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PALYNOLOGICAL ZONATION AND PALEOCLIMATIC CONDITION OF THE SEDIMENTS PENETRATED BY ASH-3 WELL IN THE GREATER UGHELLI DEPOBELT, NIGER DELTA BASIN

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ABSTRACT

Palynological zonation and paleoclimatic condition of the sediments penetrated by Ash-3 Well in the Greater Ughelli Depobelt, Niger Delta was carried out in order to determine the palynological biozonation, age and the paleoclimatic condition the sediments were formed. The palynological analysis was carried out on seventy (70) ditch cutting samples at different intervals between 15ft to 11,430ft which allowed the recovery of one thousand, three hundred and twelve (1312) palynomorphs that includes one thousand, one hundred and fifty (1150) miospores, eleven (11) dinocysts and one hundred and fifty one (151) ancillary microfossils. Five (5) palynological zones were established using palynological characteristic of the age diagnostic index markers. The palynological zones established were the lumped P650-P670, lumped P620-P630, P580, P560 and P540 Zones. The age of the sediments penetrated by the well using the age diagnostic markers range from Oligocene to Early Miocene epoch. Based on the dominance of Zonocostites ramonae over Monoporites annnulatus, it showed that the sediments were deposited in a predominantly humid climate, cooler and wetter climatic condition.

Keywords: *biozonation, depobelt, paleoclimatic, Agbada, diagnostic index markers*

INTRODUCTION

The Niger Delta is one of the major hydrocarbon producing basins in Africa. The basin petroleum system is known as Tertiary Akata-Agbada Petroleum System (Doust and Omatsola, 1990; Ekweozor and Daukoru, 1994; Kulke, 1995). The today Niger Delta covers an estimated area of about 140, 000 kilometer square. It has regressed southwestward to the Gulf of Guinea giving rise to different depobelts. It consists of Tertiary sediments that are up to 12, 000 meters of maximum thickness at its center (Doust and Omastola, 1990).

Palynology as a tool of biostratigraphy has to do with the study of pollen grains, spores and dinocysts as well as other palynomorphs that are found in geological deposits. The integration of lithofacies and palynology as a tool in evaluating sedimentary succession penetrated by a drill in any sedimentary basin has become increasingly important in recent times as seen in work by Germeraad et al. (1968), Oloto (1992), Helenes et al. (1998), Chiaghanam et al. (2013) and Lucas (2017).

Most oil companies have their own zonation scheme and a standard scheme is needed in order to understand the complex stratigraphic architecture of the Ughelli Depobelt. The oil and gas are usually

located in zones of complex stratigraphic and structural complexities. Ajaegwu (2012) stated that an excellent biostratigraphic framework is crucial for understanding the stratigraphy, characterization of the reservoirs and planning new exploration targets. Osokpor et al. (2015) cited that palynology has been proven to be an important tool for the exploration of oil and gas in the Niger Delta. Pollen, spores, dinocysts as well as ancillary microfossils have been used for palynological zonation and paleoclimatic reconstruction of the studied well section. The aim of this study is to determine the palynological zones, age and the paleoclimatic condition the sediments of the penetrated well was formed.

The study area is located in the Greater Ughelli Depobelt. The well is geographically located between latitude $5^{O}30N$ and longitude $5^{O}45E$ (Figure 1).

