ABSTRACT

Twenty ditch cutting samples compositcd and prepared at 80 ft from interval 4329 to 5892 ft of AA-1 Well in the Niger Delta Basin, Nigeria was studied and analyzed through the use of palynoflora assemblage of important diagnostic palynomorphs as well as their stratigraphic distribution with respect to a reference zonation scheme. This is to unravel the biostratigraphic and palaeoenvironmental reconstruction of the studied section. A total of 226 palynomorph species were identified of which 31 represent spores, 153 pollen, 22 dinoflagellate cysts, 13 fungal spores while 7 are microforaminifera test wall linings. The diagnostic forms recovered permitted the zonation and dating of the analyzed section. The result of the section has been broadly assigned to the P520, P480 and P470 palynological zones. The upper boundary of P520 subzone was cautiously placed at 4300 ft, the depth of the first sample analyzed while its base is marked by Last Downhole Occurrence of Racemnonocolpites hians at 4800 ft. Important species in this subzone are Racemnonocolpites hians Retitricolporites irregularis, Verrutricolporites usmensis, Psilatricolporites crassus, Monoporites annulatus, Praedapollis flexibilis and Striatopollis catatumbus. The top of P480 is marked by base occurrence of Racemnonocolpites hians at 4800 ft while the base is defined by the base occurrence of Cinctiporipollis mulleri at 5200 ft. The diagnostic species within this subzone are Proxaperites cursus, Spinizonocistites echinatus, Grimsdalea polygonalis, Polyiodiceiosporites gracilimus and Gemmamonoporites sp. The top of P470 is marked by the base occurrence of Cinctiporipollis mulleri at depth of 5200 ft which is the top occurrence of Verrutricolporites usmensis, while the base is tentatively placed 6000 ft. The diagnostic palynomorphs in this subzone are Psilatricolporites crassus, Striatopollis catatumbus, Retitricolporites irregularis, Retibrievitricolporites protrudens and Verrutricolporites usmensis. Based on the result from palynostratigraphy of the studied section, the Well interval has been dated Late Eocene to Early Oligocene. The depositional environment deciphered in this study range from transitional inner to outer neritic marine.

Keywords: Environment, Eocene, Neritic, Marine, Oligocene, Palynomorph.

I. INTRODUCTION

Microfossils are perhaps the most important group of all fossils, they are extremely useful in age-dating, correlation and palaeoenvironmental interpretation. They are the most abundant and most easily accessible fossils because they usually occur in huge numbers in all kinds of sedimentary rocks. Fossils are recognizable remains of once living plants or animals. The micro-fossils, because of their small sizes, can be collected even from the cores of the boreholes. A large number of microfossils can be collected from a relatively small number of rock samples hence giving a much wider spectrum of data. Spores and pollen, although derived from land plants are strongly climatic-dependent. Thus, their presence and distribution pattern in near-shore marine sediments allow interpretations on continental climates and their distribution can be used to monitor current movements. Palynology [1], is the study of extant and fossil pollen grains and spores of plants [2], [3], gave a pragmatic and working definition of palynology “as consisting of the study of organic microfossils that are found in the maceration preparations of sedimentary rocks. The subject has since then broadened into the other microscopic sized structure which occurs as in sediments, such as diatoms (unicellular algae), alga cyst, dinoflagellate (2 flagellates unicellular but with no definite evidence of affinity) and chitinozoans species (organic-wall microfossils of unknown biological affinity). Palynology has also been modified by [4], to refer to the study of modern and fossil pollen, spores, phytoplankton, chitinozoans, and other organic-walled, acid resistant microstructure which are collectively called palynomorphs.

A. Previous Studies

The stratigraphy of the Niger Delta has been well studied using pollen, spores and dinoflagellates. [5] covered...
extensively the palynostratigraphy of Cenozoic sediments from the tropical areas of West Africa, northern South America to Sumatra and Borneo, and erected three main zonal divisions according to their lateral extent. They used data of pollen and spores to establish six pantropical palynozones, which, from base to top were recognized as: (1) the Paleocene Proxapertites operculatus zone; (2) the Eocene Monoporites annulus zone; (3) the late Eocene Verrucatosporites usmensis zone; (4) the Oligocene Magnastriatites howardi zone; (5) the Miocene Crassoretiritelles vanraadshoveni zone; and (6) the Pliocene Echitrilocolporitesspinosus zone.

