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Foraminifera biostraigraphy and paleoenvironment of well X Niger Delta

Etaoghene OHWOHARHOHWO * and Anthonia Nwaneze ASADU

Department of Earth Sciences, Federal University of Petroleum Resources, Effurun 330102, Delta State, Nigeria.

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Abstract

The study involved the micropaleontological studies of Well X, Coastal Swamp depobelt, Niger Delta. A total of fifty (50) ditch cutting samples were taken at interval of 50ft across the total depth of (3000ft-4300ft). The ditch cutting sample were studied for their lithology and foraminifera contents for the purpose of determining the age, paleo-environment, and identification of key sequence stratigraphic surfaces penetrated by the well. Standard foraminifera preparation procedures were involved in the disaggregation of the samples and subsequent analysis. Quantitative and qualitative analysis yielded a well preserved stratigraphically significant foraminifera assemblage with a total of one hundred and twenty-nine (129) species, Ninety-Eight (98) Benthics and thirty-one (31) planktics. Six zones were created and compared with the Blow et. al 1979. These zones were Hanzawaia strattoni zone which corresponded with the terminal depth at 4300ft, Eponides sp., zone, Quinqueloculina seminulum zone, Uvigerina sp., zone, Heterostegina panamensis zone and Cassdulina neocarinata zone at the top of the well. These zones corresponded with N6, N7, N8 and N9 of the Blow et al. 1979 scheme. The paleobathemetry of the well depicted inner neritic environment.

Keywords: Agbada Formation; Niger Delta; Inner Neritic; Biostratigraphy; Foraminifera

1. Introduction

The study of stratified rock units based on their fossil richness is known as “biostratigraphy” (Bryce and Levin, 2020). Its concept is based on the fact that the fossil that denotes a particular period once extinct is never repeated. Without any doubt’s biostratigraphy has been known to play an important role in the exploration of oil and gas in the Niger Delta (Oloto, 1994).

Biostratigraphy has been a tool for identification of biotic records through time and for dating of rocks, in which it is important for producing limited correlation, reconstruction of paleogeography and calculating rates of geologic processes. Biostratigraphy is vital to the petroleum industry as a means for defining geologic constraints on prediction of exploration risk and modelling reservoir simulation (Oloto, 1994).

Petroleum has been a crucial source of energy and a foremost contributor to the economic growth in most industrialized and developing countries. The Niger Delta Basin is economically important because of its petroliferous nature and the economy of Nigeria depends largely on the oil and gas derived from it. Geologically, it is found in the Tertiary period in the geologic column. The combination of source rock, lithologic types, structures and thermal history of the basin are favorable for the generation, accumulation and preservation of hydrocarbons (Whiteman, 1982), (Stacher P. 1995), (Sonibare O. O, Ekweozor C. M, 2000).

Though petroleum exploration has taken place in five major sedimentary basins in Nigeria, namely the Niger Delta, Benue Trough, Anambra, Chad and the Benin basins, all oil production to date has occurred in the Niger Delta Basin.

* Corresponding author: OHWOHARHOHWOE

This was rewarded in 1956 with the drilling of the first producing well at Oloibiri by Shell-BP, the sole concessionaire at the time (SNEPCO 2002).

2. Literature Review

The high bearing foraminifera bearing shale unit was used by (Short and Stauble, 1967) to form the top of the Agbada Formation. (Reyment, 1959) noticed that arenaceous foraminifera dominates the shallow water sediments with low calcium carbonate (Caco3) content while plantktonic forms dominates deep water due to the presence of the abundance of algea. Sample from the Afowo – 1 well worked on by (Fayose, 1970) placed emphasis on the systematics of the foraminifera recovered which belonged to the Upper Maastritchian-Lower Miocene age.

About four (4) bathymetric biofacies were recognised on the basis of their abundance and distribution in the Niger Delta (Adegoke and Dessauvagie, 1971). Furthermore, on working the samples from the Gulf of Guinea by the Meecremer Expedition, he identified seven (7) benthonic foraminifera biospecies based on their occurrence and diversity (Adegoke and Omatsola, 1976).

There were two (2) identification of the biostratgraphic horizons in the Western Niger Delta on the basis of index plantktic foraminifera of Globorotalia tumida (Brady) and Globorotalia opima nana (Bolli) Parabe – 1 well (Petters, 1979), which he later gave the age for the sediments i.e. Oligocene-pliocene.

(Fajemila, 2012) discovered five (5) foraminifera zones in two wells formed of deep offshore samples in the Niger Delta and was able to determine an unconformity that cuts across the two wells as a result of abrupt changes in the paleobathymetric signatures of several selected benthics foraminifera species, because the prodelta paleoenvironments were rarely inhabited by indigenous benthic foraminifera, in which the inner, middle, outer, and bathyal foraminifera biofacies may be easily distinguished.

(Soronnadi et al., 2013) used integrated core samples, biostratigraphic data and wireline logs analysis of the D7000 sand to study the paleoenviroment and the sequence stratigraphy of the D7000 sand 'Erne' field of the Niger Delta. They also established the depositional enviroment as marine-estuarine settings which showed that a period of regression was followed by a transgressive phase. Also, publications have been done extensively on benthic foraminiferal assemblages in the Niger Delta, through the documentation of Bolivina which has remain substandard (Obiosio, 2013).

A strong knowledge of biostratigraphy of a well is important in the well sub-division sequence into correlatable units through dating and building of biozones (Fadiya et al., 2014).

3. Review of the Niger delta geology

The largest sedimentary basin of southern Nigeria is the Niger Delta Basin which developed along the West Coast of the African continent during the Tertiary times. It is situated at the intersection of the triple ridge junction in the eastern corner of the Gulf of Guinea from which the rifting and separation of the South American and African continents was initiated. The failure of the third arm (Benue Trough complex) to spread into an oceanic stage set the stage for the subsequent development of the Niger Delta Basin.

The Benin Formation is the uppermost unit in the basin and predominantly (over 90%) sandy with isolated clay/shale intercalations. The sands are coarse grained, granular, poorly sorted, subangular to well rounded. They are white or yellowish-brown and contain thin lignite streaks and wood fragments. The sediments are of continental to deltaic plain origin. The Formation is of Oligocene age and it is about 2,000m (Avbovbo, 1978).

The Agbada Formation comprises cyclic sequences of alternating sands (fluviatile, coastal, and fluvio-marine) and marine shales. Two (2) distinct intervals are easily recognizable: an upper sandy unit with minor shale intercalations and a more marine lower unit in which the shaly sections become prominent. The sandstones and sands are very coarse to very fine grained, unconsolidated or slightly consolidated and poorly sorted. The Agbada Formation is up to 4,000m thick in the central part of the delta, thinning seaward and towards the delta margins. Known age ranges from Eocene to Recent.

