PALYNOLOGICAL STUDIES OF LATE EOCENE TO EARLY OLIGOCENE SEDIMENTS, DEB-1 WELL, NORTHERN DELTA DEPOBELT, NIGER DELTA BASIN

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Abstract: Ditch cutting samples recovered from interval 640 to 3500 ft of Deb-1 well in the Niger Delta Basin, Nigeria were investigated for sedimentological and palynological characteristics. The stratigraphic successions in the well include shale, shaly sand, sandy shale and sand. Palynological zonation of the studied interval of the well is largely based on palynofloral assemblage of significant species recorded as well as their stratigraphic distribution with respect to a reference zonation scheme. The result of the section of the well analyzed has been broadly assigned to the P520, P480 and P470 palynological zones. The upper boundary of P520 was tentatively placed at 640 ft, the depth of the first sample analyzed while its zonal base is marked by base occurrence of *Racemonocolpiteshians* at 1,120ft. P520 zone is characterized by the presence of *Racemonocolpiteshians Peregrinipollensnigericus, Ctenolophoniditescostsatus, Verrutricolporitessp, Echiperiporitesestalae, Brevicolporitesguinetii Verrucatosporitesusmensis* and *Nymphaeaepollisclarus.* The top of P480 is defined by base occurrence of *Racemonocolpiteshians* at 1,120 ft while the base is marked by the base occurrence of *Cinctiperiporitesmulleri*at 2,130ft. P480 zone is mainly characterized by maximum development of *Spinizonocolpitesmacrobaculatus, Spinizonocolpitesechinatus* and *Spinizonocolpitesbaculatus.* The top of P470 is defined by base occurrence of *Cinctiperiporitesmulleri* at 2,130 ft while the base is tentatively placed at 3,525 ft. The assemblage of palynomorphs recovered from the well indicates coastal to marginal marine environment of deposition. The studied interval has been assigned Late Eocene to Early Oligocene age based on the evidence from palynological studies.

Keywords: Coastal, eocene, marine, Niger Delta, oligocene, palynomorph, sedimentological

Introduction

Palynological research form a strong component of applied research in the petroleum industry aimed at resolving challenges associated with stratigraphic and facies complexities. The abundance of palynomorphs in the fossil record enables statistical treatment to reveal correlatable biosignals in both onshore and offshore deposits, thereby placing event in a biochronological order. The stratigraphy of the Niger Delta has been well studied using pollen, spores and dinoflagellates. (Germeraad *et al.*, 1968) utilized pollen and spore for age characterization of the Tertiary sediments. (Ojo and Adebayo, 2001) studied the miospore biostratigraphy of Agbada Formation, Eastern Niger Delta Basin, while (Adebayo *et al.*, 2012) worked on palynology of Bog-1 Well, Southeastern Niger Delta Basin. Biffi and Grignani (1983) carried out investigation on the Oligocene sediments from fifteen boreholes of subsurface Tertiary sediments in the Niger Delta Basin. The result produced diverse dinoflagellate cyst groupings categorized by abundant Peridinioids predominantly *Lejeunecysta*, *Pheiodinium* and *Selenopemphix* species. Seven new species of *Lejeunecysta (Lejeunecystabrassiensis, Lejeunecystacommunis, Lejeunecystapulchra, Lejeunecystabeninensis, Lejeunecystaglobosa, Lejeunecystalata and Lejeunecystagranosa) were described.* Osokpor *et al*. (2015) studied thepalynozonation and lithofacies cycles of Paleogene to Neogene Age Sediments in PML-1 Well, Northern Niger Delta Basin**.** They subdivided the well into four zones (*Ephedra claricristata* zone, *Auriculopollenitesechinatus* zone,
Verrutricolporiteslaevigatus/Verrutricolporitesscabratus zone and *Verrutricolporitesrotundiporus Abundance* zone) and also reported that the lithofacies distribution indicates cyclic sedimentation occasioned by an inter play of sea level and climatic regime.

