PALYNOSTRATIGRAPHY AND PALAEOENVIRONMENTS OF DELTA -32H WELL NIGER DELTA, NIGERIA

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Abstract

Twenty-five ditch cutting samples from Delta – 32H well was analyzed for their lithologic and palynologic content.Four distinct lithofacies have been demarcated from the well that show alternations of the sandstone, siltstone and shale suggesting that the studied well penetrated the Agbada Formation of the Niger Delta. An Early Middle Miocene to Middle Miocene age was recorded for the well based on the recovery of a combination of spores and pollens including; *Zonocostites ramonae*, *Retibrevitricolporites obodoensis*, *Psilatricolporites crasus*, *Retitricolporites irregularis* and *Pachydermites diederixi*. The palynological zones; *Monoporites annulatus* taxon range zone *Zonocoltites ramonae* interval zonewas proposed for this study and they conform to the P680 and P720 subzones of Evamy *et al*. (1978). The presence of *Magnastriatites howardi*, *Pachydermites diederixi*,*Zonocostites ramonae*and *Monoporites annulatus* as well as foram test linings suggests that the interval studied represents mainly deposition in a coastal to marginal marine setting, this marine influence and high percentage of *Zonocostites ramonae* suggests deposition in mangrove environments. Due to the dominance of mangrove pollens over the occurrence of the single savanna species (*Monoporites annulatus*), the sediment of the studied well was most likely deposited in mangrove environment under a wet climatic conditions during the Miocene.

Keywords: Palynology; Palynomorphs; Pollens; Spores; Miocene; Paleoenvironment; Niger Delta; Nigeria

Introduction

Palynology deals with the study of plant remains in the sedimentary successions and their applications in biostratigraphy, it has undoubtedly become an important tool in basin analysis and researches for petroleum, resolving age and facies correlation problems. Palynology have become a universally accepted method of evaluating the stratigraphy and source rocks potential of sedimentary basins, this can be attributed to the fact that palynomorphs are common, occurring abundantly in both continental and marine deposits. The Niger Delta is an important Basin because of its hydrocarbon resources as a result it has received considerable geological interest. Though data from the several thousands of drilled wells have led to a considerable understanding of the stratigraphy and regional geology of the delta, unfortunately in the Niger Delta Basin, information on palynology is still scanty. The most comprehensive work to-date on the palynology of the Niger Delta is that of Germeraad *et al*., (1968) which was based on the palynomorph assemblages of the Tertiary sediments of three tropical areas: parts of South

America, Asia and Africa (Nigeria). Other works include Van Hoeken-Klinkenberg, (1966)who reported on the Maastrichtian Paleocene and Eocene Pollen and Spores from Nigeria, Oboh, (1992) reported on the Middle Miocene paleoenvironment of the Niger Delta and Oloto, (1994) reported on the Nigerian Maastrichtian to Miocene Dinoflagellate and Miospore biozonation. This study is aimed at identifying therecovered palynomorphs from Delta - 32H well, Niger Delta (Fig 1), then use the identified palynomorphs to zone and date the section and combining palynology and sedimentology to decipher the environments of deposition in the studied well.