Reference [6] carried out investigation on the Oligocene sediments from fifteen boreholes of subsurface Tertiary sediments in the Niger Delta Basin. The result produced diverse dinoflagellate cyst groupings categorized by abundant Peridinioidis predominantly Lejeuneycysta, Pheidodium and Selenopemphix species. Seven new species of Lejeuneycysta (Lejeuneycysta brassiensis, Lejeuneycysta communis, Lejeuneycysta pulchra, Lejeuneycysta beninensis, Lejeuneycysta globosa, Lejeuneycysta lata and Lejeuneycysta granosus) were described.

Reference [7] worked on the palynozoanation and lithofacies cycles of Paleogene to Neogene Age Sediments in PML-1 Well, Northern Niger Delta Basin. They subdivided the Well into five zones; two palynozones (Ephedra claricristata and Auriculopollenites echinatus Range zone) of Oligocene and three palynozones (Verrucatosporites laevigatus/Verrucatiporites scabratius Range zones and Verrucatosporites rotundiporaus and Margocolpites sp. Abundance zones) of Early-Late Miocene. They also reported that the lithofacies distribution indicates cyclic sedimentation occasioned by an inter play of sea level and climatic regime.

Reference [8] studied the palynological analysis of Late Eocene to Early Oligocene sediments in Deb-1 Well in the Niger Delta, three palynomorph zones were established with reference to Evamy et al. (1978) scheme. The result of the section of the Well analyzed was broadly assigned to the PS20, P480 and P470 palynological zones. This section was assigned Early Oligocene to Late Eocene based on the evidence of the palynological study. The studied interval of Deb-1 Well is dominated by Laevigatosporites sp, Verrucatosporites sp, Psilatricolporites sp, Psilatricolporites crassus, Zonocostites ramaone, Peregripnolpis nigericus, Fungal spores, Retitrilocolporites sp and Acrmistichumae. The occurrence of these marker species in association with Botryococcus braunii (fresh water algae) in the study interval suggests deposition in a largely coastal deltaic environment with frequent fresh water incursion. A predominantly wet climate is inferred for this interval due to the higher percentage of Psilatricolporites crassus and Zonocostites ramonae (Mangrove pollen).

Reference [9] conducted for the first time the palynostratigraphy and palaeoenvironment interpretation of outcrops in parts of Ini-Akwa Ibom State in the Niger Delta. Through the use of diagnostic palynomorphs, four Formations, the Imo, Ameki Ogwashi-Asaba, and Eze-Aku, were identified. The Imo samples were dated Late Paleocene-Eocene based on the presence of the following pollen key-taxa: Psilatricolporites Crassus, Retitrilocolporites irregulararies, Psilatricolporites sp. and Leiotritelles adriennis with the presence of Paleocene dinoflagellate cysts such as Lejeuneycysta beninensis and Selenopemphix nephroides, Ameki samples were assigned Early-Middle Eocene based on Proxapertites opercularus, Retistephanocolpites williamsi, Mauritidites crassiexinus, Monocolpites marginatus and Longapertites marginatus. Ogwash-Asaba shale samples were dated Late Eocene-Early Oligocene due to the abundant presence of Verrucatosporites usmensis, Laevigatosporites discordatus and Retitrilocolporites irregulararies while Eze-Aku samples were tentatively assigned Paleocene because of the presence of two pollen index fossils Proxapertites opercularus and Pachydermites diederixi. The palaeoenvironment is in a coastal deltaic to shallow-marine environment with the exception of Eze-Aku Formation and are therefore, appropriate for hydrocarbon accumulations and exploration.

B. Location of AA-1 Well

The AA-1 Well lies in the Eastern part of Niger Delta, West coast of Africa. It is one of numerous development Wells located within the concession of Oil Mining Lease (OML) 53 by one of the oil companies operating in Nigeria (Fig. 1).

