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The Significance of Biostratigraphic And Sedimentary Structures Revealed In Apani-Emeabiam-Ilom-Okwukwe Wells, Eastern Niger Delta

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ABSTRACTS

The significance of lithofacies and biofacies in sedimentary rocks encountered in Apani-Emeabiam-Okwukwe wells was studied. The study is aimed at creating a subdivision of the geological section into chronostratigraphic correlatable horizons. This was achieved by integrating micropaleontological and palynological modes at intervals of 60ft and 90ft, applying sedimentological and biostratigraphic tools in establishing formation boundaries, zonation of variously recorded microfossil and palynolgy as well as deducing age and paleoenvironment of deposition. Lithologic cuttings were collected at intervals of 60ft and 90ft and analyzed for lithologic facies changes and paleontological as well as palynological contents and variations. Six broad lithofacies sequences at different depths from the entire wells were indicated as follows: 0-344 feet is made up of continental lithofacies diagnostic of the continental Benin Formation; 3440-3880 feet is composed of transitional Benin Formation while 3880-8950 feet indicated the upper paralic Agbada Formation, 8950-9717 feet was the Upper Marine Paralic Agbada while 9717-10272 feet consisted of the Lower Paralic Agbada Formation and 10272-12520 feet constituted The Lower Marine Paralic Agbada Formation

Keywords: Lithofacies, Biofacies, Benin Formation, Agbada Formation, Niger Delta, Sedimentation, Paleoenvironment.

INTRODUCTION

For purposes of geologic significance of lithologic variations, and also the biogenic variations in sedimentary deposits, it is necessary to take a broad view at the deposit, group and simplify what we see in outcrops and well sections. This article concerns the later. Much of these variations are disguised in lithofacies and biofacies types which are the results of various environments of depositions. The term 'facies' is widely used in geology, particularly in the study of sedimentology in which sedimentary facies refers to the sum of the characteristics of a sedimentary unit (Middleton 1973). These characteristics include the dimensions, sedimentary structures, grain sizes and types, colour and biogenic content of the sedimentary rock. The existence of this natural pattern is what makes facies studies, facies modeling, and paleogeographic reconstruction possible (Miall, 1990). Accumulation of floral and faunal bearing sediments deposited are overlaid by heterogeneous continental materials resulting in the column of sedimentary deposition at the locations.

The facies concept is not just a convenient means of describing rocks and grouping sedimentary rocks seen in the field, it also forms the basis for facies analysis, a rigorous, scientific approach to the interpretation of strata (Anderton 1985; Reading & Levell 1996; Walker 1992; 2006). The lithofacies characteristics are determined by the physical and chemical processes of transport and deposition of the

sediments and the biofacies and ichnofacies provide information about the palaeoecology during and after deposition. By interpreting the sediment in terms of the physical, chemical and ecological conditions at the time of deposition it becomes possible to reconstruct
Palaeoenvironments.

Location And Geology Of The Study Area

The location co-ordinates were N133,000 and E493,700 lying within the eastern part of the Ughelli depositional belt of the Niger delta province. The study area is located in the Niger Delta Basin. Niger Delta is formed from the deposition of sediments carried by River Niger as it flows into the Atlantic Ocean. The Niger Delta separates the Bight of Benin from the Bight of Biafra within the larger Gulf of Guinea.

