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Palynological Studies of Sediments from North Chioma-3 Well, Niger Delta and its Palaeoenvironmental Interpretations

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Abstract: Problem statement: The Niger Delta Nigeria stands among the world's best-studies delta complexes but its superficial deposits are among the poorest known publicity. In spite of continuous oil prospecting production in the area, there is still a paucity of published information and data on the palynology of the Niger Delta. This study aimed at reconstructing the palaeoenvironments of the Niger Delta from a detailed palynological framework. **Approach:** Twenty ditch cutting samples from 1271-2131 m from North Chioma-3 well, Niger Delta, Nigeria, were studied and analyzed for their lithological and palynological contents. This essentially comprised of the lithological and textural characteristics survey and laboratory processing using the method of pollen analysis. **Results:** Seven lithological units were delineated for the well sediments made up sandy shale, shaly sand and shale typical of the Benin and Agbada Formations of the Niger Delta, Nigeria. The sediments of the investigated intervals are fairly rich in microflora which documents diverse, fairly well-preserved palynomorphs. A total of 46 pollen and spore species were recovered and identified from the well. The dominant pollen grains are those of *Rhizophora* spp., Poaceae and spores of pteridophytes and fungi. Palaeoecological interpretation of the interval suggests a mangrove swamp environment for the sediments and the high percentage occurrence of *Rhizophora* spp. indicates the abundance of mangrove swamp vegetation in the environment. Four pollen zones (I-IV) were recognized from the pollen diagram which reflects vegetational and climatic fluctuations during the period the studied sediments were deposited. **Conclusion:** There was a prevailence of savanna vegetation during the period covered by zone I, typified by the consistent occurrence of Poaceae pollen indicating cool and dry climate. An establishment of both wet and warm climate as well as mangrove forest vegetation was indicated for the periods covered by zones II, III and IV, with the largest extension of mangrove vegetation occurring in zone III.

Key words: Tertiary strata, pollen zones, mangrove vegetation, poaceae pollen, vegetational changes

INTRODUCTION

Information on the fossil flora in the Niger Delta, Nigeria is very limited because it has not been sufficiently studied. The initial contributions to our knowledge of the microflora in Nigeria were made by Hoeken-Klinkenberg (1964) and Clarke (1966). Clarke (1966) identified *Peregrinipollis nigericus* (*Brachystegia eurycoma*) as a new a species in the upper Tertiary of Nigeria. Similarly Clarke and Frederiksen (1968) recovered and described eight new species of pollen assignable to three new genera: *Marginipollis*, *Areolipollis* and *Nummulipollis* in the sediments of late Tertiary strata in Nigeria. They concluded that these forms are related to the modern families Acanthaceae and Lecythidaceae.

The most comprehensive contribution to our knowledge on the palynology of the Niger Delta was made by Germeraad *et al.* (1968). The study was based on the palynomorph assemblages of the Tertiary sediments of three tropical areas: parts of South America, Asia and Africa (Nigeria).

Apart from these and a few others (Alagoa *et al*., 1988; Oboh *et al*., 1992; Ige, 2009; 2011) not much work has been carried out on the palynology of the Niger Delta, Nigeria inspite of continuous oil prospecting in the area. This paucity of available information serves as impetus to carry out the present

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research aimed at reconstructing the environments of the Niger Delta, Nigeria in an effort to further contribute to the palaeofloristic diversities of the Niger Delta region.

MATERIALS AND METHODS

Source of materials: The ditch cutting samples for this study comes from North-Chioma 3 well, Niger Delta, Nigeria. It is one of the several wells drilled across Niger Delta by oil companies operating in the area. The Niger Delta is situated on the continental margin of the Gulf of Guinea on the West Coast (equatorial) of Central Africa. It lies between Latitude 3^0 and 6^0N and Longitude 5^0 and 8^0E.

