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Late Miocene to Early Pliocene Palynostratigraphy and Palaeoenvironments of ANE-1 Well, Eastern Niger Delta, Nigeria

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Abstract

Fifty ditch cutting samples composited at 60ft intervals between 6990ft and 9930ft in the Ane-1 well, Niger Delta were processed for sedimentological and palynological analyses. The sedimentological study showed that the analysed section belongs to the paralic Agbada Formation. The section is subdivided into three lithofacies subunits based on their shale/sand ratios: Lower Biafra (9,930-8,035ft), Middle Biafra (8,035-7,115ft), and Upper Biafra (7,115-6990ft). A total of 632 palynomorphs were identified from which some were selected for microphotography. The diagnostic palynomorphs recovered permitted the zonation and dating of the analysed section. A Late Miocene to Early Pliocene age was assigned to the studied section with Miocene/Pliocene boundary placed at 8150ft and marked by First Appearance Datum (FAD) of *Nymphaeapollis clarus* and increase in *Monoporites annulatus*. The section belongs to the *Echitricolporites spinosus* Zone. Palaeoenvironmental interpretation of strata penetrated by Ane-1 well was conducted by combining association of environmentally restricted marker species; percentage of *Zonocostites ramonae* in the total palynomorphs sum; nature of organic matter in the sediment; and lithological characters of the strata. The result shows that the overall environment ranges from coastal to marginal marine. Foram test linings was used to subdivide the macro environments into coastal deltaic, coastal deltaic inner neritic, and inner neritic.

Keywords: *Sedimentology, Palynology, Pollen, Spores, Ane-1, Niger Delta.*

Introduction

The Niger Delta is a major hydrocarbon producing basin in Nigeria where intensive exploration and exploitation activities have been on since early 1960's owing to the discovery of commercial oil in Oloibiri-1 well in 1956 (Reijers *et al*., 1996). Much palynological work has been done in this basin but there is little published information due to confidentiality maintained by the oil companies. Oil companies in Nigeria have their individual zonation schemes and a standard scheme is desirable. The section studied falls within the Biafra Member of the Agbada Formation as classified by Opara (1981). Most of the important hydrocarbon reservoirs in the Niger Delta are within the paralic Agbada Formation (Short and Stauble, 1967). These reservoirs are usually located in zones with structural and stratigraphic complexity. An excellent biostratigraphic framework is crucial for understanding the stratigraphy, characterization of the reservoirs and planning new exploration targets. Biostratigraphy has been shown to play an important role in the exploration of oil and gas in the Niger Delta. Spores, pollen and foram test linings were employed among other things to reconstruct the palaeoenvironments of the studied section. This is important because different depositional settings imply different reservoir qualities in terms of architecture, connectivity, heterogeneity and porosity-permeability characteristics (Simmons *et al.*, 1999). This work therefore aims at identifying the recovered palynomorphs, using the identified palynomorphs to zone and date the section and combining palynology and sedimentology to decipher the environments of deposition in the studied section in order to assess the reservoir quality.

Regional Geologic Setting

The Niger Delta Basin is situated in the Gulf of Guinea in equatorial West Africa, between latitudes 3^0N and 6^0N and longitudes 5^0E and 8^0E (Reijers et al, 1996) (Fig. 1). The Niger Delta is framed on the northwest by a subsurface continuation of the West African Shield, the Benin Flank. The eastern edge of the basin coincides with the Calabar Flank to the south of the Oban Masif (Murat, 1972). Well sections through the Niger Delta generally display three

