

Palynozonation of Akukwa-2 Well, Anambra Basin: Implications for Age and Paleoenvironment

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ABSTRACT

Palynological examination of twenty (20) ditch shale samples from sedimentary succession penetrated by Akukwa-2 Well at depth interval of 3,296 - 3,850 m was undertaken to investigate the occurrence of Palynomorph in the sediments of Anambra Basin with a view to determining the age of the sediments and reconstruct the depositional paleoenvironment. Standard Palynological procedure was followed and the samples were processed using the conventional acid maceration, alkali treatment and staining methods. The oxidized residues were sieved with 5micron nylon sieves using digital Sonifier 450 machine and mounted on glass slides with Norland adhesive gel. Laborlux 12 (Ernst Leitz) transmitting light microscope was used for identification and counting of the palynomorphs. The palynological analysis was done using the population and species of pollen grains, spores and dinoflagellate. The analyzed palynological slides yielded forty-nine (49) palynomorphs species identify in the ditch samples, forty (40) were Miospores (pollen and spores) and nine were Dynocysts. However, some diagnostic forms that are stratigraphically useful are present and are used for the palynozonation. Delineation of the well section produced three main palynological zones based on stratigraphic distribution. Zone 1 characterized by the quantitative base appearance of *Triorites Africaensis* Assemblage indicating Marginal Marine paleoenvironment and of Turonian age; Zone 2, marked by *Droseridites Senonicus* assemblage also of Marginal Marine but of Coniacian age, Zone 3, marked by *Milfordia* spp. Acme Zone, purely Marine and of Campano- Maastrichtian age. The study further revealed that Palynomorph recovery in Akukwa-2 well was not that impressive both in terms of abundance and preservation. In most cases, the macerals present seems to indicate high geothermal effect suggesting that some of the kerogen might have been overcooked to imply inability to generate hydrocarbon or such generated hydrocarbon have turned into carbon.

Keywords: Anambra Basin, Palynomorphs, Paleoenvironment, Campano- Maastrichtian

INTRODUCTION

In this ever-changing economic and political climate, petroleum explorationists and field development geologists are being asked to find more oil and develop older reserves [1] This increasing search for hydrocarbon has led to the application of improved technologies such as the use of Palynology and Paleo-environmental analyses in locating the required stratigraphic sequences and structures. The use of improved technologies helps in reducing cost of drilling or payback for drilling and production cost [2].

These technologies will assist in better delineation of paleo-environmental reconstruction, chronostratigraphic framework, stratigraphic units and depositional environment. The Benue Trough (Fig. 1) is a unique rift feature on the African Continent in that it occupies an intra-continental position and has a thick compressionally folded Cretaceous supracrustal fill which is generally divided into Lower, Middle and Upper Benue Trough [3, 4, 5, 6, 7, 8, 9, 10].

Palynology was once limited to the study of spores and pollen. However, it has recently been extended to encompass other organic-walled microfossils, collectively termed palynomorphs [1]. The palynological method had been used to determine the Age and Paleo-environment of Gongola Basin [11]. The method was also used on Ubaije-1 well samples to delineate stratigraphy, Age and Paleo- environment of Awgu Shale of Anambra Basin [12]. [13] studied the occurrence of palynomorphs in the sediments of Anambra Basin obtained from Amansiodo-1 well and used the results to arrive at the age and paleoenvironment of the Shale Samples. The aim of this study is to predict the depositional environment, determine the ages of the sediments and chronostratigraphic correlation across the basin. By studying the fossils in many wells, a geologic model for the area can be built up. Such paleogeographic maps, combined with seismic profiles and other geologic data sets, are the tools used in the search for hydrocarbons.

Location of the Study Area

The basin is roughly triangular in shape and covers an area of about 40,000 square kilometers with sediment thickness increasing southwards to a maximum thickness of 12,000m in the central part of Niger Delta. The basin lies between latitudes 5.0°N and 7.0°N and longitudes 7.0°E and 8.0°E.