The Delta is one of the world's largest, with the subaerial portion covering about 75,000 Km^2 and extending more than 300 Km. Compared with other African basins, it is the most prominent and actually the largest delta in Africa.

Lithological and laboratory methods: About 20 ditch cutting samples were analyzed for their lithological characteristics and palynological assemblages.

Lithological and textural characteristics: A lithological survey of each sample was carried out and the textural characteristics (grain size, shape, sorting) were determined using the standard grain size scale in the American/Canadian stratigraphic code.

Laboratory processing: One gram of each sample was prepared for pollen analysis in the palynology laboratory of the National Botanical Research Institute, Lucknow, India. Pollen sample preparation (Erdtman, 1969; Faegri and Iversen, 1966) included treatment with HF overnight, HCL, 20% KOH and acetolysis. The techniques were aimed largely at removing the non-pollen materials in the sediment and concentrating the palynomorphs as much as possible.

Samples were stored in 100% glycerine to prevent the palynomorphs from drying out. Ten microlitres (10µL) of the sample was transferred from the storage vial to the microscope slide for microscopic examination. Two slides were prepared in this way for each sub-sample. The prepared slides were studied i.e. scanned and counted, with the light microscope using the high power (×40) objective lens and photomicrographs of selected palynomorphs were taken with a Leica ATC 2000 Research microscope fitted with a digital camera (Nikon coolpix 4500) in the Palynology laboratory, National Botanical Research Institute, Lucknow, India.

Pollen type identification and nomenclature: Pollen and spore types were identified under a Leitz 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 given form-generic names. Those grains that could not be identified at all due to limited human knowledge are listed as unidentifiable. Spores were identified as either fungal or fern spores (Laevigatosporites, Verrucatosporites, Monolete and Trilete).

Pollen spectra and diagram constitution: The pollen spectra of the samples were constituted and the percentage composition of each pollen and spores was calculated relative to a pollen sum (Moore and Webb, 1978; Lezine and Vergnaud-Grazzini, 1993). The approach of Sowunmi (1981) was followed in classifying the taxa into different phytoecological groups. The pollen diagram was constructed using Polpa computer software. The percentage composition of individual pollen and spores as listed under the phytoecological groups were generated and used in the construction of the pollen diagram.

RESULTS

Lithology: North Chioma -3 well samples were divided into seven horizons (A-G) during this study on the basis of textural characteristics. The seven lithologic units, from top to the base of the well, are shown in Fig. 1.

The column is characterized by the presence of shaly and sandy shale materials with an occasional sequence of very coarse to coarse, moderately well sorted sand grains.

The sand grains are smooth, sub-angular, sub-rounded to rounded and light brownish grey and greyish brown in color, while the shale is grey and massive to fissile.

Palynological analysis: The percentage composition of the pollen and spores are listed in Table 1 while the major palaeo-vegetation communities in the Well area, is presented in Table 2. The pollen diagram for the well is presented in Fig. 2. According to marked vegetation changes reflected in the pollen diagram, (Fig. 2), four pollen zones were recognized in the studied sections.

Table 1: Components of the pollen spectra(occurrence represented as percentage of pollen sum)

