PALEOENVIRONMENTAL AND PALEOCLIMATIC RECONSTRUCTION OF OM-4 AND OM-A WELLS, NIGER DELTA, NIGERIA

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Abstract

Palynological studies have been carried out on 100 ditch cuttings samples penetrated by OM -4 and OM-A wells in the Niger Delta, Nigeria, with the aim of reconstructing the paleoenvironment and paleoclimate of the interval studied which ranged from 8200 – 11400 ft each in both wells. The palynomorphs yielded 51 and 44 species in OM-4 and OM-A wells respectively. The succession studied yielded rich terrestrial components of the palynomorph assemblage which gave zero to low PMI values in both wells, suggesting a paralic environment. Also, the abundance of mangrove swamp species such as *Zonocostites ramonae, Acrostichum aureum, Botryococcus braunii* and *Psilatricolporites crassus* in both wells (which are brackish water indicators) denotes an environment of deposition with higher terrestrial influences, indicated a paralic environment of deposition. The palynomorph distribution was also used to interprete the depositional climatic conditions and on the basis of changes in the vegetation shown in the nature of distr ibution of the paleoclimatic zones were established. Four zones in OM-4 well and five zones in OM-A well. These zones showed a variation between dry and wet climates.

Keywords: Paleoenvironment, paleoclimate, Palynomorphs, Miocene

Introduction

Palynology involves the study of acid resistant microfossils with organic walled microfossils, which are spores, pollen and dinoflagellates, they are the products of continental vegetation, and might best be considered as a biogenous component of fine-grained detrital or terrigenous marine sediment. Palynomorphs undergo rapid diversification, they are considerably resistant to geologic obliteration and acids, easy to process, numerous and are good facies indicators. These characteristics give them stratigraphic value and have made palynological research applicable in numerous present day studies. These applications include;

i. Paleoenvironmental studies; this entails how information from present day studies of modern organisms can be used to infer environmental conditions in the past and also predict future environmental conditions, since the distribution organisms generally, are controlled by a combination of physical conditions of the surrounding area including terrain, vegetation structure, rainfall, sea level rise or fall and temperature.

ii. Paleoclimatic reconstruction; this is based on the fact that changes in climate are most evidently reflected in the vegetation since the manner in which vegetation is distributed is dependent on the prevalent climatic conditions. Thus, reconstructing vegetation helps to reconstruct past climates (Ivanor *et al.*, 2007).

iii. Paleoecology: certain individuals or assemblages of plants are known to be characteristic of specific ecological zones and the occurrence of their fossils serves as ecological indicator species in sediments.

iv. Well correlation in hydrocarbon exploration

v. Depositional environment studies amongst many other uses.

This study focuses on the use of palynomorphs for paleoenvironmental and paleoclimatic reconstruction of the studi ed interval.

Description of the Study Area

The Niger Delta lies between latitude 4° and 6° N and longitudes 3' and 9' E in the southern part of Nigeria. The studied OM-4 and OM-A wells are located on the onshore part of the Niger Delta, on latitude 4.63° N and longitude 6.8° N and 4.627° E and 6.786° E respectively (Figure 1). OM-4 well lies in the Central depobelt while OM-A well lies within the coastal swamp depobelt.

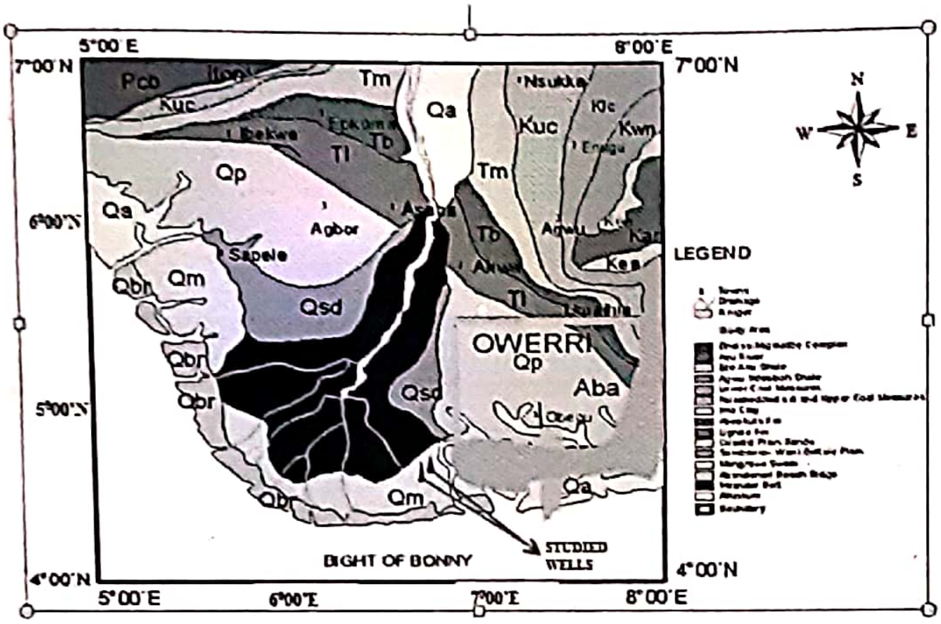

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Figure 1: Geological map of Niger Delta showing the location of the studied wells (Modified after Knox and Omotasola, 1990)

Methodology

A constant weight (30g) of each sample was initially given a hot hydrochloric acid (HCl) treatment to remove carbonates prior to complete digestion in hydrofluoric acid (HF) under a fume cupboard to remove silicates. Gentle agitation of the acid/sample mixture was carried out to aid acid digestion. The sample was then washed with over a 5micron mesh polypropylene sieve under running water to facilitate the complete removal of silt and clay particles. A spatula was used to scoop the organic-rich fraction and strewn mounted on the slides and made to dry on a hot plate by heating it up to 40° C. Two to three drops of loctite impruv were used as the mounting medium and cured over ultraviolet (UV) light. The palynomorphs were counted on each of the two slides per sample. The slides were viewed under the National binocular microscope in the laboratory of Mosunmolu Nigeria Limited, Lagos, Nigeria. Forms observed were identified and named using palynological albums as well as descriptions of previous workers (Adegoke *et al.*, 1986; Evamy *et al.*, 1978; Germeeraad et al., 1968). The identified species were noted, counted and recorded on the analysis sheet using the tally system. The process was repeated for all the slides. The results were inputted into the stratabug software to prepare the palynomorphs distribution chart.

