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Facies Analysis and Paleoenvironmental Reconstruction of Well X, Onshore Niger Delta, Nigeria

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ABSTRACT: *Biofacies and lithofacies analysis of one hundred and ninety-two (192) ditch cutting rock samples from well x, onshore Niger Delta was carried out for the purpose of the paleoenvironmental reconstruction of the rock succession. The objectives were to identify the lithofacies units and species of foraminifera and to use both quantitave and qualitative foraminiferal assemblage to recognise the benthonic foraminiferal biofacies and integrate both results for delineation of paleobathymetric and paleoenvironmental settings of sediments penetrated by well x interval studied. The rock samples were prepared through wet-sieve analysis with 63µm mesh sieve size, and subsequently through dry-sieve analysis with 250µm and 500µm mesh sieve sizes. The prepared rock samples were analyzed to generate data for sedimentological grain-size analysis and foraminifera biofacies assemblages. The grain-size analysis provided lithofacies associations, sand/shale ratio and sorting/gradational profile for the studied intervals of well-x while the micropaleontological analysis identified a total of ninety-three (93) well preserved foraminiferal species from which three (3) biofacies associations were delineated. The biofacies include: Ammonia beccarii, Ammonia beccarii/Bolivina scalprata miocenica, and Haplophragmoides compressa/ Valvulina flexilis biofacies indicating Shallow Inner Neritic, Inner-Middle Neritic, and Outer Neritic – Upper Bathyal paleoenvironment respectively. The result of the sand/shale ratio and lithofacies associations indicated penetration into the Agbada Formation of the Niger delta and deposition within shallow to deep marine paleoenvironmental settings, predominantly as channels, intercalated with overbank and distal bar/bay deposits. Synthesis of the biofacies and lithofacies indicated stratigraphic development between coastal deltaic and upper bathyal paleowater depths.*

KEYWORDS: foraminifera, biofacies, paleoenvironment, lithofacies, Niger Delta, Onshore.

INTRIDUCTION

Foraminifera have shown to be very useful in biostratigraphic research, and various forms have demonstrated evolutionary bursts at various points in the geologic record. The importance of benthic foraminifera as a biostratigraphic tool in the reconstruction of the paleo water depth has increased over the years as petroleum exploration in the propitious delta has increased since first recovery of hydrocarbon in the basin in 1956. Because they are primarily sessile, benthic foraminifera are excellent environmental indicators. Different sedimentary rocks are deposited in a variety of seemingly similar conditions. The study well lies within the marginal marine fringes of

the Niger delta in Degema Local Governments Area of Rivers State, Nigeria. Well-x is located on Longitude 0°3'47.677"E and latitude 0°2'30.506"N (Fig. 3.1). The purpose of this study is to characterize, categorize, and use foraminifera found in well-x to interpret the paleobathymetic and paleoenvironmental history of the rock succession penetrated by the well section studied.

Previous studies: Adegoke et al. (2017) developed and calibrated a unified foraminifera biozonation scheme of the Niger delta concessions by harmonizing the foraminifera zonation schemes of all the member companies of Stratigraphic Committee of the Niger delta. The chronostratigraphic compilation was done with wells that penetrated Paleocene to Pleistocene Epochs, spanning both onshore and shallow-offshore depobelts of the Niger delta. They also noted that the shallow, warm tropical Surface Waters and the deeper, colder South Atlantic Central Water mass, both influenced the foraminiferal biofacies of the Niger Delta. According to Murray (2014), several low latitude larger foraminifera, like *Amphistegina* spp. and *Heterostegina* spp., as well as cold water indicator planktonics like *Globorotalia inflate* are typical characteristics of the Neogene deeper biofacies of the Niger delta and are important in understanding the chronostratigraphy and depositional environment of the Niger delta. For an understanding of the biochronologic and biostratigraphic relevance of the main marker species in the Niger delta, Ozumba and Amajor (1999) presented the necessary evolutionary relationships of these benthonic foraminifera genera (*Lenticulina, Bolivina/Brizalina, Nonion/Florilus, Hanzawaia, Epistominella, Eponides berthelotianus/Ammonia beccarii, and Uvigerina)* in the Niger delta. In the past eight decades, foraminiferal biostratigraphy has been the subject of extensive research and has been used all over the world. This has been made possible by additional detailed taxonomic documentation of planktonic foraminifera of the low latitude Caribbean by Bolli (1957) and Blow (1979, as well as descriptions of the biology of modern planktonic foraminifera by Be et al. (1980). Excellent monographs on the evolutionary trend and paleogeographic distributions have been published by Ozumba (2011) and several other research conducted in various parts of the world. Loeblich and Tappan (2015) indicated the test compositions and morphology of various foraminifera and classified them into foraminifera taxonomy.

Niger Delta stratigraphy: Three diachronous stratigraphic units which include the Akata, Agbada, and Benin formations make up the stratigraphy of the Niger Delta. These formations have been widely studied by a many including Short and Stauble (1967), Reijers (2011), Doust and Omatsola (1989), Avbovbo, (1978), and others. The formations show an overall coarsening-upward progradational clastic wedge that was deposited in marine (Akata Formation), deltaic (Agbada Formation), and river Benin Formation (Short and Stauble, 1967; Weber, 1967; Weber and Daukoru, 1975). These prograding depositional facies are distinguished mainly on the basis of their sand-shale ratios and their age range from Eocene to Recent.

The Akata formation: The base sedimentary unit of the delta is known as the Akata Formation. It is made up of sand-covered turbidites and channel fills that are uniformly dark grey and over-pressured marine shales. It dates from the Late Eocene to the Recent Period. These turbidites are the potential reservoirs in deep-water situations. The sedimeentsry thickness of Akata formation range from 2000 to 7000 metres thick (Doust and Omatsola (1989), Whiteman (1982) and Corredor et al. (2005). the Akata formation is characteristically rich in organic matter and it is thought to be the source of hydrocarbon in the Delta (figure 2).