Species/depth (m)	1271	1344	1381	1436	1472	1509	1545	1581	1600	1618
Acacia spp										
Acrostichum aureum								8.3		
Alcornea cordifolia		9.5	8.2	7.4						
Asteraceae										
Avicennia spp					13.6	6.8			9.9	
Brachystegia eurycoma										
Canthium spp						3.4				
Carapa procera					9.1					
Ceraptoteris spp			5.4		4.5		3.3			
Chenopodiaceae/Amaranthaceae									15	
Cyperaceae	14.2	9.5	8.2	7.4		4.8	3.3	8.3		25
Daniellia olliveri										
Dipterocarpus arboccarpifolius	14.2									
Elaeis guineensis				3.8		3.4				
Fungal spore	23.8	14.2	26.9	14.8	31.8	6.8	9.7	12.5	15	
Fusiformis spp	9.5									
Grewia mollis										
Hyphaena thebaica			8.2	7.4	4.5				5.1	25
Laevigatospoorites spp					13.6	10.2				
Lonchocarpus spp							9.7			
Macaranga heudelotii						6.8	9.7			
Malacantha alnifolia				7.4			9.7			
Marginipollis concinnus										
Monoletespore	14.2	23.2	10.8	22.2	9.1	27.2	25.7	45.8	24.9	50
Morelia snegalensis			5.4	7.4						
Multiareolites spp										
Multicellaesporites										
Nympheae lotus			5.4		4.5	3.4				
Pandanus candelabrum	9.5									
Pentaclethra macrophylla		4.8				3.4		4.2	5.1	
Pentadesma butyracea							12.8			
Phyllanthus pentandrus								4.2		
Poaceae	47.6	33.3	29.7	33.3	18.2	34	16.1	37.5	39.6	50
Podococcus barteri									15	
Protea ellioti										
Pycnanthus spp		4.8								
Racemonocolpites hians							3.3			
Retibrevitricolporites obodoensis			2.8							
Retimonocolpites spp										
Rhizophora spp	66.7	76.2	45.8	40.7	113.6	88.4	70.6	79	104.8	75
Striamonocopites rectastriatus										
Symphonia globulifera		9.5	5.4					8.3	15	
Synsepalum dulcificum			2.8		9.1	6.8	3.3	8.3		
Trukete spores	14.2	9.5	10.8	11.2	9.1	17	6.4		5.1	
Uapaca paludosa		14.2		3.8						
Unidentified										25
Verrucatospovites spp				7.4			3.3		5.1	

Table 1: continue

Species/Depth(m)	1655	1811	1847	1884	1911	1948	1984	2021	2094	2131
Acacia spp										15.2
Acrostichum aureum										
Alcornea cordifolia										
Asteraceae		4.8	3.6							
Avicennia spp										
Brachystegia eurycoma										
Canthium spp										
Carapa procera										
Ceraptoteris spp				7.7						
Chenopodiaceae/Amaranthaceae										
Cyperaceae		4.8				33				7.8
Daniellia olliveri										15.2
Dipterocarpus arboccarpifolius										
Elaeis guineensis										
Fungal spore	49.6	19	42.7	46.1	28.2	33	89.3	16.7	38.3	38.3

Table 1: Continue

Fusiformis spp									4.6	
Grewia mollis								16.7		
Hyphaena thebaica		4.5			14.5					7.8
Laevigatospoorites spp			7.1						9.6	
Lonchocarpus spp										
Macaranga heudelotii										
Malacantha alnifolia										
Marginipollis concinnus									9.6	
Monoletespore	37.6	19	21.4	23.1	14.5	17			19.1	7.8
Morelia snegalensis										
Multiareolites spp									4.6	
Multicellaesporites		4.8	3.6						9.6	
Nympheae lotus										
Pandanus candelabrum										
Pentaclethra macrophylla										
Pentadesma butyracea										
Phyllanthus pentandrus										
Poaceae	12.8	33.3	10.8	30.8	71	66	44.6	66.7	38.3	60.9
Podococcus barteri										
Protea ellioti								16.7		
Pycnanthus spp										
Racemonocolpites hians										
Retibrevitricolporites obodoensis										
Retimonocolpites spp		4.8								
Rhizophora spp	27.1	47.6	46.4	69.2	14.5	33			14.2	23.0
Striamonocopites rectastriatus		9.5	7.1							
Symphonia globulifera										
Synsepalum dulcificum										
Trukete spores	12.8	9.5	3.6	7.7	14.5					
Uapaca paludosa										
Unidentified		9.5	7.1				14.9		4.6	7.8
Verrucatospovites spp		9.5		15.4			10.7	16.7	4.6	

