

Palynostratigraphic and Paleoenvironmental Interpretation of Ore-1 Well, Onshore Western, Niger Delta, Nigeria

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Abstract

The study area is Ore-1 well and it is located on latitude $6^{\circ} 03' 40''$ N and longitude $5^{\circ} 35' 44''$. The aim of this paper is to present the palynostratigraphic and paleoenvironmental interpretation of Ore-1 well, onshore western Niger Delta, Nigeria. Forty-three ditch cutting samples were taken from 2,956.56 m – 3,154.68 m intervals of Ore-1 well and subjected to standard laboratory palynofacies analysis using the acid method. The recovered palynomorphs were examined under the CX41 Olympus binocular transmitted light microscope. The samples are made up of fine to medium grained sandstone and orange to dark shale. Four types of palynomacerals were identified namely, namely: palynomaceral 1, 2, 3 and 4. palynomaceral 1 (orange-brown or dark brown structured and unstructured higher plant materials) is more than 90% while palynomaceral 2 (structureless or structured materials of relics rootlet relics, stem, leaf and relics of algal) is over 80%, palynomaceral 3 (leaf cuticle and irregular relics of plants) is less than 30% and palynomaceral 4 (dark blade, tube and needle like shape materials with cellular structured) is approximately 4%. Three interval palynostratigraphic range biozones were identified, namely: *Verrucatosporites usmensis-Ctenolophonidites coastatus*, *Pachydermites diederixi-Spinicolpites echinatus* and *Grimsdalea polygonalis-Retibrevitricolpites triangulatus* were recognized. The biozones were dated early to late Eocene based on the presence of marker palynomorphs and paleoenvironment of coastal- deltaic (lower delta and upper delta plain) was interpreted for the studied sections of Ore-1 well.

Keywords:

1. Introduction

Palynofacies studies have become a very useful tool for paleoenvironmental studies in recent times particularly in sediments where other types of fossils are lacking. The term was described by (Combaz, 1964; Powell, 1990, Batten and Stead, 2005) to designate the entire organic matter recovered from sedimentary rocks through a standard palynological preparatory method whose composition reflect a particular environment. The organic contents are called palynomorphs which include structured and unstructured vegetal materials.

The character of organic matter in sedimentary rocks provides insight to the rock hydrocarbon type and thermal maturity of a source rock. Its concept could be used for correlation of reservoirs within an oil-bearing field and areas where biomarkers are scarce (Chukwuma et al., 2019). This could aid in improving geological practices and refined biostratigraphy because different environments

have different sceneries in which the rock units were laid. Therefore, sufficient information on paleoenvironment is needed to reduce risk and cost of hydrocarbon exploration. Unfortunately, application of palynofacies data in Niger Delta Basin is scarce in comparison to the use of other microfossils (such as foraminifera and calcareous nanno-fossils) in biostratigraphy. Chukwuma et al. (2017) carried out an extensive research on the Miocene sediments in Ida-6 well, Niger Delta Basin. Based on palynofacies study, the authors identified three informal palynozones and deduced coastal deltaic environment for the strata penetrated in Ida-6 well. Chukwuma et al. (2019) further inferred a marginal marine environment to Ida-4 well located in the coastal swamp area of eastern Niger Delta Basin.

2. Study Area

Ore-1 well is in the onshore part of the western Niger Delta Basin. The Niger Delta basin lies within latitudes 4° and 6° N and longitudes 3° and 9° E. Ore-1 well is precisely located on latitude 6° 03' 40" N and longitude 5° 35' 44" E (Figure 1). The Niger Delta Basin lies in the inland lowlands in the southern part of Nigeria with elevations of 30 m to 300 m above the sea level. It is predominately by the complex dregs from Niger, Benue and Cross Rivers (Doust, 1990). Stratigraphically the lithic fills were subdivided into three major lithostratigraphic units that are interpreted based on sand and shale ratio. The lithic fills are dated based on microfossil contents (foraminifera and calcareous nannofossils) but recently the stratigraphic framework is based on the use of pollen and spores. They are the basal marine prodelta Akata Formation, the middle shallow marine delta front Agbada Formation and the top continental delta Benin Formation. The three formations consist of progradational sequences (Esan, 2002) and a gross upward coarsening deltaic marine, inter lobe and abyssal plain deposits of about 12,000 m (Weber and Daukoru, 1975). In this study, the palynostratigraphic and Paleoenvironmental interpretation of Ore-1 well, onshore western Niger Delta Basin was carried out.

