American Academic Scientific Research Journal for Engineering, Technology, and Sciences
ISSN (Print) 2313-4410, ISSN (Online) 2313-4402
http://asrjetsjournal.org/

Palynological Study of Vida-1 Well, Central Niger Delta Basin, Nigeria

Oluwakemi O. Efemena[a]*, Geoffrey C. Soronnadi-ononiwu[b], Franklin A. Lucas[c]

[a,c]*Department of Geology, University of Benin, PMB 1154, Benin City, Edo State, Nigeria*
[b]*Department of Geology, University of Port Harcourt, PMB 5323, Port Harcourt, River State, Nigeria*
[a]*Email: onomeefe1@yahoo.com*, [b]*Email: chijokesoronnadi@gmail.com*, [c]*Email: drfalucas@gmail.com*

Abstract

Palynological examination of forty (40) microscopic slides prepared from direct specimen of Agbada Formation core samples between (6,963ft – 9,866 ft), were carried out with a view to determining the age and palaeoenviroment of deposition. Standard palynological procedure was followed and the slides yielded excellent to well preserved distribution of miospore assemblages. Diagnosis uncovered one hundred and twenty-three (123) miospores. Delineation of the well section produced four palynological zones based on stratigraphic distribution. *Crassoretitriletes vanraadshooveni*/P700 Zone characterized by the quantitative base occurrence of *Crassoretitriletes vanraadshooveni* and co-occurrence of *Belskipollis elegans, Crassoretitriletes vanraadshooveni, Pachydermites diederix, Gemmastephanocolporites sp., Echiperiporites estalae,* Verrutricolporites rotundiporus *and Stephanoporites echinatus. Magnastriatites howardii*/P600 Zone characterized by quantitative base occurrence of *Praedapollis flexibilis* and co-occurrence of *Magnastriatites howardii, Peregrinipollis nigericus, Praedapollis flexibilis Spirosyncolpites brunni, Verrucatosporites usmensis, Retitricolporites irregularis. Verrucatosporites usmensis* /P500 Zone characterized by the co-occurrence of *Arecipites exilimuratus, Verrucatosporites usmensis and Gemmamonoporites sp. Verrucatosporites usmensis* /P400 Zone characterized by the quantitative base occurrence of *Verrucatosporites usmensis and co-occurrences of Psilatricolporites crassus, Pachydermites diederix and Monoporites annulatus.* Paleoecological grouping of the recovered palynomorphs assemblages revealed the presence of mangrove, freshwater swamp, coastal. riverine and savana vegetation types. However, the assemblages retrieved are dominated by terrestrially derived palynomorphs, such as spores (ferns and fungi) and pollens alongside depicting the brackish to freshwater colonial algae, marine indicator palynomorphs, including dinoflagellate cysts and foraminiferal linings, which were relatively low, indicating paralic environment with the shaly sediments being deposited in a marginally marine environment under a terrestrial influence.

----

* Corresponding author.

The palynofloral assemblage within this interval suggests deposition in environments fluctuating between marine and nearshore. The interval in the well section is dated Late Eocene - Middle Miocene.

Keywords: Palynomorphs; Environment; Marin; Zone; Assemblages; Age; Terrestrial

1. Introduction

The Niger Delta is a major hydrocarbon producing basin in Nigeria where intensive exploration and exploitation activities have been on because of its petroliferous nature. The combination of source rock, lithologic types, structures and thermal history of the basin are favorable for the generation, accumulation and retention of hydrocarbons [1, 2]. Most of the important hydrocarbon reservoirs in the Niger Delta are within the paralic Agbada Formation [3]. These reservoirs are usually located in zones with structural and stratigraphic complexity. Palynology is the most important biostratigraphic tool for subsurface evaluation most especially for exploration of oil and gas. The works of [4,5,6] kick started palynological investigations in the Niger Delta. In the recent times quite some handful of palynologists have carried out research projects revealing a better understanding of palaeovegetation, palaeoclimate, paleoecology and paleoenvironment of this basin. The constraints have been that they are unpublished, rather available as confidential reports of the different oil-prospecting companies in Nigeria. The main objective of present study is to identify and characterize the palynomorphs, as to deciphering of the age and paleoenvironment of deposition. The significant is to show that different depositional settings, imply different vegetation in the geological past and that microfossil assemblages are used as proxies for precise palaeorenvironmental determination [7].

2. Regional Geologic Setting

The Niger Delta Basin is situated in the Gulf of Guinea in equatorial West Africa, between latitudes 3° N and 6° N and longitudes 5° E and 8° E [8] (Figure 1A) on the continental margin of the Gulf of Guinea in Equatorial West Africa. The Tertiary Niger delta (Figure 1B) is one of the largest regressive deltas in the world with an area extent of about 300,000 km2 [9]**.** The Tertiary Niger Delta complex is divided into three diachronous formations, representing prograding depositional facies that are distinguished mostly on the basis of sand-shale ratios. They are the Akata, Agbada and Benin Formations. The Akata Formation is the basal unit of the Tertiary delta complex. This lithofacies is composed of shales, clays, and silts at the base of the known delta sequence. They contain a few streaks of sand, possibly of turbiditic origin [10], and were deposited in holomarine (delta front to deeper marine) environments. This formation is characteristically over pressured and range in age from the Paleocene to Recent. The Agbada Formation overlies the Akata Formation, is the principal reservoir of Niger Delta oil therefore has been well studied. The works of [10,11] are however, quite classic. The Agbada Formation is represented by an alternation of sands (fluviatile, coastal, and fluviomarine), silts, clays, and marine shales (shale percentage increasing with depth) in various proportion and thicknesses, representing cyclic sequences of offlap units. These paralicclastics are the truly deltaic portion of the sequence and were deposited in a number of delta-front, delta-topset, and fluvio-deltaic environments [12]. The upper part of the Agbada Formation often has sand percentages ranging from 50 – 75%, becoming increasingly sandy towards the overlying Benin Formation. The lower part has less than 40% sand and the shaliness increases downwards and laterally into the Akata Formation. Agbada Formation is overlain by the third formation, the Benin Formation, a continental environment from late Eocene to Recent deposit of alluvial and upper coastal plain sands that are up to 2000 m thick (Figure 2).

3. Materials and Methods

Forty core samples between 6963 and 9866 ft were prepared for this study. 10 g of each sample was prepared using the standard palynological techniques by crushing the samples in a mortar to the powder size, disaggregation and removal of carbonates and silicates with hydrochloric acid under a fume cupboard [13]. Concentrated HNO3 was used for oxidization and heated over Bunsen burner. KOH of 10% solution was added to the sample and transferred to styrofoam cups and HF added and let to stand overnight. The sample was then washed with water until a neutral reaction was reached and decanted. The slides were stained with Safranin O to enhance the study of palynomorphs present (pollen, spores, dinoflagellate cysts, acritarchs, algae, fungal remains, and some miscellaneous palynomorphs) under x40 and x100 objectives using an AmScope 3.7 camera-attached microscope. The recovered palynomorphs species were identified with the aid of Shell palynological photo album and species name and their abundance were recorded in the analysis data sheets. Specimen morphological characteristics were compared with the descriptions, monographs and diagrams of available publications. The distribution of each palynomorph present on each slide was plotted against depth using Petrel 2014. Palynological abundance and diversity pattern chart (Figure 4) of the well was produced. Photomicrographs of some marker species recovered and some diagnostic palynomorphs recovered with their respective FDA depths are presented in Figure ures 5 and 6. Figure 7 presents the photomicrograph of some fresh water algae and marine indicator palynomorphs recovered from Vida-1 Well.