The Agbada Formation: This is the major petroleum-bearing unit in the Niger Delta. It overlies the Akata Formation and consists of upward coarsening sequence of paralic to marine-coastal and fluvial-marine deposits mainly composed of sandstone and shale (Pochat et al, 2004). The Agbada Formation is characterized by According to Corredor et al (2005). The Agbada Formation can be subdivided into upper, middle and lower units. The upper unit is made up of 60 – 40% sand. The middle unit consists of 50 – 30% sand. The lower unit is made up of 20% sand inter-bedded with under-compacted shales. It is made up of paralic siliciclastics that are more than 3500 m (11,500 ft) deep and represent the real deltaic section of the delta.

Benin Formation: The Benin Formation consists of Late Eocene to Recent deposits of alluvial and upper coastal plain deposits that are up to 2000m (6600ft) thick (Avbovbo, 1978). Ajaegwu et al. (2012) and Aigbedion (2011). The Benin Formation was first identified by (Avbovbo, 1978). Sand, gravel, and back-swamp deposits make up the majority of the formation. The Benin Formation, the youngest of the three formations in the Niger delta, overlies the Agbada Formation and is dated between the Oligocene and Recent epochs. This is the water bearing formation in the Niger Delta province (figure 2).

METHODOLOGY

Nature and Source of Data.
The data used in the study was primarily generated through laboratory analysis of the ditch cutting rock sample and the gamma ray log provided for this study. The analysis carried out included sedimentology (Sieve analysis) and micropaleontology to obtain grain-size distributions, gradation pattern, sand/shale ratio and lithologic description of the ditch cutting rock samples; benthonic foraminifera distribution, abundance, diversities and bio-events. The data generated from the sedimentological analysis was used to decipher the sedimentary formations encountered in well-x based on sand/shale ratio, while from the micropaleontological end, Index fossils (marker species), significant bioevents and biohorizons which constituted the bases for paleoenvironmental synthesis were identified and populated in strataBugs v2.0 for spatial display and plotted out in A0 paper size for proper data trawl.

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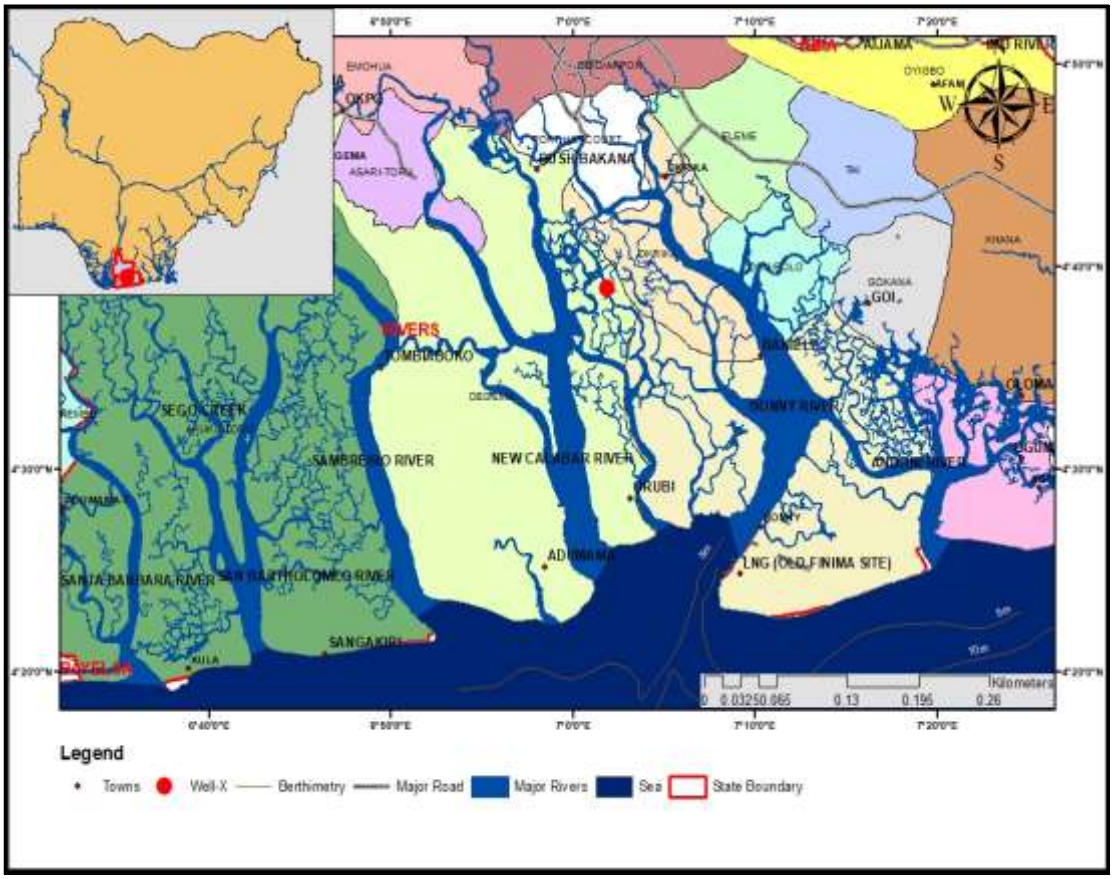


Figure 1: Location map of the well-x, onshore Niger delta (Generated from ArcGI)

S**edimentological** Sample Analysis: 30 gram each of the one hundred and ninety two (192) ditch cutting rock samples made available for this study were taken to the laboratory for sedimentological sample descriptions. The grain-size was determined through the processes of both wet and dry sieve analysis. The wet sieve analysis was done using 63 µm mesh sieve size and with 30 g of measured samples. The samples were washed under a running tap to remove clay until clean. Liquid detergents were used during wet sieving to loosen oil stain resulting from the drilling mud. The retained sand grains on the sieve were transferred into well labeled enamel plate and dried under a gentle heat on a hot plate. The sample weight loss after wet sieve analysis represented the clay fractions while the sample retained were dried under gentle heat on a hot plate. The dried samples were sieved with a set of sieves comprising 63, 250 and 500 micrometer mesh sizes which represents, the fine, the medium and the coarse sand respectively and each retained samples were weighed. The result from the wet-sieve analysis was tabulated and normalized into percentages, populated in StrataBUGs software and plotted into sand / shale ratio per depth and gradational profile of the studied interval.