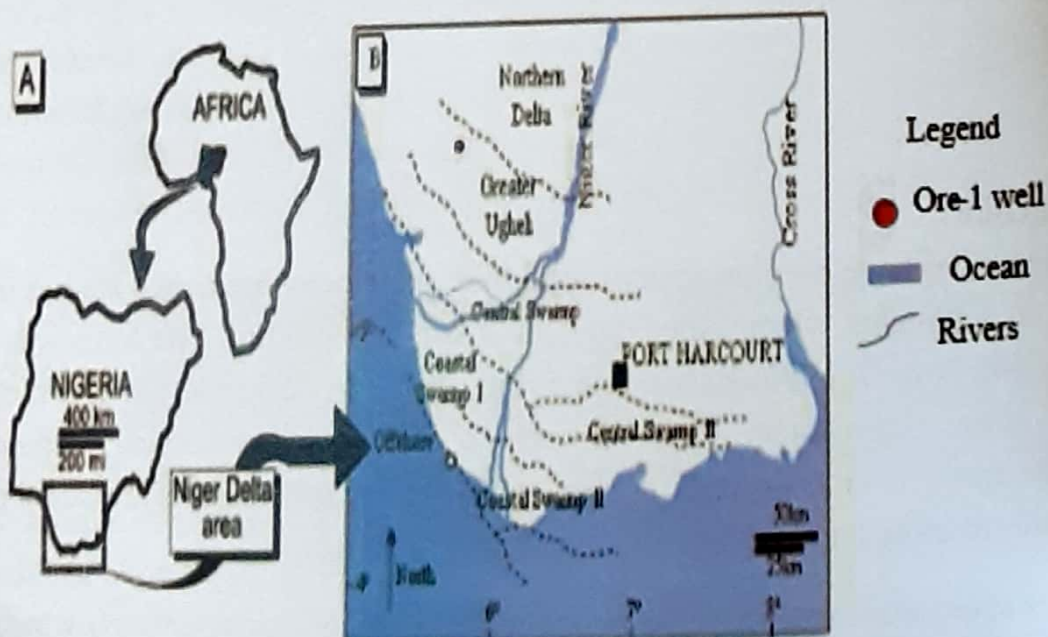


Plate 1: Palynomorph and palynomaceral recovered from Ore-1 well

3. Materials and Methods

Ditch cuttings and wire-line log were obtained from the National Petroleum Development Company (NPDC) and laboratory materials were provided by Crystal Age Limited Lagos, Nigeria wherein the analysis was done. Lithologic description were based on physical examination using hand lens, the sense of touch, feel, geology colour chart (2009). The wire line log measurement in API units was used to determine the shale and sandstone sections.

Forty-three ditch cutting samples were taken at 4.57 m intervals from 2,956.56 m - 3,154.68 m depths of Ore-1 well and subjected to standard laboratory palynofacies analysis using the acid method. Ten grams of each samples were equally weighed into clean well labelled plastic beakers and treated mildly with 10% hydrochloric acid (HCl) in a fume cupboard to thoroughly remove carbonates materials such as shell fragments, foraminifera and other microfossils present. Thereafter, complete neutralization was achieved using clean water. Then 40% hydrofluoric acid (HF) was added before being transferred to a centrifuge for twenty-four hours to speed up the rate of chemical reaction to completely dissolve the silicates. Thereafter, the HF was removed with water. Samples were then transferred into the Brason Sonifier to filter out inorganic materials that might still be present. The residues were divided into two portions; - one part for palynological analysis, while the second portion was used for palynofacies analysis. The contents of the portion for palynological analysis were stained with nitric acid for clearer identification of palynomorphs, while those for palynofacies were excepted so as to retain the actual colour of the organic contents. Two drops of each residue was pipetted into a clean circular cover slide, mix with Loctite (impruv) as a permanent mounting medium and cured in ultraviolet light for about five minutes. The prepared slides for both palynofacies and palynological analysis were observed under the CX41 Olympus binocular light transmitted microscope and compared with classical works of Germeraad et al. (1968), Van Hoeken-Klinkenberge (1966), Oyede (1992) and Ige et al. (2011).

