Paleoecology and Paleoenvironment of Wells A & B in the Deep Offshore Niger Delta

[1]*Ifeanyichukwu S. Edeh and [2]Dr. Richmond U. Ideozu
[1 and 2]Department of Geology, University of Port Harcourt

ABSTRACT

Quantitative analysis of fauna and flora recovered from wells A and B were used to interpret paleoecology and paleoenvironments of sediments in the deep offshore Niger Delta. Micropaleontology and Palynological analysis and lithologic descriptions were carried out on the ditch cuttings from the wells. The recovered microfossils were grouped based on their habitational preferences to synthesize the Paleoenvironment and Paleoecology. The foraminiferal groups are shallow water calcareous benthic, shallow water arenaceous benthic, deep water calcareous benthic, deep water arenaceous benthic, flat, globular and sub-globular planktonic. The sediments were deposited in within non-marine to Lower bathyal paleobathymeytric depositional settings in a cyclic pattern though dominated by deep marine bathymetric realms. The occurrence of mixed foraminiferal assemblages of deep water biofacies such as Gyroidina soldanii, Pullenia bulloides, Uvigerina proboscidea, Uvigerina mantaensis, Pyrgo bulloides, Cyclammina minima, Haplophragmoides obliquecameratus etc. with shallow water biofacies such as Quinqueloculina agglutinans, Quinqueloculina bicarinata, Eggerella scabra, Epistominella vitrea, Ammonia beccarii, Trochammina globigeriniformis, Ammobaculites spp., Miliammina spp., etc. within the deep marine bathymetry suggest the high influx of sediments from shelf into the slope by turbidity currents. This is further support by facies dislocation whereby deep-water facies directly overlying shallow water facies and vice versa. Dislocation of facies is a common indicator of structural deformation resulting in erosion and re-deposition of sediments down slope. Concise interpretation of mixed assemblages was achieved by the ecological grouping adopted for this study. High tides played a key role in the distribution of freshwater elements during the deposition of the sediments. Nutrient supply and oxygen content were high in the upper section compared to the middle and lower section of the studied wells leading to very high abundance and diversity of planktonic foraminifera and calcareous taxa respectively. The results have significantly enhanced the understanding of the paleoecology and paleoenvironment of the study area and minimized uncertainty associated with dilution of the fossil assemblages on the slope. It will also enhance modeling of the reservoirs in reference to their environment of deposition (paleobathymetry).

Keywords: Paleobathymetry; paleoecology; biofacies; fauna, flora

INTRODUCTION

Niger Delta sediments wedge was formed along a failed arm of a triple junction system that initially evolved during disintegration of the South American and African plates (Whiteman, 1982). Three crucial depositional episodes have been identified within Niger Delta (Short and Stauble, 1967; Doust and Omatsola, 1990). The first episode began during the mid-Cretaceous marine incursion and terminated in an extensive marine transgression in the earliest epoch of the Tertiary period. The next cycles, started during the Paleogene period and represent actual deltaic progradation. The sediments of the last complete cycle of relative sea level change have been splitted into a series of six depobelts separated by crucial synsedimentary faults (Doust and Omatsola, 1990). The depocenters are created when paths of sediment supply were confined by deformation of structures, resulting in accumulation of sediments into restricted zones on the delta. The regional depobelts are Northern Delta, Greater Ughelli, Central Swamp, Coastal Swamp, Offshore and Deep-offshore depobelts. The study area is in the Deep-offshore Depobelt of the Niger Delta basin of Nigeria. Phleger (1955), in his work has established that, different species have distinct depth interval over which they occur in addition to distinct geographic distribution. Nearshore shallow conditions can be inferred from the presence of *Triloculina, Miliola and Quinqueloculina*. Studies of foraminifera from the Northeastern Gulf of Mexico by Bandy (1956) show that *Ammonia beccarii* is a typical

---

The authors are grateful to the Management and Staff of Nigerian National Petroleum Corporation, Research and Development (NNPC R&D) Division for their support and permission to publish this paper. The staff of Exploration Section of NNPC R&D are highly acknowledged for their contributions.

shallow water taxon while in the Niger Delta, arenaceous benthic foraminifera such as Ammobaculities and Haplophragmoides dominated tidal creeks and estuaries (Asseez *et al*., 1974). Culver, (1988) and Poag, (1981) have summarized the general benthic foraminiferal biofacies trends across the northern Gulf of Mexico. The depth distributions of certain benthic foraminiferal genera are established on genera which are prevalent within each depth interval although they are not essentially constrained to these intervals. Based on the foraminiferal bathymetry by Harris (1981) and Culver (1988), Petters (1995) developed a foraminiferal biofacies model for the Offshore of the Niger Delta. Some researchers have worked on reconstruction of paleoenvironment, paleoclimatic and paleodepth of Agbada Formation in Niger Delta. (Chukwu, *et al*., 2012; Oloto, 2014). Harris (1981) used core samples from Deep Offshore Niger Delta to characterize shelf foraminiferal assemblages and concluded that water mass features, particularly temperature and depth, significantly affects the distribution of benthic foraminifera. Murray generated a trilinear plot showing the relative abundances of the foraminiferal suborders Textulariina (arenaceous), Miliolina (porcelaneous), and Rotaliina (hyaline calcareous) for comparing foraminifera with recent marine environment. (Murray, 2006; 1991; 1973). The use of planktonic to benthic foraminifera ratio for paleoenvironment interpretation have been studied (Van Der Zwaan et al., 1990). Cases of mixed foraminiferal assemblages in the Delta have been recorded in recent research. According to Beka and Oti, (1995), co-occurrence of both deep and shallow biofacies assemblages indicates displacement of the shallow-water benthics into deep-water environment by turbidity currents. Petters, (1995), reported that the microfaunal content of deltaic deposits usually diminish towards the land. The majority of planktonic foraminifera float in the surface or near-surface waters of the open ocean as part of the marine zooplankton (BouDagher-Fadel, 2013). Simple globular forms occupy the surface waters while more massive, ornamented forms can achieve neutral buoyancy at greater depth beneath the ocean surface. The heavily ornamented, or elongated or flattened chambers are characteristics of deep dwelling forms of planktonic foraminifera (BouDagher-Fadel, 2013). In fossil assemblage, the depth restricted planktonic assemblages would be mixed with all other species of planktonic foraminifera (BouDagher-Fadel, 2013).

