



Palynostratigraphy and Palaeoenvironment of the Western Niger Delta, Nigeria: A Case Study of the Well– A,

Magana, U.M., Avong, S.J., Timothy, I., *Oso, P.E., Ubong, O.S. and **Ubit, G.E.

Department of Geology, Ahmadu Bello University, Zaria, Nigeria.

*Department of Geosciences, University of Lagos, Nigeria.

**Department of Applied Geology, Abubakar Tafawa Balewa University, Nigeria.

ABSTRACT

Fifty ditch cutting samples were analyzed for Palynological analysis. The samples were prepared based on conventional methods of maceration. Several pollen and spores present include; *Zonocostites Ramonae*, *Monoporites annulatus*, *Pachydermites diderixi*, *Sapotaceoic sp.*, *Verrucastoporites sp.*, *Monocolpites sp.*, *Acrostichum aureum* and *Laevigastoporites sp.* There are also minor presences of fungal spores, hyphae, and dinoflagellate cysts (*Botryococcus braunii*). Three palynomorph zones were proposed, namely; *Pachydermites diderixi*, *Zonocostites ramonae*, and *Laevigastoporites sp.* Zones, having an Early to Late Miocene age. Using interpreted palynomorph data from the western section of the Niger delta, the study interval was characterized to have a wet climatic condition, due to the abundant occurrences of mangrove pollen and spores such as *Zonocostites ramonae* and *Psilatricolporites crassus*. The sediments within the studied interval include shale and sands of the paralic Agbada formation.

Keywords; Miocene, Pollen, Spores, Biozone, Palaeoenvironment, Niger Delta

INTRODUCTION

Palynology encompasses the study of spores, pollen, and particulate organic matter in various matrices, including the air. It is an essential tool for reconstructing past environment history and variations in several fields such as biostratigraphy, taxonomy and evolutionary studies, forensics, archaeology and hydrocarbon exploration. The petroleum industry in Nigeria has described and adopted informal biostratigraphic zonation, which remains unpublished (Evamy *et al.*, 1978). Palynological and foraminifera biozones have proved to be reliable tools for large-scale correlations. Attempts have been made to mutually validate and integrate the Shell Petroleum Development Company of Nigeria (SPDC) framework postulated by Evamy *et al.* (1978) with available published and unpublished work of other industry groups, but which is hampered by different alpha-numerical coding systems. Okosun *et al.* (2012) determined a Miocene age for the Akata field, Eastern Niger Delta, based on the presence of *Sphenolithus heteromorphus* zone with an assigned age of 15 Ma equivalent to the NN5 zone. Ajaegwu *et al.* (2012) also identified a Late Miocene to Early Pliocene age based on the First Appearance Datum (FAD) of *Nymphaeapollis clarus* and the increased abundance of *Monoporites annulatus*, based on the zonation scheme of Evamy *et al.* (1978). Inyang *et al.* (2016) analysed T-well of the Niger Delta, where two pantropical zones of *Magnastriates howardi* (P650-680) and *Crassoratiriletes vanraadshooveni* (P680-P700) were delineated using stratigraphic markers such as *Monoporites annulatus*, *Zonocostites*

ramonae, *Pachydermites diderixi* showing an Early to Middle Miocene age inferred for the depth interval. This study aim to identify the recovered palynomorphs, which was then used to determine the age, biostratigraphy and palaeoenvironment of samples penetrated by Well-A. The well location reference geographic co-ordinates are on latitude 5° 30' 29.43"N and longitude 4° 58' 00.04"E

Geological Settings of Niger Delta

The Niger Delta Basin is one of Nigeria's Sedimentary Basin and is situated in equatorial West Africa and lies between latitudes 3°N and 6°N and longitudes 5°E and 8°E (Reijers *et al.*, 1996). Niger Delta Basin generally display three vertical lithostratigraphic subsections: an upper delta top lithofacies; a middle delta front lithofacies; and a lower Pro-delta lithofacies (Reijers *et al.*, 1996). These units correspond respectively with the Benin Formation (Oligocene-Recent), Agbada Formation (Eocene-Recent) and Akata Formation (Paleocene-Recent) following the scheme of Short and Stauble (1967). The Akata Formation comprises marine shales, with sandy and silty beds that are thought to be laid down as turbidites and continental slope channel fills. The formation is estimated to be up to 7000 m thick (Doust and Omatsola, 1990). The Agbada Formation is the primary petroleum-bearing unit in the Niger Delta. The formation consists mainly 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 3700 m. The Benin Formation is

*Corresponding author. E-mail: solomonjoshuaavong@gmail.com

Author(s) agree that this article remain permanently open access under the terms of the Creative Commons Attribution License 4.0 International license

about 280 m thick but may be up to 2100 m in the region of maximum subsidence (Whiteman, 1982) and

consist of continental sands and gravels.