4. Results, Interpretations and Discussions

4.1 Lithologic Description of Ore-1 Well

Ore-1 well comprises of alternations of sandstone, sandy mudstone and shale (Figure 2). The lower paralic unit is more shaly in comparison to the sandy upper paralic unit in line with the findings of Doust and Omotsola (1990). The sandstone units are fine to medium grained with thin lenses of shale at some intervals.

4.2 Palynofacies

Palynomorphs and palynofacies that were recovered from Ore-1 well at different depths are given in Plate 1 and Figure 2. Four types of palynomacerals were identified, namely: palynomaceral 1, 2, 3 and 4. Palynomaceral 1 (orange-brown or dark brown structured and unstructured higher plant materials) is more than 90%, while palynomaceral 2 (structureless or structured materials of rootlet relics, stem, leaf and relics of algal) is over 80%, palynomaceral 3 (leaf cuticle and irregular relics of plants) is less than 30% and palynomaceral 4 (dark blade, tube and needle like shape

materials with cellular structure) is approximately 4%. Palynomorph assemblage of the recovered organic content was less than 5% (Figure 3). It was observed that palynomorph abundances and diversity increased with more freshwater palynomorphs such as *Verrucatosporites* spp, *Acrostichum aureum*, *Laevigatosporites* spp and *Psilatricolporites crassus* at deeper depths (Figure 2).

Palynomaceral 1 (PM1)

Palynomaceral 1 (PM1) is dense, structured and unstructured with orange, brown and dark brown colours (Plate1). Palynomaceral 1 (PM1) are from higher plant materials mainly resin, cortex materials and algal remnants of *Botryococcus* spp (Whitaker *et al.*, 1992). Palynomaceral 1 has lowest buoyancy in comparison to PM2, PM3 and PM4.

Palynomaceral 2 (PM2)

They are brownish orange lathy shaped remains of plants (e.g., stem, leaf, rootlet and relics of algal) known as exinites (Whitaker *et al.*, 1992).

Palynomaceral 3 (PM3).

Palynomaceral 3 (PM3) is usually pale and skinny with irregular shape and relic of a plant's stomata (Thomas *et al.*, 2015). It is more buoyant than PM1 and PM2.

