Palynostratigraphy and Palynoenvironmental Study of Adeobak-2 Well, Offshore Niger Delta, Southern Nigeria

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ABSTRACT

Sixty (60) ditch cutting samples from Adeobak-2 well (1341–2438 m), offshore Niger Delta were studied for their palynomorphs content for the purpose of biozonation, lithology identification, age determination, and in understanding the paleodepositional setting and environments of the focus area. Lithological studies revealed sandy mudstone and shale as the unit encountered in the studied well with coarsening upward sequence and grayish color. The interval shows bioturbation indicating activity of organisms and evidence of fairly rich palynomorphs; fifty–nine (59) of which were identified.

In Adeobak-2 well, the two palynozones delineated from top to bottom of the sequence (1341 - 2438) were the *Echitricolporites spinosus* zone (P600) of Early Miocene age and the *Magnastriatites horwardi* zone (P500) of Late Oligocene age. Paleoenvironmental deductions based on the palynomorphs abundance, species diversity and lithological descriptions indicated a marginal marine with high influx of fresh water. Paleoenvironmental deductions was also deciphered mathematically via Palynological Marine Index (PMI). The uppermost (1341-2000m) and the bottommost (2274-2438m) portions of the well were characterized by continental palynomorphs, while interval 2000-2091m was characterized by marine derived palynomorphs. The remaining portion of the well, interval 2091-2274m showed an alternation of continental and marine deposits. This variation in environment can be imputed to the changes in sea level, associated with fluctuating climatic conditions.

(Keywords: palynomorphs, paleoenvironments, palynozones, Oligcene, Miocene, PMI)

INTRODUCTION

The study section- Adeobak-2 well, is located in the offshore depobelt of the Niger Delta Basin. The Tertiary Niger Delta is situated in southern Nigeria and lies between latitudes 3° N and 6° N and longitude 5° E and 8° E (Reijers *et al.,* 1996). It is one of the world's largest Deltas, with sub-aerial acreage of about 75,000 km^2. It is composed of an overall regressive clastic sequence, which reaches a maximum thickness of 30,000 to 40,000 ft. (9000 to 12000 m) (Nwachukwu *et al.,* 1986), sequence of which have been categorized into six (Figure 1). Detailed studies on tectonics, stratigraphy, depositional environment, petrophysics, sedimentology and hydrocarbon potential of the Niger Delta Basin are well documented in literatures such as (Short and Stauble, 1967; Weber and Daukoru, 1975; Evamy *et al.,* 1978; Knox and Omatsola, 1989; Doust and Omatsola, 1990; Nton and Adebambo, 2009; Nton and Adesina, 2009) among others.

Biostratigraphy has been shown to play an important role in the exploration of oil and gas in the Niger Delta and the various biostratigraphical techniques applied during these exploration activities are palynology, micropaleontology and calcareous nannoplankton study (Simmons *et al.,* 1999). Despite the effectiveness of palynology as an important tool in sequence stratigraphic analysis and resolution, it is still being grossly under-utilized in petroleum exploration and production. Consequently, this work aims at identifying the recovered palynomorphs, using the identified palynomorphs to zone and date the studied section and combining the knowledge of palynology and sedimentology to decipher the environments of deposition of the studied section.

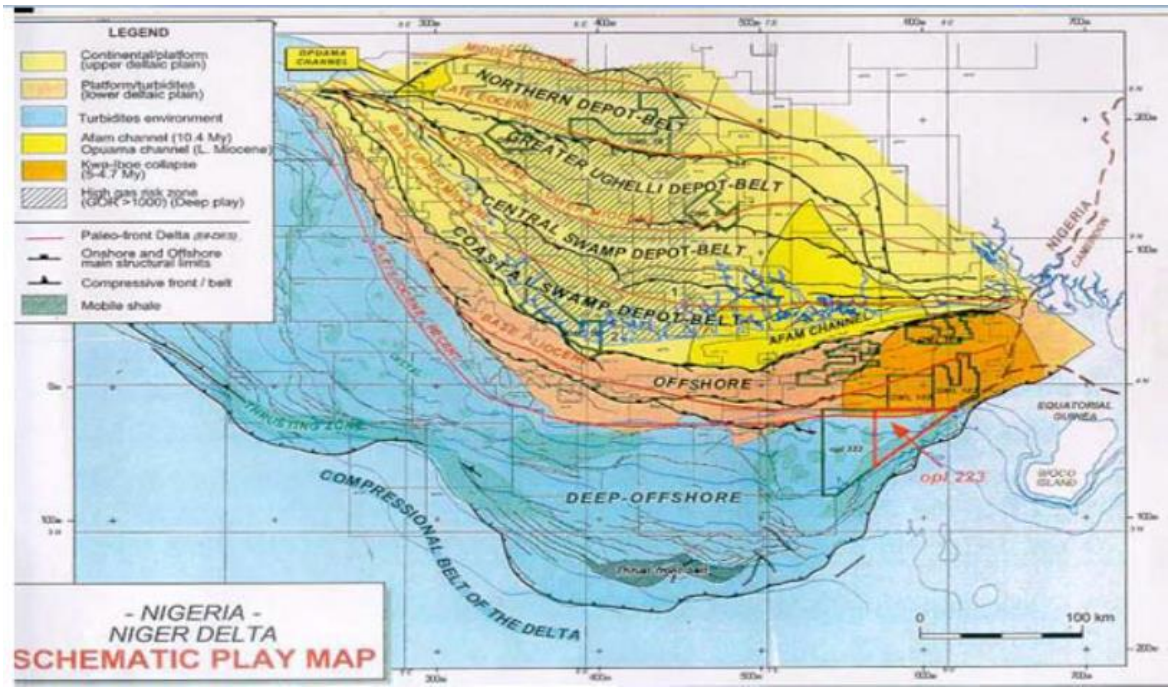


Figure 1: Section map of Nigeria showing the study area and depobelts (Whiteman, 1982).

