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Palynostratigraphy and paleoecology of chev-1 well, southwestern Niger delta basin, Nigeria

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ABSTRACT

Twenty five ditch cutting samples from southwest Niger Delta basin were analysed to determine the palynostratigraphic studies. The samples contained very rich and diverse palynomorphs dominated by pollen grains which consist of 12 species distributed among ten genera. Pollen preservation is good with concentration ranging from 1,640 to 34,900 grains/g. The stratigraphic ranges of *Circulina parva*, *Monoporites annulatus*, *Psilatricolporites operculatus*, *Multiareolites formosus*, *Zonocostites ramonae*, *Podocarpus milanjianus*, *Echitricolporites spinosus*, *Retibrevitricolporites obodoensis*, *R. protrudens* and *Retitricolpites bendensis* and some other marker species were used to demarcate nine palynozones in the study area. These palynomorphs are mainly made up of mangrove swamp floras which suggest the predominance of a high sea level and wet climatic condition in Miocene-Pliocene during the deposition of the studied sediments.

Introduction

The Niger Delta Basin is the most prominent sedimentary basin on the continental margin of the Gulf of Guinea; it is also the most prolific in terms of oil and gas. This petroliferous nature has made it, for many years, the subject of continuous, consistent and extensive geologic investigations both for academic and economic purposes. Of recent, there has being a growing concern among the petroleum explorationists working in the basin that the oil exploration effort no longer yields expected results (Ojo[1]) which has given rise to new challenges. One of such challenges is the need to revisit the geology of the basin. This requires the employment of various geological disciplines such as palynostratigraphy. Palynomorphs are ubiquitously present in sedimentary rocks of all ages from Archaean (ca. 3.8 billion years ago) to Recent, they are being used as sensitive indicators of the process of sedimentation, the direction of current, the source and age of sediments in many parts of the world (Sowunmi[2]; Poumot[3]; Eisawi and Schrank[4]). Since less than ten percent of the work so far on microfossils in the basin are on palynological studies (Adebayo[5]), hence, this work is to identify as much as possible the characteristic palynological assemblage of the sediments in the studied wells and use it to refine the biostratigraphic zones in the basin.

Geological Setting of the Niger Delta Basin

The basin is situated in the Gulf of Guinea, on the West African continental margin (Fig. 1). It extends throughout what Klett *et al.*[6] defined as the Niger Delta Province. The basin contains Upper Cretaceous to Recent marine to fluvial deposits overlying oceanic crust and fragments of the African continental crust (Doust and Omatsola[7]; Kostenko *et al.*[8]). The Delta began developing in the Eocene. From the Eocene to the present, the delta has prograded southwestward forming depobelts, each depobelt represent the most active portion of the delta at each stage of development (Doust and Omatsola[7]). The sedimentary sequence in the Tertiary basin consists in ascending order of three diachronous formations, namely: Akata (marine beds), Agbada (transitional sand-shale beds) and Benin (continental sediments) formations (Short and Stauble[9]).

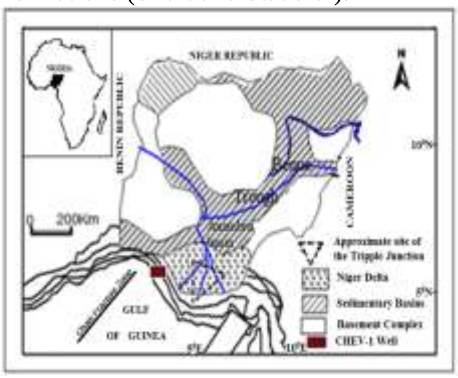

Fig. 1 Sedimentary Basins in Nigeria Showing the Niger Delta Basin and well location (Modified from Whiteman[10]; Benkhelil[11]).

Materials and Method of Study

Twenty five shaly samples taken at 60 ft interval from CHEV-1 well (3130-6031ft) in the offshore section of the western Niger Delta, Nigeria were subjected to palynological treatment. Standard maceration technique (Faegri and Inversen[12], Wood *et al.*[13]) was followed in the preparation of these samples. Samples were treated with HF and HCl to remove calcareous and siliceous materials respectively; heavy liquid separation using zinc chloride and hydrochloric acid solution (specific gravity 2.0) and finally acetolysis to dissolve cellulose for easy identification of palynomorphs. Minor modifications such as varying the percentage of hydrochloric acid (30-36%) used, staining of some residues and excluding acetolysis step for older samples with no cellulose. After treatment, samples were mounted on slides and studied under x40 and x100 objective using an Olympus CH30, camera-attached microscope. Photomicrographs of the most important palynomorphs were taken.

