



STRATIGRAPHIC INSIGHTS AND DEPOSITIONAL SYSTEMS OF OSM WELL, MEGBE FIELD, NIGER DELTA BASIN

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ABSTRACT

Foraminiferal biostratigraphy and paleoenvironmental analysis of the sediments penetrated by OSM well in the Coastal Swamp Delta Depobelt, Niger Delta Basin was carried out in order to determine foraminiferal biozonation, relative age, paleobathymetry and depositional environment of the area of interest. A total of twenty-eight (28) foraminifera species were recovered; three (03) foraminifera species were planktonic, while eight (8) and seventeen (17) foraminifera species were calcareous and agglutinated benthic foraminifera respectively. Four planktonic foraminifera biozones of Blow (1979) were identified: namely (N17-N16, N16-N15, N15-N14 and N13-N12). The result of the analysis indicates that the entire analyzed interval (6140ft – 12800ft) was deposited during the Middle Miocene to Late Miocene within a coastal deltaic to an inner neritic depositional setting.

KEY WORDS: Biozonation, foraminifera, Benthic, planktonic, stratigraphy

INTRODUCTION

The Niger Delta Basin is one of the most prolific hydrocarbon provinces in the world. The basin has a complex stratigraphic and sedimentological framework essential for understanding its geological history and resource potential (Doust and Omatsola, 1990). The petroliferous nature of the basin has led to years of intensive and comprehensive geologic and geophysical research carried out for both commercial and academic purpose (Tuttle *et al.*, 1999). A significant amount of the Niger Delta Basin's significant hydrocarbon reservoirs is typically found in areas with stratigraphic and structural complexity (Short and Stauble, 1967).

Short and Stauble (1967) opined that shales from the Agbada Formation were the primary source rocks. The basin's formation is attributed to plate tectonics during the Late Jurassic period, involving the movement and deposition of clastic sediments along ancient rifts known as aulacogens (Burke, 1972; Whiteman, 1982). Durugbo (2013) discussed the potentials of dinoflagellate cyst abundance and diversity in two wells in the Niger Delta. Where he identified six sequence boundaries and seven maximum flooding surfaces.

On the basis of the analysis of dinoflagellate cysts found in the Igbomotoru-1 Well, Central Swamp, Niger Delta Basin, Oloto (2014) assigned an Upper Miocene to Pleistocene age to the well. On the basis of foraminifera morphogroup triangular cross-plot of the ratios between *Textularina*, *Miliolina*, and *Rotalina*, the ratio of planktic to benthic foraminifera (P/B ratio), and the presence of paleodepths indicator fossils, Obaje and Okosun (2013) interpreted the Tomboy Field Offshore Western Niger Delta as shelf (inner to outer neritic) environment of deposition. The percentage ratios of calcareous benthic to arenaceous benthic foraminifera (FOBC/FOBA) in the five wells, along with lithofacies and fossil accessories, suggested a shallow marine paleoenvironment. Planktonic foraminiferal biostratigraphic studies were done by Ajayi and Okosun (2014) on four wells offshore the Niger Delta Basin. Three foraminifera zones and forty-two foraminifera species were observed. They assigned a Late Miocene and the Early Pliocene age to the sedimentary successions. The environment of deposition of the sedimentary succession was established to be deep water environment. Nwaejije *et al.* (2017) worked on the foraminiferal biostratigraphy and palaeoenvironment of Well 5, OML 34, Niger Delta, Nigeria.

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They recognized three planktonic foraminiferal zones: *Catapsydrax dissimilis*, *Praeorbulina glomerosa* and *Orbulina universa* corresponding to Partial-range zone, interval zone and taxon - range zone respectively. These zones are equivalent to (Blow, 1969) N6 - N7, N8 - N9 and N9 zones and (Berggren *et al.*, 1995) M4, M4 - M5, and M5 zones. By conducting a comprehensive foraminiferal biostratigraphic study of OSM well, this study aims at contributing significantly to our understanding of the Niger Delta Basin.