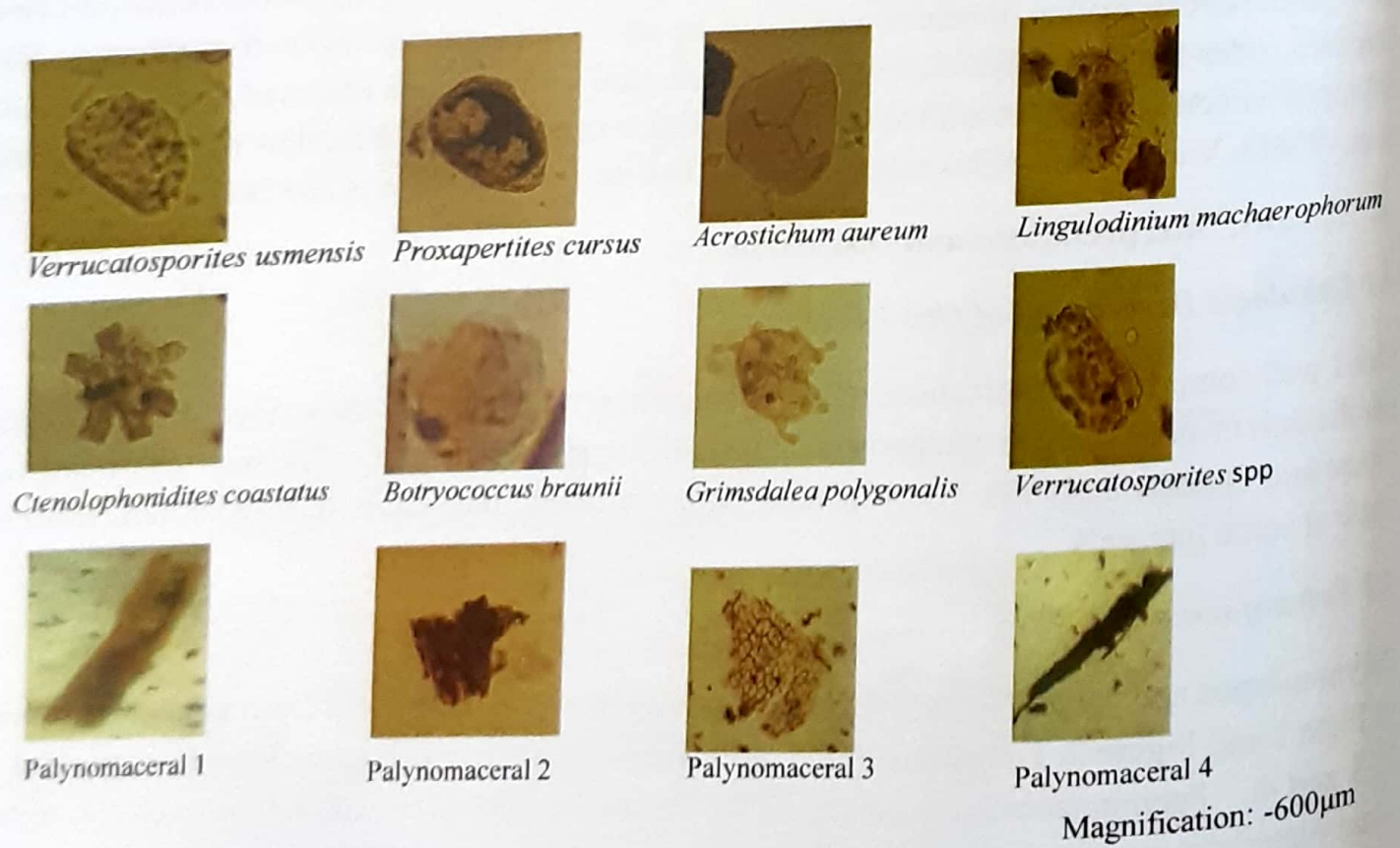


Plate 1: Palynomorph and palynomaceral recovered from Ore-1 well

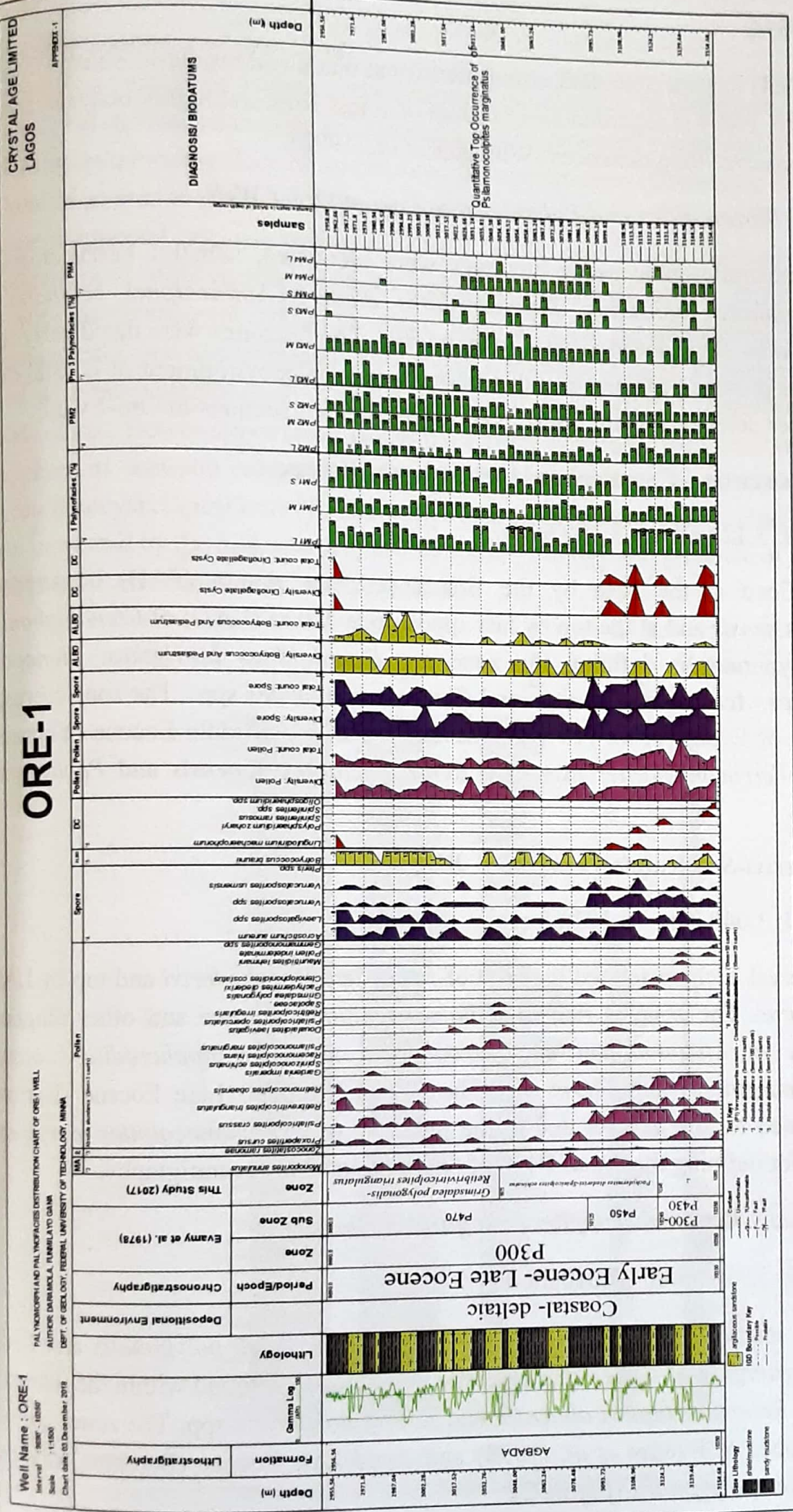


Figure 2: Lithology, palynomorph and palynofacies chart of Ore-1 well

Palynomaceral 4 (PM4)

Palynomaceral 4 (PM4) has variable dark equidimensional blade and needle-like shape materials with cellular structure. PM 4 is regarded as a product of forest fires and highly buoyant, resistant and can be transported over long distances (Whitaker *et al.*, 1992).

Palynostratigraphic Biozonations and Palynochronology of Ore-1 Well

Three interval palynostratigraphic range biozones were identified, namely: *Verrucatosporites usmensis*-*Ctenolophonidites coastatus*, *Pachydermites diderixi*-*Spinicolpites echinatus* and *Grimsdalea polygonalis*-*Retibrevitricolpites triangulatus*. The biozones were dated early to late Eocene based on the presence of marker palynomorphs and palaeoenvironment of coastal-deltaic (lower delta and upper delta plain) was interpreted for the studied sections of Ore-1 well.

***Verrucatosporites usmensis* – *Ctenolophonidites coastatus* Biozone**

Stratigraphic interval: 3,122.68 m - 3,154.68 m.

The interval is defined at the base by the first appearance datum (FAD) occurrence of *Verrucatosporites usmensis* and at the top by last appearance datum (LAD) of *Ctenolophonidites coastatus*. Other palynomorphs defining the zone are *Doaulaidites laevigatus*, *Monoporites annulatus*, *Sapotaceae*, *Acrostichum aureum* and *Gemmamonoporites* spp. The zone correspond with the P300-P430 of Evamy *et al.