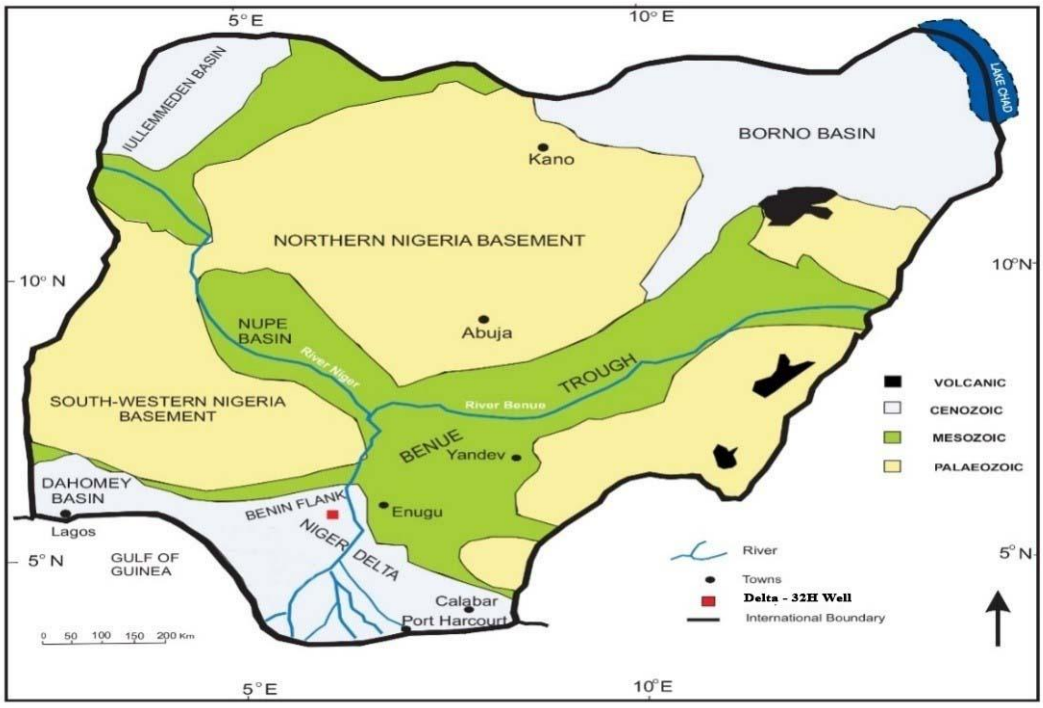

Fig. 1. Geological map of Nigeria showing sample locations
(Modified from Geological Survey of Nigeria 1974)

Geological setting of the basin

The Niger Delta Basin is situated in the Gulf of Guinea, located on the West African continental margin. With a sedimentary thickness of about 12 km in the basin centre, the Niger Delta lies between latitudes 4°Nand 6°N and longitudes 5°E and 8°E. It is bounded to the west and northwest by the Western African shield, which terminates at the Benin Hinge Line and to the east, it is bounded by the Calabar Hinge Line, whereas the northern limit is marked by the Anambra Basin and Abakaliki Anticlinorium, to the south, it is bounded by the Atlantic Ocean (Nwaejije *et al*., 2017). The basin occupies the oceanward part of a larger and older tectonic feature, the Benue Trough; hence its evolution has been linked to the Benue-Abakaliki Trough – a sedimentary complex. According to Murat, 1972 and Weber, & Daukoru, 1975, the stratigraphic history of the Niger Delta Basin in terms of tectonic event revealed that the basin

represents the third cycle in the evolution of the southern Nigerian sedimentary basins in this order: Benue-Abakaliki phase (Aptian - Santonian),followed by the Anambra-Benin phase (Santonian - Early Eocene) and finally the Niger Delta phase (Late Eocene - Recent).It is made up of upper Cretaceous to Recent marine to fluvial deposits overlying oceanic crust and fragments of the African continental crust. The Delta proper began developing in the Eocene. From the Eocene to the present, the delta has prograded southwestward, forming depobelts that represent the most active portion of the delta at each stage of development (Doust and Omatsola, 1990). These depobelts are characterized by enormous progradational and agradational paralic sequences with some retrogradational marine deposits at intervals. The sedimentary sequence in the Tertiary Niger Delta basin consists of three diachronous formations (Murat, 1972; Nwaejije *et al*., 2017); the Akata Formation (marine beds), the Agbada Formation (transitional sand – shale beds) and the Benin Formation (continental sediments).