The Akata Formation is the basal unit of the Niger Delta complex. It consists of uniformly developed shales deposited in an open marine environment. There is the presence of some sand beds considered to be of continental slope, channel-fills and turbidites (Weber and Daukoru, 1975). The formation is largely under compacted (overpressure). The actual

thickness is not known due to inability to penetrate the formation fully except on the basin flanks. The age span is Eocene to Recent.

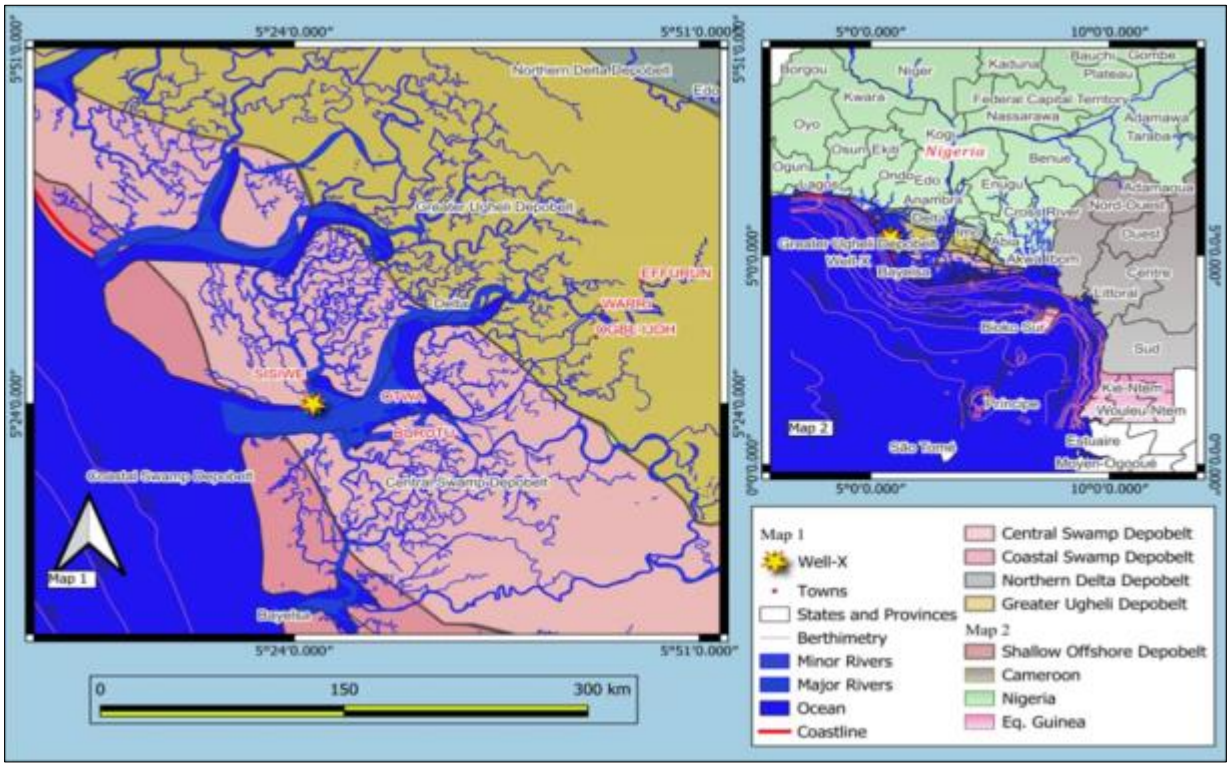

Figure 1 Location Map of Well X

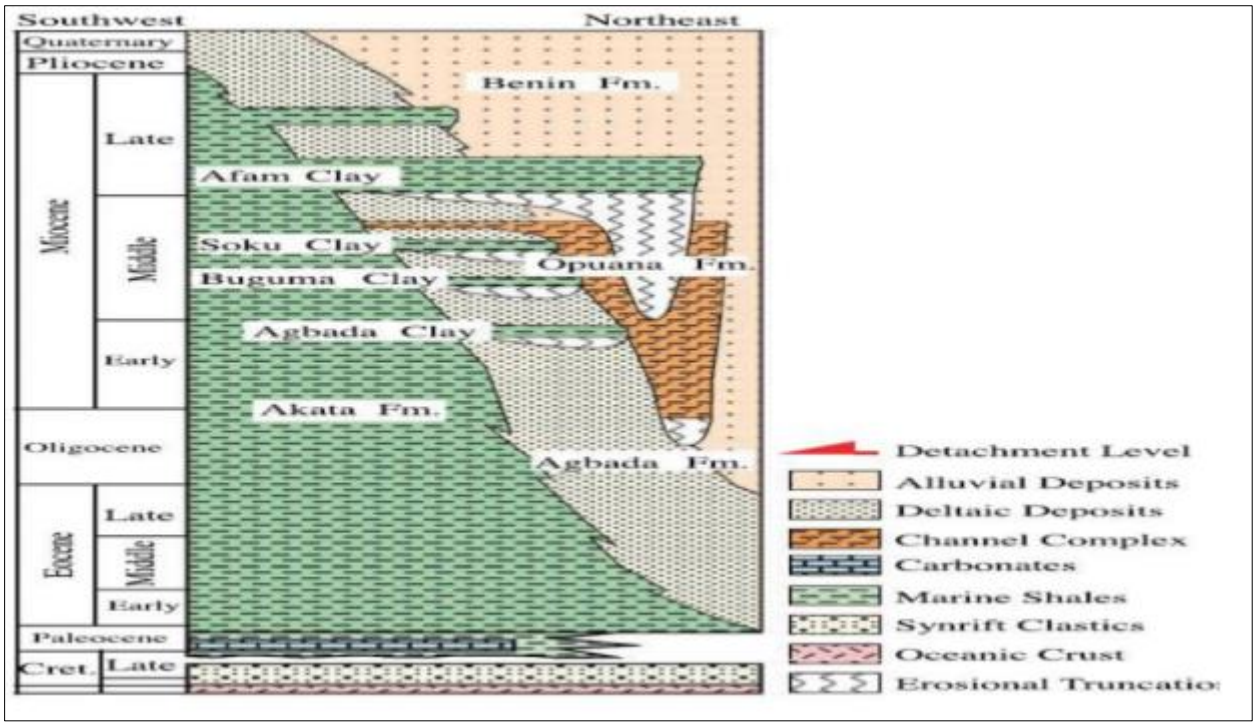

Figure 2 Niger Delta Regional Stratigraphy

4. Methodology

Micropaleontological analysis was carried out on a total of fifty (50) samples, obtained from intervals 3000 – 4300ft of the Well-X. The samples were prepared using the standard procedures and analysed at 50ft intervals in the upper section (3000 – 3500ft) and 20ft intervals in the lower (3500 – 4300ft) section of the well.