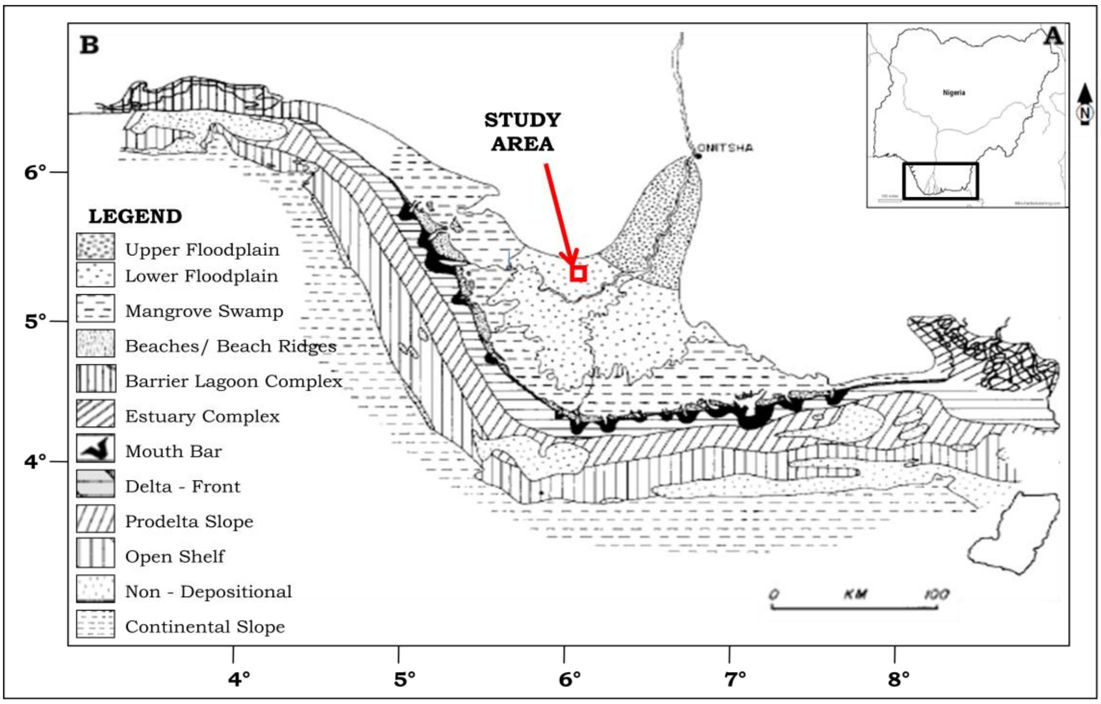

Figure 1: Map of Nigeria (insert) showing Niger Delta in the rectangular box;

B - Sedimentary environments of Niger Delta area and study area [14].

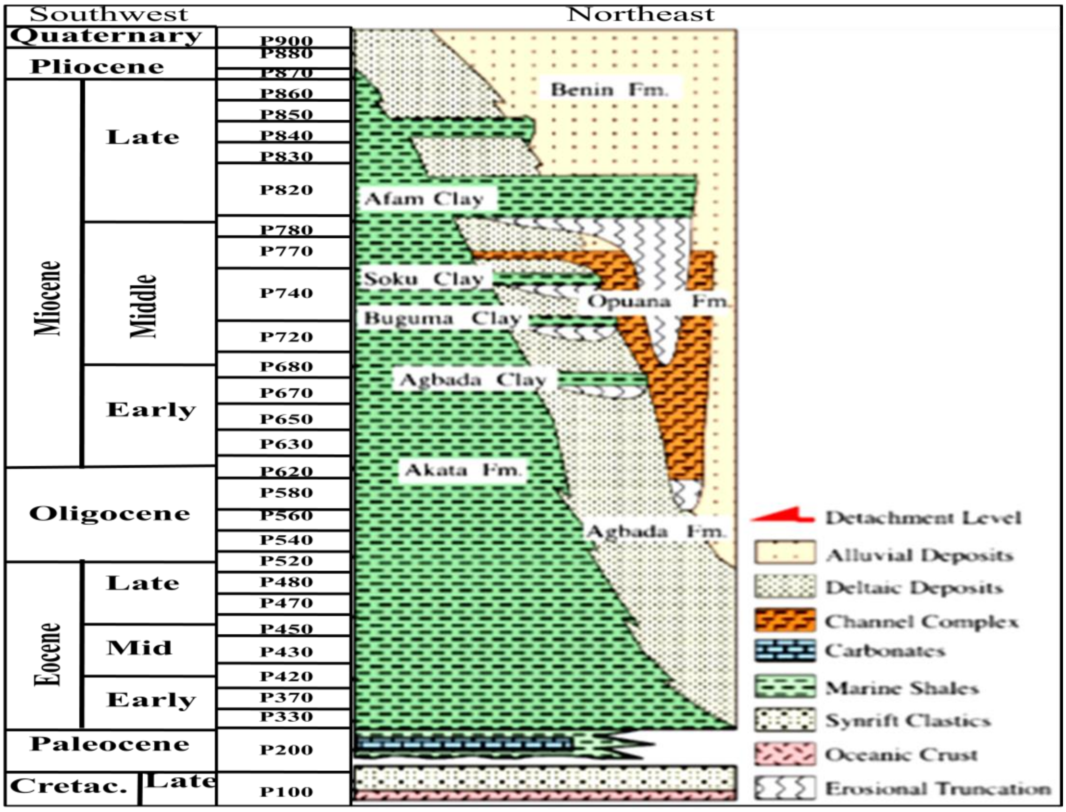

Figure 2: Schematic representative of Stratigraphic column showing formations of the Niger Delta [15]. Palynological zones used by Shell are indicated.

4. Results and Discussion

4.1. Palynology

The Palynostratigraphy, P-zones and age of the well section were interpreted from the palynomorphs marker species that were recovered in the analyzed samples as reflected by changes in palaeoecology [16,17]. The sediments yielded rich to well preserved pollen and spores numbering one hundred and twenty-three (123) miospores which were useful for biozonation. Pollen species occurred in abundance two thousand, nine hundred and sixteen (2916) and diversity one hundred and six (106), spore species occurred in abundance seven hundred sixty-seven (767) and diversity seventeen (17), while forty (40) were dinoflagellate cysts. One (1) acritarchs, 3 algae (*Botyococcus braunii, Pediastrium sp. and Scenedesmus sp.)* in abundance five hundred and fifty-seven (557), sixty-one (61) fungal spore, forty-three (43) foram test lining and thirty-six (36) indeterminate were recovered and percentage of occurrence was calculated (Table 1) (Figure 3) [18,19].

4.2. Biozonation and Age determination

The biozonation of the studied section was based on the pollen and spores. The reference scales used were those of [5,6,4]. The subsurface of Niger Delta basin palynological studies of [20,21,22,23,23,25,26,27,28] were reviewed. On the basis of first and last downhole occurrences of these palynological events, four (4) zones and four (4) subzones were erected and used to characterize the age of the sediments. Some of the subzones were lumped together because some of diagnostic fossils that mark their boundaries were not found.

Table 1: Total occurrence of different palynomorph groups recovered.

S/N	PALYNOMORPHS GROUP	TOTAL COUNTS (Abundance)	PERCENTAGE OF OCCURRENCE
1	Pollen	2916	65.66
2	Spore	767	17.27
3	Fresh Water Algae	573	13
4	Dinoflagellatte Cysts	40	0.9
5	Acritarchs	5	0.1
6	Fungal Spore	61	1.3
7	Foraminifera test lining	43	0.97
8	Indeterminate	36	0.8
	TOTAL	**4441**	**100**