Micropaleontology Sample Preparation
30 grams of the samples were measured and transferred into the Pyrex beaker. The Pyrex with the samples were heated on the laboratory hot plate to burn out organic materials. Few granules of anhydrous sodium hexametaphosphate were added to the samples while on the hot plate, topped with water, stirred and allowed to boil for few minutes to deflocculate the clays. The samples were

allowed to cool and was washed with 63µ sieve mesh under a running tap with distilled water until all the clays and the sodium hexametaphosphate were completely washed out. The residue was carefully and gently transferred into the enamel plate and dried on a gentle heat on the hot plate. The dried samples were sorted according to grain sizes by separating into fine, medium and coarse using 63, 250 and 500 sieve sizes for easy analysis.

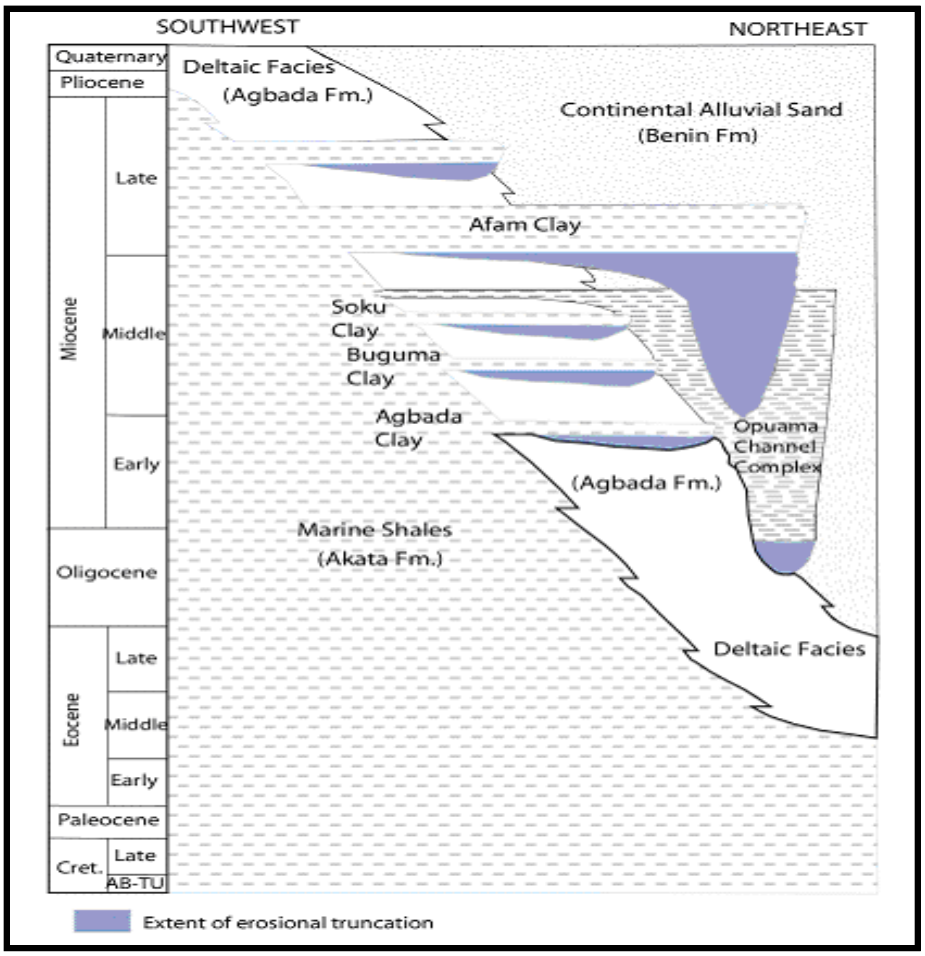


Figure 2:Lithostratigraphy of the Niger Delta (after Doust and Omatsola, 1989).

Micropaleontology Sample Analysis

Each of the fractions was sprinkled sparsely but evenly across a picking tray, all the foraminifera identified was picked and placed in a foraminifera slide using the wet tip of a picking pin, transferred into the foraminifera slide and glued with Tragacanth, adhesive, for microscope study. The recovered foraminifera were identified to species level as much as possible and their abundances per field of view, recorded using standard manuals such as Oligocene to Holocene Planktonic Foraminifera (Bolli and Saunders, 1985; incorporating Blow, 1969 and 1979), SPDC's Catalogue of Benthonic Foraminifera and TOTAL's *Principaux Foraminiferes observes dan less series deltaiques du Neogene.* The taxonomic classification followed the standard of Loeblich and Tappan (2015). All the foraminifera identified were grouped into benthonic and planktonic forms, counted, populated in stratabug software and plotted in charts, indicating total occurrences of each

species, total diversity and abundance down the borehole. Other miscellaneous microfossils identified were also noted.

RESULTS AND DISCUSSION

Results

Sedimentological and micropalaeontological analysis was carried out on one hundred and ninety-three (192) ditch cutting samples of the well-x obtained from interval 5480 – 11256ft. Sedimentological description of the ditch cutting rock samples provided data for sand / shale ratio, sorting or gradational profile of the study well (Figure 3). A total of Ninety-three (93) foraminiferal species were identified (Figure 4 and Plate 1). Calcareous benthonics accounted for about 35% of these species; agglutinated benthonics constituted about 42%, while the planktonic species made up the remaining 23%. This is exclusive of the miscellaneous microfossils recorded within the analysed interval of the well (figure 5). Micropalaeontological analysis indicated that the following intervals 5840 –7070ft, 7790 – 8480ft, 9050 – 10610ft and 11060 – 11256ft yielded moderately rich assemblages of planktonic, calcareous and agglutinated benthonic foraminifera; while intervals 5480 – 5840ft, 7070 - 7790ft, 8460 – 9050ft and 10610 – 11060ft were either completely barren or recorded few occurrences of foraminifera.

Discussions

The results of the micropaleontology and sedimentological descriptions of the ditch cutting rock samples was applied to paleoenvironmental and paleobathymetric reconstruction, of the studied interval of well-x. Lithofacies interpretation was based on (rock type, their association with one another, textural characteristics, accessory minerals and microfossils) and forms the primary tool for identifying the depositional conditions under which the sediments encountered in well-x were deposited and preserved. Gamma Ray response to variations in grain size was also used to infer depositional environments where they are of good quality. Biofacies associations of dominant benthonic foraminifera species were also recognised. These benthonics are known to be very sensitive to various environmental conditions such as salinity and availability of oxygen and sunlight among others. The qualitative and quantitative biofacies associations were therefore very useful in the palaeoenvironmental synthesis of the entire studied interval of well-x.