Materials and methods

Twenty-five ditch cutting samples obtained from Delta -32H well, Niger Delta collected at 18m (60ft.) interval ranging between 1347 - 2234 m were analyzed. Sedimentologic analysis was carried out on the samples by visual inspection, physical characteristics such as colour, texture, hardness, fissility, rock type etc. were noted. Two grams of the samples were broken to a grain size of 4 mm, and transferred to plastic beakers. The beakers were then labeled according to the sample depths. All the samples were then treated with commercial grade hydrofluoric acid to separate the fossils from the rock debris. Most of the calcareous samples showed effervescence, the samples were displaced in a water bath and stirred, with plastic rods twice a day for the period of maceration. The effect of the acid was neutralized by decanting and settling. The residual rock particle and mega fossils were separated from the finer disaggregated material by passing them through a mesh of 106 μm and 200 μm. The filtrate was thoroughly washed with water using the 10 μm mesh nylon sieve. The subsequent residue was swirled on a 24 cm diameter watch glass. The lager residual was discarded while the final top material was boiled for a few seconds in water to which a few drops of concentrated hydrochloric acid was added. The residual was again washed in the 10 μm mesh nylon sieve and stained with safranin- O in a mild alkaline medium stored in small glass centrifuge tubes and labeled. The stained specimens were further diluted and washed out with water and the finished residual transferred into a tube with two drops of diluted solution of glue is added. A few of the residual is pipetted out on a clean dry cover slip, allowed to dry on a hot plate. Canada balsam is smeared on a slid on a hot plate at 100°C. When warmed enough, the dried cover slip was stuck to the slide, pressed uniformly to avoid air bubble and allowed to dry. The prepared slides were cleaned, labeled correctly then examined binocular microscope, the palynomorphs were identified with and named after Germeraad *et al*. (1968); Moore and Webb (1978); Salard-Cheboldaeff (1990); Elsik and Ediger (1990); Sowunmi (1973; 1995) and Kuyl *et al*. (1955). The few whose identification cannot be ascertained using botanical nomenclature or whose relationship with modern flora cannot be categorically ascertained were listed as undifferentiated.

Results

The studied intervals range from 1347 - 2234 m, consist mainly of:

Shale: Brown to grey, fissile, moderately hard, micromicaceous and occasionally carbonaceous.

Sandstone: Smoky white to orange, fine-grained, sub-angular to sub-rounded, well-sorted and occasionally ferruginized.

Siltstones: White, very fine-grained, micromicaceous and carbonaceous plus traces of sand and shale plus woody materials in some samples coal fragments woody materials and muscovite flakes are present).

Table 1: Total Recovered Palynomorph counts of studied well

Recovered Palynomorphs	Total Counts	Recovered Palynomorphs	Total Counts
Beskipollis elegans,	3	Smooth trilete spore,	131
Gemmamonoporites spp.,	6	*Verrucatosporites favus*,	2
Magnastriatites howardi,	10	*Verrucatosporites tenellis*,	73
Retibrevitricolporites obodoensis	8	*Verrucosisporites* sp.,	1
Stereisporites spp.,	2	*Echitriletes* sp.,	1
Verrutricolporites rotundiporus,	10	*Lycopodiumsporites fastiginoides*,	1
Crassoretitriletes vanraadshooveni,	2	*Aletesporites* spp.,	5
Racemonocolpites hians,	5	*Lycopodiumsporites* spp.	2
Peregrinipollis nigericus,	2	*Fusiformisporites* spp.,	10
Echiperiporites estalae,	2	Fungal spores,	32
Spirosyncolpites bruni.	1	*Stradiporites* sp.	1
Psilatricolporites crasus,	105	Dinocysts indeterminate,	23
Zonocostites ramonae.	171	*Selenopemphix* sp.,	8
Monoporites annulatus	9	*Spiniferites* sp.	3
Brevitricolporites guinetti,	2	Foraminifera test lining	17
Pachydermites diederixi,	41	*Achritarch* spp.,	5
Polyadopollenites vancampori,	3	*Leoisphaeridia* spp.	3
Retitricolporites amazoensis,	4	*Concentricystes circulus*	1
Retitricolporites irregularis,	35	*Psilatricolporites* spp.,	7
Striatricolpites catatumbus,	2	*Margocolporites vanwijhei*,	1
Retimonocolpites spp.,	1	*Tricolporopollenites* sp.,	1
Psilamonocolpites spp.,	1	*Echiperiporites* spp.,	4
Praedapollis flexibilis,	3	*Psilatricolpites* spp.,	1
Ctenolophonidites costatus,	2	*Retitricolporites* spp.,	1
Psilastephanocolporites laevigatus,	4	*Echitricolporites spinosus*,	1
Perfotricolpites digitatus.	1	*Psilatriporites* sp.	2
Polypodiaceoisporites retirugatus,	15		
Smooth monolete spore	69		

The sediments in this section yielded a rich assemblage as listed below:

Marker species: *Beskipollis elegans*, *Gemmamonoporites* spp., *Magnastriatites howardi*, *Retibrevitricolporites obodoensis Stereisporites* spp., *Verrutricolporites rotundiporus*, *Crassoretitriletes vanraadshooveni*, *Racemonocolpites hians*, *Peregrinipollis nigericus*, *Echiperiporites estalae*, *Spirosyncolpites bruni*. Mangrove species: *Psilatricolporites crasus*, *Zonocostites ramonae*. Savanna species: *Monoporites annulatus*. Freshwater Forest: *Brevitricolporites guinetti*, *Pachydermites diederixi*, *Polyadopollenites vancampori*, *Retitricolporites amazoensis*, *Retitricolporites irregularis*, *Striatricolpites catatumbus*, *Retimonocolpites* spp., *Psilamonocolpites* spp., *Praedapollis flexibilis*, *Ctenolophonidites costatus*, *Psilastephanocolporites laevigatus*, *Perfotricolpites digitatus*. Sporomorphs: *Polypodiaceoisporites retirugatus*, Smooth monolete spore, Smooth trilete spore, *Verrucatosporites favus*, *Verrucatosporites tenellis*, *Verrucosisporites* sp., *Echitriletes* sp., *Lycopodiumsporites fastiginoides*, *Aletesporites* spp., *Lycopodiumsporites* spp. Fungi: *Fusiformisporites* spp., Fungal spores, *Stradiporites* sp. Dinocyst: Dinocysts indeterminate, *Selenopemphix* sp., *Spiniferites* sp. MRF: Foraminifera test lining MRA: *Achritarch* spp., *Leoisphaeridia* spp. FA: *Concentricystes circulus* Undifferenciated: *Psilatricolporites* spp., *Margocolporites vanwijhei*, *Tricolporopollenites* sp., *Echiperiporites* spp., *Psilatricolpites* spp., *Retitricolporites* spp., *Echitricolporites spinosus*, *Psilatriporites* sp.

Table 2: Recovered Palynomorph count per sample depth from studied well.

Sample Depth (m)	Pollens	Spores	Mangrove species	Fresh water forest species
1347	100	38	66	33
1375	16	40	5	8
1402	15	10	11	2
1420	4	2	3	1
1585	136	17	127	6
1612	2	3	1	1
1640	0	2	0	0
1667	0	2	0	0
1695	9	10	7	1
1722	3	3	0	3
1750	1	3	0	1
1777	7	16	3	4
1804	7	11	3	1
1831	2	9	1	1
1840	16	29	6	7
1987	40	61	17	15
2015	16	12	10	6
2042	5	6	0	3
2070	3	1	2	0
2100	1	7	1	0
2128	0	0	0	0
2152	8	12	4	4
2179	8	1	7	1
2207	2	2	2	0
2234	1	3	0	1
Total	402	390	276	99