GEOLOGIC SETTING

The Niger Delta, a petroleum producing region of Nigeria, is situated in the Gulf of Guinea continental margin in Equatorial West Africa. Its southern border is the Gulf of Guinea. The Anambra Basin and the Abakaliki Anticlinorium delineate its northern border. It is bounded at the northwest by the West African Shield, ending at the Benin hinge line, and the Calabar hinge line to the east. The Niger Delta is indeed a vast arcuate delta that is influenced by wave action and is known for its dynamic and often destructive nature (Efu-Efeotor, 1997). It is made up of a mainly regressive clastic series that thickens to a maximum of around 12 km in the area of the basin center (Whiteman, 1982).

The origin of the Niger Delta can be traced to the opening of the South Atlantic in Aptian. According to Short and Stauble (1967), the coastal sedimentary basin of Nigeria has undergone three depositional cycles. The first began with a marine intrusion in the middle Cretaceous and ended with a small folding

phase in the Santonian epoch. The second resulted in the establishment of a proto-Niger Delta in the late Cretaceous and a major marine transgression during the Paleocene. During the third cycle, which covered the Eocene to Recent era, the major Niger Delta kept growing (Burke 1972).

Research carried out in the Niger Delta has revealed three vertical lithostratigraphic subdivisions or Formations: The Agbada Formation, which contains the hydrocarbon reservoirs, the Benin Formation, which is an upper delta top lithofacies, and the lower Akata Formation, which is the source of hydrocarbon generation and contains overpressured shales (Short and Stauble 1967). The aforementioned lithostratigraphic units of Paleocene to Recent age that make up the Niger Delta sediments are dispersed throughout onshore and offshore depobelts, forming a vast regressive cycle (Avbovbo 1978). The Benin Formation, which is made up of continental, backswamp, and fluvial deposits is the thickest unit. The Benin Formation has a thickness of up to 2500 meters. The paralic Agbada Formation, comprising brackish to marine, coastal, and fluvio-marine deposits arranged in coarsening upward cycles, is situated underneath the Benin Formation. The Akata Formation (Eocene–Recent) is the oldest lithostratigraphic unit in the Niger Delta. It is a marine sedimentary succession that is laid in front of the advancing delta and ranges from 1,968 to 19,680 ft. in thickness. It consists of mainly uniform under-compacted shales, clays, and silts at the base of the delta sequence with lenses of sandstone of abnormally high pressure at the top (Avbovbo, 1978)

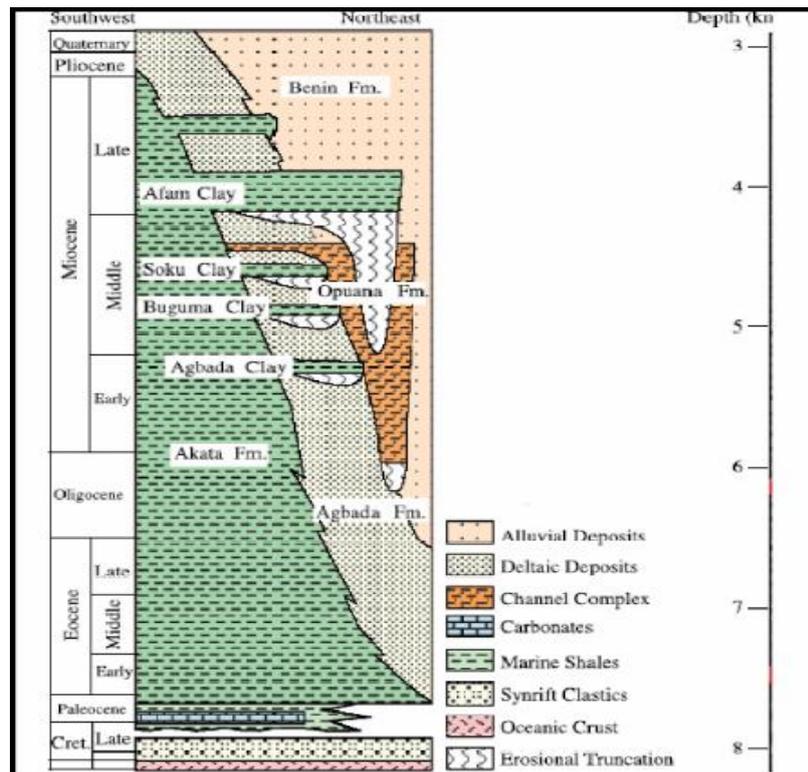


Figure 1: Stratigraphic column showing the three formations of the Niger Delta. Modified from (Doust and Omatsola, 1990).