Anambra Basin is located west of the lower Benue Trough and often considered newest formation from the Benue Trough [14]. The basin is bounded to the south by the Niger Delta Basin hinge line [15]. It extends north-westward into the Niger valley, northward to the Jos massif and north east-ward into Lafia. The eastern and western limits of the basin are defined by Abakaliki Anticlinorium and Ibadan massif, respectively [15]. The well of interest falls between Longitude 7°08'32"E and Latitude 5°54'48"N as shown in Figure 2.

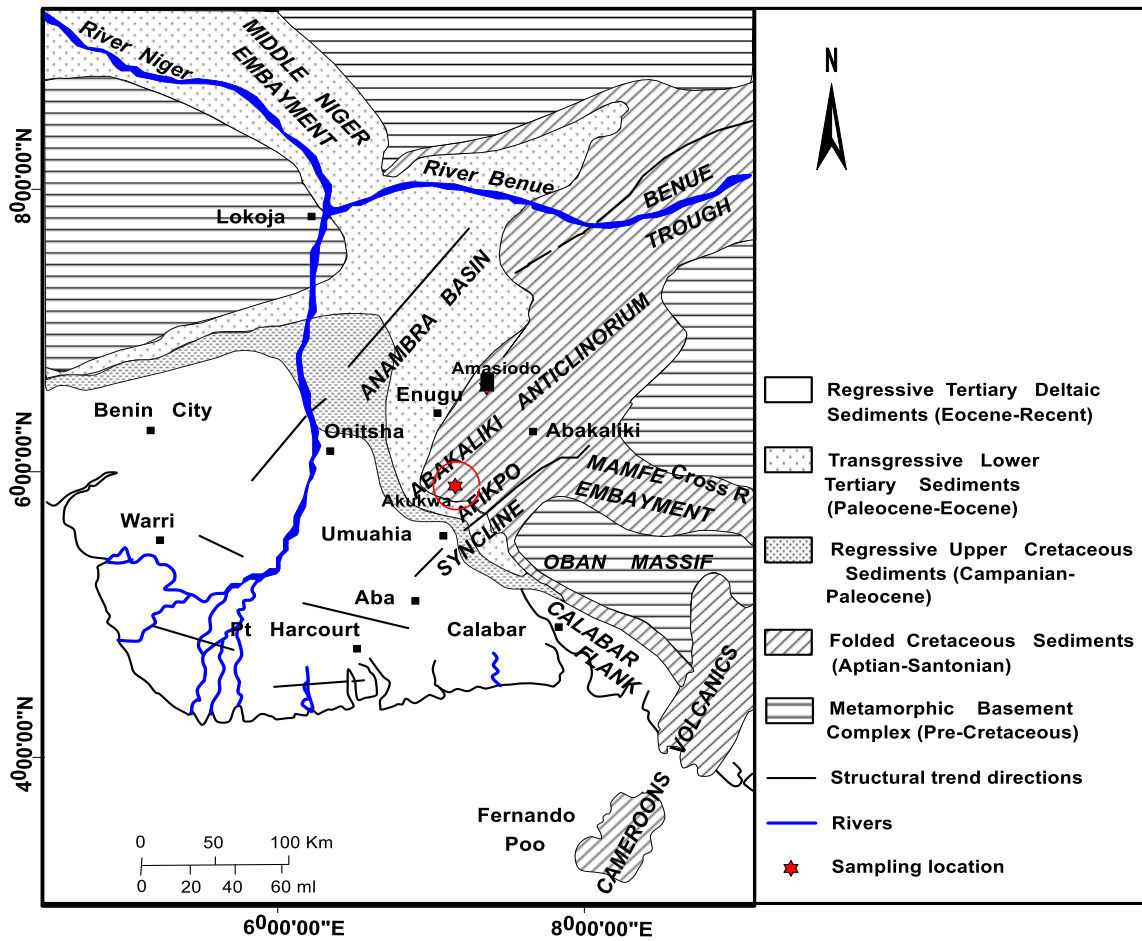


Figure 1: Regional Stratigraphy of the Anambra Basin showing sampling location [16].