The Niger Delta Basin is located in the Gulf of Guinea, Central West Africa, into which it progrades. It is a large arcuate delta of destructive wave-dominted type (Weber and Daukoru, 1975; Evamy*et al.*, 1978). Niger Delta Basin is one of the sedimentary basins formed by the rift faulting of the Nigerian Precambriam rock (Evamy *et al.*, 1978). The delta is considered one of the most prolific hydrocarbon provinces in the world hosting giant oil fields bothonshore and offshore. Exploratory activities in the Niger Delta provided accessibility to the sub-surfaceformations that characterize the basin. Exploration andother investigation have contributed to documented stratigraphic and micropaleontologic data base for the region.Since the first discovery of crude oil in 1956, many geological researches have been undertaken, especially by oil companies. Detailed study of the wells drilled within the Niger Delta basin has revealed evidences of hydrocarbon generation, migration and accumulation.

The work of (Short and Stauble, 1967; Avbovbo, 1978; Frankl and Cordry, 1967) discussed the subsurface distribution of stratigraphic units in the Niger Delta. They recognized three main formations (Benin, Agbada and Akata) within the Niger delta complex. The Akata, Agbada and Benin formations are interfingeringfacies equivalents representing pro-delta, delta-front and delta-top environment, respectively. The Benin Formation comprises entirely of non-marine sand deposited in alluvial or upper coastal plain environments (Doust and Omatsola, 1989). The Agbada Formation consists mostly of shore face and channel sands with minor shales in the upper part, and alternation of sands and shales in equal proportion in the lower part (Whiteman, 1982). Most of the important hydrocarbon reservoirs in the Niger Delta are within the paralicAgbada Formation. These reservoirs are usually located in zones with structural and stratigraphic complexity. The Agbada Formation which is the major hydrocarbon prospective sequence, deposited in a transitional to marine paralic environment. The Akata Formation is of marine origin and composed of thick shale sequence.

Several authors have carried out a detailed study on wells drilled within the Niger Delta Basin and have revealed the subsurface distribution of stratigraphic units (Short and Stauble 1967; Avbovbo, 1978; Frankl and Cordry 1967; Lucas and Omodolor, 2018).

The focus of this study is on the application of pollen, spore and diniflagellate in dating, zoning and paleoenvironmental reconstruction of Deb-1 well, Niger Delta Basin.