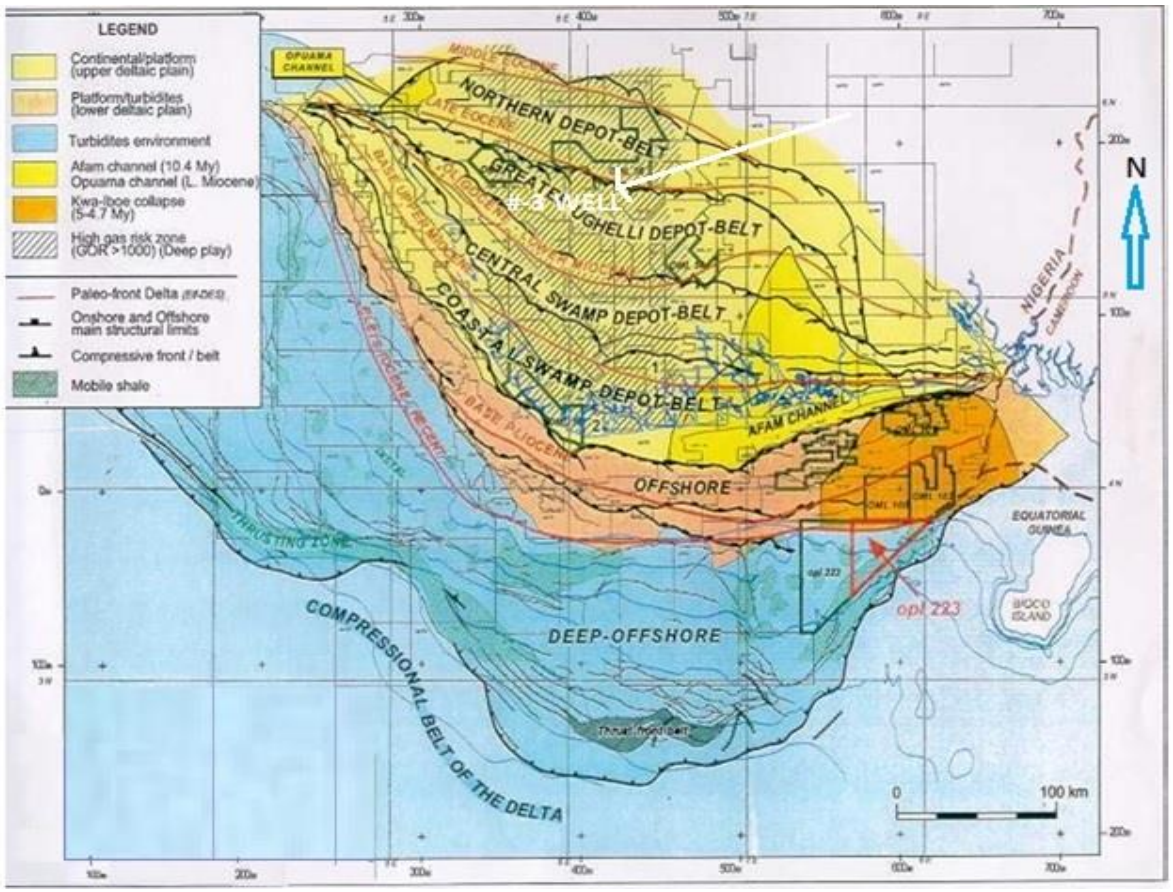

Figure 1: Location map of Study Area (Doust and Omatsola, 1990)

Geology of the Study Area

Short and Stauble (1969) outline the Niger Delta general geology. They gave a detailed write up on the origin of the Niger Delta. They established that the Tertiary deltaic sediments comprises of an upward-coarsening regressive association of deposits that are strongly diachronous (Eocene to Recent). The sediments in the Niger Delta are divided into Marine Akata, Paralic Agbada and Continental Benin Formations (Table 1).

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Table 1: Age and Formations of the Niger Delta Sedimentary Basin (Short and Stauble, 1967).

SUBSURFACE			SURFACE OUTCROPS		
YOUNGEST KNOWN AGE		OLDEST KNOWN AGE	YOUNGEST KNOWN AGE		OLDEST KNOWN AGE
RECENT	BENIN FORMATION Afam Shale Memb.	OLIGOCENE	HOLOCENE E. HOLOC. TO L. PLEISTOCENE PLIO/PLEIST.	ALLUVIUM DELTAIC PLAIN DEPOSITS BENIN FM.	MIOCENE?
RECENT	AGBADA FORMATION	EOCENE	MIOCENE EOCENE	OGWASHI - ASABA FM. AMEKI FM.	OLIGOCENE EOCENE
RECENT	AKATA FORMATION	EOCENE	L. EOCENE	IMO SHALE	PALEOCENE
			PALEOCENE	NSUKKA FM.	MAESTRICH.
			MAESTRICH.	AJALI FM.	MAESTRICH.
EQUIVLENTS NOT KNOWN			CAMPANIAN	MAMU FM.	CAMPANIAN
			CAM./MAE.	NKPORO SHALE	SANTONIAN
			CONIACIAN/ SANTONIAN	AGWU SHALE	TURONIAN
			TURONIAN	EZE AKU SHALE	TURONAN
			ALBIAN	ASU RIVER GROUP	ALBIAN