MATERIALS AND METHOD

Thirty (30) ditch cutting samples were collected from the shaly and sandy shale intervals of interest between 6140ft to 12800ft. The samples were prepared using standard foraminifera preparation technique and the analysis was carried out with the use of reflected light microscope.

Materials: Sieves, slides, microscope, picking trays, needles, brushes, digital camera, hot plates, distilled water, water jet, kerosene and liquid soap.

Method: Twenty-five (25) grams of the samples were weighed, packaged and labeled. The samples were soaked with kerosene for about six (6) hours, after which the samples were decanted. Water was later added to the samples and allowed to stay for 24 hours. Samples were washed through 270 mesh sieve with 53 micron (μm) aperture under running tap water.

Washed samples were dried on hot plate at about 50°C for about 20 minutes. Micro sieves of different sizes (coarse, medium and fine) were stacked on each other and the samples were sieved manually. Each fraction collected was spread on gridded foraminifera tray, picked and the recovered foraminifera were observed under a reflected microscope. Recognized fossils were picked and placed in the cavity of appropriately labeled slides. Sorting and grouping of fossils were done according to their morphological similarity. Identification of foraminifera was carried out considering the test composition, chamber arrangements, sutures, apertures, habits and ornamentation. Published references of Fayose (1970), Blow (1979) and Bolli and Saunders (1985) also aided in the identification.

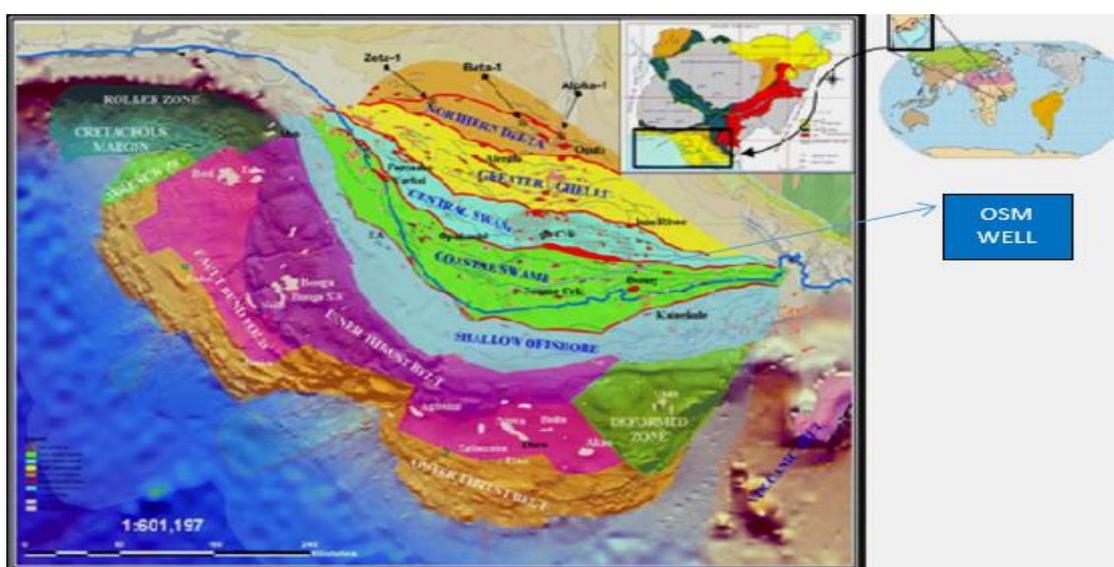


Figure 1: Location map of study area, (Oluwajana *et al.* 2017; Tuttle *et al.* 1999)

