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Palynostratigraphic and Paleoenvironmental Study of an Offshore Well in the Niger Delta Nigeria

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Abstract

Palynomorphs were employed in this study to deduce the palynozones, age and paleoenvironment of an exploratory well drilled in the Niger Delta area.

Sixty (60) ditch cutting samples were selected at intervals of 60ft from the depth of 6110ft to 11690ft and subjected to palynological laboratory analysis. The residual samples which comprise of Particulate Organic Matter (POM) were identified under optical microscope and the information from the abundance of pollens and spores identified were imputed into the Stratabug software.

The lithostratigraphy of the section penetrated by the well comprises of intercalation of sandy mudstone, argillaceous sandstone to coarse sandstone. Also, a total of one hundred (100) palynomorph species were identified, out of which some marker species such as *Botryococcus braunii*, *Laevigatosporites sp, Striatopollis catatumbus, Stiamoncolpites rectostriatus, Peregrinipollis nigericus, Cicatricosisporites dorogensis, Verrucatosporites sp,* and *Pachydermites diederixi* were identified. This was followed by biozonation with the aid of standard zonation scheme and four (4) zones of pollen and spores comprising of P540, P560, P580 and P5620 were identified based on the Last Downhole Occurrence (Base) and First Downhole Occurrence (Top) of some marker species.

Based on the palynozones identified, the age of the sections penetrated by the well ranges from late Oligocene to early Oligocene, which falls within the Rupelian and Chattian stage while the paleoenvironmental studies of the abundance and diversity of pollens and spores with respect to their environment, shows that most of the species falls within the Brackish water and the Freshwater swamps environments.

Keywords: Palynomorphs; Biozonation; Species; Oligocene; Palynozones

Introduction

"Pollen and spores" also known as sporomorphs are produced by plants. Lower plants such as ferns produce spores while higher or flowering plants –angiosperms and gymnosperms, produce pollen grains.

Sporomorphs are generally small with sizes ranging from 10 to 20 microns. Shape and ornamentation of the grains vary greatly and allow for their morphological classification.

Previous studies on Pollen and Spores was carried out by Ajaegwu, et al. (2012) [1], Bankole, et al. (2006) [2], Oboh-Ikuenobe, et al. (1999) [3], Oloto (1989) [4], Biffi, et al. (1983) [5], Ravn (1981) [6], Romans (1975), May, et al. (1973) [7], Agasie (1969) [8], Simmons, et al. (1966) [9], Hedlund (1966) [10] and Brenner (1963) [11], where they used it to infer the age of sedimentary deposits and its paleoenvironment.

Though palynological works have been carried out in the Niger Delta basin, but there is little published information due to confidentiality maintained by oil companies within the basin.

Thus, the present study was undertaken to determine the lithostratigraphy of the formation, age and environment of deposition of an oil exploratory well drilled in the Niger Delta through the use of diagnostic palynomorphs.

Geologic Setting of the Area

The Niger Delta Basin is situated in the Gulf of Guinea in equatorial West Africa, between latitudes 4^0N and 6^0N and longitudes 5^0E and 8^0E as shown in Figure 1. The Niger Delta is framed on the northwest by a subsurface continuation of the West African Shield, the Benin Flank. The eastern edge of the basin coincides with the Calabar Flank to the south of the Oban Masif [12] as shown in Figure 1.