MATERIALS AND METHODS

Seventy (70) ditch cutting samples from Ash-3 Well between the intervals of 15 feet to 11430 feet were taken from the shaly and sandy shale intervals of interest for palynological slides preparation. The following materials were used for palynological slides preparation, they include: Microscope, fume cupboard, slides, sieves, brushes, centrifuge machine, digital camera, hot plates, photo album of palynomorphs and chemicals (Hydrogen peroxide, HCL, HF, HNO_3, Canada balsam)

Palynological Slides Preparation: 20 g of ditch cutting samples were poured into a beaker and decarbonization was achieved by adding about 36% hydrochloric acid (HCL) and was allowed to stand for about 30 minutes. The Hydrochloric acid used was decanted and the beakers were filled with distilled water. The samples were allowed to settle and decanted. This process was repeated three times.

Enough hydrofluoric acid (HF) was added to cover the samples and left overnight, then filled with distilled water, allowed to settle and was decanted. This process was repeated three times to remove the HF completely, because the HF and silicates give gels which can hinder the production of quality palynological slides.

Concentrated nitric acid (HNO_3) was added to half of the residue and left for about 10 minutes, filled up with water and then centrifuge at 2000 RPM for three minutes,

then decanted. This process was repeated until the residue was clear thereby facilitating the identification of palynomorphs. It was then poured into a glass beaker and sieved with 5 micron nylon sieve using digital sonifier machine to concentrate the organic residue and to retain as much palynomorphs as possible.

Potassium hydroxide alkaline solution was added to neutralize the nitric acid. Potassium hydroxide solution washes the sample clean by removing and dissolving unwanted particles such as plant roots and debris. A little residue was pipette out into another 100 ml beaker and two pellets of potassium hydroxide was added to the residue in water bath and watched. When residue goes brownish to dark brown, distilled water was used to fill it up. Centrifuge was allowed before decanting. This process was repeated until the liquid was clear. It was then sieved through the desired sieve mesh with the aid of sonifier machine.

The separation of the organic matter from the inorganic matter was done by the addition of zinc bromide solution to the samples. The sample residue was transferred into a test tube and a little zinc bromide solution was added, stirred and then filled up with approximately 25 ml of zinc bromide up to three quarter full. Centrifuge at 2000 RPM for ten minutes, the organic matter floated to the surface and it was removed using a pipette.

The residues were spotted with pipette on cover slip, left to dry and were then mounted on glass slides using loctite as adhesive mounting medium. The slides were then labeled for palynological studies after cleaning with acetone. Palynological slides were examined using a transmitted light microscope (olympus binocular microscope) and photomicrograph of the palynomorphs were taken with the aid of a digital camera.

RESULTS

Detailed analysis of the prepared palynological slides resulted to the quantitative count of the recovered pollen and spores, dinocysts, ancillary microfossils of which consist of foraminifera test linings, fungal spores, pediastrums and botrycoccus.

Quantitative Counts: Analysis of the prepared palynological slides resulted to the recovery of one thousand three hundred and twelve (1312) palynomorphs, of which one thousand one hundred and fifty (1150) were miospores (pollen and spores) and eleven (11) dinocysts. The ancillary microfossils recovered were one hundred and fifty one (151) which consist of twenty three (23) Foraminifera test linings, one hundred and twenty four (124) fungal spores, two (2) pediastrums and two (2) Botrycoccus (Table 2). Photomicrographs of some of the recovered miospores are shown in Plate 1.