The ratio of arenaceous and calcareous taxa reflects the oxygen content of the bottom water since low oxygen content may cause problems for foraminiferal calcite secretion (Phleger and Soutar 1973). Bernhard (1986) categorized different oxygen levels as follows: anoxic (0.1 ml/LO$_2$), dysoxic (0.1–0.5 ml/LO$_2$), and oxic (0.5 ml/LO$_2$). Anoxic bottom conditions are depicted by no occurrences of calcareous benthic foraminifera and the exclusive occurrence of planktonic species (Eicher and Worstell, 1970; Kaiho, 1994). Thus, arenaceous benthic foraminifera can survive dysoxic to anoxic conditions (Vercoutere *et al,* 1987; Kaiho, 1994). Planktonic foraminifera, initially employed as biostratigraphic markers are now used as tools in palaeoecological studies. Generally, nutrient supply increases with increase in abundance and diversity of planktonics (Nichols, 2009). Gebhardt (1998), recorded that Gabonita *spp*. and Prebulimina are high nutrient flux indicators whereas Gabonita *spp*. is very common in upwelling areas of the same age (Kuhnt and Wiedmann 1995; Gebhardt *et al*., 2004). According to Oloto (1992), changes in depositional environment may be inferred from the composition and comparative richness of diverse groups of palynomorphs. High richness of *Classopollis* has been found to be associated to arid environments (Srivastava, 1976; Vakhrameev, 1981; Doyle *et al.,* 1982; Lima, 1983). Vakhrameev (1981) proposed climatic belts based on the richness of *Classopollis*, where a low abundance (1-10%) of the genus indicates a temperate climate, 20-50% warm subtropical, and 60-100% semi-arid to arid conditions. In contrast, high abundance of fern spores reflects near shore environments under humid conditions. This hypothesis is directly related to the importance of humidity on the reproductive cycle of modern pteridophytes (Doyle *et al.,* 1982; Lima, 1983). It is worthy of note that *Botryococcus brauni* live in fresh water (Gray, 1960), even some of its species tolerate brackish settings (DeDeckker, 1988). Dinoflagellates had been identified as indicator of marine environment (Piasecki, *et al*., 2002). *Polysphaeridium sp*. is a lagoonal genus whereas *Areoligera* group and *Homotryblium tenuispinosum* are suggestive of deposition in near- shore marginal marine environment. *Cordosphaeridium sp.* and *Exochosphaeridium sp.* are suggestive of open neritic conditions (Torricelli *et al*., 2005; Carvaliho, 2004) whereas *Impletosphaeridium sp., Cyclonephelium sp.* and *Spiniferites* group particularly *Spiniferites ramosus* indicates inner neritic, shallow to middle neritic and outer neritic (open marine) environment respectively (Oloto, 1992; Lana, 1997; Torricelli *et al*., 2005). *Senegalinium sp.* flourishes mostly in the area of high nutrient availability (Johan, 2010).

MATERIALS AND METHODS

This study used ditch cuttings samples and wireline logs. A well-defined Standard Operating Procedures was applied in sample preparations. The ditch cutting samples were washed in a water/liquid soap medium using a 53micron sieve to avoid the loss of the very small species. The washed samples were dried in an oven at a temperature of about 500°F and subsequently separated into three size fractions (coarse, medium and fine) and packed into separate well-labeled sample bags. Samples were thereafter picked and subsequently analyzed under microscope

Micropaleontological analysis was carried out on the washed residues of the ditch-cuttings of the two wells used

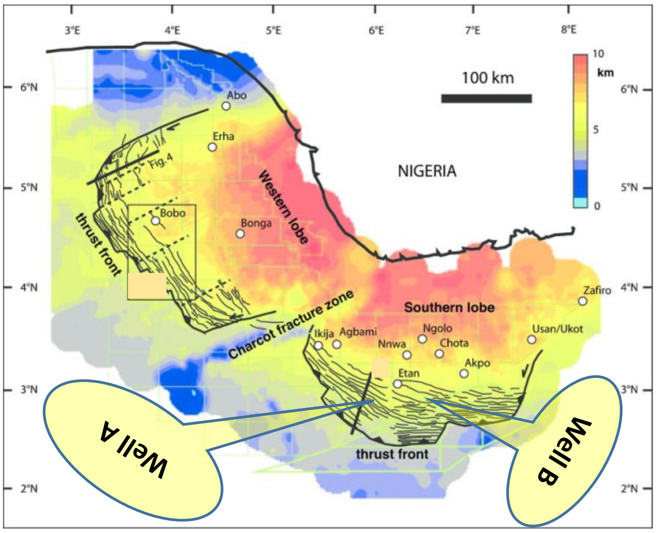


Figure 1: Location Map demonstrating the Study Area (Peter *et al.,* 2009).

In this study two (2) wells were considered, and they are: Well A (2860 – 5273m) and Well B (2500 – 4380m). Both wells are located in Deep Offshore Niger Delta at the frontal toe-thrust zone of the southern lobe (Figure 1).

The study is aimed at concise interpretation of the paleoecology and paleoenvironment of the study area by grouping microfossils based on their habitational preferences to solving the problem of dilution of the fossil assemblages in the slope area for proper modeling of the reservoirs in Deep Offshore Niger Delta.

in this study. A clear Standard Operating Procedures was used in sample preparations. The samples were washed through a 53 µm-mesh sieve to retain very small species and, if not completely disintegrated, boiled with hydrogen hydroxide and sieved again. Samples prepared for micropalaeontology were subsequently separated into three size fractions (coarse, medium and fine) to enhance picking of the taxa. Each fraction is packed into separate well-labeled sample bags. The picked samples were analyzed under an incident ray microscope for identification referencing the Foraminiferal Photo Album of SPDC and literatures. The name of fossil and number of each species are recorded in an analysis sheet. Species identified are plotted in distribution charts using Stratabugs software. The species are subdivided into biofacies groups based on their habitational preferences following the biofacies models of Petters (1995), Culver (1988) and Poag (1981).

To extract pollen and spores, the samples are crushed, soaked in liquid detergent and the resulting mixture was heated to 100°C for 12 minutes. The mixture was topped up with water and left overnight. The supernatant was decanted the next morning and the residue was washed thrice with water before 40 ml of Sodium Hexametaphosphate (0.5M) was added to it. The mixture was filtered using 63µm sieve. Greater than 63 µm particles were discarded and less than 63 µm particles were retained. Little water was added to the retained fraction and the mixture was separated using centrifuge at 2000 rpm for about 3 minutes using Zinc Bromide solution (2.2s.g.). The residues were sieved with 15 µm on a nylon mesh, transferred into 15ml vials, mounted on slides using glycerine jelly and cleaned for analysis. Analysis of these slides was achieved by viewing them under a digital binocular microscope. The species were identified by comparison with those in standard manuals such as the SHELL and STRATCOM (2000) manuals. Similarly, species are plotted in distribution chart using StrataBugs Software. Delineation of various ecological communities are done following the approach of Sowunmi, (1972) and (1975).

The various groups of foraminifera assemblages and palynological assemblages were put into consideration in determining and interpreting the environment and paleobathymetry. The biodata was grouped based on their habitational preferences for concise interpretation of the paleoecology and paleoenvironment of the deep offshore field. The abundance and diversity of foraminiferal were classified into seven groups which are shallow water calcareous benthic, shallow water arenaceous benthic, deep water calcareous benthic, deep water arenaceous benthic, globular planktonic, sub-globular planktonic and flat planktonic. The paleobathymetric ranges of each taxon were considered in interpreting the paleoenvironment in line with the biofacies models of Petters (1995), Culver (1988) and Poag (1981).

Results and Discussions

Lithologic log and Lithostratigraphy of Well A & B: The development of the shale, sandstones and siltstones mixture in well-A (2860 – 5273m) is typical of the Agbada formation (Figure 2). The accessories are abundant ferruginous and black carbonaceous materials. Glauconite, gypsum and mica flakes are rare to moderate. Also, Shale is the dominant lithology of well-B (interval 2500 – 4380m) with sandstone and siltstone intercalations at different horizons but thickens towards the middle and lower section of the lithologic log. The development of the lithologies indicates penetration of Agbada Formation in this well section (Figure 3). The accessories in this well include abundant gypsum, carbonaceous, ferruginous and gypsiferous materials. Pyritized grains and micaceous materials are rare to moderate in abundance.

Well A: The microfossils recovered are grouped as follows.

Shallow Water Arenaceous Benthic

Ammo baculites spp, Eggerella scabra, Eggerella spp., Miliammina spp, Textularia spp, Trochammina globigeriniformis and Trochammina spp.