C. Geology and Stratigraphy of Niger Delta

The Niger Delta is situated on the Gulf of Guinea, the west coast of central Africa. The sub aerial portion of the delta covers an area of about 100,000 km² and stretches for nearly 30 km. Niger Delta originated during the separation of the South American plate from the African plate during the Mesozoic break up of Gondwanaland [10]. The Niger Delta basin is an important hydrocarbon province and is one of the largest Delta systems in the world. It occurs at the southern end of Nigeria bordering the Atlantic Ocean and extends from latitudes 4°30' N to 5°20'N and longitude 3°E to 9°E. The Onshore portion of the Niger Delta province is defined by the Geology of southern Nigeria and southwestern Cameroon. The northern boundary is the Benin Flank while the northeastern is bounded by outcrops of the Cretaceous on the Abakaliki High and further southeast by the Calabar Flank. The offshore boundary of the province is defined by the Cameroon volcanic line (CVL) to the east, the eastern boundary of the Dahomey Basin to the west. The province (offshore and onshore) covers 300,000 km² and includes the

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geologic extent of the Tertiary Niger Delta (Akata-Agbada) petroleum system. Exploratory activities in the Niger Delta provided accessibility to the sub-surface formations that characterize the basin. Exploration and other investigation have contributed to documented stratigraphic and micropaleontologic database for the region. Since the first discovery of crude oil in 1956, many geological researches have been undertaken, especially by oil companies. Detailed study of the wells drilled within the Niger Delta basin has revealed evidences of hydrocarbon generation, migration and accumulation.

The work of [11]–[13] discussed the subsurface distribution of stratigraphic units in the Niger Delta. They recognized three main formations (Benin, Agbada and Akata) within the Niger delta complex (Fig. 2). The Akata, Agbada and Benin formations are interfingered facies equivalents representing pro-delta, delta-front and delta-top environments, respectively. The Benin Formation comprises entirely non-marine sand deposited in alluvial or upper coastal plain environments [14]. The Agbada 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 [10]. Most of the important hydrocarbon reservoirs in the Niger Delta are within the paralic Agbada Formation. These reservoirs are usually located in zones with structural and stratigraphic complexity. The Agbada Formation which is the major hydrocarbon prospective sequence, deposited in a transitional to marine paralic environment. The Akata Formation is of marine origin and composed of thick shale sequence. The main objective of this study is on the application of pollen, spore and dinoflagellate in dating, zoning and palaeoenvironmental reconstruction of AA-1 Well, Niger Delta Basin.

II. MATERIALS AND METHODS

Twenty ditch cutting samples from AA-1 Well, drilled in the Eastern part of the Niger Delta, Nigeria at 80 ft interval between depths 4329 to 5892 ft were processed and analyzed for their palynological contents using standard analytical reagents and materials as suggested by [15], [16]. 30 g of each crushed sample was soaked in hydrofluoric acid (HF) to remove silicate materials present in the sample, and then dilute hydrochloric acid (HCl) to remove calcium carbonate (CaCO₃) present from the sample. This was followed by the addition of distilled water (H₂O) and decanting. The sieving process was carried out using a Brason sonifier with 5 μm sieve. The remaining debris of the samples was mildly oxidized. This was then followed by heavy mineral liquid separation of the macerals by using Zinc chloride (ZnCl₂) with a specific gravity of 2.0. The palynomorphs were mounted using Loctite impruv as the mounting medium and altogether twenty slides were produced and analyzed under the light Leitz laborlux 12 microscope using (x25) objective lens. Light photomicrographs of palynomorphs were taken with Nikon Coolpix P6000 digital camera. The morphological characteristics of the palynomorphs were then likened with the available journals on monographs, descriptions and diagrams, this includes works of [5], [17]–[21]. The palynozones were interpreted by means of the zonation scheme of [5] and [22].

III. RESULTS AND INTERPRETATIONS

A. Sedimentological Analysis

Three lithofacies, sand, shale and sandy shale were observed in a combination of gross lithologic and grain attributes derived from grain microscopy. This enabled the definition of facies types for the Well section. The shales are grey to dark grey, moderately hard and well fissile. The sands are moderately fine to coarse-grained, subrounded and moderately well sorted. The sediments were generally shaly towards the bottom of the Well. Mica flakes, carbonates and ferruginous materials were also present.