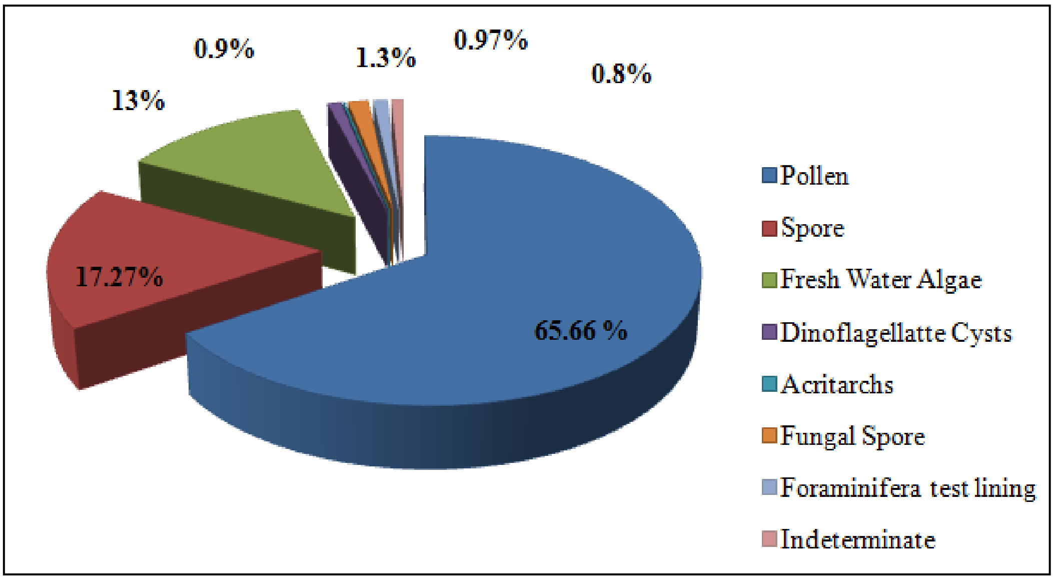

Figure 3: Pie chart of the percentage occurrence of palynomorphs recovered in Vida -1 well.

The well is dated Late Eocene – Early Middle Miocene based on the common occurrences of the diagnostic Niger Delta Middle Miocene marker species *Verrutricolporites rotundiporus*, *Belskipollis elegans* and *Crassoretitriletes vanraadshooveni*, Mid - Early Miocene marker species *Peregrinipollis nigericus*. *Magnastriatites howardi*, *Spirosyncolpites brunni*, *Verrucatosporites usmensis* and *Praedapollis flexibilis*, Early Oligocene *Psilatricolporites crassus*, *Retitriculporites irregularis* and *Arecipites exilimuratus* and Late Eocene marker species *Monoporites annulatus*, and *Verrucatosporites usmensis*. Based on the aforementioned, four palynological assemblage zones from phytoecological groupings of mangrove, freshwater swamp, coastal. riverine and savana vegetation types were recognized in the studied section of the Vida-1 well a (Figure 8) and the zones are defined from base to top. The approach of [29, 30] was followed in classifying the taxa into different phytoecological groups. Reference was made to [31, 6] in grouping the taxa to their ecological ranges.

- PZ1 (9,866 – 9,710 ft) P400 Subzone 470 Late Eocene

The zone is defined by quantitative base occurrence of *Verrucatosporites usmensis*, at 9838ft [6]. The microfloral assemblage is characterized by the low occurrence of freshwater swamp species (*Verrucatosporites usmensis),* mangrove/coastal swamp species (*Psilatricolporites crassus*) and savanna pollen (*Monoporites annulatus*). There is paucity of palynomorphs especially pollens and spores as well as records of dinoflagellate cysts fungal elements and foram test lining in this interval. The age assigned to this interval is Late Eocene (Bartonian) of Agbada Formation.

- PZ2 (9,154 – 8,925.50 ft) P500 Subzone P540 Middle Early Oligocene

The zone is defined by base continuous occurrence of *Arecipites exilimuratus* at 9,119 ft. The microfloral assemblage is characterized by the very high occurrence of freshwater swamp species (*Verrucatosporites usmensis)* mangrove/coastal swamp species (Psilatricolporites crassus) and savanna pollen (*Monoporites annulatus*) with low evergreen forest (*Retibrevitricolporites irregularis*). *Botryococcus brauni* and fern spores are higher than overlying interval. There were increases in the number of dinoflagellate cysts recorded. Thus, the general environment was that of a dense rain forest, with palms and fresh water swamp forest. The age assigned to this interval is Middle Early Oligocene (Rupelian) of Agbada Formation.

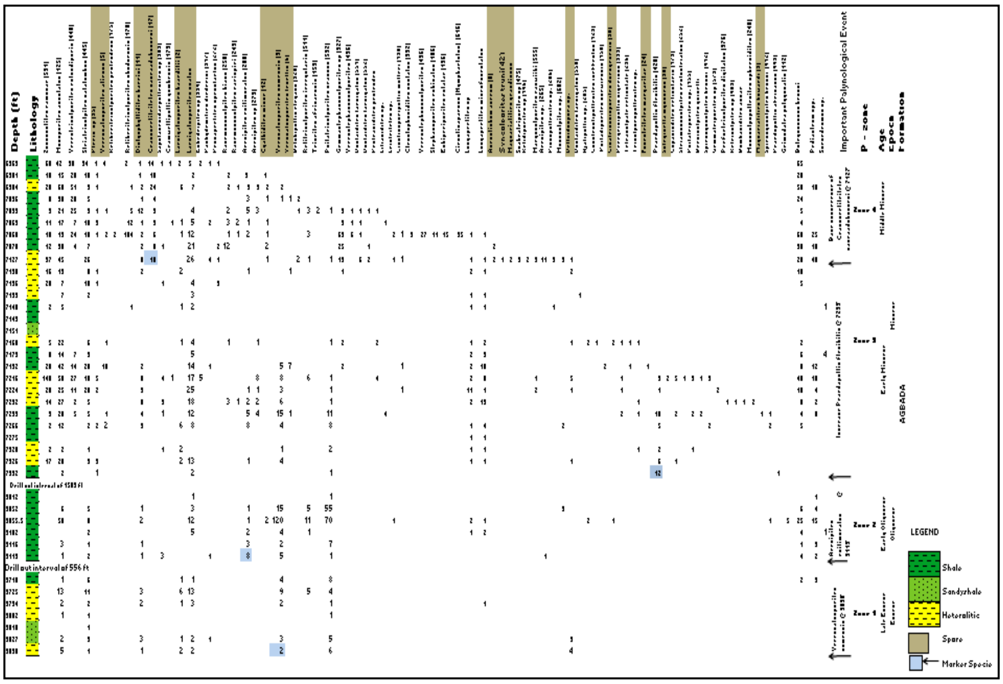

Figure 4: Stratigraphic ranges of age maker abundance and diversity pattern chart in Vida -1 well [32]