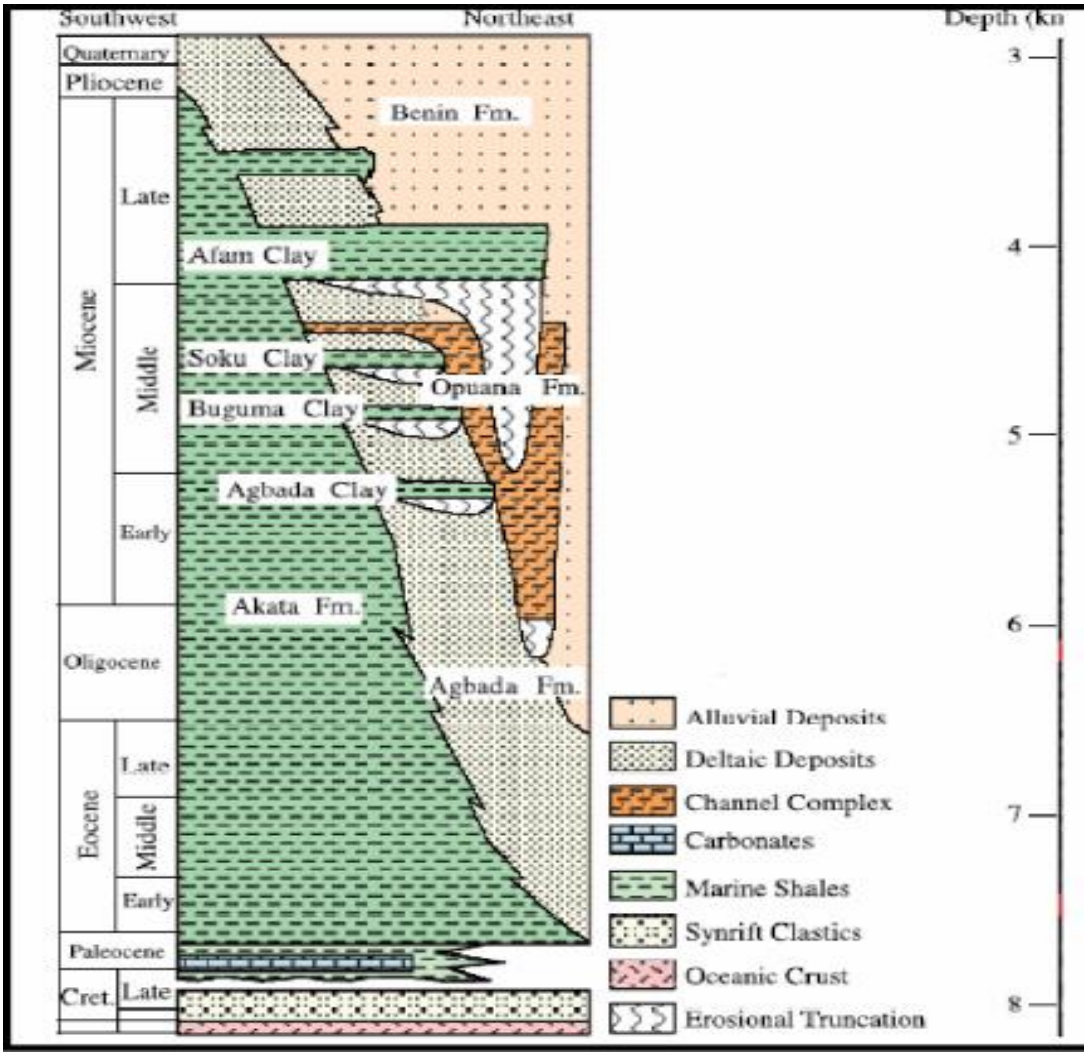

Fig. 1: Stratigraphic column showing the three formations of the Niger Delta (modified after Doust and Omatsola, 1990)