B. Palynological Assemblage

A total of 226 palynomorph species were recovered from the ditch cutting samples provided between 4329-5892 ft in AA-1 Well. This comprises 31 spores, 153 pollen, 22 dinoflagellate cysts, 13 fungal spores and 7 microforaminifera test wall linings. The Well is well preserved with common and diverse microflora assemblages dominated by Peridophtye spores such as Verrucatosporites usensis and Laevigatosporites sp. and other non-categorized spores such Polypodiaceoisporites gracilimus, Cyathidites minor, Pollen such as Racomonoecolpi hians, Retitrilcorporites irregularis, Retimonocolpites sp. Retitrilcopites sp. Retistephanocolpites sp. Retibrivirilcorporites protrudens, Psiilamonoecolpites sp. Psiilatricolpites (Verrutricolporities) sp. Psiilastephanocolpites sp. Psiilatricolpites operculatus, Psiilatricolpites sp. Psiilatricolpites crassus, Cinctiporipollis muller, Longapertites marginatus, Pachydermites dierexi, Striamonocolpites sp. Striatopollis catatumbus, Spinizonocostites echinatus, Spiroscoccolpites brunii.

Fig. 2. Schematic representative of Stratigraphic column showing the three formations of the Niger Delta modified after [14].

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Monoporites annulatus Gemmamnonoporites sp., Echiperiopites echinatus, Proxapertites cursus, Lejeunecysta species, Grimsdalea Polygonalis as well as palaeoenvironmental indicators like dinoflagellate cysts, foraminiferal test and fungal spores, as shown in Table I and Fig. 3 below. The recovered palynomorphs species were used for biostratigraphic zonation, age dating and the palaeoenvironmental interpretation of the stratigraphic studied interval.

### TABLE I: TOTAL OCCURRENCE OF DIFFERENT PALYNOmorph GROUPS RECOVERED

| S/N | Palynomorphs Group          | Total Counts (Abundance) | Percentage of Occurrence |
|-----|-----------------------------|--------------------------|--------------------------|
| 1   | Spores                      | 31                       | 13.72                    |
| 2   | Pollen                      | 153                      | 67.70                    |
| 3   | Dinoflagellate cysts        | 22                       | 9.73                     |
| 4   | Fungal spores               | 13                       | 5.75                     |
| 5   | Foraminifera test linings   | 7                        | 3.10                     |
|     | Total                       | 226                      | 100                      |

Fig. 3. Pie chart of the percentage occurrence of palynomorphs recovered in AA-1 Well.

C. Biozonation and Age Determination

The palynomorphs recovered from the analyzed section were correlatable with board pan-tropical Verrucatosporites usmensis, zone of [5], and the P400–P500 Zones of [22]. The three palynological zones recognized are P470, P480 and P520, respectively. The age of the sediment was determined based on the first and last appearances (FAD and LAD) of stratigraphically significant taxa supported by their general distribution within the studied Well as seen in Table II below. The section thus ranges in age from Late Eocene to Early Oligocene with some occurrence of Paleocene forms particularly Longapertities marginatus and Proxapertites cursus which suggest the reworking of older sediments within the Well analyzed.

Some of the photomicrographs of these events are illustrated in Fig. 4–6. The zones and subzones recognized from the analyzed section are described briefly below and represented graphically in Table III and IV.

1) **ZONE P500**

Subzone P520.

Interval: 4300–4800 ft.

Age: Early Oligocene.

Discussion:

This is the youngest of the subzones within the interval studied. The top occurrence is placed at 4300 ft, the depth of the first sample analyzed while the base is marked by the base occurrence of Racemocolpites hians at 4800 ft. Important species in this sub zone are Retitricolporites irregularis, Verrucatosporites usmensis, Psilatricolporites crassus, monoporites annulatus, Praedapollis flexibilis and Striatopollis catatumbus. Racemocolpites hians is mainly found in the Oligocene to Miocene [19]. The evolution First Appearance Datum (FAD) of the Racemocolpites hians marks the Eocene-Oligocene Boundary [22]. Therefore, the age assigned to this zone is Early Oligocene (Rupelian) of Agbada Formation.

2) **ZONE P400**

Subzone P480.

Interval: 4800-5200 ft.

Age: Late Eocene.