Results

Palynomorph Distribution

The distribution of palynomorphs, (pollen, spores, dinoflagellates and algae) in the studied section varied from one depth to another in diversity and abundance. Pollen and spore preservation was fair in both wells with total species count of fifty-one and forty-four in OM-4 and OM-A wells. Dinoflagellates were poorly represented with 2 species each, found in both wells. Figures 2 and 3 show palynomorph distribution chart from samples analysed, plotted using the stratabug software for OM-4 and OM-A wells respectively. The lists of the forms of palynomorphs as recovered from the ditch cuttings from both wells as plotted on the charts are listed below:

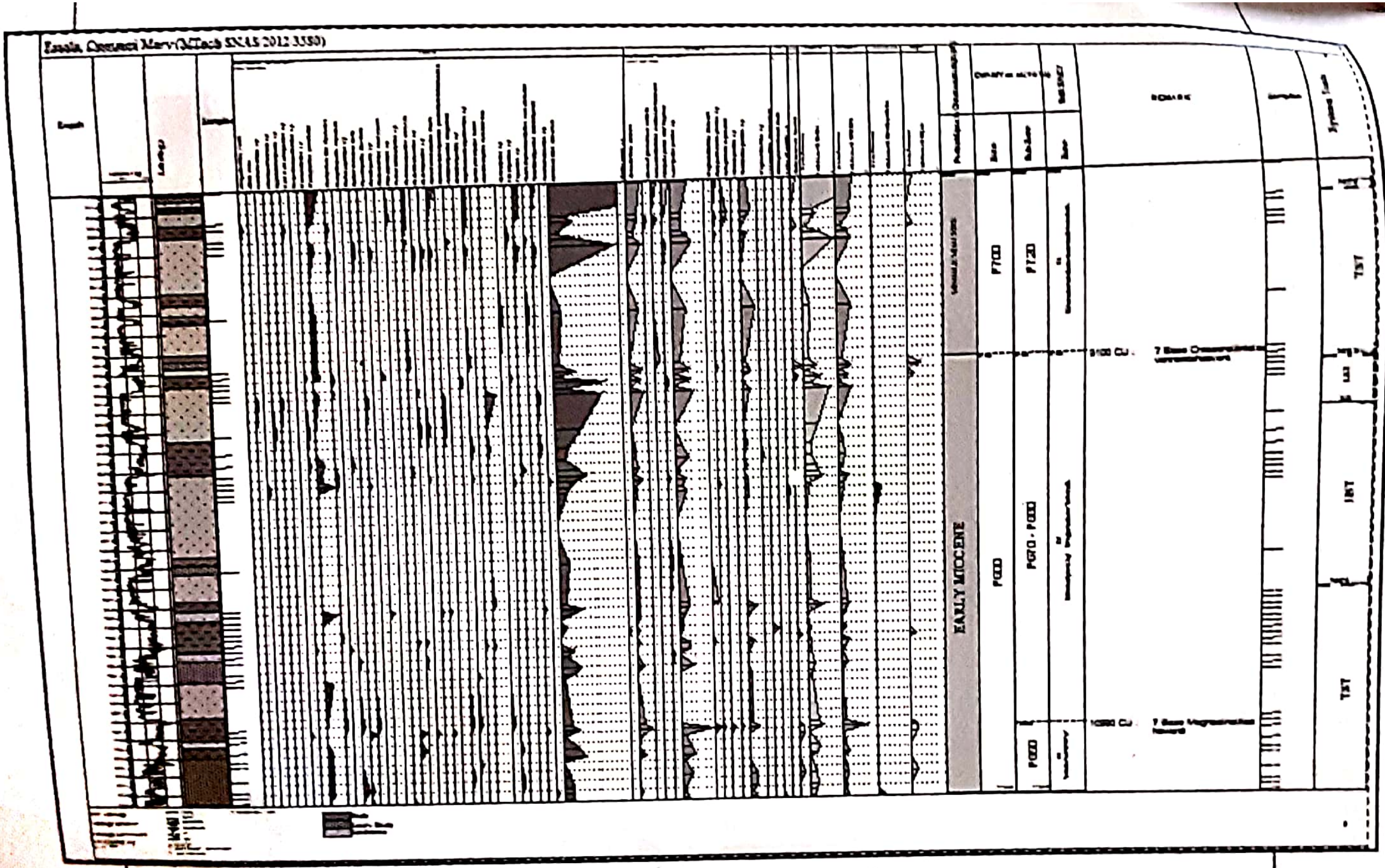
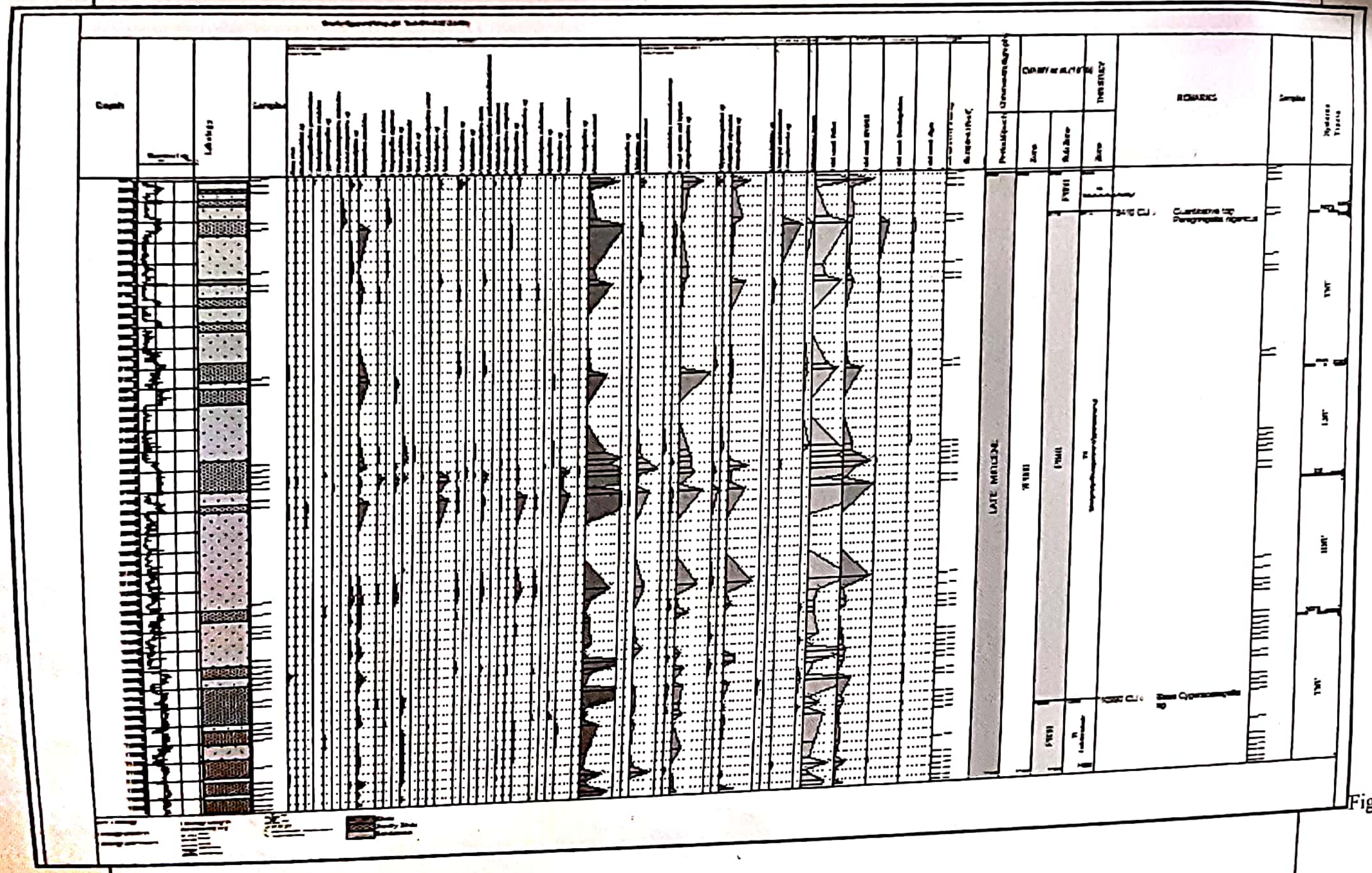