- **Labeling and Weighing:** About 20g of each collected sample was weighed, packaged and labeled accordingly indicating the well name, sample type and depth e.g. Well A 450 ft Ditch cuttings.
- **Soaking:** Bowls were labeled for indicated sample depths contained and soaked with kerosene for about four (4) 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 230 mesh sieve with 63 micron (um) aperture under running tap water with a shower head. Washed samples were dried on hot plate at about 60°C for about 45minutes.
- **Dry sieving and Bottling:** A set of micro sieves (coarse, medium and fine) was stacked on each other and dried residue for each sample was run through them and sieved manually. The respective fractions were collected and bottled in three (3) already cleansed and properly labelled bottles.
- **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 centred binocular microscope. Using a picking needle recognized fossils were picked and placed in the cavity of appropriately labeled slide. The recovered foraminifera were recorded in a picking sheet.
- **Splitting:** This is the sorting/separation and grouping of fossils according to their morphological similarity. Different species are grouped together with the tip of a moistened fine brush and stocked in 10s, 20s, and 50s depending on the richness of the interval on the slide and glued onto the slide with a gum.
- **Analysis:** Identification of the picked foraminifera was done with the aid of type collection and foraminifera album considering the test composition, chambers arrangement, sutures, aperture, habits and ornamentation. The results of the micro fauna analysis are plotted on range and distribution charts to show the sequence of occurrences of the species. The groups of species identified will be described systematically later.
- **Dating and Biozonation:** Age was determined based on the presence of marker species and correlated with the published chronostratigraphy of Blow et. al 1979. They were further used in zoning the stratigraphic build-up in accordance with the SPDC Chronostratigraphic chart as well as unravelling the geologic age of the sediments at the time of deposition. The N-zones are of immense help in recognizing MFS and in understanding the cycle concept as well as sequence stratigraphy

5. Results and discussion

Lithological characteristics including well log signatures, sand/shale ratios, textural attributes of sand/shale of samples were used to determine the lithologic unit penetrated by the well interval, two (2) lithofacies was delineated which are as follows:

5.1. Continental Environment: (3000 feet – 3150 feet)

The logged interval 3000 feet – 3150 feet which is an upward increase in sandstone thickness/volume for the upper part of Well X suggests Continental environment settings of high energy conditions. This Continental environment defined from 3000ft – 3150ft as a result of the prevalence of Clayey sandstone and Sandstone.

5.2. Paralic Environment: 3150 feet – 4300 feet)

The interval 3150 feet to 4300 feet depicts Paralic environment characterized by the occurrence of both sandstone/siltstone (continental) and shale (marine). The shale lithology is known to be deposited from suspension load in low energy conditions. Also, closer to coastline with higher energy because of wave activities, coarser sediments are deposited here resulting to the alternation of sandstone/siltstone and shale. The alternation of Sandstone, Shale, Sandy shale and Shaly siltstone suggest Paralic environment typical of the Agbada Formation with the Shale becoming thicker downward. The environment of deposition of Well X was based on Shell Petroleum Development Company (SPDC) and (Boggs, 2006) zonation scheme.

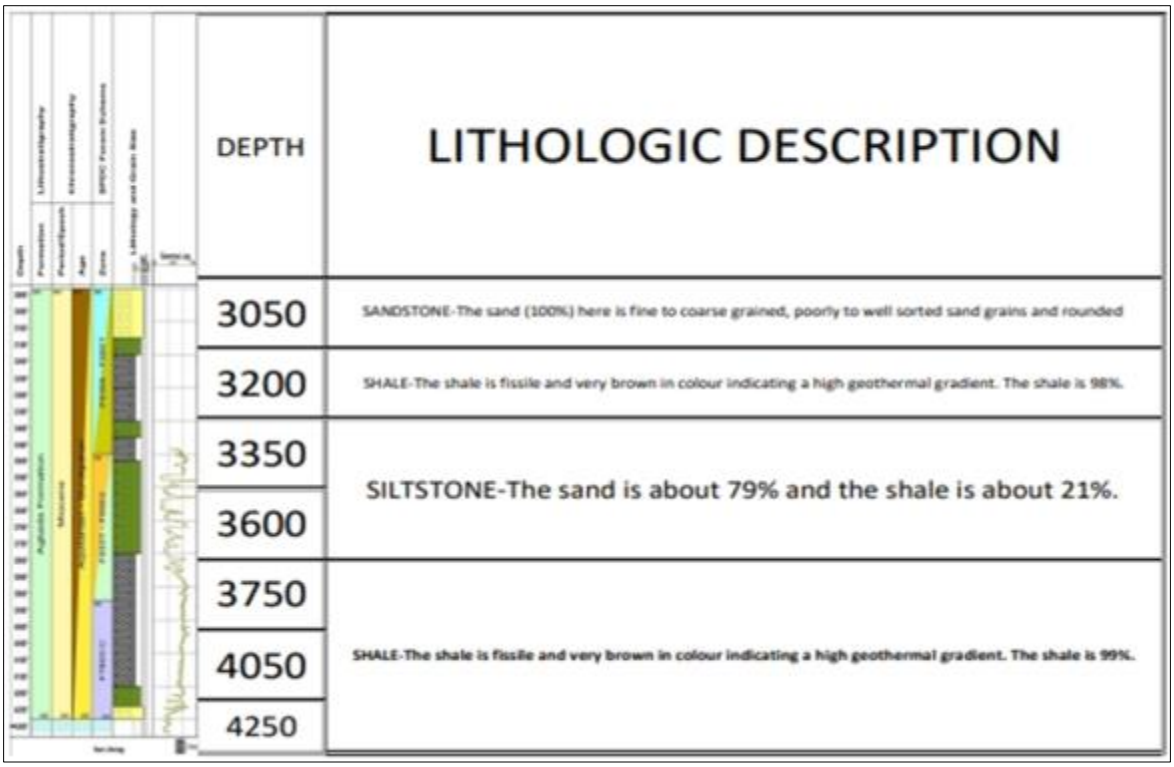

Figure 3 Lithologic Description of Well X

6. Age Characterization

Interval: 3000 – 3500ft

F- Zone: F9501 – F9305

Reliability Gradient: 3

Epoch:?Middle - Early Miocene

Age: ?Langhian - Burdigalian

This Interval is Characterized by:

Occurrence of Globigerinoides obliquus at 3200ft. FDOs of Globigerinoides primordius and Fursenkoina punctata at 3500ft. The Top of this composite Zone was probably not penetrated in this study. The occurrence of Globigerinoides obliquus at 3200ft could be an indication of the penetration of the N8 (Early Miocene) Planktonic Zone of Bolli and Saunders, 1985. The LDO of this taxon usually marks the N8/N7 boundary; which falls within the F9501 zone.

