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Miocene-Pliocene Vegetation and Climate Dynamics of the Niger Delta Basin Based on Palynological Signatures

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Abstract

The palaeoclimate is interpreted on the basis of the identified palynomorphs in the light of their ecological preferences.The problem of how to recognize the effect of changes in climate in the stratigraphical distribution patterns of the many species studied was approached in a direct way by botanical identification of fossil pollen and spore types with the extant parent plants or nearest living relatives, which have well-defined climatological tolerances. The Miocene-Pliocene Paleoenvironment in the southwestern offshore of the Niger Delta fluctuates from marginal marine (inner shelf) and swampy freshwater to slightly brackish water environment in a humid condition. Regional climate is interpreted as warm and humid, with mangrove communities dominating.

Keywords: Paleoclimate, Palynomorphs, Vegetation, Niger delta, Miocene-Pliocene

Introduction

Plants are one major component of the environment. A close relationship exists between vegetation and the rest of the environment, particularly climate. According to Sowunmi (1987) the flora of an area, generally speaking, provides a good reflection of the major climatic regime of that area. Hence, it may be possible to reconstruct past climates and environments through the study of fossil plants. This is based on the premise that the current distributions of nearest living relatives of fossil taxa offers a window through which palaeoclimates might be understood (Mosbrugger and Utescher, 1997). The approach assumes that modern climatic distributions of extant species mirror that of their co-generics in earlier geological epochs (Ghazoul, 2012). Pollen and spores are particularly valuable in this regard because they are, on the whole, small, with size range of 5-500µm, with distinct morphological features, abundant and are mostly well preserved in shale and other silt-sized sediments (Barreda, *et al.,* 2009) under certain conditions.

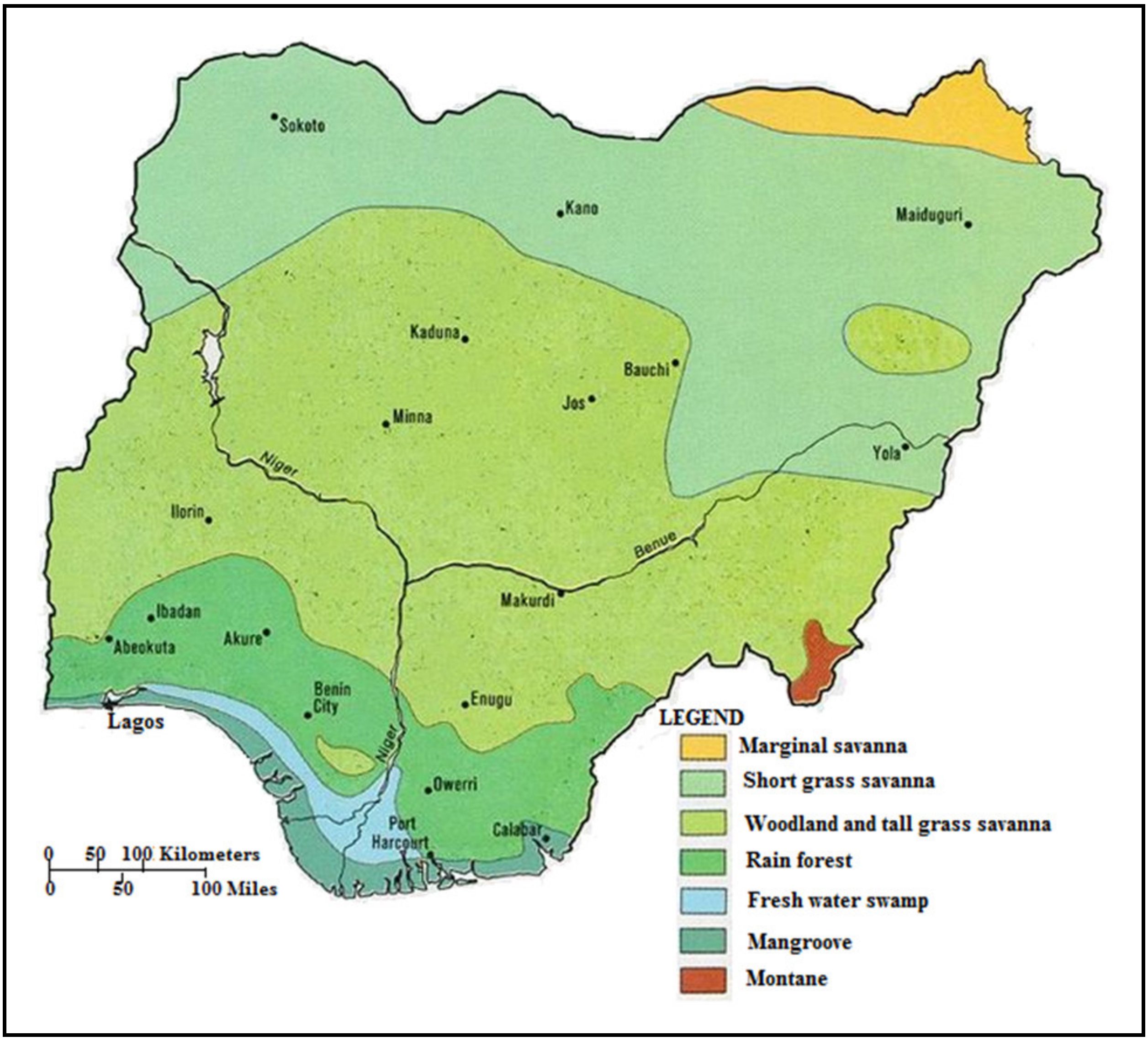
Climate, tectonic context, salinity, degree of agitation and water depth are important attributes of subaqueous environments and these affect and control the organisms living on or in the sediment or forming the sediment. The first two have been recognized to be the most important and therefore the determinants, to a very reasonable degree, of the other factors. Climate is a major factor in sub-aerial weathering and erosion and this relates to the composition of terrigenous clastic sediments; it is also instrumental in the formation of some lithologies such as evaporites and limestones. Tectonic context determines the depositional setting, whether it is a stable craton, intracratonic basin or rift or continental margin, ocean floor, trench or arc-related situations. Rates of subsidence or uplift, level of seismic activity and occurrence of volcanoes (with attendant eustatic changes) are also dependent on the tectonic context and are reflected in the sediment deposited. Therefore, climate and tectonic context jointly control sediment supply and organic productivity. While sediment supply is important in so far as low rates favour limestones, evaporites, phosphates and ironstones formation, high level of organic productivity favours the formation of limestones, phosphates, cherts, coal and oil shale.