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Table 2: Palynomorphs Abundance for Ash-3 Well

Depth (ft)	Pollen	Spores	Miospores	Dinocyst	Total	Pediastrium	Foram lining	Fungal sp.	Botrycocccus
6030	5	2	2		2		2	5	
6225	3	4	7		7		3	3	
6795	3	5	8		8			2	
7005	2	2	4		4			4	
7140	10	11	29		29		1	1	
8100	5	2	7		7		1		
8280	9	9	18		18			1	
8535	13	15	28		28		1	1	
8610	16	7	23		23			1	1
8955	6	5	11		11			5	
9285	10	8	18		18			6	
9585	27	11	38		38			5	
9660	14	9	23		23		1	4	
9675	4	13	17		17		1	4	
9690	5	6	11		11			4	
9705	8	27	35		35		1	2	
9735	10	6	16	1	17		1	4	
9765	16	12	28	3	31			3	
9810	1	7	8		8		4		
9825	6	13	19		19			4	
9885	2	10	12		12			4	
9900	4	3	7		7			2	
9915	1	3	4		4		1	2	
9930	7	4	11		11			1	
9945	13	3	16		16			1	
9960	17	10	27	1	28			3	1
9975	5	6	11		11			4	
9990	5	3	8		8			1	
10005	7	13	20		20			6	
10020	8	11	19		19				
10035	8	6	14		14			2	
10050	9	13	22		22			4	
10065	4	7	11		11				
10095	11	13	24		24			4	
10125	2	6	8		8			1	
10140	1	8	9	1	10		1	1	
10155	3	24	27		27			3	
10260	7	21	28		28				
10275	12	13	25		25				
10290	4	2	6		6				
10305	0	1	1		1			1	
10515	2	6	8		8				
10530	6	2	8		8				
10545	4	2	6		6			1	
10560	31	16	47		47	1			
10575	11	19	30		30				
10590	16	24	30		30				
10620	4	10	14		14			1	
10635	5	2	7		7				
10665	1	4	5		5				
10680	13	25	35		35		1		
10695	12	37	49	1	50				
10755	6	5	11		11				
10770	3	5	8		8		1		
10785	4	5	9		9				
10800	5	5	10		10		1	1	
10815	7	6	13		13			2	
10860	4	8	12		12	1			
10875	6	5	11	1	12				
10890	2	0	2		2				
10905	13	9	22		22			2	
10920	22	11	33		33			4	
10935	13	21	34	2	36	1	1	3	
10950	7	6	13		13		1	1	
10965	2	6	8		8			2	
10980	7	4	11		11				
11010	11	2	13		13			3	
11115	19	9	28		28			4	
11265	2	0	2		2				
11280	6	1	7		7			1	
	450	700	1150	11	1161	2	23	124	2

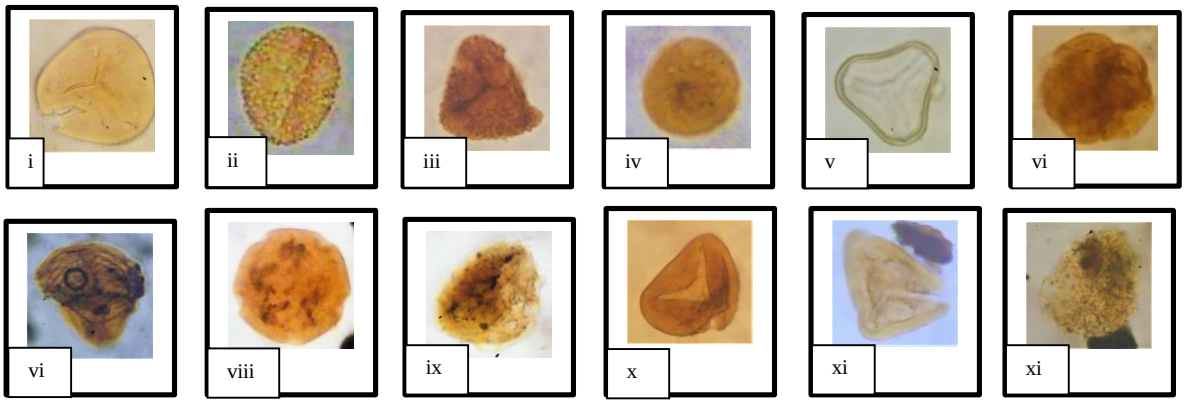

Plate 1:

(i) *Acrostichum aureum,* (ii) *Arecipites exilimuratus*, (iii) *Cicatricosisporites dorogensis,* (iv) *Cinctiporopollis mulleri,* (v) *Elaeis guineenes,* (vi) *Ereciptes sp.*, (vii) *Magnariatites hawardi* (viii) *Pachydermites diederixi,* (ix) *Peregrinipollis nigericus,* (x) *Polypediaceisporites sp. (33),* (xi) *Polypediaceisporites sp (35),* (xii) *Praedapollis flexibilis*

Palynological Zonation and Age for Ash-3 Well

Palynological zonation for Ash-3 Well was achieved by considering the palynological characteristics of the index markers/age diagnostic palynomorphs to indicate palynological zones. The age of the well was deduced by juxtaposing these palynological zones with the standard chronostratigraphic chart. The palynological zones and age for the sedimentary succession was straddled with the Niger Delta Chronostratigraphic Chart and the time stratigraphy and microfloral zonation by Boom (1977).

Five (5) palynological zones: P540, P560, P580, lumped P620-P630 and lumped P650-P670 Zones have been established using the palynological characteristics of the index/age diagnostic markers. These characteristics are; base continous *Arecipites exilimuratus*, increase *Retibrevitricolporites obodoensis/protrudens*, quantitative base *Peregrinopollis nigericus, top Cicatricosisporites dorogensis*, increase *Praedapollis flexibilis* and quantitative base of *Pachydermites diederixi* (Table 3).

Stratigraphic Interval: 11265ft – 10785ft

Zone: P540

Age: Early Oligocene

The top of this zone is characterized by increase in *Retibrevitricolporites obodoensis* and the base is characterized by the base continous of *Arecipites exilimuratus*. This zone is characterized by common occurrence of *Peregrinipollis nigericus*. There is low occurrence of *Pachydermites diederixi* and *Dictyphyllidites harassi* in this zone.

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Stratigraphic Interval: 10785ft – 10275ft

Zone: P560

Age: Mid-Oligocene

The top of this zone is marked by the quantitative base of *Peregrinipollis flexibilis* and the base by increase in *Retibrevitricolporites protrudens/obodoensis.* Other characteristics found within this zone are abundance of *Verrucatosporites usmensis, Pachydermites diederixi, Psilatricolporites crassus* and *Acrostichum aureum*; common occurrence of *Dictyphyllidites harassi* and *Cicatricosisporites dorogensis*; rare occurrence of *Gemmamonoporites sp.* and *Polypediaceisporites sp*.

Stratigraphic Interval: 10275ft – 10095ft

Zone: P580

Age: Late Oligocene

The top of this zone is characterized by top of *Cicatricosisporites dorogensis* and the base by quantitative base of *Peregrinipollis nigericus*. There is increase in *Verrucatosporites usmensis,* abundance of *Laevigatosporites haarditii*. There is rare occurrence of *Pachydermites diederixi, Psilatricolporites crassus* and *Verrucatosporites sp.* There is common occurrence of *Polypediaceisporites sp*. and *Acrostichum auruem*. Also characterized this zone is low occurrence of *Dictyphyllidities harassi, Deltoidspora minor* and *Retibreitricolporites protudensis.*

Stratigraphic Interval: 10095ft - 9825ft

P620-P630

Age: Early Miocene

The top of this zone is marked by increase in *Praedapollis flexibilis* and the base is marked by top of *Cicatricosisporites dorogensis*. There is common occurrence of *Verrucatosporites usmensis, Zonocostites ramonae* and *Acrostichum aureum.* Also within this zone is abundance of *Laevigatosporites haartidii*, rare occurrence of *Verrucatosporites tenellis* and *Filtrotriletes nigericus*.