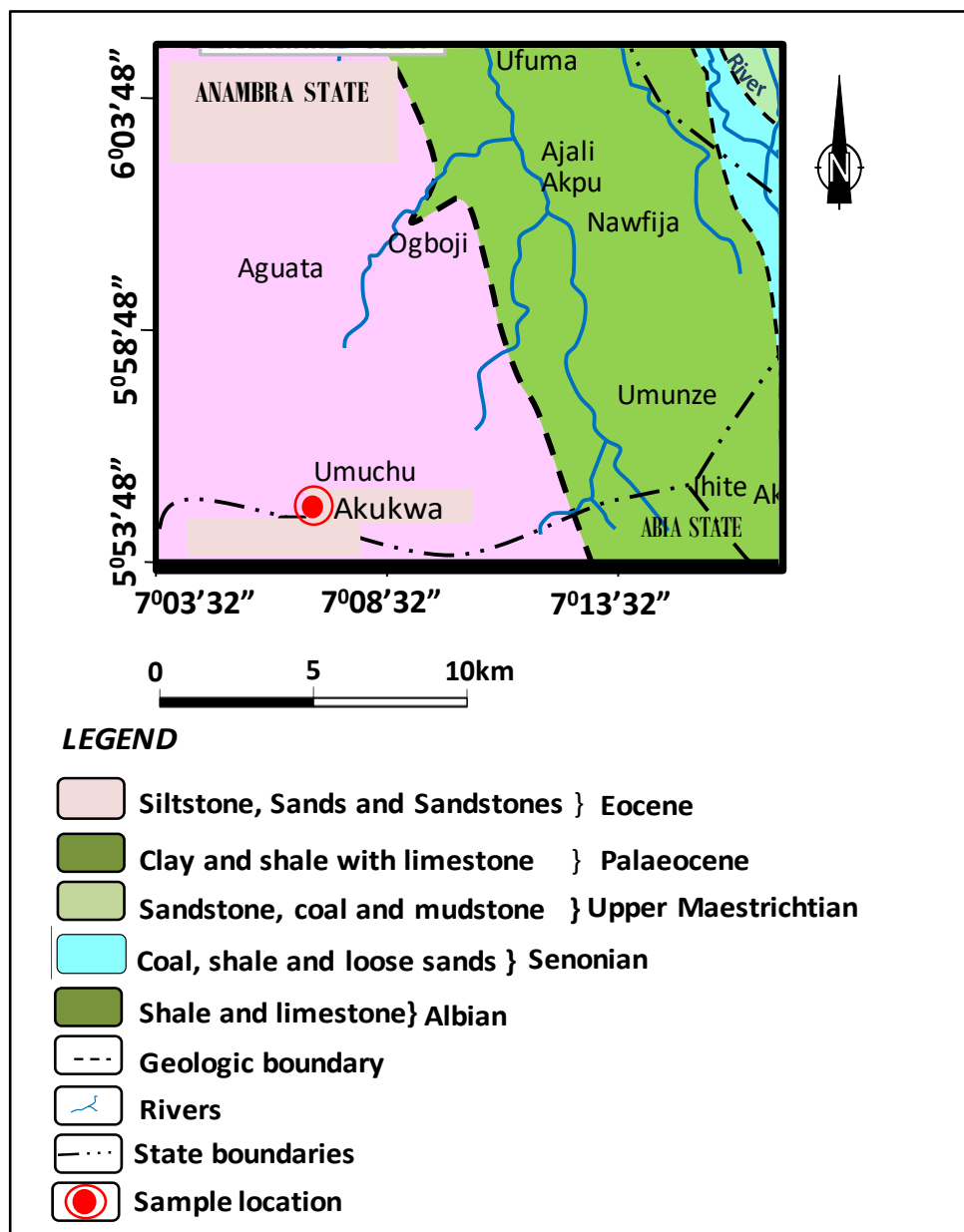


Figure. 2: AKUKWA-2 Well Location, Anambra Basin

MATERIALS AND METHODS

The ditch-cutting samples of Akukwa-2 wells were collected from the Nigerian Geological Survey Agency (NGSA) Kaduna. The detailed stratigraphic description of each sample was made (Table 1). Stratigraphic and lithologic descriptions were provided for Akukwa-2 well, especially those samples that fall within the depth of interest. The standard palynological analysis methods of [17, 18, 19, and 11] were used. The samples were processed using the conventional acid maceration, alkali treatment and staining methods. These help to concentrate and recover the acid insoluble organic microfossils. The oxidized residues were sieved with 5micron nylon sieves using digital Sonifier 450 machine and mounted on glass slides with Norland adhesive gel. Laborlux 12(Ernst Leitz) transmitting light microscope was used for identification and counting of the palynomorphs. The pollen, spores, dinoflagellates, fungal and spores were