MATERIALS AND METHODS

Sample Description

Sixty (60) composite ditch cuttings samples obtained from Adeobak-2 well, offshore Niger Delta were analyzed lithologically and palynologically. The sample depth intervals extend from 1341 meters to 2438 meters at an interval of about 18.3 meters. The lithological description of the samples were done by visual examination of the samples and with the aid of a hand lens.

Sample Preparation for Palynological Analysis

The samples were prepared following the standard palynological analysis procedure (Hopking, 1967). 10% Hydrochloric acid (HCL) were poured into the pulverized measured samples to test for carbonates. The samples were then soaked into 40% Hydrofluoric acid (HF) in plastic cups (HF attacks glass) and kept in a fume cupboard overnight to remove silica and silicates present in the samples. The samples were afterward treated with $ZnCl_2$/HCl solution (specific gravity 2.0) for heavy liquid separation and acetolysis was then carried out to remove cellulose to give greater concentration of pollens and spores. The recovered organic matters were uniformly spotted on arranged cover slips of 22 by 32 mm and then mounted on glass slides with aid of Norland optical adhesive.

These were then studied using the Olympus polarizing microscope. The essential requirement of the microscope is an X100 oil immersion objective lens with a good condenser and XPL illumination. The slides were examined under cross polarized and transmitted light, and the cascading method was employed in determining the relative abundance and diversity of the assemblages. The microscopically observed attributes of palynomorphs were considered to separate the assemblages into broad groups like Dinoflagellates, Pollens and Spores, via using STRATABUG software for the interpretation of the data. For each group type, specimens were selected and their morphologies were compared with generic or specific descriptions and illustrations given in various standard faunal treatises and catalogues such as Germeraad *et al.* (1968**),** Evamy *et al.,* (1978**)**, Clarke (1966) and Sowunmi (1995). Thus, identification up to generic and specific level was done and frequency was determined for all identified fossils. The data of faunal frequency vs. depth was afterwards plotted.

RESULTS INTERPRETATION AND DISCUSSION

Lithostratigraphic Description

The sample interval of Adeobak-2 well include a total length of 1097 m (1341 – 2438 m). The well is located offshore and as would be expected, the length of the well is dominated by shale, mudstone and shaly mudstone. Adeobak-2 well is lithologically characterized by a coarsening upward sequence of interbedded shale into sandy mudstone units. The top of the sample interval (1341 – 1505 m) was found to be sandy mudstone. The 164 m interval is relatively rich in palynomorphs with good to moderate diversity of forms. Below the 1505 m mark, the lithology of the well is dominantly shale/mudstone, extremely fine grained and dark colored. The interval is 933 m thick and has a good palynomorphs record, though with varying degree of abundance and diversity. Figure 2 shows the lithologic log of Adeobak-2 well.