Stratigraphic Interval: 9825ft – 9585ft

Zone: P650-P670

Age: Early Miocene

The top of this zone is marked by quantitative base of *Pachydermites diederixi* and the base by increase in *Praedapollis flexibilis.* Within this zone there is abundance of *Laevigatosporites haarrditii*; common occurrence of *Verrucatosporites usmensis* and *Acrostichum aureum*; rare occurrence of *Stramonocolpites rectostriatus, Retibrevitricolporites obodoensis* and *Gemmatriporites sp*. and low occurrence of *Zonocostite ramonae.*

Table 3: The Palynological Zones and Age for Ash-3 Well

Depth(ft.)	Retibre. abodoensis	P. diederixi	Gemmotriporites sp.	C. vanvaadshooveni	Retibre. protudensis	Peregl. nigericus	A. eximiuratus	Prae. flexibilis	Magna. howardi	Cicatri. dorogensis	Racemo. hians	P-Zone	Palynological characteristics	Age
6030	2	1												
6225														
6795														
7005														
7140		4												
8100		1	1											
8280	1			1	1									
8535		2												
8610		5			2	1	2							
8955							1	1						
9285		1						3						
9585		8		1	1							680?	Qb 317 (9585)	
9660		4					3							
9675		1										P650 - P670		
9690		1		1										
9705		6												
9735		4						2						
9765	1	1	2	2		1		1						
9810								1						
9825	1							2					Increase 420 (9825 ft)	
9885														
9900														
9915							1							
9930														
9945	1				1		2	2						
9960	1	5												
9975		2												
9990				1			2	1						
10005	3													
10020		1					1		1					
10035		1												
10050		1		1			1							
10065		1												
10095		3								2			Top 30 (10095)	
10125		1												
10140												P580		
10155					1	1				2				
10260	1				1	2	1			2	1			
10275	2	1				3	2	1			2		Qb 399 (10275 ft)	
10290						1	1				1			
10305						1	1							
10515														
10530		2					2			1	1			
10545	1	1			1									
10560		5					5			2	3			
10575		5												
10590		6								2				
10620										2				
10635														
10665							1							
10680		3												
10695		1						1		1				
10755	1					1								
10770	2													
10785	3	1											Increase 178 (10785 ft)	
10800	1							1						
10815	3													
10860	1					2		1						
10875				1		1		4						
10890														
10905	1		2			2								
10920							1				1			
10935		3				1	3		1					
10950														
10965														
10980		2							1					
11010	1	2					1							
11115	1	1				1	1							
11265							3				1		Bc 280 (11265 ft)	
11280	2													

P650 - P670

P620 - P630

P560

P540

EARLY MIOCENE

EARLY TO LATE OLIGOCENE

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Paleoclimatic Condition for Ash- 3 Well: The paleoclimatic condition of the studied intervals for Ash-3 well was achieved based on the pollen and spores recovery which offered clue to the paleoclimatic interpretation. The number of individual species against depth is shown in Table 4. The paleoclimatic condition across the sediments of the well was determined by comparing the plot of mangrove swamp pollen (*Zonocostites ramonae*) to graminae pollen (*Monoporites annulatus*) (Figure 2).

Table 4: Number of individual species against depth for Ash-3 Well

Depth (ft)	*Zonocostites Ramonane*	*Monoporites Annulatus*
6030	1	0
6225	0	1
6795	0	0
7005	0	0
7140	1	1
8100	1	0
8280	0	0
8535	1	0
8610	0	0
8955	0	0
9285	0	0
9585	1	0
9660	0	0
9675	0	0
9690	2	0
9705	0	0
9735	0	0
9765	0	0
9810	0	0
9825	0	0
9885	0	0
9900	0	0
9915	0	0
9930	0	0
9945	0	0
9960	0	0
9975	0	0
9990	0	0
10005	0	0
10020	0	0
10035	0	0
10050	0	0
10065	1	0
10095	0	0
10125	3	0
10140	0	0
10155	0	0
10260	0	0
10275	1	0
10290	0	0
10305	0	0
10515	0	0
10530	0	0
10545	0	0
10560	0	0
10575	0	0
10590	0	0
10620	1	0
10635	4	0
10665	0	0
10680	0	0
10695	1	0
10755	0	0
10770	0	0
10785	0	0
10800	0	0
10815	0	0
10860	0	0
10875	0	0
10890	0	0
10905	0	0
10920	0	0
10935	0	0
10950	0	0
10965	0	0
10980	0	0
11010	0	0
11115	2	0
11265	0	0
11280	3	0