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Results and Discussion

Palynological Assemblage

Rich and diverse assemblage of palynomorphs species was recovered. In general, pollen preservation in the analyzed sediments is good (Plate 1) and concentrations are high, ranging from 1,640 to 34,900 grains/g. The assemblage consists of pollen (74%), spores (3%), indeterminate species (1%) and fungal spores (22%).

The recovered palynomorphs in this study is dominated by angiospermous pollen. The angiosperms consist of several species of *Stephanoporites*, *Echiperiporites*, *Echiporites*, *Monocolpites*, *Tricolporites*, *Dicolporites*, *Brevitricolporites* and *Monoporites* (see chart).

Palynostratigraphy

Eighty percent of the recovered palynoflora association encompasses palynomorphs that are of Late Miocene-Pliocene age (Germeraad *et al.*[14]; Morley and Richards[15]). Some of these palynomorphs are *Circulina parva*, *Monoporites annulatus*, *Psilatricolporites operculatus*, *Multiareolites formosus*, *Zonocostites ramonae*, *Podocarpus milanjianus*, *Echitricolporites spinosus*, *Retibrevitricolporites obodoensis*, *R. protrudens* and *Retitricolpites bendensis.* These and others are used to study the palynostratigraphy of the studied well.

The palynostratigraphic analysis was based on the works of Evamy *et al.*[16], Richards and Morley[15] and Morley[17]. The informal zones recognised are designated as JM and JP, meaning "Jide Miocene" and "Jide Pliocene" respectively (see Table 1 and Chart). The zones are:

JMI Zone (5,800 – 6,030 ft): P800 zone, subzone P850, Late Miocene.

The base of the zone is expediently marked at 6,030 ft since it is the base of the analyzed interval in the well. The top is marked by the absence of *Monoporites annulatus* (Poaceae) at 5,800 ft and uphole increase of Sapotaceae. The zone is characterized by low occurrence of *Monoporites annulatus* and abundance of *Multiareolites formosus.*

JM2 Zone (5,700-5,800 ft): P800 zone, subzone P850; Late Miocene.

The base is placed at 5800ft, at the first appearance of Sapotaceae and the absence of *Monoporites annulatus* while the top was recognized at 5,700 ft by the first appearance (base occurrence of *Circulina parva* (*Nymphaea lotus*) and quantitative base of *Monoporites annulatus*. The quantitative first appearances (bases) of Sapotacae and *Pachydermites diederixi* characterize this zone.

JM3 Zone (5,300-5,700 ft): P800 zone, subzone P860; Late Miocene.

The base is at 5,700 ft based on the first appearance of *Circulina parva* and the quantitative base of *Monoporites annulatus*. The top was recognized at 5,300ft by the base occurrence of *Retistephanocolpites gracilis* (*Borreria* spp.) and downhole increase of *Monoporites annulatus*. This zone characterised by the acme of *Zonocostites ramonae* (*Rhizophora* sp.), *Retistephanocolpites gracilis* and *Multiareolites formosus.* Other diagnostic forms are *Psilatricolporites crassus* and *Echitricolporites spinosus*.

JP1 Zone (5,000-5,300 ft): P800 zone, subzones P870-P880; Early Pliocene.

The base occurrence of *Retistephanocolpite gracilis* at 5,300 ft and downhole increase in *Monoporites annulatus* mark the base of this zone. The top at 5,000 ft was marked by the base occurrence of *Retitricolpites bendensis*. The peculiarity of the zone is, the first appearance of *Retitricolpites bendeensis* and *Retibrevitricolporites obodoensis;* significant occurrence of *Retibrevitricolporites protrudens*, Sapotaceae and quantitative event of *Psilatricolpites* spp.

JP2 Zone (4,700-5,000 ft): P800 zone, subzones P870-880; Early Pliocene.

The base was recognized at 5,000 ft by the first appearance of *Retitricolpites bendeensis* while the first appearance of *Podocarpus milanjianus* at 4,700 ft marks the top of the zone. High occurrence of *Zonocostites ramonae,* occurrence of *Echiperiporites estalae* and *Psilatricolpites* ssp. characterize the zone

JP3 Zone (4700-4600 ft): P800, Late Pliocene.