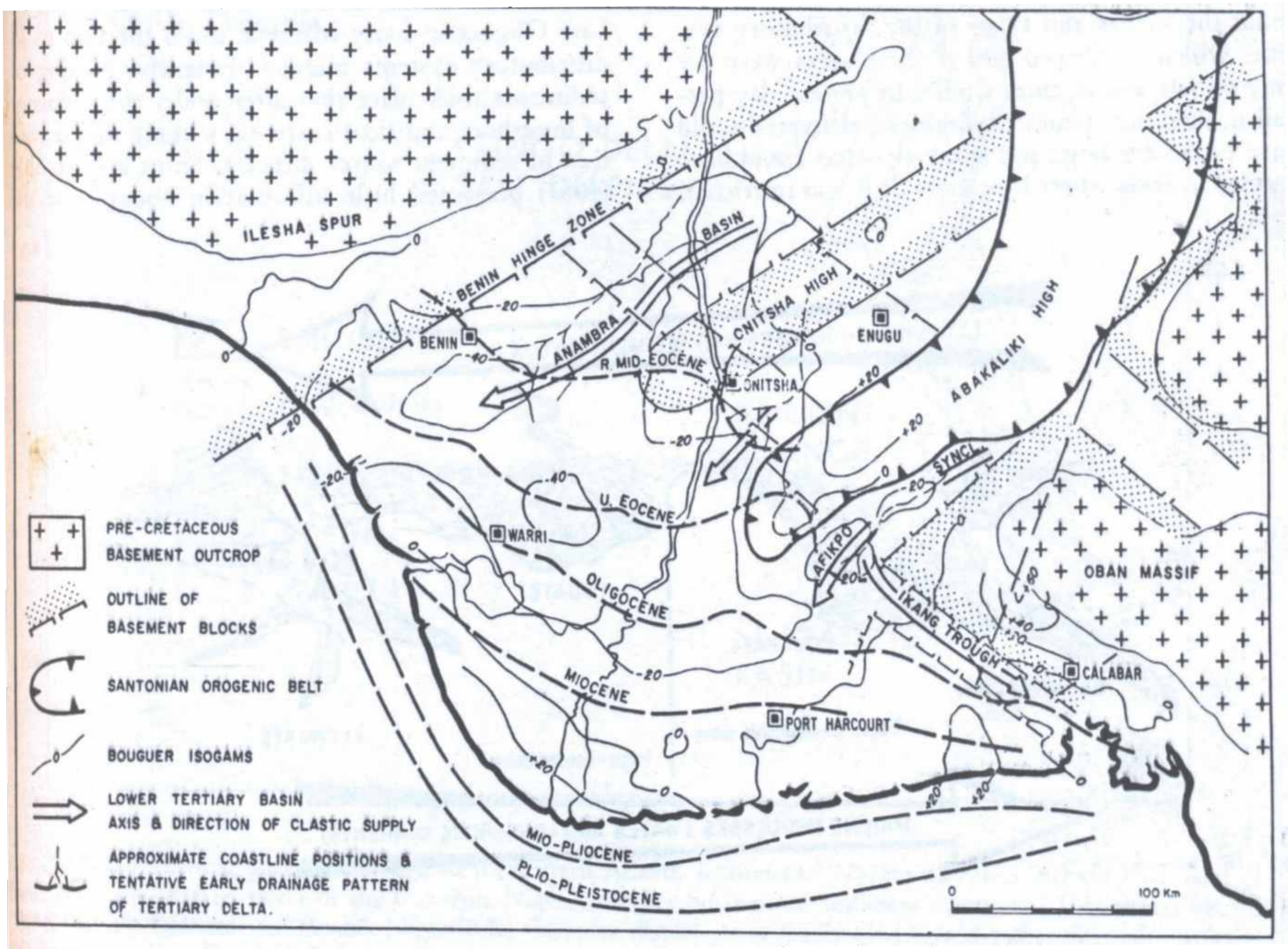


Fig.1: Map of Niger Delta showing the position of the well and magatectonic framework of the basin (modified after Murat, 1972)

vertical lithostratigraphic subdivisions: an upper delta top facies; a middle delta front lithofacies; and a lower pro-delta lithofacies (Reijers *et al,* 1996). These lithostratigraphic units correspond respectively with the Benin Formation (Oligocene-Recent), Agbada Formation (Eocene-Recent) and Akata Formation (Paleocene-Recent) of Short and Stauble (1967). The Akata Formation is composed mainly of marine shales, with sandy and silty beds which are thought to have been laid down as turbidites and continental slope channel fills. It is estimated that the formation is up to 7,000 metres thick (Doust and Omatsola, 1990). The Agbada Formation is the major petroleum-bearing unit in the Niger Delta. The formation consists mostly of shoreface and channel sands with minor shales in the upper part, and alternation of sands and shales in equal proportion in the lower part. The thickness of the formation is over 3,700 metres. The Benin Formation is about 280 metres thick, but may be up to 2,100 metres in the region of maximum subsidence (Whiteman, 1982), and consists of continental sands and gravels.

Materials and Methods

Ditch cutting samples from Ane-1 well were supplied by Mobil Producing Nigeria Unlimited (MPN) and were composited at 60ft intervals. A total of 50 composited samples from depth of 6990ft to 9930ft were processed and analysed for sedimentological and palynological studies. These studies were carried out at Petrostrat Services Limited (PSL), Nigeria.

For sedimentological processing, about 80 grams of each sample was crushed and soaked with hot water and liquid detergent for about 24 hours. The

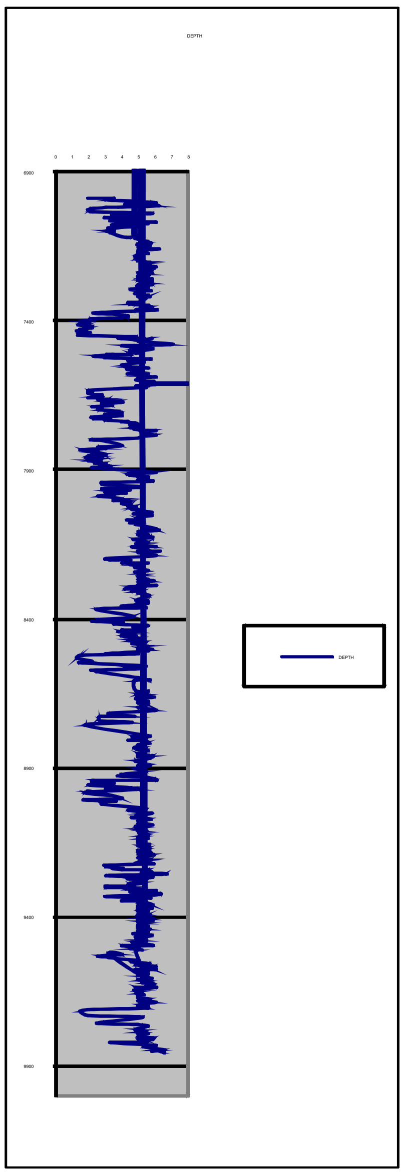


Fig. 2: Ane-1 GR log

soaked samples were briskly washed under a distilled water nozzle tap using a 63μm sieve mesh. The retained samples on 63μm sieve were dried over hot plates. The essential parameters studied were: (i) the main rock types; (ii) colour and texture such as grain size, sorting and grain shape (roundness); and (iii) accessory mineral and fossil contents. The results are displayed in Fig. 3.

Palynological processing involved of 25 grams of dry sample being crushed between 0.25mm and 2.5mm. Standard palynological processing procedures employed were as follows: (i) disintegration of mineral matrix with dilute HCl for carbonates and digestion with concl. HF for silicates (15 hours); (ii) Removal of fluoride gel using hot concl. HCl (40 minutes) and wet sieving of samples using 10μm polypropylene Estal Mono sieve; (iii) oxidation (3 minutes) and heavy liquid separation using $ZnCl_2$ (sp. gr. 2.0). Slides were mounted using cellosize as a spreading medium and loctite as adhesive. One slide per sample was analysed under the optical microscope and the microphotography of the best palynomorphs specimens was done with the aid of an Olympus CHB microscope. Residues are stored at Petrostrat Services Laboratory while the slides are stored in the Geological Sciences Laboratory of Nnamdi Azikwe University, Awka, Nigeria.

Specimen morphological characteristics were compared with the descriptions, monographs and diagrams of available publications, (Leidelmeyer, 1966; Vander Hammen and Garcia, 1966; Van Hoeken-Klinkenberg, 1966; Gonzalez Guzman, 1967; Clarke and Frederiksen, 1968; Germeraad et al, 1968; Knaap, 1969; Salard-Cheboldaeff, 1972, 1974, 1975a, 1975b, 1978, 1979, 1980, 1990; Salard-Cheboldaeff and Locquin, 1980; Salard-Cheboldaeff et al, 1992, 1995; Legoux et al, 1972; Legoux, 1978; Regali et al, 1974; Adegoke et al, 1978; Salami, 1983; Jarzen and Elsik, 1986; Lorente, 1986; Sowunmi, 1995, 1999). The palynological and lithological charts of the studied section are displayed with the aid of StrataBug graphical software. Representatives photographs of the palynofloral assemblages were captured and presented as Fig. 5, 6 and 7.