This Zone is considered a composite F9501 – F9305 because there is no bioevent that could be used to demarcate the F9501/F9305 boundary. The Base of this composite F– Zone was delineated at 3500ft based on the FDOs of Globigerinoides primordius and Fursenkoina punctata at this depth. These bioevents represent the Top of the F9303, which coincides with the Base of the F9305 zone.

- **Diagnostic Benthic Assemblage:** Eponides eshira, Cibicorbis inflata, Bolivina miocenica, B. mandoroveensis, Hanzawaia strattoni, Lenticulina inornata, Hopkinsina semiornata, Uvigerina sparsicostata, Rich Heterostegina sp, Ammonia beccarii, Florilus atlanticus and Epistominella vitrea

Interval: 3500 – 3940ft

F - Zone: F9303 – F9301

Reliability Gradient: 1

Epoch: Early Miocene

Age: Burdigalian

Interval Charaterised by:

FDOs of Globigerinoides primordius and Fursenkoina punctata at 3500ft. FDO of Epistominella pontoni and LDO of Globorotalia obesa at 3940ft. The Top of this composite F - Zone that is, the Base of the preceding zone is as described in the preceding interval. The F9303/F9301 boundary could not be delineated in this study due to absence of clear Top occurrences of taxa such as Quinqueloculina rhodiensis and Megastomella africana within the interval.

The Base of this composite F - Zone was however delineated at 3940ft, where the top occurrence of Epistominella pontoni was observed. This bioevent marks the Top of the F7800C zone. Also the LDO of Globorotalia obesa observed at this depth further supports the penetration of this stratigraphic interval; that is, the F9301/F7800 boundary.

- **Diagnostic Benthic Assemblage:** Hanzawaia strattoni, Eponides eshira, Cibicorbis inflata, Bolivina miocenica, B. mandoroveensis, Lenticulina inornata, Hopkinsina semiornata, Uvigerina sparsicostata, Heterostegina sp, Ammonia beccarii, Florilus atlanticus and Epistominella vitrea.

Interval: 3940 – 4300ft

F - Zone: F7800 C

Reliability Gradient: 2

Epoch: Early Miocene

Age: Burdigalian - Aquitanian

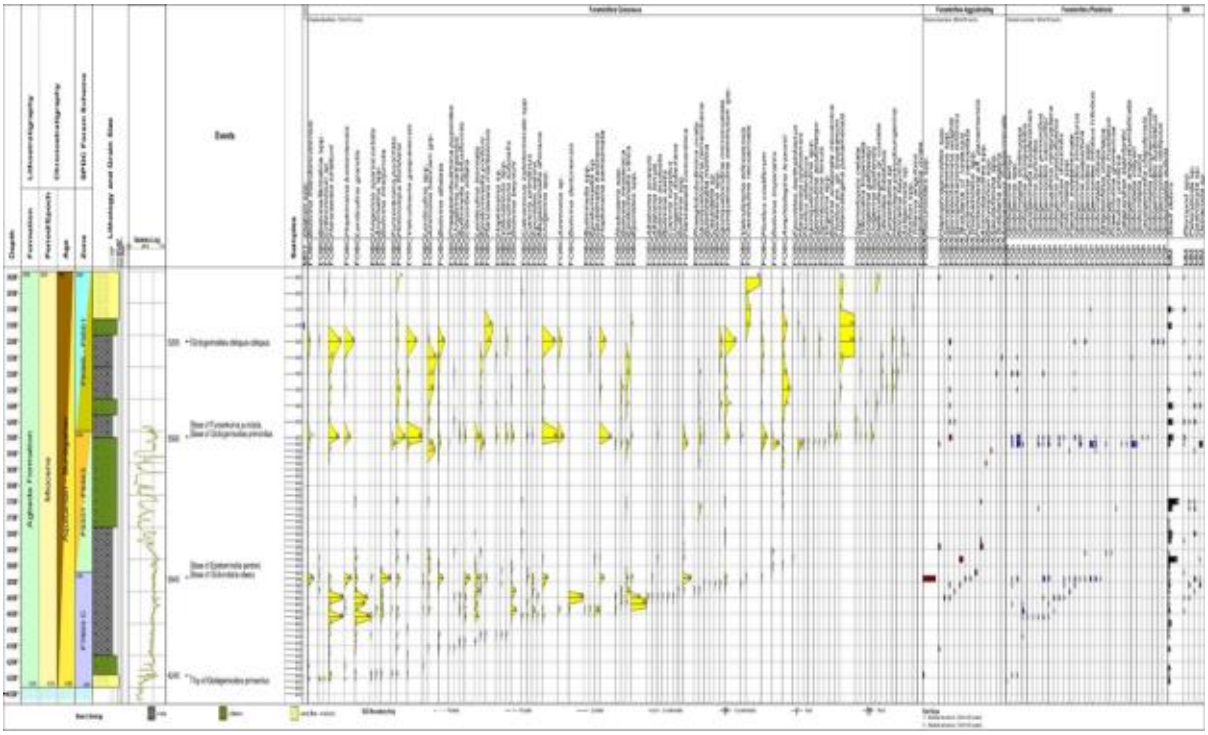

Figure 4 Abundance & Diversity of Foraminifera, Age, and Paleoenviroment of Well X

Interval Charaterised by:

Top of Epistominella pontoni and LDO of Globorotalia obesa at 3940ft. LDO of Globigerinoides primordius at 4240ft. The Top of the F7800 C zone was observed 3940ft and is as described in the preceding interval.

The LDO of Globigerinoides primordius observed at 4240ft is an indication of the penetration of the 'earliest' part of Early Miocene according to Bolli and Saunders, 1985.

Diagnostic Benthic Assemblage: Ammonia beccarii, Eponides eshira, Cibicorbis inflata, Bolivina miocenica, B. mandoroveensis, B. interjuncta, B. dertonensis, Lenticulina grandis, Uvigerina sparsicostata and Buliminella subfusiformis.

7. Foraminiferal biostratigraphic zonation

7.1. ZONE 1: Hanzawaia strattoni Zone (Early Miocene)

The micropaleontological event that defines this zone are the last downhole occurrence of Bolivina spp., LDO Uvigerina sparsicosta, LDO Bolivina interjuncta and LDO Lenticulina grandis at a top of 4100ft. The Hanzawaia strattoni Zone has a base depth of 4250ft which is the terminal depth. The analyzed section of the well penetrated N6 zone of the Blow et al 1979 scheme which is Early Miocene age which is marked by the Last down occurrence of Catapsydrax dissimilis. and the F7800 zone of the SPDC scheme of the Niger Delta.