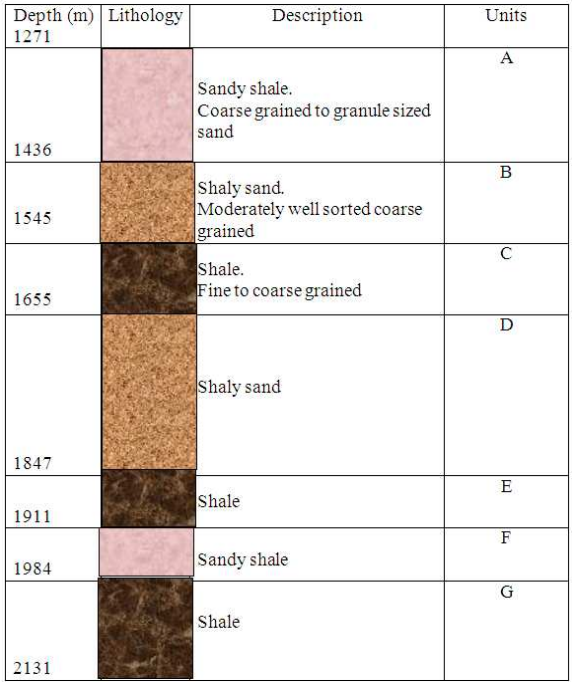

Fig. 1: Lithology of North Chioma-3 well, Niger Delta, Nigeria

Description of the pollen diagram:

Zone I (2131-1911m): At the beginning of this zone, there was a very low to zero percentage of mangrove forest vegetation (*Rhizophora* spp. 23.0, 14.2%) at 2131 and 2094m respectively. There were zero percent occurrences at 2021 and 1984m respectively. In sharp contrast to this feature, a higher percentage of Poaceae pollen (60.9-71%) was recorded for this zone (Table 2). A total absence of fresh water swamp species and lowland forest species is a major noticeable feature of this zone. There was a noticeable presence of Cyperaceae pollen (7.8-33%) in this zone. There were also noticeable fluctuations in the occurrence of ferns. The zone also witnessed the presence of savanna elements typified by *Acacia* spp., (15.2%); *Protea elliotii* (16.7%); *Erythrophyleum* spp. (17.0%); *Daniellia oliverii* (15.2%) and *Grewia mollis* (16.7%).

Zone II (1911-1618m): This zone is marked by a sudden increase in the percentage occurrence of *Rhizophora* pollen, from 0% at 2021m and 1984m and between 14.2-33% in zone 1, to 69.2% at1884m and 75% at 1618m and a decrease at 1655m (27.1%). There is also an overall increase in the percentage occurrence of Poaceae in this zone (30.8-50%)

Table 2: The major palaeovegetation communities in North-Chioma 3 well area

	Mangrove forest			Fresh water swamp forest					
Depth (m)	*Acrosticlu aureum*	*Acicennia spp*	*Rhizophora spp*	*Carapa procera*	*Lonchocarpus spp*	*Macaranga heudelotii*	*Pandoanus candelabrum*	*Symphonia globulifera*	*Uapaca paludosa*
1271	-	-	66.7	-	-	-	9.5	-	-
1344	-	-	76.2	-	-	-	-	9.5	14.2
1381	-	-	45.8	-	-	-	-	5.4	-
1436	-	-	40.7	-	-	-	-	-	3.8
1472	-	13.6	113.6	9.1	-	-	-	-	-
1509	-	6.8	88.4	-	-	6.8	-	-	-
1545	-	-	70.6	-	9.7	9.7	-	-	-
1581	8.3	-	79.0	-	-	-	-	8.3	-
1600	-	9.9	104.8	-	-	-	-	15	-
1618	-	-	75.0	-	-	-	-	-	-
1655	-	-	27.1	-	-	-	-	-	-
1811	-	-	47.6	-	-	-	-	-	-
1847	-	-	46.4	-	-	-	-	-	-
1884		14.5	69.2	-	-	-	-	-	-
1911	-	-	14.5	-	-	-	-	-	-
1948	-	-	33.0	-	-	-	-	-	-
1984	-	-	-	-	-	-	-	-	-
2021	-	-	-	-	-	-	-	-	-
2094	-	-	14.2	-	-	-	-	-	-
2131	-	-	23.0	-	-	-	-	-	-

