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Vegetation and Climatic History of the Late Tertiary Niger Delta, Nigeria, based on Pollen Record

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ABSTRACT

Results of a palynological analysis of sediments from Bassan-1 well, Niger delta, Nigeria are presented. These form the basis for reconstructing of the vegetation and climate history for the tertiary period covered by the studied sediments. In all the strata, pollen and spores are well represented and diversified. Five pollen zones (PZ 1-V) were recognized in the sequences penetrated by the well. Only one period of markedly dry, seasonal climate is indicated. This period corresponds to pollen zone I. It is suggested that during this period, savanna vegetation extended over most of the delta and the climate was dry and cool. This dry period was followed by wet phases corresponding to pollen zones II, III, IV and V. During these wet periods, mangrove swamp forest flourished and occupied most of the delta region with patches of freshwater swamp and lowland rain forest.

Key words: Tertiary pollen, vegetation history

INTRODUCTION

There are very few literature available on palynological data on the tertiary of the Niger delta, Nigeria. They are either of the illustrative type, with essentially systematic descriptions of pollen and spores, or are in the form of palynological zonations. Such studies includes those of Oboh *et al*. (1992), Oboh (1995) and Leroy and Dupont (1997). Several published works have appeared on deltaic environments since the late 1950s, but emphasis had always been laid on lithofacies and the relationship between benthonic micro faunas and the dynamic and hydro-chemical components of the environment (Carbonel and Moyes, 1987). Some relevant palaeoenvironmental studies carried out in West Africa for the late quaternary period include those of Behling (1996), Sowunmi (1991, 2002), Ballouche and Neumann (1995), Dupont and Welnelt (1996), Jahns (1996), Jahns *et al*. (1998), Salzmann and Waller (1998), Marchant and Taylor (2000), Mijarra *et al*. (2007) and Wille *et al*. (2007).

In spite of continuous oil prospecting and production in the Niger Delta, there is still a paucity of published information and data on the palynology of the Niger Delta. According to Whiteman, (1982), the Niger delta certainly stands among the world's best-studied delta complexes, but its superficial deposits are among the poorest known publicly. This situation is not peculiar to Nigeria alone as Morley (1991) reported that for the Southeast Asian region, there have been no adequate monographs available for Tertiary palynological studies.

The present study was therefore undertaken in order to reconstruct the palaeoenvironments of the Niger delta from a detailed, integrative palynological framework. Most of the studies carried out in the Niger delta in the past made use of form generic names, which essentially are illustrated or systematic descriptions. But this study is based on the identification of fossil palynomorphs using botanical nomenclature where possible. Identification of the possible botanical affinity is essential in order to make palaeoecological inferences, provided the limitations of this procedure are taken into cognizance. Such data will be a timely input in the present search of oil companies operating in the area for information on the flora of the Niger Delta (Okoli, 1999). It will also serve as a further contribution to knowledge on the Niger Delta environmental changes as reflected by vegetation particularly during the late tertiary period.

MATERIALS AND METHODS

Bassan-1well is an exploratory well drilled in the coastal swamp of the Niger delta, Nigeria. The Niger delta is situated on the continental margin of the Gulf of Guinea on the west coast (equatorial) of Africa (Fig. 1). It lies between Latitudes 3 °N and 6 °N and Longitudes 5 °E and 8 °E. The Niger delta is one of the world's largest, with the sub-aerial portion covering about 75,000 km^2 and extending more than 300 km from the apex to the mouth. Compared with other African basins, it is the most prominent and the largest delta in Africa (Doust and Omatsola, 1992).