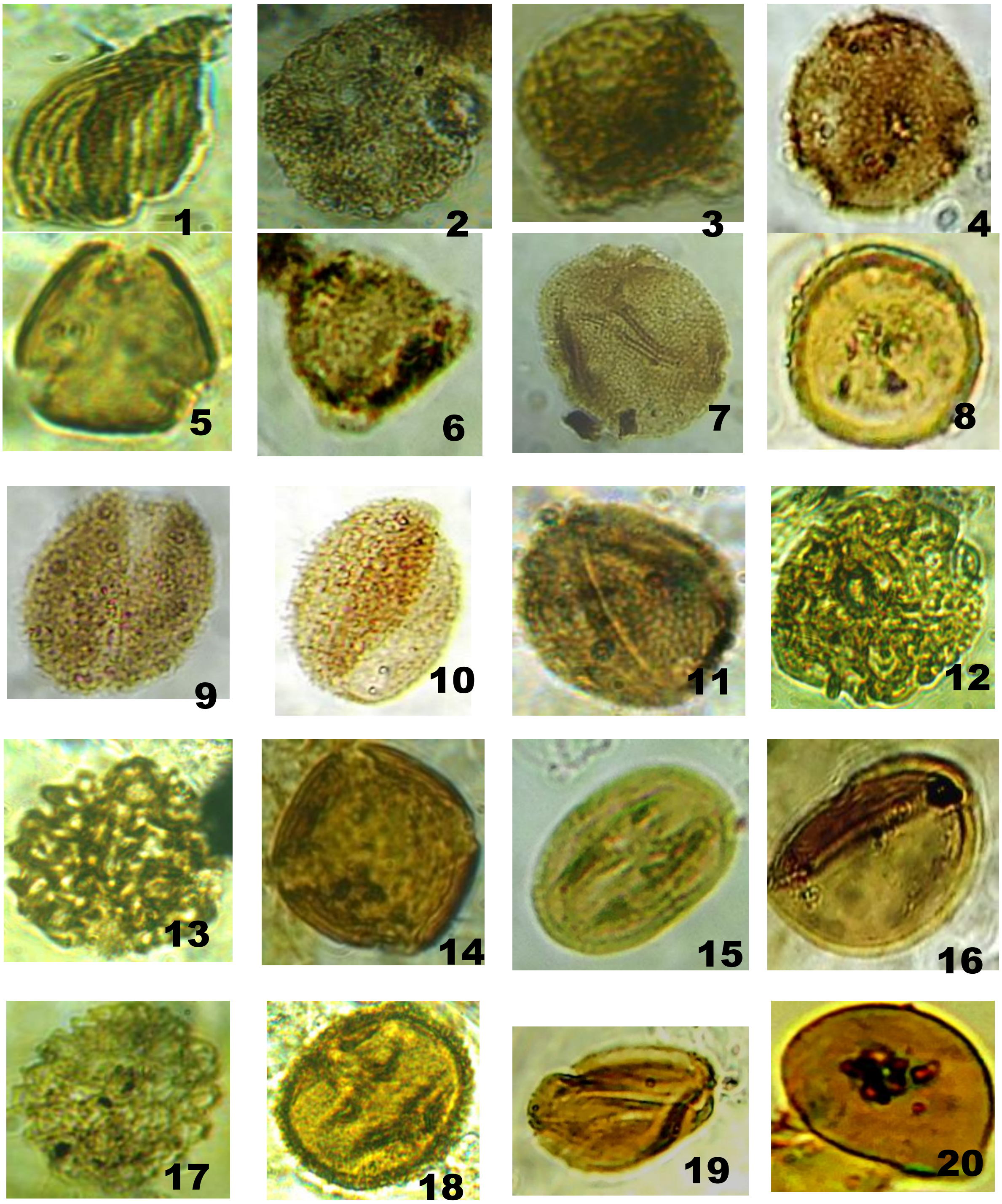

Figure 5: Photomicrograph of some marker species recovered from Vida -1 well 1, Magnariatities howardi (7262 ft); 2, Crassoretitriletes vanraadshooveni, (6963 ft); 3, Cicatricosisporites dorogenesis, (7160 ft); 4, Cramwellipollis gombensis, (6963 ft); 5, Gemmatriporites sp., (7224 ft); 6, Retibreitricolporites protrudens, (7068 ft); 7, Retibreitricolporites obodoensis, (6963 ft); 8, Cincticoporipollis mulleri, (7068 ft); 9, Racemonocolpites hians, (6981 ft); 10, Racemonocolpites rarispiri, (6984 ft); 11, Arecipites exilimuratus, (6981 ft); 12, Praedapollis flexibilis, (7216 ft); 13, Peregrinipollis nigericus, (7160 ft); 14, Pachydemities diederixi, (6963 ft) 15, Belskipollis elegans, (6963 ft); 16, Verrutricolporites rotundiporis, (6963 ft); 17, Spirosyncolpites brunni, (7266 ft); 18, Sapotaceoidaepollenites sp. (6963 ft); 19, Striatricolpites catatumbus, (6963 ft); 20, Anacolosidites luteoides, (6984 ft)

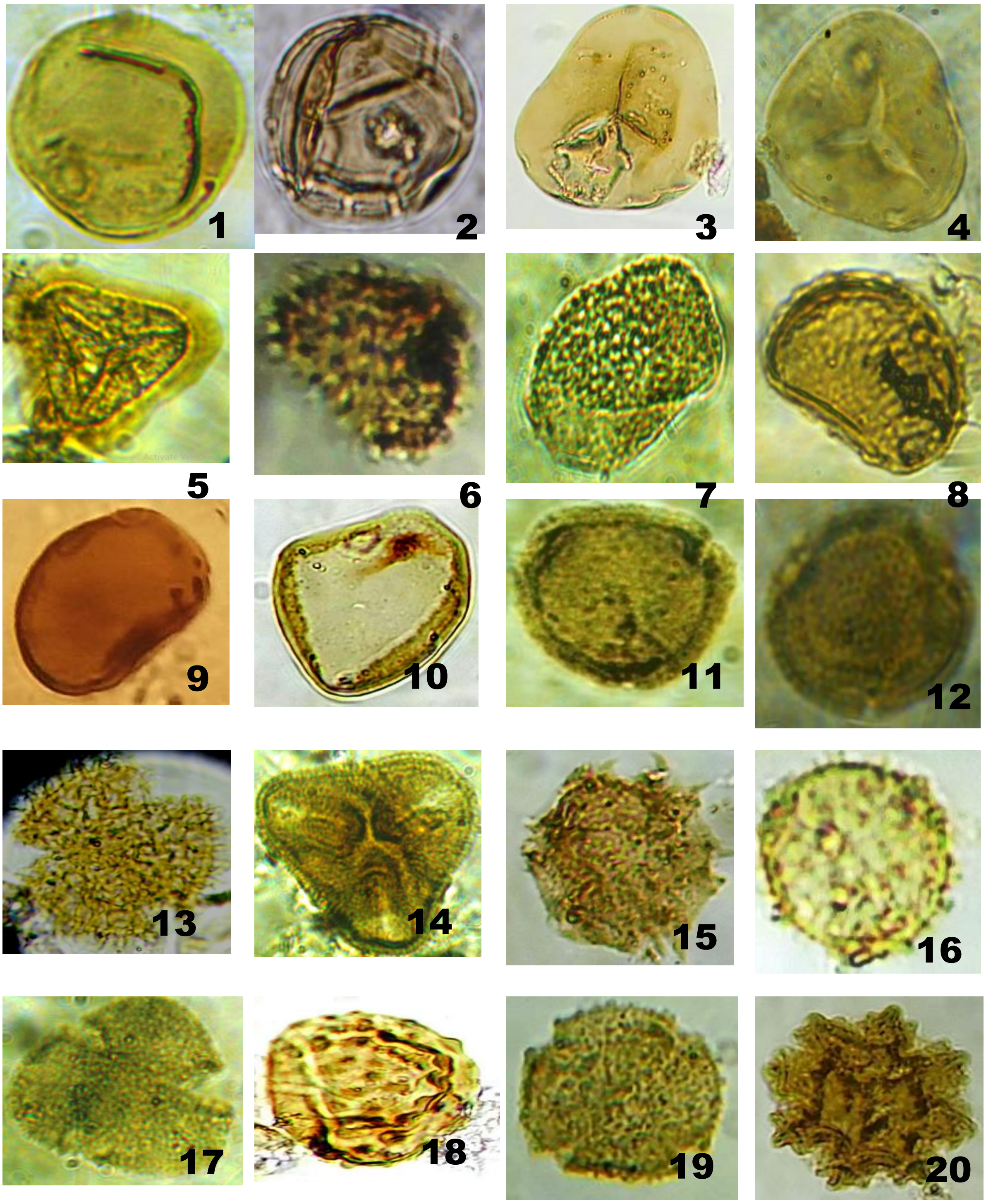

Figure 6: Photomicrograph of some palynomorps recovered from Vida-1 well. 1, Zonocostites ramonae, (6963 ft); 2, Monoporites annulatus, (6963 ft); Dictyophyllidites harrisi, (6963 ft);4, Deltoidospora minor, (7070 ft); 5, Pteris sp. (6963 ft); 6, Verucatosporites usmensis, (6984 ft); 7, Verrucatosporites alienus, (6963 ft); 8, Verucatosporites tenellis, (7036 ft); 9, Laevigatosporites ovatus, (6963 ft); 10, Circulinaparvus (7068 ft); 11, Psilatricolporites crassus (7039 ft) 12, Psilatriporites rotundus, (7127 ft); 13, Retitricolporites irregularis, (7039 ft); 14, Syncolporites sehrankii, (7326 ft); 15, Stephanoporites echinatus, (7068 ft); 16, Echiperiporites estalae 17, Bombacacidites sp., (7232 ft); 18, Gemmastephanocolporites sp., (7039 ft); 19. Verrustephonocolporites sp.