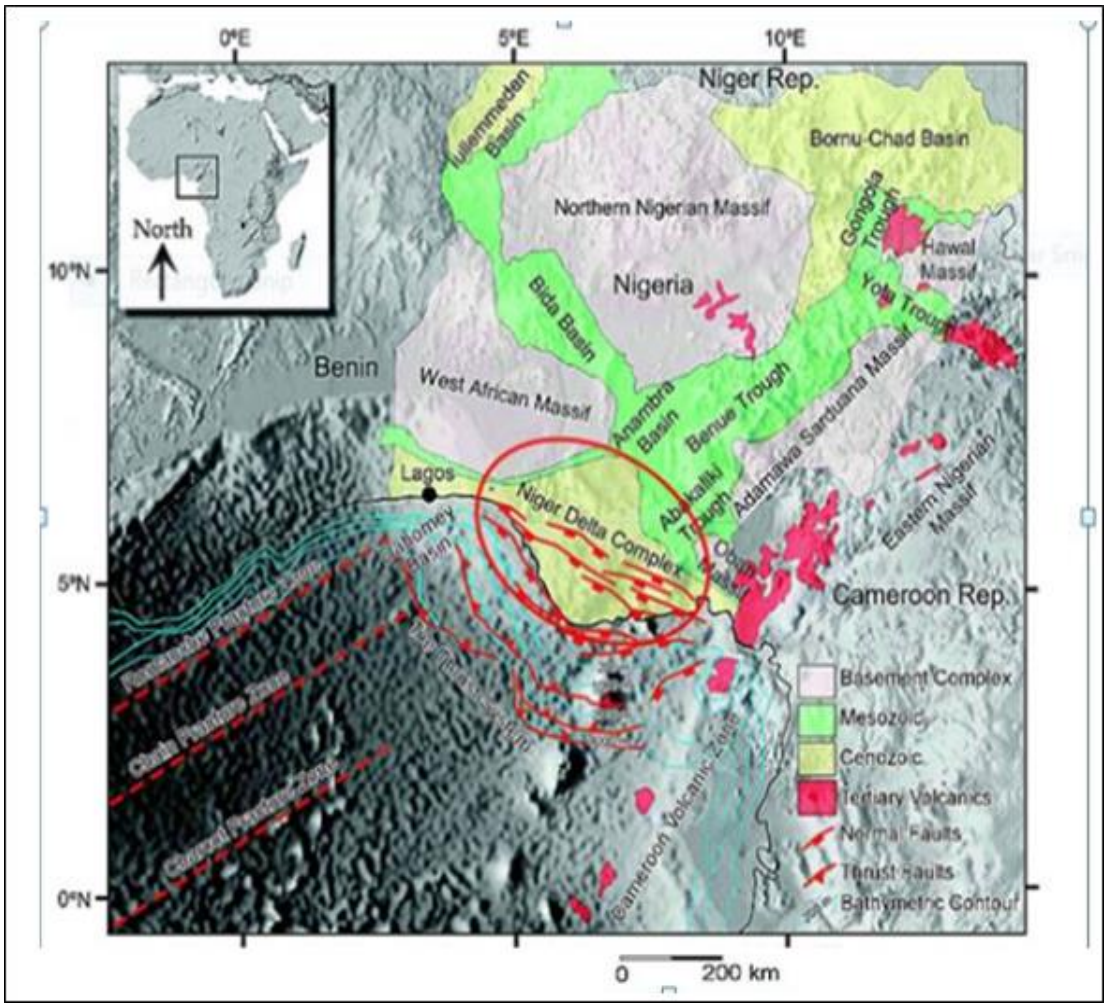

Figure 1: Geologic map of the Niger Delta region (after Correldor, et al. 2005) [13].

Well sections through the Niger Delta generally display three vertical lithostratigraphic subdivisions: an upper delta top facies; a middle delta front lithofacies; and a lower pro-delta lithofacies [14]. These lithostratigraphic units are shown in Figure 2 and correspond respectively with the Benin Formation (Oligocene-Recent), Agbada Formation (Eocene-Recent) and Akata Formation (Paleocene-Recent) of Short, et al. (1967) [15]. The Akata Formation is composed mainly of marine shales, with sandy and silty beds which are thought to have been laid down as turbidites and continental slope channel fills. It is estimated that the formation is up to 7,000 metres thick [16]. The Agbada Formation is the major petroleum-bearing unit in the Niger Delta. The formation consists mostly of shoreface and channel sands with minor shales in the upper part, and alternation of sands and shales in equal proportion in the lower part. The thickness of the formation is over 3,700 metres. The Benin Formation is about 280 metres thick, but may be up to 2,100 metres in the region of maximum subsidence [17], and consists of continental sands and gravels.