7.2. ZONE 2: Eponides sp., Zone (Early Miocene)

The micropaleontological event that defines this zone are the occurrence of Bolivina mandoroveensis, Cribrononium sp., Hanzawaia strattoni, Lenticulinar grandis, Valvulineria gasparensis, Ammonia beccanrii, Bolivina dilatate, FDO Altistoma scalaris and FDO Bulimina aculeata at a top depth of 3900ft. The Eponides sp., Zone has a base depth of 4100ft. The analyzed section of the well penetrated N7 zone of the Blow et al 1979 scheme which is Early Miocene which is marked by the First down occurrence of Globigerinatella insueta and the F7800 zone of the SPDC scheme of the Niger Delta.

7.3. ZONE 3: Quinqueloculina seminulum Zone (Early Miocene)

The micropaleontological event that defines this zone are the occurrence of Lenticulina grandis, Heterolepa floridana, Ammonia becarri sp., Lenticuna inornate, Calcareous inderterminate spp., Hanzawaia concentrica and Florilus costiferum at a top depth 3700ft. The Quinqueloculina seminulum Zone has a base depth of 3900ft. The analyzed section of the well penetrated N7 zone of the Blow et al 1979 scheme which is Early Miocene which is marked by the First down occurrence of Globigerinatella insueta and the F9301 to F9303 zone of the SPDC scheme of the Niger Delta.

7.4. ZONE 4: Uvigerina sp., Zone (Early Miocene)

The micropaleontological event that defines this zone are the occurrence Bolivina mandoroveensis, Hanzawaia strattoni, Fursenkoina punctate, Ammonia becarri, Eponides spp., and Praeglobobulimina ovata at a top depth of 3500ft. The Uvigerina sp., Zone has a base depth of 3700ft. The analyzed section of the well penetrated N8zone of the Blow et al 1979 scheme which is Early Miocene which is marked by the First down occurrence of Praeobulina sicana and the F9301 to F9303 zone of the SPDC scheme of the Niger Delta.

7.5. ZONE 5: Heterostegina Panamensis Zone (Middle to Early Miocene)

The micropaleontological event that defines this zone are the occurrence of Hanzawaia strattoni, Hopkinsina beniniensis Fursenkoina punctate, Vavulineria gaaparensis, Lenticulina spp., Uvigerina sp., Epistomenella, vitrea, Quinqueloculina microcosta and Quinqueloculina seminulum at a top depth 3250ft. The Heterostegina Panamensis Zone has a base depth of 3500ft. The analyzed section of the well penetrated N9zone of the Blow et al 1979 scheme which is Middle to Early Miocene which is marked by the First down occurrence of Orbulina universa and the F9501 to F9305 zone of the SPDC scheme of the Niger Delta.

7.6. ZONE 6: Cassidulina neocarinata Zone (Middle to Early Miocene)

The micropaleontological event that defines this zone are the First down occurrence of Bolivina mandoroveensis, FAD Hanzawaia strattoni, FAD Heterolepa floridana, FDO Hanzawaia mantaensis, FDO Cassidulina neocarinata and FDO Heterostegina panamensis at a top depth of 3000ft which correspond to the top of the well. The Cassidulina neocarinata Zone has a base depth of 3250ft. The analyzed section of the well penetrated N9zone of the Blow et al 1979 scheme

which is Middle to Early Miocene which is marked by the First down occurrence of Orbulina universa and the F9501 to F9305 zone of the SPDC scheme of the Niger Delta.

8. Correlation of Biozones created in Well X in comparism with Blow et. al. 1979 scheme

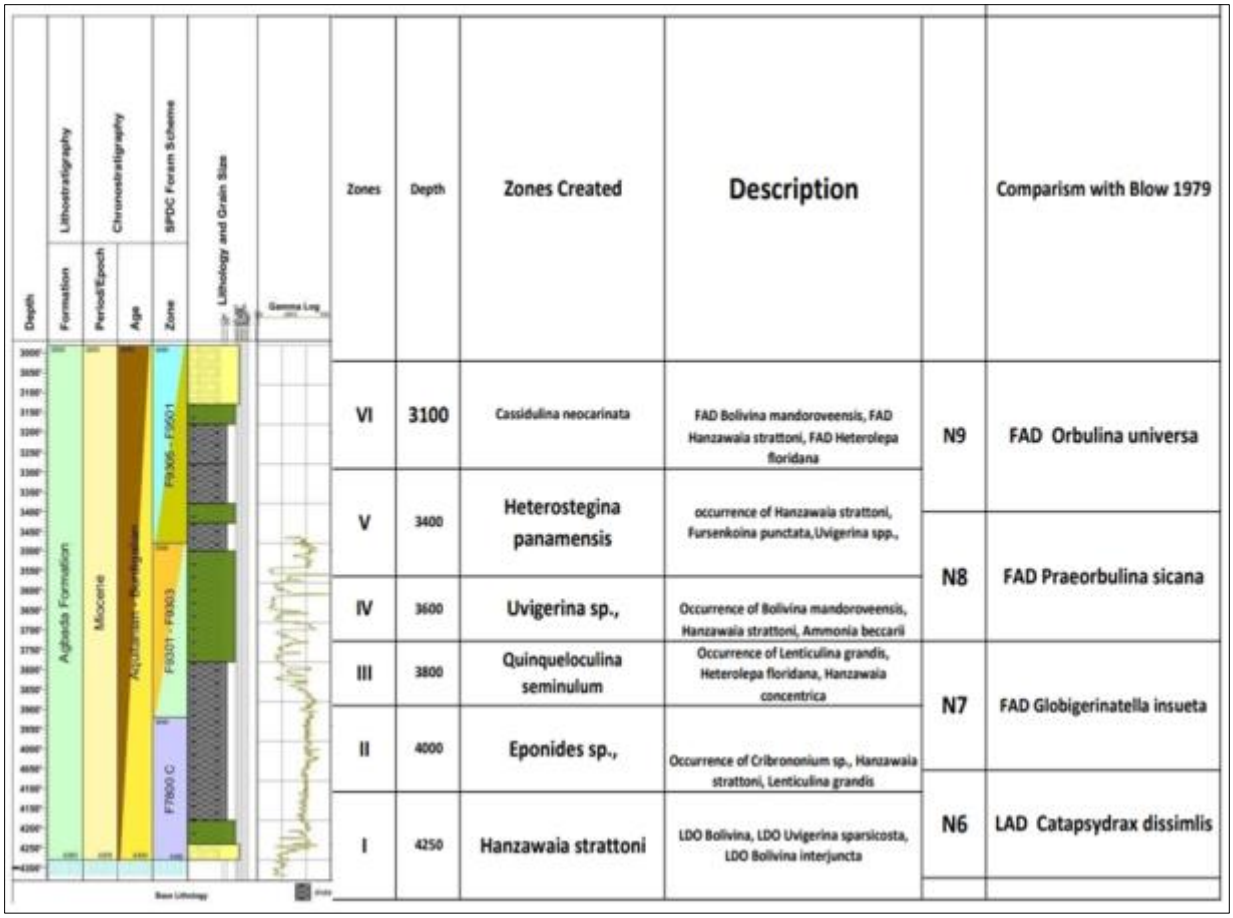

Figure 5 Depicting Biozonation of Well X in comparism with Blow et al scheme 1979