The first appearance of *Podocarpus milanjianus* at 4,700 ft and the uphole decrease in the occurrence of Sapotaceae at 4,600 ft mark the base and the top of this zone respectively. The uphole decrease of *Zonocostites ramonae* and the high occurrence of *Leotriletes* spp. are the unique characteristic of the zone

JP4 Zone (4,600-4,250 ft): P900, Late Pliocene.

The base was recognized at 4,600 ft by uphole decrease in Sapotaceae while the last appearance of *Retibrevitricolporites obodoensis* at 4,250 ft mark top. Uphole increase of *Zonocostites ramonae* and high occurrence of *Retibrevitricolporites obodoensis* characterize the zone.

JP5 Zone (4,250-3,400 ft): P900 zone; Late Pliocene.

The first appearance of *Retibrevitricolporites obodoensis* at 4,250ft marks the base while the top was recognized with the last appearance of *Retitricolpites bendeensis*. High occurrence of *Monoporites annulatus* and the flunctuating occurrence of *Zonocostites ramonae*; the first appearances of *Retitricolpites bendeensis*, *Retibrevitricolporites protrudens* and *Brevitricolpites guineti* are the uniqueness of this zone.

JP6 Zone (3,400-3,150 ft): P900 zone; Late Pliocene.

The base is at 3,400 ft where *Retitricolpites bendeensis* last appearanced. The top of this zone may be shallower than the top of the analyzed interval. Since the zone belongs to the youngest of Evamy *et al.*[16] zones, the abundance of *Podocarpus milanjianus* enabled the tentative placing of the top of this zone at 3,150 ft.

Contemporary angiospermous palynomorphs of Eocene and Oligocene ages such as *Pachydermites diederixi* and *Echiperiporites estalae* together with the fern spore, *Verucatosporites usmensis* (Germeraad *et al.*[14]) were also recovered. The rare occurrence of Late Cretaceous *Spinizonocolporites baculatus* and *Racemonocolpites hians* (Germeraad *et al.*[14]) pollen grains was probably due to the reworking of the older Anambra basin sediments and their subsequent deposition in the Niger Delta basin.

The recognised zones correlated well with P900 and P800 of Evamy *et al.*[16]. Three of the P800 subzones were demarcated using the base occurrences of *Circulin parva* (*Nymphaea lotus*) and *Retibretricolporites gracilis*. The recovered foraminifera species from these samples by the second author showed that JM1 to JM3 correlates with N17 of Blow[16, 19], JP1 to JP4 with N17-N18 and JP5 to JP6 with N18-N19.

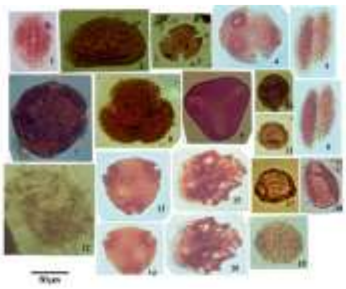
Paleoecology

Paleoenvironmental reconstruction is usually hampered by gaps in the stratigraphic record and inability to observe and measure most features of ancient environments directly. This leads most workers to, according to Raup and Sepkoski[20], rely on partial reconstruction of environments by stratigraphical and sedimentological techniques. Therefore, in making paleoenvironmental reconstruction, it is important to determine how representative the fossil palynomorphs are, bearing in mind the differential pollen production and preservation (Havinga[21]). Hence the paleoecological deduction in this work was based largely on the palynomorphs with known Nearest Living Relatives (NLR) (Poumot[3]; Morley[22]). This is because Paleogene and younger plant fossils often represent vegetation communities faithfully; older records can be difficult to interprete paleoecologically (Jacobs[23]). The environment of deposition of the studied sediments was dominated by mangrove swamp. *Zonocostites ramonae* (*Rhizophora* sp.), a mangrove species, whose high productivity in the coastal-continental shelf of the Niger Delta has been noted (Sowunmi[24]), constitutes 77% of the total occurrence of the recovered palynomorphs. The presence of some fresh water swamp pollen is equally significant; these include *Psitricolporites operculatus* (*Alchoornea cordifolia*), *pachydermites diederixi* (*Symphonia globulifera*), *Retibrevitricolporites obodoensis* and *R. protrudens*. Therefore, the paleoecological groups in the studied sediments indicate a high sea level and wet climatic condition (Feakins, *et al.*[25]; Urrego, *et al.*[26]) during the deposition of the sediments.