Shallow Water Calcareous Benthic

Ammonia beccarii, Ammonia inflata, Cancris auriculus, Epistominella vitrea, Florilus costiferum, Fursenkoina spp, Nonzonally auris, Nonionella spp, Quinqueloculina agglutinans, Quinqueloculina bicarinate, Quinqueloculina seminulum, Quinqueloculina seminulum and Quinqueloculina vulgaris.

Deep Water Arenaceous Benthic

Alveolophragmium crissum, Ammodiscus incertus, Ammodiscus spp., Cyclammina cancellate, Cyclammina minima, Cyclammina spp, Eggerella bradyi, Gravellina narivaensis, Haplophragmoides bradyi, Haplophragmoides compressa, Haplophragmoides excavate, Haplophragmoides obliquecameratus, Haplophragmoides spp, Karreriella spp., Reophax spp, Saccammina complanate, Saccammina spp and Valvulina flexilis.

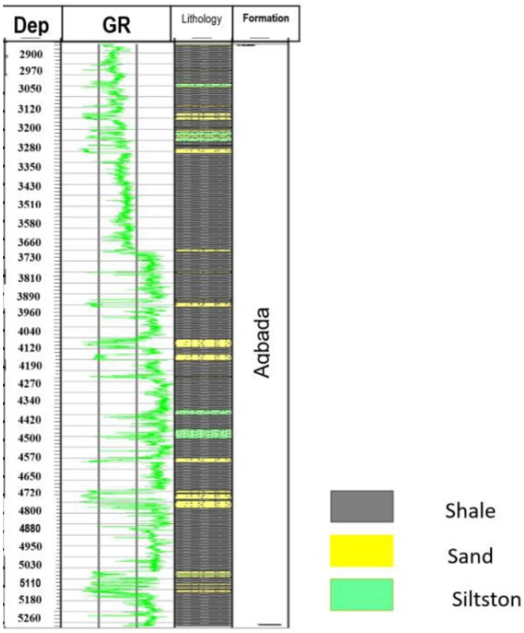


Figure 2: Lithologic log and Lithostratigraphy of Well A.

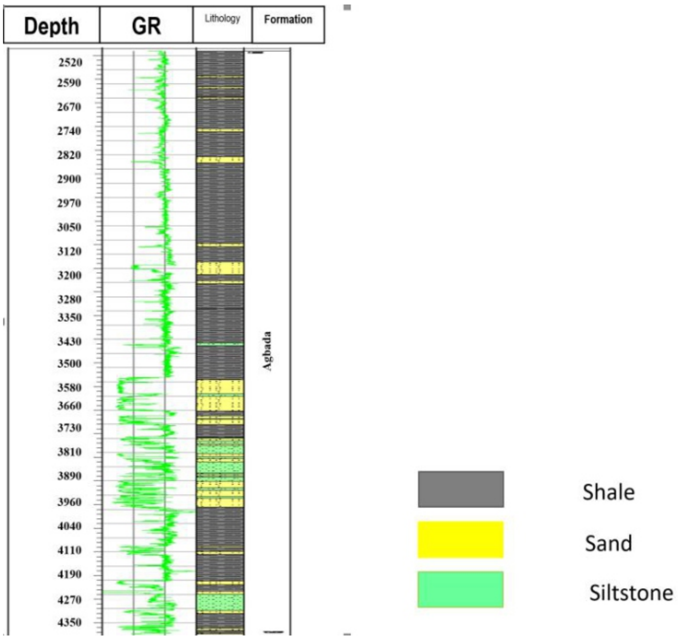


Figure 3: Lithologic log and Lithostratigraphy of Well B.

Biofacies Groups Based on Habitational Preferences

Deep Water Calcareous Benthic

Anomalinoides spp., Bolivina advena, Bolivina aenariensis, Bolivina antiqua, Bolivina catanensis, Bolivina dilatate, Bolivina spp., Brizalina miocenica, Bulimina costata, Bulimina infata, Bulimina spp., Ceratobulimina pacifica, Cibicides lobatulus, Cibicides pseudoungerianus, Cibicidoides pseudoungerianus, Cibicidoides reflugens, Cibicidoides robertsonianus, Dentalina leguminiformis, Fissurina spp, Globocassidulina subglobosa, Globulina spp, Gyroidina soldanii, Gyroidinoides neosoldanii, Gyroidinoides umbonatus, Heterolepa bellincionii, Heterolepa floridana, Heterolepa praecincta, Heterolepa pseudoungeriana, Lagena spp, Lagena striata, Lenticulina inornate, Hanzawaia spp, Neoeponides schrebersii, Nodosaria spp, Planulina ariminensis, Pullenia bulloides, Pullenia quinqueloba, Pyrgo bulloides, Rectuvigerina spp, Trifarina spp, Uvigerina canariensis, Uvigerina mantaensis, Uvigerina peregrina, Uvigerina proboscidea and Uvigerina spp.

Flat Planktonic

Globorotalia plesiotumida, Globorotalia praemenardii, Globorotalia pseudomiocenica, Globorotalia scitula, Globorotalia tumida, Sphaeroidina bulloides and Sphaeroidinellopsis seminulina.

Globular Planktonic

Globigerina bulloides, Globigerina nepenthes, Globigerina praebulloides, Globigerina quinqueloba, Globigerina spp, Globigerina venezuelana, Globigerinita naparimaensis, Globigerinoides bolli, Globigerinoides bulloideus, Globigerinoides conglobatus, Globigerinoides extremus, Globigerinoides immaturus, Globigerinoides obliquus, Globigerinoides quadrilobatus, Globigerinoides ruber, Globigerinoides sacculifer, Globigerinoides trilobus, Globigerinoides spp, Globoquadrina spp, Globorotaloides spp, Globorotaloides suteri, Hastigerina siphonifera, Neogloboquadrina dutertrei, Orbulina suturalis and Orbulina universa,

Sub-globular Planktonic

Globorotalia acostaensis, Globorotalia continuosa, Globorotalia exilis, Globorotalia humerosa, Globorotalia pseudopima and Globorotalia spp.

Well B: The microfossils recovered are grouped as follows.

Shallow Water Arenaceous Benthic

Ammobaculites strathearnensis, Ammobaculites spp, Eggerella scabra, Eggerella ex. gr. Forestensis, Miliammina spp, Textularia spp, Trochammina globigeriniformis and Trochammina spp.

Shallow Water Calcareous Benthic

Epistominella aff.vitrea, Epistominella vitrea, Epistominella spp., Florilus atlanticus, Florilus costiferum, Florilus ex.gr. costiferum, Florilus spp., Florilus ex. gr. boueanum, Fursenkoina punctata, Hanzawaia spp, Hopkinsina spp, Nonion costiferum, Nonion spp, Nonionella auris, Nonionella spp, Quinqueloculina agglutinans, Quinqueloculina microcostata and Quinqueloculina spp.

Deep Water Arenaceous Benthic

Alveolophragmium crissum, Alveolophragmium spp., Ammodiscus glabratus, Ammodiscus incertus, Ammodiscus spp., Cyclammina cancellate, Cyclammina compressa, Cyclammina minima, Cyclammina spp, Eggerella bradyi, Gravellina narivaensis, Gravellina spp., Haplophragmoides bradyi, Haplophragmoides compressa, Haplophragmoides obliquecameratus, Haplophragmoides spp., Karreriella spp., Recurvoides spp, Reophax spp, Saccammina complanate, Saccammina spp, Textularia parvula, Valvulina flexilis and Valvulina spp.