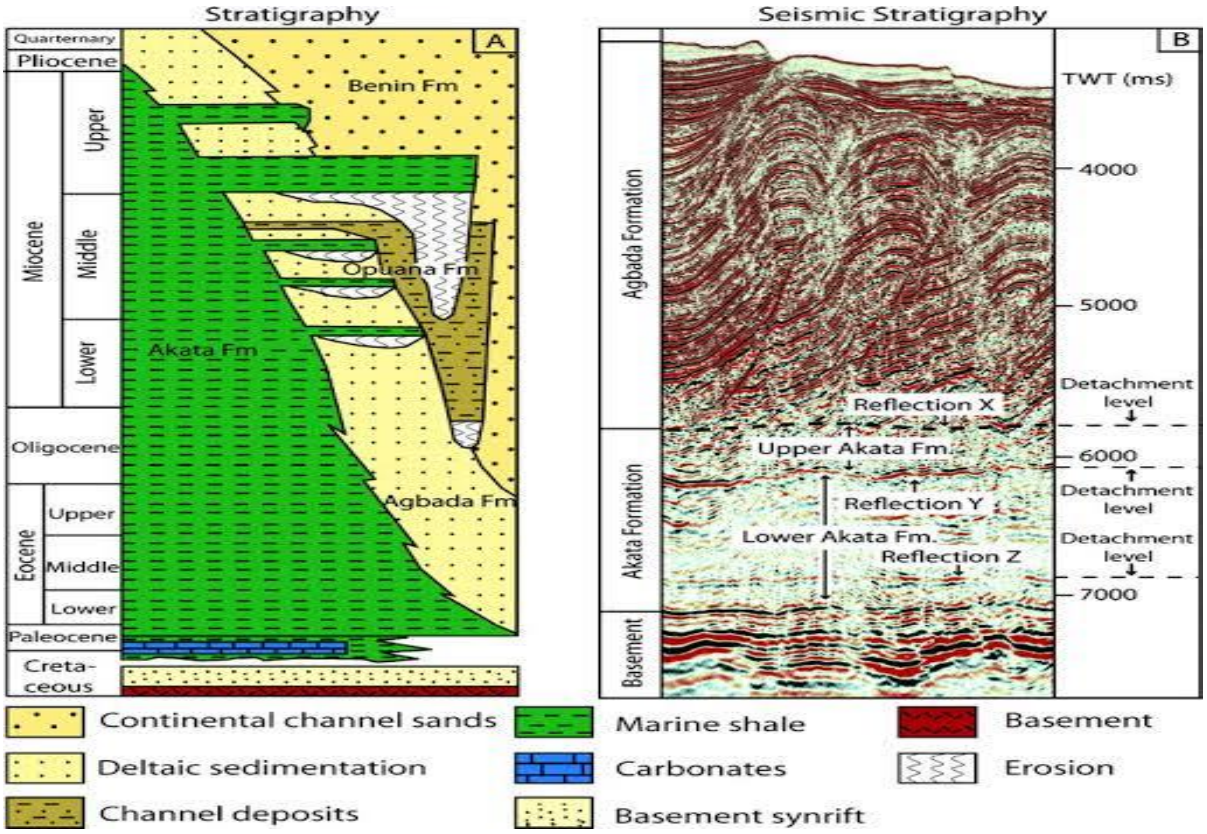

Figure 2: Stratigraphic Section of Niger Delta [16].

The section studied falls within the Biafra Member of the Agbada Formation of the Niger Delta basin as classified by Opara, 1981 [18].

Materials and Methods

In carrying out palynomorphs' analysis using ditch cutting samples, the following tools were put into use for extraction of pollen and spores: ditch cuttings, centrifuge machine, fume cupboard, brason sonifier 250, well labelled plastic cups, hot plate, beakers, test tubes, warmer, distilled water, glass slides/bottle cover slips, pipette, sample bags, water distiller, loctite impruv (adhesive), hand gloves and optical microscope.

Ditch cutting samples were used and they were composited at 60ft intervals. A total of 60 samples from depth of 6100ft to 11690ft were processed and analyzed

for sedimentological and palynological characteristics. The sedimentological characterization was done by visual inspection of the colour, grain size and textural composition of the various lithologies penetrated by the well.

Palynomorphs processing involves the use of 30 grams of each samples which was crushed to size between 0.25mm and 2.5mm. This is followed by the addition of concentrated hydrofluoric acid (HF) to remove the silicate materials. This process is called "soaking" and was done overnight (15hours) in a fume cupboard after which water was added, stirred and allowed to settle before it was decanted leaving behind the residue.

Hydrochloric acid (HCl) was later added to the sample to remove the calcareous material. This was followed by the addition of H_2O (distilled water) and decanting.

Nitric acid was then added to help concentrate the palynomorphs by burning off cellulose so that the slide will be clearer. $ZnBr_2/ZnCl_2$ was used for density separation. That is to separate the palynomorphs from larger fragments. This allows the floating and easy collection of the palynomorphs which was then carefully collected into a test tube.

The palynomorphs were then mounted using the mounting medium to produce the slides and one slide per sample was analyzed under the optical microscope and the microphotography of the best palynomorphs specimen was done with the aid of an "Olympus CBH" microscope.

The specimen (palynomorphs) morphological characteristics were then compared with the descriptions, monographs and diagrams of available publications which include publications of Gonzalex (1967) [19], Germeraad, et al. (1968) [20], Legoux (1978) [21], Adegoke, et al. (1978) [22], Salami (1983) [23] and Sowunmi (1995,1999) [24,25] and the palynozones were described using the zonation scheme of Germeraad, et al. 1968 [20] and Evamy, et al. 1978 [26]. While the palynological and lithological chart of the Well were displayed with the aid of the Strata Bug Graphical software.

Results and Interpretation

Lithologic Description

A lithostratigraphic unit is defined as a body of rock which is distinguished and delineated on the basis of lithic characteristics and stratigraphic position. This unit generally conforms to the Law of Superposition and is commonly stratified and tabular in form.