Results and Discussion

Sedimentology

In general, the well shows a clastic regressive succession with sand predominating. It is made up of alternating sand and shale including appreciable siltstone. The shale/sand ratio increases progressively towards the base of the studied interval as seen from the log of the well section in Fig. 2. Glauconite pellets are few to common mineral found in the studied interval. Shell fragments, ferruginous materials, pyrite and mica flakes are rare to few (see Fig. 3).

The sands are predominantly clean white to grayish, buff or brownish, fine to coarse grained, sometimes pebbly, angular to well rounded, moderately to poorly sorted and occasionally well sorted in some samples. The shales are light to dark grey or brownish, soft to moderately indurated, platy, flaggy, slabby and blocky in appearance. Based on sedimentological and palynological data, the interval studied in Ane-1 well belongs to the paralic Agbada

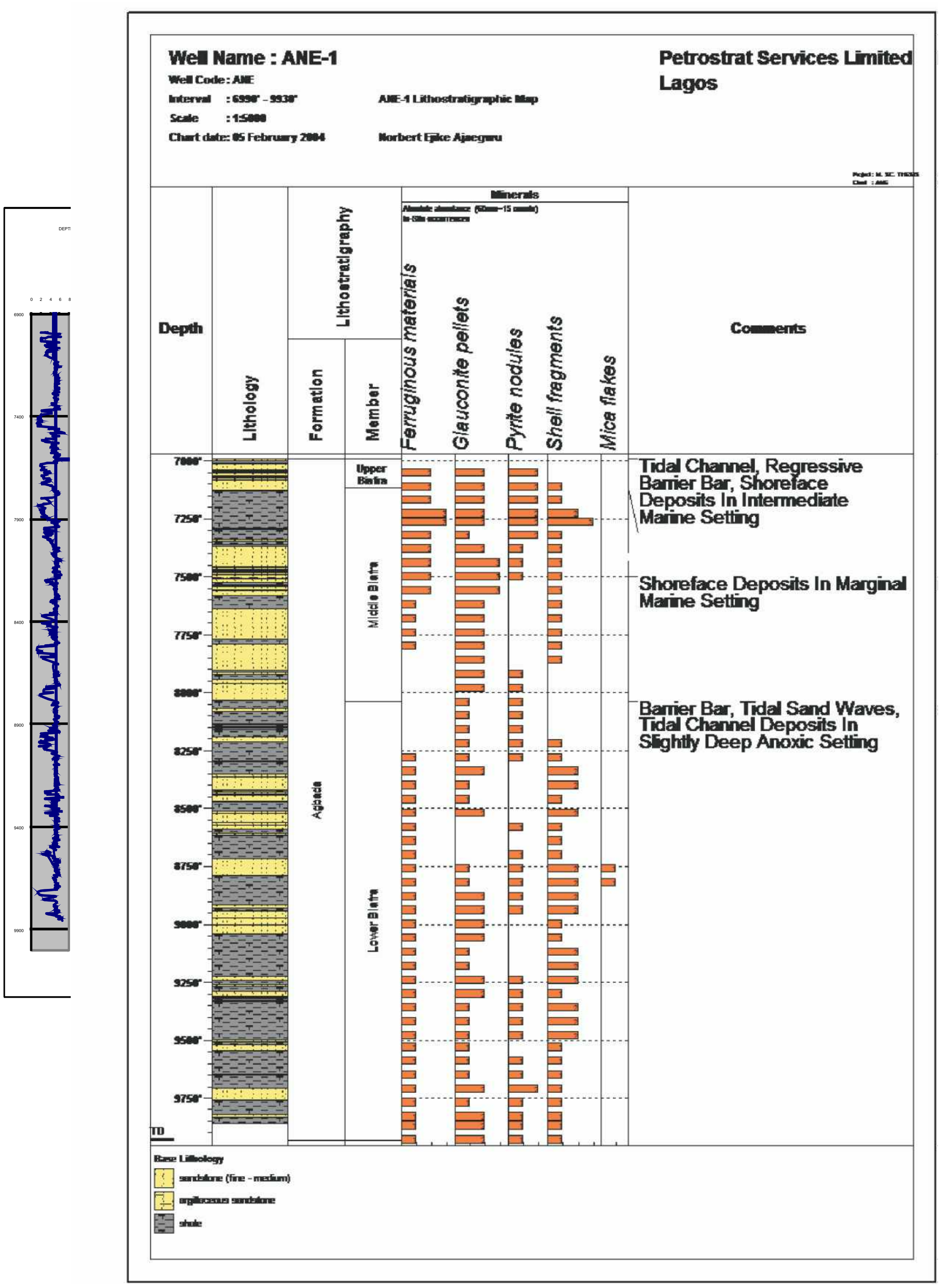


Fig.3: Lithostratigraphic/accessory mineral chart of Ane-1 well

Formation. The lithostratigraphic units recognized in the well are presented below on Table 1.

Biostratigraphy

A total of 632 palynomorphs were counted after screening comprising spores, pollen grains, fungal spores, *Botryococcus,* and foram test linings. Some of the corroded or highly distorted palynomorphs were not counted since they could not be placed within any group. Marine indicators found were foram test linings. The biozonation of the studied section was based on the pollen and spores. The reference scales used were those of Evamy *et al.* (1978) and Morley (1997). Some of the subzones of these two schemes were lumped together because some of diagnostic fossils that mark their boundaries were not found (Fig. 4 and Table 2). The entire section falls within the *Echitricolporites spinosus* Zone of Germeraad *et al.* (1968). The diagnostic palynomorphs recovered permitted the zonation and dating of the analysed section. A Late Miocene to Early Pliocene age was assigned to the studied section with Miocene/Pliocene boundary placed at 8150ft and marked by First Appearance Datum (FAD) of *Nymphaeapollis clarus* and increase in *Monoporites annulatus*.