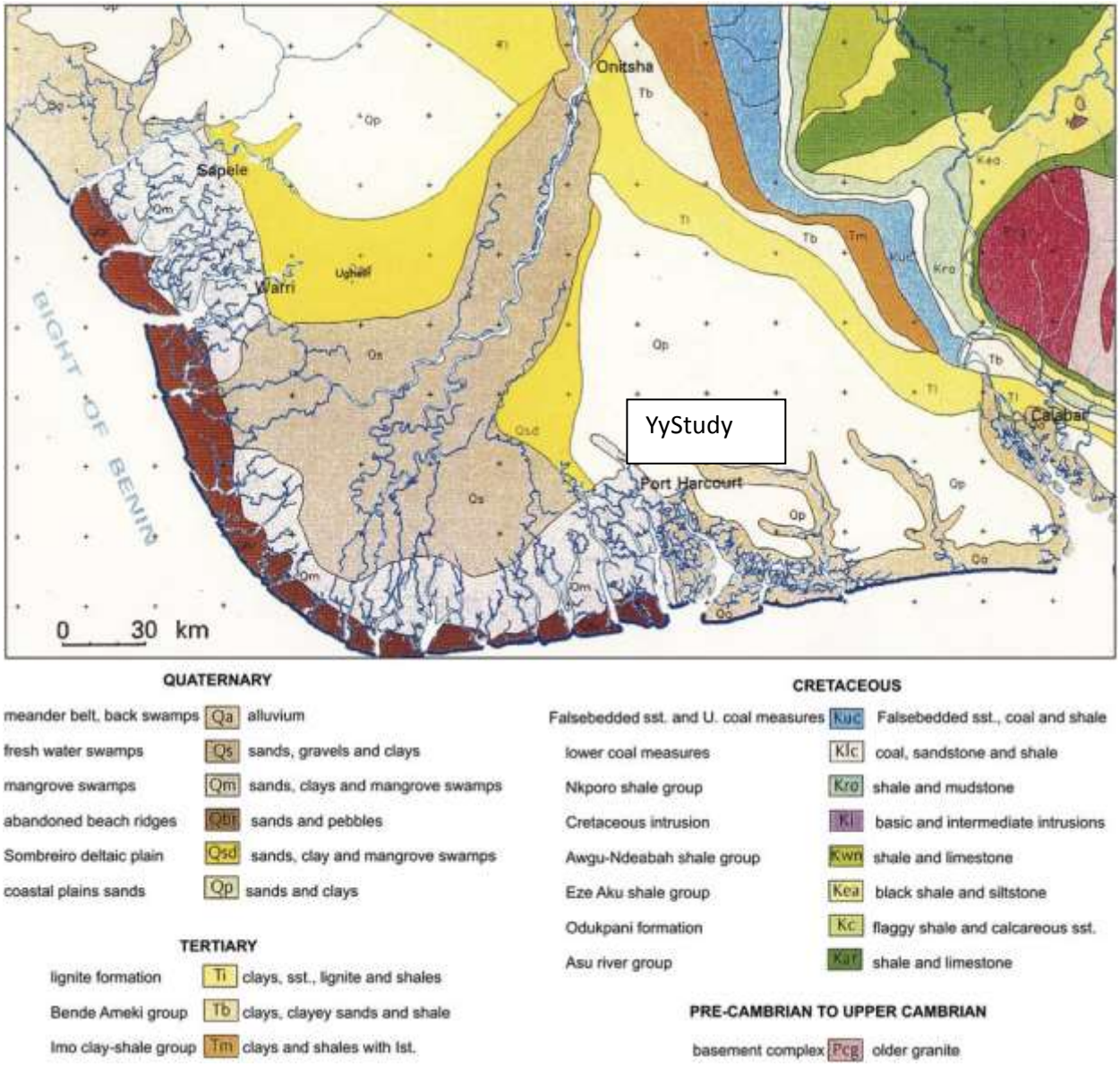

Fig. 1. Map showing the location of study area and Geology of Niger Delta

The Niger Delta oil province covers about 300,000 square kilometers and consists of the geologic Tertiary Niger Delta. It consists of the present day Nigerian South South Zone of Nigeria which includes Akwa Ibom, Bayelsa, Cross River, Delta, Edo and Rivers states.

The Niger Delta sedimentary basin is a result of three depositional cycles namely: Firstly, the marine incursion in the Cretaceous which deposited some shales and was terminated by mild folding in the Santonian (Reijers et al., 1997). The second was the development of the pro Niger Delta that ended in the Paleocene marine transgression. The third cycle marked the continuous development of the main Niger Delta from Eocene to Recent.

Three lithostratigraphic subdivision exist in the subsurface of Niger Delta. This is made up of the upper sandy Benin formation, a middle layer of alternating sandstone and shale known as Agbada Formation and the underlying shaly deposit known as Akata Formation. Afam clay is a separate member of Benin formation known as an ancient valley fill. Akata, Agbada an Benin Formation range in age from Tertiary to Recent

MATERIALS AND METHODS

Lithologic logs and reports of cuttings were collected at intervals of 60ft and 90ft and analyzed for lithologic facies changes and paleontological as well as palynological contents and variations. The fossils that the sediments contain are extracted by a variety of physical and chemical laboratory techniques, including sieving, density separation, and chemical digestion of the unwanted fractions. The resulting concentrated sample of fossils and most especially microfossils was mounted on a slide for analysis using a microscope. Taxa were identified and counted