The SEG-1 well is lithologically characterized by a coarsening upward sequence from a sequence of intercalation of sandy mudstone and argillaceous sandstone, to mixed sandstone (70% coarse) and at the top sandstone (coarse) (as shown in Table 1, Figures 3 & 4). The intercalation of sandy mudstone, argillaceous sandstone, to mixed sandstone and coarse sandstone reveals that SEG-1 well penetrates the Agbada Formation of the Niger Delta basin. This is because of its similarities to the Agbada Formation which is made up of shoreface and channel sands with minor shales in the upper part, and alternation of sands and shales in equal proportion in the lower part.

DEPTH (ft)	LITHOLOGY
6110-6620	Sandstone
6640-6800	Argillaceous sandstone
6800-6975	Mixed sandstone
6975-7175	Argillaceous sandstone
7175-7200	Sandy mudstone
7200-7850	Argillaceous sandstone
7850-8250	Intercalation of argillaceous sandstone and mudstone
8250-8510	Argillaceous sandstone
8510-8925	Intercalation of argillaceous sandstone and mudstone
8925-9025	Argillaceous sandstone
9025-9750	Intercalation of argillaceous sandstone and mudstone
9750-10100	Sandy mudstone
10100-10175	Argillaceous sandstone
10175-10200	Sandy mudstone
10200-10250	Argillaceous sandstone
10250-10630	Sandy mudstone
10630-10650	Argillaceous sandstone
10650-11040	Sandy mudstone
11040-11135	Argillaceous sandstone
11135-11250	Sandy mudstone
11250-11315	Argillaceous sandstone
11315-11500	Sandy mudstone
11500-11650	Argillaceous sandstone
11650-11690	Sandy mudstone

Table 1: Lithostratigraphic characteristics of SEG-1 Well.