RESULTS AND DISCUSSIONS

Lithologic Description

Three lithologic units were observed within the analyzed section. These lithofacies were delineated basically by the percentage of shale to sand volume within several intervals of the analyzed section. The following depositional units were delineated; sandy shale, shaly sand and shale

Sandy shale unit: This can be observed in the intervals between 6,100ft-7,000ft, 7,600ft-7,900ft, 8,900ft-9,600ft, 10,500ft-10,600ft, and 10,900ft-12,100ft. Grains within the aforementioned intervals show similar characteristics such as dark grey colour, fine to medium, sub-angular to sub-rounded, moderately sorted, and most importantly possess a higher percentage of shale particles of as high as 70%, hence the nomenclature 'sandy shale'.

Shaly sand facies: This can be observed in intervals 7,100ft-7,500ft, 8,000ft-8,900ft, and 10,700ft-10,800ft. Grains within these intervals are generally light/dark grey in colour, fine/medium to coarse, sub-angular to sub-rounded, moderately sorted. These intervals possess a higher percentage of sand particles of about 80% compared to shale which brought about the nomenclature 'shaly sand'.

Shale unit: This can be observed in intervals 9,700ft-10,400ft and 12,200ft-12,800ft. The grains are generally dark grey, fine to medium, sub-angular to sub-rounded and moderately sorted. The shaly particles are very high reaching about 95%.

A detailed representation of the lithofacies observed in OSM well is shown in table 1

Table 1: Lithologic log of OSM well

S/No.	DEPTH (Ft.)	LITHOLOGY	MUD/WACKES										GRAVEL	IR GRAVELS	SEDIMENTOLOGICAL DESCRIPTION	SH-SD%	LITHOFACIES	LITHOZONES	ASSOCIATED MINERALS UNIT	
			Mud		Silt		Clay		Sand		Grains									R. GRAVELS
			Clay	Silt	V.Fine	Fine	Medium	Coarse	V.Coarse	Gravel	Cobbles	Boulders								
1	6100																			
2	6200																			
3	6300																			
4	6400																			
5	6500																			
6	6600																			
7	6700																			
8	6800																			
9	6900																			
10	7000																			
11	7100																			
12	7200																			
13	7300																			
14	7400																			
15	7500																			
16	7600																			
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38	9800																			
39	9900																			
40	10000																			
41	10100																			
43	10200																			
44	10300																			
45	10400																			
46	10500																			
47	10600																			
48	10700																			
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61	12000																			
62	12100																			
63	12200																			
64	12300																			
65	12400																			
66	12500																			
67	12600																			
68	12700																			
69	12800																			

LEGEND	
	Sandy shale
	Shaly sand
	Shale

Foraminiferal recoveries over the thirty (30) samples were generally sparse to moderate. Most of the samples were populated by arenaceous benthic species. Calcareous species (planktic and benthic) were rare. This could be attributable to the depositional environments of the sediments. Important foraminiferal species recorded include: *Haplophragmoides narivaensis*, *Ammobaculites agglutinans*, *Ammobaculites strathearnensis*, *Saccammina complanata*, *Florilus costiferum*, *Haplophragmoides sp*, *Haplophragmoides compressa*, *Eggerella scabra*, *Heterolepa*

pseudoungeriana, *Uvigerina subperegrina* and planktonic species such as *Cassigerinella chipollensis*, *Globorotalia continua* and *Globigerinoides subquadratus*. The distribution, abundance, and diversity chart of the recorded foraminiferal species together with the foraminiferal zones recognized are presented in table 2 while the foraminiferal biostratigraphic summary is presented in table 3. Index forms among the recovered foraminiferal species have been used in dating and zoning the intervals.