Deep Water Calcareous Benthic

Amphicoryna scalaris, Bolivina antiqua, Bolivina catanensis, Bolivina dilatate, Bolivina punctata, Bolivina spp, Brizalina dilatate, Brizalina punctata, Brizalina spp, Bulimina spp, Buliminella spp, Cassidulina spp., Cibicides spp, Cibicidoides pseudoungerianus, Cibicidoides robertsonianus, Dentalina spp, Eponides cf multiseptus, Eponides spp, Gavelinella spp, Gyroidina soldanii, Gyroidinoides neosoldanii, Heterolepa bellincionii, Heterolepa floridana, Heterolepa mckannai, Heterolepa praecincta, Heterolepa pseudoungeriana, Heterolepa spp, Lenticulina inornate, Lenticulina spp, Melonis pompilioides, Nodosaria spp, Planulina ariminensis, Praeglobobulimina ovata, Praeglobobulimina spp, Praeglobulimina spp, Pullenia bulloides, Pullenia spp, Pyrgo bulloides, Sigmoilina sp, Uvigerina auberiana, Uvigerina mantaensis, Uvigerina peregrina, Uvigerina spp, Uvigerina subperegrina and Virgulina spp.

Flat Planktonic

Globorotalia crassaformis, Globorotalia menardii, Globorotalia menardii, Globorotalia menardii cultrate, Globorotalia merotumida, Globorotalia plesiotumida, Globorotalia pseudomiocenica, Globorotalia scitula, Sphaeroidinellopsis seminulina, Sphaeroidinellopsis sphaeroides and Sphaeroidinellopsis spp.

Globular Planktonic

Globigerina bolli, Globigerina bulloides, Globigerina nepenthes, Globigerina spp, Globigerina venezuelana, Globigerinoides bolli, Globigerinoides bulloideus, Globigerinoides conglobatus, Globigerinoides extremus, Globigerinoides merotumida, Globigerinoides obliquus, Globigerinoides quadrilobatus, Globigerinoides ruber, Globigerinoides sacculifer, Globigerinoides spp, Globigerinoides trilobus, Globoquadrina altispira, Globoquadrina dehiscens, Globoquadrina spp, Neogloboquadrina dutertrei, Neogloboquadrina spp, Orbulina bilobate, Orbulina suturalis and Orbulina universa.

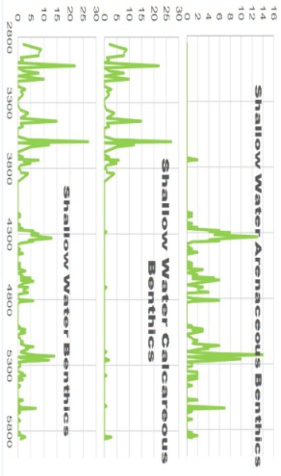
Sub-globular Planktonic

Globorotalia acostaensis, Globorotalia acostaensis, Globorotalia continuosa, Globorotalia humerosa, Globorotalia mayeri, Globorotalia obesa, Globorotalia pseudopima and Globorotalia spp.

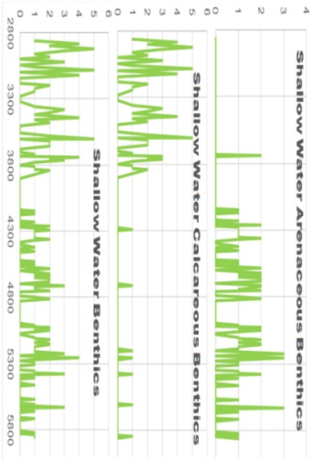
Discussion

Paleobathymetry:

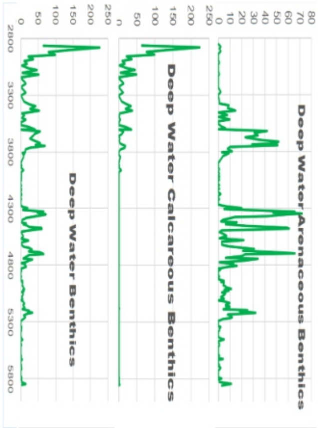
The recovery of the different groups of foraminifera and palynomorphs indicate that sediments encountered in the area of study as observed in the two (2) wells were deposited within non-marine to Lower bathyal paleobathymetric depositional settings. Cyclic paleobathymetric settings have been observed in both wells, with deep marine bathymetric realms predominanting while non-marine and shallow marine are sandwiched at different intervals. Within the Slope area, four bathymetric realms were defined for Well-A as Upper Bathyal (3120 - 3360m), Upper Bathyal to Middle Bathyal (3040 – 3120m, 3560 – 3660m and 3700 – 3770m), Middle Bathyal (4490 – 4645m) and Middle Bathyal to Lower Bathyal (2860 – 3000m, 3360m – 3440m, 4270 – 4490m, 4645 – 4830m and 4940 – 5280m). Other bathymetric realms are Outer Neritic – Upper Bathyal (3000 – 3040m), Middle Neritic - Outer Neritic (3770 – 4010m), Inner Neritic - Middle Neritic (3440 – 3560m and 5780 – 5860m), Inner Neritic (3660m – 3700m and 4010 - 4270m) and Shallow Inner - Inner Neritic (4830 – 4940m). For well B, the bathymetric realm are Middle Bathyal - Lower Bathyal (3340 – 3480m, 3650 – 3800m and 3850 – 4250m), Upper Bathyal – Middle Bathyal (2520 – 2600m, 3250 – 3340m, 3800 – 3850m and 4330 – 4712m), Upper Bathyal (2600 – 2780m), Inner Neritic – Middle Neritic (3480 – 3550m), Inner Neritic (2800 – 2860m and 2940 – 3000m), Non-Marine – Shallow Inner Neritic (2860 – 2940m, 3000 – 3250m and 4250 – 4330m) and Non Marine (2780 – 2800m and 3550 – 3650m). There is considerable occurrence of shefal foraminiferal assemblages in the deeper paleobathymetic setting which is not expected



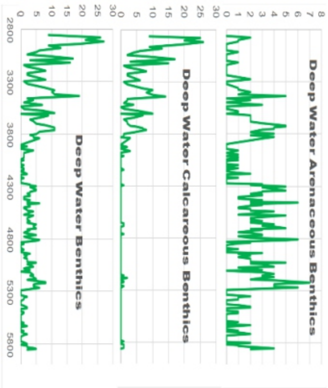
Figures 5: Abundance of Shallow Water Benthic Foraminifera Groups for Well A.



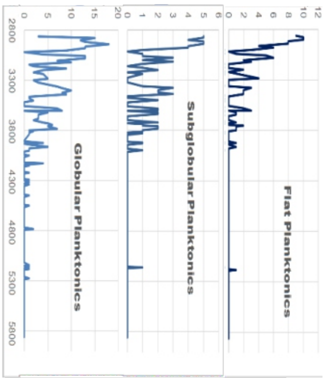
Figures 6: Diversity of Shallow Water Benthic Foraminifera Groups for Well A.



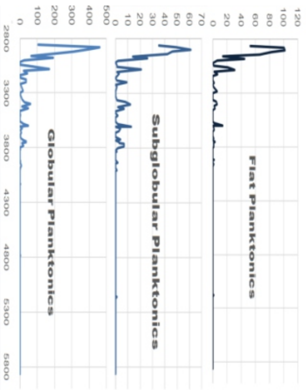
Figures 7: Abundance of Deep Water Benthic Foraminifera Groups for Well A.



Figures 8: Diversity of Deep Water Benthic Foraminifera Groups for Well A.