determined for each sample in terms of abundance and diversity; and were interpreted by comparison with established works [20]. Photographs of important palynomorphs were taken with Nikon Koolpix P6000 digital camera.

RESULTS AND INTERPRETATION

Palynology

The abundance and diversity of Palynostratigraphy of the well section (Table 2) were interpreted from the palynomorphs marker species that were recovered in the analyzed samples. Palynomorph recovery in Akukwa-2 well is not that impressive both in terms of abundance and diversity (Table 2). In most cases the macerals present seems to indicate high geothermal effect suggesting that some of the kerogen might have been overcooked to imply inability to generate hydrocarbon or such generated hydrocarbon have turned into carbon. The analysis also suggests that probably only samples 3,576 and 3,591m that do not show effect of overheating. The recovery of pollen and spores is moderate to relatively high in upper segment of the interval, while the upper part of the lower segment is poor in Palynomorph abundance and diversity. Some diagnostic forms that are stratigraphically useful are present and are used for the palynozonation.

Table 1: Lithologic description of the studied interval of AKUKWA-2 Well, Anambra Basin

EPOCH	FORMATION	DEPTH (M)	LITHOLOGY	SAMPLE NUMBER	LITHOFACIES UNITS	ENERGY/ ENVIRONMENT
CAMPANO-MAASTRICHTIAN	NKPORO SHALE	3300		AK1	Grayish, silty shale.	Low Energy
		3320		AK2		
		3340		AK3		
		3360		AK4		
		3380		AK5	Dark grayish medium grained shale	High to Medium Energy
		3400		AK6		
		3420		AK7		
		3440		AK8		
		3460		AK9		
		3480		AK10		
		3500		AK11		
		3520		AK12		
		3540		AK13		
		3560		AK14		
		3580		AK15		
		3600		AK16		
		3620		AK17		
		3640		AK18		
		3660		AK19		
		3680			Grayish, fine to medium grained sandy shale. Highly	Low Energy
		3700				
		3720			Brownish medium grained sandstone interbedded with shale	High to Medium Energy
		3740				
		3760				
		3780				
		3800				
		3820				
		3840				
		3860				

Table 2: Abundance and diversity of Palynomorphs groups recorded in AKUKWA-2 well

Depth (m)	Pollen & Spores Diversity	Pollen & Spores Frequency	Dynocysts Diversity	Dynocysts Frequency	Fungi Spore Frequency	B. Braunii Frequency
3297	9	14	0	0	1	0
3314	2	6	0	0	0	3
3346	4	4	0	0	1	8
3369	13	21	0	0	0	9
3412	14	19	1	1	0	8
3474	5	8	0	0	0	7
3481	6	8	0	0	0	6
3514	6	8	1	1	0	2
3543	12	21	2	3	0	6
3558	11	15	2	2	2	8
3576	3	7	0	0	0	4
3591	5	5	0	0	0	2
3619	9	10	1	1	0	7
3647	4	4	1	1	0	3
3689	2	2	0	0	0	1
3704	0	0	1	1	0	0
3766	2	2	1	1	1	1
3793	7	7	2	3	0	3
3809	7	9	2	3	0	8
3850	2	3	2	3	0	0
Total		173		20	5	86