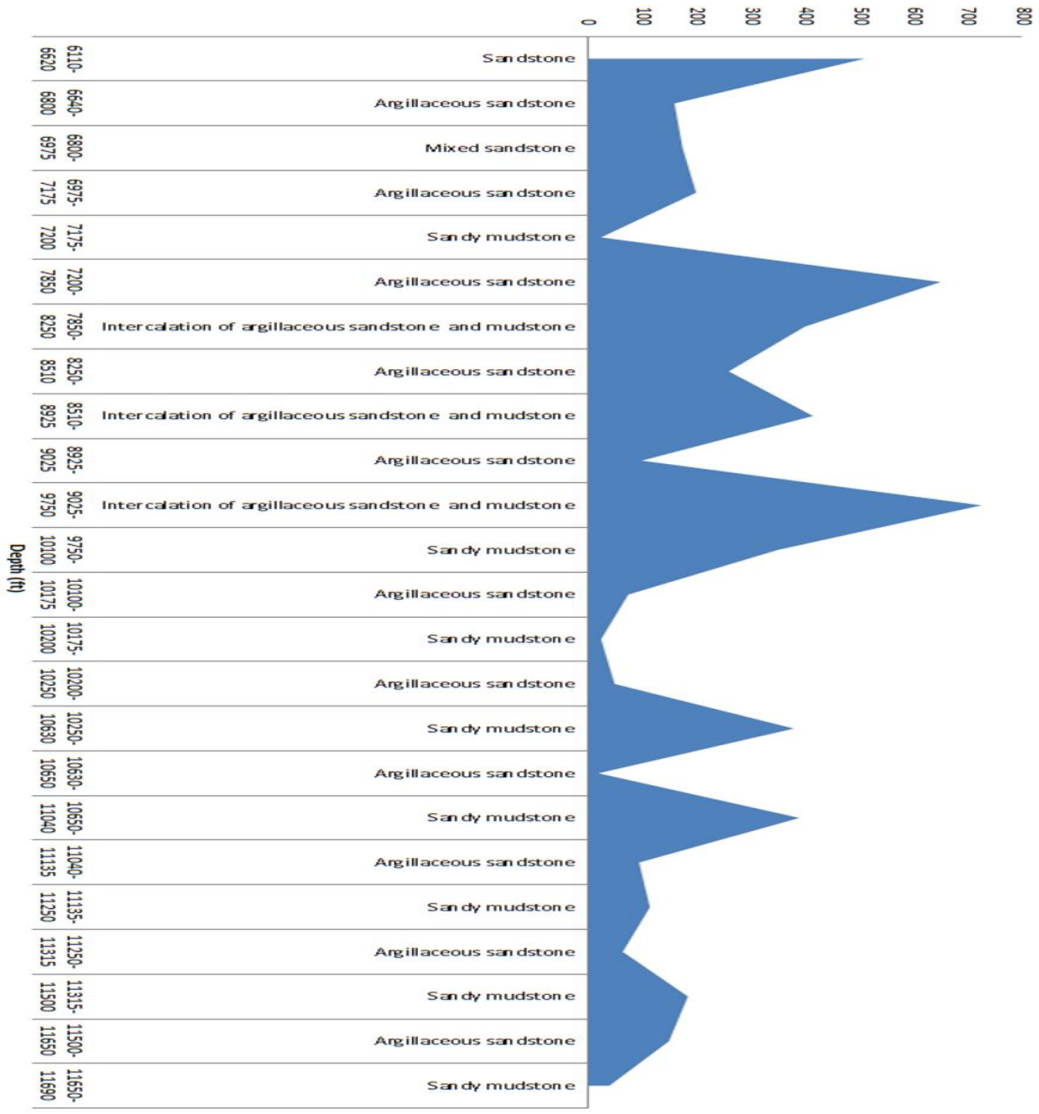

Figure 3: Lithostratigraphic characteristics of the SEG-1 Well.

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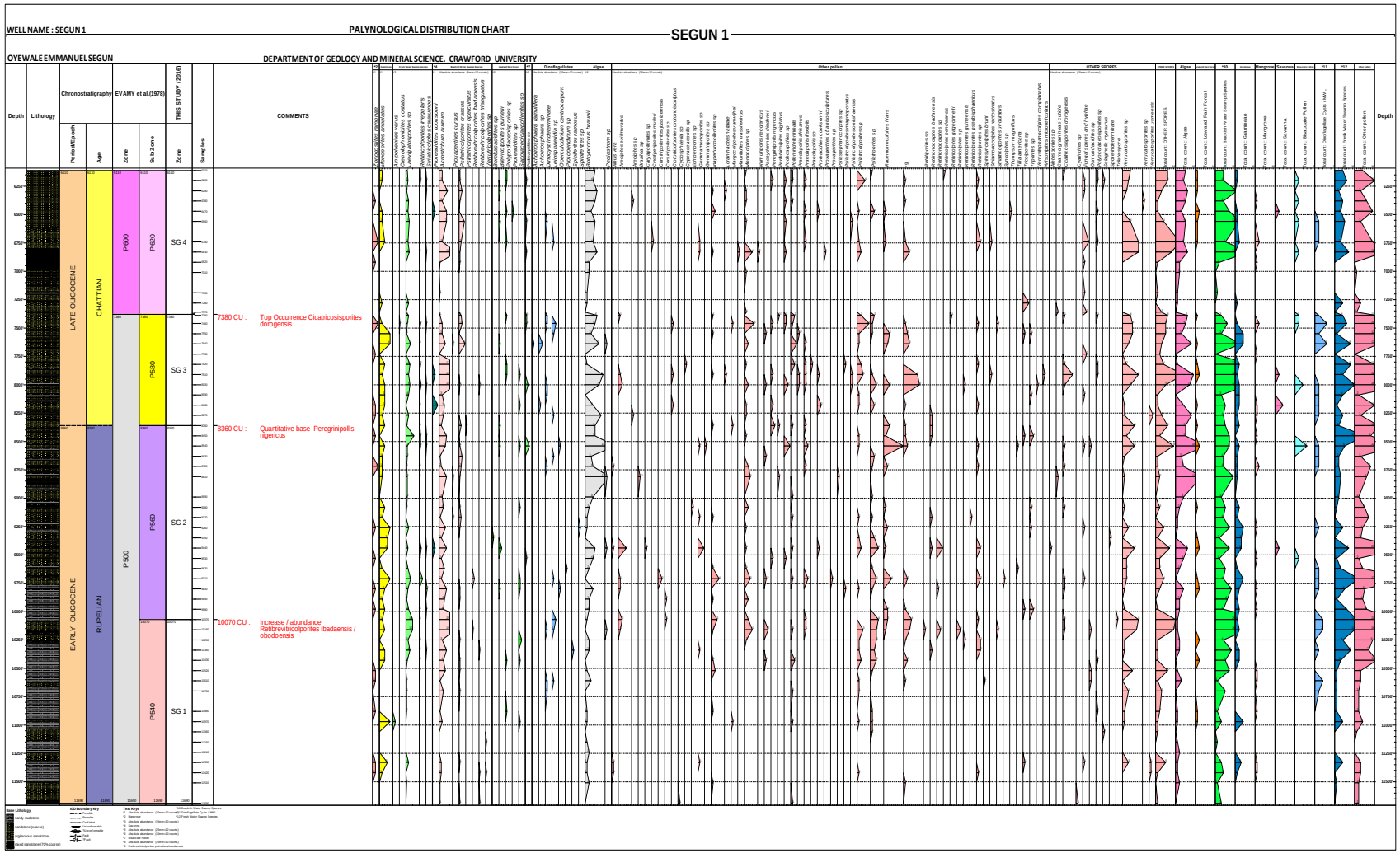

Figure 4: Chart showing the distribution, abundance and the paleoenvironment of the palynomorphs.