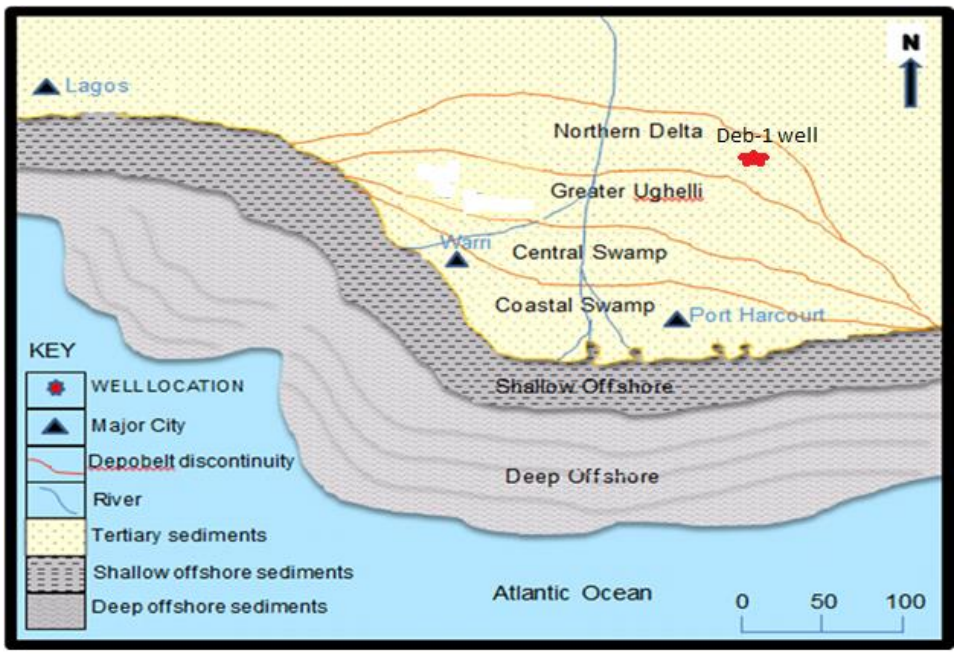

Fig. 2: Map of Niger Delta basin showing the locations of Deb-1 Well

Materials and Methods

Ditch cutting samples from Deb-1 well were subjected to palynological analysis using standard analytical reagents and materials. About 25 g of each sample was soaked in hydrofluoric acid (HF) to remove silicates, and dilute hydrochloric acid (HCl) to remove any carbonates present. Sieving process was carried out over a 5 µm mesh. The retrieved debris of the samples were mildly oxidized, followed by heavy mineral liquid separation of the macerals using zinc bromide ($ZnBr_2$) at 2.1 g/cc. Residue was mounted on glass slides with DPX mountant. This standard method of preparation was in accordance with Faegri and Iversen (1989); Wood *et al.* (1996) and Adebayo *et al.* (2015). Photomicrographs of diagnostic species were taken with Nikon Koolpix P6000 digital camera; abundance of pollen, spores, dinoflagellates, fungal spores, and other stratigraphically significant forms present were determined for each sample using a semi-quantitative approach. These were further interpreted by comparison with established works (Germeraad*et al*., 1968)

Results and Discussion

Sedimentological analysis

A synthesis of gross lithologic and grain attributes derived from grain microscopy enabled the definition of facies types for the well section. Four lithfacies (sand, shale, sandy shale and shaly sand) were observed. The shales were grey to darkish grey, flaggyto platy and moderately hard. The sands were fine tocoarse-grained and granular, occasionallymedium to fine-grained, moderately to poorlysorted.The sediments were generally more shaly towards the bottom of the well. Mica flakes, carbonates and ferruginous materials were the accessories present.

Palynostratigraphy

A total number of fifty (50) ditch cutting samples from Benin-1 well were provided for palynological analysis. The data was used for dating, biozonation and paleoenvironmental reconstruction of the well.

A moderate recovery of palynomorphs dominated byPteridophyte spores such as *Laevigatosporites* and *Verrucatosporites* and other non-categorized spores such as *Cyathidites sp, Polypodiaceoisporites sp, Lycopodium sp, Granulatisporites* sp were present. Pollens such as, *Racemonocolpiteshians, Polyadopollenitesvancampoe, Psilatricolporites sp, Retitricolporites sp, Elaeisguinensis, Echiperiporitesestale, Praedapollisafricanus, Marginipollisconcinnus, Pachydermitesdiederixi, Inaperturopollenitesgemmatus, Proxapertitesoperculatus, Arecipitesexilimuratus, Arecipites sp, Gemmamonoporites sp, Peregrinipollisnigericus, Perfotricolpitesdigitatus, Mauritiditescrassibaculatus, Spinizonocolpitesmicrobaculatus, Spinizonocolpitesbaculatus, Spinizonocolpitesechinatus, Retibrevitricolpitestriangulatus, Psilatricolporitescrassus, Brevicolporitesguinetii, Corsinipollenitesjussiaensis, Striamonocolpitesundertostriatus, Proteacidites sp, Cinctiperiporitesmulleri,* and *Grimsdaleapolygonalis* were recorded. Dinoflagellate cysts such as *Lingulodiniummachaerophorium* and Polysphaeridiumsubtile constitute the other environmentally significant palynomorphs

Palynological zonation

Palynological zonation of the study interval of the well is largely based on palynofloral assemblage of significant species recorded as well as their stratigraphic distribution with reference to the zonation schemes of (Evamy *et al.*, 1978). The result of the section of the well analyzed has been broadly assigned to the P520, P480 and P470 palynological zones. These zones have been assigned Early Oligocene and Late Eocene based on the evidence of the palynological study.