* (1978) and dated Early to Middle Eocene (Yepressian-Lutetian) based on *Verrucatosporites usmensis*, *Retimonocolptes obaensis* and *Pachydermites diderixi*.

***Pachydermites diderixi*-*Spinicolpites echinatus* Biozone.**

Stratigraphic interval: 3,040.38m - 3,122.68 m.

The base of this interval is characterized by FAD of *Pachydermites diderixi* and top by LAD of *Spinicolpites echinatus*. The zone is rich in *Psilamonocolpites crassus* and other diagnostics palynomorphs such as *Lingulodinium machaerophorum* and *Ctenolophonidites coastatus*, *Psilamonocolpites marginatus* and *Pteris* spp. The age of Middle - Late Eocene (Bartonian-Priabonian) is assigned to this interval due to the presence of *Psilamonocolpites marginatus* a marker pollen used for defining the top of P450 of Niger Delta Chronostratigraphy.

***Grimsdalea polygonalis*-*Retibrevitricolpites triangulatus* Biozone**

Stratigraphic interval: 2,956.56 m – 3,040.38 m.

Characteristics: The interval is characterized by FAD of *Grimsdalea polygonalis* and LAD of *Retibrevitricolpites triangulatus*. Other characteristic palynomorphs found within the interval are *Gardenia imperelis*, *Retimonocolptes obaensis* and *Laevigatosporites* spp. The zones correlates with the P470 subzones of Evamy *et al.* (1978) and dated Late Eocene (Batonian) due to the occurrence *Grimsdalea polygonalis* (Figure 2).