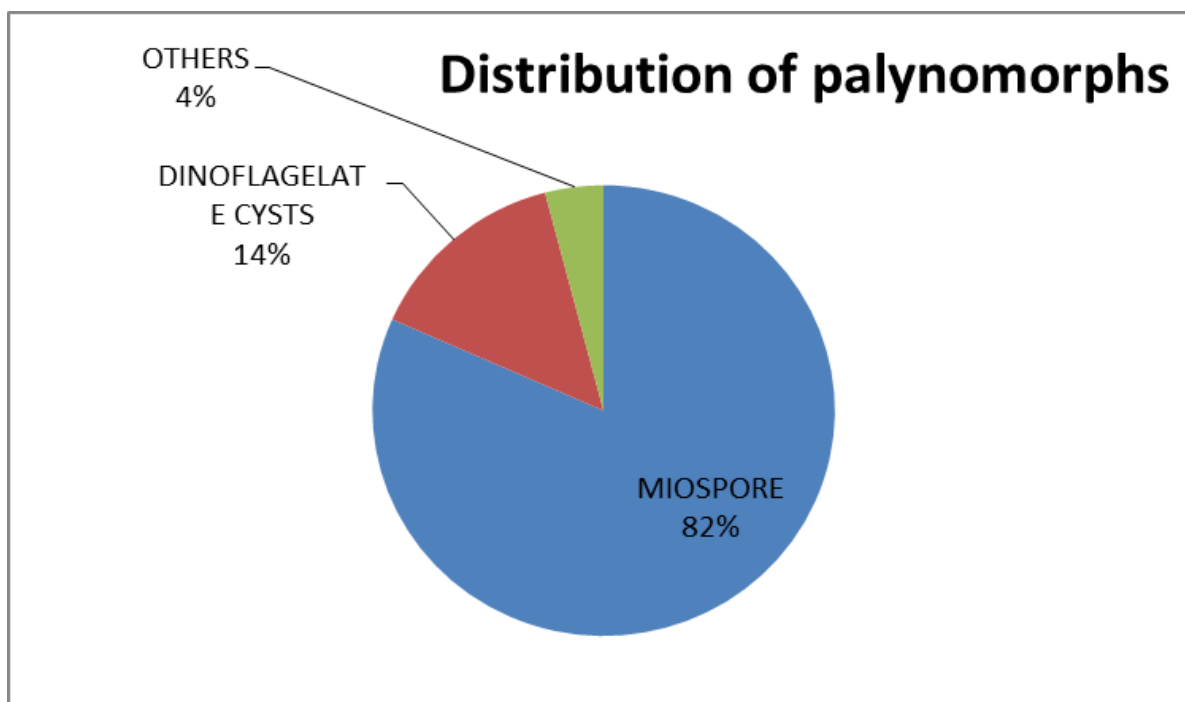


Fig.3: Percentage Distribution of Palynomorphs Recovered

Biozonation and Age Determination**Interval:** 3,766 m - 3,863 m**Zone:** *Triorites africaensis* Assemblage Zone 1**Age:** Turonian

Characteristics: the base of the interval is marked by the appearance of *Triorites africaensis*, *Classopollis* sp, and *Cyathidites* sp. The interval is further characterized by relative moderate palynomorph abundance, *Syncolporites* sp, *Monosulcate pollen* and *Tricolporopollenites* sp. The top of the interval is marked by the top appearance of *Triorites africaensis* and *Inaperturopollenites* sp. Other forms that appear within the interval include *Retimonocolpites* sp., *Zlavisporites blanensis*, *Monocolpites marginatus*, *Ulmoideipites krempii*, trilete spore, *Syncolporites* sp, *Senegalinium* sp., *Andalusiella* sp., *Andalusiella polymorpha* and *Batiacasphaera* sp. Importantly, *Cretacaeioporites* spp which also characterize this zone is absent or better described to have disappeared before reaching the interval analyzed for this study. Its non-appearance in the interval suggests that the interval belongs to the upper part of *Cretacaeioporites* spp. acme zone described by [21] for the Eze Aku Formation in Anambra Basin, Nigeria. The interval also correlates very well with zone 1 described for the Ubiaja-1 well in Anambra Basin, Nigeria [22]. The interval is thus conveniently dated Turonian age; stratigraphically equivalent to Eze-Aku Formation deposited in a marginal marine environment based on the co-occurrence of *Andalusiella* spp. and *Senegalinium* sp.