Biofacies association: The dominant biofacies associations recorded within the well and the palaeoenvironments they indicate are presented below.

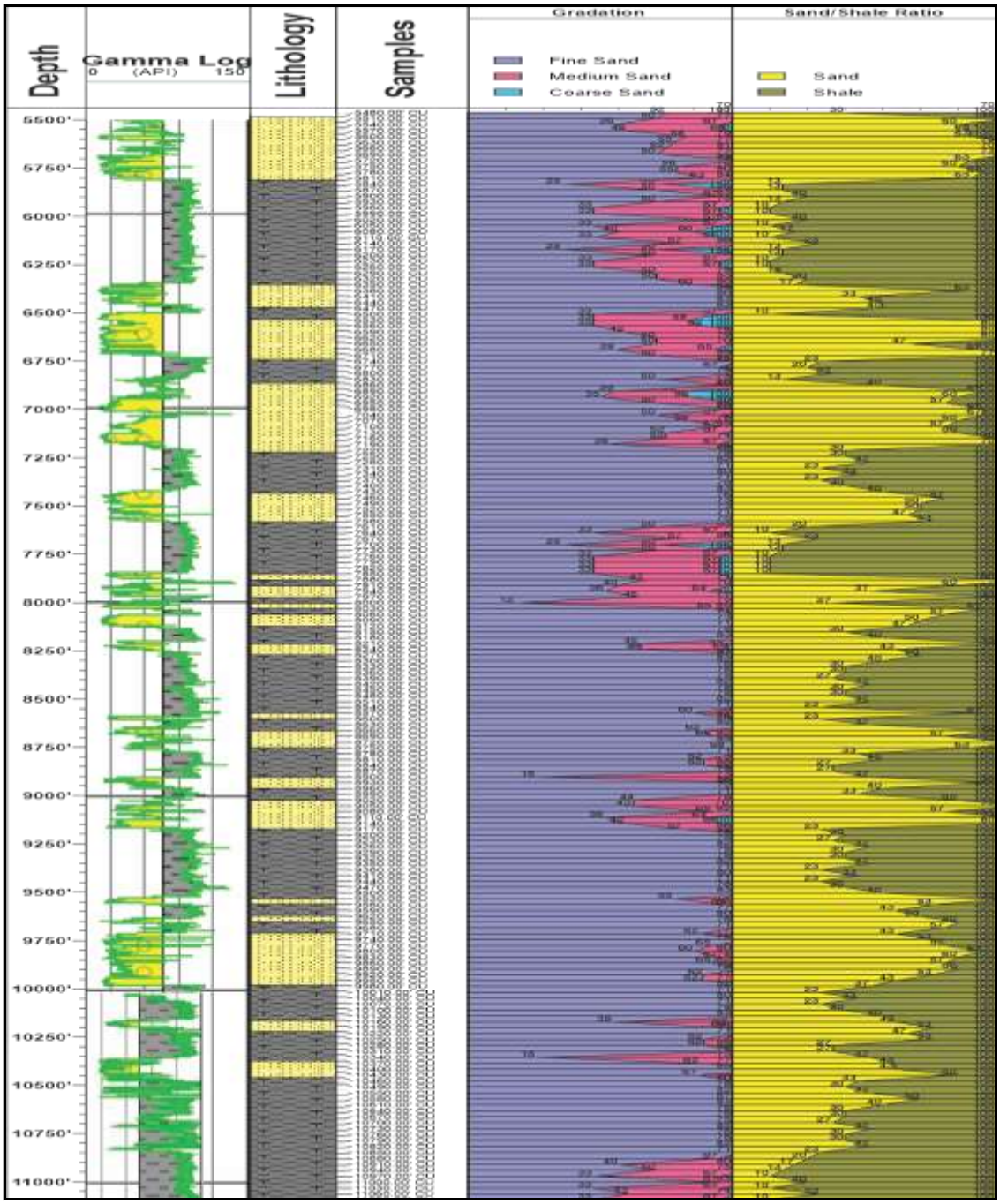
1. *Ammonia beccarii* Biofacies:

Few *Ammonia beccarii*, *Bolivina scalprata miocenica*, *Florilus atlanticus*, *Epistominella vitrea*, *Bolivina punctata* and *Quinqueloculina lamarckiana* co-occurring with rare *Globigerinoides ruber* and *Globigerinoides trilobus*. Palaeoenvironment: Shallow Inner Neritic.

2. Ammonia beccarii / Bolivina scalprata miocenica Biofacies:

Few *Pullenia bulloides* co-occurring with few to common *Globobulimina ovata, Alveolophrragmium cf crassum*, *Praeglobobulimina ovata*, *Heterolepa floridana*, *Ammonia*

beccarii, *Bolivina scalprata miocenica*, *Quinqueloculina lamarckiana*, *Lenticulina inornata*, *Bolivina punctata*, *Heterolepa pseudoungeriana*, *Alveolophragmium crassum*, *Globigerinoides ruber*, *Globigerinoides immaturus* and *Globigerina bulloides*. Palaeoenvironment: Inner- Middle Neritic.