Wilson (1971) reported that Arthur Leblanc was one of the first palynologists to study specifically the model of preservation of the palynomorphs in transgressive-regressive environments. Leblanc established the taphonomic conditions for pollen and spores records in the Gulf of Mexico. He found out that pollen grains from highland plants are distributed by wind transport and spread over great distances whereas spores (and pollen from lowland plants) have a smaller area of geographical distribution closer to the coastline. This is because the latter have no morphofunctional adaptations for wind transport and thus depend on an aquatic environment for their dispersion.

Among the first to compare sequence stratigraphy concepts with the palynologcal records were Gregory and Hart (1992). Gregory and Hart (1992) established a predictive model for the pollen and spore record of Gulf Coast Palaeogene with respect to relative sea level changes. Chow (1995) employed the ratio of the stratigraphic occurrence of the fossils of *Rhizophora* and *Camptostemon* for sequence stratigraphic deductions in offshore Sabah and Sarawak, Malaysia. Chow (1995) identified the inverse relationship in the occurrence trends of the two genera in relation to system tracts, noting that the ratio of *Rhizophora*: *Camptostemon* was high in HST and low in LST and TST. This discovery was used to solve problems that were beyond the resolution ability of seismic method (a limitation that was due to great depth) and recommended it for areas of poor foraminiferal and nannofossils data. The distribution of pollen and spores in marine sediments has been found to reflect rather accurately the distribution of the vegetation on the adjacent continent (Dupont, 1999; Traverse, 2007). The source of pollen and spores in the Niger Delta, according to Sowunmi (1986), can be confidently related to the regions transversed by rivers Niger and Benue, which include Sahelian and Sudanian vegetation zones as well as

Guinea-Congolian rainforests and the mangrove swamps. Hence, majority of the pollen in the Niger Delta come from the regions north and northeast of the Gulf of Guinea (Fig. 1). Floristic stages which followed one another in intertropical Africa are closely linked to climatic changes (Salard-Cheboldaeff and Dejax, 1991).