Essala, Ozumeci Mary (MTech SNAS 2012 3380)
REMARK
EARLY MIOCENE
P700
P720
P600
P670 - P600
P600
9100 CU
10550 CU
TST
LST
HST
TST

Figure 2: Palynomorph distribution chart for OM-4 well



Figure

3: Palynomorph distribution chart for OM-A well.

From Figures 2 and 3, it can be seen that the most abundant palynomorphs were of the pollen family, which accounts for about 71% of the total palynomorph assemblage in OM-4 well (Figure 4) and 75% in OM-A well (Figure 5), the second most abundant group are the spores, with 23% and 18% of all palynomorphs in both wells respectively. Both OM-4 and OM-A wells are characterised by very low counts of marine palynomorphs (dinoflagellates) with 4% and 5% in both wells respectively. Algaes were rare, comprising about 2% in both wells (Figures 4 and 5).

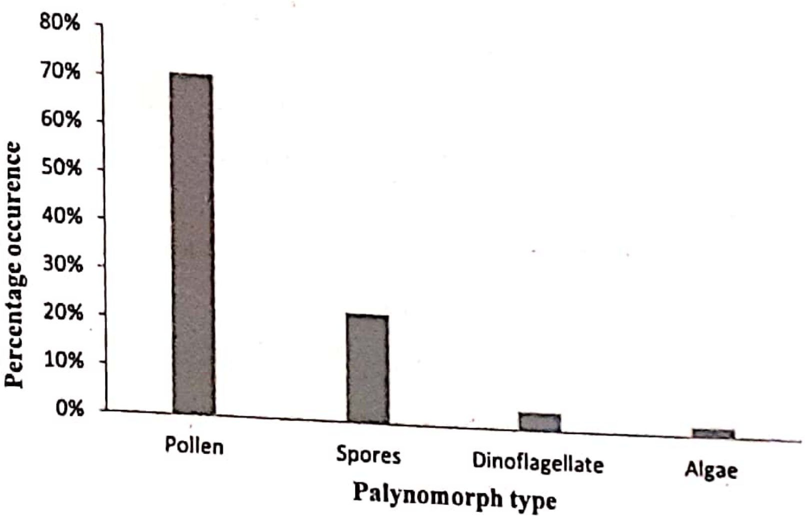


Figure 4: Percentage palynomorph distribution in OM-4 well

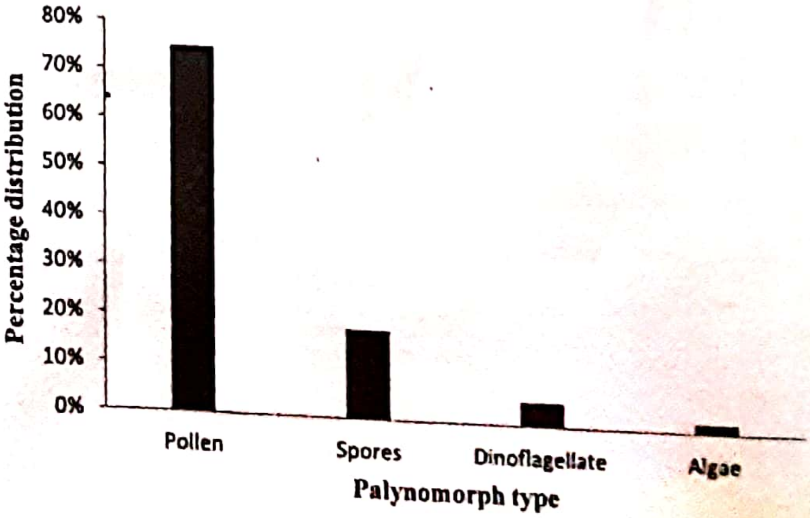


Figure 5: Percentage palynomorph distribution in OM-A wells

Paleoenvironmental Analysis

This is concerned with the use of microfossils (microflora and fauna) to infer environmental conditions in the past (Culver *et al*, 2011). Information on the palynological assemblage is useful in reconstructing paleoenvironment. (Van Bergen *et al*., 1990; Petters and Edet, 1996; Ojo and Akande, 2004), this is because changes in the environment are reflected in palynologic assemblages (Oloto, 1989; Ojo and Akande, 2004). The tools adopted in establishing the paleoenvironment for this study are: PMI, environment markers and dominant species group

Palynological Marine Index (PMI) of OM-4 and OM-A wells

This index was proposed by (Helenes *et al*., 1998) to interprete environments of deposition, using the PMI formula: PMI = (Rm/Rt + 1)100, with Rm being the number of marine palynomorphs which include dinoflagellates, acritarchs and foraminiferal test linings and Rt, the number of terrestrial palynomorphs (pollens and spores). In this study, Rm and Rt were expressed as the number of species per sample. High PMI values were interpreted to indicate normal marine depositional conditions, low values as brackish and nil values as fresh water (Helenes *et al*., 1998). In relations to the classification by (Helenes *et al*., 1998), this study adopts 0% as nil PMI values indicating freshwater, 1-50% as low PMI values indicating brackish and 51-100% as high PMI values indicating marine environment.