Figures 9: Abundance of Planktonic Foraminifera Groups for Well A



Figures 10: Diversity of Planktonic Foraminifera Groups for Well A

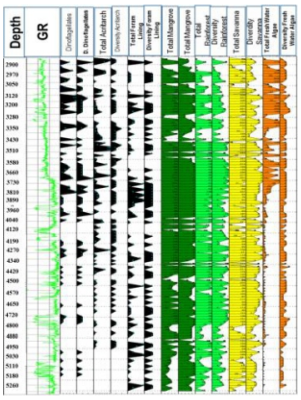


Figure 11: Palynological Assemblages for Well A Based on Habitational Preference

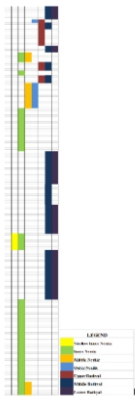
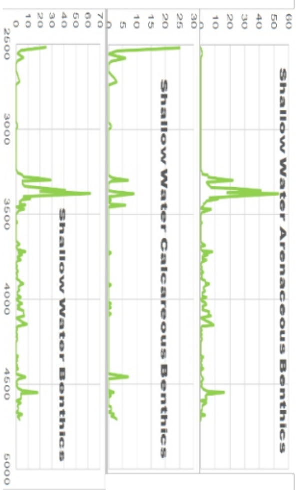


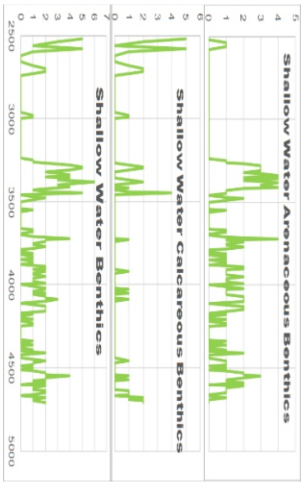
Figure 12: Interpreted Paleobathymetry Summary of Well A

Table 1: Paleoenvironment and Paleobathymetry Summary of Well A.

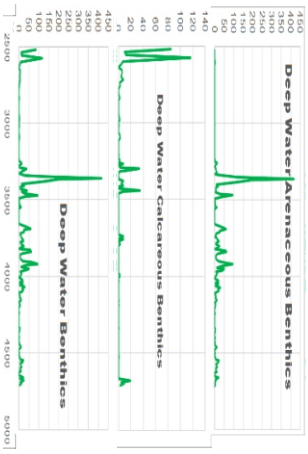
Depth Interval (Meters)	Paleobathymetry	Paleoenvironment
2860– 3000	Middle – Lower Bathyal	Deep Marine
3000– 3040	OuterNeritic - Upper Bathyal	Deep Marine
3040– 3120	Upper Bathyal - Middle Bathyal	Deep Marine
3120– 3360	Upper Bathyal	Deep Marine
3360– 3440	Middle – Lower Bathyal	Deep Marine
3440– 3560	Inner– Middle Neritic	Shallow Marine
3560– 3660	Upper Bathyal - Middle Bathyal	Deep Marine
3660– 3700	Inner Neritic	Shallow Marine
3700– 3770	Upper Bathyal - Middle Bathyal	Deep Marine
3770– 4010	Middle - Outer Neritic	Shallow Marine– Deep Marine
4010– 4270	Inner Neritic	Shallow Marine
4270– 4490	Middle - Lower Bathyal	Deep Marine
4490– 4645	Middle Bathyal	Deep Marine
4645– 4830	Middle - Lower Bathyal	Deep Marine
4830– 4940	Shallow Inner – Inner Neritic	Marginal Marine – Shallow Marine
4940– 5280	Middle - Lower Bathyal	Deep Marine
5280– 5780	Inner Neritic	Shallow Marine
5780– 5860	Inner - Middle Neritic	Shallow Marine



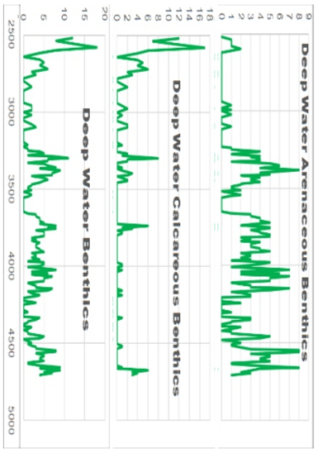
Figures 13: Abundance of Shallow Water Benthic Foraminifera Groups for Well B.



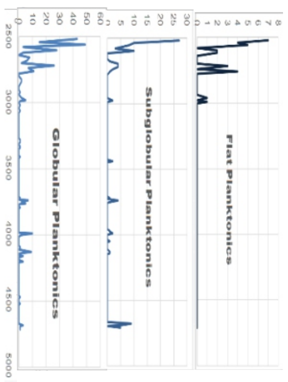
Figures 14: Diversity of Shallow Water Benthic Foraminifera Groups for Well B.



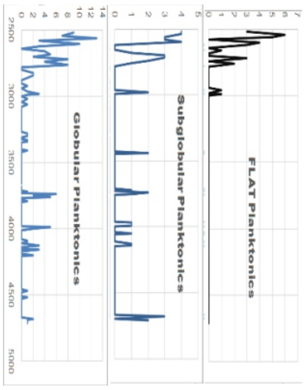
Figures 15: Abundance of Deep Water Benthic Foraminifera Groups for Well B.



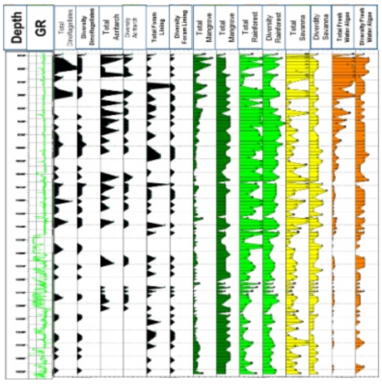
Figures 16: Diversityof Deep Water Benthic Foraminifera Groups for Well B.



Figures 17: Abundance of Planktonic Foraminifera Groups for Well B



Figures 18: Diversity of Planktonic Foraminifera Groups for Well B



Figures 19: Palynological Assemblages for Well B Based on Habitational Preference

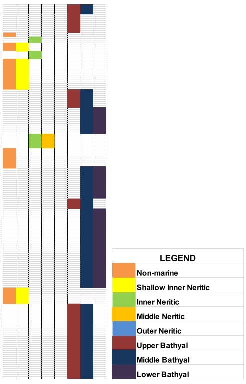


Figure 20: Interpreted Paleobathymetry Summary of Well B.

Table 2: Paleoenvironment and Paleobathymetry Summary of Well B.