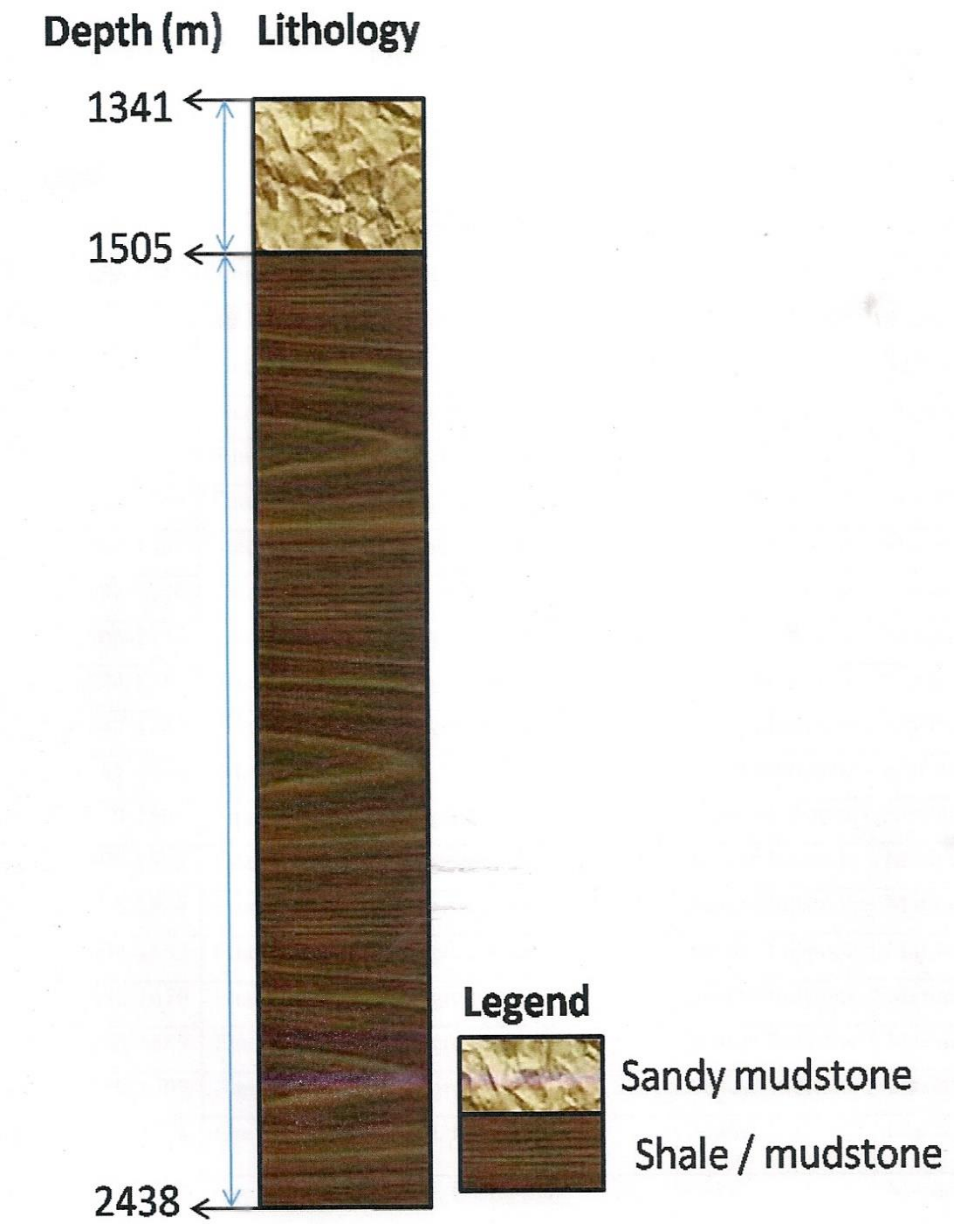


Figure 2: Lithologic log of Adeobak-2 Well.

Palynological Biozonation

The 1341 – 2438 m interval of the Adeobak-2 well flora falls within the pan tropical *Echitricolporites spinosus* zone and the *Magnastriates howardii* zone of Germeraad *et al., (*1968) which corresponds to the P600 and P500 zones of Evamy *et al.,* (1978) respectively. The P600 was further sub divided into the P620, P630, P650 and P670 subzones, while the P580 subzone was the only subzone identified within the P500 zone. Details of the zones and the subzones recognized are briefly discussed below and shown in both Figures 3 and 4.

Zone: P600
Subzone: P670
Interval: 1341 – 1487 meters
Age: Early Miocene

This is the first and youngest subzone recognized within this interval. The top of this subzone is placed at 1341 m, while the base is placed at 1487 m defined by the base rich occurrence of *Magnastriatites howardii*. This interval is further confirmed by the presence of *Verrucatosporites rotundiporus, Magnastriatites howardii*, and *Racemonocolpites hians*. About 122 palynomorphs were recovered at this subzone with high abundance of *Laevigatos spp*, *Zonocostatites ramonae*, *Pteris spp* and *Monoporites annulatus*. Some other palynomorphs recovered include *Psilatricolporites crassus*, *Acrostichum aureum*, *Peregrinipollis nigericus*, *Cyperacenepollis spp* and *Sapotaceas*. Two different dinoflagellates – *Operculodinium centrocarpum* and *Spiniferites ramosus* were recovered within this subzone as well.

Subzone: P650
Interval: 1487 – 1707 meters
Age: Early Miocene

The top of this subzone is placed at 1487 m and defined by the rich occurrence of *Magnastriatites howardii*. The base is placed at 1707 m. This subzone is further confirmed by the abundant land – derived palynomorphs and *Gemmamonoporites spp*. This interval is dominated by *Zonocostites ramonae* with abundance of 360. The total count of pollens was 413 while that of spores was 70. Dinoflagellate cysts had a count of one (1). This range of interval denotes a mangrove environment as indicative of *Zonocostites ramonae*, *Monoporites annulatus* (grass pollens), *Acrostichum aureum* and the first downhole occurrence of *Laevigatosporites spp* (terrigeneous species sporomorph).

Sub zone: P630
Interval: 1707 – 1835 meters
Age: Early Miocene

The top of this subzone is placed at 1707 meters, while the base is placed at 1835 meters defined by the base occurrence of *Praedapollis africanus.* This subzone is further characterized by the presence of *Praedapollis africanus, Verrucatosporites rotundiporus, Verrucatosporites usmensis and Echitricolporites spinosus.* This range has a high diversity but low abundance of pollens and spores and also barren of dinoflagellate cysts. Some of the forms recovered here include *Lycopodium spp, Praedapollis africanus*, *Zonocostites ramonae, Verrucatosporites rotundiporus, Magnastriatites howardii*, *Botryococcus braunii*, *Peregrinipollis nigericus*. Total pollen count was 38, while spores was 33.

Sub zone: P620
Interval: 1835 – 2201 meters
Age: Early Miocene

This is the last subzone recognized within this zone. The top of this subzone is placed at 1835 meters and it is defined by the top occurrence of *Praedapollis africanus* while the base is placed at the depth of 2201 meters and it is defined by the base rich occurrence of *Verrutricolporites rotundiporus*. This subzone is further characterized by the presence of *Verrucatosporites usmensis,* regular records of *Praedapollis africanus, Praedapollis flexibilis, Arecipites exilimuratus* and *Racemonocolpites hians*.

Zone: P500
Subzone: P580
Interval: 2201 – 2438 meters
Age: Late Oligocene

This is the oldest and the last subzone identified within the studied section of the well. The top of the P580 subzone is placed at 2201 m defined by the rich occurrence of *Verrutricolporites rotundiporus*. The base is placed at 2438 m, the depth of the last sample analyzed.