PMI values for OM-4 well were generally nil with most depth recording 0.0% PMI values (Table 2, Figure 6), this indicates a fresh water environment. However, at few depths 9160 ft, 9760 ft, 10510 ft, 10990 ft, 11020 ft, 11230 ft and 11350 ft, low PMI values of 14.0%, 20%, 33.3%, 6.7%, 25%, 12.5% and 16.7% were obtained respectively (Table 1, Figure 6) denoting a brackish environment. In OM-A well, most depths also had PMI values of 0.0% (Table 2, Figure 7), representing freshwater environment. Depths with low PMI values include 8440ft (14.3%), 9160 – 9670ft (14.3%), 10610 ft (50%), 10810 – 10780 ft (10 – 50%), 10960 ft (20%) and 11260 ft (12.5%) as seen in Table 2, Figure 7. These depths indicate brackish water environment. From the PMI values, it is can be inferred that sediments were deposited in a paralic environment.

Table 1: PMI values for OM-4 well

Marine Diversity Rm	Terrestrial Diversity Rt	PMI (Rm/Rt+1)X100	Depth
0	13	0	8200
0	11	0	8350
0	13	0	8380
0	4	0	8440
0	11	0	8470
0	15	0	8500
0	7	0	8830
0	7	0	9100
1	9	10	9130
1	6	14.3	9160
0	0	0	9190
0	6	0	9220
0	11	0	9250
0	6	0	9430

Rm Marine Diversity	Rt Terrestrial Diversity	PMI (Rm/Rt+1)X100	Depth
0	7	0	9590
0	8	0	9640
0	7	0	9670
0	11	0	9700
0	6	0	9730
1	4	20	9760
1	2	33.3	10510
0	8	0	10540
0	3	0	10570
0	4	0	10600
0	3	0	10660
0	3	0	10690
0	3	0	10720
0	9	0	10960
1	14	6.7	10990
1	3	25	11020
1	7	12.5	11230
0	7	0	11290
0	7	0	11320
1	5	16.7	11350

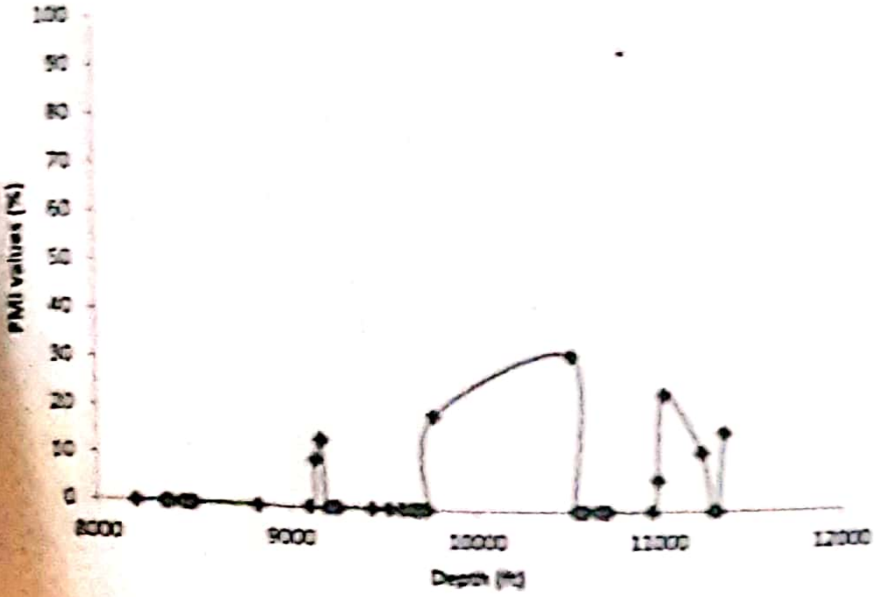


Figure 6: PMI plot for OM-4 well

Table 2: PMI values for OM-A well

Marine Diversity Rm	Terrestrial Diversity Rt	PMI (Rm/Rt+1)X100	Depth
0	6	0	8200
0	12	0	8230
0	3	0	8260
Rm Marine Diversity	Rt Terrestrial Diversity	PMI (Rm/Rt+1)X100	Depth
1	6	14.3	8440
0	4	0	8650
0	6	0	8710
0	8	0	8740
1	6	14.3	9160
1	6	14.3	9190
1	11	8.3	9580
0	7	0	9610
1	10	9.1	9640
1	20	4.8	9670
0	13	0	9700
0	5	0	9760
0	17	0	9790
0	13	0	10270
0	4	0	10330
0	7	0	10390
0	3	0	10450
0	2	0	10480
0	5	0	10570