Conclusion

Sediments from CHEV-1 well were subjected to palynological analysis. The study shows the sediments contained very rich, diverse and well preserved palynomorphs that were in most cases identified to the species level. The recovered marker species such as *Zonocostites ramonae*, *Psilatricolporites operculatus*, *pachydermites diederixi*, *Retibrevitricolporites obodoensis* and *R. protrudens* indicate the predominance of high sea level and wet climatic condition in the southwestern Niger Delta basin in Miocene-Pliocene during the deposition of the sediments.

Plate 1



1.*Multiareolites formosus,* 2. *Verrucatosporites usmensis,* 3. *Psilatricolporites operculatus,* 4. *Retibrevitricolporites protrudens,* 5-6. *Racemonocolpites hians,* 7. *Pachydermites diederixi*, 8. *Retitricolpites bendeensis,* 9. *Trichotomosulcites* sp. (*Elaeis guineensis),* 10-11. *Zonocostites ramonae,* 12. *Spinizonocolpites baculatus,* 13-14. *Retibrevitricolporites obodoensis,* 15-16. *Peregrinipollis nigericus,* 17. *Echitricolporites spinosus,* 18. *Monoporites annulatus,* 19. *Echiperiporites estalae*.

Systematic palynology

Division sporites h. Potonie, 1893.

Class Monoletes IBRAHIM 1933.

Genus *Verrucatosporites* (PFLUNG, 1952) ex R. Potoni 1956.

Verrumonoletes usmensis VAN DER HAMMEN, 1956d, p.116, fig.7.

Verrucatosporites usmensis GERMERAAD *et al.,* 1968, p. 290, pl. 3, fig. 3.

Description: Verrucate spore, single grain, bilaterally symmetrical, anisopolar with convex distal outline and straight or slightly concave proximal outline, ellipsoidal in polar view. Laesura monolete.

Comment: This species has a larger laesura than that of Germeraad *et al.* 1968.

Botanical Affinity: *Stenochlaenapalustris*, *Phlebodium aureum.*

Age: Late Eocene.

Division pollenites r. Potonie, 1931.

Class Monoporatae INVERSEN et TROELS SMITH, 1950.

Genus *Monoporites* (COOKSON, 1947) ex VAN DER HAMMEN, 1954.

Monoporites annulatus VAN DER HAMMEN, 1954, p.90, pl.6, fig.4.

Monoporites unipertusus VAN DER HAMMEN 1956b, p.82, pl.5, fig.10.

Monoporites annulatus GERMERAAD *et al.*, 1968, p.292, pl.III, fig.3.

Description: Psilate pollen, single grain, radially symmetrical, anisopolar, almost spherical. Single, circular penetrating pore with annulus.

Comment: This species' annulus is smaller than that of Germeraad *et al.*, 1968.

Botanical Affinity: Poaceae (Gramineae)

Age: Eocene/Miocene.

Class Stephanoporatae INVERSEN et TROELS SMITH, 1950.

Genus *Pachydermites* GERMERAAD *et al.*1968

Pachydermites diederixi Germeraad *et al.*1968, p.315, pl.X, figs.2.

Description: Psilate, stephanoporate pollen. Single grain, with 5 rather irregularly shaped less distinct pores. Endexine finely perforated around the pores, covered with a thin tectate-psilate ectexine. Radially symmetrical, isopolar and oblate-suboblate. Outline circular in polar view. Interrior surface is irregularly verrucate.

Botanical Affinity: *Symphonia globulifera*.

Age: Mid-Eocene.

Class Periporatae INVERSEN et TROELS SMITH, 1950.

Genus *Echiperiporites* VAN DER HAMMEN et WYMSTRA, 1964.

Echiperiporites estelae GERMERAAD *et al.*, 1968, p.315, pl. X, fig. 1.

Description: Stephanoporate pollen; single grain, centro-symmetrical, isopolar, spherical; densely spinose, periporate pores 20-24.

Botanical Affinity: *Thespesia populnea* (Malvaceae), *Hibiscus tiliaceus* (Malvaceae).

Age: Oligocene.