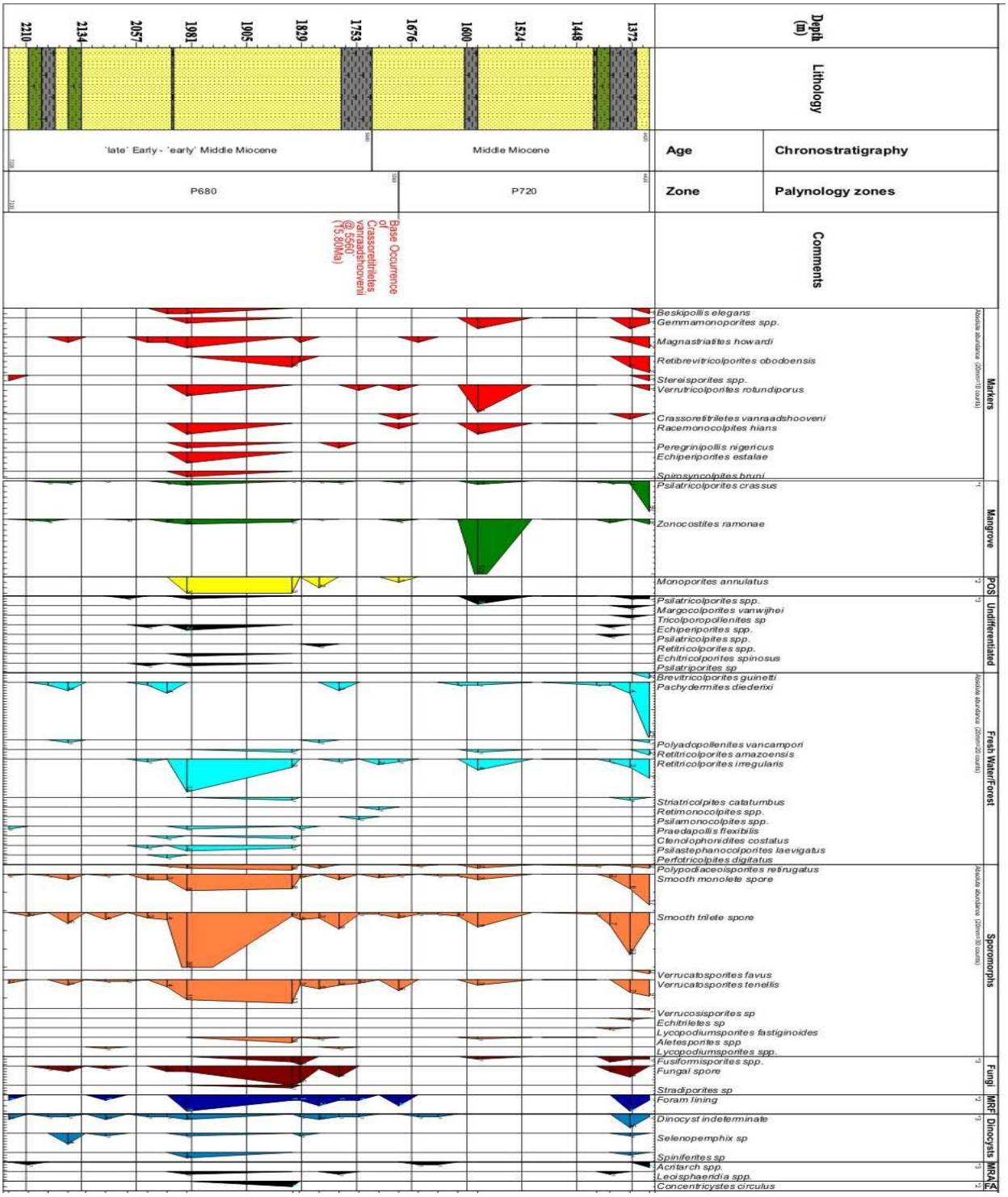

Figure 2: Palynology chart of Delta – 32H well, Niger Delta

Discussion

Lithostratigraphy: This is study body bodies which are distinguished and delimited on the basis of lithic characteristics and stratigraphic position. A lithostratigraphic unit generally conforms to the Law of Superposition and is commonly stratified and tabular in form. Four distinct lithofacies have been demarcated from the well as follows:

i. Siltstone + Shale + Sandstone (1347– 1395m)
ii. Sandstone + Shale (1395 – 2100m)
iii. Sandstone + Siltstone (2100 – 2180m)
iv. Sandstone + Siltstone + Shale (2180 – 2234m)

The alternation of the sandstone, siltstone and shale in the studied well interval suggests that it penetrated the Agbada Formation of the Niger Delta. According to Short and Stauble (1967), the Agbada Formation is generally marine and the alternation of sandstone, siltstone and shale are the result of differential subsidence, variation in the sediment supply, and shifts of the delta depositional axes which cause local transgressions and regressions. The high sandstone percentages suggest progressive seaward advancement of the Niger Delta.

Palynostratigraphy:

The palynostratigraphic biozonation of the wells was defined using the recovered diagnostic markers and ecologically significant species. The first two informal subzones, which are established in these wells, are correlated with P680 – P720 subzones of Evamy *et al.*, (1978). The well section is sub divisible into two biozones: P600 and P700 zones. The P680 subzone was only recognized within the P600 zone while the P720 is found in the P700 zone. This sequence is further correlated with the *Echitricolporites spinosus* zone of Germeraad *et al*., (1968). The zone and subzones recognized are discussed briefly below

Zone 1: *Monoporites annulatus* taxon range zone (interval: 2234 m – 1695 m, thickness: 539 m)