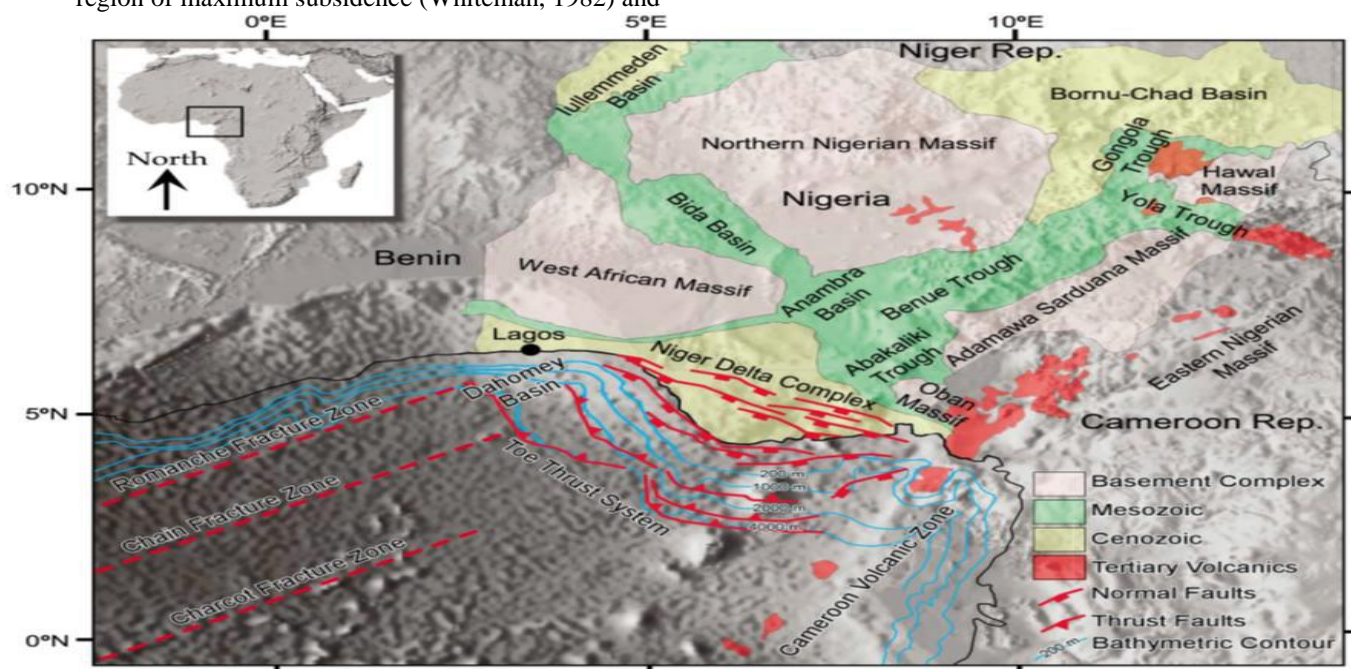


Figure 1: Part of West Africa and the Gulf of Guinea Showing Nigeria’s Sedimentary Basin and some features controlling Sedimentation in the Niger Delta. In set is a map of Africa showing the Location of the Niger Delta region (Corredor *et al.*, 2005).