1	1	50	10600
0	4	0	10630
0	6	0	10690
0	4	0	10720
1	1	50	10780
1	9	10	10810
0	4	0	10900
0	9	0	10930
1	4	20	10960
0	7	0	10990
0	6	0	11140
0	4	0	11230
1	7	12.5	11260
0	3	0	11290
0	3	0	11320
0	3	0	11350
0	5	0	11380

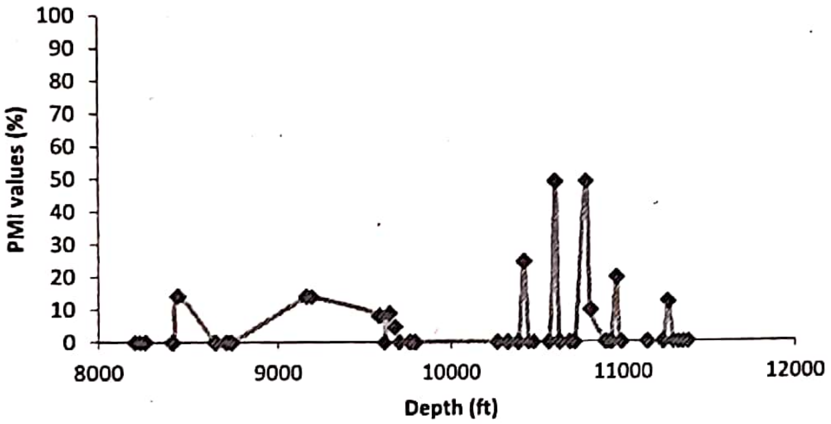


Figure 7: PMI plot for OM-A well

Marker Species and dominant species groups for paleoenvironmental studies.

Generally, the freshwater swamp species which include *Laevigatosporites* sp, *Peregrinipollis nigericus, Racemonocolpites hians, Retitricolporites irregularis, Striatricolpites catatumbus, Crassoretitriletes vanraadshooveni* and *Magnastriates* sp, were observed to be well represented in terms of diversity in both wells (Figures 2, 3, 8 and 9). These species were observed to occur at depths with 0.0% PMI values (although not restricted to only those depths), hence, confirming those depth intervals to have been deposited in a freshwater environment. Generally, of the all the palynomorphs recovered from both wells (OM-4 and OM-A), *Zonocostites ramonae* was the most abundant species accounting for about 48% in OM-4 well and 52% in

OM-A well, next to it is *Laevigatosporites* sp with about 19% in OM-4 well and 15% in OM-A well, *Acrostichum aureum* 12%, *Verrucatosporites* sp 7%, *Monoporites annulatus* 5% and other palynomorphs accounting for about 9% in both wells respectively (Figures 6 and 7).