The samples for this study, conducted between September, 2001 and June, 2003 come from Bassan-1 well situated in the Vampire Creek field OML 36 (Fig. 2). Bassan-1 well penetrated a total depth of 3991 m. A total of 45 samples between 1174 and 3991 m were studied. Samples for pollen analysis were treated according to the methods of Erdtman (1968) modified by Berglund and Ralska-Jasiewiczowa (1986). These consist of soaking the samples in HF overnight to remove siliceous materials, HCL treatment, heavy liquid separation and finally acetolysis to dissolve cellulose and render the palynomorphs more translucent (Moore and Webb, 1978). Two grams each from the sub-samples were used and two microscopic slides were prepared and studied for each sub-sample. The prepared slides were studied using the high power (X40) objective lens of a light microscope.

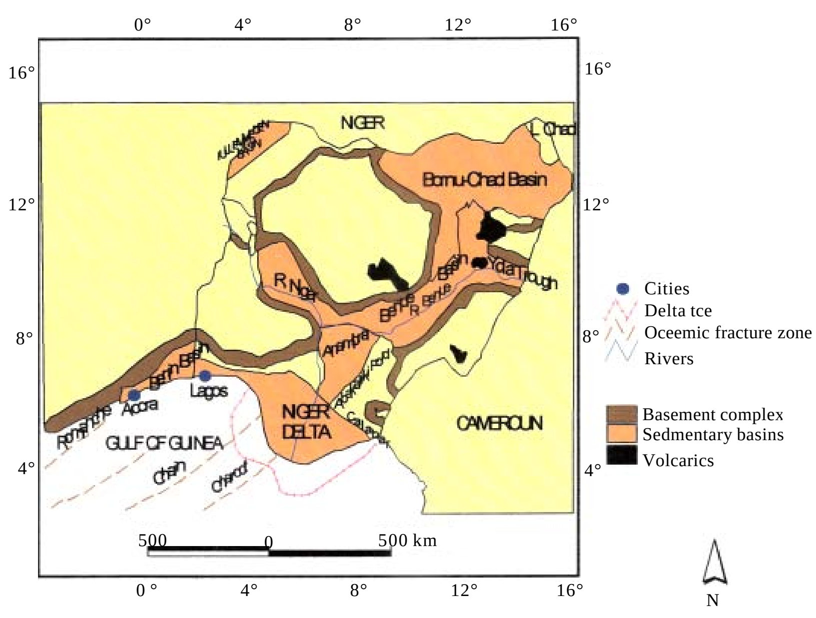

Fig. 1: Regional setting of Cenozoic Niger Delta

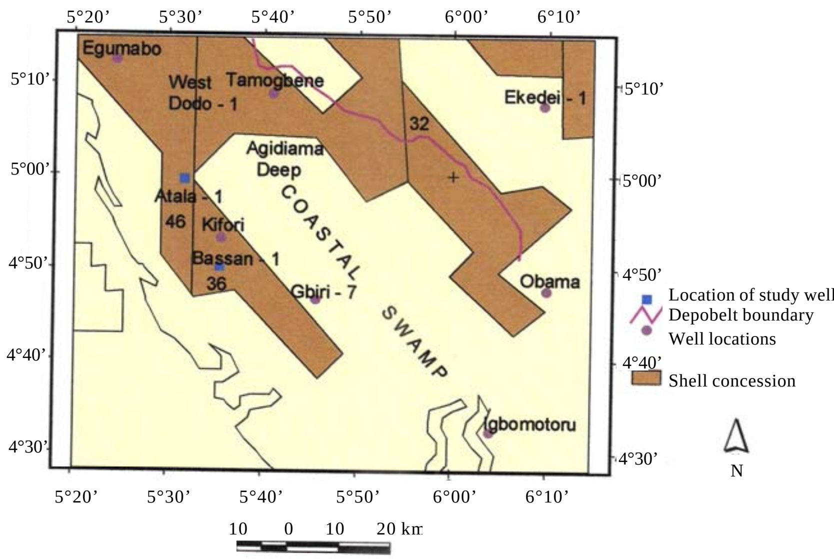

Fig. 2: Concession map of Western Niger Delta showing the location of Bassan-1 well (after SPDC, 1993)

Pollen identification was carried out at the Palynology laboratory, Department of Archaeology and Anthropology, University of Ibadan, with the aid of reference pollen slides as well as photomicrographs published in literature such as Salard-Cheboldaeff (1990), Salard-Cheboldaeff *et al.* (1992), Elsik and Ediger (1990), Sowunmi (1973, 1995) and Kuyl *et al.* (1955). From the palynomorphs recovered, the pollen spectra of the samples were constituted and the percentage composition calculated and used for the construction of the pollen diagram using Tilia and Tilia graph computer software (Grimm, 1991).