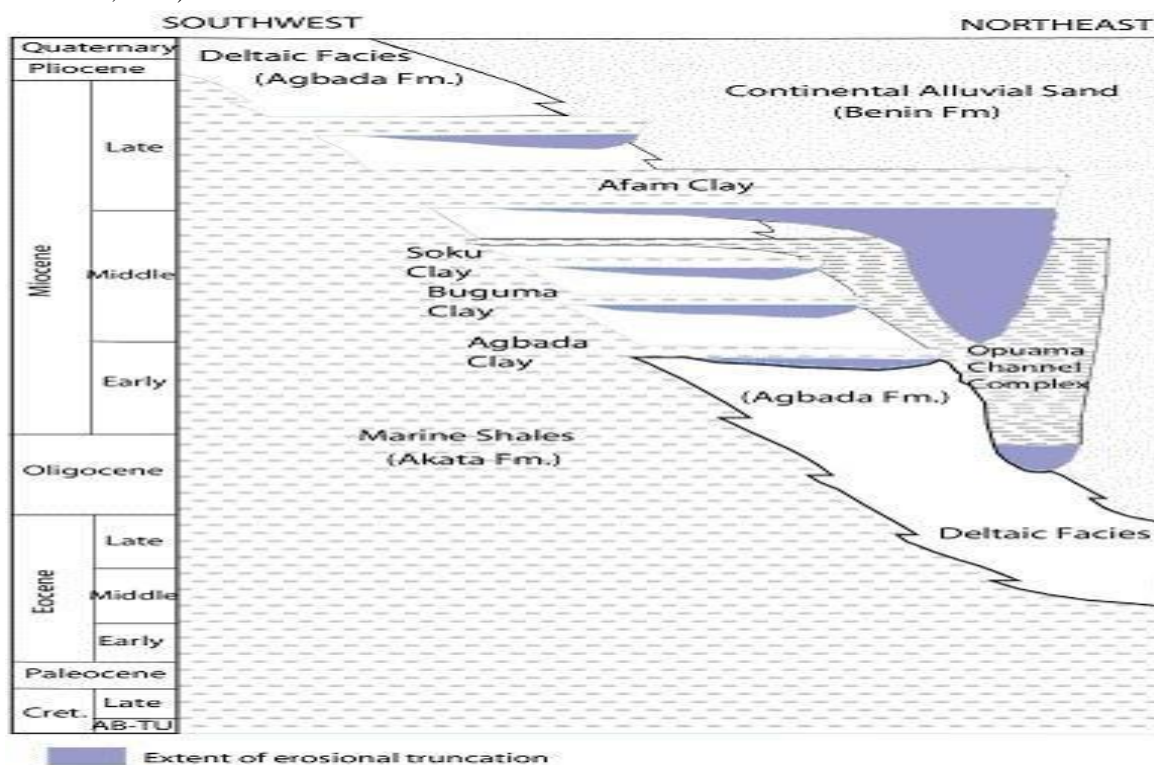


Figure 2: Schematic diagram of Regional Stratigraphy of the Niger Delta (Shannon and Naylor, 1989 and Doust and Omatsola, 1990).

METHODOLOGY

Sample Preparation

Fifty ditch cutting samples within the interval of 4000-5450 ft were analyzed for their palynomorph contents. 20g was taken from each sample and treated using hydrochloric to remove carbonates from it. It is then digested in hydrofluoric acid under a fume cupboard. The hydrochloric acid solution was applied and then sieved under a gentle water tap over a 5-micron mesh polypropylene sieve. After sieving, oxidation of the prepared sample is controlled using concentrated nitric acid (HNO₃). The level of oxidation required by each sample was closely monitored under a palynological light microscope. The residues are dried and mounted on a slide. Detailed Palynological analysis and quantitative identification of pollen, spores, algae, dinoflagellates and other floral relevant remains were identified. Total counts of all palynomorph contained in slides obtained from samples of Well-A were recorded on a palynomorph distribution chart for interpretation. International Published names and scientific palynological nomenclature were all identified and followed.

RESULTS AND DISCUSSION

The lithostratigraphic sections of the well was interpreted using ditch cutting samples description and shown to be having lithology of mainly sandstone and shale layers intercalation.