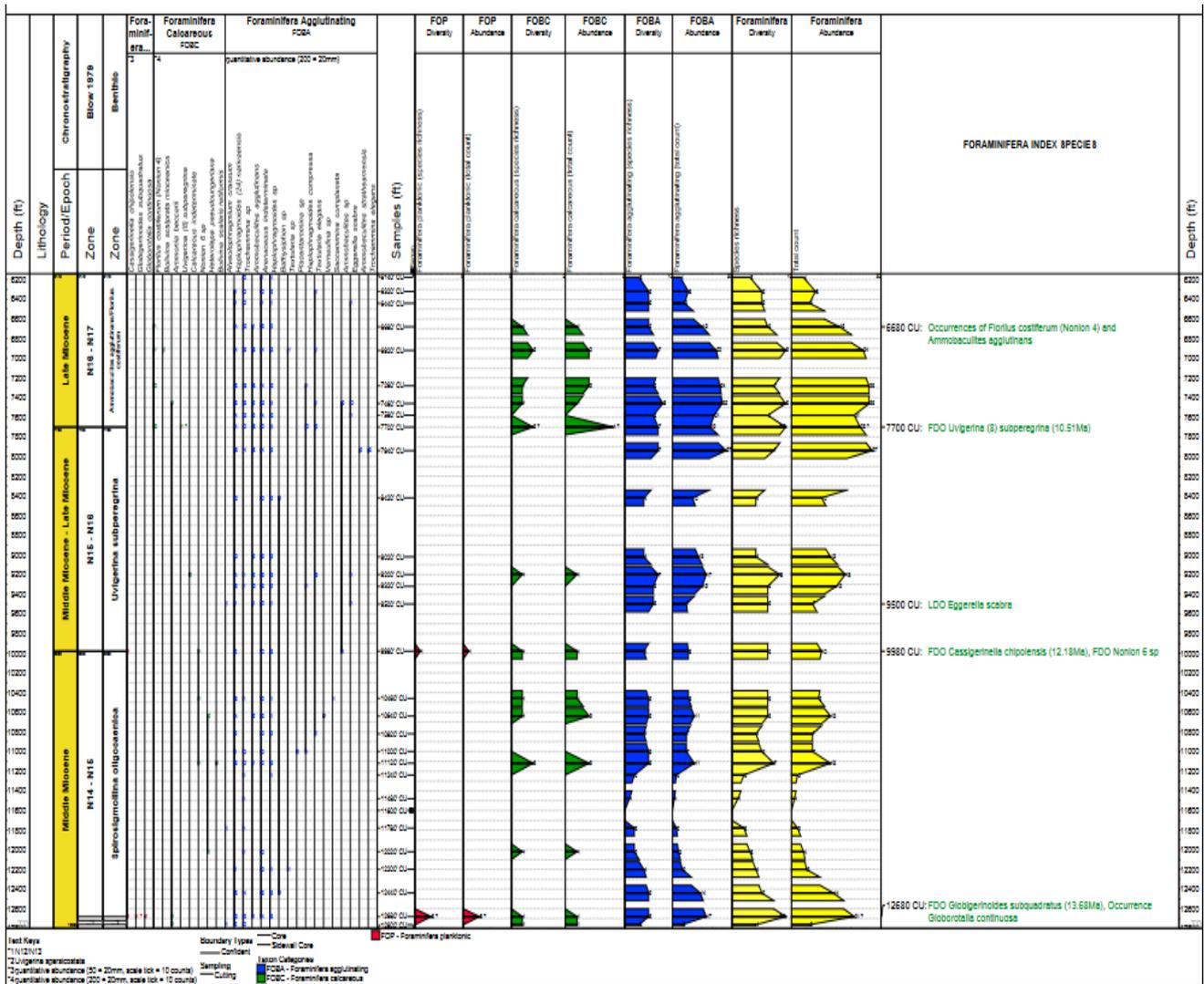


Figure 3: Biostratigraphic distribution chart for OSM well

ZONATION AND DATING

The foraminiferal dating and zonation of the OSM well was guided by the works of Blow (1969, 1979), Bolli and Saunders (1985), and the harmonized stratigraphic distributions of foraminiferal species in the Niger Delta by Stratcom (edited by Adegoke *et al* 2017). Planktonic foraminiferal species were quite rare in the samples Benthic foraminiferal species whose stratigraphic distributions have been well

established in the Nigerian sedimentary basins were used to assign ages. The following Important foraminiferal dating-events were used: First Downhole Occurrence (FDO) of chronostratigraphically significant planktonic/benthic foraminiferal species and Last Downhole Occurrence (LDO) of planktonic/benthic foraminiferal marker species.