In order to reconstruct the palaeo-vegetation communities, the pollen were grouped into phytoecological units based on the present day natural distribution of their modern analogues using the approach of Sowunmi (1981a, b). Reference was made to Hutchinson and Dalziel (1954, 1963, 1968) and Germeraad *et al.* (1968) in grouping the taxa according to their extant ecological ranges.

RESULTS

The distribution of palynomorphs varied considerably from one depth to another throughout the section studied. Pollen preservation was good in most of the samples and the microflora was rich and well diversified. The total number of palynomorphs counted per gram of sample ranged from 525 to 19,541 with the lowest and highest abundances at depths 3684 and 1246, respectively. The percentage palynomorph occurrences in the zones are listed in Table 1.

Pollen zonation: The pollen diagram (Fig. 3) shows the 57 most important taxa for Bassan-1 well. These are considered to be ecologically significant and have therefore been classified according to their ecological zones. Based on marked vegetation changes reflected in the pollen diagram (Fig. 3), five pollen zones were recognized.

Table 1: Pollen zones showing percentage palynomorph occurrence

Zones	Palynomorph occurrence
Zone I (3991-2835 m)	*Rhizophora* sp., 8.3%, Poaceae, 31.2%, *Macaranga heudelotii* 2.1-5.8%, *Pandanus candelabrum* 2.5%, *Symphonia globulifera* 2.1-4.4%, *Uapaca* sp., 2.1%, Cyperaceae pollen 4.3 to 18.2%, *Canthium* sp., 2.1-11.8%, *Malacantha alnifolia* 2.1%, *Psychotria* sp., 14.3%, 0-76.2%, *Brachystegia eurycoma* 2.5-7%, *Platostoma africanum* 1.6-5.9%, *Acacia* sp., 14.2%, *Isoberlina* sp., 3.0%, *Protea elliotii* 2.3-3% and *Securidaca longepeduculata* 2-33%, *Podocarpus milianjianus*, 15.8%.
Zone II (2835-2294 m)	*Rhizophora* sp., 23.1-53.6%, Poaceae 23.2-69.9%, Ferns 57.2%, *Acacia* sp., 1.4%, *Protea eliotii* 1.4%, *Macaranga heudelotii* 2.7- 4.8%, *Symphonia globulifera* 1.1-1.6%, *Uapaca* sp., 1.1%, *Hippocratea vignei* 1.0%, *Canthium* sp., 4.2%, *Entandrophragma* sp., 1.1%, *Pentaclethra* sp., 1.4%, *Pentadesma* sp., 1.6%.
Zone III (2294-1553 m)	*Rhizophora* sp., 21.9-78.9%, *Avicennia* sp., 1.2-5.1%, Poaceae 44.4%, *Acacia* sp., 2.7-8.2%, *Erythrophleum suaveolens* 0.8-2.1%, *Grewia mollis* 3.4-7.9%, Cyperaceae 40%, *Bombax buonopozense* 0.4-0.5%, *Canthium* sp., 0.5-4.2%, *Ceiba pentandra* 1.0%, *Entadrophragma* sp., 0.4-3.1%, *Khaya* sp., 0.2-0.5%, *Kigelia africana* 0.4-1.7%, *Leea guineensis* 0.3-1.4%, *Malacantha alnifolia* 0.8-4.3%, *Maprounea membranacea* 1.4%, *Newbouldia laevis* 1.1%, *Pentadesma butyracea* 0.6-1.2%, *Phyllanthus pentandrus* 0.8-4.5%, *Piptadeniastrum africana* 0.5-1.5%, *Podococcus barteri* 0.5%, *Synsepalum dulcificum* 