Since palaeoclimate changes had been found to provide the best means of correlating regionally (Germeraad *et al.*, 1968; Morley and Richards, 1993), the aim of this paper is to present an attempt to use the changes in the recovered terrestrially derived palynomorphs to reconstruct the paleoclimatic fluctuations over time in the studied wells.



Fig, 1. Vegetation zones in Nigeria.

GEOLOGICAL SETTING OF THE BASIN

The Niger Delta Basin is situated in the Gulf of Guinea, located on the West African continental margin. It extends throughout what Klett *et al.* (1997) defined as the Niger Delta Province (Fig. 2). The basin contains upper Cretaceous to Recent marine to fluvial deposits overlying oceanic crust and fragments of the African continental crust (Doust and Omatsola, 1990; Kostenko *et al.*, 2008). 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). The depobelt are characterised by enormous progradational and agradational paralic sequences with some retrogradational marine deposits at intervals.

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.

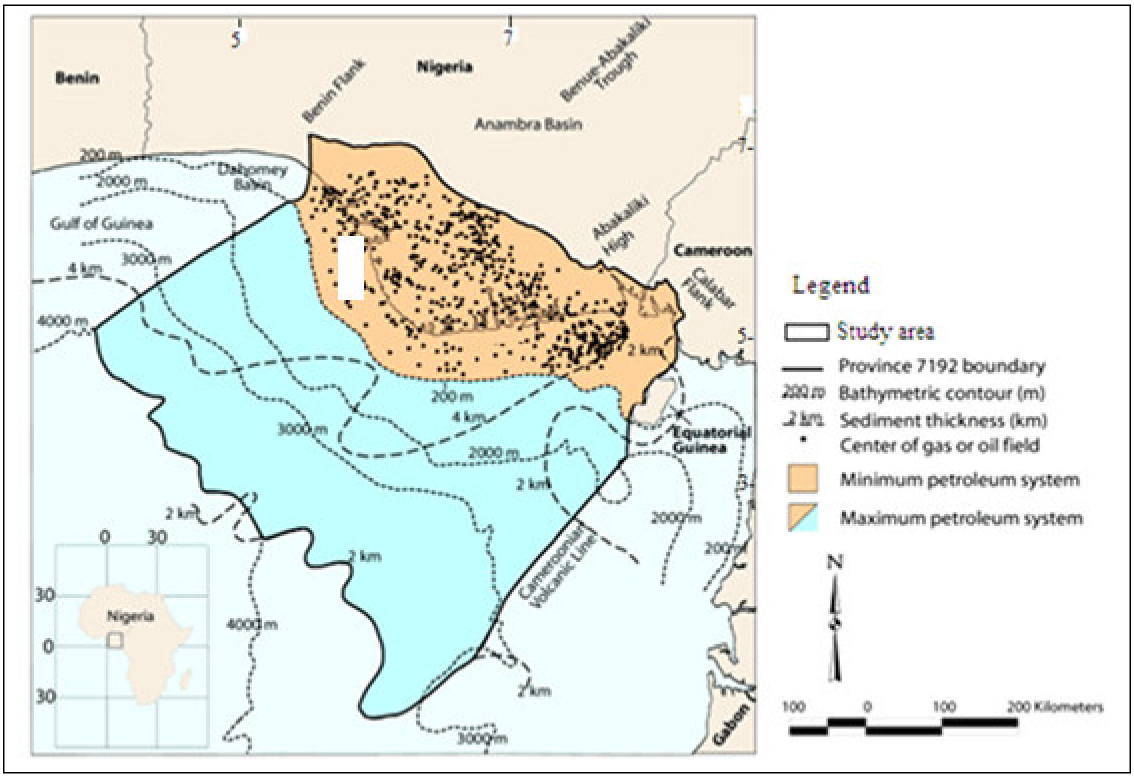


Fig 2. Map of the Niger Delta Basin Showing the Study Area and Province Outline
(Adapted from Petroconsultants, 1996 and Michele et al. 1999).