Descriptions of the palynological zones recognized are provided:

Stratigraphic interval **:** 610 – 1,120 ft

Zone **:** P520

Age **:** Early Oligocene & Younger

Definition: The upper boundary of the zone was tentatively placed at 640 feet, the depth of the first sample analyzed while lower boundary is marked by base occurrence of *Racemonocolpiteshians* at 1,120 ft.

Characteristic features

The zone is characterized by the presence of *Racemonocolpiteshians, Peregrinipollensnigericus, Ctenolophoniditescostsatus, Verrutricolporites sp, Echiperiporitesestalae, Brevicolporitesguinetii Verrucatosporitesusmensis* and *Nymphaeaepollisclarus. Racemoncolpiteshians* occurs mainly in the Oligocene to Miocene (Legoux, 1978). The evolution (FAD) of the *Racemonocolpiteshians* or extinction (LAD) of *Doualaiditeslaevigatus* marks the Eocene-Oligocene Boundary (Evamy *et al.*, 1978). Therefore, the age attributed to this zone is Oligocene & younger due to occurrences of Miocene assemblages such as *Nymphaeapollisclarus, Cyperaceapolis sp and Sterisporites sp.* recorded over this zonal interval.

Stratigraphic interval **:** 1120 – 2130 ft

Zone **:** P480

Age **:** Late Eocene

Definition: The top is defined by base occurrence of *Racemonocolpiteshians* at 1,120 ft. while the base is marked by the base Occurrence of *Cinctiperiporitesmulleri* at 2,130 ft.

Characteristic features

The zone is mainly characterized by maximum development of *Spinizonocolpitesmacrobaculatus, Spinizonocolpitesechinatus* and *Spinizonocolpitesbaculatus.* This interval recorded good significant amount of *Inaperturopollenitesgemmatus, Verrucatosporitesusmensis Cinctiperiporitesmulleri* with First down hole occurrence of *Proxapertitesoperculatus. Spinizonocolpitesechinatus, Spinizonocolpitesbaculatus, Spinizonocolpitesmacrobaculatus and Proxapertitesoperculatus* are assemblages of palynomorphs usually recorded in Eocene of West African Basins. This evidence was corroborated by the findings of (Germeraad et al., 1968) that *Proxapertitesoperculatus* and *Spinizonocolpitesechinatus* are absent from Post Eocene Strata in West Africa, but have been recorded in the Pliocene to Pleistocene in Borneo and the Caribbean Basins.

Stratigraphic interval **:** 2130 ft-3526 ft

Zone **:** P470

Age **:** Late Eocene

Definition: The top is defined by Base occurrence of *Cinctiperiporitesmulleri* at 2,130 ft. while the base is tentatively placed at 3,525 ft., the TD.

Characteristic features

The palymorphs events which dominated the assemblages in this interval are *Corsinipollenitesjussianensis ,Mauritiditescrassbaculatus, Proxapertitesoperculatus, Retibrevitricolpites triangulates, Monocolpites sp,*

Spinizonocolpitesbaculatus, Spinizonocolpitesechinatus, Spinizonocolpitesechinatus. Psilatricolporitescrassus exhibits a maximum development in this interval while *Retibrevitricolporitesobodoensis/protudens* shows a quantitative base.

An important element in this zone is *Corsinipollenitesjussianensis* because it is largely restricted to the Eocene in West Africa (Salad-Cheboldaeff, 1990), and it is one of the two index species of sub-zone 4b of Eocene age in the Muglad Basin (Stead and Awad, 2005). Other Species which have stratigraphic range from Maastrichtianto Eocene in Africa as reported by (Germeraad *et al.*, 1968; Salad-Cheboldaeff1, 1990) are *Mauritiditescrassbaculatus, Proxapertitesoperculatus* and *Spinizonocolpitesechinatus*.