0.3-1.0%, *Anthocleista liebrechtsiana* 1.3-12.3%, *Carapa procera* 1%, *Dalbergia ecastaphyllum* 0.4%, *Hippocratea vignei* 0.5-1.3%, *Lonchocarpus cyanescens* 0.5% *Macaranga heudelotii* 0.9-4.6%, *Pandanus candelabrum* 1.6%, Sp.,*ondianthus preusii* 0.8-1.0%, *Symphonia globulifera* 0.2-3.9%, *Uapaca* sp., 0.5-4.3%, *Berlinia grandifolia* 0.2%, *Brachystegia eurycoma* 0.06-1.3%, *Hygrophila auriculata* 0.5-1.3%, *Morelia senegalensis* 1.0%, *Platostoma africanum* 0.4-2.4%, Sp., *athodea* sp., 0.4-2.2%.
Zone IV (1553-1355 m)	*Rhizophora* 23.3-41.8%, Poaceae 15.6-14.8% *Anthocleista liebrechstiana*, 2.4-12.1%, *Dalbergia ecastaphyllum* 0.4-1.4%, *Lonchocarpus cyanescens* 0.7%, *Macaranga heudelotii* 0.5-4.6%, Sp., *ondianthus preusii* 0.9-1%, *Symphonia globulifera* 0.3-0.6% *Uapaca* sp., 1.4-1.7%, *Bombax buonopozense* 0.3%, *Canthium* sp., 0.3-0.7%, *Combretodendron macrocarpa* 0.2%, *Entandrophragma* sp., 0.2-1.7%, *Khaya* sp., 0.2-1.0%, *Kigelia africana* 1.0%, *Leea guineensis* 0.3-1.7%, *Malacantha alnifolia* 1.7-2.3%, *Maprounea membranacea* 0.8-1.4%, *Pentadesma butyracea* 0.3-0.7%, *Phyllanthus pentandrus* 0.7-1.1%, *Podococcus barteri* 0.3-0.8, *Pycnanthus angolensis* 0.3%, *Sterculia oblonga* 0.5%, *Synsepalum dulcificum* 0.3%, *Triplochiton scleroxylon* 0.2%, *Brachystegia eurycoma* 0.6-1.3%, *Morelia senegalensis* 0.2-1.7%, *Platostoma africanum* 0.3-1.3%, sp., *athodea* sp., 0.4-0.9%, *Acacia* sp., 1.4-4.0%, *Borassus aethiopium* 0.3%, *Bridelia* sp., 0.5%, *Erythrophleum suaveolens* 1.4%, *Securidaca longepeduculata* 0.2-0.4%.
Zone V (1355-1174 m)	*Rhizophora* sp., 23.3-53.8%, *Avicennia* sp., 0.2%, Poaceae 14.8-23.7%, *Anthocleista liebrechtsiana* 0.3-2.8%, *Dalbergia ecastaphyllum* 1.4%, *Gardenia imperialis* 0.2-0.3%, *Hippocratea vignei* 0.3-0.5%, *Lonchocarpus cyanescens* 0.3-2.0%, Sp., *ondianthus preusii* 0.3-1.7%, *Symphonia globulifera* 0.3-0.9%, *Pandanus candelabrum* 0.3-0.5%, *Uapaca* sp., 0.1-3.0%, *Macaranga heudelotii* 0.6-3.1%, *Podococcus barteri* 0.3-2.5%, *Psychotria* sp., 0.3-1.8%, *Canthium* sp., 0.5%, *Khaya* sp., 0.3-0.7%, *Pycnanthus angolensis* 0.3-0.9%, *Phyllanthus pentandrus* 0.3-0.8%, *Piptadeniastrum africanum* 0.2-0.9%, *Malacantha alnifolia* 0.2%, *Synsepalum dulcificum* 0.3-5.6%, *Pentaclethra macrophylla* 0.3-0.9%, *Entandrophragma* sp., 0.3-1.7%, *Maprounea membranacea* 0.2-1.4%, *Bombax buonopozense* 0.3%, *Kigelia africana* 1.4-8.1%, *Leea guineensis* 1.2%, *Newbouldia laevis* 0.3-1.8%, *Pentadesma butyracea* 0.2-0.7%, *Psychotria* sp., 0.3-1.8%, *Sterculia oblonga* 1.4%, *Synsepalum dulcificum* 0.3-5.6%, *Brachystegia eurycoma* 0.7-1.2%, *Morelia senegalensis* 0.3-3.4%, *Platostoma africanum* 0.3-1.8%, *Hygrophila auriculata* 0.3-0.5%, Fern sp.,ores 14.8-43.0%, Cyperaceae 7.8-11.9%.