Materials and Methods of Study

Two hundred and seventy ditch-cutting samples from CHEV-1, 2 and 3 wells (Fig. 3) were subjected to lithological analysis and description using Leitz Wetzler binocular microscope. This assists in the determination of colour, average grain size, roundness, sorting and sand-shale percentages. One hundred and three shaly samples out of these were carefully chosen for palynological analysis due to the affinity of palynomorphs for shaly and silt-sized rocks. Standard maceration technique was followed in the preparation of the samples (Faegri and Iversen, 1989; Wood *et al.*, 1996). Modifications (staining, varying the percentage of HCl solution and sometimes excluding acetolysis) were sometimes introduced to achieve

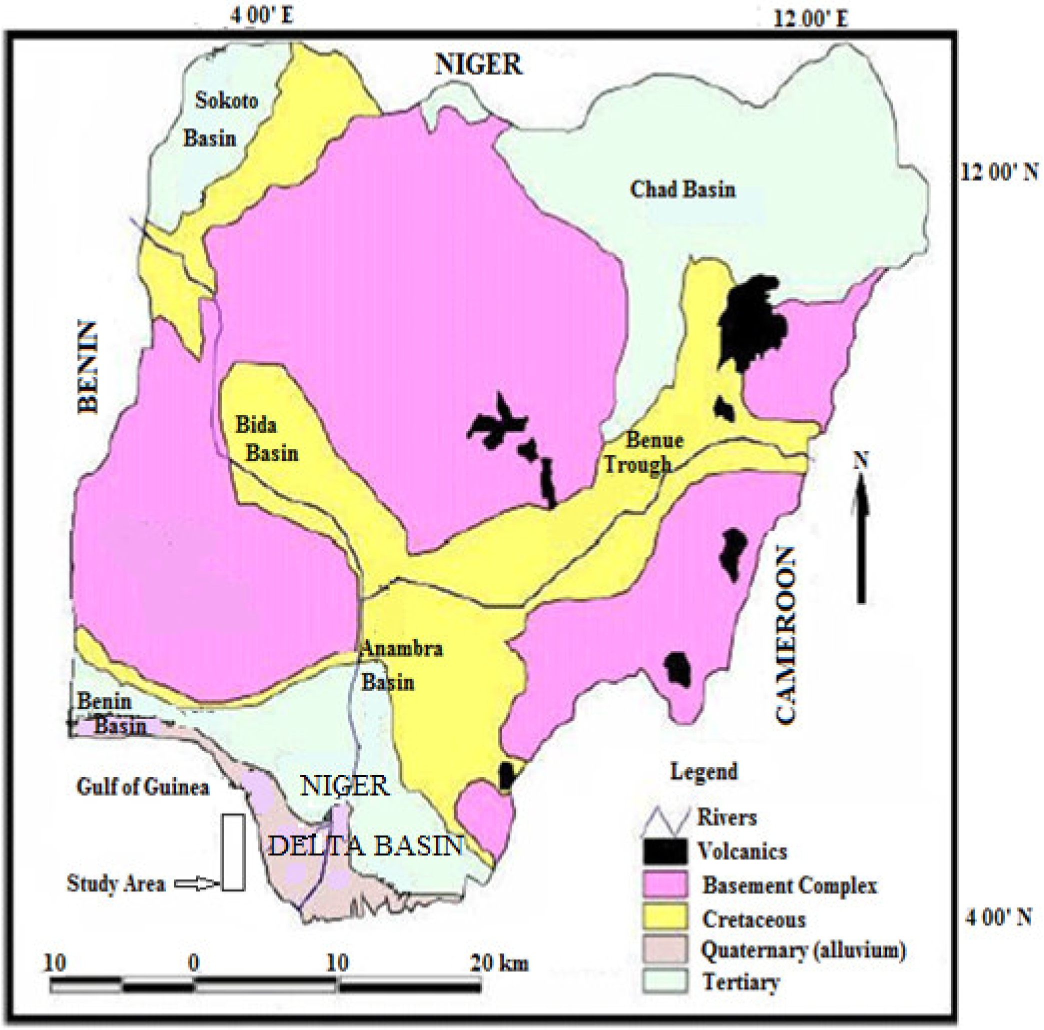


Fig 3. Geological map of Nigeria showing the study area (Modified after Afegbua et al. 2011).

maximum concentration of the palynomorphs and to make them visible enough for microscopic study. Ten microlitre of the glycerol-residue mixture taken with 10µl pipette tip was used to prepare each slide. Microscopic analysis of the prepared slides was carried out quantitatively using an OLYMPUS CH30 (MODEL CH30RF200) light transmitted microscope. Identification was done by reference to literature such as Germeraad *et al.*,1968; Traverse, 1988, Raine *et al.*, 2008. Counts of at least 250 grains were achieved for each sub-sample except those in which the palynomorph contents were too low (< 250 grains). Pollen sum was used in computing the percentage composition of the recovered palynomorphs. *Zonocostites ramonae* was excluded from the pollen sum because it is locally dominant in the area of study.