Discussion: The top of this subzone is marked by base occurrence of Racemocolpites hians at 4800ft while the base is marked by the Top occurrence of Cinctiperipollis mulleri at 5200ft. This subzone is characterized by the regular and abundant records of Spinizonocostites echinatus, Proxapattites cursus, Verrucatosporites usmensis, Cinctiperipollis mulleri Grimsdalea polygonalis, Polypodiceosporites gracillimus and Gemmamnonoporites sp. Spinizonocostites echinatus and Proxapertites operculatus are assemblages of palynomorphs mostly found in Eocene of West African Basins. [5], concurred that Proxapertites operculatus and Spinizonocostites echinatus are absent from post Eocene strata in West Africa, but have been recorded in the Pliocene to Pleistocene in Borneo and the Caribbean Basins. The age assigned to this subzone is Late Eocene (Bartonian) of Agbada Formation.

3) **ZONE P400**

Subzone P470.

Interval: 5200-6000 ft.

Age: Late Eocene.

Discussion: This is the last and oldest subzone recognized in the interval. The top of this zone is marked by the base occurrence of Cinctiperipollis mulleri at 5200 ft depth, and it is the top occurrence of Verrucatosporites usmensis placed at 6000ft tentatively. The main characteristics palynomorphs are Psilatricolporites crassus, Striatopollis catatumbus, Retitricolporites irregularis, Retibrevitricolporites protrudens, Verrucatosporites usmensis with some fungal spores. [5], [8], [23]-[31]. The age assigned to this subzone is Late Eocene (Bartonian) of Agbada Formation.

D. Description of Selected Palynomorphs

Eight (8) pollen and spores are selected for description. However, not all the palynomorphs identified are selected for the description. Those selected are the ones whose forms appear very well as well as some stratigraphical important ones. For the purpose of description, the species are classified according to the under-listed criteria.

1) **Classification Criteria**

The classification adopted for the fossil pollen and spores is based on their morphological characteristics. The significant morphological characteristic considered are:

1. Type and number of Apertures.
2. Types of Sculpture or ornamentations.
### TABLE II: BIOZONATION OF THE SEQUENCES RECOGNIZED IN THE AA-1 WELL, NIGER DELTA

| Depth (feet) | Series | Sub-series | Germeraad et al. [5] | Evamy et al. [22] Zone | Sub-zone | Diagnosis/Remarks |
|-------------|--------|------------|----------------------|------------------------|----------|-------------------|
| 4300        | OLIGOCENE | EARLY OLIGOCENE | - | P500 | P520 | Last Downhole Occurrence of Racemonocolpites hians |
| 4400        | EOCENE | LATE-EOCENE | VERRUCATOSPORITES USMENSIS | - | P400 | P470 | Top Occurrence of Verrucatosporites usmensis |
| 4500        | EOCENE | LATE-EOCENE | - | - | - | - |
| 4600        | EOCENE | LATE-EOCENE | - | - | - | - |
| 4700        | EOCENE | LATE-EOCENE | - | - | - | - |
| 4800        | EOCENE | LATE-EOCENE | - | - | - | - |
| 4900        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5000        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5100        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5200        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5300        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5400        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5500        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5600        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5700        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5800        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5900        | EOCENE | LATE-EOCENE | - | - | - | - |
| 6000        | EOCENE | LATE-EOCENE | - | - | - | - |

### TABLE III: STRATIGRAPHIC DISTRIBUTION OF PALYNOMORPHS IN AA-1 WELL

| POLLEN |
|--------|

| Depth (feet) | Series | Sub-series | Germeraad et al. [1968] | Evamy et al. [1978] Zone | Sub-zone | Diagnosis/Remarks |
|-------------|--------|------------|-------------------------|------------------------|----------|-------------------|
| 4329        | OLIGOCENE | EARLY OLIGOCENE | - | P500 | P520 | - |
| 4405        | OLIGOCENE | EARLY OLIGOCENE | - | - | - | - |
| 4488        | OLIGOCENE | EARLY OLIGOCENE | - | - | - | - |
| 4567        | OLIGOCENE | EARLY OLIGOCENE | - | - | - | - |
| 4648        | OLIGOCENE | EARLY OLIGOCENE | - | - | - | - |
| 4720        | OLIGOCENE | EARLY OLIGENE | VERRUCATOSPORITES USMENSIS | - | P400 | P470 | - |
| 4803        | EOCENE | LATE-EOCENE | - | - | - | - |
| 4884        | EOCENE | LATE-EOCENE | - | - | - | - |
| 4966        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5040        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5096        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5164        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5247        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5329        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5412        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5494        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5577        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5659        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5740        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5812        | EOCENE | LATE-EOCENE | - | - | - | - |
| 5892        | EOCENE | LATE-EOCENE | - | - | - | - |
### Table IV: Stratigraphic Distribution of Palynomorphs in AA-1 Well