Palynomorph MicroFauna

Fifty-two (52) pollen and spores species were identified. The sediments in this section yielded a rich assemblage of pollens, spores and dinocysts species. The pollen grains are: *Zonocostites Ramonae*, *Monoporites annulatus*, *Brevicolporites guinetii*, *Polypodiaceisporites spp*, *Sapotaceoidaepollenites sp*, *Acrostichum aureum*, *Proxapertites cursus*, *Psilatricolporites crassus*, *Psilatricolporites operculatus*, *Verrutricolporites sp*, *Laevigatosporites sp*, *Retitricolporites irregularis*, *Striatricolpites catatumbus*, *Proteacidites cooksonni*, *Dinoflagellate cysts*, *Leiosphaeridia sp*, *Botryococcus braunii*, *Alnus vera*, *Asteraceae sp*, *Brazilea sp*, *Canthiumidites sp*, *Crototricolporites crotonoscultus*, *Cyperaceaeipollis sp*, *Echiperiporites icacinoides*, *Gemmamonoporites sp*, *Inaperturopollenites sp*, *Monocolpites sp*, *Multiareolites formosus*, *Nymphaepollis sp*, *Pachydermites diderixi*, *Peregrinipollis nigericus*, *Podocarpidites sp*, *Pollen indeterminate*, *Proteacidites cooksonni*, *Psilatricolpites sp*, *Psilatriporites sp* *Racemonocolporites hians*, *Retibrevitricolporites protrudens/obodoensis*, *Retitricolporites guinensis*, *Retitricolporites sp*, *Spirosyncolpites bruni*, *Tricolpites sp.complanatus*, *Verrutricolporites rotundiporus*, *Cyathidites sp*, *Fungal spores and hyphae*, *Magnastriatites howardi*, *Polypodiaceoisporites sp*, *Selaginella*

Table 1: Quantity of each palynomorph in Percentage and Degree

S/n	List of Palynomorph	Quantity	Quantity %	Quantity in Degree
1	<i>Zonocostites ramonae</i>	339	44.7	160.8
2	<i>Monoporites annulatus</i>	25	3.29	11.86
3	<i>Brevicolporites guinetii</i>	2	0.26	0.95
4	<i>Polypodiaceisporites spp</i>	11	1.45	4.98
5	<i>Sapotaceoidaepollenites sp</i>	19	2.5	8.6
6	<i>Acrostichum aureum</i>	51	6.72	24.2
7	<i>Proxapertites cursus</i>	5	0.66	2.37
8	<i>Psilatricolporites crassus</i>	10	1.32	4.74
9	<i>Psilatricolporites operculatus</i>	2	0.26	0.95
10	<i>Verrutricolporites sp</i>	3	0.4	1.42
11	<i>Laevigatosporites sp</i> ,	75	9.88	35.6
12	<i>Retitricolporites irregularis</i>	9	1.19	4.27
13	<i>Striatricolpites catatumbus</i>	3	0.4	1.42
14	<i>Proteacidites cooksonni</i>	1	0.13	0.47
15	<i>Dinoflagellate cysts</i>	2	0.26	0.95
16	<i>Leiosphaeridia sp</i>	4	0.53	1.9
17	<i>Botryococcus braunii</i>	6	0.8	2.85
18	<i>Alnus vera</i>	1	0.13	0.47
19	<i>Asteraceae sp</i>	1	0.13	0.47
20	<i>Brazilea sp</i>	1	0.13	0.47

21	<i>Canthiumidites sp</i>	2	0.26	0.95
22	<i>Crototricolporites crotonoscutus</i>	1	0.13	0.47
23	<i>Cyperaceaepollis sp</i>	1	0.13	0.47
24	<i>Echiperiporites icacinoides</i>	1	0.13	0.47
25	<i>Gemmamonoporites sp</i>	5	0.66	2.37
26	<i>Inaperturopollenites sp</i>	4	0.53	1.9
27	<i>Monocolpites sp</i>	22	2.9	10.4
28	<i>Multiareolites formosus</i>	1	0.13	0.47
29	<i>Nympheapollis sp</i>	1	0.13	0.47
30	<i>Pachydermites diderixi</i>	14	1.85	6.64
31	<i>Peregrinipollis nigericus</i>	1	0.13	0.47
32	<i>Podocarpidites sp</i>	2	0.26	0.95
33	<i>Pollen indeterminate</i>	15	1.98	7.12
34	<i>Proteacidites cooksonni</i>	1	0.13	0.47
35	<i>Psilatricolpites sp</i>	14	1.85	6.64
36	<i>Psilatriporites sp</i>	1	0.13	0.47
37	<i>Racemonocolporites hians</i>	5	0.66	2.37
38	<i>Retibrevitricolporites protrudens/obodoensis</i>	11	1.45	5.22
39	<i>Retitricolporites guinensis</i>	1	0.13	0.47
40	<i>Retitricolporites sp</i>	5	0.66	2.37
41	<i>Spirosyncolpites bruni</i>	2	0.26	0.95
42	<i>Tricolpites sp</i>	4	0.53	1.9
43	<i>Tricolporites sp</i>	3	0.4	1.42
44	<i>Verrustephanocolpites complanatus</i>	1	0.13	0.47
45	<i>Verrutricolporites rotundiporus</i>	5	0.66	2.37
46	<i>Cyathidites sp</i>	3	0.4	1.42
47	<i>Fungal spores and hyphae</i>	11	1.45	5.22
48	<i>Magnastriatites howardi</i>	4	0.53	1.9
49	<i>Polypodiaceoisporites sp</i>	11	1.45	5.22
50	<i>Selaginella myosurus</i>	1	0.13	0.47
51	<i>Spore indeterminate</i>	1	0.13	0.47
52	<i>Verrucatosporites sp</i>	35	7.51	27.03
	Total	759		

