiroplectammina wrightii*	
11265	1	2					1		1			
11280	2	2			1							

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Paleoenvironmental Study for Ash-3 Well

Foraminifera are marine organism; hence their presence in sedimentary rock is a direct indication of marine environment. Bandy (1960) stated that foraminifera have shown to be useful environmental indicator than any other microfossil group because of their occurrence in widespread geological environment.

The interval 11280ft – 10980ft consist of shale and sandy shale units. This depth recorded high amount of foraminifera abundance and diversity. The presence of paleobathymetric indicators such as *Florilus costiferum, Haplophragmoides sp, Spirosigmoilina oligocaenica, Lenticulina grandis, Hopkinsina bononiensis, Bolivina dertonensis, Florilus atlanticus, Valvulina sp.* and *Spiroplectammina wrightii* indicate inner to middle neritic zones (shallow to deep marine environments) (Murray, 1991, Brandy,1967) (See Table 2). The presence of *haplophragmoides species*, which is infaunal and detritivore foram occur in muddy to sandy substrates suggest anoxic condition.

The interval 10980ft to 10815ft consist of shale and sandy shale units. The presence of paleobathymetric indicator such as *Florilus costiferum, Florilus atlanticus, Haplophragmoides sp.* and *Aleoveophragmium crassum* suggest littoral to inner neritic zones (marginal to shallow marine environments) (Murray, 1991, Bandy, 1967) (See Table 2). The dominance of arnaceous forms show anoxic condition for this part of the well (Gehhardt, 2006), this could be as a result of input of organic matter concentration.

The interval 10815ft to 10665ft consists of shale and sandy shale interval. There is a low recovery of foraminifera at the base of this interval and increase in calcareous and arenaceous forminifera close to the top. The presence of paleobathymetric indicators such as *Spiroplectammina wrightii, Florilus costiferum* and *Florilus atlanticus* suggest inner neritic zone (shallow marine environment) (Murray, 1991, Bandy, 1967) (See Table 2). The absence of foraminifera in this zone suggests highly stressed and high oxygen concentrated zone.

The interval 10665ft to 10275ft consists of shale and sandy shale intervals. The absence of foraminifera in this interval is an indication of littoral zone (marginal environment) (Murray, 1991, Bandy, 1967).

The interval 10275ft to 9735ft is a heterogeneous sequence. It consists of shale, sandy shale and shaly sandstone lithofacies. The amount of calcareous benthic and arenaceous benthic foraminifera is evenly distributed. The environment of deposition within the interval fluctuates between littoral and inner neritic zones (marginal to shallow marine environments), based on the recovery of paleobathymetric indicators such as *Eggerella scabra, Florilus costiferum, Florilus atlanticus, Lenticulina inornata, Lenticulina grandis and Reophax sp* (Adegoke et al., 1976, Murray, 1991) (See Table 2).

The interval 9735ft to 9285ft consists of sandy shale and shaly sandstone. The paucity of foraminifera and paleobathymetric indicators such *as Florilus costiferum, Calcareous indeterminate* and *Florilus atlanticus* suggest littoral zone (marginal environment). The low number of species in this zone suggest environmental highly stressed zone (Murray, 1994) (See Table 2). The absence of arenaceous forms shows oxic condition within this zone.

Some of the foraminifera that are diagnostic of certain environments are been shown in Plate 1.

Table 2: Foraminifera distribution chart, biozonation, age and paleoenvironment of Ash-3 Well