| Depth (Feet) | Series | Sub-series Genesai et al. (1968) Evamy et al. (1978) | Zone | Sub-zone (P20) | Spores | Dino Cysts | FT |
|--------------|--------|-----------------------------------------------------|------|---------------|--------|------------|----|
| 4329         | Oligocene | Early Oligocene | Verrucatosporites usmensis | Evamy et al. (1978) | - | - | 1 | - | 1 | 2 | - | - | - | - | - |
| 4405         |        |          |                          | Evamy et al. (1978) | 2 | 1 | - | - | - | - | 2 | - | - | 2 | 4 |
| 4488         |        |          |                          | Evamy et al. (1978) | - | - | - | - | - | - | 2 | - | - | 4 |
| 4567         |        |          |                          | Evamy et al. (1978) | - | 1 | 1 | - | - | - | - | - | 1 | - |
| 4648         |        |          |                          | Evamy et al. (1978) | 4 | - | - | - | - | - | 1 | - | - | 2 | 5 |
| 4720         |        |          |                          | Evamy et al. (1978) | - | 1 | - | - | - | - | 1 | - | - | 2 |
| 4801         |        |          |                          | Evamy et al. (1978) | 2 | - | 2 | - | - | 1 | - | - | - | 3 |
| 4884         |        |          |                          | Evamy et al. (1978) | 3 | - | - | 1 | 2 | - | 3 | 1 | - | - | 7 |
| 4966         |        |          |                          | Evamy et al. (1978) | 3 | - | - | - | - | - | 1 | - | - | 4 |
| 5040         |        |          |                          | Evamy et al. (1978) | - | - | - | - | - | - | - | - | - | 1 |
| 5096         |        |          |                          | Evamy et al. (1978) | - | - | - | - | - | - | - | - | - | 1 |
| 5164         |        |          |                          | Evamy et al. (1978) | - | - | - | - | - | - | - | - | - | 1 |
| 5247         |        |          |                          | Evamy et al. (1978) | - | 2 | - | 1 | - | - | - | - | 1 | - |
| 5329         |        |          |                          | Evamy et al. (1978) | - | - | - | - | - | - | - | - | - | 1 |
| 5412         |        |          |                          | Evamy et al. (1978) | 1 | - | - | 2 | - | - | - | - | - | 4 |
| 5494         |        |          |                          | Evamy et al. (1978) | 1 | 1 | - | - | 1 | 3 | 1 | - | - | 2 |
| 5577         |        |          |                          | Evamy et al. (1978) | - | - | - | - | - | 1 | - | - | 1 | - |
| 5659         |        |          |                          | Evamy et al. (1978) | - | 1 | - | 1 | 1 | - | - | - | 1 | - |
| 5740         |        |          |                          | Evamy et al. (1978) | 12 | - | 2 | 1 | - | - | 4 | - | - | 4 | 5 |
| 5812         |        |          |                          | Evamy et al. (1978) | 31 | 7 | 4 | 7 | 9 | 6 | 22 | 2 | 1 | 12 | 49 |

**Fig. 4.** Magnification x 1000. 1: Retitricolporites americana, 2: Retitricolporites irregularis, 3 and 4: Retitricolporites sp., 5 and 9: Retimonocolpites sp., 6: Gemmanamonopores sp., 7: Racemonocolpites hians, 8: Stratopollis catatumbus, 10: Verrucatosporites scrabratus, 11: Spinizonocostites echinatus.