RESULTS

The well bore was drilled as a deviated well with maximum deviation angle of 30 degrees to a total depth of 12,520ft (Below Drill Floor). The well revealed only the Benin Formation and Agbada Formation of the Niger delta sedimentary basin. The lithologic extents encountered in the well study lying between the interval 5200- 12520 ft BDF made up of the Agbada Formation and was subdivided into four lithofacies sequences comprising,

i). The Upper Paralic Sequence (5200-8950ft BDF) A predominantly sandy sequence with three identifiable shaly intervals.

ii). The Upper Marine Paralic Sequence (8950-9717 ft BDF). Mainly composed of shales but also with 3 relatively thin sandy intervals.

iii). The Lower Paralic Sequences (9717-10272 ft BDF). This consists of two major sandy intervals separated by a moderately defined shaly interval.

iv). The Lower Marine Paralic Sequence (10272-12520 ft BDF). Composed of a predominantly shaly sequence with three sandy intervals.

DISCUSSION

The Upper part of the analyzed interval (5200-8500ft) was completely barren of foraminifera. This non-recovery, a common phenomenon in the eastern Niger Delta, has been attributed to unfavourable paleonvironmental conditions most probably due to high clastic dilution from the adjoining basement complexes. Thus, the amount of carbonates – a major requirement for foraminiferal test building – is low. Age determination over this interval consequently relied solely on palynological characteristics whilst paleoenvironmental deductions were based on a combination of palynological and sedimentological indications.

Palynomorph recovery over the entire analyzed interval provided adequate data base for identifying two major zones and four subzones. The two major zones are equivalent to the P600 and P500 zones of Evamy et al (1978). These zones correspond to the Trans-Atlantic VERRUTRICOLPORITES ROTUNDIPORUS AND CICATRICOSISPORITES DOROGENSIS Zones of Germeraad et al (1968)

respectively. They are also the age equivalents of the Pan Tropical MAGNASTRIATITES HOWARDII zone established by the same authors.

The two major zones and their respective subzones are as follows:

A: The P600 zone (5200-10840 ft BDF) RF-4 of Early Miocene age. This consists of:

i). The P630 Subzone (5200-9370 ft BDF) (RF-3) and ii). The P620 subzone (9370-10840 ft BDF) RF-2

B: The P500 zone (10840-12520 ft BDF) RF-4 of Late Oligocene age. This is also composed of two subzones. i). The P580 subzone (10840-11890 ft BDF) RF-3 and

ii). The P560 subzone (11890-12520 ft BDF) RF-2

The relatively fair recovery and diverse suite of foraminifera from the fossiliferous lower half of the analyzed interval (8500-12520 ft BDF) enabled the recognition of two benthic and one planktic zones. These are:

1). The AMMONIA BECCARII (NONION – LENTICULINA-BOLIVINA biofacies) partial range zone (8860-10630 ft BDF) of Early Miocene age.

2). The EPONIDES BERTHELOTIANUS Assemblage zone (10630-12520ft BDF) RF-4 of Late Oligocene-Early Miocene age.

The planktic zone- GLOBIGERINA CIPEROENSIS (P22/N3) Zone (11840-12520 ft BDF) (RF-2) of Oligocene age was recognized within the benthic EPONIDES BERTHELOTIANUS Assemblage zone.

The four lithofacies sequences recognized in the analyzed interval are interpreted to be representative of several transgressive and regressive phases of a prograding delta. Sediments of the Lower marine Paralic Sequence were inferred to be sub-aqueous tidal channel fill sequences and shales deposited in delta front to prodelta environments during a general retreat of the sea. However, three transgressive events were recognized within this sequence, which are represented by the intervals,

12400-11920 ft BDF;

10900-10620 ft BDF, and

10450-10300 ft BDF.

transgressive event represented by the interval 10900-10620 ft BDF constitutes the most geologically significant. This event during which middle neritic water depths were attained is ascribed to the major Early Miocene transgression along the Gulf of Guinea.

In the Lower Paralic Sequence, sedimentation commenced with barrier foot, barrier bar and channel sands deposited under supralittoral and inner neritic conditions most probably in a general retreating sea. This regressive event was replaced by another major transgression during which fine grained subaqueous channel sands that cap the sequence were deposited. Middle to outer neritic water depths were attained during this period.