(7068 ft); 20, Ctenolophonidites costatus (7068ft)

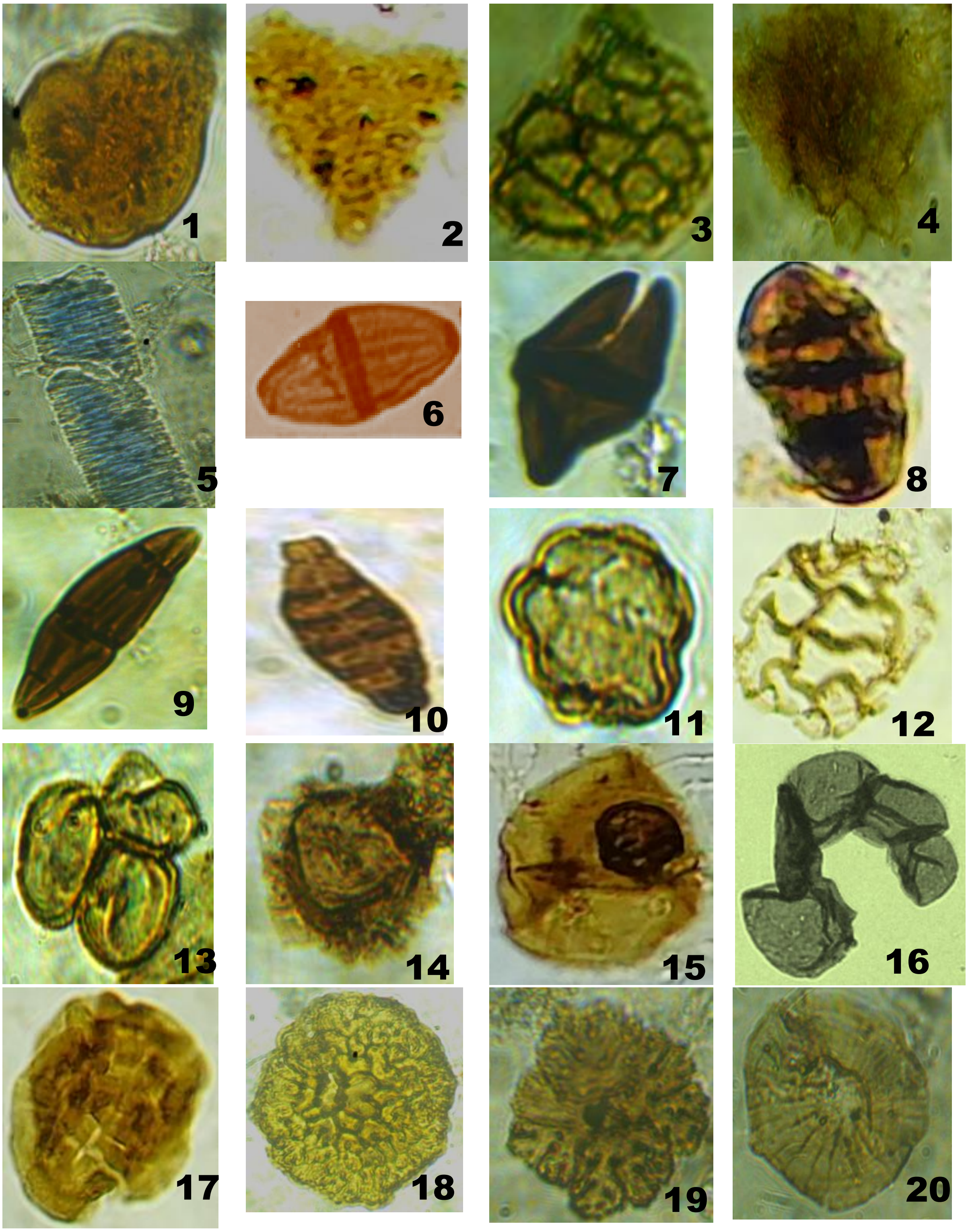

Figure 7: Photomicrograph of some Fresh water Algae and marine indicator palynomorphs recovered from Vida-1 Well. 1 -2, *Botryoccoccus brauni* , (6963 ft) 3 – 4, *Padeiatrium sp*. (6984 ft); 5, *Scenedesmus sp*.(7140 ft); 6 – 10, Fungal Spore (6963 ft); 11 – 12 , Foraminifera test lining, (6981 ft); 13, *Sphaeromorph acritarchs*, (7127 ft); 14, *Hystrichokolpoma rigauda*, (7127 ft) 15, *Alterbidinium varium*, (7068 ft) 16, *Lycopodiumsporites sp* (6984 ft); 17, *Tuberculodinium vancampoae*, (7068 ft); 18 – 20 Indeterminate.

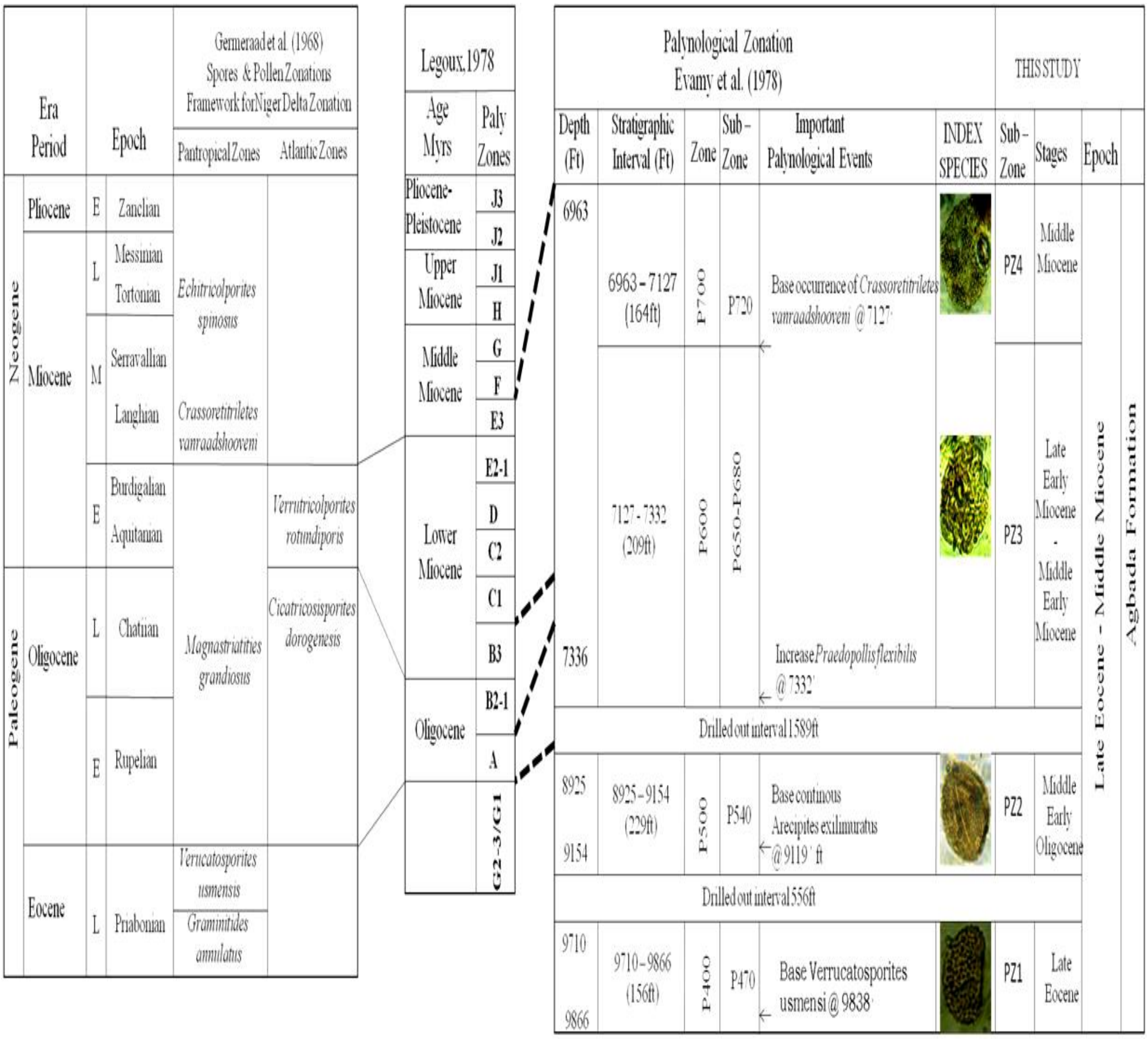

Figure 8: Correlation of inferred palynological zones (PZ1 – PZ4) with the established zones of some other authors. The stratigraphic succession in Vida-1 Well is showing the transition from Late Eocene to Early Middle Miocene in Niger Delta, Nigeria.