**Fig. 5.** Magnification x 1000. 1 Proxapertites cursus, 2: Mauritiites crassirhinos, 3 and 4: Retibrevitricolporites protrudens, 5: Pachydermites diederixi, 6: Monoporites annulatus, 7: Psilastephanocolpites sp.
3) **Systematic Description**

**DIVISION I** Sporites [32]

| Class | Triletes [33] |
|-------|---------------|
| **Genus:** | Cyatheacidites minor [34] |
| **Description:** | Miospore convex-triangular in proximal view, radially symmetrical, heteropolar, laesura trilete, contact area at the center of the exine, the arms of the laesura do not extend to the radial zones, radial zones rounded, exine thick and psilate. |
| **Location:** | 5247-5329 ft; Fig. 8, Item 6 |
| **Remarks:** | Rarely occurred |
| **Botanical Affinity:** | Identical to the species of genus Dennstaedtiaceae [35] |

**DIVISION II** Pollenites [32]

| Class | Monocolpites [40] |
|-------|------------------|
| **Genus:** | Polypodiaceiosporites gracillimus [36] |
| **Description:** | Monocolpate spore, laesura on the distal part, bilaterally symmetrical, heteropolar, exine thick and tectate, margin echinate, gemmate to verrucate, spore plano – convex in shape. |
| **Location:** | 4329-4405 ft; Fig. 8, Item 5 |
| **Remark:** | Rarely occurred |
| **Botanical Affinity:** | This spore belongs to the group of plant called Pteridophyte [37] |

| Class | Monoletes [38] |
|-------|----------------|
| **Genus:** | Verrucatosporites usmensis [39], [5] |
| **Description:** | Monoletes spore, laesura on the distal part, bilaterally symmetrical, heteropolar, exine thick and tectate, margin echinate, gemmate to verrucate, spore plano – convex in shape. |
| **Location:** | 5417-5494 ft; Fig. 8, Items 1 & 2 |
| **Remark:** | Commonly encountered throughout the depth |
| **Botanical Affinity:** | Resembles recent spore of Pyrrhosia schimperiana (Polypodiaceae) [35] |

**DINING III** Miospores [32]

| Class | Stephanoportaeae [40] |
|-------|------------------------|
| **Genus:** | Pachydermites diekeri [5] |

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**Fig. 6.** Magnification x 1000. 1 and 2: Verrucatosporites usmensis, 3 and 4: Laevigatosporites sp., 5: Polypodiaceiosporites gracillimus, 6: Cyatheacidites sp., 7 and 8: Fungal spores.

a) **The Aperture**

The primary criterion used in the morphological classification is based on the general apertural structures which are:

| i. Inaperturates: Those without an aperture. |
| ii. Sacrates: Those without air sac. |
| iii. Colpates: Those with slits as apertures. |
| iv. Porates: Those whose apertures consist of pores. |
| v. Colporates: Those having both slits and pores. |

Spores’ classification is however simpler than the pollen’s classification. They are:

| a. Monoletes: Those with a single slit or a single germinal scar. |
| b. Triletes: Those with triradial marks. |

The secondary criterion is based on the number of those characters listed in the primary criterion. Thus, we determined the number of colpi, pores, and colpi with pores in the colpates, porates and colporates respectively.

b) **The Ornamentation**

Ten basic types of ornamentation are used in this study. They are:

| i. Psilate or laevigate: Smooth exine. |
| ii. Granulate: Exine covered with small grains or granules. |
| iii. Foveolate: Pitted surface. |
| iv. Reticulate: With mesh-like surface. |
| v. Striate: With fine grooves. |
| vi. Verrucate: Warty or covered by verrucae. |
| vii. Baculate: Rod – like projection. |
| viii. Echinate: With pointed projection. |
| ix. Clavate: With club-like projection. |
| x. Scabrate: With knobs or points. |