Table 1: Lithostratigraphic subdivisions of ANE-1 Well

Depth interval (ft)	Thickness (ft)	Member	Formation	Shale/ Sand Ratio
6990-7115	125	Upper Biafra	Agbada	30/70%
7115-8035	920	Middle Biafra	Agbada	50/50%
8035-9930	1895	Lower Biafra	Agbada	70/30%

Early Pliocene Interval

Two subzones *Podocarpus milanjianus* (P880) and *Gammamonoporites* sp. (P870-P860) of Evamy *et al.* (1978) and four subzones *Retibrevitricolporites obodoensis* (P2), *Arecipites* sp. (P3), *Sapotaceoideapollenites* sp. (P4/P5) and *Zonocostites ramonae*/ Charred graminae (P6/P7) of Morley (1997) are recognized in the Early Pliocene interval of this well. The boundary of *Podocarpus milanjianus* (P880) and *Gammamonoporites* sp. (P870-P860) subzones is defined by Last Appearance Datum (LAD) of *Gammamonoporites* sp. The boundary between *Retibrevitricolporites obodoensis* (P2) and *Arecipites* sp. (P3) subzones is defined by FAD of *Arecipites* sp. Boundary between *Arecipites* sp. (P3) and *Sapotaceoideapollenites* sp. (P4/P5) subzones is defined by downhole increase in *Sapotaceoideapollenites* sp., while that of *Sapotaceoideapollenites* sp. (P4/P5) and *Zonocostites ramonae*/Charred graminae (P6/P7) subzones is defined by increase in Zonocostites ramonae and charred graminae cuticle. Some of the subzones were combined because their diagnostic marker species were not found. Some characteristic palynomorphs in this interval are *Stereisporites spp., Retimonocolpites sp., Monoporites annulatus, Pachydermites diederixi, Multiareolites formosus, Elaeis guineensis, Retibrevitricolporites obodoensis/protrudens, Perfotricolpites digitatus, Verrucatosporites prosecundus, Polypodiaceoisporites gracillimus, Arecipites crassimuratus, Echiperiporites estelae, Nymphaeapollis clarus, Cyatheacidites sp. Magnastriatites howardi, Crototricolpites densus, Spirosyncolpites brunii, Crassoretitriletes vanradshooveni, Psilastephacolporites laevigatus, Podocarpus milanjianus*, etc.

Late Miocene Interval

Evamy *et al.* (1978) used the FAD of *Nymphaeapollis clarus* to mark the Miocene/Pliocene boundary. This FAD is found at a depth of 8150ft. Morley (1997) in his zonation scheme used increase in *Monoporites annulatus* to mark Miocene/Pliocene boundary which was also found at the same depth of 8150ft. Thus Miocene/Pliocene boundary was confirmed at that depth.

The *Multiareolites formosus* (P800) Zone and *Nympheapollis clarus* (P850-830), *Stereisporites* sp. (P820), and *Multiareolites formosus* (P780) subzones of Evamy *et al.* (1978) were recorded in the Late Miocene of the Ane-1 well. The boundary between *Nympheapollis clarus* (P850-830) and *Stereisporites* sp. (P820) subzones is defined by FAD of *Nympheapollis clarus* at 8150ft while that of *Stereisporites* sp. (P820) and *Multiareolites formosus* (P780) subzones is defined by FAD of *Multiareolites formosus at* 9420ft.

Morley (1997) uses increase and decrease in abundance of *Zonocostites ramonae* and *Monoporites annulatus* to subdivide the Late Miocene. M1, M2, M3 and M4 subzones of Morley (1997) were recorded in the Late Miocene interval of this well. The boundary between M1 and M2 subzones is defined by increase in abundance of *Zonocostites ramonae* while the boundary between M2 and M3 subzones is defined by