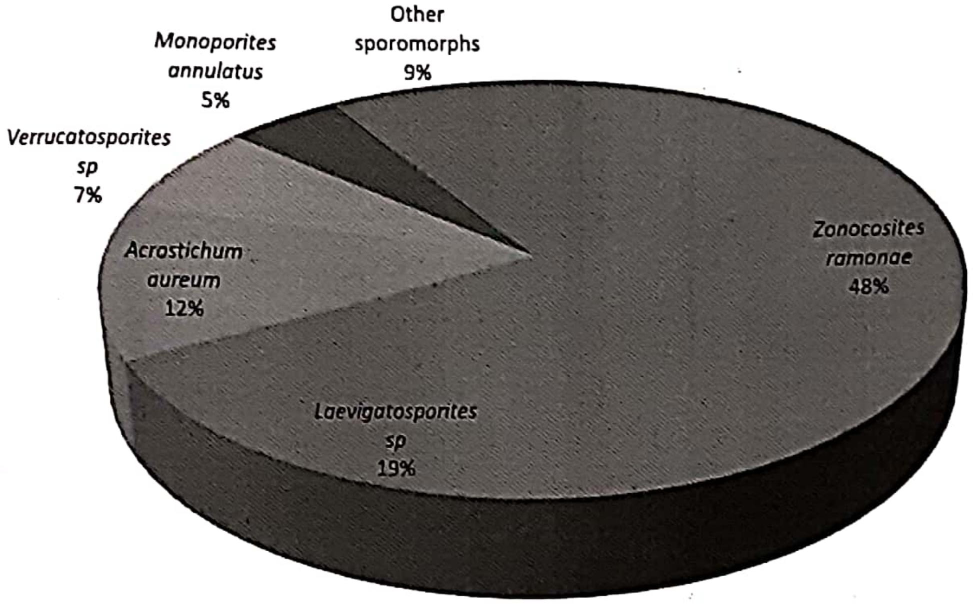


Figure 8: Percentage palynomorph species abundance in OM-4 well

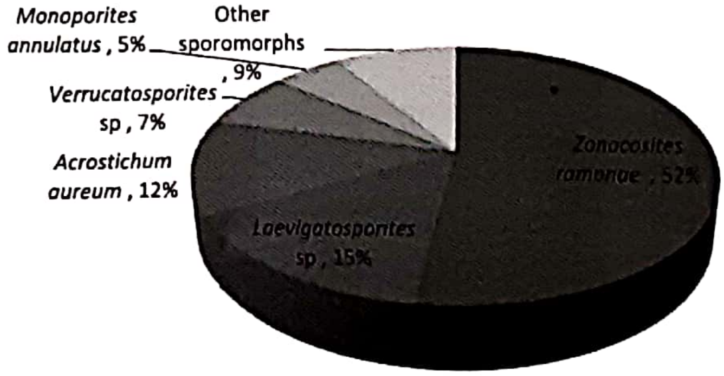


Figure 9: Percentage palynomorph species abundance in OM-A well

In both wells, high percentages of mangrove species (brackish water indicators) which includes *Zonocostites ramonae, Acrostichum aureum, Psilatricolporites crassus, Verrucatosporites* sp and *Botryococcus braunii* (Ige, 2009; Sowunmi, 1981; Jennifer *et al.*, 2012; Oboh *et al.*, 1996), were recorded (Figures 8 & 9). Also depths intervals with low PMI values showed an assemblage of at least two mangrove swamp species. For instance, in OM-A well, at 8440 ft with PMI value of 14.3% (Table 3), *Zonocostites ramonae, Acrostichum aureum,* and *Botryococcus braunii* were present at that depth. Although, the presence of these species was not limited to the depths with low PMI values, their presence at such depths had higher population than the freshwater species. These mangrove species were generally most abundant in terms of population in both wells especially *Zonocostites ramonae* and *Acrostichum aureum* (Figures 8 & 9). The presence of these Mangrove swamp species further confirms that the depths with low PMI values were deposited in a brackish environment. The major palynomorph groups that were used in the paleoenvironmental studies are pollen, spores and dinocyts, representing the terrestrial and marine influences (Soronnandi-Ononiwu *et al*., 2014). From Figures 4 and 5, it can be seen that pollen and spores accounted for 71% and 23% in OM-4 well and 75% and 18% in OM-A well respectively, compared to the low counts of marine influences (dinoflagellates) which had 4% and 5% in OM-4 and OM-A wells respectively, indicating an environment with greater terrestrial influences. Shrank (1994) has suggested that palynomorph assemblages with higher content of pollen from land indicates terrestrial influence and vice versa, hence the succession of sediments in OM-4 and OM-A wells show it is strongly dominated by terrestrial palynomorph, denoting a generally continental environment. The presence of marine influences denotes an environment prone to marine interactions, hence, suggesting a paralic environment. Moreover, the nature of the sediments is also an important factor in the distribution of the palynomorphs. Being allochthonous sediments, generally the siliciclastic sediments deposited in marine environments show higher abundances of terrestrial than marine palynomorphs (Traverse and Ginsburg, 1966; Groot and Groot, 1966; Lana, 1997).

From the PMI values, dominat species group and presence of marker species, sediments within both wells were deposited in a paralic environment denoting a fluvial to coastal environment.

Paleoclimatic Studies

Paleoclimate is the study of changes in climate. This study employs the use of palynomorphs to carry out paleoclimatic studies, this is because, changes in climate are most evidently reflected in the vegetation since the vegetation of any area is an integral and important of an ecosystem and are responsive to change in the ecosystem (Ivanor, *et al.*, 2007). The palynomorph distribution charts of both wells (Figures 3 and 4), show the important taxa of the wells which are also ecologically significant. These taxa have been used to delineate the wells ecologically and to interprete the depositional climatic conditions. On the basis of observed changes in vegetation, which was reflected in pollen distribution, a total of nine (9) paleoclimatic zones have been recognized; 4 zones in OM-4 well and 5 zones in OM-A well.

Paleoclimate of OM-4 well

Dry climates

Of the four paleoclimatic zones established in this well, two zones (Zones A and C) showed dry climates.

Zone A (11350-9700 ft) shows a consistent general reduction in percentage occurrence of *Zonocostites ramonae* and other mangrove species such as *Psilatricolporites crassus* as seen in Figure 2. Sparse distribution of rain forest species such as *Pachydermites diederixi* and *Sapotaceoidaepollenites* sp suggests a dry condition during deposition of the sediments. The presence and relative increase in the distribution of *Monoporites annulatus* (Poaceae) (Morley, 1995), indicates the thriving of open vegetation in the area. The reduction in percentage distribution of *Zonocostites ramonae* in this zone is relative in comparism to its distribution in other zones; hence the zone may not represent an extremely dry climate, but suggests a drier condition since there are evidences of sparse distribution of the forest species. The reduction in percentage of *Zonocostites ramonae* may be as a result of a drop in the level of the sea since mangrove swamps species respond to changes in the sea level hence are pointers of sea level fluctuation. According to (Ige, 2011; Sowunmi, 1981; Lexine and Vergnaud- Grazzini, 1993), high value of *Rhizopora* (*Zonocostites ramonae*) represent rise in sea level and vice versa. The presence of *Podocarpus* sp. is significant as it represents a cool montane climate (Knapp, 1971).

Zone C (9150-8680 ft) showed a fall in the number of *Zonocostites ramonae* in this zone coupled with the sparse occurrence of savanna and the forest species may denote the prevalence of a more adverse climatic condition. A reduced but relatively stable sea level might have dominated in this zone. Although there was a drop in the general distribution of species, mangrove swamp species; *Zonocostites ramonae* and *Psilatricolporites crassus* still dominated the entire zone, still denotes a wet climate although not as in zone B.

Wet climates

Two zones (B and D) had wet climates. Zone B (9700-9150 ft) showed gradual upward rise in the number of *Zonocostites ramonae* suggests a gradual increase in the sea level and the setting in of a wetter climate compared to Zone A (Figure 10). Fresh water swamp species such as *Striatricolpites catatumbus* and rain forest species such as *Pachydermites diederixi* were represented in higher percentage than in the preceeding zone although they are generally sparsely distributed compared to the mangrove swamp species. This confirms a gradual change from a drier climatic condition to the wetter one with gradual sea level rise.

Zone D (8650-8200 ft) displayed good representation of *Zonocostites ramonae* with an initial gradual increase in its percentage. This suggests a rise in sea level. Although within the zone, there was evidence of a local fluctuation in sea level shown by a drop in *Zonocostites ramonae* with corresponding presence of charred gramineae cuticle, fungal spores and hyphae and other savanna species, showing about the same percentages, suggests the prevalence of an open vegetation condition indicating a relatively drier climate.
Following this stage was the sharp rise in distribution of *Zonocostites ramonae*. This zone records the peak of its occurrence in the entire section denoting rise in sea level and a wet climate.