Table 2: continue

	Low land Rain forest								Fringing forest	
Depth (m)	*Canthium spp*	*Pentadesma butyracea*	*Pentaclethra macrophylla*	*Phyllanthus pentandrus*	*Podococus barteri*	*Pycnanthus spp*	*Synsepalum dulcificum*	*Malacantha alnifolia*	*Brachystegia eurycoma*	*Morelia senegalensis*
1271	-	-	-	-	-	-	-	-	-	-
1344	-	-	4.8	-	-	4.8	-	-	-	-
1381	-	-	-	-	-	-	2.8	-	-	5.4
1436	-	-	-	-	-	-	-	7.4	-	7.4
1472	-	-	-	-	-	-	9.1	-	-	-
1509	3.4	-	3.4	-	-	-	6.8	-	-	-
1545	-	12.8	-	-	-	-	3.3	9.7	-	-
1581	-	-	4.2	4.2	-	-	-	-	-	-
1600	-	-	5.1	-	15	-	-	-	-	-
1618	-	-	-	-	-	-	-	-	-	-
1655	-	-	-	-	-	-	-	-	-	-
1811	-	-	-	-	-	-	-	-	-	-
1847	-	-	-	-	-	-	-	-	9.5	-
1884	-	-	-	-	-	-	-	-	-	-
1911	-	-	-	-	-	-	-	-	-	-
1948	-	-	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	-	-	-	-
2021	-	-	-	-	-	-	-	-	-	-
2094	-	-	-	-	-	-	-	-	-	-
2131	-	-	-	-	-	-	-	-	-	-

Table 2: Continue

		Savannah					Secondary forest		Fern spores			
Depth (m)	Poaceae	*Acacia spp*	*Erythurophyleum suaveolens*	*Danrielia oliverii*	*Grewia mollis*	*Protea elliotii*	*Alchornea cordifolia*	*Elaeis guineernsis*	*Verrucatosporites usmensis*	*Laevigatosporites*	Monolete spore	Trilete spore
1271	47.6	-	-	-	-	-	-	-	9.5	-	14.2	14.2
1344	33.3	-	-	-	-	-	9.5	-	-	-	23.2	9.5
1381	29.7	-	-	-	-	-	8.2	-	-	-	10.8	10.8
1436	33.3	-	-	-	-	-	7.4	3.8	7.4	-	22.2	11.2
1472	18.2	-	-	-	-	-	-	-	-	13.6	9.1	9.1
1509	34	-	-	-	-	-	-	3.4	-	10.2	27.2	17
1545	16.1	-	-	-	-	-	-	-	3.3	-	25.7	6.4
1581	37.5	-	-	-	-	-	-	-	-	-	45.8	-
1600	39.6	-	-	-	-	-	-	-	5.1	-	24.9	5.1
1618	50	-	-	-	-	-	-	-	-	-	50	-

Table 2: Continue

1655	12.8	-	-	-	-	-	-	-	-	-	37.6	12.8
1811	33.3	-	-	-	-	-	-	-	9.5	-	19	9.5
1847	10.8	-	-	-	-	-	-	-	-	7.1	21.4	3.6
1884	30.8	-	-	-	-	-	-	-	15.4	-	23.1	7.7
1911	71	-	-	-	-	-	-	-	-	-	14.5	14.5
1948	66	-	-	17.0	-	-	-	-	-	-	17	-
1984	44.6	-	-	-	-	-	-	-	10.7	-	-	-
2021	66.7	-	-	-	16.7	16.7	-	-	16.7	-	-	-
2094	38.3	-	-	-	-	-	-	-	4.6	9.6	19.1	-
2131	60.9	15.2	15.2	-	-	-	-	-	-	-	7.8	-