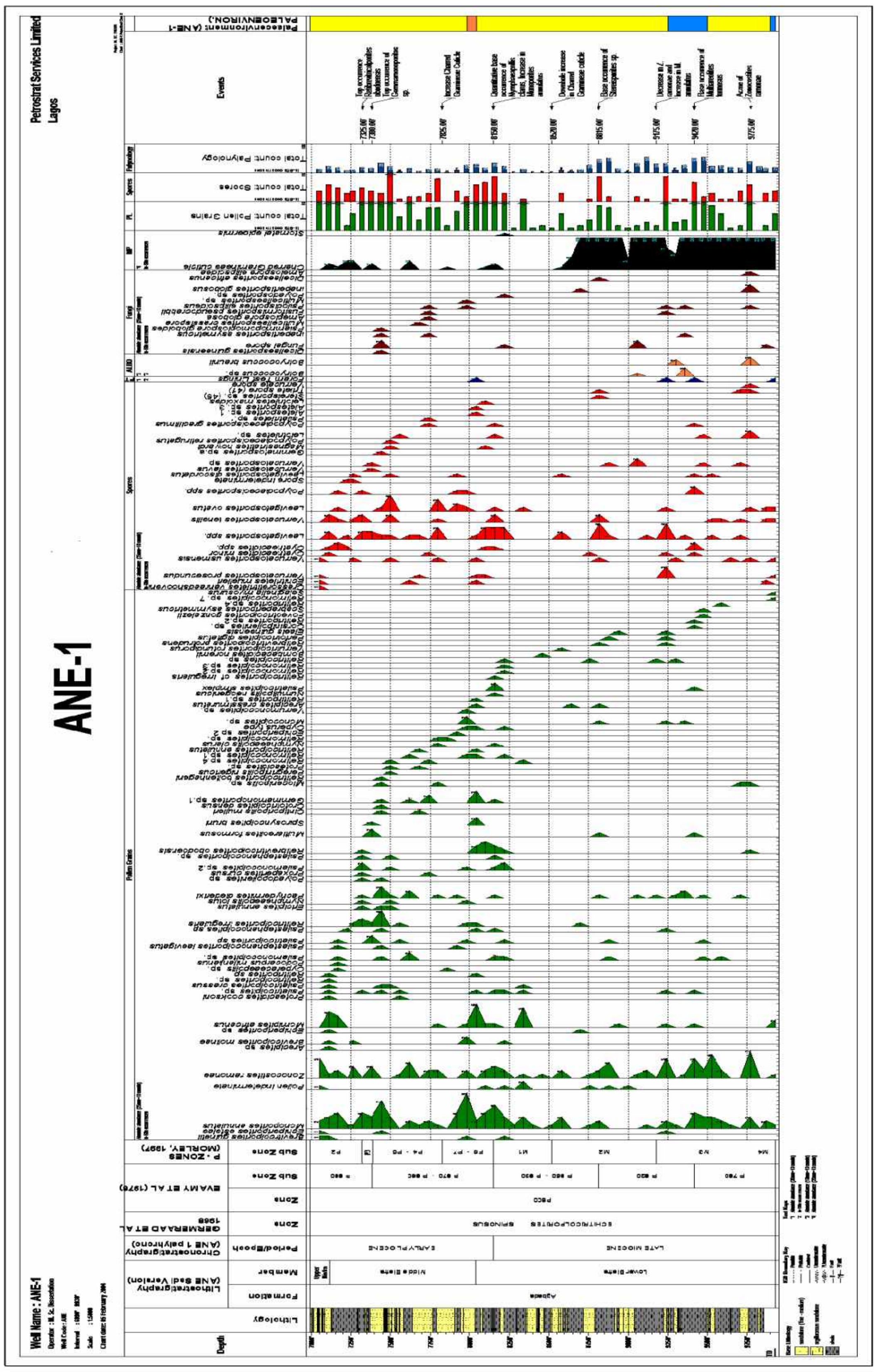


Fig. 4: Palynofloral distribution chart of Ane-1 well

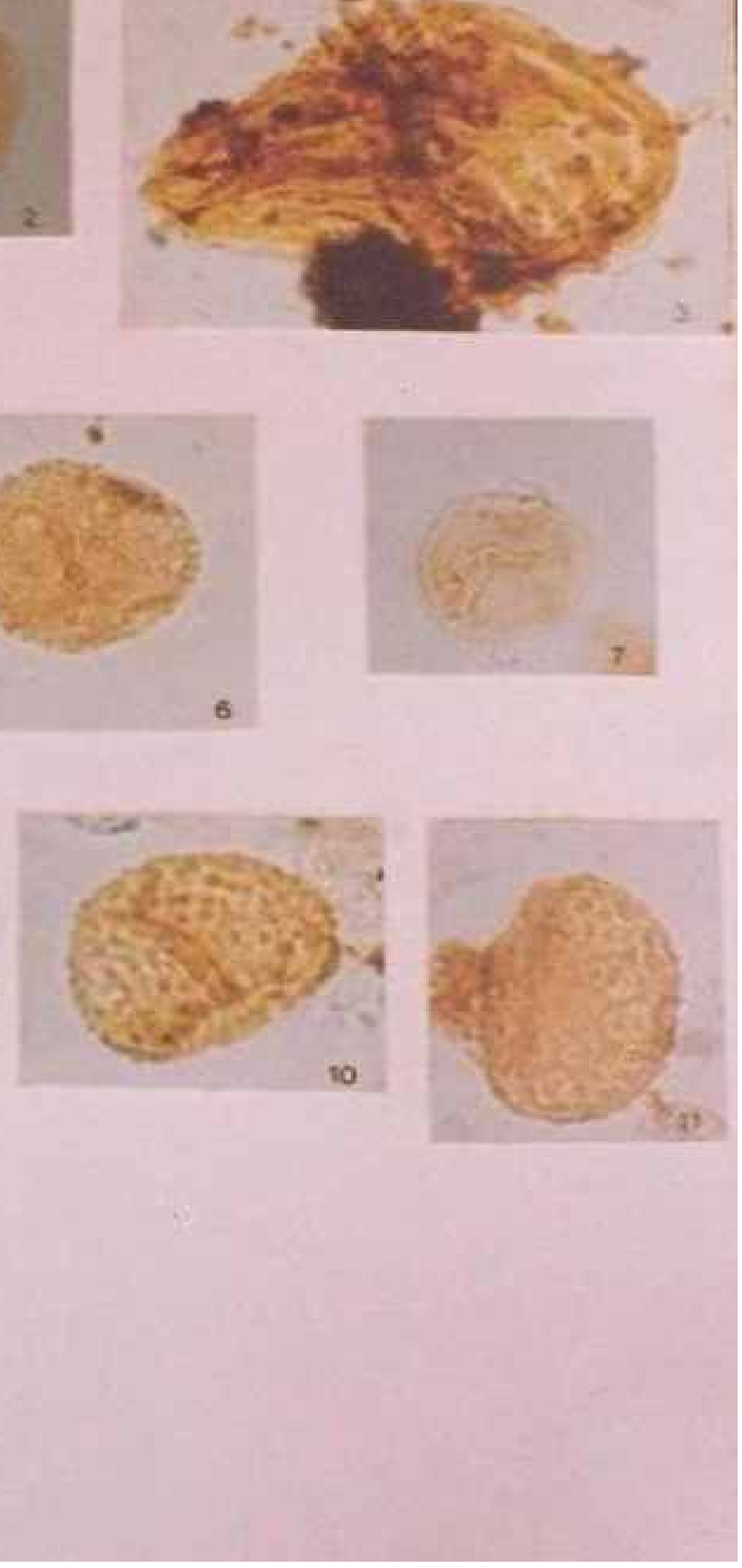


Fig. 5: Representative spores in Ane-1 well

PLATE 1 (X 1000)
Figures: 1&2: *Magnastria tites how ard i:*
2: *Cyatheacidites minor;*
4: *Polypodiaceo is porites gracillim us*
5, 6&7: *Echitriletes muelleri*
8 & 11: *Verrucato sporites usm ensis*
9 & 10: *Verrucato sporites tenellis;*
12: *Laevigato sporites discordatus*
13: *Laevigato sporites ovatus*