Results and Data Generation

The recovered sporomorphs were differentiated into paleoecological groups based on the main source areas (vegetation zones) of the extant parent plants or the Nearest Living Relatives (NLR). The grouping follows the order of the present positioning of the vegetation zones from shore. This method of grouping pioneered by Poumot (1989) was based on the fact that the nature, quantity and quality of recovered pollen and spores are functions of their proximity to shore, ecology and eustacy. The paleoecological deduction in this study is guided by the work of Poumot (1989) and other workers such as Keay (1959), Sowunmi (1973, 1981a and b, and 1995), Dupont and Awgu (1991), Morley (1995), Mosbrugger and Utescher (1997), Dupont (1999), Adeonipekun (2007), Tekleva and Krassilov (2008) and Kujau *et al.*, (2013).

However, it has to be recognized that, because of the degree of taxonomic precision possible with sporomorph identifications, the palynoecological groupings in this study only include the taxa with known botanical affinities.This is a reasonable thing to do since it has been recognized that extant cogenerics often vary widely in their modern climatic envelopes. Inferences about palaeoclimates using palaeobotanical evidence is, therefore, better based on a taxonomically broad range of fossil taxa and their nearest living relatives, and ideally taxa that are entirely distributed within narrow climatic boundaries (Mosbrugger and Utescher 1997, Uhl et al. 2003, Wang et al. 2010). Some of the recovered pollen and spores in the studied wells, their botanical affinities and the palynoecological groups are shown in Tables 1 and 2 respectively. The relationship in the occurrence trends of the palynoecological groups in relation to system tracts in the studied wells (Adebayo, 2011) was identified.