Definition: the zone is defined by the entire appearance of *Monoporites annulatus*. The top is marked by the LAD of *M. annulatus* and the base occurrence of *C. vanraadshooveni*. This zone correlates to the P680 subzone of Evamy *et al*., (1978). This zone occurs in the Agbada Formation. The suggested age for this zone is early Middle Miocene. This zone is further characterized by the occurrence of *Beskipollis elegans, Gemmamonoporites* spp. *Magnastriatites howardi, Retibrevitricolporites obodoensis, Stereisporites* spp. *Verrutricolporites rotundiporus, Retitricolporites amazoensis, Retitricolporites irregularis, Striatricolpites catatumbus, Retimonocolpites* spp. *Psilamonocolpites* spp. *Praedapollis flexibilis, Ctenolophonidites costatus,* sporomorphs present in this zone include: *Polypodiaceoisporites retirugatus,* Smooth monolete spore, Smooth trilete spore, *Verrucatosporites favus, Verrucatosporites tenellis*.

Zone 2: *Zonocoltites ramonae* interval zone (interval: 1695 m – 1347 m, thickness: 348 m)

The zone is defined by the highest occurrence of *Zonocoltites ramonae*, the base is marked by the base occurrence of *C. vanraadshooveni*. This zone correlates to the P720 subzone of Evamy *et al*., (1978). It occurs in the Agbada Formation. The suggested age of this zone is Middle Miocene. This zone is further characterized by the regular records of *Beskipolis elegans*, *Gemmamonoporites* spp., *Magnatriatites howardi*, *Retibrevitricolporites obodoensis*, *Stereisporites* spp. *Verrutricolporites rotundiporus*, *Racemonocolpites hians*, *Brevitricolporites guinetti*, *Pachydermites diederixi*, *Polyadopollenites vancampori*, *Retitricolporites amazoensis*, *Retitricolporites irregularis*, *Striatricolpites catatumbus*, *Zonocoltites ramonae*. Spores present in this zone include: *Polypodiaceoisporites retirugatus*, Smooth monolete spore, Smooth trilete spore, *Verrucatosporites favus*, *Verrucatosporites tenellis*, *Verrucosisporites* sp. *Echitriletes* sp. *Lycopodiumsporites fastiginoides*, *Aletesporites* spp.

Species Richness/Paucity

Species diversity was quite low as at 2,234 m, with no palynomorphs recovered at 2,128 m (barren) being the lowest figure recorded, this is significant because the preceding level, 2,151 m had 33 species suggesting a brief dry spell within this humid condition. However, it gradually increased to 150 species at 1,987 m, then it fluctuated to as low as 4 at 1,667 m before increasing again to 289 species at 1,585 m, this is the highest number of pollen species recovered in a single level throughout the well. Over 47% of the 289species are found in forest regions, while 44% was mangrove swamp forest (MSF) and Fresh water swamp forest (FWSF) was 2%. Considering the fact that the mangrove swamp MSF and FWSF are both edaphic varieties of lowland rain forest (LRF), the figures for the MSF and FWSF were added to that of forest i.e. 47%, making a total of 93% for the LRF alone. Climate, at 1,585 m would have been wet and the major tributaries of the Niger River would have been active and contributed to an increase in sea level. The abundance of MSF species indicates a coastal environment and a probable high sea level; this suggests that the vegetation was a combination of mangrove swamp and seasonally flooded rainforest". Though mangrove swamp forest constitutes 44% of the species diversity figure at 1,585 m, it constitutes 26% of the entire pollen sum. It is assumed the forest would have been quite extensive at this time. Afterwards, the species diversity decreased drastically before increasing to 242 species at 1,347 m. The absence of *Elaeis guineensis* (a sun-loving, open vegetation species) is noteworthy. It is also pertinent to note that the area at this time was LRF-dominated, with diverse forest plant species. Some of these forest species include *Retitricolporites irregularis* and *Pachydermites didierixii*, thus, the general environment was that of a dense rain forest, with palms and fresh water swamp forest.

Paleoenvironment

Detailed study of palynological information shows that environmental changes are usually reflected in the palynologic assemblages, this is in agreement with Oloto (1994) and Ojo and Akande (2004) that palynological data is a useful tool in paleoenvironmental analysis. The depositional environment of the well was evaluated following detailed analysis and characterization of the sedimentary lithofacies coupled with the palynological characteristics. The major groups utilized in this study are pollen/spores and dinoflagellates, other associated element includes foraminiferal test linings.