Interval: 3,689 m - 3,766m**Zone:** *Droseridites senonicus* Assemblage Zone 2**Age:** Coniacian

Characteristics: The base of the zone coincides with the top of the lower and older zone belonging to *Triorites africaensis* assemblage zone. The top of the zone is marked by the first uphole appearance of *Cingulatisporites ornatus*, *Constructipollenites ineffectus*, *Periretisyncolpites magnosagenatus* and *Longapertites* sp. The interval shows paucity of palynomorph while there is no appearance of marker forms that characterize the zone. Therefore, the tentative erection of the zone is based on the stratigraphic position and paucity of palynomorphs. This characteristic feature was reported in Ubiaja 1 well, Anambra Basin, Nigeria [22]. The interval is dated Coniacian age and stratigraphically equivalent to Awgu Shale (Table 1).

Interval: 3,297m - 3,647m**Zone:** *Milfordia* spp. Acme Zone 3**Age:** Campanian

Characteristics: the base of the zone is defined by the appearance of Campanian to Maastrichtian forms such as *Constructipollenites ineffectus*, *Periretisyncolpites magnosagenatus* and *Cingulatisporites ornatus*. The zone is characterized by well development of *Milfordia* sp, *Milfordia jardinei* and *Auriculiidites* spp such as *Auriculidites* sp and *Auriculiidites reticulatus*. The interval is relatively richer in abundance and diversity of palynomorphs than the older zones 1 and 2.

The top of the interval is marked by the appearance of *Echitriporites trianguliformis*, *Longapertites vaneendenburgi*, moderate occurrence of *Auriculiidites sp* and rare occurrence of *Milfordia sp*. The interval shows relatively moderate to high frequencies of *Milfordia spp.*, *Auriculiidites spp.*, and *Syncolporites spp*. Other stratigraphically significant forms present are *Proxapertites cursus*, *Concavissimisporites punctatus*, *Longapertites marginatus*, *Longapertitesmicrofoveolatus*, *Syncolporites reymentii*, *Milfordia jardinei*, *Auriculiidites retulatus*, *Tricolporopolenites sp.*, *Verrucosisporites sp*, *Monosulcites sp*, *Syncolporites marginatus*, *Foveotrilites magaritae*, *Zlivisporites blanensis*, *Periretisyncolpites sp.*, *Retidiporites magdalenensis*, *Syncolporites subtilis*, *Proteacidites spp*, *Buttinia andreevi*, *Monosulcites sp* and *Cyathidites sp*. The palynomorph assemblage of this interval is similar in part to those reported for Campanian to Maastrichtian sediments of Senegal and Cote d' Voire [23], *Longapertites sp 3* for the upper Benue trough, Nigeria [24], for the Nkporo Shale in the Orekpekpe-Imiagba area of Anambra Basin, Nigeria [25], and the Nkporo Formation delineated in the Ubiaja-1 well, Anambra Basin, Nigeria [22].

Therefore, the interval is conveniently dated Campanian age based on the top occurrence of *Echitriporites trianguliformis* reported not to range beyond Campanian age [24] and also based on the continuous quantitative occurrence of *Milfordia spp* and *Auriculiidites spp*. [26]. Thus, the interval is stratigraphically equivalent to Nkporo Shale. The sediments were deposited in deltaic to marginal marine setting based on the absence and presence of dinoflagellate cysts respectively (Table 3).