	Calcareous Foraminifera																	Agglutinated foraminifera												
Depth (ft.)	*Heterolepa pseudoungeriana*	*Florilus costiferum (Nonion 6)*	*Calcareous indeterminate*	*Florilus atlanticus*	*Lenticulina inornata*	*Lenticulina grandis*	*Eponides esaira*	*Hanzawaia concentrica*	*Valvulineria sp.*	*Nonion sp. 4*	*Cristellaria sp.*	*Altistonia scalaris*	*Altistonia sp.*	*Hopkinsina bononiensis*	*Spirosigmoilina oligocaenica*	*Bolivina dertonensis*	*Nonionella turgidus*	*Poritextularia panamensis*	*Eggerella scabra*	*Arenaceous indeterminate*	*Reophax sp.*	*Spiroplectammina wrightii*	*Haplophragmoides sp.*	*Bathysiphon sp.*	*Alveolophragmium crassum*	*Haplophragmoides narivaensis*	N/P Zones Blow (1969/1979)	Age	Paleobathymetry	Depositional Environment
6030																											Indeterminate		Littoral zone	Marginal
6225																														
6795																														
7005																														
7140																														
8100																														
8280																														
8535																														
8610																														
8955																														
9285																		1												
9585	1	1																									N4-N5	Early Miocene		
9660																														
9675																														
9690																														
9705																														
9735		1	1	1																									Littoral to inner neritic zones	Marginal to shallow marine
9765		1																4	1	2										
9810																		1												
9825		4			4	2												15		1	1									
9885																														
9900						1	1											3												
9915																														
9930																														
9945		1																1												
9960		1						1										1												
9975																				1							LOWER N2-N4	Oligocene		
9990																														
10005		1		1																1										
10020																		7												
10035																		2												
10050		1		1														4				1								
10065																														
10095																														
10125		1		1					2									1	1											
10140	1																	3	1	1										
10155		1				7	1											10		1										
10260		1		1			1			1								1												
10275		2		2														2		1										
10290																													Littoral zone	Marginal
10305																														
10515																														
10530																														
10545																														
10560																														
10575																														
10590																														
10620																														
10635																														
10665																		1											Inner neritic zone	Shallow marine
10680																														
10695				2						1								3		1										
10755		1		7														1		1			1							
10770		17																					1							
10785																								1						
10800				2																1										
10815				1														2				1		1					Littoral to inner neritic	Marginal to shallow marine
10860		1		2														1												
10875				2														1												
10890				1																			1							
10905		1																												
10920			1																											
10935			1								1												1		1					
10950				1																										
10965				1																										
10980				1																		1							Inner to middle	Shallow to deep
11010																														
11115		11		7								1	1	5	1	2		3				1								
11265		1		2													1	3					1			1				
11280		2		2						1						2		1				1		1						

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PLATE 1

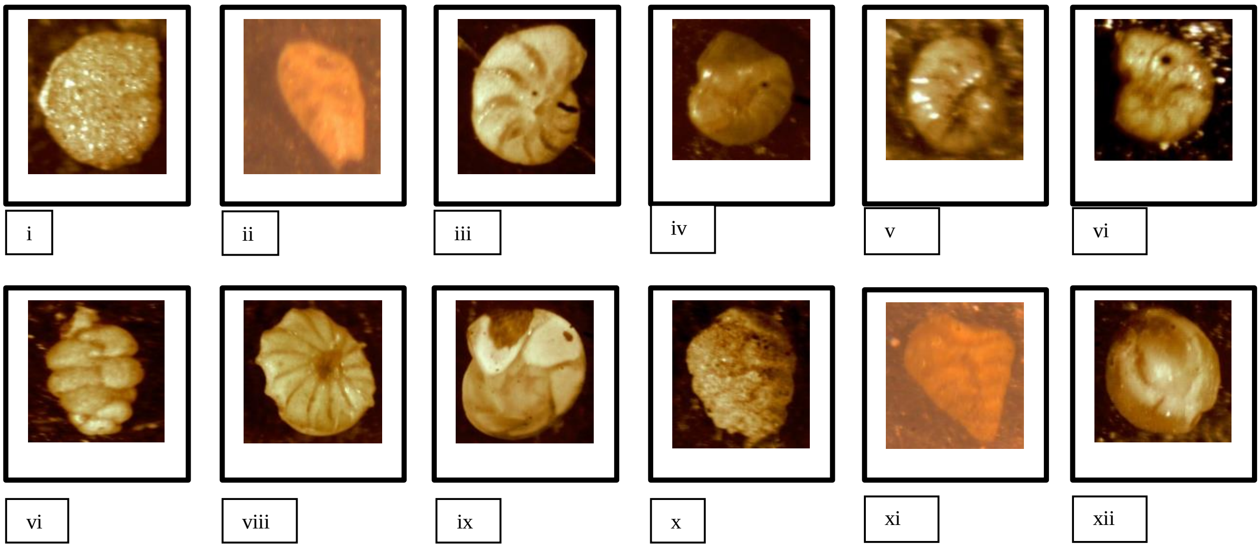

PLATE 1

(i) Alveolophragmium crissum, (ii) Bolivina dertonensis ,(iii) Cibicorbis inflate (iv) Florilus atlanticus,

(v) Florilus costiferum, (vi) Hanzawaia concentrica, (vii) Hopkinsina bononiensis, (viii) Lenticulina grandis,

(ix) Lenticulina inornata, (x) Poritextularia panamensis, (xi) Spiroplectaminna wrightii,

(xii) Spirosigmoilina oligocaenica.