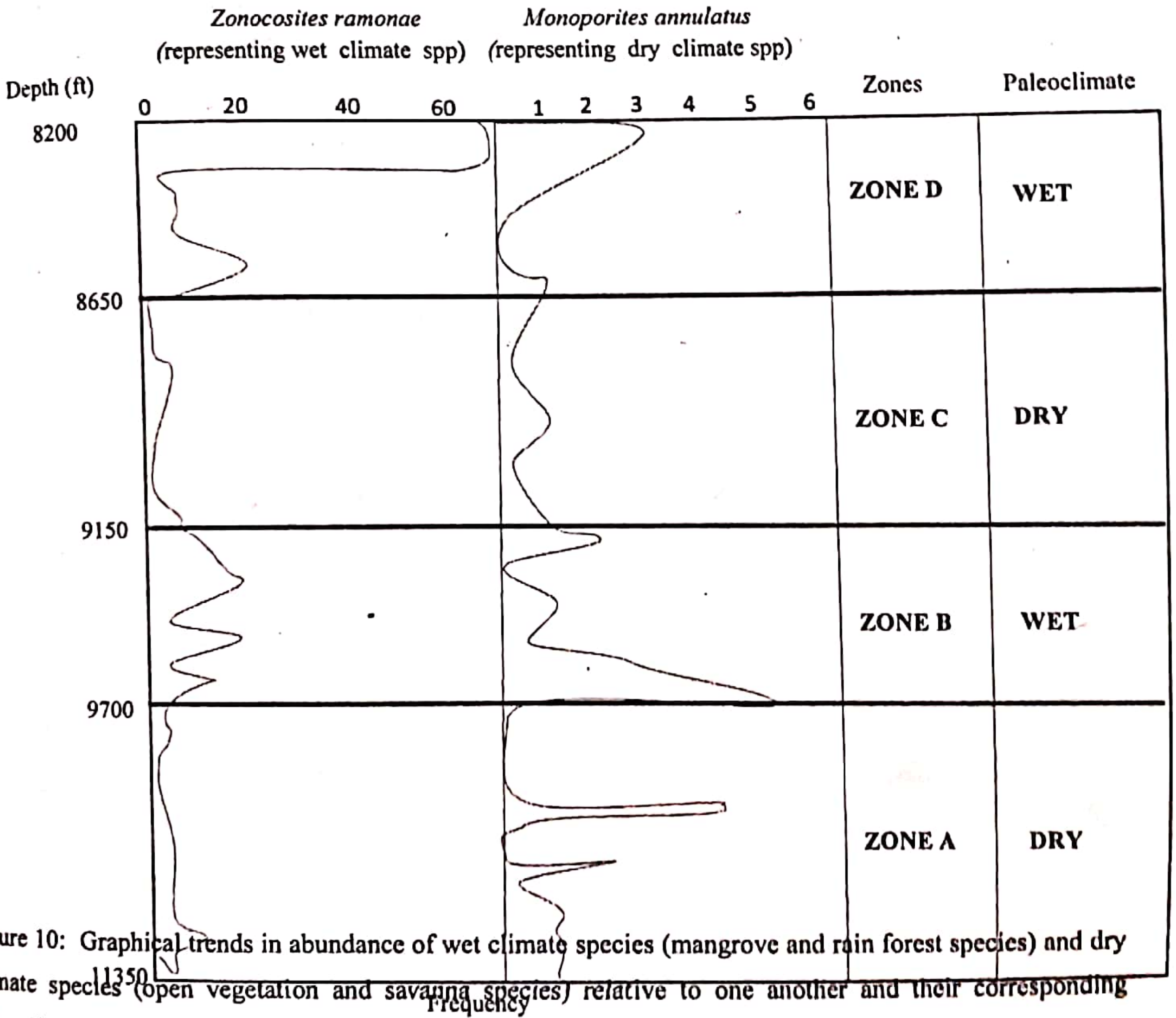


Figure 10: Graphical trends in abundance of wet climate species (mangrove and rain forest species) and dry climate species (open vegetation and savanna species) relative to one another and their corresponding paleoclimatic zones for OM-4 well.

Generally, within this zone, there was prevalence of wet climate, besides the local adverse condition between 8440 ft and 8350 ft of the zone. The presence of rain forest, fresh water swamp species and savanna species suggests that all the vegetation throve in the zone but was dominated by the mangrove swamp forest vegetation.

Paleoclimate of OM-A well

Wet climates

Three zones (A, B and D) showed wet climates. Zone A (11350-10900 ft) shows consistent fluctuation in the percentage of *Zonocostites ramonae* within it. This rise and drop in its percentage maybe due to gradual oscillation in sea level (Ige, 2009). The zone generally shows high percentages of mangrove species (*Zonocostites ramonae)* and presence of few rain forest species such as *Pachydermites diederixi* and *Sapotaceoidaepollenites* sp. denoting wet climate with sea level fluctuations (Germeraad *et al.*, 1968; Morley, 1991, 1995).

Zone B (10900-10630 ft) showed that mangrove swamp forest vegetation flourished at that time. Abundance of *Zonocostites ramonae* suggests an increase in sea level with local fluctuations. Presence of *Pachydermites diederixi* and absence of poaceae species confirms the prevalence of a wetter climate.

Zone D (9900-9580 ft) showed mangrove swamp forest vegetation to be well established as represented by the peak occurences of *Zonocostites ramonae* and *Psilatricolporites crassus.* This suggests that mangrove swamps throve and expanded along the coast (Ige, 2009). This high value of *Zonocostites ramonae* indicates sea level rise. Presence of rain forest taxon in the zone such as *Bombacacidites* sp, *Ctenolophonidites coastatus* and absence of *Cyperacaceaepollis* sp (Figure 3), confirms a prevalent wet and warm climate in the zone (Sowunmi, 1981).