The prodelta to shallow marine shales that constitute the basal part of the Upper Marine Paralic Sequence were believed to have been deposited during the above inferred major transgression that commenced towards the Upper part of the Lower Paralic Sequence. Thereafter, barrier foot barrier bar and channel sands were all laid down in delta front platform environmental setting probably during a regressive phase of a delta buildout.

In the Upper Paralic Sequence, sediments were believed to have been laid down in environments which grade from fluviomarine at the base to brackish at the top. Sedimentological evidences indicate the presence of one transgressive episode within the sequence.

Table 1 .Lithostratigraphic sequences across the wells

Depth Interval	Lithofacies Sequences	Formation
0-3440 ft	The Continental	BENIN
3440-3880 ft	The Transitional	BENIN
3880-8950 ft	The Upper Paralic	AGBADA
8950-9717 ft	The Upper Marine Paralic	AGBADA
9717-10272 ft	The Lower Paralic	AGBADA
10272-12520 ft	The Lower Marine Paralic	AGBADA

The above subdivision is based on the lithostratigraphic subdivision of the Niger Delta by Short and Stauble (1967). The Continental sands occurring at shallow depths together with the underlying relatively thin transitional zone constitute the Benin Formation within the well. Although barren of microfauna, the shale units which underlie the sands of the Benin Formation, are believed to constitute an integral part of the Agbada Formation. This formation often described as a paralic sequence is characterized by an alternation of sand bodies interbedded with shale layers. Over certain intervals at deeper horizons, where the shale units predominate, particularly towards the base of the formation, such intervals have been described as being Marine Paralic.

The analyzed sequence in this well falls entirely within the Agbada formation. The following four broad lithofacies sequences have identified within the interval,

a). The Upper Paralic Sequences (5200-8950 ft BDF)
b). The Upper Marine Paralic Sequence (8950-9717 ft BDF)
c). The Lower Paralic Sequence (9717-10272 ft BDF)
d). The Lower Marine Paralic Sequence (10272-12520 ft BDF).

Details of the four categories of lithological and textural attributes of the sediments of these sequences are as follows,

a). The Upper Paralic Sequence (5200-8950 ft BDF)

This predominantly sandy Sequence with relatively thin shale intercalations, forms the topmost lithofacies unit within the analyzed interval. The sands range in thickness from 20-220 ft and are usually whitish, coarse to very coarse, angular to sub-rounded and well to very well sorted. Few smoky and citrine varieties are also present. Granules are common and occasionally become the dominant grain size towards the top of the sequence. Fine and medium sands are also locally present, particularly within the upper part of the sequence (5380-6070 ft BDF). These usually impart a moderate/poor sorting characteristic on the sands. Log indications show that these sand bodies exhibit both sharp and gradational upper and lower contacts. Hence, upward fining (bell-shaped) and upward coarsening (funnel shaped) log motifs are observed.

The sequence becomes locally shaly in few places and also contains mudstone, lithic and occasionally ferruginised sandstone fragments. Three remarkable shaly intervals are defined within the Upper Paralic Sequence. The shallowest of these intervals is about 190ft thick and spans the interval 5890-6080 ft BDF. It consists of grey, fissile shales which range in thickness from 25-80 ft interbedded with very thin (about 10 ft) sands. Most of the sand bodies within the interval exhibit an upward coarsening log profile.

The second interval (6404-6552 ft BDF) consists of a well developed upward fining sand body sandwiched between two well developed shale units. Lithological observations from ditch cutting descriptions over this interval suggest a thicker shale development (6400-6730 ft BDF) than actual log thickness indications. The top of the interval is also defined by a sharp decrease in the predominant grain size from the overlying sandy unit. The first downhole occurrence of glauconite pellets observed within this interval. A rare but continuous occurrence of mica flakes also characterized this interval.

The third shaly interval (7846-8530 ft BDF) occurs towards the lower part of the sequence. Here some fairly well developed (10-120ft) shale bodies alternate with slightly thinner (up to 60ft) sand bodies. The remarkably shaly log motif of the upper part of this interval could not be identified from ditch cutting sample descriptions. The interval is characterized by the first observed downhole occurrence of broken shell fragments.