Salinity

The salinity for Ash-3 well was deduced from the alpha diversity index plot. This has to do with the amount of benthonic foraminifera species in standard-sized sample (Nwojiji, 2014). It has been established that lower the alpha index value, the shallower the marine condition, while the higher the alpha index value, the deeper the marine environment (Nwojiji, 2014). The number of individuals and number of species against depth for Ash-3 Well is shown in Table 3.The alpha diversity index for Ash-3 Well ranges from $\alpha 2 - \alpha 5$ (Figure 3). This therefore indicates that the salinity during the deposition of Ash-3 Well was within the hyposaline marshes – hyposaline shelf sea, which implies that the salinity of the water condition during this time was abnormally low salinity.

Table 3: Number of individuals and number of species against depth for Ash-3 Well

Depth (ft)	No. Of Individuals	No. of Species
6030	0	0
6225	0	0
6795	0	0
7005	0	0
7140	0	0
8100	0	0
8280	0	0
8535	0	0
8610	0	0
8955	0	0
9285	1	1
9585	2	2
9660	0	0
9675	0	0
9690	0	0
9705	0	0
9735	3	3
9765	8	4
9810	1	1
9825	24	6
9885	0	0
9900	5	3
9915	0	0
9930	0	0
9945	2	2
9960	3	3
9975	2	2
9990	0	0
10005	3	3
10020	7	1
10035	2	1
10050	7	4
10065	0	0
10095	0	0
10125	6	5
10140	6	4
10155	20	5
10260	5	5
10275	7	4
10290	0	0
10305	0	0
10515	0	0
10530	0	0
10545	0	0
10560	0	0
10575	0	0
10590	0	0
10620	0	0
10635	0	0
10665	1	1
10680	0	0
10695	8	4
10755	11	5
10770	18	2
10785	0	0
10800	3	2
10815	5	4
10860	4	3
10875	3	2
10890	2	2
10905	0	0
10920	0	0
10935	4	4
10950	0	0
10965	0	0
10980	2	2
11010	0	0
11115	31	9
11265	9	8
11280	10	7

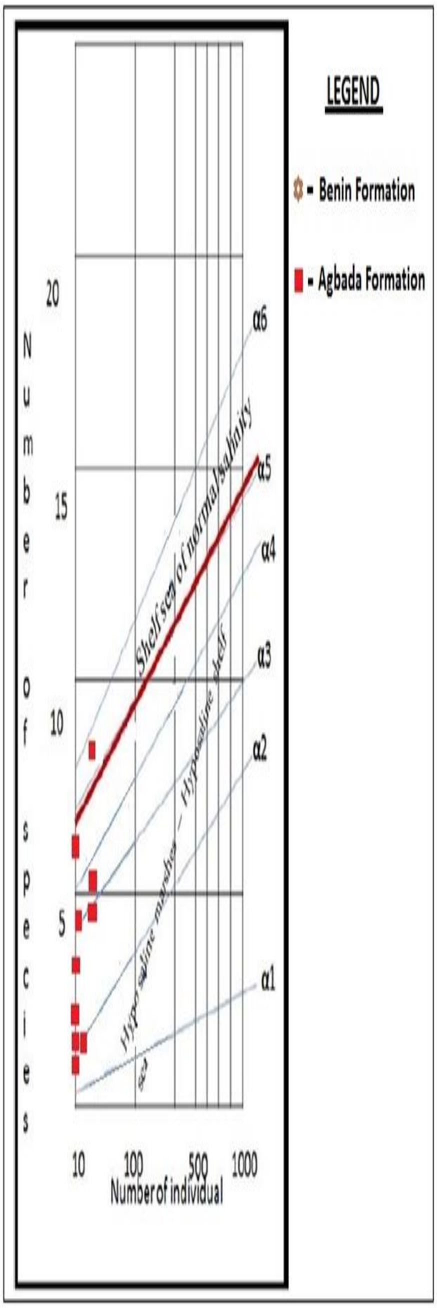

Figure 3: Number of species against number of individuals forms for #3 Well

CONCLUSION

Foraminifera biostratigraphy and paleoenvironmental study of the sediments of Ash-3 Well shows that two foraminifera zones which are N4-N5 and lower N2-N4 Zones were identified and the age of the sediments ranges from Oligocene to Early Miocene. The paleoenvironmental study based on recovered benthic foraminiferal association revealed that the sedimentary sequences were deposited in environments ranging from marginal marine (littoral zone) to deep marine environments (middle

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neritic zone). The salinity during the deposition of the sediments of Ash-3 Well was within the hyposaline marshes – hyposaline shelf sea, which implies that the salinity of the water condition during this time was abnormally low salinity.

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