Table 2: Table showing the total counts of palynomorph of Well-A

Palynomorph	Total Counts of palynomorph	Percentage Abundance
Rainforest	33	4.25
Mangrove	339	43.69
Brackish Water Swamp	70	9.02
Fresh Water Swamp	98	12.63
Savanna	1	0.13
Total	776	100

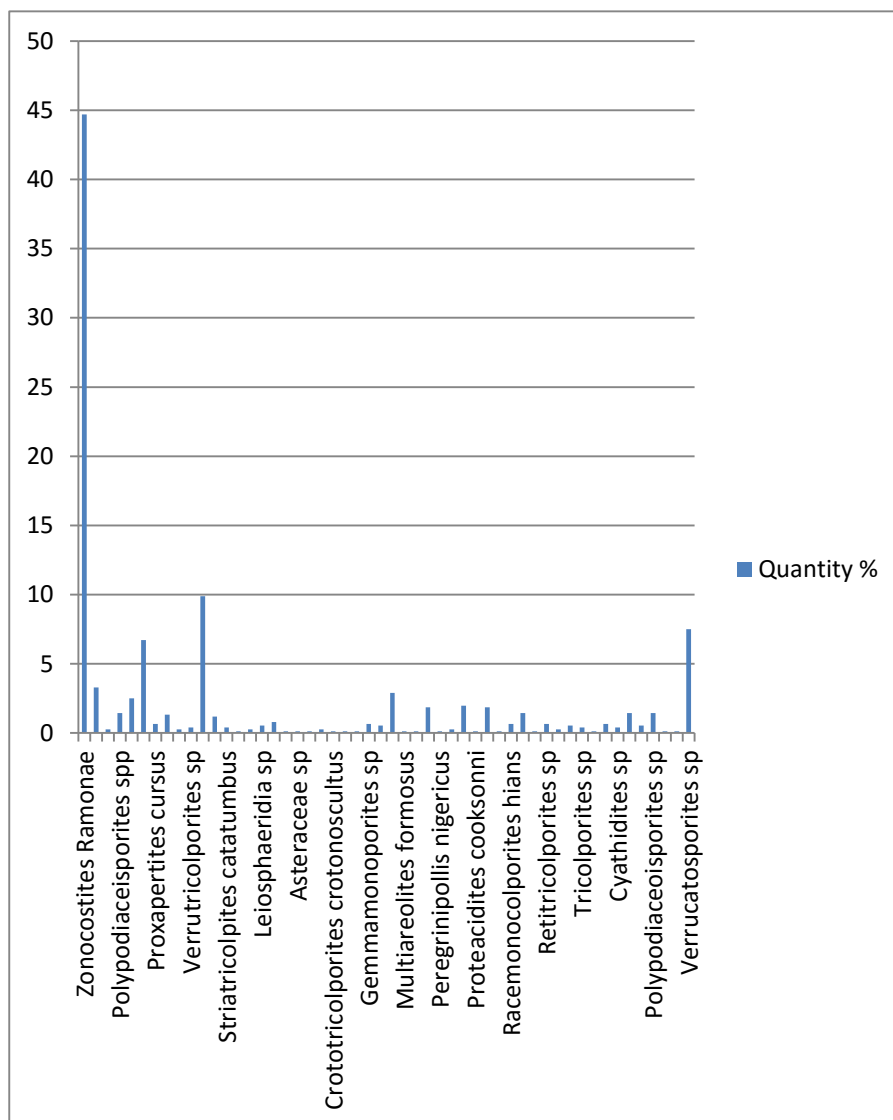


Figure 3: Bar Chart showing Percentage Composition of Palynomorph.