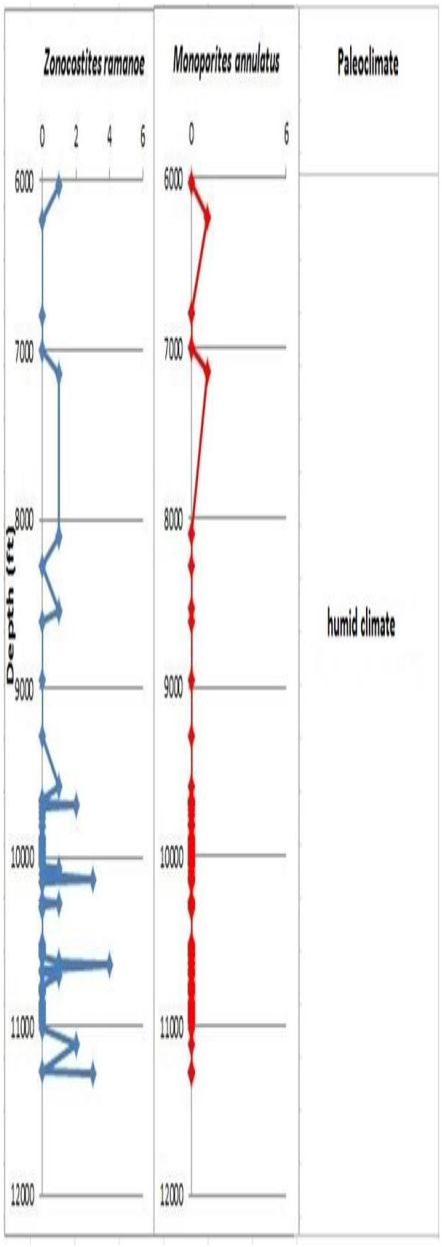

Figure 2: Paleoclimatic indicator plot of the amount *Zonocostites ramonae* and *Monoporites annulatus* for Ash-3 Well.

DISCUSSION

Palynological analysis of the studied samples was used to determine the palynological zonation, age and paleoclimatic condition of the sediments penetrated by the drill. Five (5) palynological zones: P540, P560, P580, lumped P620-P630 and lumped P650-P670 Zones have been established using the palynological characteristics of the index/age diagnostic markers and the age of the well ranges from Oligocene to Early Miocene.

The P540 Zone has age of Early Oligocene and the top of this zone was characterized by increase in *Retibrevitricolporites obodoensis* and the base was characterized by the base continuous of *Arecipites exilimuratus*. The P560 Zone has age of Mid-Oligocene and the top of this zone was marked by the quantitative base of *Peregrinipollis flexibilis* and the base by increase in *Retibrevitricolporites protrudens/obodoensis.* The P580 Zone has age of Late Oligocene and the top of this zone is characterized by top of *Cicatricosisporites dorogensis* and the base by quantitative base of *Peregrinipollis nigericus*. The lumped P620-P630 Zone has age of Early Miocene and the top of this zone was marked by increase in *Praedapollis flexibilis* and the base is marked by top of *Cicatricosisporites dorogensis.* The lumped P650-P670 Zone has age of Early Miocene and the top of this zone is marked by quantitative base of *Pachydermites diederixi* and the base by increase in *Praedapollis flexibilis.*

The Ash-3 Well was formed in predominantly humid climate and the sediments were deposited during a cooler and wetter condition. *Zonocostites ramonae* is an indicator of humid climate and indicates that the sediments were deposited during a cooler and wetter condition, while *Monoporites annulatus* is a warm climatic indicator (Hooghiemstra et al., 1986). The total count of *Zonocostites ramonae* is generally higher than that of *Monoporites annulatus* suggesting a predominantly humid climate for the well and the sediment were deposited during a cooler and wetter condition.