TABLE 1. Some of the Recovered Pollen and Spores and their Botanical Affinities

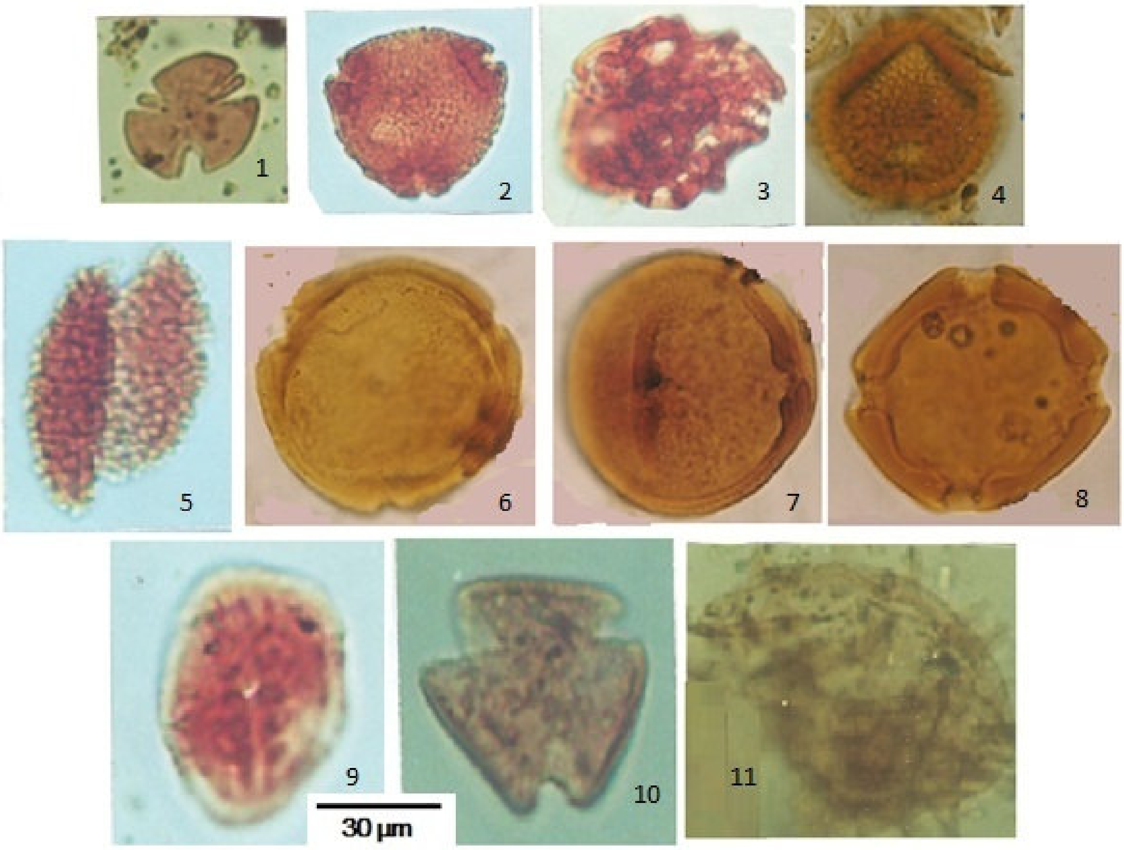
Family	Botanical Nomenclature	Morphogeneric Name
PTERIDOPHYTES		
Parkeriaceae	*Ceratopteris cf cornuta*	*Magnastriatites howardii*
Polypodiaceae	?*Pteris* sp.	*Polypodiaceisporites gracilimus*
	Adiantum? Sp.	*Leotriletes adriannis*
		Laevigatosporites gracilis
	Polypodium sp.	*Verrucatosporites* spp.
	Polypodium vulgare	*Verrucatosporites usmensis*
SPERMATOPHYTES		
ANGIOSPERMS		
Monocotyledons		
Arecaceae/Palmae	*Elaies guineensis*	*Trichotomonosulcites* sp.
	aff. *Iriartea* sp.	?*Racemonocolpites hians*
Poaceae		*Monoporites annulatus*
Dicotyledons		
Acanthaceae	*Justicia* sp.	*Multiareolites formosus*
	Issoglossa lactea	*Nummulipollis neogenicus*
Annonaceae	*Cleistopolis patens*	*Gemmamonocolpites* spp.
Asteraceae	*Aspillia Africana*	*Echitricolporites spinosus*
Cyperaceae	*Cyperus* sp.	*Cyperaceaepollis* sp.
Euphorbiaceae	*Amanoa oblongifolia*	*Retitricolporites irregularis*
	Alchornea cordifolia	*Psilatricolporites operculatus*
Rhizophoraceae	*Rhizophora* sp.	*Zoncostites ramonae*
Rubiaceae	*Borreria verticilatta*	*Retistephanocolpites gracilis*
	Canthium sp.	*Canthiumidites* sp./*Retitriporites* sp.
Sapotaceae	*Butryrospermum* sp.	*Sapotaceoidaepollenites* spp.
Apocyanaceae	*Tabernaemontana crassus*	*Psilatricolporites crassus*
		Psilamonocolpites spp.
	Psychotria sp.	*Retitricolpites bendensis*
Clusiaceae	*Symphonia globulifera*	*Pachydermites diederixi*
	Brachystegia cf. *eurycoma*	*Peregrinipollis nigericus*
Caesalpiniaceae	*Anthonotha gilletti*	*Striatricolporites catatumbus*
Lythraceae	*Crenea* sp.	*Verrutricolporites rotundiporis*