Paleoenvironments

Interval 610 –1,870 ft

Pteridophyte spores such as species of *Laevigatosporites* and *Verrucatosporites, Psilatricolporites sp, Psilatricolporitescrassus, Zonocostitesramonae, Peregrinipollisnigericus, Fungal spore* and *Acrostichumaureum* dominate the microfloral assemblages. The presence of these marker species co-occurrence with fresh water algea-*Botryococcusbrauni* in the study interval suggests deposition in a largely coastal deltaic environment with frequent fresh water incursion. A predominantly wet climate is inferred for this interval due to the higher percentage of *Psilatricolporitescrassus* and *Zonocostitesramonae* (Mangrove pollen).

Interval 1,870 –3,525 ft

Verrucatosporites sp, Laevigatosporites sp, Acrostichumaureum, Psilatricolporitescrassus, Retitricolporites sp Retibrevitricolporitesobodoensis, Spinizonocolpitesbaculatus, Spinizonocolpitesechinatus and *Fugal spore* still dominate the microfloral assemblages. Spot occurrence of dinoflagellate cyst like *Polyshaeridiumsubtile* with *microforaminiferal wall linings* characterize this interval. Fresh water algea-*Botryococcusbrauni* in the study interval suggests deposition in a largely coastal to marginal marine environment with frequent fresh water incursion. A predominantly wet climate is also inferred for this interval due to the abundance of *Psilatricolporitescrassus* and *Zonocostitesramone* (Mangrove pollen).