Palynostratigraphy

A total of one hundred (100) species of pollen and spores were identified in SEG-1 well as shown in Figure 4. This comprises of spores, pollen, dinoflagellates and algae while 12 marker species comprising of *Retibrevitricolporites obodoensis/ibadanensis*, *Peregrinipollis nigericus*, *Cicatricosisporites dorogensis, Sapotaceoidaepollenite sp, Pachydermites diederixii, Zonocostites ramonae, Acrostichum aureum, Botryoococcus braunii, Polypodiacoisporite sp and Monocoporites annulatus* amongst others as shown in Figures 4 & 5 were identified.

Based on the distribution, diversity and abundance of the pollen and spores identified in the studied well, various deductions were made from the chart generated by the Stratabug software. These include the palynozones by Evamy, et al. [26] and Germeraad, et al. 1968 [20], age of the lithologies penetrated by the well and the environment of deposition of the sediments as well as the pollen and spores species identified.

Using the zonation scheme of Evamy, et al. 1978 [26], two (2) palynozones were recognized in the well based on the first and last downhole occurrence of the marker species. These are P500 with subzones P540, P560, P580 and P600 with subzone P620 as shown in Figures 4-6.

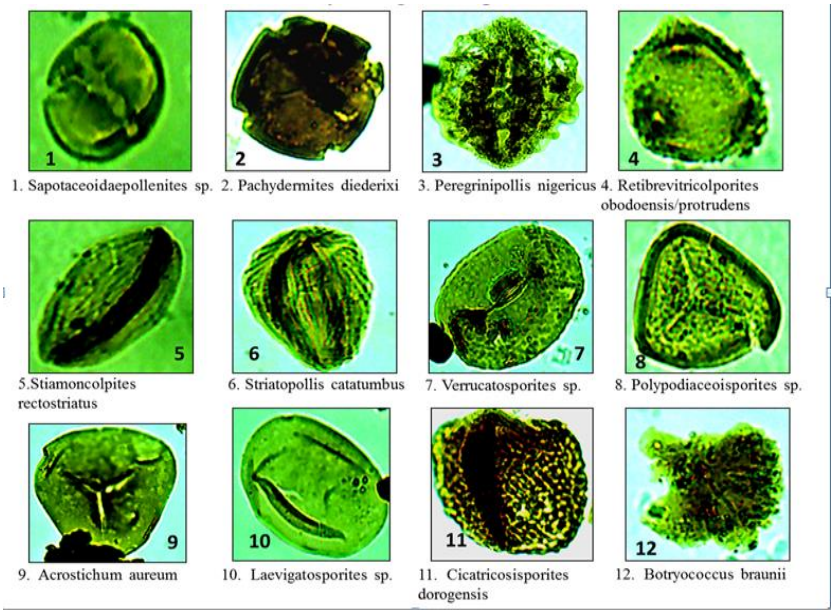

Fig. 5: Identified marker species comprising of pollen and spores in SEG-1 Well (x400)

1. *Sapotaceoidaepollenites sp (***Protonie et al.***);* 2*. Pachydermites diederixi* **(Germeraad, et al.) [20];** 3. *Peregrinipollis nigericus* **(Clark)***;* 4. *Retibrevitricolporites obodoensis/protrudens* **(Van Hoeken-Klinkenberg)***;* 5. *Stiamoncocolpites rectotriatus;* 6. *Striatopolls catatumbus* **(Gonzalez-Gruzman)***;* 7. *Verrucatosporites sp* **(Pflug and Thomas)***;* 8*. Polypodiaceoisporites sp***(Potonie);** 9. *Acrostichum aureum (***P.H. Frietel)***;* 10. *Laevigatosporites sp* **(Ibrahim)***;* 11. *Cicatricosisporites dorogensis* **(Potonie and Gelletich)***;* 12*. Botryococcus braunii* **(Kutzing).**

Palynozones of the Pollen and Spores

The palynozones established is based on the work of Evamy, et al. 1978 [26] and Germeraad, et al. 1968 [20] as shown in Figure 5. These include the following:

Zone: P620

Age: Late Oligocene (Chattian).

Interval: 6020ft-7380ft.

Discussion: The upper part of this interval coincides with the first set of samples analyzed. The base of the interval is marked by the first downhole occurrence of *Cicatricosisporites dorogensis* at 7380ft. This zone is related to the P620 palynological zone of Evamy, et al. (1978) [26] and lies within the *Magnastriatites Howardi* palynozones of Germeraad, et al. (1968) [20]. Other palynomorphs characterizing these zones include *Monocoporites annulatus*, *Zonocostites ramonae and Striastriocolpites catatumbus.*

Zone: P580.