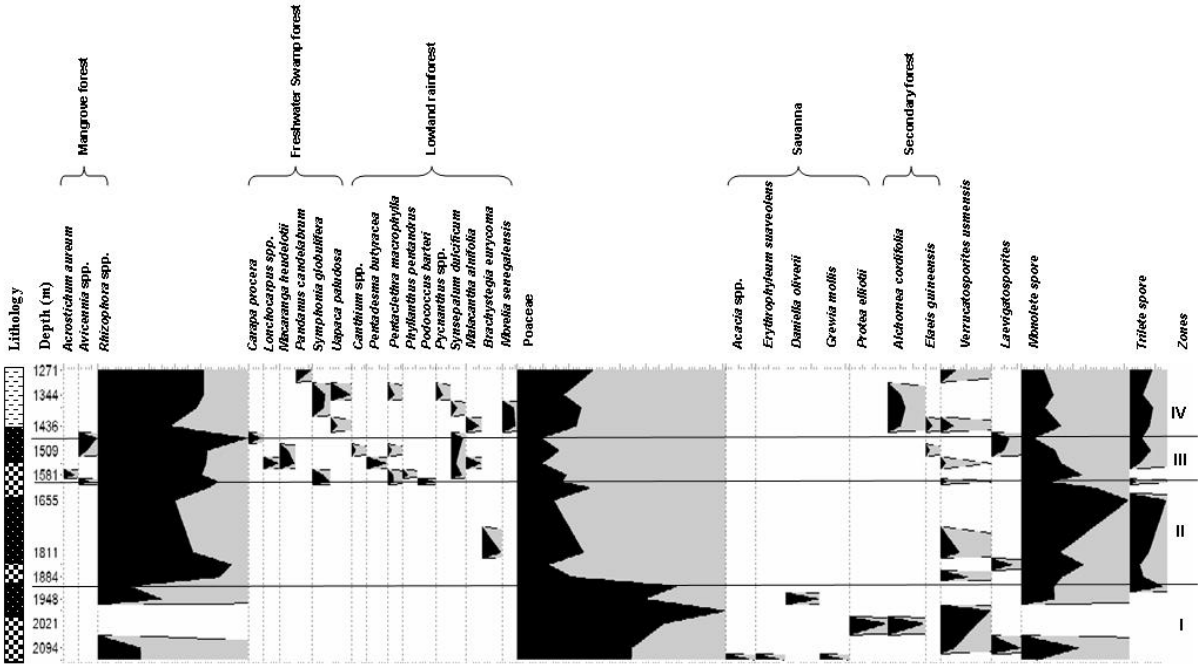

Fig. 2: Pollen diagram of North Chioma-3 well, Niger Delta, Nigeria

The zone also witnessed high percentage occurrence of ferns. Savanna elements are not represented. An almost total absence of lowland rainforest vegetation communities was noted in this zone with the exception of the occurrence of riverine/fringing forest represented by only *Brachystegia eurycoma* (9.5%).

Zone III (1618-1472 m): This zone is characterised by a consistent increase in percentage occurrence of *Rhizophora* pollen. The highest percentage occurrence of 113.6-104.8% for *Rhizophora* at 1472 and 1600 m respectively was noted in this zone. The presence of other mangrove plant communities (*Avicennia* spp. 6.8-13.6%) and *Acrostichum aureum* (8.3%) was also noted in this zone. Relatively low percentages of Poaceae were a major feature in this zone with the average percentage occurrence of 29.08%.