Table 2.Palynoecological Group/ Vegetation Zone

MANGROVE	*Foveotricolporites crassiexinous* (*Avicennia* type), *Psilatricolporites crassus* (*Tabermaemontanacrassa*) *Spinizonocolpites baculatus* and *S. echinatus* (*Nypa fruticans*).
FRESHWATER SWAMP (FS)	*Circulinaparvus* (*Nymphaelotus*), *Pachydermites diederixi* (*Symphonia globulifera*), *Proteacidtes* spp (*Protea* spp), *Retibrevitricolporites obodoensis* and *Uacapa* spp.
OPEN COASTAL VEGETATION (OCV)	*Echitricolporites spinosus* (Asteraceae), *Nummilipollisneogenicus* (*Isoglossa lactea*), *Perfotricolporitesdigitatus*, Chenopodiaceae/Amaranthaceae and Asteraceae.
RAINFOREST	*Elaeis guineensis* (Palmae), *Daniellaogea*, Sapotaceae and *Canthium* spp.
SPORES	*Verrucatosporites usmensis*, Monolete and Trilete spores
POACEAE	*Monoporites annulatus*
RIVERINE	*Peregrinipollis nigericus (Brachystegia cf eurycoma*) and *Psilatricolporites operculatus* (*Alchornea cordifolia*).
SAVANA	*Polyadopollenites* spp, *Striatricolpites catatumbus (Anthonotha gilletti)*, *Retistephanocolporites gracilis* (*Borreria* spp), *Bridellia cf feruginea*, *Entada* spp, *Parkia biglobosa* and *Lannea* spp. and *Hymenocardia acida*
MONTANE	*Podocarpus milanjianus*, *Multiareolites formosus* (Justicia spp), *Alnipollenites versus* (Alnus spp) and *Ilex mitis* type.

Zonocostites ramonae (*Rhizophora* spp.) was excluded from the mangrove group because of its dominant characteristic in the study area. Its high pollen productivity in the coastal-continental shelf of the Niger Delta has been noted with an average of 66, 432 and 531,460 grains per anther and flower respectively (Sowunmi, 2004). It is particularly abundant in the three wells studied with a mean occurrence of 77% indicating a warm and humid climatic condition.

The average percentages of the palynological groups at each depth in the studied wells were averaged to know the nature of the occurrence of each group. The mean percentages were classified as either high or low (based on the chosen standard; 9%) within the system tracts delineated from the composite logs of the studied wells. The theoretical model used for this study to establish the character of deposition of the system tracts, and the miospores contained are discussed with reference to the models of Posamentier *et al*,.(1988), Morley (1995) and Posamentier and Allen (1999).



1.*Zonocostites ramonae,*2. *Retibrevitricolporites obodoensis*,
3. *Peregrinipollis nigericus,*4. *Fovoetricolporites crassiexinous*,
5. *Racemonocolpites hians,*6-7. *Psilatricolporites crassus*,
8. *Pachydermitesdiederixi*, 9. *Multiareolites formosus,*
10. *Fovoetricolpites crassiexinous* 11. *Spinizonocolpites baculatus,*

Palynological Signatures of the Studied Wells

It has been established that climate and eustacy had significant control on the vegetation of the source areas of the palynomorphs in marine sediments (Germeraad *et al.*, 1968; Evamy *et al.*, 1978; Batten, 1984; Poumot, 1989; Morley and Richards, 1993; Abbink*et al.*, 2004). Nine palynoecological groups were differentiated using Nearest Living Relatives (NLR) or botanical affinities of the fossil taxa. Therefore based on the calculations of the mean percentages of the pollen sums of the palynoecological groups, 9% and above for the mangrove group (excluding the over-represented *Rhizophora*) is taken to be high while lower values are considered to reflect low representation. Similar calculations were carried out for other palynoecological groups giving the following average values: fresh water swamp, 8%; open coastal vegetation, 5%; spores, 17%; Poaceae, 36%; riverine, 9%; savanna, 6%; rainforest, 14% and montane, 12% (Tables 3 a&b).

Table 3a. Palynological Signature in the Studied Wells

Syst. Tracts \ Paly. gps.	LST			TST			HST			Possible determinant factor
	CHV-1	CHV-2	CHV-3	CHV-1	CHV-2	CHV-3	CHV-1	CHV-2	CHV-3	
Mangrove	High 9.2%	High 11.8%	Low 5.0%	Low 7.7%	High 15.6%	Low 5.0%	Low 7.7%	High 11.1%	Low 8.5%	Climate & Eustacy
FS	High 13.6%	Low 5.3%	Low 1.4%	High 10.8%	High 10.4%	Low 3.9%	High 9.8%	High 9.4%	High 8.2%	Fluvial/Climate
OCV	High 7.7%	Low 4.8%	High 5.7%	Nil	Low 3.9%	High 8.6%	Low 2.6%	Low 4.6%	High 10.7%	Eustacy
Spores	Low 4.0%	Low 12.9%	Low 14.7%	Low 11.3%	High 23.7%	Low 14.2%	High 15.7%	High 25.1%	High 15.6%	Fluvial/Climate
Poaceae	Low 19.0%	High 50.6%	High 44.3%	Low 21.0%	High 45.8%	High 37.2%	Low 23.6%	High 41.7%	High 41.3%	Ubiquity
Riverine	High 20.3%	Low 2.0%	Nil	Low 4.9%	Low 4.5%	Low 4.0%	High 31.4%	Nil	Low 2.7%	Fluvial
Savanna	Low 1.7%	Low 5.6%	High 13.4%	Low 2.3%	High 12.8%	Low 5.3%	Low 4.0%	High 7.9%	Low 3.4%	Distance
Rainforest	High 20.8%	Low 3.8%	Low 6.1%	High 26.2%	Low 9.8%	Low 3.8%	High 33.2%	High 17.5%	Low 4.0%	Fluvial/Climate
Montane	High 21.4%	Low 5.6%	Nil	High 23.3%	Low 8.6%	Low 3.0%	High 25.0%	Low 5.8%	Low 3.6%	Transportation medium(air/water)