The Cassidulina neocarinata zone (zone vi) correlated with the N9 zone of the Blow et al 1979 scheme and is marked by FAD Orbulina universa. The Heterostegina panamensis zone (zone v) correlated with the N9 zone and N8 zone of the Blow et al 1979 scheme and is marked by FAD Orbulina universa at the top and FAD Praeorbulina sicana at the bottom. The Uvigerina sp., zone (zone iv) correlates with the N8 zone of the Blow et al. 1979 scheme which is marked by FAD Praeorbulina sicana. The Quinqueloculina seminulum zone (zone iii) correlates with the N7 zone of the Blow et al 1979 scheme and is marked by FAD Globigerinetella insueta. The Eponides sp., zone (zone ii) correlates with the N7 zone at the top and N6 zone at the bottom and is marked by FAD Globigerinettal insueta at the top and LAD Catapsydrax dissimilis at the bottom. The Hanzawaia strattoni zone (zone i) correlates with the N6 zone of the Blow et al. 1979 scheme and is marked by LAD Catapsydrax dissimilis.

9. Paleoenvironment

9.1. Outer Neritic (Subtidal) zone

The environment is found the shallower part of the Niger delta in the shelf environment within the Outer Neritic Marine environment due to the scanty occurrence of agglutinated forams and high presence of calcareous planktonic forams such as Globigerinoids ruber, Globigerinella calida, Pulleniatina obliquiloculata, Globorotalia truncatulinoides, Orbulina universa, Globigerina bulloides and Turborotalia quinqueloba. The calcareous planktic forams are about 90% in abundance and diversity while the agglutinated benthic forams are about 10% in abundance and diversity in the well. And it is important to note that most forams found in the well occur above the Calcium compensation depth (CCD) which prognosticates the environment as a shallow marine environment where the water is well oxygenated and the salinity

is normal not hypersaline or brackish. There is a scant occurrence of agglutinated forams such as Ammobaculites agglutinans, Haplophragmoides canariensis and Vereneulina advena.

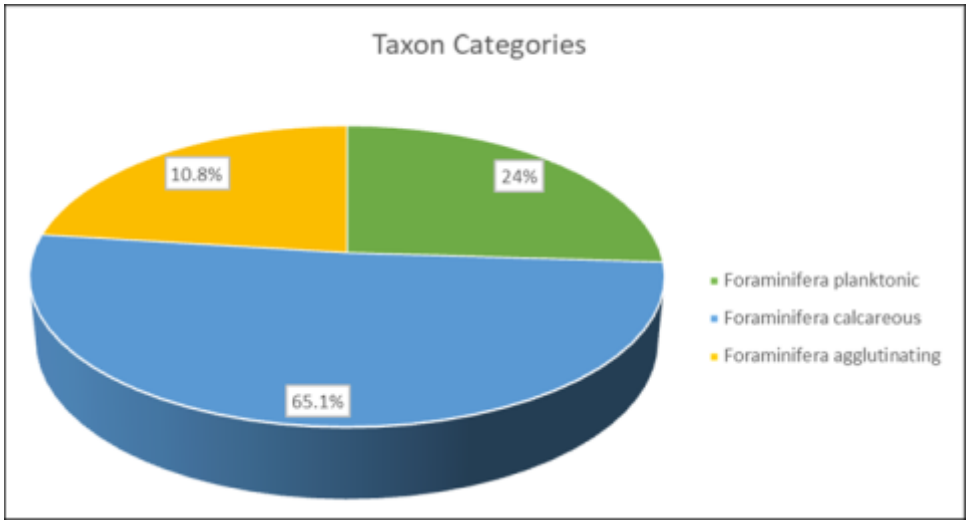

Figure 6 Pie Chart Showing Taxon Categories with their Percentages of Well X

10. Sequence stratigraphy

The methods of recognizing chronostratigraphic surfaces using patterns of faunal and floral abundance and diversity as proposed by (Armentrout et al., 1990) were also utilized. Foraminiferal diversity minima and maxima were used for defining candidates for sequence boundary, condensed section and Maximum Flooding Surfaces respectively. Furthermore, identifiable systematic variations in foraminifera abundance and diversity correlated with similar variations in strata stacking patterns as seen on the available gamma ray log as well as the distribution chart and paleobathymetric data aided the recognition of system tracts.

The sequence stratigraphic framework proposed here has been correlated with the Global Cycle Chart of (Hardenbol et al., 1998). The correlation has been guided by chronostratigraphically significant bioevents recorded over the studied section.

10.1. Interval 3400 – 3200ft: Transgressive Systems Tract (TST)

This depth range is characterised by increasing-upward foraminifera abundance and diversity, deepening upward trend, in which there is a termination with the condensed section marked by foraminiferal abundance and diversity maxima at 3200ft.

The Maximum Flooding Surface (MFS) marking the top of the Trangressive System Tract (TST) is picked at the gamma peak at 3400ft and 3200ft within the Condensed Section. The Maximum Flooding Surface (MFS) has been dated 19.4Ma based on the correlation with the Global Cycle Chart of (Hardenbol et al., 1998). The assigned age is associated with the First Downhole Occurrence (FDO) of the planktic foraminiferal specie Globigerinoides obliquus. This correspond with the Heterostegina panamensis Zone and N8 zone of the Blow et al. 1979 scheme.

10.2. Interval 3500 – 3400ft: Transgressive Systems Tract (TST)

The depth range is characterised by fining upward profile, increasing-upward foraminiferal abundance and diversity, deepening-upward trend, and also the termination in the condensed section marked by foraminiferal abundance and diversity maxima at 3500ft. The Maximum Flooding Surface (MFS) marking the top of the Transgressive System Tract is picked at the Gamma peak at 3500ft within the condensed section. The MFS has been dated 19.40Ma based on the correlation with the Global Cycle Chart of (Hardenbol et al., 1998). horizon is marked with the First Downhole Occurrence (FDO) of the benthic foraminifera specie Globigerinoides Primordius with the age 19.10Ma at 3500ft. This correspond with the Uvigerina sp., Zone and the N8 zone of the Blow et al 1979 scheme.