Figre. 3. Graphical representation of sedimentology data showing logs, sand/shale ratio and gradational profile of well-x

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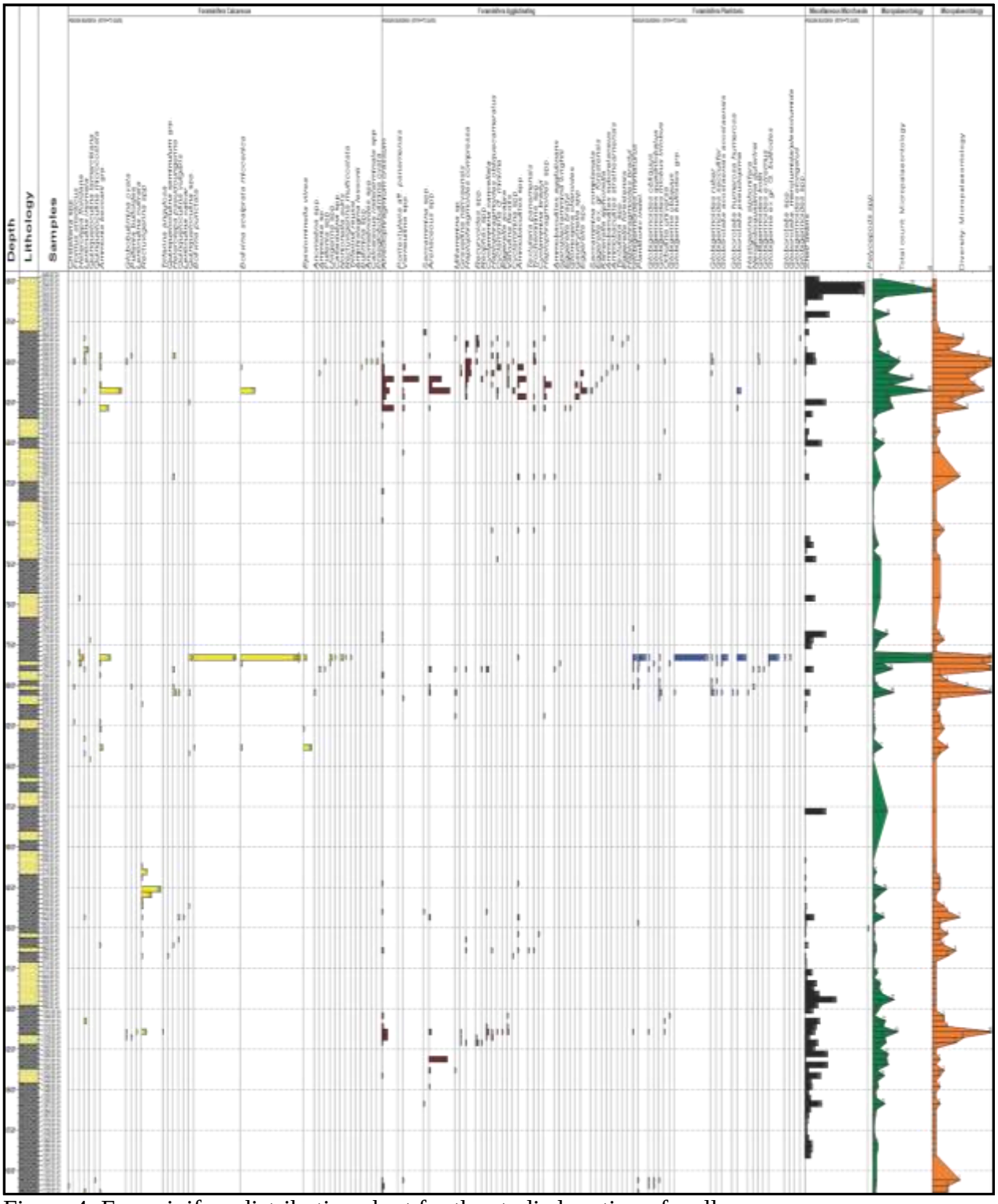

Figure 4: Foraminifera distribution chart for the studied section of well-x

3. Haplophragmoides compressa/ Valvulina flexilis Biofacies:

Few *Haplohragmoides compressa* and *Valvulina flexilis* co-occurring with common to abundant *Cyclammina cf minima, Haplohragmoides obliquicameratus, Saccammina complanata,Gravellina narivaensis, Alveolophragmium crassum, Karreriella siphonella, Trochammina spp* and *Recurvoides spp in* association with Gl*obigerinoides ruber, Globigerinoides bolli, Globorotalia pseudopima,* and *Globorotalia acostaensis*. Palaeoenvironment: Outer Neritic – Upper Bathyal.

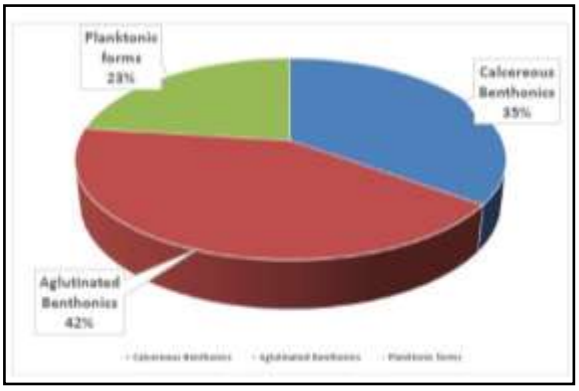

Figure 5: distribution of foraminifera in well x

Palaeobathymetric Characterization:

The biofacies and lithofacies data were integrated in the estimation of paleowater depthswith subsequent paleoenvironment as follows.

Interval:	5480 – 5900ft
Palaeobathymetry:	Coastal Deltaic – Shallow Inner Neritic
Lithofacies:	Sand facies / Siltstone facies
Environment of Deposition:	Distributary Channel

This interval is almost completely barren of foraminifera, depicting a Coastal deltaic paleobathymetric setting with few shallow inner neritic influence.
This interval is predominantly Sand with Siltstone intercalations. The sand is light grey to white, predominantly fine to medium-grained; sometimes medium to fine-grained, subrounded to rounded; sometimes subangular to subrounded, moderately sorted; occasionally well sorted and ferruginized. The siltstone is light to brown, consolidated, soft and ferruginized. These lithofacies are associated with shell fragments as well as carbonate materials and are characterized by stacks of blocky/ fining upward GR log motifs; suggestive of a Distributary Channel deposit in Delta plain setting.

Interval:	5900 – 6350ft
Palaeobathymetry:	Outer Neritic – Upper bathyal
Lithofacies:	Shale facies
Environment of Deposition:	Distal bay

The low to high occurrences of agglutinated benthonic taxa such as *Cyclammina cf minima*, *Haloprragmoides compressa*, *H. obliquicameratus*, *Valvulina flexilis*, *Alveolophragmium cf crassum* and species of *Trochammina* and *Veneulina* associated with low occurrences of *Ammonia beccarii*, *Lenticulina inornata*, *Praeglobobulimina ovata* and *Heterolepa floridana* were recorded in this interval. This is indicative of Neritic to Upper bathyal paleobathymetric setting.