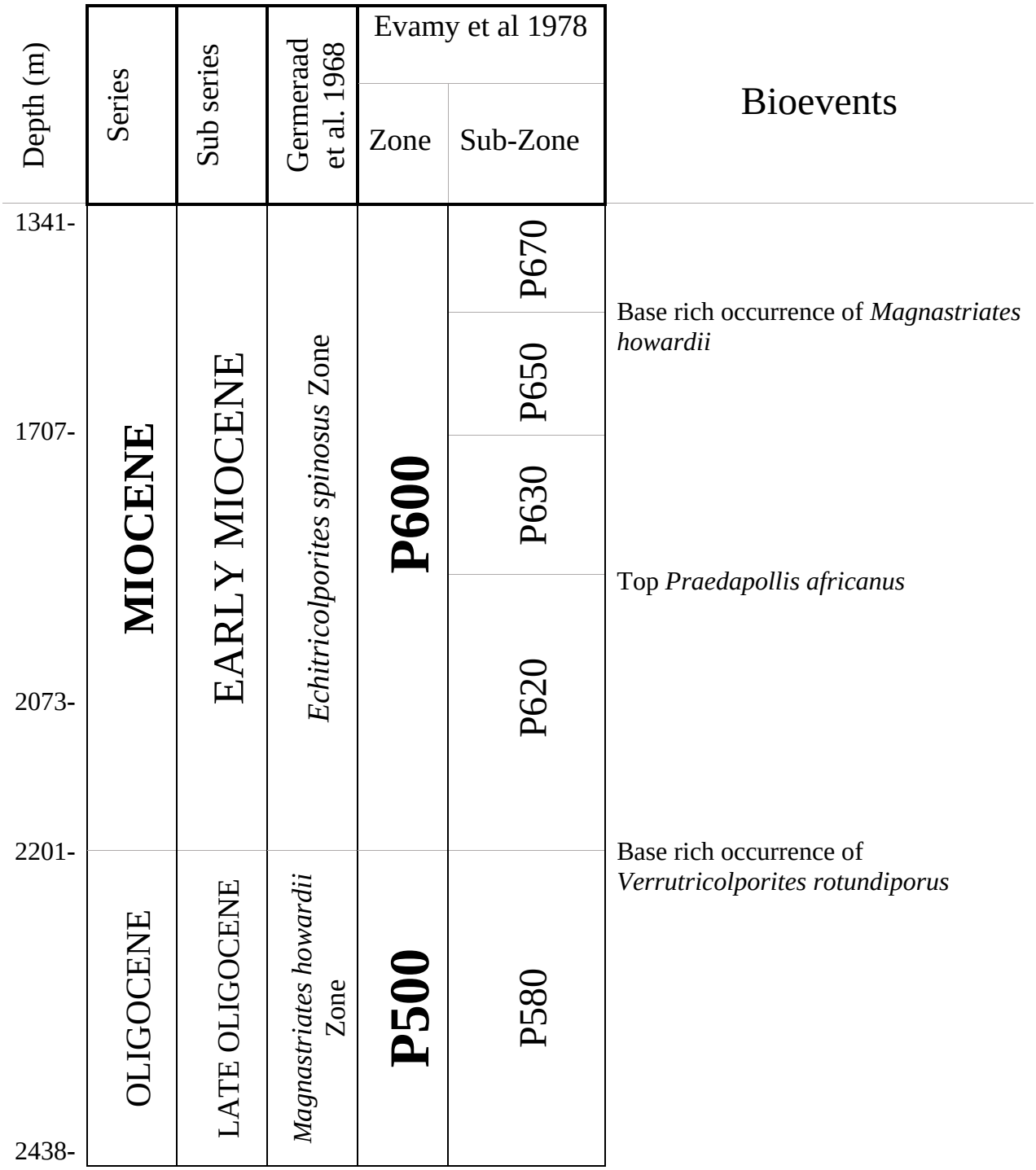


Figure 3: Palynomorph Zones and Subzones Established in Adeobak-2 Well.