Zone I: (3991-2835 m)
Zone II: (2835-2294 m)
Zone III: (2294-1553 m)
Zone IV: (1553-1355 m)
Zone V: (1355-1174 m)

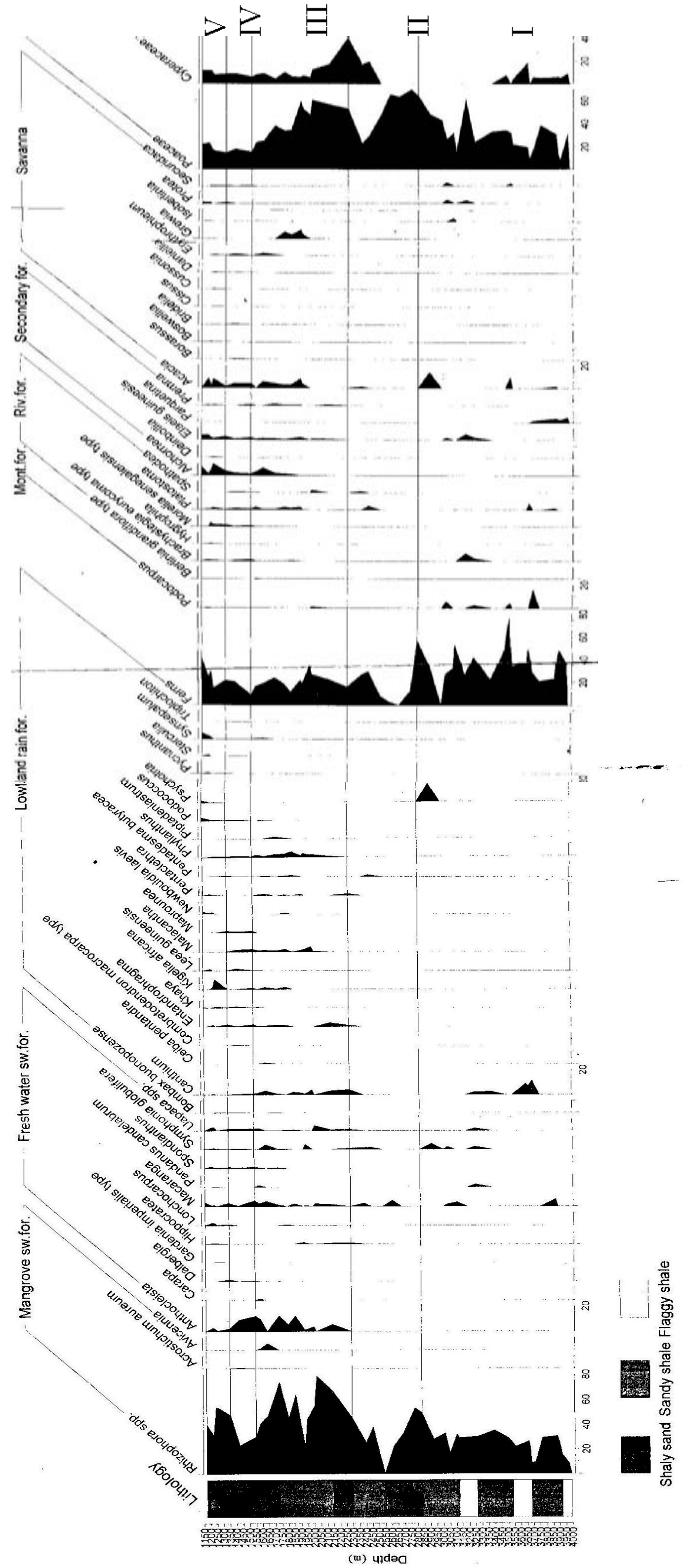

Fig. 3: Pollen diagram of Bassan-1 well, Niger Delta, Nigeria

DISCUSSION

Zone I: The relatively high, though fluctuating occurrence of Poaceae throughout this zone, the occurrence of savanna elements and the low occurrence of fresh water swamp forest in this zone indicate that open vegetation with extensive savanna was more prevalent. This suggests a dry condition during the period of deposition of these sediments. Brenac (1988) reported that an increase in grass pollen is an indication of a dry and cool climate. Morley (1995) also reported that a relatively high abundance of Poaceae reflects dry climate, which indicates sea level fall. It is significant to note that an increase in fungal spores was recorded for this interval. The increased occurrence of fungal spores in this zone supports the suggestion that conditions were adverse during this period. Fungal spores are a means of surviving unfavourable environmental conditions. On the restoration of conducive conditions, the spores germinate to produce hyphae and more spores. The occurrence of *Podocarpus milianjianus* in this zone is also very significant as its presence is an indication of a cool, montane climate (Knapp, 1971). The low occurrence of mangrove swamp species (8.3-35.7%) is probably related to a lower sea level. The occurrence of small quantities of *Rhizophora* pollen in this zone was probably due to a lowering of sea level, thereby allowing only a very limited establishment of mangroves near the coast. These mangrove swamps are sensitive to sea level changes and are therefore good indicators of fluctuations in sea level. As is now well known, high values of *Rhizophora* in pollen diagrams characterize periods with a high sea level (Sowunmi, 1981a, b; Fredoux and Tastet, 1988; Lezine and Vergnaud-Grazzini, 1993) while intervals with low *Rhizophora* are associated with lower sea level.