The zone is also characterized by the occurrence of Cyperaceae with average percentage occurrence of 3.28%. The lowland rain forest vegetation occurring for the first time is represented by *Canthium* spp. (3.4%), *Malacantha alnifolia* (9.7%), *Pentadesma butyracea* (12.8%), *Pentaclethra* spp. (3.4-5.1%), *Phyllanthus pentandrus* (4.2%), *Podococcus barteri* (15%) and S*ynsepalum dulcificum* (3.3 - 9.1%). Before this period, lowland rain forest elements were non-existent. Fresh water swamp forest vegetation was also noted in this zone. It is represented by *Carapa procera* (9.1%), *Lonchocarpus cyanescens* (9.7%), *Macaranga heudelotii* (6.8-9.7%) and *Symphonia globulifera* (8.3-15.0%).

Large representation of fern spores was also a major feature with its highest occurrence in this zone.

Zone IV (1472-1271 m): This zone witnessed a significant drop in the occurrence of *Rhizophora* from

113.6% at 1472-40.7-23.3% at 1436m. The zone also witnessed the consistent fair occurrence of Poaceae (29.7-47.6%). There are low occurrences of fresh water swamp forest represented by *Symphonia globulifera* (5.4-9.5%), *Uapaca* spp. (3.8-14.2%) and *Pandanus candelabrum* (9.5%). The lowland rain forest vegetation communities are also present in this zone. It is characterised by *Malacantha alnifolia* (7.4%), *Pycnanthus angolensis* (4.8%), *Synsepalum dulcificum* (2.8%) and *Pentaclethra macrophylla* (4.8%).

Fringing/riverine forest vegetation was represented only by *Morelia senegalensis* (5.4-7.4%). Secondary forest represented by *Alchornea cordifolia* (7.4-9.5%) and *Elaeis guineensis* (3.8%) was also noticed in this zone.

DISCUSSION

Lithologic units: Figure 2 shows the summary of the lithology for the well. A formal lithostratigraphic subdivision of the Tertiary Niger Delta was established by Short and Stauble (1967), to consist of Benin Formation, Agbada Formation and Akata Formation.

In this study, the first lithologic unit (A) between 1271-1436m is predominantly sandy with very thin shale. The sand is predominantly characterized by fine to coarse textured sands and sandstones (Short and Stauble 1967; Avbovbo, 1978; Whiteman, 1982). The textural characteristics of the sand are moderately well sorted, sub-angular and rounded.

The underlying lithologic section (B) 1436-1545m is made up of massive shale with minor occurrence of sand alternations at intervals. The texture of the sand bodies is coarse, sub-angular to subrounded and poorly sorted.

The result also showed that five lithologic units (C-G) are present between the intervals 1545-2131 m. The lithology is predominantly alternation of sand and shale sequences of varying thickness while three of the units (C, E and G) comprise massive shale without sand bodies.

Vegetation Development in and around the Niger Delta region, Nigeria during the Late Tertiary:

Zone I (2131-1911 m): The relatively high percentage occurrence of Poaceae, the occurrence of savanna elements and the total absence of fresh water swamp forest in this zone suggest a dry condition during the period of deposition of this sediment. This pollen record indicates that open vegetation with extensive savanna dominated the vegetation. Vermoere *et al*. (1999) in a study in SW Turkey reported that high percentages of Poaceae pollen types in sediment points to drier local conditions.

There was a significant increase in the values of fungal spores in this interval with its highest occurrence of 89.3% at 1984m (Table 2). This further supports the suggestion that conditions were adverse during this period. The increase of Cyperaceae and very low occurrence of mangrove swamp species (0-33.0%) is probably related to a lower sea level. The occurrence of small quantities of *Rhizophora* pollen in this zone was probably due to minor local short-lived transgressions of the sea inland, thereby allowing only very limited extension of mangrove vegetation near the coast. The absence of *Rhizophora* pollen at 2021 and 1984m suggests that some drastic climatic change especially towards aridity featured prominently during this period.