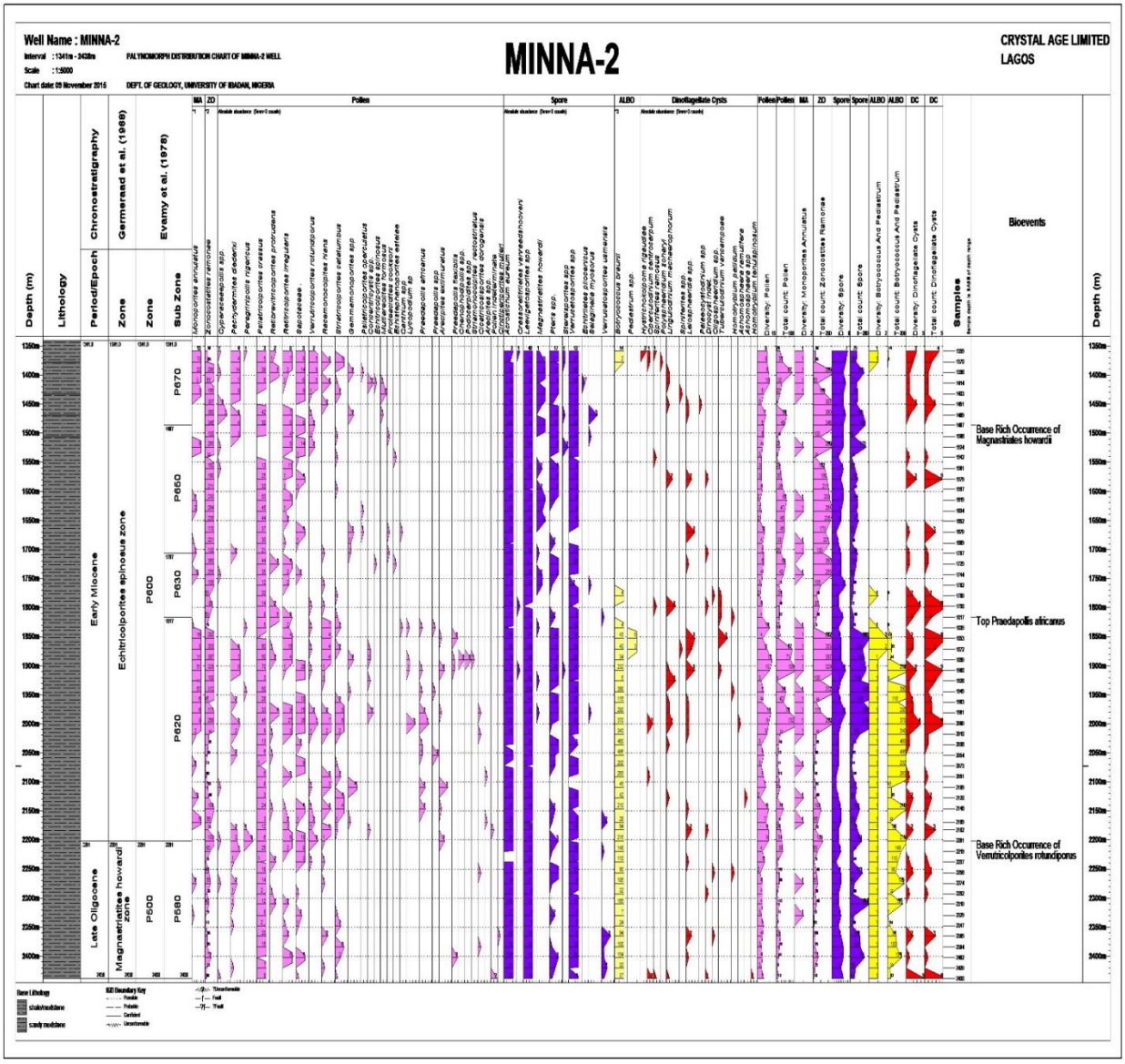


Figure 4: Palynological Distribution Chart of Adeobak-2 Well.

Palynomorphs Frequency Distribution of Adeobak-2 Well

Figures 5 and 6 show the abundance and distribution of the recovered palynomorphs from the studied section (1341 – 2438 m). Paleoenvironmental deduction based on the distribution patterns of palynomorph types using the bar chart and the abundance plots show a shift in coastline position from landward to seaward at different periods.

A similar graphical pattern- pie chart, constructed for the well shows that land derived palynomorphs accounted for 75% (i.e. 48% pollens and 27% spores), dinoflagellates- 0 to 1%, and algae 25% (Figure 7). This suggests an alternation of fluviatile and marine regimes for the interval. An interplay of sea level changes in association with fluctuating climatic conditions could be suggested for the paleoenvironment, based on the patterns observed (Figure 5).

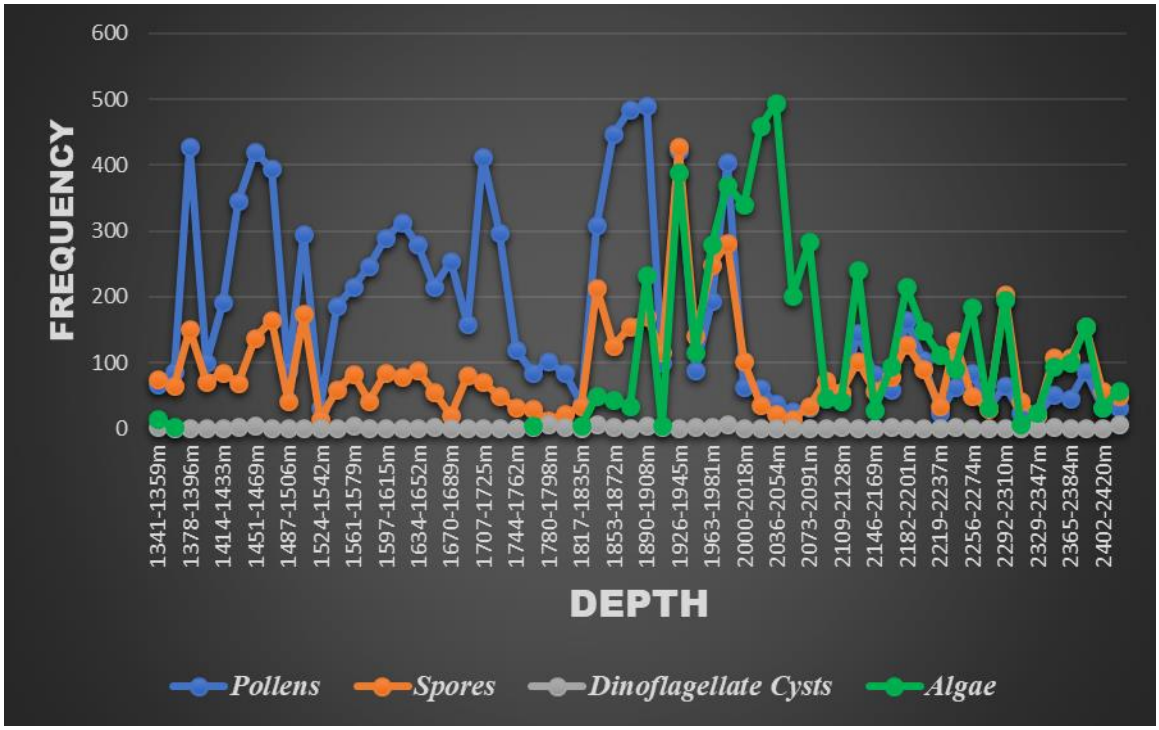


Figure 5: Plot of the Abundance of the Palynomorphs Recovered from Adeobak-2 Well (1341- 2348m).