- PZ3 (7,336 – 7,127 ft) P600 Subzone P650-P680 Middle Early Miocene to Late Early Miocene

This zone was lumped together and was established based at the top of the composited subzone of the base occurrence of *Crassoretitriletes vanraadshooveni and by the* base increase occurrence of *Praedapollis flexibilis* at 7332 ft. The microfloral assemblage is characterized by the top regular occurrence of freshwater swamp species (*Verrucatosporites usmensis, Arecipites exilimuratus),* very high occurrence of mangrove species (*Zonocostites romonae) and Spirosyncolpites brauni* has a quantitative top within this interval and show a top regular occurrence while *Praedapollis flexibilis* exhibit high frequencies than the overlying subzone. Savanna pollen (*Monoporites annulatus*) has a base rich at 7216 ft while *Magnastriatites howardi and Racemonocolpites hians* have low occurrence. The age assigned to this interval is Early - Miocene (Burdigalian) of Agbada Formation [27].

- PZ4 (7127 – 6963 ft) P700 Subzone P720 Early-Mid Miocene

This zone is defined at the top, marked by the rich occurrence of *Striatricolpites catatumbus* with age range of Early-Mid Miocene and increased occurrence of the freshwater algae *Botryococcus braunii*, and its base is defined by the base occurrence of *Crassoretitriletes vanraadshooveni* at 7127 ft. The microfloral assemblage is characterized high occurrences of mangrove pollen species (*Zonocostites ramonae* and *Verrutricolporites rotundiporus*), low frequencies/ LAD occurrence of montane forest (*Belskipollis elegans*), savanna pollen (Proxapertites opecularties), brackish-water swamp species (*Acrostichum aureum*) and freshwater swamp species (*Retibreitricolporites protrudens, Pachydermites diederixi* and *Proteacidites spp.*) Dinoflagellate cysts show an increase compared with the underlying subzone.The peak occurrence of savanna pollen (*Monoporites annulatus*) first at 7,127 ft and further at 6,984 ft corroborates the proliferation of grasses earlier noted in the Neogene [33]. Other species here is *Striatocolpites catatumbus*, with age range of Early-Mid Miocene [6]. These possibly denotes a brief dry period sandwiched in-between a predominantly wet climate characterized by brief marine transgressions with frequent freshwater influx. The age assigned to this interval is Early – Mid Miocene (Langhian) of Agbada Formation [34].

4.3. Palaeoenvironments

Abundance and diversities of terrestrially derived palynomorphs and low proportions of marine derived elements guided the interpretation of palaeoenvironments in the studied section of the Vida-1 well as shown in Figure 9. The sediments revealed fluctuations between nearshore/coastal deltaic, characterized by moderate to abundant records of the mangrove pollen co-occurring with common freshwater swamp species and large to medium sized phytoclasts indicating deposition in a nearshore setting. Records of dinoflagellate cysts, fungal remains, foraminiferal test lining and algae characterize the marine sections [35].

- 9,866 – 9,710 ft – Marine and Deltaic Environment

The microflora is dominated by the savanna pollen (*Monoporites annulatus and Striatricolpites catatumbus*) with common pteridophyte spores *(Verrucatosporites* sp. and *Laevigatosporites* sp.). Within this section was first occurrence of the *Sphaeromorph acritarch*s, co-occurring with rare foraminifera test lining, fungal spore and dinoflagellate cyst at 9838 ft were indicating a brief period of marine dominated deposition. The poor preservation of dinocysts along the interval maybe related to physical and chemical conditions which prevailed in the depositional settings during a probable drop in sea level that caused a decrease in the water column and induced turbulence. The paucity of palynomorphs especially pollens and spores within this interval limits the well to late Eocene. The dinoflagellates are not markers and cannot be used to further establish this subzone. There was transgression in the Middle Neritic at the base of the section (9866 – 9838 ft) overlain by a regression suggesting to have taken place again around Late Eocene causing sediments to be deposited in Outer Neritic – Inner Neritic (9,838 – 9,731 ft), went further the top of the subzone is a transgression in the Middle Neritic (9,731 – 9,710 ft).

9154 – 8925.50 ft – Nearshore and Marine Environment

The microfloral assemblage is characterized by the very high occurrence of freshwater swamp species (*Verrucatosporites usmensis*) mangrove/coastal swamp species (*Psilatricolporites crassus*) and savanna pollen (*Monoporites annulatus*) with low evergreen forest (*Retibrevitricolporites irregularis*). There was increase in dinoflagellate cysts as well as foraminifera test lining, fungal spore recovered than the previous section. The presence of *Verrucatosporites usmensis*, a fern commonly found in the wet forest seems to point to the persistence of some humid conditions. The diversity of dense rain forest, with palms and fresh water swamp forest were indicating mixed vegetation zones. This suggests that the interval took place in a wet climatic condition in an environment fluctuating between marine dominated and mixed energy deposition. At the bottom of this section of Early Oligocene, an unconformity is suggested to have taken place after which a regression happened allowing the recording of sediments in Middle Neritic – Inner Neritic (9,154 – 9,090 ft), after which another regression happened recording another unconformity at 9,090 ft in Middle Neritic (9,090 – 9,060 ft) there was a transgression from Middle Neritic to Inner Neritic (9,060 – 8980 ft) and a regression again to Middle Neritic (8980 – 8925.50 ft).

- 7336 – 7127 ft - Nearshore/Coastal Deltaic environments

The microflora is dominated by the mangrove pollen *Zonocostites ramonae* with common pteridophyte spores *Verrucatosporites sp., Laevigatosporites sp*., *Psialtricolporites crassus* and *Sapotaceoidaepollenites spp*. with spot records of the dinoflagellate cysts co-occurring with common freshwater algae *Botryococcus braunii* and fungal remains. This section witnesses a regression from Middle Neritic briefly and at about the end of Early Miocene there was a transgression from Outer Neritic to Inner Neritic (7,336 – 7,127 ft). This assemblage suggests sediment deposition in a shallow marine environment with frequent incursion of freshwater.

- 7127 – 6963 ft - Continental/Marginal marine environments

The preponderance of typical diagnostic marker species *Racemonocolpites hians*, *Verrutricolporites rotundiporus*, *Belskipollis elegans* and *Crassoretitriletes vanraadshooveni* and moderate records of *Zonocostites ramonae, Monoporites annulatus, Verrucatosporites sp., Laevigatosporites sp., Psialtricolporites crassus, Gemmastephanocolporites sp., Sapotaceoidaepollenites sp., Psilastephanocolporites spp., Acrostichum aureum, Retibrevitricolporites obodoensis/ Retibrevitricolporites protrudens, Psilamonocolpites sp., Pachydermites diederixi*, together with abundant freshwater algae, spot records of dinoflagellate cysts and fungal remains characterized this interval. The dominance occurrence of continental miospores, significant occurrence of mangrove species and the presence of *Dinogyminum sp*. suggests a deltaic - tidal swamp shoreline inhabited by mangroves [27]. During Middle Miocene, in a wet climate and brackish water environment, there was a regression, an unconformity is suggested to have taken place at 7,120ft recording of sediments in Middle Neritic from Inner Neritic. Within this time and environmental setting, there was a transgression from Middle Neritic to Inner Neritic (7,127 ft – 6,963 ft) and a regression again to Middle Neritic. The palynofloral assemblage within this interval suggests deposition in environments fluctuating between marine and nearshore.