The result of the analysis indicates that the study interval (12,800–6,140ft) of OGB Well was deposited during the Late to Middle Miocene epoch, of estimated numerical age of 13.68Ma to 8.80Ma straddling the N13 – N12 to N17 – N16 planktonic zones of Blow (1969, 1979) and Bolli and Saunders (1985).

Stratigraphic Interval 7,700 - 6,140ft.

This interval corresponds to the N17 - N16 planktic zone and *Ammobaculites agglutinans-Florilus costiferum* benthic zone. The interval was dated late Miocene age with an estimated numerical age of 8.80 – 9.50Ma. The age of stratigraphic interval 6140-7700ft was based on occurrences of *Florilus costiferum* (*Nonion* 4) and *Ammobaculites agglutinans* at 6680ft. The upper boundary of this zone is placed at the first sample analyzed. The lower boundary of this zone is defined by the FDO *Uvigerina subperegrina* at 7,700ft. The interval is characterized by the occurrences of *Haplophragmoides narivaensis*, *Ammobaculites agglutinans*, *Florilus costiferum* (*Nonion* 4), *Trochammina sp*, *Eggerella scabra* and *Textularia elegans*.

Stratigraphic Interval 9,980 - 7,700 ft.

This interval corresponds to the N16- N15 planktic zone and *Uvigerina subperegrina* benthic zone. The interval was dated middle Miocene with an estimated numerical age 9.50Ma – 12.18Ma. The age of the stratigraphic interval 7,700–9,980ft was based on the first downhole occurrence of *Uvigerina subperegrina* at 7,700ft. The upper boundary of this zone is defined by the FDO *Uvigerina subperegrina* at 7,700ft. Foraminiferal species that characterized this interval include *Uvigerina subperegrina*, *Eggerella scabra*, *Haplophragmoides narivaensis*, *Textularia elegans*, *Ammobaculites agglutinans*, *Florilus costiferum*, and *Haplophragmoides sp*. The interval is defined by the last downhole occurrence (LDC) of *Eggerella scabra*

at 9,500ft and the first downhole Occurrence FDO of *Cassigerinella chipollensis* at 9,980ft.

Stratigraphic Interval 12,680 - 9,980ft.

This interval corresponds to the N15 – N14 planktonic zone and *Spirosigmoilina oligocaenica* benthic zone. The interval was dated middle miocene with an estimated numerical age of 12.18Ma – 13.68Ma. The age of stratigraphic interval 9,980 –12,680ft was based on first downhole occurrence of *Cassigerinella chipollensis* at 9,980ft. The upper boundary of this zone is defined by the FDO of *Cassigerinella chipollensis* at 9,980ft. Foraminiferal species that characterized this interval include *Cassigerinella chipollensis*, *Florilus costiferum* (*Nonion* 6), *Eggerella scabra*, *Haplophragmoides compressa*, *Haplophragmoides narivaensis*, *Saccamina complanata*, *Heterolpa pseudounghiana*, *Textularia elegans*, *Verneulina sp.*, *Bolivina scalprata retiformis*, *Alveolophragmium crassum* and *Placentamina sp*. The lower limit of this zone is marked by the FDO of *Globigerinoides subquadratus* at 12,680ft.

Stratigraphic Interval 12,800 - 12,680ft.