Zone II: Mangrove swamp forest vegetation seemed to have flourished during the period covered by this zone. Following the observation of Sowunmi (1981a, b), an abundance of fossil *Rhizophora* above 40% in sediments indicates a good representation of mangrove swamp, suggestive of a rise in sea level and a humid, tropical, lowland climate. Subsequent to the wetter phase at the beginning of this period, with an increased occurrence of Rhizophora, was the prevalence of unstable and unfavourable climatic conditions. This climatic inference is based on a number of concomitant developments in the vegetation. First and perhaps most significant, was a reduction and then a complete absence of *Rhizophora*. Secondly, savanna vegetation, with a predominant cover of grasses was well established probably in the coastal areas. As is well known from the present vegetation complexes in the tropics, an abundance of grasses in the tropics is typical of more open vegetation such as the savanna or in river valleys (Germeraad *et al.*, 1968). Thirdly, there was an absence or low occurrence of lowland rain forest and fresh water swamp forest. This was probably due to an initial rise in sea level with the mangrove vegetation increasing in extent. Subsequently, there were variations in sea level leading to changes in the intensity and extent of the tides into and out of bays, estuaries and other restricted coastal openings. These oscillations in sea level were likely to have caused fluctuations in the percentage occurrence of *Rhizophora*. A drier climatic condition is inferred for this period, which brought about a fall in sea level, coupled with a reduction of forest vegetation, ferns and Cyperaceae, concomitantly with an expansion of the savanna.