The lithology of consists of shale facies. The shale is dark grey, occasionally greenish in colour, fissile, moderately hard and occasionally ferruginized; associated with shell fragments as well as carbonaceous materials and characterized by aggradational GR log motif, which is suggestive of a Distal bay deposit in the Open shelf to Upper slope setting.

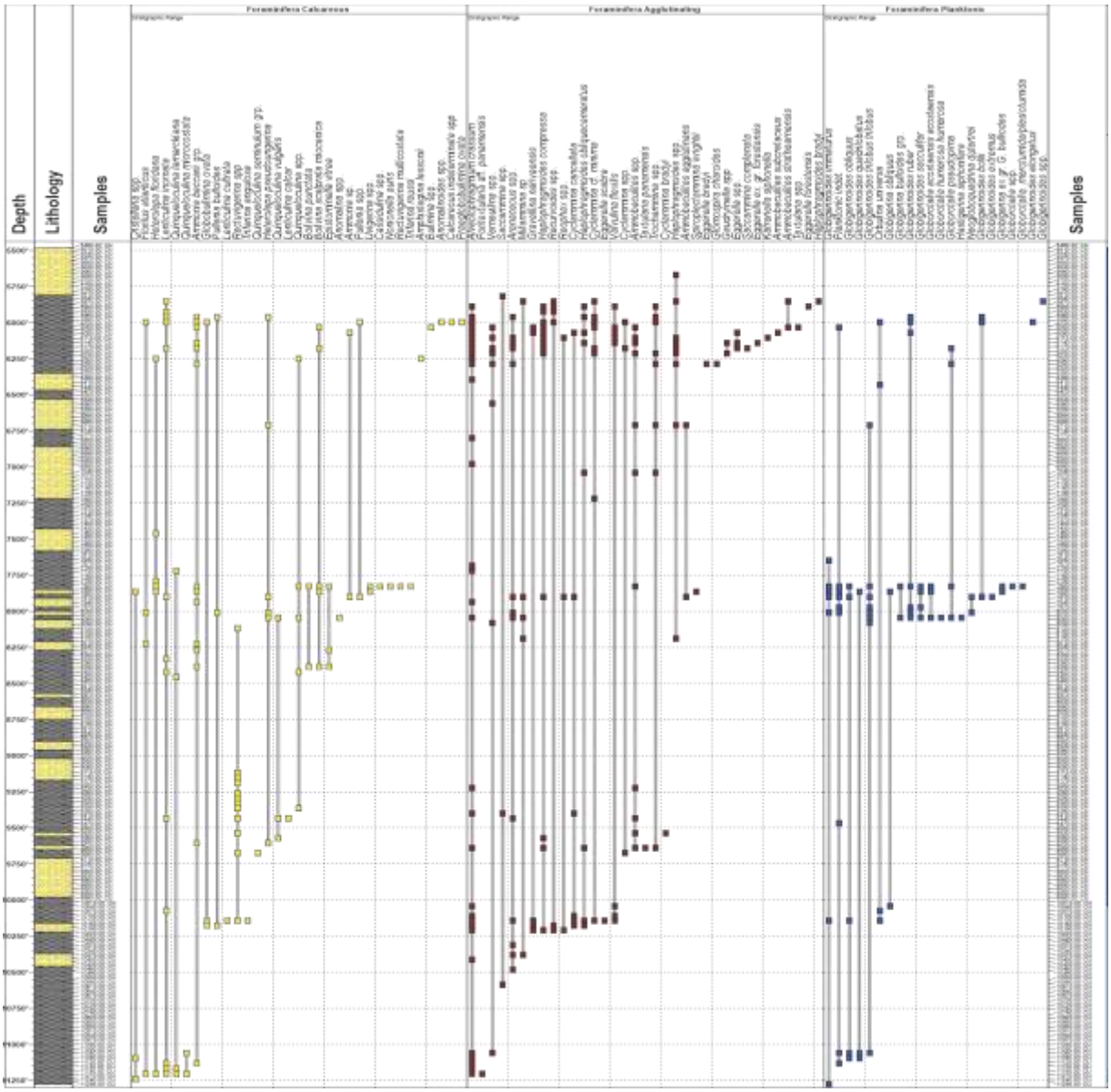

Figure 5: Foraminiferal distribution chart showing biofacies associations of well-x.

Interval:	6350 – 7400ft
Palaeobathymetry:	Coastal Deltaic – Shallow Inner Neritic
Lithofacies:	Sand facies /Shale facies/ Siltstone facies
Environment of Deposition:	Distributary channel.

The poor occurrences of foraminifera in this interval suggests predominantly Coastal deltaic paleobathymetric setting; with Marginal to Shallow marine incursions at few intervals (Shallow Inner Neritic) expressed by the rare occurrences of *Alveolophragmium cf crassum* and species of *Ammobaculites*, *Verneulina* and *Trochammina.*
This interval is predominantly Sandy (with Shale and Siltstone intercalations) interval. The Sand is light grey, predominantly fine grained, sub-angular to angular and well sorted, while the intercalating Siltstone is light brown, consolidated, soft and ferruginized. The shale is dark grey, fissile and moderately hard. The siltstone is light to brown, consolidated, soft and ferruginized. These lithofacies are associated with pyrite as well as carbonate materials and characterized by blocky/fining upward GR log motif; suggestive of a Distributary channel deposit in a Delta plain setting.

Interval:	7400 – 7820ft
Palaeobathymetry:	Coastal Deltaic – Shallow Inner Neritic
Lithofacies:	Sand facies / Shale facies
Environment of Deposition:	Channel / Overbank

Rare occurrences of *Alveolopghragmium cf crassum*, *Heterolepa floridana* and *Quinqueloculina lamarckiana* defined this paleobathymetric setting which is predominantly, fluctuating between Coastal deltaic and Shallow Inner Neritic.

The lithology consists of Sand and Shale intercalations. The sands are light grey, predominantly fine to medium grained, moderately sorted, sub-angular to sub-rounded, and occasionally ferruginized. The shale is dark grey, fissile and moderately hard. These lithofacies are associated with shell fragments and carbonate materials and are characterized by stacks of alternating blocky and aggradational GR log motifs; suggestive of Channel / Overbank deposit in a predominantly Delta plain setting.