PALYNOSTRATIGRAPHY

Detailed palynological analysis was carried out on fifty ditch cutting samples of well-A. The samples had moderately rich pollen spores and dinoflagellate cyst. The palynomorphs recorded includes *Monoporites annulatus*, *Zonocostites ramonae*, *Sapollaceoidae pollenites*, *Acrostichum aureum*, *Polypodiaceoisporites sp*, *Laevigastoporites sp.*, *Retitricolporites irregularis*, *Pachydermites diderixi*, *monocolpites sp.*, *pollen indentermate*, *Retibrevitricolporites protudens*, *Magnastriatites howardi*, and *Polypodiaceoisporites* and a few dinoflagellate cysts such as *leiosphaeridia sp*. The well-A section contains three zones; *Pachydermits diderixi*, *Zonocostites ramonae* and *Laevigastoporites sp*. zones which were correlated

with already published schemes (Evamy *et al.*, 1978 and Germeraad *et al.*, 1968) as seen in Figure 4.

***Pachydermites diderixi* Zone**

Stratigraphic interval: 4000-4690 ft

The occurrence of *Echiperiporites icacooides* pollen marks this zone; it can be used as an indicator of a wet climate which means it occurred in a marine environment. There is also a reduced presence of the savanna taxa encroachment from dry land. **Diagnosis:** This is the youngest subzone recognized in the studied section of Well-A. The top of the sub-zone is marked by the occurrence of *Echiperiporites icacooides*, while the base is defined by the quantitative base occurrence of *Pachydermites diderixi*. This zone corresponds to the P680 zone of Evamy *et al.* (1978) and is assigned an Early- Late Miocene age.

Zonocostites ramonae Zone

Stratigraphic interval: 4690-4960 ft

This zone is also marked by the abundance of *Zonocostites ramonae*, which indicates a wet climate at the time of deposition. A quantitative base of *Pachydermites diderixi* characterized the top of this section, and the base has a concentration of *Magnastriatites howardi*. This zone corresponded to the P670 zone of Evamy *et al.* (1978) and assigned an Early Miocene age.

Laevigastoporites Zone

Stratigraphic interval: 4960-5450ft

A wet climate characterizes this zone due to *Laevigastoporites sp.*, which occurs abundantly in this

zone and the slight appearance of *Zonocostites ramonae* and *Psilatricolporites*. These pollens are from the mangrove environment. The top of the subzone is marked by the quantitative base occurrence of *Magnastriatites howardi*. The sub-zone is characterized by the abundant presence of *Laevigastoporites sp.*, common occurrence of *Verrucatosporites sp.*, *Zonocostites ramonae* and *Acrostichum aureum*. It is the last and oldest zone recognized at Well A. This zone corresponds P650 zone of Evamy *et al.* (1978) and was dated Early Miocene.