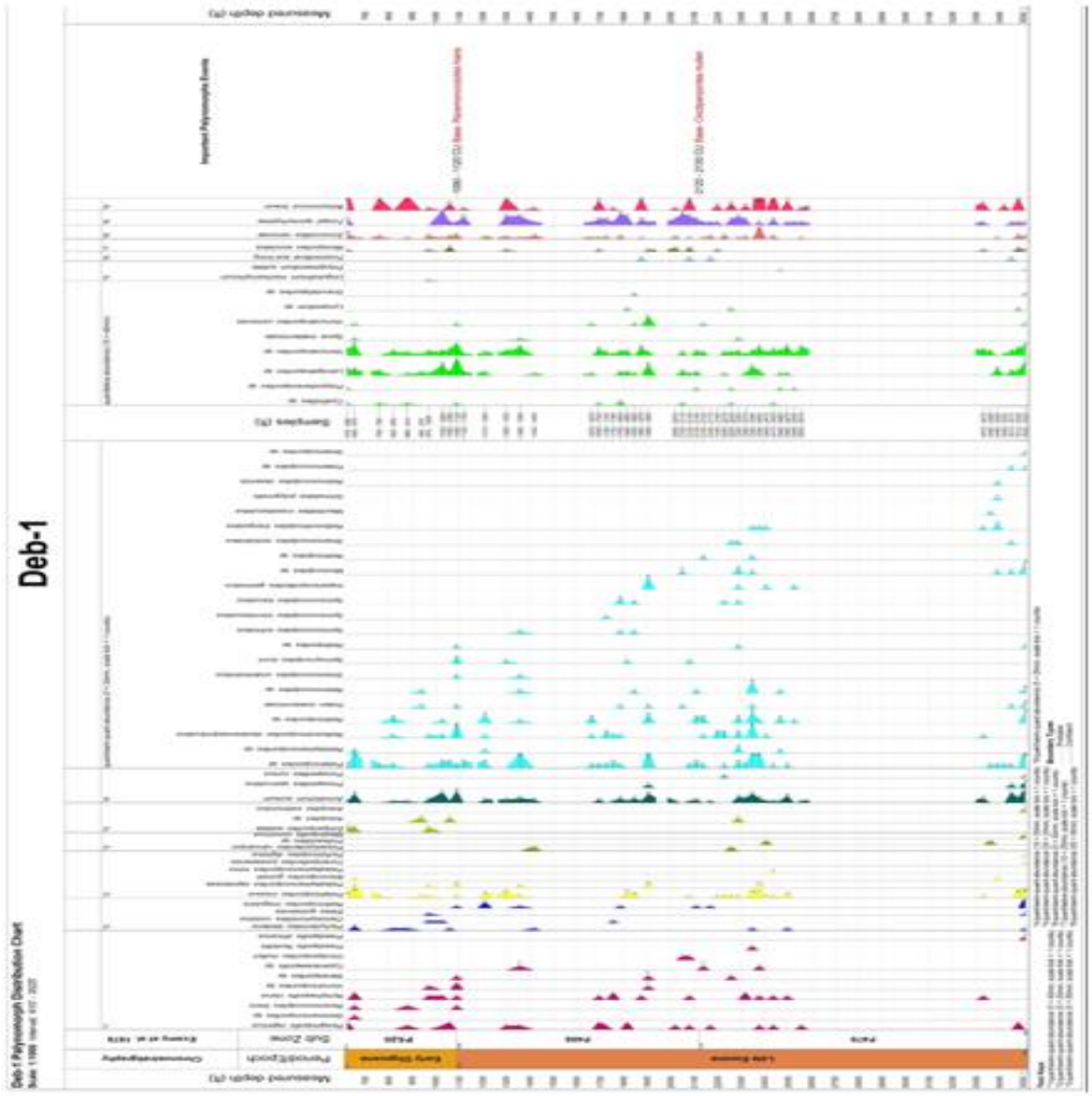

Fig. 3: Palynomorph distribution chart for Deb-1 well

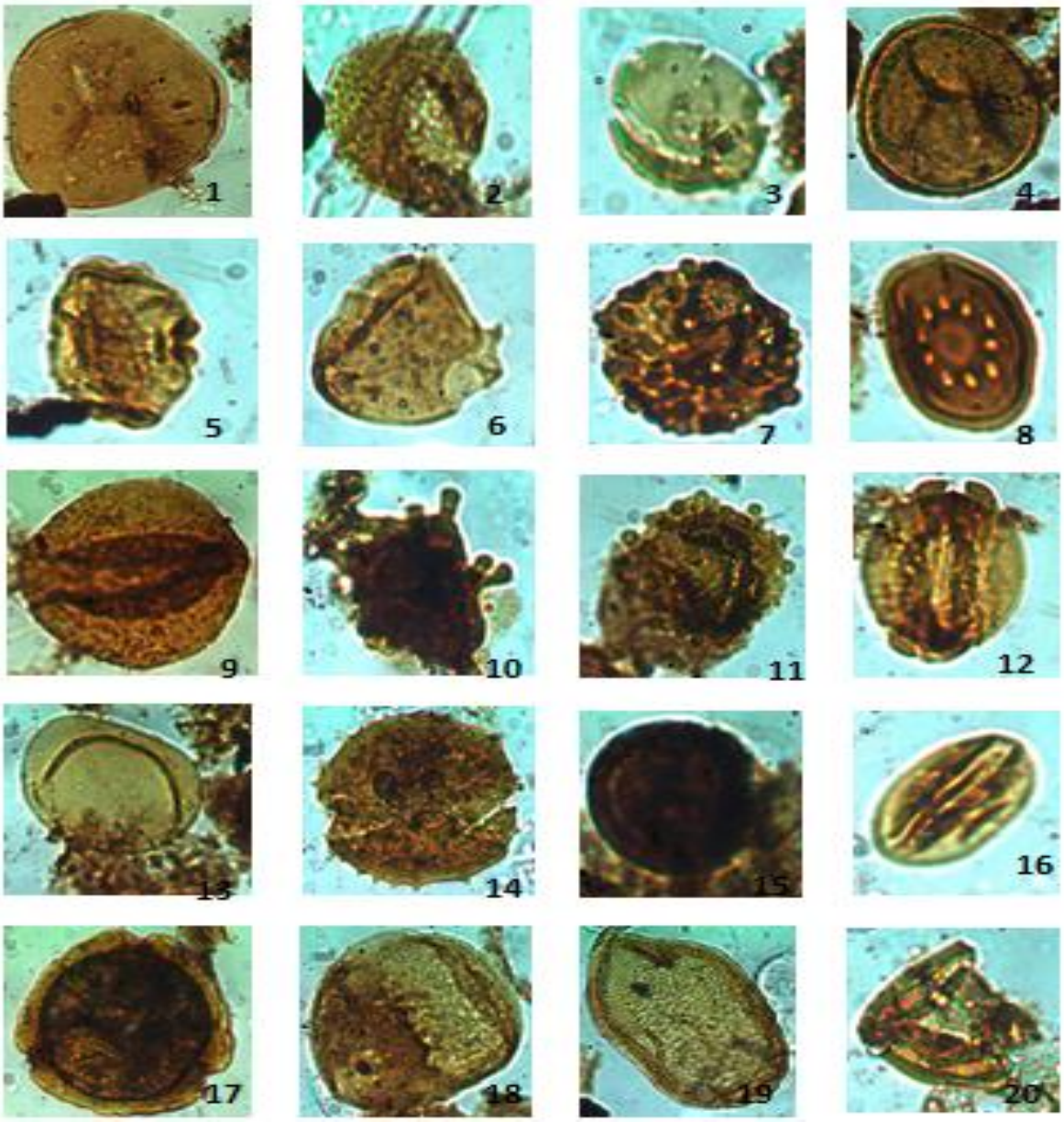

Plate 1: Photomicrographs of some important species

List of photomicrographs

1. Acrostichum aureum (depth:3520-3525)
2. Arecipites sp (depth: 1060-1090)
3. Brevicolporites guinetii (depth: 640-670)
4. Granulatisporites sp (depth: 3520-3525)
5. Corsinipollenites jussiaenensis (depth: 3520-3525)
6. Cyperaceaepollis sp (depth: 1360-1390)
7. Inaperturopollenites sp (depth: 1880-1890)
8. Cinctiperiporites mulleri (depth: 2120-2130)
9. Granulatisporites sp (depth: 1840-1850)
10. Grimsdalae poligonalis (depth: 3490-3500)
11. Inaperturopollenites sp (depth: 2340-2350)
12. Marginipollis concinnus (depth: 3520-3525)
13. Laevigatosporites sp (depth: 1090-1120)
14. Mauritidites crassbaculatus (depth: 3495-3500)
15. Nymphaeapollis clarus (depth: 640-670)
16. Monocolpites sp (depth: 2340-2350)
17. Psilatricolporites crassus (depth: 2380-2390)
18. Proxapertites operculatus (depth: 1880-1890)
19. Proxapertites operculatus (depth: 3520-3525)

Conclusion

This study reports on palynomorph assemblages from sediments penetrated by Deb-1 well in the Niger Delta Basin. Three palynomorph zones were established with reference to (Evamy *et al*., 1978) scheme. The result of the section of the well analyzed has been broadly assigned to the **P520, P480 and P470** palynological zones. This section has been assigned Early Oligocene to Late Eocene based on the evidence of the palynological study. The studied interval of Deb-1 well is dorminated by *Laevigatosporites sp*, *Verrucatosporitessp*, *Psilatricolporites sp*, *Psilatricolporitescrassus*, *Zonocostitesramonae*, *Peregrinipollisnigericus*, *Fungal spore*, *Retitricolporites sp* and *Acrostichumaureum*. The presence of these marker species occurring in association with *Botryococcusbrauni* (fresh water algae) in the study interval suggests deposition in a largely coastal deltaic environment with frequent fresh water incursion. A predominantly wet climate is inferred for this interval due to the higher percentage of *Psilatricolporitescrassus* and *Zonocostitesramonae* (Mangrove pollen).

Conflict of Interest

The authors declare that there is no conflict of interest related to this work.

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