10.3. Intervals 3150 – 3000ft: Highstand Systems Tract (HST)

This is depicted by thickening-upward profile, decreasing – upward foraminiferal abundance and diversity, which is stratigraphically positioned directly above a Maximum Flooding Surface (MFS). The Sequence Boundary (SB) dated 17.70Ma is correlated with the Global Cycle Chart of (Hardenbol et al., 1998), in which its age is associated with the base of Fursenkoina punctata zone. This correspond with the Cassidulina neocarinata Zone and the N9 zone of the Blow et al. 1979 scheme.

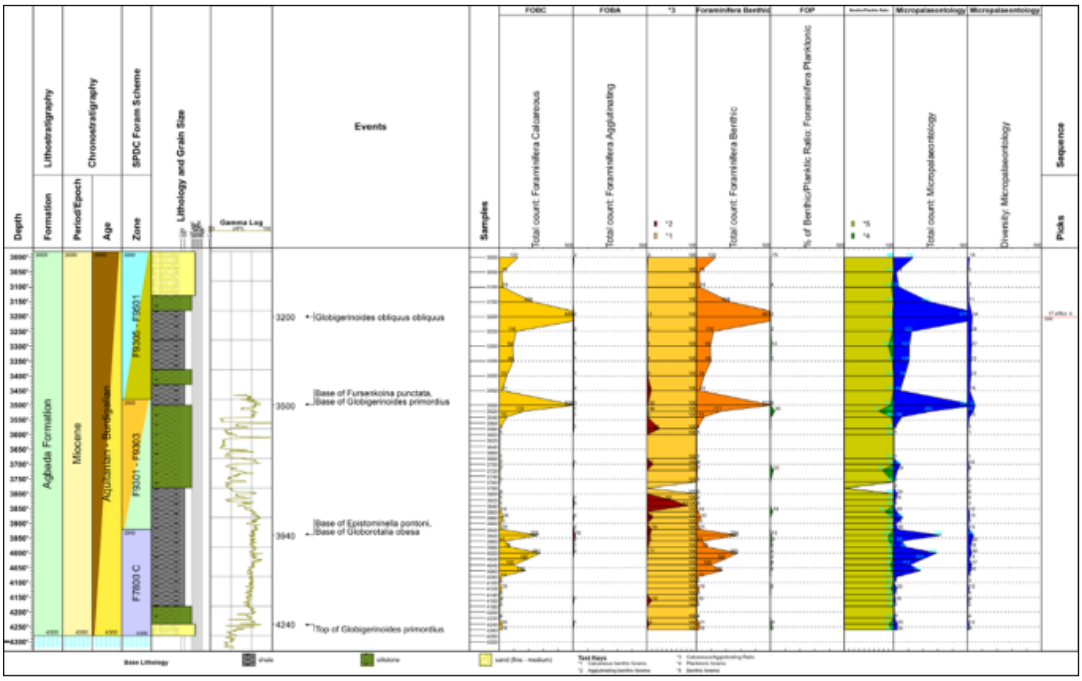

Figure 7 Sequence Stratigraphic Chart of Well X

Table 1 Miospores present in the Well X

1. Bolivina mandoroveensis	*7. Fursenkoina punctate*	*13. Epistominella vitrea*
2. Hanzawaia strattoni	*8. Hanzawaia mantaensis*	*14. Nodosaria sp.*
3. Hopkinsina bononiensis	*9. Ammonia sp.*	*15. Eponides sp.*
4. Heterolepa floridana	*10. Buliminella sp.*	*16. Altistoma scaleris*
5. Lenticulina grandis	*11. Epistominella sp.*	*17. Bulimina exilis*
6. Uvigerina sparsicostata	*12. Hopkinsina semiornata*	*18.Quinqueloculina lamarckiana*