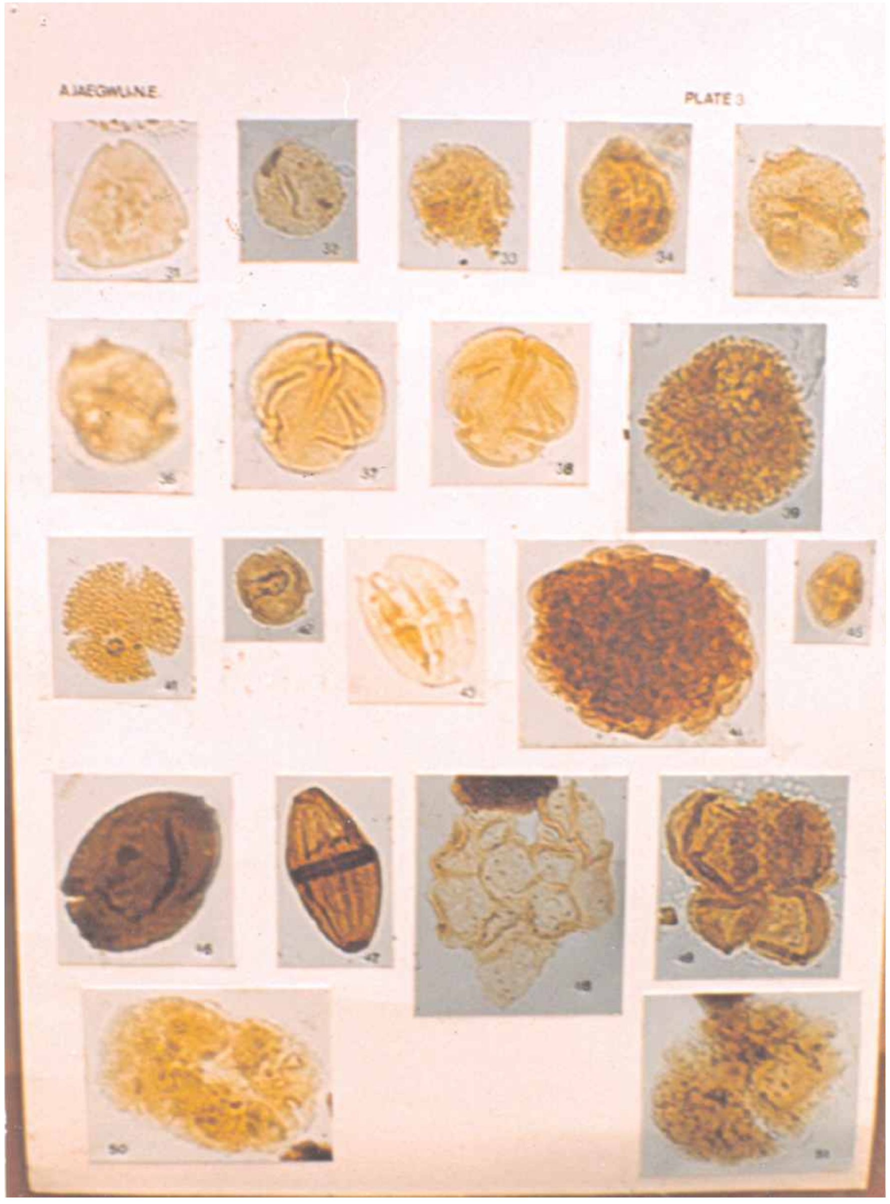


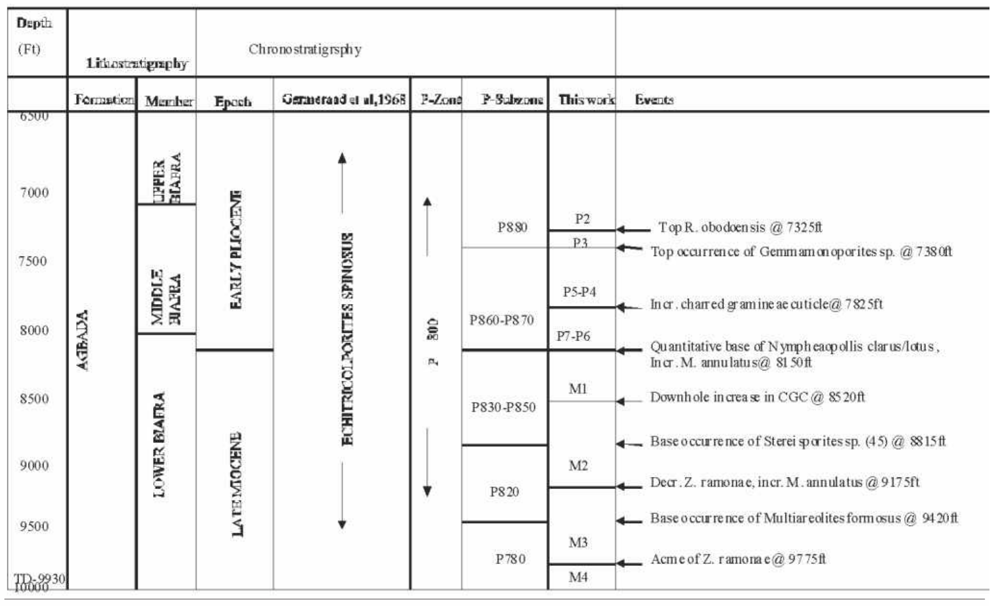
Fig. 3 (X 1000)
Figures: 31: *Brevicolporites molinae*
32 &33: *Retibrevitricolporites obodoensis*
34, 35 & 36: *Retibrevitricolporites protrudens*
37 & 38: *Psilatricolporites crassus*
39 & 41: *Retitricolporites irregularis*
42 & 45: *Zonocostites ramonae*
43: *Psilastephanocolporites laevigatus*
44: *Polyadosporites* sp.
46: *Psilodiporites ellipsoideus*
47: *Fusiformisporites pseudocrabbi*
48 & 49: Foram test linings
50 & 51: *Botrococcus braunii*

Fig. 6: Representative pollen, fungal spores and others in Ane-1 well

Fig. 7: Representative pollen in Ane-1 well

PLATE 1 (X 1000)
Figures: 14: *Psilamonocolpites sp.*
15: *Arecipites sp.*
16 & 17: *Arecipites crassimuratus*
18: *Psilamonocolpites simplex*
19 & 20: *Perfotricolpites digitatus*
21: *Monoporites annulatus;*
22: *Nummulipolis neogenicus*
23: *Brevicolporites guinetii*
24 & 25: *Momipites africanus*
26 & 27: *Pachydermites diederixi*
28: *Echiperiporites estelae*
29 & 30: *Multiareolites formosus*

Table 2: Biostratigraphic summary table of Ane-1 well



decrease in abundance of *Zonocostites ramonae* and increase in *Monoporites annulatus.* The boundary between M3 and M4 subzones is defined by increase in *Zonocostites ramonae.*

Some characteristic palynomorphs within this interval include: *Monoporites annulatus, Pachydermites diederixi, Zoncostites ramonae, Laevigatosporites* spp., *Verrucatosporites tenellis/usmensis, Echitriletes muelleri, Retibrevitricolporites obodoensis, Momipites africanus, Polypodiaceoisporites gracillimus, Retitricolporites irregularis, Arecipites crasssimuratus, Echiperiporites estalae, Nummulipollis neogenicus,* and fungal spores.

Environmental Interpretation

Four main criteria are involved in this environmental interpretation:

(i) Association of environmentally restricted marker species such as *Magnastriatites howardi*, *Pachydermites diederixi, Zonocostites ramonae* and foram test linings;

(ii) percentage of *Zonocostites ramonae* (Rhizophora type) in the total palynoflora sum;

(iii) nature of organic matter in the sediment; and

(iv) lithological characters of the strata.