Depth Interval (Meters)	Paleobathymetry	Peleoenvironment
2520– 2600	Upper– Middle Bathyal	Deep Marine
2600– 2780	Upper Bathyal	DeepMarine
2780– 2800	Non Marine	Non Marine
2800– 2860	Inner Neritic	Shallow Marine
2860– 2940	Non Marine - Shallow Inner Neritic	Non Marine- Marginal Marine
2940– 3000	Inner Neritic	Shallow Marine
3000– 3250	Non Marine - Shallow Inner Neritic	Non Marine - Marginal Marine
3250– 3340	Upper - Middle Bathyal	Deep Marine
3340– 3480	Middle - Lower Bathyal	Deep Marine
3480– 3550	Inner- Middle Neritic	Shallow Marine
3550– 3650	Non Marine	Non Marine
3650– 3800	Middle - Lower Bathyal	Deep Marine
3800– 3850	Upper - Middle Bathyal	Deep Marine
3850– 4250	Middle - Lower Bathyal	Deep Marine
4250– 4330	Non Marine - Shallow Inner Neritic	Non Marine- Marginal Marine
4330– 4712	Upper - Middle Bathyal	Deep Marine

because bathyal assemblages are expected more in the setting. The co-occurrence of mixed foraminiferal assemblages (deep and shallow biofacies) within the deep-water bathymetry was observed on both wells at different intervals (Figure 4.19 and 4.20) is suggestive of high influx of sediments into the slope by turbidity currents. The presence of both deep and shallow biofacies assemblages suggests displacement of the shallow-water benthic into deep-water environment by turbidity currents (Beka and Oti, 1995). The bio-facies, though ecologically controlled, display a truncated pattern; deep water facies directly overlying shallow water facies and vice versa (Figure 4.21 and 4.22). Thus, this is an indication of facies dislocation; a common indicator of structural deformation resulting in erosion and re-deposition of sediments down slope. Occurrence of freshwater algae especially *Botryococcus brauni* at the deep marine bathymetry realm within the upper section of the studied wells in large numbers (Figure 4.23 & Figure 4.24), is because of the influence of high tides that brought in these freshwater elements during the deposition of the sediments.

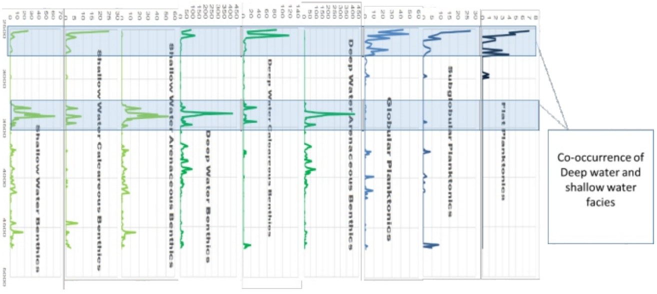


Figure 21: Co-occurrence of deep and shallow water facies in Well A.

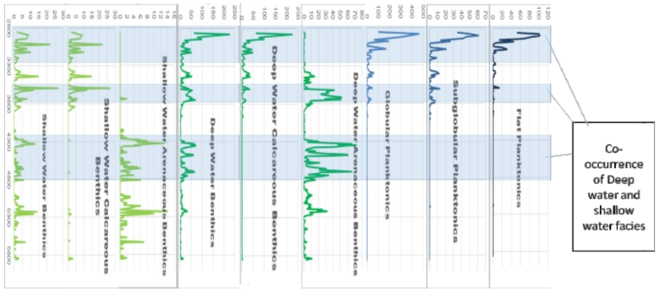


Figure 22: Co-occurrence of Deep and shallow water facies in Well B.

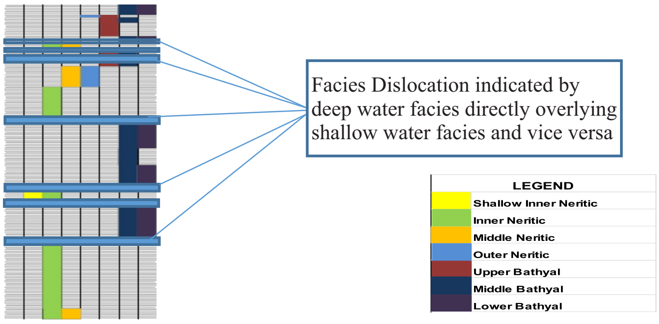


Figure 23: Facies Dislocation in Well A.

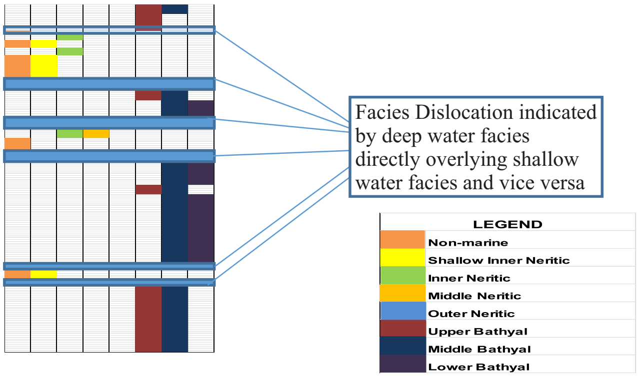


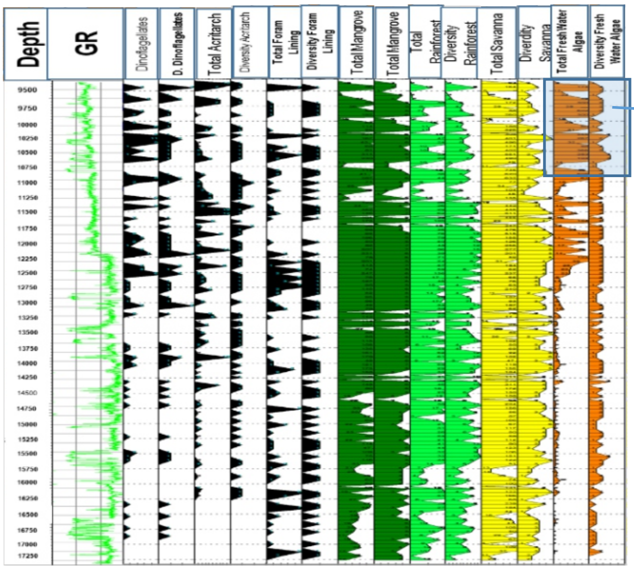
Figure 24: Facies Dislocation in Well B.

Nutrient Supply

Water depth is probably not a limiting factor in benthic foraminiferal distribution, but factors connected with water depth, like substrate or nutrient supply may have strong influences (Douglas and Heitmann 1979, Kaminski et al. 1999, van der Zwaan et al. 1999). According to Nichols (2009), the abundance of planktonic foraminifera increases with nutrient supply. Nutrient supply is abundant in the upper section of the studied wells as indicated by high to very high abundance and diversity of planktonic foraminifera occurring in deep marine setting (Figure 4.25 and 4.26). This occurred between the interval of 2860 to 3780 meters in Well A and in Well B the interval of 2520 to 2760 meters. This is an indication of high organic productivity. Nutrient supply was poor below these upper intervals resulting in little or no recovery of planktonic foraminifera even at others intervals where deep marine settings were encountered probably due to poor vertical current circulation common in low latitude region.

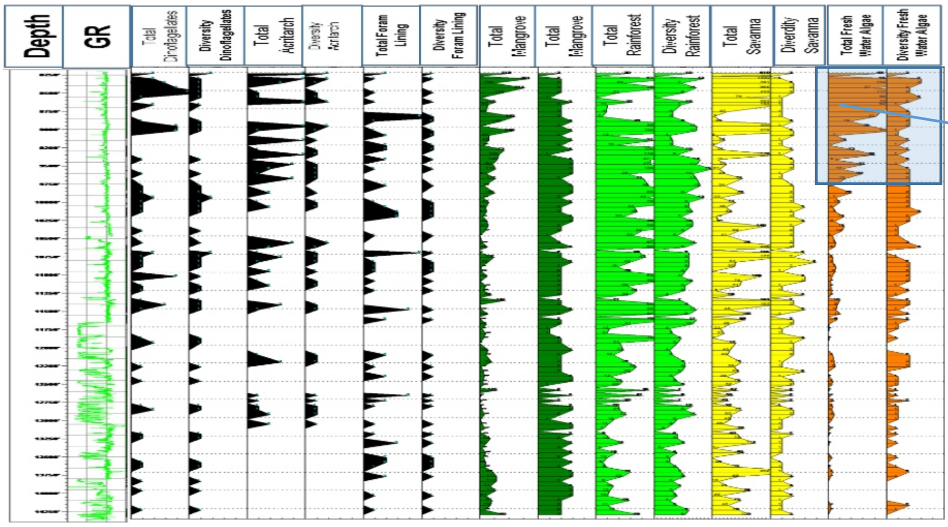
Paleo-oxygenation:

At the upper section of Well B, from the interval of 2520 to 2760, calcareous taxa dominated the benthic assemblages accounting for 96% of the recovery indicating high oxygen content of bottom water. Below this interval, calcareous taxa recovery was very poor and the benthics were mostly dominated by arenaceous foraminifera indicating low oxygen conditions of the depositional environment except at few intervals where there is slight incursion of calcareous taxa (Figure 4.27). Similarly, at the upper section of Well A, calcareous taxa dominated the benthic assemblages accounting for 91% of the recovery indicating high oxygen content of bottom water (Figure 4.28). Below this interval, calcareous taxa recovery decrease downward and became very poor and the benthics were mostly dominated by arenaceous foraminifera indicating low oxygen conditions of the depositional environment. The poor recovery of calcareous taxa at the middle and lower intervals of the studied wells is due to low oxygen content which made it difficulties for foraminiferal calcite secretion (Phleger and Soutar 1973).



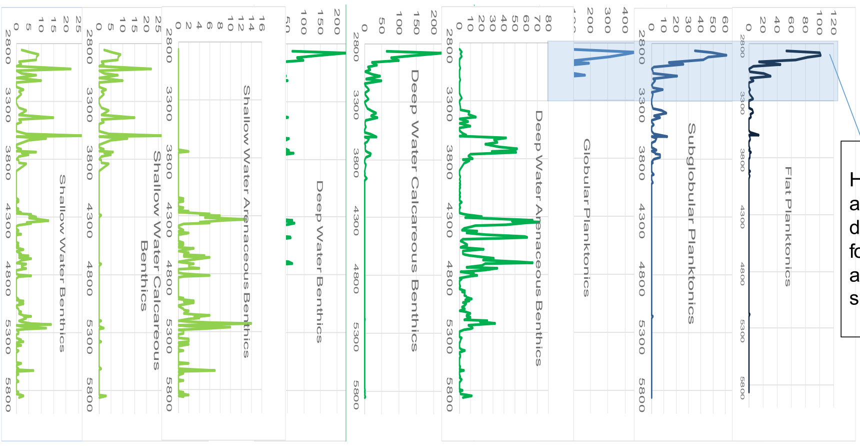
High occurrence of freshwater algae at the deep marine bathymetry realm due to influence of high tides during deposition

Figure 25: High Occurrence of Fresh Water Element in Deep Marine Realm in Well A.



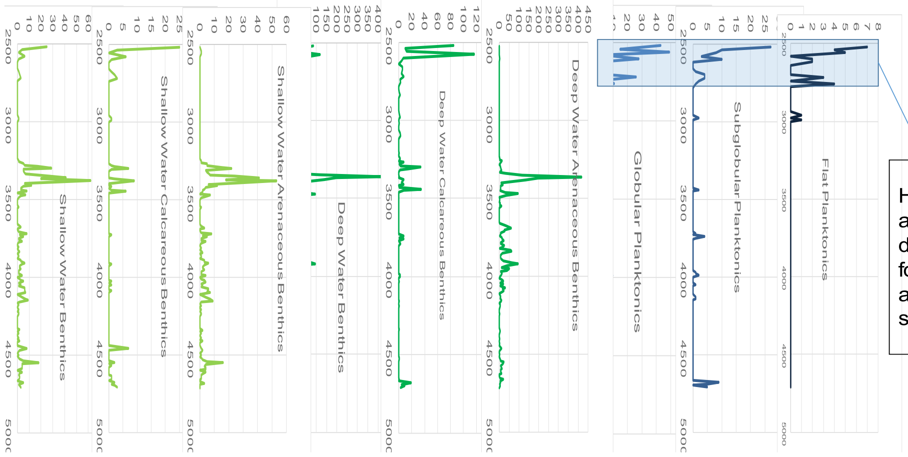
High occurrence of freshwater algae at the deep marine bathymetry realm due to influence of high tides during deposition

Figure 26: High Occurrence of Fresh Water Element in Deep Marine Realm in Well B.



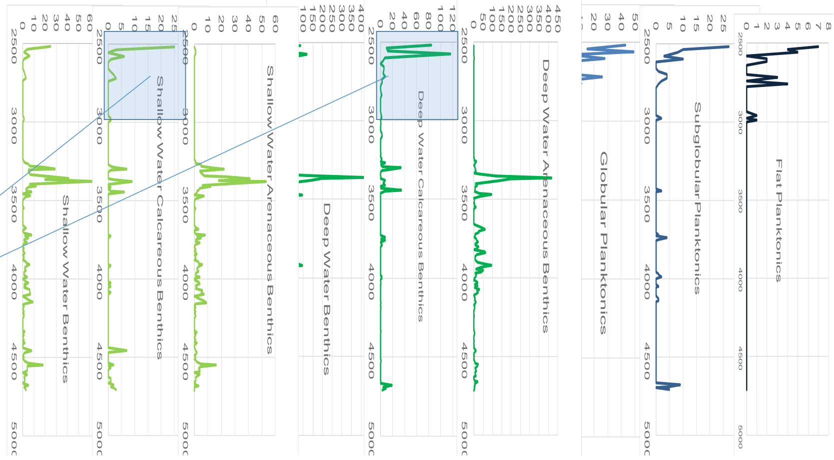
Highto very high abundance and diversity of planktonic foraminifer indicating abundant nutrient supply

Figure 27: High Abundance of Planktonic Foraminifera Indicating Abundant Nutrient Supply in Well A.



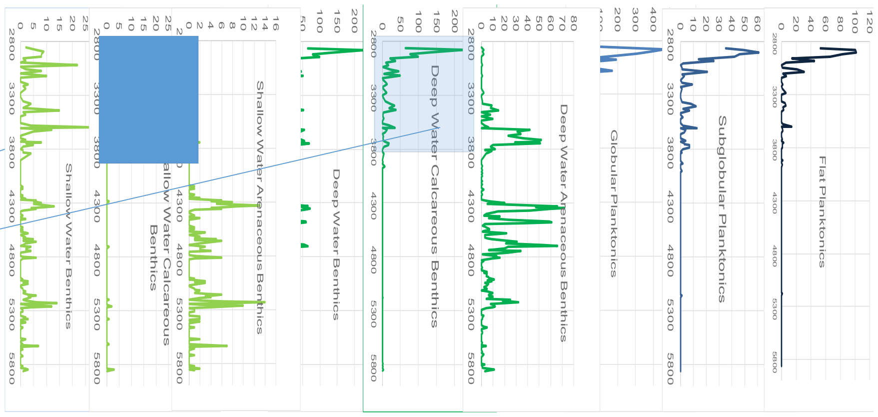
Highto very high abundance and diversity of planktonic foraminifer indicating abundant nutrient supply

Figure 28: High Abundance of Planktonic Foraminifera Indicating Abundant Nutrient Supply in Well B.



Dominated of calcareous taxa indicating high oxygen content of bottom water at the upper Section

Figure 29: Dominance of Calcareous Taxa in the Upper Section Indicating High Oxygen Content of Bottom Water in Well B.