4.2 Paleoenvironment of Ore-1 well

Paleoenvironmental study is the interpretation of depositional environments in which a rock unit is formed. Palynofacies data play an important role in paleoenvironmental studies because a close relationship between the flora of an area and its environment (Sowunmi, 1987). Thus, this makes the floral of an area to be useful in the reconstruction of past environment.

Paleoenvironmental reconstruction of Ore-1 well was based basically on percentage of palynomacerals and palynomorphs recovered from the studied section. The studied section reveals over 90% palynomaceral 1 (PM 1), more than 80% of palynomaceral 2, less than 30% of palynomaceral 3 and approximately 4% of palynomorphs (Fig 3). Palynomacerals of this kind are related with palynofacies 1, 2, 3 and 4 of (Tyson *et al.*, 1995). Therefore, an environment of coastal-deltaic (lower-upper delta plain) has been suggested for Ore-1 well. Furthermore, the dominance of common palynomorphs such as *Laevigatosporites* spp and *Acrostichum aureum* with few dinocysts (*Spiniferites*) further suggest an environment close to land (coastal deltaic). This is also supported by the dark and grey colour shale lithology and presence of *Botryococcus braunii* which point to an environment not far from land.

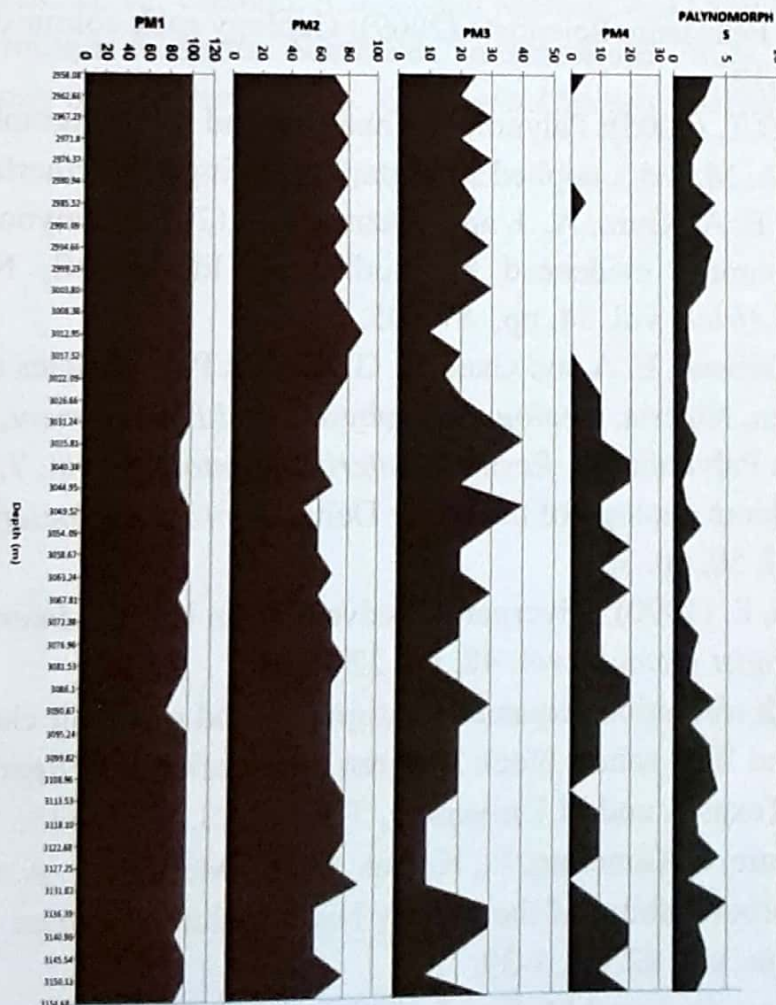


Figure 3: Percentage of palynofacies plot of Ore-1 well

1. Conclusion

In Ore-1 well, three interval palynostratigraphic range biozones were identified, namely: *Verrucatosporites usmensis-Ctenolophonidites coastatus*, *Pachydermites diederixi-Spinicolpites echinatus* and *Grimsdalea polygonalis-Retibrevitricolpites triangulatus*. The biozones were dated Early to Late Eocene based on the presence of marker palynomorphs and the paleoenvironment of coastal-deltaic (lower delta and upper delta plain) was interpreted for the studied intervals of Ore-1 well.

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