During the Miocene times there was widespread emergence of the coastline with the establishment of conditions favorable for the deposition of freshwater sediments, (Reyment, 1965). These environmental changes are reflected in the palynologic assemblages and are especially noticeable in the composition and relative proportions of different groups of palynomorphs

Two main criteria have been used in the paleoenvironmental interpretation of the studied well:

1. Association of environmentally restricted marker species such as *Magnastriatites howardi*, *Pachydermites diederixii*, *Zonocostites ramonae* and foraminifera test linings;
2. Percentage of *Zonocostites ramonae* in the total palynoflora sum

Species such as *Magnastriatites howardi* (a small aquatic fern of alluvial plain and coastal swamps), *Pachydermites diederixi* (an angiosperm of coastal swamps) *Zonocostites ramonae* (mangrove pollen) and *Monoporites annulatus* (pollen suggesting open vegetation found in coastal savannah) as well as foraminifera test linings are present. The abundance of these species (with exception of foraminifera test linings) and regular occurrence of fungal spores suggests that the interval studied represents mainly deposition in a coastal to marginal marine setting. The intermittent occurrence of *Magnastriatites howardi* shows the incursion of fresh water in the immediate vicinity and the presence of more open vegetation. *Zonocostites ramonae* is a distinctive pollen type found in extant genera of mangroves notably (Germeraad *et al*., 1968). Its quantitative distribution therefore, makes it a useful species for environmental interpretation. *Zonocostites ramonae* is abundant in the well interval described here; suggesting its presence in the area, the absence of this species from some horizons indicates that deposition of those sediments occurred some distance from the mangrove edge. Foraminifera test linings are good indicators of marine environments, the paucity of foraminifera test linings indicates a slight marine influence. The slight marine influence and high percentage of *Zonocostites ramonae* suggests deposition in mangrove environments.

The presence of the dinocyst species *Spiniferites* sp. in some sample depths (1987 m and 1647 m) may be interpreted to indicate open marine environment (Downie *et al*., 1971), it may therefore imply there was intermittent incursion of the marine water into the environment.

Paleoclimate:

Distribution of the present-day vegetation is dependent on the climatic conditions such as temperature and precipitation. Similarly, spores and pollen derived from different vegetation types can be used as a proxy to reconstruct the climate of the past. For instance, ferns represent cold and arid upland conditions whereas palms mostly represent much warmer and humid climates. This is the general principle of the paleoclimatological analysis in palynology. The changes in plant community or variation in their composition or abundance of an assemblage or individual species are usually a direct consequence of variation in climate and / or environment. In this study two main palynomorph variables mangrove species depicting wet climate against savanna species and depicting dry climate. The mangrove pollens (*Psilatricolporites crasus* and *Zonocostites ramonae*) are dominant over the occurrence of the single savanna species (*Monoporites annulatus*), thus suggesting that the sediment of the studied well was deposited in mangrove environment under a wet climatic conditions during the Miocene.

Conclusion

Lithological and palynological analyses of Delta – 32H well have contributed to the stratigraphic study of the section. Four distinct lithofacies have been demarcated from the well that shows alternations of the sandstone, siltstone and shale suggesting that the studied well penetrated the Agbada Formation of the Niger Delta. A combination of spores and pollen is the basis for dating the section as Early Middle Miocene to Middle Miocene based on the recovery of *Zonocostites ramonae*, *Retibrevitricolporites obodoensis*, *Psilatricolporites crasus*, *Retitricolporites irregularis* and *Pachydermites diederixi*. The palynological zones; *Monoporites annulatus* taxon range zone *Zonocoltites ramonae* interval zone proposed for this study conforms to P680 and P720 subzones of Evamy *et al*., (1978). The presence of *Magnastriatites howardi*, *Pachydermites diederixi*, *Zonocostites ramonae* and *Monoporites annulatus* as well as foraminifera test linings suggests that the interval studied represents mainly deposition in a coastal to marginal marine setting, this marine influence and high percentage of *Zonocostites ramonae* suggests deposition in mangrove environments. Due to the dominance of mangrove pollens over the occurrence of the single savanna species (*Monoporites annulatus*), the sediment of the studied well was most likely deposited in mangrove environment under a wet climatic conditions during the Miocene.

Acknowledgment

The authors wish to acknowledge Chevron Nigeria Limited for providing ditch cutting samples used in this study.

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