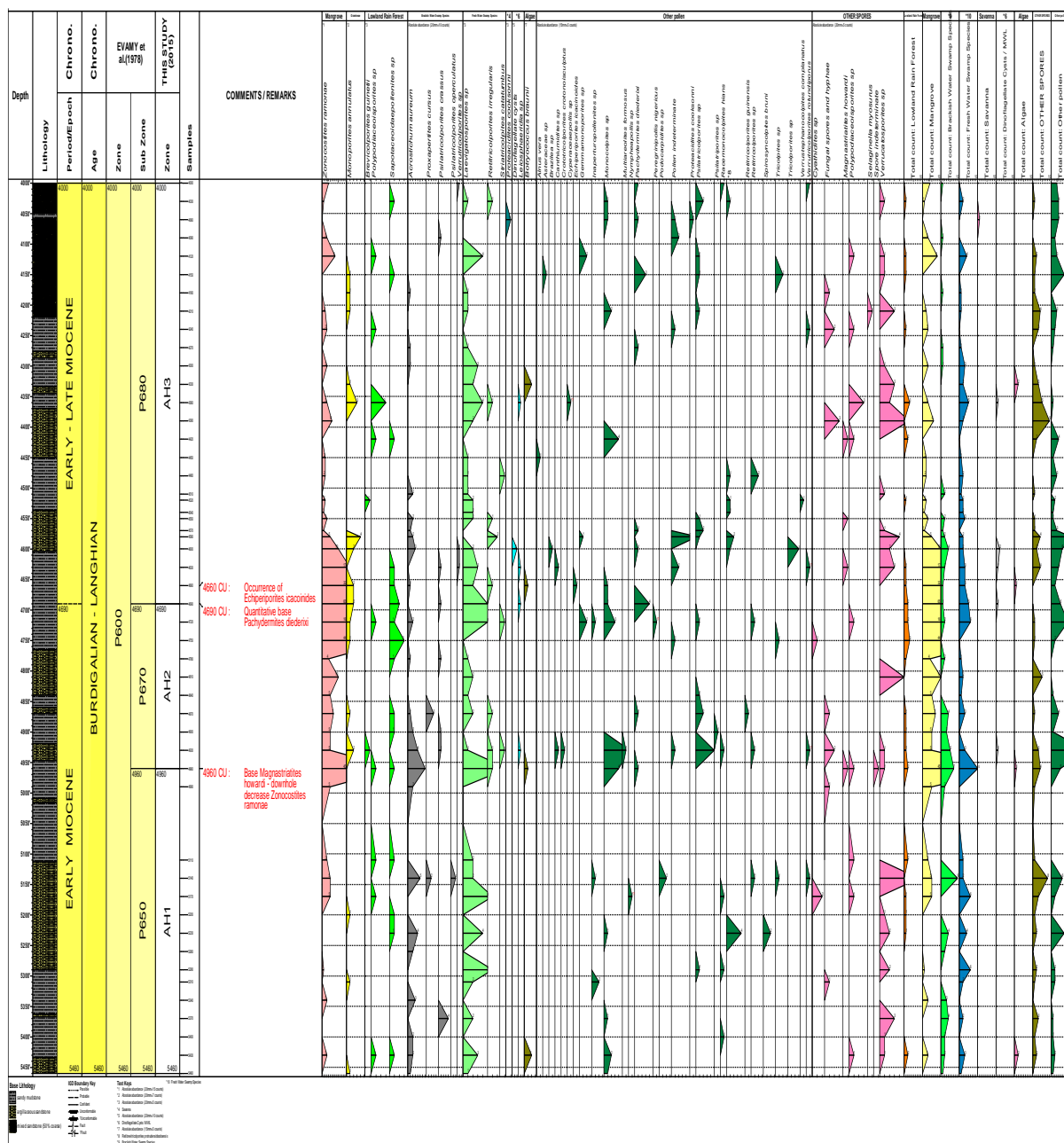


Figure 4: Palynomorph Distribution Chart

Table 3: Biozonation Summary of the Sequence Penetrated by Well-A

DEPTH (FEET)	PERIOD	EPOCH	AGE	GERMERAAD et al.(1968)	EVAMY et al. (1978)		THIS STUDY (2015)	COMMENTS
					ZONE	SUB-ZONE		
4000	TERTIARY (Neogene)	EARLY - LATE MIOCENE	Burdigalian - Langhian	<i>Magnastriatites howardi</i> - <i>Echitricolporites Spinusos</i>	P 600	P680	AH 3 (Pachydermites diederixi zone)	<ul style="list-style-type: none"> Occurrence of <i>Echiperiporites icacoinides</i> Quantitative base <i>Pachydermites diederixi</i>
4660								
4690		P650				AH 1 (Laevigatosporites Zone)		
4960								
5450TD		EARLY - MIOCENE						

PALAEOENVIRONMENT OF WELL A

Climatic factors have a different influence on the rainforest and savanna (hinterland) taxa and less directly on the mangroves and freshwater swamp taxa. Basically, the mangrove and the freshwater forest taxa are more directly influenced by sea-level fluctuation. Variations in vegetation are usually a direct reflection of humidity changes. The main criteria employed for environmental interpretation were: Marker species such as *Magnastriatites howardi* (a small aquatic fern of alluvial plain and coastal swamps), *Pachydermites diederixi* (an angiosperm of coastal marshes), and *Zonocostites ramonae* (mangrove pollen). *Z. ramonae* is a distinctive pollen type found in extant genera of mangroves, notably *Rhizophora* (Germeraad et al.,

1968) and *Monoporites annulatus* (Gramineae pollen suggesting open vegetation found in savannah).