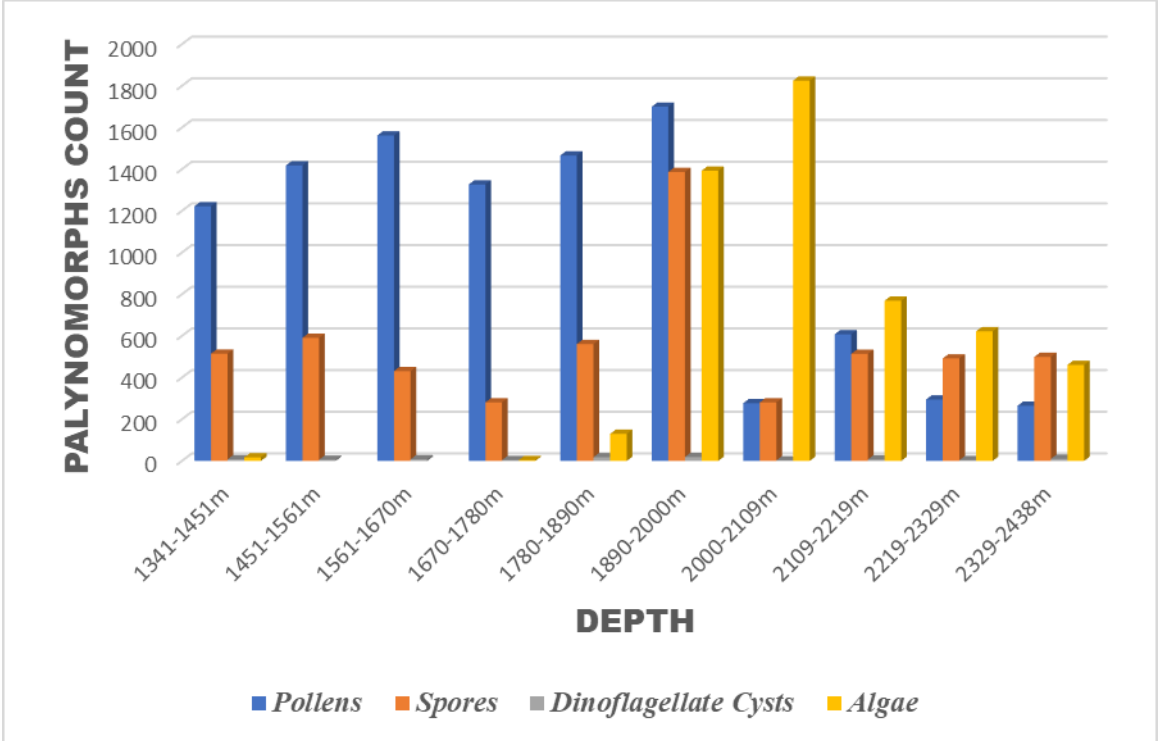


Figure 6: Bar Chart showing the Palynomorphs Distribution in Adeobak-2 Well.

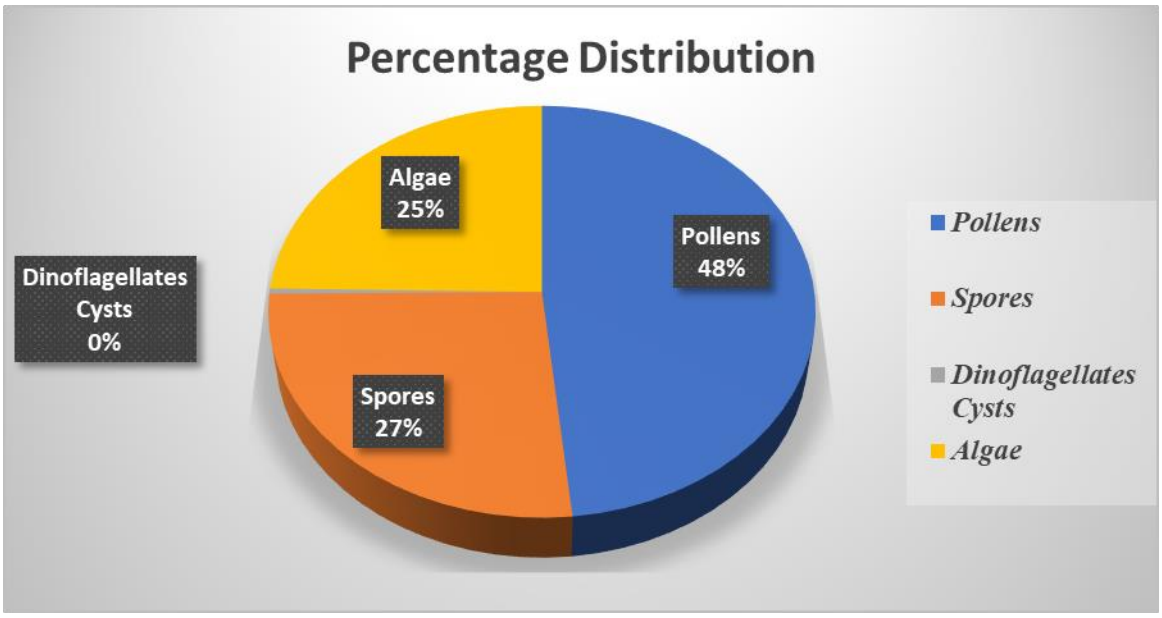


Figure 7: Pie Chart showing Palynomorphs Distribution in Adeobak-2 Well.

Paleoenvironment

Generally, the recovery from Adeobak-2 well was excellent; forms were well preserved and diverse in most of the horizons studied. The assemblages were dominated by abundant terrestrial forms including *Zonocostatites ramonae, Monoporites annulatus, Retitricolporites irregularis*, *Psilatricolporites crassus, Acrostichum aureum, Sapotaceae, Operculodinium centocarpum, Pteris spp, Spiniferites spp, Laevigotosporites and Verrucatosporites spp* (Plate 1).

Environmental marker species such as *Zonocostatites ramonae* (mangrove pollen), *Monoporites annulatus* (gramineae pollen suggesting open vegetation found in coastal Savannah), *Acrostichum sp* (suggestive of blackish/mangrove environment), *Leoisphaeridae sp* (indicative of neritic environment) and microforaminiferal wall linings (which are good indicators of marine environment) were all present in the studied section (Van der Hammen and Wymstra, 1964). The abundance of these marker species, especially at the topmost part of the well (with exception of microforaminifera wall linings) suggests that the sequence studied represents mainly deposition in coastal to marginal marine setting.