Table 3b. Average of percentages of palynoecological groups in system tracts from the studied wells and their percentage proportions

Palynoecological Group	**LST %**	**TST %**	**HST %**	**AV %**
Mangrove	8,9	9.4	9.1	**9**
FS	6.8	8.4	9.1	**8**
OCV	6.1	4,2	6.0	**5**
Spores	10.5	16.4	18,8	**17**
Poaceae	38.0	34.7	35.5	**36**
Riverine	11.2	4,5	11.4	**9**
Savana	6.9	6.8	5.1	**6**
Rainforest	10.2	13.3	18.2	**14**
Montane	13.6	11.6	11.4	**12**

The analysis of the palynoecological groups shows that, in the shale-dominated sequences of shallow offshore, western Niger Delta, lowstand systems tract (LST) records higher proportions of savanna and open coastal vegetation and high value of riverine elements. Occurrences of freshwater swamp, spores, rainforest and montane groups are low. Transgressive systems tract (TST) is characterized by higher proportions of mangrove and montane groups as well as high values of freshwater swamp, spores and rainforest groups along with low values of open coastal vegetation and riverine groups. Higher values of freshwater swamp, open coastal vegetation, riverine and rainforest groups are recorded in the highstand systems tract (HST). High values are recorded for mangrove and montane groups while savanna records low value. The value of Poaceae in all the system tracts is consistently high probably due to its ubiquitous nature.

The low values of fresh water swamp, spores and rainforest groups and higher proportions of savanna and open coastal vegetation within the LST could have been due to the dry climatic condition that usually prevails during the deposition of the tract. Higher proportion of fresh water and spores group characterize HST because of the expansion of the upper deltaic setting.

Higher and high proportions of mangrove group within TST and HST respectively are consistent with the expansion of brackish water environment setting during transgression and aggradation. The combined effect of air transportation and marine transgression favours the higher proportion of montane group within TST in the studied wells. Wind carries the pollen into the sea while transgression brings them back to the coastal and shallow offshore areas. Though there is usually low wind activity during the early part of HST, montane group records high proportion because their buoyant characteristic ensures deposition from suspension as long as aggradation condition persists.

Occurrence of riverine group is high in both HST and LST but low in TST. The highest occurrence in HST indicates the combined effect of a substantial fresh water influx and progradation characteristic of the tract. Higher proportion in LST indicates fresh water influx from rivers.

The average occurrence of 77% of *Zonocostites ramonae* (*Rhizophora* spp.) in the studied wells indicates that it cannot be included in the palynoecological group as a paleoclimatic tool in the shallow offshore, western Niger Delta. Its prolific production will mask the effect of other pollen forms and hence yield no meaningful inference.

Conclusion

Palynological signature bioevents can be of regional importance since these events reflect climatic and eustatic changes. The relationship in the occurrence trends of the palynoecological groups in relation to system tracts in the studied wells suggests LST records higher proportions of savanna and open coastal vegetation, TST is characterized by higher proportions of mangrove and montane groups while higher values of freshwater swamp and open coastal vegetation are recorded in the HST. The application of palyno-sequence stratigraphy in the shallow offshore western Niger Delta should provide solutions to some pre-drilling and drilling problems, since it will allow correlations of genetically related chronostratigraphic units, irrespective of the mode of deposition; it also offers a model for a better recognition of stratigraphic plays.

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