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Description: Medium to large in size, circular in polar view, isopolar, stephanoporatare, three to six pores, pores marginal. Exine thick, pslitate, tectate with cinulum.
Location: 4884-4966 ft; Fig. 7, Item 5
Remark: Occasionally occurrence
Class E: Tricolporitae [40]
Genus: Retiricicolporites irregularis [41]
Description: Pollen grain isopolar, radially symmetrical, spheroidal in polar view, tricolporate, exine tectate, reticulation very coarse, sexine without tectum, baculate at the amb.
Location: 5329-5412 ft; Fig. 6, Item 2
Remark: Frequently occurred throughout the intervals
Botanical affinity: Has a close resemblance with Amanoa oblongifolia (Euphorbiaceae), Germeraad et al., 1968
Genus: Cinctiporipollis milleri [35]
Description: Polyporate pollen grain; circular in outline in polar view. Pores eight to twelve “most often ten”, arranged in 4 to 6 pairs in two concentric circular planes one “on each face of the grain”; the pores making up each pair are often one directly below the other or not coincident, “situated mid-distance between the pole are the equator”. Pores “generally round, direct diameter ranges from 2.5-3.5m,” annulate. “Exine punctuate”, comparatively thick at least 3.5m in the polar region, (but) may be up to 6m at the equator, structure complex. It seems to have an endexine ca 2m thick, subtending a layer of “bacules” which are straight or short, tectum indistinct. Size “equatorial diameter 30-40m” [35].
Location: 4405-4488 ft
Remark: Frequent

E. Palaeoenvironmental Interpretation of AA-1 Well

Abundance and diversities of terrestrially derived palynomorphs and small proportions of marine dinocysts guided the interpretation of palaeoenvironments in the studied section of the AA-1 Well. The environmental marker species present in the study section are: Monoporites annulatus (gramine pollen suggesting open vegetation found in coastal savannah), Pachydermites diederixi (an angiosperm of coastal swamps), microforaminifera test wall linings, dinocysts and fungal spores. The presence of some brackish and fresh water swamp species is equally significant, which are Retiricicolporites irregularis, Retibrevitricolporites protrudens, Psilatricolporites operculatus, Psilastephanoconolpites sp., Gemmanomonoporites sp., Psilatricolporites crassus, Verrucatosporites sp., Racemonocolpites hians, Proxapatites cursus Polypodiaceosporites gracilimus, Laevigatosporites sp. and Striatopollis catatumbus. The abundance of these marker species though with rare occurrence of Pachydermites diederixi and regular occurrence of marine dinocysts and fungal spores suggests that the sequence studied represents mainly deposition in coastal to marginal marine setting [42].

Morphologically, comparable modern equivalent of the recovered laevigate trilete spores is similar to those of the Polypodiaceae which generally inhabit marsh or swamp environment [42]. If such fossil forms as Cyathaeacidites which compare in their morphology with modern members of the above family are indeed related to them this would suggest that the depositional environment could have been marshy or swampy [43]. The presence of dinoflagellate cysts and microforaminifera wall linings indicates marine or at least brackish water environment [44]. This study, therefore, reveals a high sea level and wet climatic condition during the deposition of the sediments.

IV. CONCLUSION

The Palynological study of sediments from AA-1 Well indicates very rich, common and diverse well preserved palynomorphs. The biostratigraphic zonation, age dating and environment of deposition of the studied Well were carried out. The studied sediments are of Late Eocene to Early Oligocene based on the recovery of Psilatricolporites crassus, Spinzonocostites echinatus, Striatopollis catatumbus, Retitricolporites irregularis, Proxapatites cursus, Verrucatosporites usmensis, Cinctiporipollis milleri monoporites annulatus, Racemonocolpites hians with some Paleocene forms such as Longapertites marginatus and Proxapatites operculatus which suggest reworking of older sediments into the younger ones. The palynological zonation of the Well and the stratigraphic distribution based on the zonation schemes of [5] and [22] respectively are broadly assigned to Verrucatosporites usmensis and the P400–P500 Zones. Two zones (P500 and P400) and three subzones (P520, P480 and P470) were established in this study, Environmental marker species such as Monoporites annulatus, Pachydermites diederixi, Psilatricolporites crassus, Laevigatosporites sp., Verrucatosporites sp., microforaminiferal wall linings, dinoflagellate cysts and Fungi spores were used in the delineation of the palaeoenvironments. The abundance of these marker species suggests deposition in a coastal to marginal marine settings or transitional inner – outer neritic. The palynology and palaeoenvironmental study of AA-1 Well have provided an opportunity to verify some works done by other authors as well as to further elucidate the palynostratigraphy of the Niger Delta.

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