Results of Environmental Interpretation

(i) ***Environmental marker species:*** Marker 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* (gramineae pollen suggesting open vegetation found in coastal savannah) and foram test linings are present. The abundance of these marker species (with exception of foram test linings*)*, though with rare occurrence of *M. howardi* and regular occurrence of fungal spores suggests that the interval studied represents mainly deposition in a coastal to marginal marine setting. Foram test linings are good indicators of marine environments was used to further divide the macro environment into coastal deltaic, coastal deltaic inner neritic and inner neritic.

(ii) ***Percentage of Zonocostites ramonae:*** *Z. ramonae* is a distinctive pollen type found in extant genera of mangroves notably *Rhizophora* (Germeraad *et al.*, 1968). *Rhizophora* shows its optimal development on unconsolidated clayey to sandy soils in a marine to brackish environment. Its quantitative distribution therefore, makes it a useful species for environmental interpretation. *Rhizophora* is frequent to abundant throughout the interval described here, suggesting the presence in the area. The percentage of *Z. ramonae* ranges from

4% to 36% in the studied interval. The absence of this species from some horizons indicates that deposition of those sediments occurred some distance from the mangrove edge.

The intermittent occurrence of *M. howardi* from 8100ft and above shows the incursion of fresh water in the immediate vicinity and the presence of more open vegetation.

The paucity of foram test linings from 7980ft depth to the base of the well indicates a slight marine influence. The slight marine influence and high percentage of *Z. ramonae* suggests deposition in mangrove environments.

(iii) ***Organic matter:*** The accumulation and degradation of organic matter is related to surface conditions in the depositional environment and to diagenetic changes (Oboh *et al.*, 1992). The organic matters recorded in this study ranges in size from small to large, indicating that sediments have not been long transportated. Deposition occurs under conditions of variable energy where both coarse and fine particles settled out. The organic matter is predominantly structured woody material with sparse opaque organic matter, cuticles, pollen and spores. Macerals present are liptinite-like alginite typified by *Botryococcus* and showing fresh water influence (Bustin, 1988). Terrestrially derived kerogen types II and III predominate showing that the organic matter is from higher plants (Bustin, 1988).

(iv) ***Lithology:*** In the studied intervals, glauconite is rare to common while pyrite, shell fragments, ferruginous materials and mica flakes are rare (Fig. 2). Glauconite and pyrite are the most important accessories used for environmental studies. Glauconite forms as an authigenic mineral during the early stage of diagenesis of marine sediment. It is extremely susceptible to sub-aerial weathering and is not known as a reworked second cycle detrital mineral (Selley, 1980). The presence of glauconite in sand, therefore, indicates a marine origin. On the other hand, pyrite in the shale bodies suggests reducing conditions. The combination of these accessory minerals with a gamma ray log helps in the sub-division of the environments. The sub-environments recognised here are: regressive barrier bar, tidal sand wave, and tidal channels. These sub-environments suggest shoreface deposits in marginal marine setting. The presence of pyrite in the Upper Biafra unit (6990-7115ft) indicates deposition in a slightly anoxic marine setting.

Summary and Conclusion

Lithological and palynological analyses of the Ane-1 well have contributed to the stratigraphic study of the section. A combination of spores and pollen is the basis for dating the section as Late Miocene to Early Pliocene. The palynological zonation conformed to those of Evamy *et al.* (1978) and Morley (1997) and shows that the two zonation schemes can be combined for better resolution. The combination of parameters showed the environments of deposition to be coastal to marginal marine which was further subdivided into coastal deltaic, coastal deltaic inner neritic and inner neritic. The sub-environments recognized are tidal channel, regressive barrier bar and shoreface deposits.

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REFERENCES

Adegoke, O.S., R.E. Jan du Chene, A.E. Agumanu, and P.O. Ajayi, 1978, Palynology and age of Kerri-Kerri Formation, Nigeria: Revista Espanola de Micropaleontologia, vol. X, no. 2, pp. 267-283.

Ako B.D., S.B. Ojo, C.S. Okereke, F.C. Fieberg, T.R. Ajayi, A.A. Adepelumi, J.F. Afolayan, O. Afolabi, and H.O, Ogunnusi, 2004, Some observation from gravity/magnetic data interpretation of the Niger Delta: Nigerian Association of Petroleum Explorationists Bulletin, vol 17, no. 1, pp. 4-8.

Bustin R.M., 1988, Sedimentology and characteristics of dispersed organic matter in Tertiary Niger Delta: origin of source rocks in a deltaic environment: American Association of Petroleum Geologists Bulletin, vol. 73, no. 3, pp. 277-298.

Clarke, R.T. and N.O. Frederiksen, 1968, Some new sporomorphs from the Upper Tertiary of Nigeria: Grana palynologica, vol.8, No.1, pp. 210-224.

Doust, H., E. Omatsola, 1990, Niger Delta, in J.D. Edwards and P.A. Santogrossi, eds., Divergent/Passive margin basins: American Association of Petroleum Geologists Memoir 48, pp. 201 236.

Evamy, D.D., J. Haremboure, P. Wikanerling, W.A. Knaap, F.A. Lolloy, and P.H. Rowlands, 1978, Hydrocarbon habitat of Tertiary Niger Delta: American Association of Petroleum Geologists Bulletin, 62 (1), pp. 1 39.

Germeraad, J.H., C.A. Hopping and J. Muller, 1968, Palynology of Tertiary sediments from tropical areas: Review of Paloebotany and Palynology, 6, pp.189-348.

Gonzalez Guzman, A.E., 1967, A palynological study of the Upper Los Cuervos and Mirador Formations (Lower and Middle Eocene; Tibu area, Colombia): E. J. Brill, Leiden, pp. 23-48.

Jarzen, D.M. and W.C. Elsik 1986, Fungal palynomorphs recovered from recent river deposits, Luangwa valley, Zambia: American Association of Stratigraphic Palynologists Publication, vol.10, pp.35-60.

Knaap, W.A., 1969, A montane pollen species from the Upper Tertiary of the Niger Delta: Journal of Mining and Geology, vol. 6, nos. 1&2, pp. 23-27.

Legoux, O., C.Y. Belsky and S. Jardine, 1972, Pollens nouveaux de l'Eocene d'Afrique occidentale: Quatrieme colloque Africain de Micropaleon., Pp.226-236.