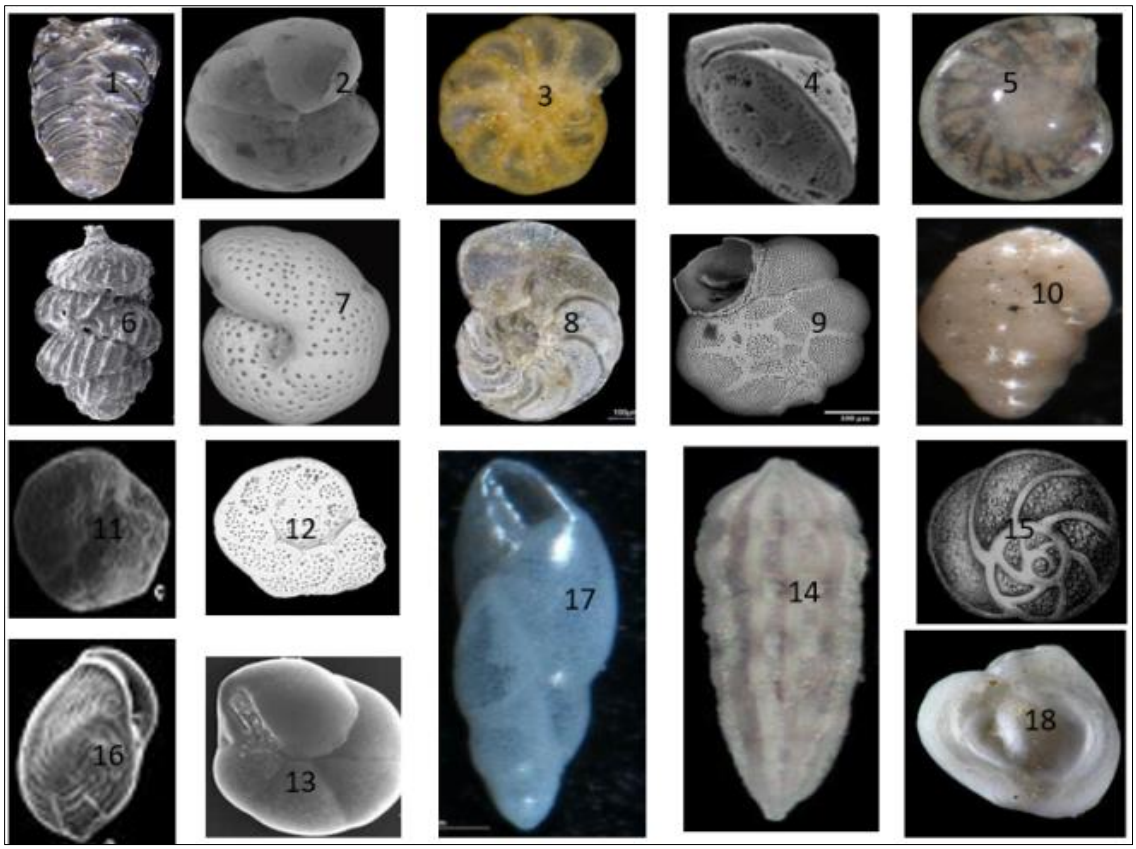

Figure 8 The Miospores present in the Well X

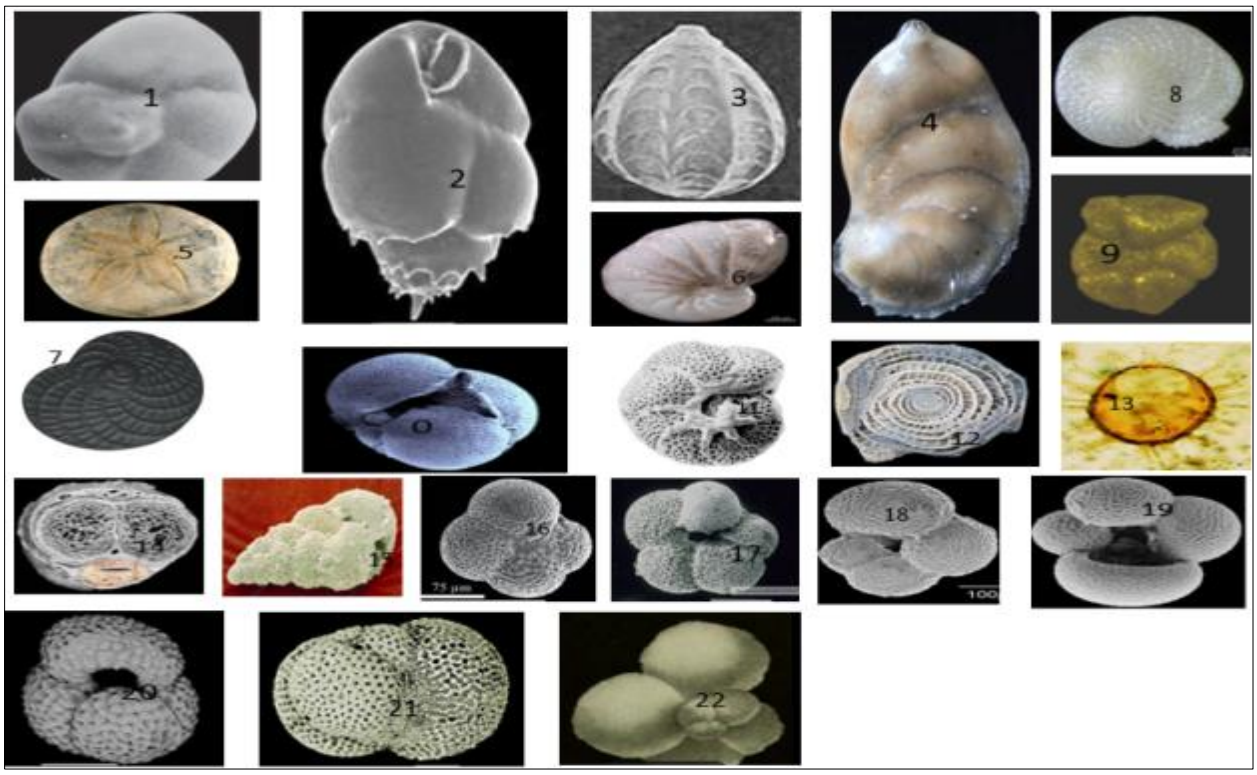

Figure 9 The Miospores present in the Well X

Table 2 The Miospores present in the Well X

1 Praeglobobulimina ovata	*9 Haplophragmoides sp.*	*17 Globigerina quinqueloba*
2 Buliminellita mirifica	*10 Spiroplectammina sp.*	*18 Globigerina bulliodes*
3 Cassidella sp.	*11 Spiroplectammina biformis*	*19 Globigerina praebulliodes*
4 Dentalina sp.	*12 Ammobaculites sp.*	*20 Globigerinoides obliquus*
5 Casidulina neocarinata	*13 Bathysiphon sp.*	*21Globigerinoides immaturus*
6 Florilus atlanticus	*14 Saccammina sp.*	*22 Globorotalia obesa*
7 Heterostegina costata	*15 Textularia elegans*	
8 Heterostegina panamensis	*16 Globorotalia continuosa*	

11. Conclusion

Micropaleontological analysis of fifty (50) samples of Well X within the depth intervals of 3000 - 4300ft were carried out, inference from the lithological and foraminferal analysis showed that the interval study penetrated the Agbada Formation and is dated 17.7ma, 19.10ma, and 19.40ma respectively, which is of the Middle Miocene. The lithologic description of the samples revealed two (2) lithofacies units which are the Continental and the Paralic.

A total of One Hundred and Twenty-Nine (129) species were identified, these includes one hundred and fifteen calcareous species (foraminifera planktonic and formaninfera benthics) in which the Benthics accounted for Eighty-Four (84) and the planktics accounted for thirty-one (31) species, while the remaining fourteen (14) are foraminifera agglutinating (Arenaceous).

The foraminfera zones has been proposed for the well in which the (blow, 1969) scheme was used for zoning, which are as follows F9501 - F9305 (Globigerinoides Obliquus Obliquus), F9303 - F9301 (Fursenkoina Punctata), and F7800C (Globigerinoides Primordius). In terms of the abundance and diversity for the Well X, the foraminfera calcareous benthic was dorminant species and the foraminifera planktics were scarce in terms of abundance and diversity. The ACME Zone (Highest peak/occurrence in abundance and diversity) of Well X is the Globigerinoides Obliquus Obliquus at 3200ft, base of Fursenkoina punctata and the base of Globigeriniodes primordius at 3500ft.

The identification of the key sequence stratigraphic surfaces of the Well comprises of the Transgressive System Tract (TST), Highstand System Tract (HST), Sequence Boundary (SB), and the Maximum Flooding Surfaces (MFS) were identified within the Condensed Sections (CS).

The Transgressive System Tract (TST) at 3200ft and 3500ft are both characterized by fining upward profile, increase in forminiferal abundance and diversity and deepening upward trend.

The Highstand System Tract (HST) was recognized at 3150ft characterized by thickening upward profile, decreasing foraminiferal abundance and diversity. The Sequence Boundary (SB) at 3000ft found at the top of the Highstand System Tract (HST), the Sequence Boundary (SB) is marked at a zone of low abundance and diversity of the micro faunal species, which is dated 17.70Ma.

The two (2) Maximum Flooding Surfaces (MFS) were identified in the Well, which are dated 19.40Ma and 19.10Ma respectively, in which their associated ages were delineated from the First Downhole Occurrence (FDO) of the planktic foraminiferal specie Globigerinoides obliquus obliquus and the First Downhole Occurrence (FDO) of the benthic foraminifera specie Globigerinoides Primordius dating respectively.

Compliance with ethical standards

Disclosure of conflict of interest

I declare that there is no conflict of interest.

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