Zone III: Mangrove swamp forest vegetation became well established during the period covered by the zone. The highest percentage occurrences of *Rhizophora* pollen recorded in the entire section of the well studied (78.9 and 74%) was in this zone. This is indicative of a large extension of mangrove swamps along the coast during this period. It is also an indication of a rise in sea level.

Crowley and Gagan (1995) in their study on pollen in sediments drilled from the coastal plain of north east Queensland, Australia, also reported the extensive development of *Rhizophora*-dominated mangroves in response to a sea level rise. The presence in this zone of *Avicennia* sp., which, is found only as single trees at the edges of hardened beaches (Keay, 1959), also points to the extensive development of mangrove swamp forest during this period.

The appreciable occurrence of ferns (21.4%) and consistent occurrence of Cyperaceae with its highest occurrence (40%) in this zone, along with large extensions of fresh water swamp forest and lowland rain forest communities' further inland indicate a change from the open vegetation prevalent in the preceding zone to one of dense and luxuriant communities. Dupont and Agwu (1991) reported that the occurrence of fern spores and Cyperaceae in sediments is indicative of the existence of wet conditions. It is very significant to note that the diversification of lowland rain forest began in this zone-a further confirmation of the prevalence of wet conditions.

Zone IV: Though there was a drop in the percentage occurrence of *Rhizophora* in this zone, mangrove vegetation was still in existence. A lower but probably relatively stable sea level prevailed during this period. It is suggested that environmental conditions became more adverse with the low occurrence of Poaceae and savanna species as well as a drop in the percentage of *Rhizophora* in contrast to the situation in Zone III. Furthermore, the formerly dense forests became more open as indicated by the low occurrences of fresh water swamp forest, lowland rain forest and riverine forest communities. Montane forest vegetation thrives under a cool but moist climatic condition. The total absence of montane forest pollen in this zone is additional evidence of the prevalence of drier conditions.

Zone V: The predominant vegetation during the period covered by this zone was mangrove swamp forest as indicated by the predominance of *Rhizophora* and the presence of *Avicennia* sp. Furthermore, the good representation of freshwater swamp forest vegetation suggested its continued existence in this zone while lowland rain forest vegetation was still well established further inland with the ground covered by pteridophytes. It is suggested that the climate was wet and warm with the mangrove growing extensively along the coast as a result of a rise in sea level.

CONCLUSIONS

Inferences drawn from the pollen analysis of the section in Bassan-1 well studied provide further evidence of a series of climatic and other environmental changes in the Tertiary period as had been reported by several other workers (Salard-Cheboldaeff and Dejax, 1991; Oboh *et al.*, 1996; Leroy and Dupont, 1997; Popescu, 2001). Sowunmi (1986) had earlier reported that the climates in West Africa were characterized mainly by alternating wet and dry phases from the Neogene, ca.26 my.BP to the present. The pattern of occurrences of the vegetation during the period covered by Zone 1, notably high percentages of Poaceae, occurrences of savanna elements and the very low representation to absence of *Rhizophora* sp. is suggestive of savanna-like vegetation not far from the coast and very sparse mangrove vegetation, respectively; the lowland rain forest was also sparse. This pattern is indicative of dry climatic conditions and low sea level. Of all the strata studied, the ones in Zone 1 stand out as reflecting an overall prevalence of adverse conditions.

During the subsequent periods, covered by Zones II, III, IV and V, the environment changed drastically. The sea level rose and the mangrove swamps grew over large areas while fresh water swamp forest and lowland rain forest became well established in the area. The diversification of the lowland rain forest began some time during the Late Tertiary. The expansion of the mangrove swamp in the Niger Delta in the late Tertiary was greatest during these periods. These developments signalled the establishment of wet and warm climatic conditions even though there were oscillations to unstable and unfavourable phases.

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