Class Monocolpatae INVERSEN et TROELS SMITH, 1950.

Genus *Spinizonocolpites* Muller, 1968.

Spinizonocolpites baculatus MULLER, 1968.

Spinizoncolpites echinatus group GERMERAAD *et al.*, 1968, p.293, pl.IV, figs.2,3.

Description: Echinate pollen, single grain, radially symmetrical, slightly anisopolar, suboblate-spherical. Covered by a thin coarser reticulate tectum. Baculae scattered on tectum are straight with rod-like tips.

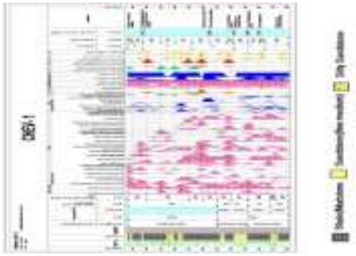
Botanical Affinity: *Nypa fruticans*.

Age: Late Cretaceous/Paleocene.

Genus *Racemonocolpites* PIERCE 1961.

Racemonocolpites hians MULLER 1968.

Description: Monocolpate pollen; single grain, bilaterally symmetrical and isopolar. Colpus almost spliting grain into two halves; exine somewhat pluribaculate.
Botanical affinity: *Iriartea* sp.
Age: Late Cretaceous.
Trichotomosulcites COUPER, 1953.
Trichotomosulcites sp.
Description: Pollen is monocolpate or trichotomocolpate. Colpi have wavy margins and usually rounded ends. Exine pattern is minutely reticulate.
Class Dicolportae GERMERAAD *et al.*, 1968.
Genus *Multiareolites* GERMERAAD *et al.*, 1968.
Dicolporites formosus VAN DER HAMMEN, 1956, p.85, pl.6, fig.16
Multiareolites formosus (VAN DER HAMMEN, 1956) ex GERMERAAD *et al.*, 1968, p.301, pl.VI, fig.1,2.
Description: Pollen with double rows of areoli. Single grain, radially symmetrical, isopolar, prolate. Dicolporate, narrow colpi with straight borders and pointed ends.
Botanical Affinity: *Justicia American* and *Dianthera Americana*.
Age: Miocene.
Class Tricolporate INVERSEN et TROELS SMITH, 1950.
Genus *Psilatricolporites* (VAN DER HAMMEN, 1956) ex VAN DER HAMMEN et WYMSTRA, 1964.
Psilatricolporites operculatus VAN DER HAMMEN et WYMSTRA, 1964.
Description: Single grain pollen, radially symmetrical, isopolar, oblate, circular in outline. Tricolporate, colpi long ectexinous marginate with distinct opercula.
Botanical Affinity: *Alchornea cordifolia*
Age: Miocene.
Genus: *Zonocostites* GERMERAAD *et al.*, 1968.
Zonocostites ramonae GERMERAAD *et al.*, 1968, p.329, pl. XV, figs.6,7.
Description: Tricolporate Pollen. Single grain, radially symmetrical, isopolar, spherical. Colpi ectexinous, medium long, straight with pointed ends, slightly costae.
Botanical Affinity: *Rhizophora* (Rhizophoraceae).
Age: Oligocene/Miocene.
Genus: *Echitricolporites* VAN DER HAMMEN, 1956b
Echitricolporites spinosus VAN DER HAMMEN, 1956b, p.92, pl.10, fig.30
Description: Single grain, radially symmetrical, isoplar and spherical in shape. Tricolporate, colpi ectexinous, straight with pointed ends, pores indistinct. Spines are always separated and not connected by a reticulate pattern of muri.
Botanical Affinity: *Riencourtia glomerata* Cass.
Age: Miocene/Pliocene.
Genus *Brevitricolporites* ANDERSON, 1960.
Retibrevitricolporites obodoensis LEGOUX, 1978.
Description: Tricolporate pollen, single grain, radially symmetrical and isoplar. Ora are prominent, prominent annulus with very short colpi that are hardly observed. Exine pattern is reticulate; pollen shape is spheroidal.
Botanical Affinity: Unknwon botanical affinity
Age: Oligocene – Pliocene.
Retibrevitricolporites protrudens LEGOUX, 1978.
Description: Same as *R. obodoensis* but strikingly different in that its ora are prominently protruding.
Age: Oligocene – Pliocene.



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