This interval corresponds to the N13 – N12 and *Uvigerina sparsicostata* Benthic zone. The interval was dated middle Miocene with an estimated numerical age of 13.68Ma. The age of stratigraphic interval 12,680ft –12,800ft was based on the first downhole occurrence of *Globigerinoides subquadratus* at 12,680ft. The upper boundary of this zone is defined by the FDO of *Globigerinoides subquadratus* at 12,680ft. Foraminiferal species that characterized this interval include *Globigerinoides subquadratus*, *Globorotalia continua*, *Ammobaculites agglutinans*, *Cassigerinella chipollensis*, *Haplophragmoides narivaensis*, *Ammonia beccarii*, *Alveolophragmium crassum* and *Haplophragmoides sp*. The occurrence of planktic foraminifera *Globorotalia continua* at 12,680ft suggests a Middle Miocene age at this depth. The lower boundary of this zone was not reached at the last sample analyzed. It was tentatively placed at the terminal depth (12,800ft) of the study interval.

Table 3: Biostratigraphic Summary for OSM well

Depth (ft)	Age	Planktic Zone (Blow 1979)	Benthic Zone	Important Foraminiferal Bioevents
6140	LATE MIOCENE	N16 - N17	Florilus costiferum - Ammobaculites agglutinans	8680ft. Occurrences of <i>Florilus costiferum</i> (Nonion 4) and <i>Ammobaculites agglutinans</i>
7000				7700ft. FDO <i>Uvigerina subperegrina</i> (9.5Ma)
8000	MIDDLE - LATE MIOCENE	N15 - N16	<i>Uvigerina subperegrina</i>	9500ft. LDO <i>Eggerella scabra</i>
9000				9980ft. FDO <i>Cassigerinella chipollensis</i> (12.18Ma) FDO <i>Florilus costiferum</i> (Nonion 6)
10000	MIDDLE MIOCENE	N14 - N15	<i>Spirosigmoina oligocaenica</i>	
11000				
12000				
12800				12680ft. FDO <i>Globigerinoides subquadratus</i> (13.68Ma) Occurrence <i>Globorotalia continuosa</i>
12800		N12 - N13	<i>Uvigerina sparsicostata</i>	

PALEOENVIRONMENTAL RECONSTRUCTION

The foraminiferal assemblages in the study interval of OSM well were used to establish depositional environments. Paleoenvironmental deductions were guided by the works of Petter (1979,1982) and Murray (1991), where abundance and diversity of species played key roles in paleoenvironmental reconstruction.

The depositional environments of the sediments are predominantly marginal marine (coastal deltaic) to inner neritic settings based on the recorded foraminiferal assemblage dominated by arenaceous benthic species such as *Haplophragmoides narivaensis*, *Ammobaculites agglutinans*, *Ammobaculites strathearnensis*, *Saccamina complanata*, *Florilus costiferum*, *Haplophragmoides sp*, *Haplophragmoides compressa*, *Eggerella scabra*, *Heterolepa pseudoungeriana*, *Uvigerina subperegrina*, and planktonic species such as *Cassigerinella chipollensis*, *Globorotalia continuosa* and *Globigerinoides subquadratus* Petters (1979a, 1982) has used the dominance of arenaceous species *Haplophragmoides*, *Ammobaculites*, *Reophax* and *Miliammina* to assign very shallow neritic environment to Pindiga Formation of the Gongola Basin. Adegoke *et al.* (1976) have inferred near shore turbulent

environment in the modern Niger Delta on the basis of arenaceous foraminiferal species like *Ammobaculites*, *Haplophragmoides* and *Trochammina*. On the basis of the arenaceous benthic and planktonic foraminiferal assemblages, marginal marine to inner neritic paleoenvironment was assigned to the studied interval.

CONCLUSION

Foraminiferal biostratigraphy and paleoenvironmental analysis of the sediments penetrated by OSM well was carried out to determine the age, paleobathymetry and depositional environment. Four benthic foraminifera zones were identified: *Ammobaculites agglutinans*-*Florilus costiferum* zone, *Uvigerina subperegrina* zone, *Spirosigmoina oligocaenica* zone and *Uvigerina sparsicostata* zone were established. Four planktonic (4) foraminifera biozones: N17-N16, N16-N15, N15-N14 and N13-N12 which correspond to Late Miocene to Middle Miocene age were identified. The environment of deposition ranges from coastal deltaic to inner neritic.

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