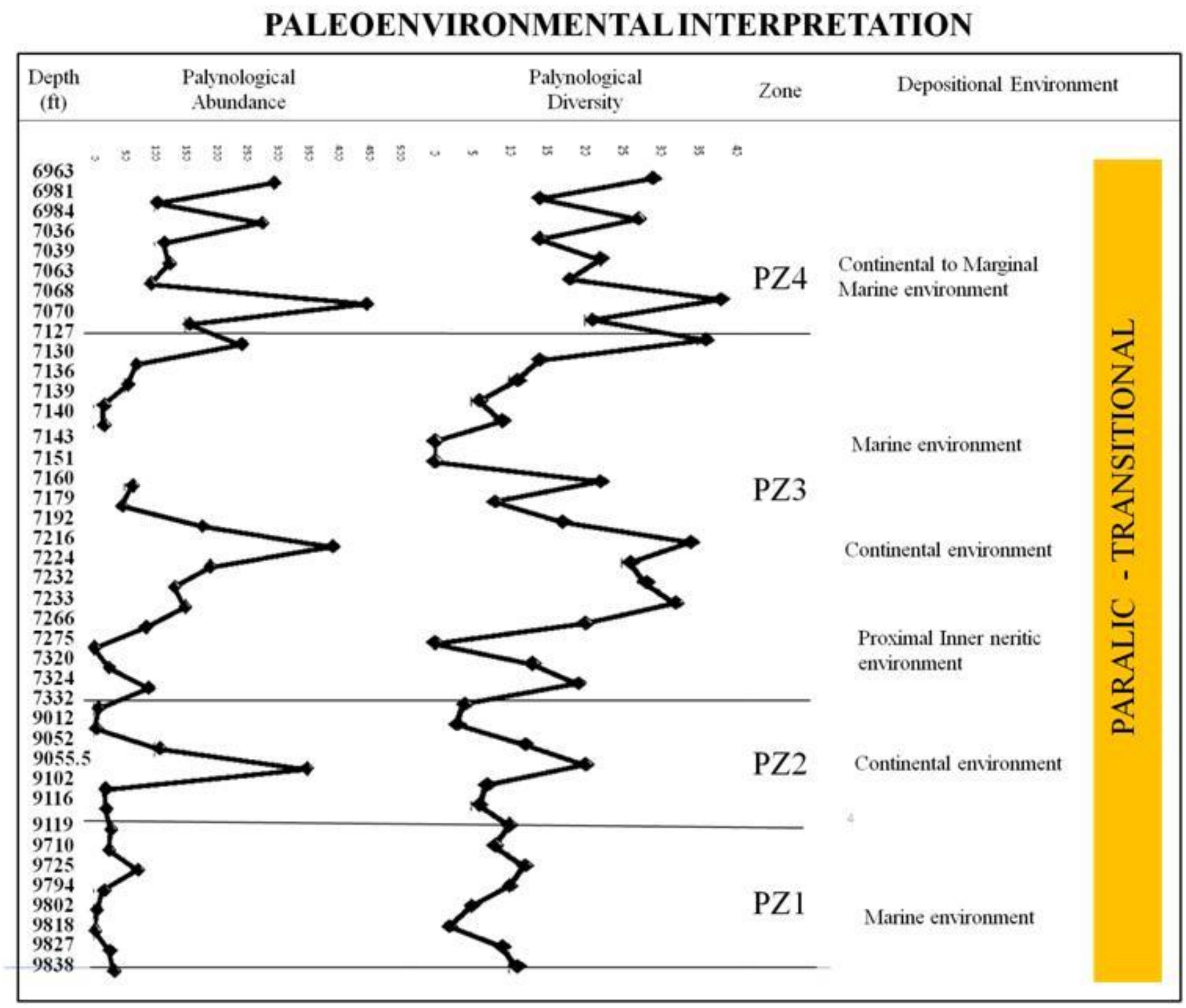

Figure 9: Environment of deposition shown from plot of palynomorphs abundance and diversity with the P-zones.

5. Conclusions

Palynonologial analysis of forty (40) samples of Vida – 1 well within interval of 6963 ft and 9866 ft were processed, prepared and analyzed. The lithology, age, zonation, and environment of deposition of the studied well were carried out. This reveals that the well penetrated a major sedimentary formation in the Niger Delta, comprising of shale, sandstone, sandy shale and shaly sand, probably the paralic sequence of Agbada Formation. A very rich recovery of palynomorphs, dominated by land-derived species of pollen and spores, low dinoflagellates cysts, brackish water spore and fungal remains and foraminifera test lining were recorded. The studied sediments are of Late Eocene-Mid Miocene age based on the recovery of *Zonocostites ramonae, Monoporites annulatus, Striatocolpites catatumbus , Verrutricolporites rotundiporus, Retribrevitricolporites obedensis, Retribrevitricolporites protundens Belskipollis elegans, Racemonocolpites hians, Crassoretitriletes vanraadshooveni, Magnastriatites howardi, Cicatricosisporites dorogenesis, Peregrinipollis nigericus, Praedapollis flexibilis, Verrucatosporites usmensis, Spirosyncolpites brauni, Arecipites exilimuratus, Psilatricolporites crassus.* There were some occurrences of none to low species diversity at few depths which was interpreted as high energy environment that was unfavourable for them. An increase in relative abundance of the freshwater algae *Botryococcus braunii* and *Pediastrum* Middle Miocene (Langhian) is interpreted to reflect a change to less saline surface water. The palynological zonation of the well and their stratigraphic distribution based on the zonation schemes of Germeraad and his colleagues 1968 are broadly assigned to *Crassoretritriletes Vanraadshooveni* /P700 Zone, *Magnastriates Howardii* / P600 Zone, and / P500 Zone and *Verrucatosporites usmensis* / P400 Zone which were further subdivided to the following subzones P720, P680 - P650, P540, and P470. The boundary between Early Miocene and Middle Miocene was at 7127 ft, Quantitative base occurrence of *Crassoretritriletes Vanraadshooveni*. Late Oligocene and Early Miocene, Late Eocene and Early Oligocene were not delineated due to insufficient data. The palynofloral assemblage within this interval suggests deposition in environments fluctuating between marine and nearshore, indicating paralic environment with the shaly sediments being deposited in a marginally marine environment under a terrestrial influence. This alternating trangressive – regressive movement and bathymetric ranging from Outer – Nerirtic - Inner Nerirtic – Middle Neritic observed actually fall within the paralic sequence known as Agbada Formation. Palynology and palaeoenvironmental study of Vida – 1 well is here by suggested to have penetrated the Agbada Formation of the Niger Delta Basin, Nigeria. However, the present study is insufficient to understand its subsurface, therefore, a continuous undisturbed core sediments from the well section are necessary to unravel the palaeoecology and palaeoenvironmental history of this basin.

Acknowledgement

The researchers wish to acknowledge N P D C, Benin City for the permission given to access the data used for this study. Also special thanks go to the managing director and staff members of Delta/TerraTek Limited, Lagos for their cooperation during first stage of the study. The support of Biostratigraphical Laboratory, Geology Department, University of Port Harcourt, is highly appreciated.

References

[1]. A. Whiteman. Nigeria: Its Petroleum Geology, Resources and Potential. Grahamand Trotman, London, 1982, p.394.

[2]. P. Stacher. “Present understanding of the Niger Delta hydrocarbon habitat,” in Geology of Deltas, M. N. Oti and Postma, G. eds., A.A. Balkema, Rotterdam: 1995, pp.257-267.

[3]. A. J. Short and K. L. Stauble. “Outline of the geology of the Niger Delta.” American Association of Petroleum Geologists Bulletin, vol. 51, pp.761-779, 1967.