Age: Late Oligocene (Chattian).
Interval: 7380ft-8360ft.
Discussion: The top of this zone was marked by the *cicatricosisporites dorogensis* at 7380ft. The base is marked by occurrence of *peregrinipollis nigericus* at 8360ft. This zone is related to the P580 palynological zone of Evamy, et al. (1978) [26] and the Magnastriatites *Howardi* Zone of Germeraad, et al. 1968 [20]. Other palynormorps characterizing this zone include *Acrostichum aureum, Proxapertites cursu Monoporites annulatus* and *Retibrevitricolporites triangulatus.*

Zone: P560.
Age: Early Oligocene (Rupelian).
Interval: 8360ft-10070ft.
Discussion: The top of this zone was marked by the *Peregrinipollis nigericus* at 8360ft. The base is marked by the occurrence of *Retibrevitricolporites ibadaensis/obodoensis* at 10070ft. This zone is correlated to the P560 palynological zone of Evamy, et al. (1978) [26] and the *Magnastriatites Howardi* Zone of Germeraad, et al. 1968 [20]. The other pollen and spores abundant at this zone include *Acroticum aureum, Monoporites annulatus, Cicatricosisporites dorogenesis* and *Retiricolporites irregularis.*

Zone: P540.
Age: Early Oligocene (Rupelian).
Interval: 10070ft-11690ft.
Discussion: The top of this zone was marked by the *Retibrevitricolporites ibadaensis/obodoensis* at 10070ft. the base of this zone coincides with the last sample analyzed at 11690ft of the early Oligocene (Rupelian) age. The zone is correlated to the P540 of the palynological zone of Evamy, et al. (1978) [26] and the Magnastriatites *Howardi* Zone of Germeraad, et al. (1968) [20]. Other abundant species in this zone are *Botryoccocus braunii* and *Spirosyncolpite bruni.*

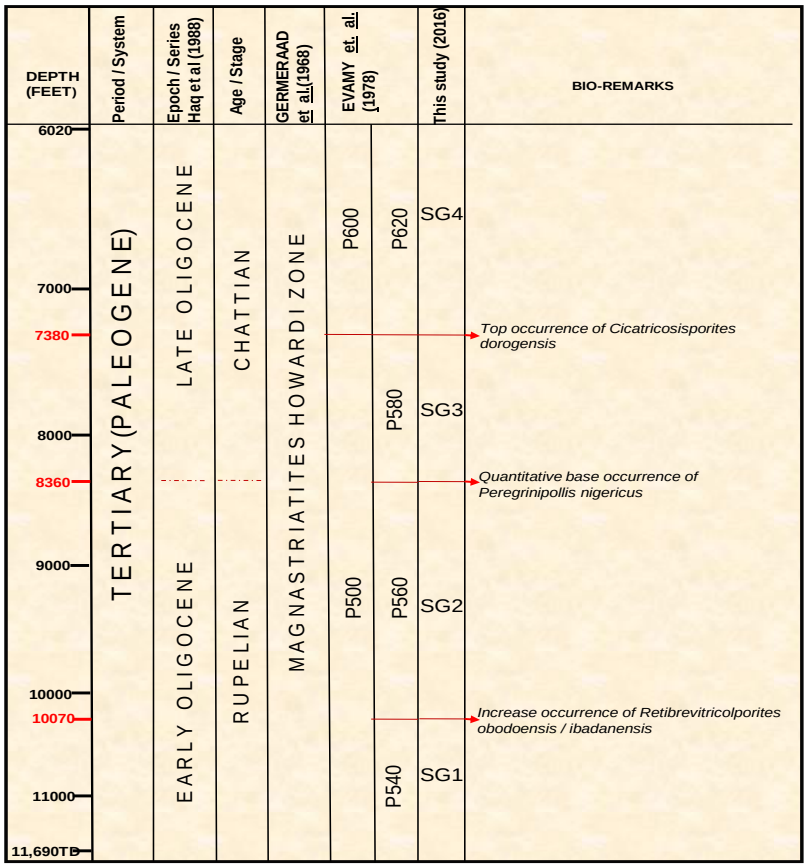

Figure 6: Comparism of Palynozones in SEG-1 Well (6020ft-11,690ft) with other workers.

Stratigraphic Age of the Palynomorphs Identified

SEG-1 well is an exploratory well drilled in the offshore Western Niger Delta. The age of the formations penetrated by the well is in the Paleogene and the sections penetrated by the well ranges from early Oligocene to late Oligocene in the Chattian, et al. [26], which divides the P-Zones to P540, P560, P580 and P620 zones as shown in Figure 5 above.