Interval:	7820 – 8060ft
Palaeobathymetry:	Inner – Middle Neritic
Lithofacies:	Sand facies/Shale facies
Environment of Deposition:	Inter-distributary bay fills

The interval is characterized by high occurrences of foraminifera. The calcareous benthonic foraminifera recorded within this interval include *Ammonia beccarii*, *Heterolepa pseudoungeriana*, *Heterolepa floridana*, *Pullenia bulloides*, and species of *Trifarina*, *Uvigerina* and *Cassidulina.* The planktonic taxa recorded include *Globigerinoides trilobus*. *Globigerinoides obliquus*, *Globigerinoides sacculiferus, Globigerinoides immaturus* and *Globorotalia acostansis,* the agglutinated taxa are represented by *Alveolophragmium cf crassum* and species of *Miliammina* and *Verneulina.* This suggests that sediments were probably deposited in a predominantly Inner to

Middle Neritic palaeobathymetric setting with relative deepening into Outer Neritic in the uppermost part.
The lithological composition of this interval consists of intercalation of sand and shale facies. The sand is light to dark grey, fine to medium grained, moderately sorted, sub-angular to sub-rounded and occasionally ferruginized, while the shale is grey and fissile to sub-fissile. These lithofacies are associated with shell fragments and characterized by sawtooth GR log motif; suggestive of their deposition as Inter-distributary bay facies in a Delta front to Prodelta setting.

Interval:	8060 – 9950ft
Palaeobathymetry:	Coastal Deltaic - Shallow Inner Neritic
Lithofacies:	Sand facies/Shale facies
Environment of Deposition:	Channel / Overbank

This interval yielded rare to low recovery of foraminifera. The agglutinated benthonic foraminifera recorded within the interval include *Alveolophragmium cf crassum, Haplophragmoides compressa, Textulari panamensis,* and *Ammobaculites spp*. Calcareous benthonics recorded include *Ammonia beccarii* and *Rectuvigerina* spp. suggesting deposition in a Coastal deltaic to Shallow inner neritic paleoebathymetric settings.
The sand encountered in this interval is predominantly light to dark grey, fine to medium-grained, moderately sorted, sub-angular to sub-rounded. The Shale is dark grey, fissile and moderately hard. These lithofacies are associated with carbonate materials and are characterized by stacks of alternating blocky and fining upward GR log motifs; suggestive of Channel / Overbank facies in a predominantly Delta plain setting.

Interval:	9950 – 10160ft
Palaeobathymetry:	Outer Neritic
Lithofacies:	Sand facies/ Shale facies
Environment of Deposition:	Distal Bar / Bay Deposits

This interval is characterized by low to high *Alveolophragmium crassum, Gravellina narivaensis, Cyclammina cancellata, Valvulina flexilis,* species of *Recurvoides* and *Cyclammina (*agglutinated taxa*)* associated with rare to low occurrences of calcareous benthic taxa such as *Pullenia bulloides, Globobulimina ovata* and *Trifarina angulosa.*
The lithofacies encountered in this interval consists of sand and shale. The shale is dark grey, sub-fissile to fissile and moderately hard. The sediments are characterized by blocky / fining upward GR log motif and are associated with common occurrences of carbonate materials and shell fragments in the entire interval. These sediments were probably deposited as Distal Bar / Bay deposits in a predominantly open shelf setting.

Interval:	10160 – 11256ft
Palaeobathymetry:	Coastal Deltaic – Shallow Inner Neritic
Lithofacies:	Sand facies/ Shale facies / Silt facies
Environment of Deposition:	Channel flood plain

The foraminiferal assemblage in this interval consists of rare to low occurrences of agglutinated taxa such as *Alveolophragmium crassum*, and species of *Saccammina* and *Miliammina* in association with low occurrences of *Lenticulina inornata*, *Ammonia beccarii*, *Quinqueloculina lamarckiana, Quinqueloculina microcostata* and *Cristellaria* spp.

The calcareous planktonics recorded within the interval include *Globigerinoides trilobus, Globigerinoides immaturus* and *Globigerinoides quadrilobatus.* This foraminiferal assemblage depicts a predominantly Coastal deltaic paleobathymetric setting deepening into Shallow Inner Neritic and Inner Neritic at upper (10160 – 10640ft) and lower (11060 – 11240ft) sections respectively.

The lithofacies encountered in this interval is shale with sand intercalations. The shale is dark grey, fissile and moderately hard while the sand is predominantly light to dark grey, coarse to medium-grained, poorly sorted, occasionally consolidated and ferruginized. These facies are further characterized by aggradational/progradational log motifs and are associated with common occurrences of carbonate and ferruginous materials. This probably indicates that the interval is deposited as Channel flood plain facies in a Delta plain to Delta front setting. The shale/sand ratio in this interval approximates the channel sand and flood plain shale and is expressed in the overall GR log motif as channel cuttings and filling of the flood plain; with the geometry of the sand hardly showing a discrete channel pattern (Selley, 2013).

The biofacies association indicate that the sediments encountered in the well-x were deposited in a Non-Marine to Upper Bathyal paleobathymetric settings; in Coastal Deltaic to Deep marine paleoenvironments. The interpreted paleobathymetry and depositional settings of the studied interval of well-x are presented (figure. 6).