[4]. B. D. Evamy, J. Haremboure, P. Kamerling, W. A. Knap, F. A. Molloy and P. H. Rowlands, “Hydrocarbon habitat of Tertiary Niger Delta.” American Association of Petroleum Geologist Bulletin vol.62, pp.1–39, 1978.

[5]. O. Legoux. “Quelques espèces e pollen caractéristiques du Neogene du Nigeria.” Bulletin Centres Recherche Exploration-Production d’Elf- Aquitaine, vol. 2(2), pp.265–317, 1978.

[6]. J. J. Germeraad, C. A. Hopping and J. Muller. “Palynology of Tertiary sediments from tropical areas.” Review of Paleobotany and Palynology, vol. 6(3-4), pp.189-348, 1968.

[7]. M. D. Simmons, M. D. Bidgood, P. Brenac, P. D. Crevello, J. J. Lambiase and C.K. Morley.

"Microfossil assemblages as proxies for precise palaeorenvironmental determination-an example from Miocene sediments of northwest Borneo," in Biostratigraphy in Production and Development Geology, R.W. Jones and M.D. Simmons, eds., Geological Society Special Publication, vol.152, 1999, p.219.

[8]. T. J. A. Reijers. "Selected chapters on Geology: Sedimentary Geology, Sequence Stratigraphy," Three case studies and a Field Guide. SPDC, Warri, 1996, p 197.

[9]. H. Kulke. "Nigeria," in Regional petroleum geology of the world, part II: Africa, America, Australia and Antarctica, H. Kulke ed., Gebrüder Borntraeger, Berlin, 1995, pp.143-172.

[10]. A. A. Avbovbo. "Tertiary lithostratigraphy of Niger Delta." American Association of Petroleum Geologists Bulletin, vol. 62(2), pp.295–300, 1978.

[11]. M. L. W. Tuttle, R. R. Charpentier and M. E. Brownfield. "The Niger delta petroleum system: Niger delta province, Nigeria, Cameroon, and Equatorial Guinea," Africa: USGS Open-file report 99-50-H. 1999.

[12]. P. O. Onyeanusi, M. U. Udoh, I. O. Imasuen, S. Tsaku, H. E. Omodolor and B. O. Aduomahor. "The Effect of Facies Changes on Hydrocarbon Production in Osisioma Field, Onshore, Niger Delta," Nigeria. Journal of Geosciences and Geomatics. 2018; 6(2):35-40. doi: 10.12691/jgg-6-2-1.

[13]. K. Faegri and J. Iversen. Textbook of Pollen Analysis. 4th edn. New York, John Wiley and Sons, 1989.

[14]. J. R. L. Allen. "Late Quaternary Niger Delta, and adjacent areas-sedimentary environments and lithofacies." American Association of Petroleum Geologists Bulletin, vol. 49, pp.547-600, 1965.

[15]. H. Doust and E. Omatsola. "Niger Delta," in Divergent/Passive margin basin, J.D. Edwards and P. A. Santogrossi, eds., AAPG Memoir, vol. 48, 1989, pp.201-238.

[16]. C. Hoorn. Miocene Palynostratigraphy and Paleoenvironments of Northwestern Amazonia. Amsterdam, University of Amsterdam, 1994.

[17]. N. O. Frederiksen. "Review of Early Tertiary sporomorph paleoecology." American Association of Stratigraphic Palynologists Contribution Series No. 15. Dallas, American Association of Stratigraphic Palynologists Foundation, 1985.

[18]. M. A. Sowunmi. "Palynological studies in Niger Delta," in The Early History of the Niger Delta, E. J. Alagoa, F.N. Anozie and N. Nzewunwa, eds. Helmat Buske Verlag Hamburg, Uk., 1987, pp.29-59.

[19]. F. A. Lucas and T. J. Fregene. "Palynological Zonation of Oligocene to Early Miocene Sediments of Greater Ughelli Depobelt, Niger Delta Basin." Journal of Applied Sciences and Environmental Management, Vol. 21 (7), pp.1341-1345, Dec, 2017.

[20]. R. J. Morley. "Biostratigraphic characterization of Systems Tracts in Tertiary sedimentary basins." Proceeding of the International Symposium on Sequence Stratigraphy in S.E. Asia, 1995, pp.49–71.

[21]. I. N. Oloto. Palynology and sequence Stratigraphy: Case study from Nigeria. Legacy Integrations Nig. Ltd. 2009, p254.

[22]. F. E. Oboh, M. B. Salami and J. L. Chapman. "Palynological interpretation of the palaeoenvironments of Miocene strata of the well Igbomotoru-1, Niger Delta." Journal of Micropalaeontology vol. 11, pp.1–6, 1992.

[23]. O. E. Ige, K. Datta, K. Sahai, and K. K. Rawat. "Palynology studies of sediments from North Chioma-3 well, Niger Delta and its palaeoenvironmental interpretations." American Journal of Applied Sciences vol.8 (12), pp.1249–1257, 2011.

[24]. F. E. Oboh. "Sedimentological and palynological characteristics of the E2.0 reservoir (Middle Miocene) in the Kolo Creek Field, Niger Delta," in Geology of Deltas. M. N. Oti, and G. Postma, eds., A. A. Balkema Publishers, Rotterdam, 1995, pp.243-256.

[25]. E. U. Durugbo, O. T. Ogundipe and O. K. Ulu. "Palynological evidence of Pliocene- Pleistocene climatic variations from the Western Niger Delta, Nigeria." International Journal of Botany vol. 6(4), pp.351–370, 2010.

[26]. E. U. Durugbo and M. A. Olayiwola. "Palynological dating and palaeoenvironments of the M1 well, Middle Miocene, Niger Delta, Nigeria." Palaeontologia Africana, vol. 52, pp.45-47, July, 2017.

[27]. O. F. Adebayo, A. E. Orijemie and A.O. Aturamu. "Palynology of Bog-1 well, southeastern Niger Delta Basin, Nigeria." International Journal of Science and Technology vol. 2(4), pp.214–222, 2012.

[28]. G. C. Soronnandi-Ononiwu, A. O. Omoboriowo and Y. Yikarebogha. "Palynology and paleoenviromental study of Akukwa-1 well, Niger delta and Anambra basins, Nigeria." International Journal of Scientific and Technology Research, vol. 3 (2), pp.297-304, 2014.

[29]. M. A. Sowunmi. Late Quaternary environmental changes in Nigeria. Pollen et spores **23**(1), 125–148. 1981a.

[30]. M. A. Sowunmi. "Aspects of Late Quaternary vegetation changes in West Africa." Journal of Biogeography, vol. 8, pp.457–474, 1981b.

[31]. V. Mosbrugger and T. Utescher. "The coexistence approach-a method for quantitative reconstructions of Tertiary terrestrial palaeoclimate data using plant fossils." Elsiveir. Palaeogeography, Palaeoclimatology, Palaeoecology, vol.134, pp.61- 86, 1997.

[32]. F. A, Lucas. "Miospores and Geological Boundaries in Maastrichtian to Lutetian Succession of Ajire-1 well, Anambra Basin, Nigeria." International Journal of Science and Advanced Innovative Research, vol. 2(1), pp.74- 84, 2017.

[33]. J. Maley. "The African rain forest – main characteristics of changes in vegetation and climate from the Upper Cretaceous to the Quaternary." Proceedings of the Royal Society of Edinburgh, vol. 104B, pp.31-73, 1996.

[34]. O. H. Adekanmbi and M. A. Sowunmi. "Palynological biosignals and depositional environments within the Niger Delta basin, Nigeria." Nigerian Journal of Botany, vol. 20, pp.457–466, 2007.

[35]. N. E. Ajaegwu, B. I. Odoh, E.O. Akpunonu, I. I. Obiadi and E. K. Anakwuba. "Late Miocene to Early Pliocene Palynostratigraphy and palaeoenvironments of ANE-1 Well eastern Niger Delta, Nigeria." Journal of Mining and Geology vol. 48(1), 31–43, 2012.