Paleoenvironment of the Well

The depositional environment of the well was interpreted based on the sedimentological characteristics and the palynomorphs identified in the section penetrated by the well.

The vegetation of the studied area mostly depends on ecological conditions, thus any palynomorphs association is characteristic of a specific environment. The distribution of the species identified with respect to their environment is shown in Tables 2 & 3 below.

Species	Age Range	Environment
Botryococcus braunii	295.0 to 11.608Ma	Fluvial, Mire/Swamp, Coastal
Cicatricosisporites dorogensis	125.45 to 40.4Ma	Fluvial-Deltaic
Laevigatosporites sp	391.9 to 0.126Ma	Marine, Lacustrine, Fluvial-deltaic,Coastal, Mire/Swamp Lagoonal, Fluvial-Lacustrine
Acrostichum aureum	55.8 to 0.0Ma	Fluvial, Marginal Marine, Terrestrial
Polypodiaceoisporites sp	125.45 to 5.332Ma	Fluvial-Deltaic, Mire/Swamp, Terrestrial
Verrucatosporites sp	112.6 to 11.608Ma	Deltaic, Lagoonal, Lacustrine, Marine, Coastal
Striatopollis catatumbus	48.6 to 37.2Ma	Fluvial-Deltaic, Terrestrial
Retibrevitricolpites obodoensis/protrudens	55.8 to 37.2Ma	Fluvial-Deltaic, Lagoonal
Sapotaceoidaepollenites sp	84.9 to 11.608Ma	Terrestrial, Coastal, Alluvial Fan

Table 2: Environment of deposition of marker species identified in SEG-1 Well.

S/N	Environment	Total Counts of Species
1	Lowland Rain Forest	29
2	Brackish Water Swamp specie	298
3	Mangrove	21
4	Savanna	5
5	Freshwater Swamp	207

Table 3: Distribution of Pollen and Spores identified in SEG-1 well and their corresponding environment.

Savanna Group

In this environment, a total number of five (5) species were identified. The rare existence of pollen and spores in this environment indicates that Savanna is not the major environment in the studied section, but the least as regard the abundance of the pollen and spores present in the section. An example of pollen identified is the *Monoporites annulatus* which is suggestive of vegetation found in the savanna.

Mangrove Group

The total count of species in this environment is twenty one (21), indicating that it is not the major environment in the studied well. An example identified in the well is *Zonocostites ramonae* which is a pollen found in the mangrove that botanically belongs to the Rhizophoraceae [20,27].

Low land Rain Forest Group

In this environment, a total count of twenty nine (29) species was identified, which implies that it is not a prevailing environment in the section. Examples of these species include *Polypodiaceoisporites sp*, *Bombacacidites sp* and *Pachydermites diederixii* which are an angiosperm of plant from dense rain forest.

Fresh Water Swamp Group

The freshwater swamp is the second most dominant environment in the studied area as two hundred and seven (207) total counts species were identified in the drilled exploratory well. Examples of these species include *Alnipollenites verus, Laevigatosporites sp* and *Striatricolpites catumbus.*

Brackish Water Swamp Group

The brackish water swamp environment has the highest total counts of species, of which two hundred and

ninety eight (298) pollen and spores were identified. This implies that this environment supported the growth and reproduction of pollen and spores, with favourable conditions in their life span. Examples of these species include *Acrostichum aureum* which are principal climbing fern adapted to coastal areas. That is areas inundated with saline water, open salt marshes, coastal swamps and estuaries [28-30].

Conclusion

Sixty (60) ditch cutting samples retrieved from the SEG-1 Well drilled in the shallow offshore of Niger Delta, from 6110ft to 11690ft at 60ft intervals were employed for palynostratigraphic study of the well. The total number of pollen and spores identified were one hundred (100) species.

Based on the distribution and occurrence of marker species, four palynozones were established: P540 (*Retibrevitricolporites obodoensis/ibadanensis*), P560 *(Peregrinipollis nigericus*), P580 (*Cicatricosisporites dorogensis*) and P620 (*Monocoporites annulatus*). In the paleoenvironment distribution of the species identified, the highest diversity is found in the brackish water swamp while the least exists in the savanna.

Thus, the zones have been assigned an early Oligocene to late Oligocene [31] with a corresponding Rupelian and Chattian stage according to the work of Evamy et al., 1978, and stratigraphic age ranging from 33.9Ma to 23Ma.

Also, the paleoenvironmental studies based on the abundance of the pollens and spores with respect to their paleoenvironment revealed that most of these species falls within the brackish water and the freshwater swamps.

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