Over the entire Upper Paralic Sequence, the common to abundant top occurrence of carbonaceous detritus becomes reduced with depth. Ferruginized materials and Sulphur coatings are rare to few. Rare occurrence of glauconite and shell fragments is restricted to the bottom of the sequence

b). The Upper Marine Paralic Sequence (8950-9717 ft BDF)

767 ft thick predominantly shaly unit underlies the Upper Paralic Sequence. The shales of this sequence are brownish to dark grey, fissile and occasionally sandy, and also with traces of siltstone, lithic and mudstone fragments.

One fairly developed and two poorly developed composite sand units within the intervals 9208-9316 ft BDF, 8998-9010- ft BDF and 9088-9120 ft BDF respectively, all occurring towards the Upper part of the sequence. The sands are coarse to very coarse (predominantly coarse), angular to subrounded, well sorted, very shaly and exhibit both the bell and funnel shaped log motifs.

Throughout the entire analyzed interval in the well, glauconite pellets become abundant only within the Upper Marine Paralic Sequence. This abundant occurrence is restricted to the middle part of the sequence and attenuates with depth. Shell fragments are rare, although they become few towards the sequence. Pyrites are also rare throughout the sequence. Rare occurrence of carbonaceous detritus and rare to few mica flakes become restricted to the upper part. Also within the upper part, ferruginized materials are observed, becoming scanty with depth.

The major shaly sand unit within the sequence (9208- 9316 ft BDF) was a reservoir sand hydrocarbon bearing with 47 ft net gas in a gas down to GDT situation.

c). The Lower Paralic Sequence (9717-10272 ft BDF)

This is a predominantly sandy sequence composed of two major sand intervals (9717-9885 ft and 10050-10272 ft BDF) and an intervening moderately defined shaly interval.

The sands of the upper sandy interval (9717-9885 ft BDF) are mainly fine grained, consolidated and veryshaly. GR log indications are at variance with actual lithological observations from ditch cutting samples over the interval. This apparently shaly log motif may be attributed to the fine grained nature of the sands. SP log indications however confirm the sandy nature of this interval.

A second and well developed 222 ft thick sand body is observed at the base of this sequence. Unlike the Upper section, the sands of this unit are mainly coarse to very coarse, angular to subrounded, well sorted and locally shaly. Few fine grained sandstone subunits however occur towards the base of this interval.

The overall upward improvement in sand development is observed for the two sands units. These units are composite bodies composed of smaller upward fining sand subunits. Few upward coarsening subunits were also observed. The shales of the Lower Paralic Sequence are mainly grey to dark grey although few brownish grey varieties existed. They are occasionally sandy and also contain rare to few lithic, siltstone and mudstone fragments. Pyrite is also rare over the entire sequence. Rare to few carbonaceous detritus also occur. Ferruginized materials were common to abundant towards the top becoming reduced with depth. Glauconite pellets were rare although they become few towards the upper part.

d). Lower Marine Paralic Sequence (10272-12520 ft BDF)

This almost entirely shaly sequence forms the basal sequence of the analyzed interval. The shales are mainly brownish to dark grey becoming occasionally black, extremely fissile with few fissile layers towards the top of the sequence. There are also localized sand, rare siltstone, lithic and mudstone fragments.

A few relatively thin (usually <25 ft) predominantly upward fining and sand intercalations occur within this sequence. Lithological observations from cutting core samples suggest the presence of a poorly developed sandy shale lithofacies unit within the depth interval 11290-11580 ft BDF. This micaceous unit is made up of coarse to very coarse, angular to sub-rounded well sorted sands, rare siltstone and mudstone fragments, ferruginized materials, pyrites, carbonaceous detritus, and an almost complete absence of glauconite and shell fragments. The top common occurrence of mica flakes is observed to wane with depth. However, wireline log motifs do not accurately delineate the existence of this unit. Elsewhere within the sequence, two moderately developed sandy intervals are also identified. The first occurring between the interval 11711-11905 ft BDF is composed of a stack of thinly interbedded sand and shale bodies. An upward decrease in sands range from fine grained sandstones to coarse, angular to sub-rounded, well sorted unconsolidated sands.