Given the palynomorph zones of this study (*Pachydermites diederixi* zone, *Zonocostites ramonae* zone and the *Laevigatosporites* zone), the paleoclimatic zones of Well A was based on the palynofloral assemblages identified, which were shown to be moderately rich, and well preserved since the time of deposition. This assemblage indicates a marine environment of deposition because of the high amount of mangrove and brackish water swamp species, with the occurrence of fresh water and little presence of pollen grain from the savanna. The well section is characterized by countless spores and pollen, including *Zonocostites Ramonae*, *Monoporites*

annulatus, *Pachydermites diederixi*, *sapotaceoidacpollenites* sp, *Verrucatosporites* sp. *Monocolpites* sp., *Acrostichum aureum*, *Laevigastoporites* sp., *Pollen indeterminate*, *polypodiace oisporites*, *funga spores*, and *hyphae* with a slight appearance of *Dinoflagellate cyst (Botryococcus braunii)*. The pollen and spores assemblage as mentioned above suggests a marine palaeoenvironment, with an influence of freshwater because of the presence of *Botryococcus braunii*.

CONCLUSION

Palynological analysis of Well-A contributed to the stratigraphic description of the studied section. Well-A was characterized by fifty-two palynomorph species, with spores, pollen, dinocysts, algae cysts and fungal spores were identified. A combination of spores and pollen is the basis for dating the section as Early to Late Miocene. Three palynological zonation were proposed; *Pachydermites diederixi*, *Zonocostites ramonae*, and *Laevigastoporites* sp. zones based on schemes by Evamy *et al.* (1978) and Germeraad *et al.* (1968). Based on the palynofloral assemblages and richness, the well interval was inferred to have sediments of coastal deltaic to marine environment of deposition.

REFERENCES

- Ajaegwu, N.E., Odoh, B.I., Akpunomu, E.O., Obiadi, I.I. and Anakwub, E.K. (2012). Late Miocene to Early Pliocene Palynostratigraphy and Palaeoenvironments of ANE-1 well, Eastern Niger Delta, Nigeria. *Journal of Mining and Geology*, 48(1): 31-43.
- Corredor, F., John, H.S. and Frank, B. (2005). Structural Styles in the deep-water fold and thrust belts of the Niger Delta: *American Association of Petroleum Geologists Bulletin*, 89 (6): 753 – 780.
- Doust, H. and Omatsola, E. (1990), Niger Delta, in J.D. Edwards and P.A. Santogrossi, eds., *Divergent/Passive margin basins: American Association of Petroleum Geologists Memoir* 48: 201: 236.
- Evamy, B.D., Haremboure, J., Karmerling, P., Knaap, W.A., Molloy, F.A. and Rowlands, P.H. (1978). Hydrocarbon habitat of Tertiary Niger Delta. *American Association of Petroleum Geologists Bulletin, United States of America*, 62 (1): 1-39.
- Germeraad, J. H.; Hopping, C.A. and Muller, J. (1968). Palynology of tertiary sediments from Tropical Areas. *Review Paleobotany Palynology*, 6 (34): 189-348.
- Inyang, D.O. (2016). Palynological analysis of T-well located south-western Niger Delta, the implication in Age and Palaeoenvironment. *Journal of Geography, Environment and Earth Science International*. 8(3); 1-9.
- Okosun, E.A., Chukwu, J.N., Ajayi, E.G. and Olatunji, O.A. (2012). Biostratigraphy, Depositional Environment and Sequence Stratigraphy of Akata Field (Akata 2, 4, 6 and 7 Wells), Eastern Niger Delta, Nigeria. *International Journal of Scientific and Engineering Research*, 3 (7): 1 – 27.
- Reijers, T.J.A., Petters, S.W. and Nwajide, C.S. (1996). The Niger Delta Basin, in: T.J.A. Reijers (ed.), *Selected Chapters on Geology: SPDC corporate reprographic services*, Warri, Nigeria, pp. 103-114.
- Shannon, P. M. and Naylor N. (1989). *Petroleum Basin Studies: London, Graham and Trotman Limited: 153-169*
- Short, A.J. and Stauble, K.L. (1967). Outline of the Geology of the Niger Delta. *American Association of Petroleum Geologists Memoir*, 51: 761-779.
- Whiteman, A. (1982). *Nigeria: its petroleum geology, resources and potential: Graham & Trotman Ltd., vol. 1, pp. 114-131.*