Zone II (1911-1618 m): The first signs of a gradual development and expansion of mangrove swamp forest vegetation is visible in this zone by the gradual and consistent rise in the values of mangrove pollen as is indicated in the pollen record. Sowunmi had reported that an abundance of fossil *Rhizophora* above 40% in sediments indicates a good representation of mangrove swamp, suggestive of a humid tropical lowland climate.

A period of unstable and unfavourable climatic conditions is suggested for this zone with savanna vegetation well established probably in the coastal areas. Germeraad *et al*. (1968) reported that abundance of Poaceae in the tropics is largely confined to more open vegetation such as is found in river valleys. The non-to low occurrence of lowland rain forest, fresh water swamp forest and higher occurrence of Poaceae further points to this open vegetation theory.

An initial rise in sea level with the mangrove vegetation increasing in extent is suggested for this zone. The fluctuations in percentage occurrence of *Rhizophora* may probably be a result of variations in the intensity and extent of the tidal streams thereby causing fluctuations in the extent of *Rhizophora*. This rise and fall of the tides may also bring about drier conditions inland resulting in a reduction of forest vegetation and subsequently promoting the southward expansion of the savanna.

Zone III (1618-1472 m): The pollen record indicates that during this period, mangrove swamp forest vegetation was now well established. The highest percentage occurrences of *Rhizophora* pollen recorded in this zone (113.6 and 104.8%) respectively indicate a large extension of mangrove swamps and a rise in sea level with the mangrove growing extensively along the coast. It has been reported that high values of Rhizophora in pollen diagrams characterize periods with a high sea level (Lezine-Vergnaud and Grazzini,

1993; Crowley and Gagan, 1995). The presence of *Avicennia* spp. and *Achrostichum aureum* (both mangrove plants) in this zone also points to the extensive development of mangrove swamp forest during this period.

The highest occurrence of ferns and occurrence of Cyperaceae in this zone and the existence of large extension of fresh water swamp forest and lowland rain forest vegetation communities' indicate a prevalence of wet and humid conditions that supported the luxuriant vegetation communities encountered with the ground covered by pteridophyte in this zone. The occurrence of fern spores and Cyperaceae in sediments has been reported to be indicative of humid conditions (Dupont and Agwu, 1991; Tossou, 2002).

Zone IV (1472-1271 m): There was a decrease in the values of *Rhizophora* in this zone. However, a mangrove vegetation consting of mangrove plants still dominated the vegetation. A lower, probably relatively stable sea level, dominated this zone. It is suggested that environmental conditions became more adverse during this period with the low occurrence of Poaceae and decrease in the value of *Rhizophora*. Open vegetation without a closed forest canopy is suggested for the period covered by this zone. This suggestion is supported by the presence, though in low quantities, of secondary forest elements, fresh water swamp forest, lowland rain forest and riverine forest communities. The non occurrence of savanna species also points to this fact.

CONCLUSION

The pollen record of the ditch cutting samples in this study has enabled reconstruction of changing vegetation patterns during the Late Tertiary in and around the Niger Delta, Nigeria. Four pollen zones (I-IV) have been documented. Zone I was inhabited mainly by savanna vegetation while Zones II-IV were mainly dominated by mangrove swamp vegetation. Other plant communities recognized in this study as constituting the immediate vegetation of the Niger Delta area during the Late Tertiary are freshwater swamp forest and lowland rain forest.

The climate was dry and arid around the period covered by 2131-1911m which was marked by the reduction or total absence of fresh water swamp and lowland rain forest vegetation communities. This deduction is further supported by the fact that a very low occurrence of mangrove forest vegetation was recorded in this zone with concomitant very high percentages of Poaceae, which is usually associated with dry Guinea and Sudan savanna except as occasional patches in lowland rain and freshwater swamp forest. The climate changed to wet conditions from the period covered by the depth 1600-1271m. This is indicated by the relative abundance of mangrove forest, fresh water swamp forest vegetation and the abundance of monolete and trilete spores.

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