Sands within the interval 12280-12430 ft BDF are coarse to very coarse, angular to subrounded, well sorted, very shaly. They also exhibit an upward decrease in sand development. Within the entire Lower Marine Paralic Sequence, rare occurrence of the index accessories, eg.Feruginized materials, carbonaceous detritus, pyrites, shell fragments, and glauconite pellets were observed. The abundant basal occurrence of carbonaceous detritus is attributed mostly to mud additives through the drilling mud system.

Palynological Analysis

Palynological analysis and interpretations of Apani-1 were based on 235 samples from the depth range of 5200ft – 12520ft. The sampling interval varied from 6ft to 90ft which introduced some variation in frequency rate. The microfloral and dinocyst contents of the palynomorph assemblage exhibited significant variation and diversity in terms of species, distribution and abundance. They provided a good data base for the recognition of two major zones, P600 and P500, and four subzones (the P630, P620, P580, and P560) of Evamy et al 1978.

Environmentally diagnostic pollen, spores dinocysts, and microforaminifera constitute the major tools used for deducing the environment of deposition. The tested pollen zones of Germeraadetal (1968), Evamyetal were adopted for this study because of their regional correlatable characteristics across the Tertiary Niger Delta.

Palynostratigraphic Units of the Analyzed Interval

Two major zones and four subzones recognized within the analyzed interval between 5200 ft and 12520 ft BDF. The two major zones are:

1. The P600 Zone (5200-10840 ft BDF (RF-4) consists of 2 subzones which comprises,

i). The P630 subzone (5200-9370 ft BDF)

ii) The P620 subzone (9370-10840 ft BDF)

2. The P500Zone (10840-12520 ft BDF) (RF-4) subdivided into:

i). The P580 Subzone (10840-12520 ft BDF) and

ii). The P560 Subzone (11890-12520 ft BDF) into

Based on the Pantropical scale of Germeraad et al (1968), the two major zones The P600 and P500 correspond to the MAGNASTRIATITES HOWARDII ZONE. They are the respective correlates of the VERRUTRICOLPORITES ROTUNDIPORUS and CICATRICOSISPORITES DOROGENSIS ZONES. The P600 (VERRUTRICOLPORITES ROTUNDIPORUS) ZONE 5200-10840 ft BDF

The entire MAGNASTRIATITES HOWARDII Zones had been dated Oligocene – Early Miocene. However, the parts therefore displaying the characteristic assemblage identified between 5200 and 10840 ft BDF of Apani belong entirely to Early Miocene section of the zone. This was therefore interpreted to be the equivalent of the VERRUTRICOLPORITES ROTUNDIPORUS ZONE recognized by Germeraad

et al (1968) on the Atlantic scale. A similar assemblage had also been dated Early Miocene in the Tertiary Niger Delta by Legoux (1978).

The top and bottom of a complete P600 zone are marked by the base occurrence of CRASSORETITRILETES VANRAADSHOOVENII and top occurrence of CICATRICOSISPORITES DOROGENSIS / GEMMATRICOLPITES SP 573 respectively.

In Apani, only a part of the entire zone (the Lower) was recognized. Characteristic microfloral elements peculiar to the upper part of the zone were not identified. The miospore assemblage merely gives indication of the P630 and P620 subzones from 5200ft BDF (top of analyzed interval) to 10840 ft (Lower unit of P620). **Courtesy: Seplat Petroleum Development Company PLC.**

CONCLUSIONS

Four categories of lithological and textural attributes of the sediments were identified. They include the upper parallic sequence which is predominantly sandy sequence with relatively thin shale intercalations. The upper marine paralic sequence is predominantly brownish to dark grey fissile shaly unit. The Lower paralic sequence is a predominantly sandy sequence composed of two major sand intervals and an intervening moderately defined shaly interval. The lower marine paralic sequence is almost entirely shaly sequence and forms the basal sequence of the analyzed interval.

The microfloral and dinocyst contents of the palynomorph assemblage exhibited significant variation and diversity in terms of species, distribution and abundance. Two major zones and four subzones recognized within the analyzed interval between 5200 ft and 12520 ft BDF. Based on the Pantropical scale, the two major zones, correspond to the MAGNASTRIATITES HOWARDII ZONE. They are the respective correlates of the VERRUTRICOLPORITES ROTUNDIPORUS and CICATRICOSISPORITES DOROGENSIS ZONES. The fossils are of Oligocene-Early Miocene age.

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