REFERENCES

Ajaegwu, N.E., Odoh, B.I., Akpunonu, E.O., Obiadi I.I. and Anakwuba, 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.

Boom J.K.W. (1977). A Review of the Microfloral Zonation in the Tertiary of Nigeria. *Mosunmolu limited.* pp. 1-22.

Chiaghanam, O. I., Nwozor, KK., Chiadikobi, KC., Omoboriowo, AO., Soronnadi-Ononiwu, C G., Onuba, LN., Ofoma, AE (2013). Lithofacies, Palynology and Paleoenvironmental Study of Early Campanian to Mid-Maastrichtian Deposits of Udi and Environs. *Int. Journ. of Sci. and Tech*, 2 (14-16).

Doust, H. and Omatsola, E. (1989). Niger Delta. *America Association of Petroleum Geologist Bulletin*, 48: 201-238.

Doust, H. E. and Omatsola, E. M. (1990). Niger Delta. In: Edwards J. D. and Santagrossi, P. A (eds), Divergent/Passive Basins. *AAPG. Bull.* Mem. 45. Tulsa Okhlahoma, pp. 201-238.

Ekweozor, C. M., and Daukoru, E. M. (1994). Northern delta depobelt portion of the Akata-Agbada(!) petroleum system, Niger Delta, Nigeria, in, Magoon, L.B., and Dow, W.G., eds., The Petroleum System--From Source to Trap, AAPG Memoir

Scientia Africana, Vol. 19 (No. 1), April, 2020. Pp 37-48
© Faculty of Science, University of Port Harcourt, Printed in Nigeria *ISSN 1118 – 1931*

60: Tulsa, *American Association of Petroleum Geologists*, 599-614.

Gemeraad, J. H., Hopping, G.A and Muller J. (1968). Palynology of Tertiary sediments from Tropical Areas Rev. PaleobotPalynol., 6, pp. 189-348.

Helenes, J. De Guerra, C. and Vasquez, J. (1998). Palynology and chronostratigraphy of the upper Cretaceous in the subsurface of the Barnas area Western Venezuela, *American Association of Petroleum Geologists Bulletin,* 82: 1308-1328.

Hooghiemstra, H., Agwu, C.O.C. and Beug, H.J. (1986) Pollen and Spore Distribution in Recent Marine Sediments: A Record of NW-African Seasonal Wind Patterns and Vegetation Belts, Meteor Forschungsergebnisse, Deutsche Forschungsgemeinscaft, Reihe C Geologie und Geophysik, GebruderBorntrager, Berlin, Sttugart, C40, 87-135.

Kulke, H. (1995). Nigeria, in, Kulke, H., ed., Regional Petroleum Geology of the World. Part II: Africa, America, Australia and Antarctica: Berlin, Gebrüder Borntraeger, pp. 143-172.

Lucas, F.A. (2017). Miospores and Geological Boundaries in Maastrichtian to Lutetian Succession of Ajire-1 well, Anambra Basin, Nigeria. *International Journal of Science and Advanced Innovative Research,* 1: (74- 84).

Oloto I. N. (1992). Succession of palynomorphs from the early Eocene of Gbekebo-1 Well in SW Nigeria. *Journal of Africa Earth Science.* 15 (3/4): 441-452.

Osokpor, J., Lucas F. A., Omawumi, J. O., Brume, O., Izeze O. E. and Oghenero E. A. (2015). Palynozonation and Lithofacies Cycles of Paleogene to Neogene Age Sediments in PML-1 Well, Northern Niger Delta Basin. *The Pacific Journal of Science and Technology*. 12 (2): 286-297.

Short, K. C. and Stauble, A. J. (1967). Outline Geology of Niger Delta: *AAPG Bulletin,* vol. 51, pp.761-779.