Legoux, O., 1978, Quelques especes de pollen caracteristiques du Neogene du Nigeria: Bull.Cent. Rech. Explor.-Prod. Elf-Aquitane, vol.2, no.2, pp.265-317.

Leidelmeyer, P., 1966, The Paleocene and Lower Eocene pollen flora of Guyana: Leise Geologische Mededelingen, vol.38, pp. 49-70.

Locquin, M.V., D. Pons and M. Salard-Cheboldaeff, 1981, Thyriotheces d'ascomycetes fossiles: Cashiers de Micropaleontology, vol.81, no.1, pp.109-119.

Lorente, M.A., 1986, Palynology and palynofacies of the Upper Tertiary in Venezuela: Dissertationes Botanicae, pp.143-213.

Morley, R.J., 1997, Offshore Niger Delta palynological zonation: (Manuscript) prepared for the Niger Delta Stratigraphic Commission, pp.8

Murat, R.C., 1972, Stratigraphy and Palaeogeography of the Cretaceous and Lower Tertiary in Southern Nigeria, in African Geology, T.F.J. DEssauvagie and A.J. Whiteman, eds: Ibadan University Press, pp. 251- 266.

Oboh, F.E., M.B. Salami and J.L. Chapman, 1992, Palynological interpretations of the paleoenvironments of Miocene strata of the well Igbomotoru-1, Niger Delta: Journal of British Micropaleontology Society, vol. 11, part1, pp. 1-5.

Opara, G.E., 1981, A review of the Tertiary Unam "B" Field in OML67, Niger Delta: Journal of Mining and Geology, no. 18, vol. 1, pp. 86-95.

Regali, M.S.P., N. Uesugui and A.S. Santos, 1974, Palinologia dos sedimentos-Mesocenozoicos do Brasil: II-Bol.Tecn. Petrobras, vol.17, no.4, pp.263-301.

Reijers, T.J.A., S.W. Petters and C.S. Nwajide, 1996, The Niger Delta Basin, in: T.J.A. Reijers (ed.), Selected Chapters on Geology: SPDC corporate reprographic services, Warri, Nigeria, pp. 103-114

Salami, M.B., 1983, Some Late Cretaceous and Early Tertiary Pteridophytic spores from the Southern

Nigeria sedimentary basin: Revista Espanola de Micropaleontologia, vol.xv, no.2, pp.257-272.

Salard-Cheboldaeff, M., 1972, A propos la microflore cryptogamique Tertiarie du bassin sedimentaire cotier du Cameroun: Revue de Micropaleontologe, vol.18, no.2, pp.97-116.

Salard-Cheboldaeff, M., 1974, Grains de pollen Tertiaires du Cameroun rapports a la famille des Bombacacees: Comptes Rendus du 100e Congres National des Societes Savants, 81, pp.359-367.

Salard-Cheboldaeff, M., 1975a, Quelques grains de pollen peripores Tertiaires du Cameroun: Revue de Micropaleontologe, vol. 17, no. 4, pp. 182-190.

Salard-Cheboldaeff, M., 1975b, Grains de pollen Tertiaires du Cameroun rapports a la famille des guttiferes: Comptes Rendus du 100e Congres National des Societes Savants, fas. II, pp. 83-92.

Salard-Cheboldaeff, M., 1978, Sur la palynoflore Maestrichtienne et Tertiaire du bassin sedimentaire littoral du Cameroun: Pollen et Spores, vol. xx, no.2, pp.215-260.

Salard-Cheboldaeff, M., 1979, Palynologie Maestrichtienne et Tertiaire du Cameroun. Etude qualitative et repartition verticale des principales especes: Review of Paleobotany and Palynology, 28, pp.365-387.

Salard-Cheboldaeff, M., 1980, Pollens Tertiaires du cameroun rapports a la famille des Rubiacees: Actes du VIe eoll. Afr. de Micropaleo. Tunis, Tome III, no.28, pp. 279-289.

Salard-Cheboldaeff, M., 1990, Intertropical African palynostratigraphy from Cretaceous to Late Quaternary times: Journal of African Earth Sciences, vol.11, no.½, Pp.1-24.

Salard-Cheboldaeff, M. and M.V. Locquin, 1980, Champignons presents au Tertiaire de eong du littoral de l'Afrique equatoriale: 105e Congres National Societes Savants, Caen, fasc.1, pp. 183-195.

Salard-Cheboldaeff, M., J. Mouton and M. Brunet, 1992, Paleoflore tertiaire du bassin d'Anloua Plateau de l'Adamaoua, Cameroun: Revista Espanola de Micropaleontologia, vol.XXXIV, no.2, pp.131-162.

Salard-Cheboldaeff, M., I. Miko-Angoula and J. Lang, 1995, Palynological approach of "Continental terminal" Palaeoenvironments in the Illummeden Basin (Niger): Revue de Micropaleon., vol.38, no.4, pp.329-338.

Selley, R.C., 1980, Ancient Sedimentary Environments and their Sub-surface Diagnosis: Chapman and Hall, London, pp. 13 33.

Simmons, M.D., M.D. Bidgood, P. Brenac, P.D. Crevello, J.J. Lambiase and C.K. Morley, 1999, Microfossil assemblages as proxies for precise palaeorenvironmental determination-an example from Miocene sediments of northwest Borneo, in R.W. Jones and M.D. Simmons, eds., Biostratigraphy in Production and Development Geology: Geologiocal Society Special Publication, no. 152, 219p.

Short, K.C., A.J. Stauble, 1967, Outline of geology of Niger Delta: American Association of Petroleum Geologist Bulletin, vol.51, no.5, pp.764-772.

Sowunmi, M.A., 1995, Pollen of Nigeria Plants: Scandinavian University Press, pp.120-141.

Sowunmi, M.A., 1999, The significance of oil palm (Elaeis guineensis Jacq.) in the Late Holocene environments of west and west central Africa: a further consideration: Vegetational History and Archaeobotany, vol.8, pp.199-210.

Van der Hammen, T.C. Garcia de Mutis, 1966, The Paleocene pollen flora of Colombia: Leidse Geologische Mededelingen, dl. 35, blz. 10 5-116.

Van- Hoeken- Klinkenberg, P.M.J., 1966, Maastrichtian, Paleocene and Eocene pollen and spores from Nigeria: Leidse Geologische Mededelingen, vol.38, pp.37-48.

Whiteman, A., 1982, Nigeria: its petroleum geology, resources and potential: Graham & Trotman Ltd., vol. 1, pp. 114-131.

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