Also, moderate record of highly diverse deep water dinoflagellate cysts– *Polysphaeridium zoharyi*, *Lingulodinium machaerophorum*, *Spiniferites ramosus, Spiniferites spp, Achomosphaera ramulifera and Operculodinium centocarpum* and *Leiosphaeridia spp* were noted from the well. Abundant *Botryococcus braunii*, which is indicative of freshwater environment, was also recorded from the well. (Fredericksen, 1985, Ruta et al., 2007) (Plate 1).

The above assemblages indicate or show that the studied sediments of Adeobak-2 well as inferred from the diagnostic markers (Table 1) were deposited in a marine environment with high influx of freshwater.

Similarly, a semi quantitative interpretation technique was also employed to further determine the paleoenvironment of deposition of this well (1341-2438m). This technique is refer to as Palynological Marine Index (PMI) (Figure 8). The method is dependent on the amount of terrestrially and aquatic derived palynomorphs separately. Heles et al., (1998) defined PMI as:

$$PMI = (R_m / R_t + 1) \times 100$$

Where R_m = number of aquatic palynomorphs (Dinoflagellates + Algae+ Acritarch + Prasinophytes + Foraminiferal linings)

R_t = number of terrestrial palynomorphs (Pollen + Spores + Fungal remains)

From the graph below (Figure 8), it can be interpreted quantitatively that intervals with PMI value range of 200-700 are: 2000-2091m, 2128-2146m, 2219-2237m, and 2256-2274m and they are equivalent to marine deposits; while PMI value <200 such as intervals 1341-2000m, 2091-2128m, 2146-2219m, 2237-2256m and 2274-2438m are equivalent to fluviatile deposits. A general overview of the plot of PMI values show that the topmost portion of the well (1341-2000m) and the bottommost portion of the well (2274-2438m) were defined of PMI value of about 100, suggestive of continental deposit due to dominance of land derived palynomorphs. The interval 2000-2091m is characterized by marine derived palynomorphs only, because of its high PMI value (i.e. 200-700); while interval 2091-2274m showed an alternation of value range of 100-300, suggesting an alternation of continental and marine deposits.

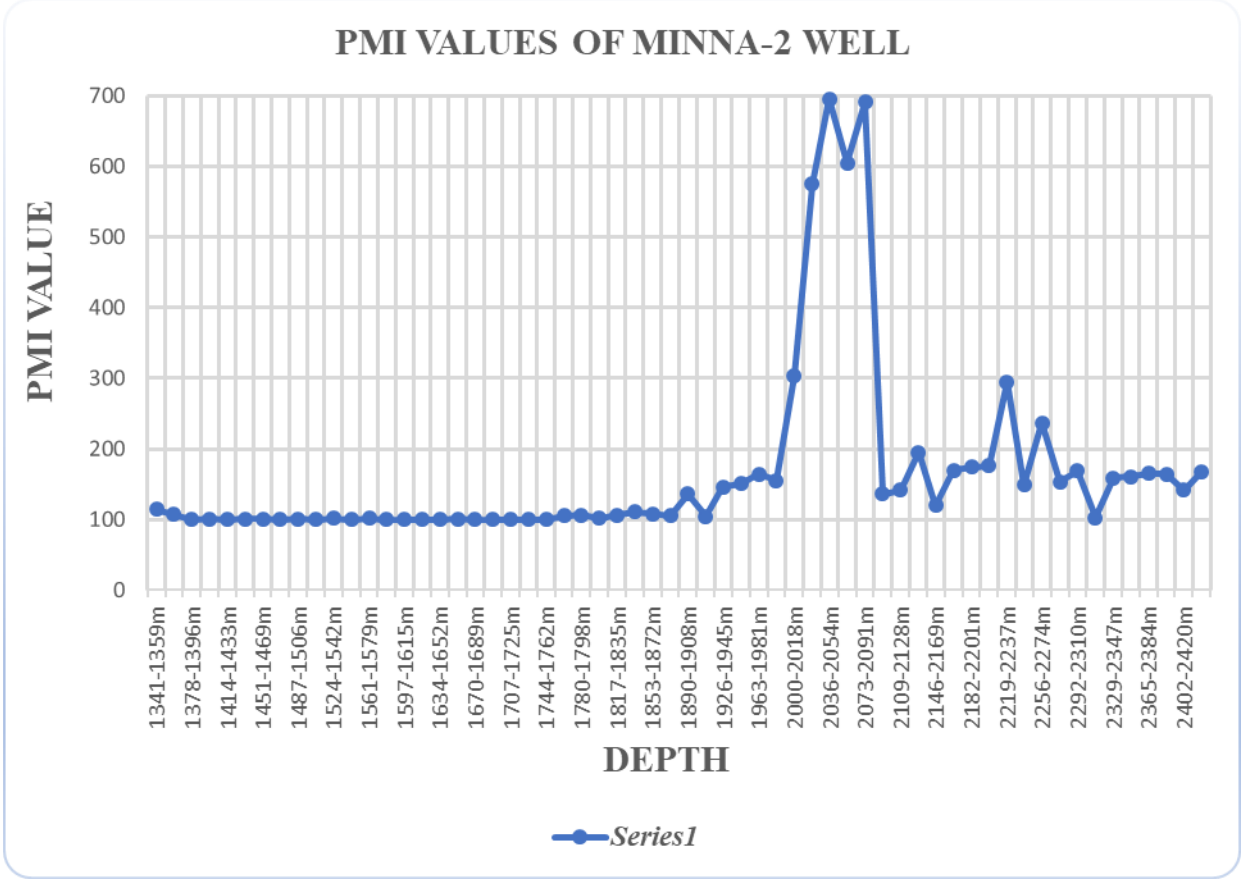


Figure 8: Palynomorph Marine Index (PMI) Chart of Adeobak-2 Well.