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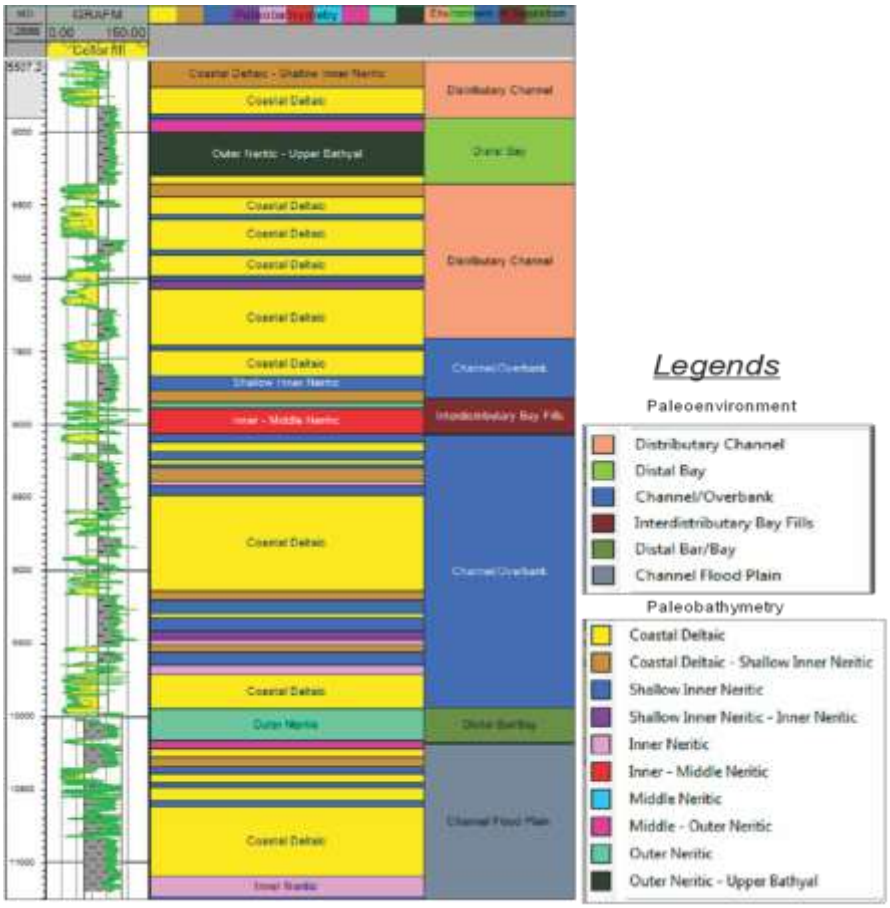

Figure 6: Paleoenvironmental interpretation of well-x showing the paleobathymetry and depositional settings of the ditch cutting rock samples.

SUMMARY AND CONCLUSION

This study was carried out using ditch cutting rock samples from well-x. The rocks sample comprised of 192 (One hundred and ninety-two) intervals sampled at 60ft and ranged from 5480ft to 11256ft. Well-x is located on Longitude 0°3'47.677"E and latitude 0°2'30.506"N (Fig. 3.1).
The data used in the study was primarily generated through sedimentology and micropaleontology laboratory preparation and analysis of the ditch cutting rock samples. The sedimentology sample analysis involved wet and dry sieve analysis using 63 micrometer mesh size, 250 micrometer mesh size and 500 micrometer mesh size. The micropaleontology was prepared through wet sieve analysis with sodium hexametaphosphate as a deflocculant. The micropaleontology analysis and taxonomic classification followed the Loeblich and Tappan (2015) method for foraminifera analysis.

The sedimentological description of the ditch cutting rock samples provided data for sand / shale ratio, sorting or gradational profile of the study well which was plotted as a chart. Micropalaeontological analysis result was also populated in charts. The charts indicated that the following intervals 5840 –7070ft, 7790 – 8480ft, 9050 – 10610ft and 11060 – 11256ft yielded moderately rich assemblages of planktonic, calcareous and agglutinated benthonic foraminifera;

while intervals 5480 – 5840ft, 7070 - 7790ft, 8460 – 9050ft and 10610 – 11060ft were either completely barren or recorded few occurrences of foraminifera. Ninety-three (93) foraminiferal species were identified using standard manuals. Calcareous benthonics accounted for about 35% of these species while the agglutinated benthonics constituted about 42%. The planktonic species made up the remaining 23%.

The result of the micropaleontology and sedimentological descriptions of the ditch cutting rock samples were applied in paleoenvironmental and paleobathymetric synthesis of the studied interval of well-x. and achieved through the integration of biofacies and lithofacies data and wireline log (Gamma Ray) data.

The dominant biofacies associations recorded within the well include *Ammonia beccarii, Ammonia beccarii / Bolivina scalprata miocenica,* and *Haplophragmoides compressa/ Valvulina flexilis* indicating Shallow Inner Neritic, Inner- Middle Neritic, and Outer Neritic – Upper Bathyal paleoenvironment respectively.

The palaeo-water depth was based on relative abundance and diversities, occurrence of environmentally significant benthonic foraminifera and lithofacies associations. The palaeobathymetry identified in the studied interval suggested deposition within Coastal Deltaic – Shallow Inner Neritic in a distributary channel, channel / Overbank and channel flood plain depositional setting; Inner – Middle Neritic in an inter-distributary bay fills depositional setting; Outer Neritic in a distal bar / bay depositional setting; and Outer Neritic – Upper bathyal in a distal bay depositional setting.

In conclusion, the lithofacies and biofacies results show that the sediments encountered in the well-x were deposited in a Non-Marine to Upper Bathyal paleobathymetric settings; in Coastal Deltaic to Deep marine paleoenvironments.

Plate 1
1 *Glomospira charoides* (Magnification - 200µm)
2 *Globigerinoides immaturus* (Magnification - 200µm)
3 Karreriella *siphonella* (Magnification - 200µm).
4 *Valvulina flexilis* (Magnification - 200µm)
5 *Globigerina ex gr. G. bulliodes* (Magnification - 200µm)
6 *Pullenia bulloides* (Magnification- 200µm).
7 *Saccammina spp* (Magnification - 200µm).
8 *Globigerinoides obliquus* (Magnification - 200µm)
9 *Cyclammina* cf. *minima* (Magnification - 200µm)
10 *Cyclammina cancellata* (Magnification - 200µm).
11 Globigerinoides ruber (; Magnification - 200µm)
12 *Ammobaculites strathearnensis* (Magnification - 200µm).
13 *Textularia spp,* (Magnification - 200µm).
14 *Globigerinoides quadrilobatus* (Magnification - 200µm).
15 *Globorotalia acostaensis acostaensis* (Magnification - 200µm)
16 *Textularia* spp. (Magnification - 200µm).

17 *Globorotalia humerosa humerosa* (Magnification - 200µm).
18 *Orbulina universa* (Magnification - 200µm)
19 *Globorotalia. merotumida/plesiotumida* (Magnification - 200µm)
20 *Cyclammina cancellata* (Magnification - 200µm).
21 Florilus atlanticus (Magnification – 200µm).

Plate 1

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