Dominated of calcareous taxa indicating high oxygen content of bottom water at the upper Section

Figure 30: Dominance of Calcareous Taxa in the Upper Section Indicating High Oxygen Content of Bottom Water in Well A.

CONCLUSION

The sediments in the two (2) wells were deposited within non-marine/shallow marine to Lower bathyal paleobathymetric settings in a cyclic pattern though dominated by deep marine bathymetric realms. Co-occurrence of deep and shallow biofacies (mixed assemblages) within the deep-water bathymetry was observed on both wells at different intervals. The mixed assemblages were resolved by the ecological grouping. The mixed assemblage is suggestive of high influx of sediments into the slope by turbidity currents. The bio-facies, though ecologically controlled, display a truncated pattern; deep water facies directly overlying shallow water facies and vice versa. This is because of facies dislocation; a common indicator of structural deformation resulting in erosion and re-deposition of sediments down slope. The occurrence of freshwater algae especially *Botryococcus brauni* at the deep marine is due to the influence of high tides that brought in these freshwater elements during the deposition of the sediments. Nutrient supply is abundant in the upper section compared to the middle and lower section of the studied wells as indicated by high to very high abundance and diversity of planktonic foraminifera. Oxygen content of the bottom water is high at the upper section of the studied wells as indicated by dominance of calcareous taxa while the oxygen content diminishes down the well section with the result of dominance of arenaceous foraminifera with little or no calcareous counterpart. Complex structuration of the deep offshore is one of the contributors to the mechanism that redistribute fossil assemblages. Transport and deposition of terrigenous sediments beyond the shelf might have been influenced by complexity in the structural style and sequence of imbrication observed in the deep-water Niger Delta (Corredor *et al*., 2005). The presence of both deep and shallow biofacies assemblages suggests displacement of the shallow-water benthic into deep-water environment by turbidity currents (Beka and Oti, 1995). The outcome from the research has provided information that enhanced the stratigraphic and structural resolution in exploration and development of the study area in Deep Offshore Niger Delta. The study has shown the importance of grouping microfossils based on their habitational preferences for paleoenvironmental and paleoecological synthesis to resolve the problem of dilution of fossil assemblages often experienced in the deep offshore Niger Delta.

REFERENCES CITED

Bandy, O.L., 1956, Ecology of foraminifera in the northeastern Gulf of Mexico: U.S. Geological Survey, Professional Paper 274-G, p. 179– 204.

Beka, F. T. and Oti, M. N. 1995. The distal offshore Niger Delta: Frontier prospects of a mature petroleum Province. In Oti, M.N., and Postma, G., eds., Geology of Deltas: Rotterdam, A.A. Balkema, p. 237-241.

BouDagher-Fadel, M.K., 2013, Biostratigraphic and Geological Significance of Planktonic Foraminifera, 2nd edition: London, UK, Office of the Vice Provost Research (OVPR), University College, 307 p

Corredor, F., Shaw, J. H., and Bilotti, F. (2005). Structural styles in the deep-water fold-and-thrust belts of the Niger Delta. American Association of Petroleum Geologists Bulletin, 89, 753–780.

Culver, S. J., 1988, New foraminiferal depth zonation of the northwestern Gulf of Mexico: Palaios, v. 3, p. 69–85.

Demaison, G. J., and Moore, G. T., 1980, Anoxic environments and oil source bed genesis: American Association of Petroleum Geologists Bulletin, v. 64, no. 8, p. 1179–1209.

Doust, H. and Omatsola M.E. 1990. Niger Delta. In: Divergent /Passive Margin Basins, edited by JD Edwards and Santogrossi PA, American Association Petroleum Geologists Memoir 48 201-238

Eicher, D. L., and Worstell, P., 1970, Cenomanian and Turonian foraminifera from the Great Plains, United States: Micropaleontology, v. 16, no. 3, p. 269–324.

Gebhardt, H., 1998. Benthic foraminifera from the Maastrichtian lower Mamu Formation near Leru (southern Nigeria): paleoecology and paleogeographic significance. Journal of Foraminiferal Research, 28: 76-89.

Gebhardt, H., 2004. Planktonic foraminifera of the Nkalagu Formation type locality (Southern Nigeria, Cenomanian - Coniacian): Biostratigraphy and paleoenvironmental interpretation. Cretaceous Research. 25, 191-209.

Geological Rock Colour Chart. 2009. A revision of the previously published chart by Geological Society of America (GSA) Rock Color Chart prepared by the Rock Color Chart Committee (representing the U.S Geological Survey, GSA, the American Association of Petroleum Geologists, the Society of Economic Geologists and the Association of American State Geologists).

Kaiho, K., 1994, Benthic foraminiferal dissolved-oxygen index and dissolved-oxygen levels in the Modern Ocean: Geology, v. 22, p. 719–722.

Kuhnt, W. and Wiedmann, J., 1995. Cenomanian – Turonian source rocks: paleobiogeographic and Paleoenvironmental aspects. In: Huc, A.-Y., Ed. Paleogeography, paleoclimate and source rocks. Studies in Geology vol. 40. American Association of Petroleum Geologists: 213-232.

Lehner, P., and De Ruiter, P.A.C. (1977). Structural history of Atlantic Margin of Africa: American Association of Petroleum Geologists Bulletin, 61, 961-981.

Murray, J. W. 1973. Distribution and ecology of living benthic foraminiferids. Crane Russak & Co., New York. Xiii + 274 p.

Nichols, G., 2009. Sedimentology and Stratigraphy, 2nd edition. Blackwell Publishers.

Oloto, I. N. and Promise, W. 2014. Biostratigraphic Study and Paleoenvironmental reconstruction of cores from offshore (Smith Western) Niger Delta, Nigeria. – International Journal of Scientific & Technology Research. 3.

Petters, S. W., 1995. Foraminiferal biofacies in Nigeria rift and continental margin deltas, in: M. N., Oti and G., Postma eds., Geology of Deltas. A. A., Balkema, Rotterdam. 219-235

Phleger, F .B. and Soutar, A., 1973. Production of benthic foraminifera in three east Pacific oxygen Minima. Micropaleontology, 19: 110-115.

Poag, C.W., 1981, Ecologic Atlas of Benthic Foraminifera of the Gulf of Mexico: Woods Hole, Massachusetts, Marine Science International, 174 p.

Van Der Zwaan, G. J., Duijnstee, I. A. P., Den Dulk, M., Ernst, S. R., Jannink, N. T. and Kouwenhoven, T. J., 1999. Benthic foraminifers: proxies or problems? A review of paleocological concepts, Earth-Science Reviews, 46: 213-236.

Van der Zwaan, G.J., Jorissen, F.J. and De Stigter, H.C., 1990. The Depth-Dependency of Planktonic / Benthic Foraminiferal Ratios; Constraints and Applications. Marine Geology, 95, 1-16.

Vercoutere, T. L., Mullins, H. T., Mcdougall, K., and Thompson, J. B., 1987. Sedimentation across the Central California oxygen minimum zone: an alternative coastal upwelling sequence: Journal of Sedimentary Petrology, v. 57, no. 4, p. 709–722. [24] Whiteman, A.J. (1982). Nigeria: Its Petroleum Geology, resource and potential, Vol. I. Graham and Trotman, London, 394.

Wu, S., and Bally, A. W. (2000). Slope tectonics-comparisons and contrasts of structural styles of salt and Shale tectonics of the Northern Gulf of Mexico with shale tectonics of offshore Nigeria in Gulf of Guinea, In W. Mohriak and M. Talwani, Eds., Atlantic Rifts and Continental Margins: American Geophysical Union, 151-172.