Table 1: Diagnostic Palynomorph Markers Encountered in Adeobak-2 Well.

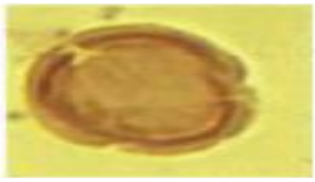
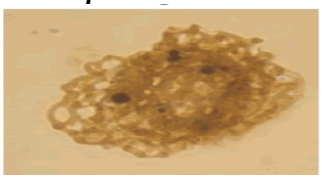
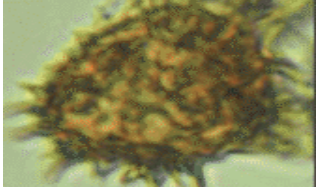
Diagnostic markers	Intervals found (m)	Age	Habitat
Botryococcus braunii 	1341-1396, 1762-1798, 1817-2438	Late Oligocene (Legoux, 1978)	Fresh to brackish water
Zonocostatites ramonae 	1341-2348	Early Miocene (Germeraad *et al.,* 1968)	Mangrove swamp Forest
Monoporites annulatus 	1341-1451, 1506-1542, 1597-1652, 1670-1762, 1817-2036, 2054-2091, 2109-2182, 2256-2292, 2310-2347	Miocene (Morley,1997)	Open vegetation found in coastal Savannah
Verrutricolporites rotundiporus 	1341-1542, 1780-1926, 1963-2036, 2091-2256	Early Miocene (Legoux, 1978)	Fresh water Swamp forest
Magnastriates howardii 	1341-1506, 1542-1670, 1689-1780, 1836-1853, 1926-1945, 1963-2000	Late Oligocene (Germeraad *et al.,* 1968)	Small aquatic fern of alluvial plain and coastal swamps
Praedapollis africanus 	1835-1853, 1908-2073, 2091-2169	Early Miocene (Legoux, 1978)	Tropical forest
Echitricolporites spinosus 	1414-1433, 1725-1744	Early Miocene (Germeraad *et al.,* 1968)	Mangrove to Lowland forest

PLATE 1

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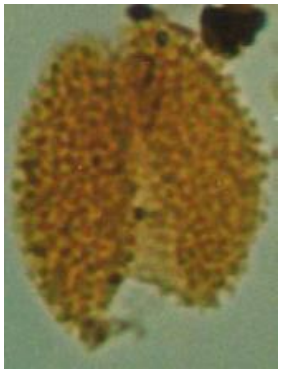

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(1) Psilatricolporites crassus

(2) Monoporites annulatus

(3) Racemonocolpites hians

(4) Retitricolporites irregularis

(5) Pachydermites diederixi

(6) Botryoccocus braunii

(7) Retibrevitricolporites protrudens

(8) Stereisporites spp

(9) Zonocostatites ramonae

(10) Verrutricolporites spp.

(11) Striatricolporites catatumbus

(12) Gemmatricolporites spp.

CONCLUSIONS AND RECOMMENDATIONS

Palynological analysis was carried out on sixty (60) composite ditch cutting samples of Adeobak-2 well located in the offshore section of Niger Delta basin, Southern Nigeria with depth interval ranging from 1341 m to 2438 m. The lithological section of the well shows coarsening upward sequence of interbedded shale into sandy mudstone units.

The studied section of the well (1341 m – 2438 m) falls within the pan tropical *Echitricolporites spinosus* zone and the *Magnastriates howardii* zone Germeraad *et al., (*1968) which correlates to the P600 and P500 zones of Evamy *et al.,* (1978) respectively. The P600 was further sub divided into the P620, P630, P650 and P670 subzones, while the P580 subzone was the only subzone identified within the P500 zone. Based on the presence of some selected marked species (Table 1), the studied interval was dated Late Oligocene to Early Miocene and the boundary between the two epochs was placed at the depth of 2201 m (i.e. the boundary between the P500 and P600 zones).

The paleoenvironment of deposition varies from brackish to open marine and this was done with help of environmental marker species (Table 1 and Plate 1) such as *Zonocostatites ramonae* (mangrove pollen), *Monoporites annulatus* (gramineae pollen suggesting open vegetation found in coastal Savannah), *Acrostichum sp* (suggestive of blackish/mangrove environment), *Leoisphaeridae sp* (indicative of neritic environment) and microforaminiferal wall linings were present. The abundance of these marker species, especially at the topmost part of the well (with exception of microforaminiferal wall linings) suggests that the sequence studied represents mainly deposition in coastal to marginal marine setting with high influx of fresh water.

Frequency percentage distribution of the studied interval shows that the percentage of land derived palynomorphs accounted for 75% (i.e. 48% pollens and 27% spores), dinoflagellates- 0 to 1%, and algae 25%. High resolution paleoenvironmental deductions carried out through relative frequency of land derived forms to marine derived forms (PMI) showed that the upper portion of the well with interval 1341-2000m and the lower portion of the well (interval 2274-2438m) were mainly of terrestrial deposits, while interval 2091-2274m is characterized by alternation of continental and marine depositional environment and interval 2000-2091m is characterized by marine derived palynomorphs only. It is hereby suggested that sea level changes in association with fluctuating climatic conditions were responsible for the environmental variation. Hence, the paleoenvironment of deposition of Adeobak-2 well fluctuates between continental and shallow marine environment.

It is hereby recommended that similar studies using core samples should be carried out and deeper depths should also be examined.

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