ZONE E (9580-8200 ft)

This zone shows consistent fluctuation in the percentage of *Zonocostites ramonae*, ranging from reduction, at the bottom of the zone to complete absence at the top of the zone. This fluctuation may have resulted from continuous rise and drop in sea level with its rise resulting in the increase in *Zonocosites Ramonae* and vice versa. This fluctuation in sea level results to both wet and dry climatic conditions occurring within the zone. Peaks of Poaceae (*Monoporite annulatus*) which indicates a drier climate (Ige, 2009), was observed in this zone (Figure 11), suggesting the existence of open vegetation. Reduced percentages of *Pachydermites diederixi* and *Sapotaceoidaepollenites* sp confirms this zone has a drier climatic condition compared to the preceding zone.

Dry climate

ZONE C (10630- 9900 ft)

This zone was the only zone marked as dry. This is due to the upward reduction in the occurrence of *Zonocosites ramonae* to its complete absence indicates a fall in sea level (Figure 11). Sparse distribution of

Rain forest fossils such as *Sapotaceoidaepollenites* sp (Morley, 1991) and savanna fossils suggest the prevalence of an adverse climatic condition. The absence of *Podocarpus* sp which suggests a cool and moist climate indicates the presence of a drier climate (Knapp, 1971).

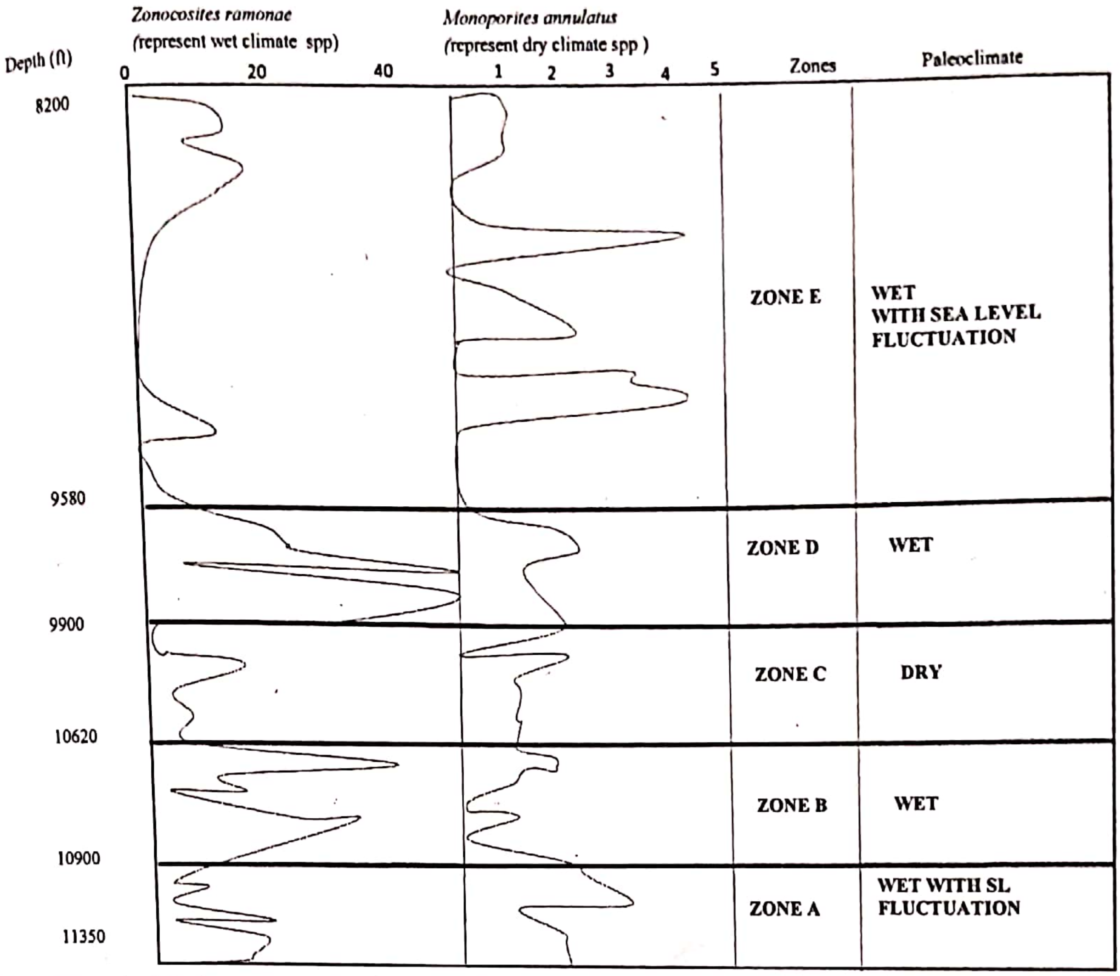


Figure 11: Graphical trends in abundance of *Zonocostites ramonae* representing wet climate species (mangrove and rain forest species) and *Monoporites annulatus* representing dry climate species (open vegetation and savanna species) relative to one another and their corresponding zones for OM-A well.

CONCLUSION

Zero to low PMI values in both wells denotes an environment of deposition with higher terrestrial influences, indicated a paralic environment of deposition. Presence of mangrove swamp species such *Zonocostites ramonae, Acrostichum aureum, Botryococcus braunii* and *Psilatricolporites crassus* in both wells (which are brackish water indicators), as well as the poor yield of nannofossils in both wells confirmed a paralic environment of deposition.

The palynomorph distribution was used to interprete the depositional climatic conditions. On the basis of changes in the vegetation shown in the nature of distribution of the palynomorphs, a total of nine (9) zones were recognized; four zones in OM-4 well and five zones in OM-A well. In OM-4 well, the four zones established were observed to show a variation between dry and wet climates, with zone A indicating the only dry climate in the zone. Although zones B, C and D indicated wet climates, zone B was wetter than zone C as it showed more mangrove and rainforest species compared to zone C. Zone D showed a predominantly wet climate with peak percentages of mangrove species as well as other rain forest species within the zone. The five zones identified in OM-A well showed a predominantly wet climate in four zones (Zones A, B, D and E) and dry climate in one zone (zone C).

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