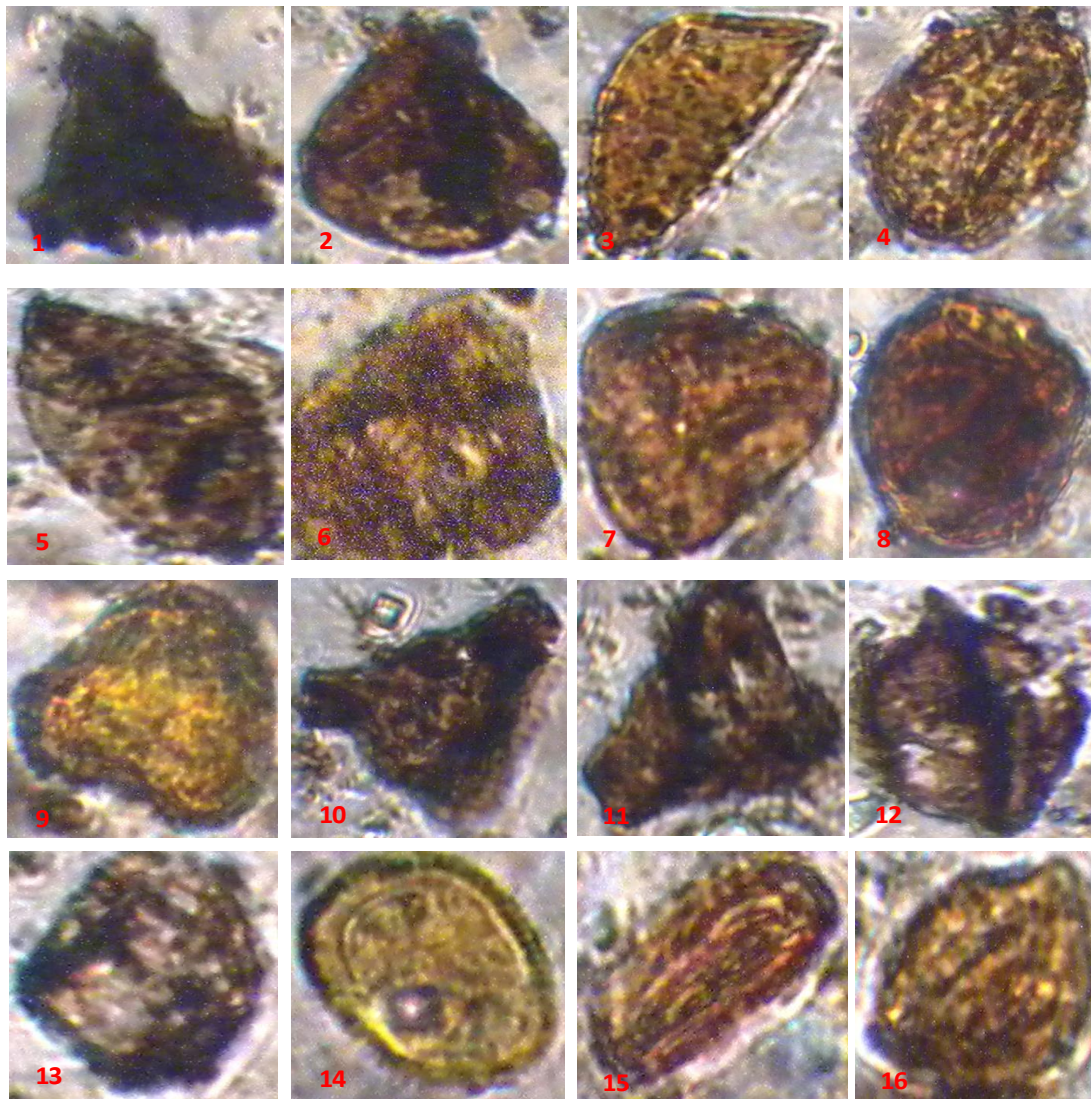


PLATE 1

- 1 *Echitriporites trianguliformis* Van Hoeken-Klinkenberg, 1964
- 2 *Cyathidites* sp
- 3 *Longapertites marginatus* Van Hoeken-Klinkenberg, 1964
- 4 *Tricolpites* sp
- 5 *Monosulcites* sp 1
- 6 *Triorites africaensis* Jardine and Magloire, 1965
- 7 *Cyathidites* sp
- 8 *Stephanocolpites costatus*
- 9 *Syndemicolpites typicus* Van Hoeken-Klinkenberg, 1964
- 10, 11 *Tricolporopollenites* sp. S. 152 in Jardine and Magloire, 1965
- 12 *Auriculiidites* sp Elsik, 1964
- 13 *Senegalinium* sp Lawal, 1982
- 14 *Constructipollenites ineffectus* Van Hoeken-Klinkenberg, 1964
- 15 *Tricolporopollenites* sp in Jardine and Magloire, 1965
- 16 *Senegalinium* sp 5 Lawal, 1982

Figure 4: Photomicrograph of some palynomorphs recovered from Akukwa-2 well, Plate 1.

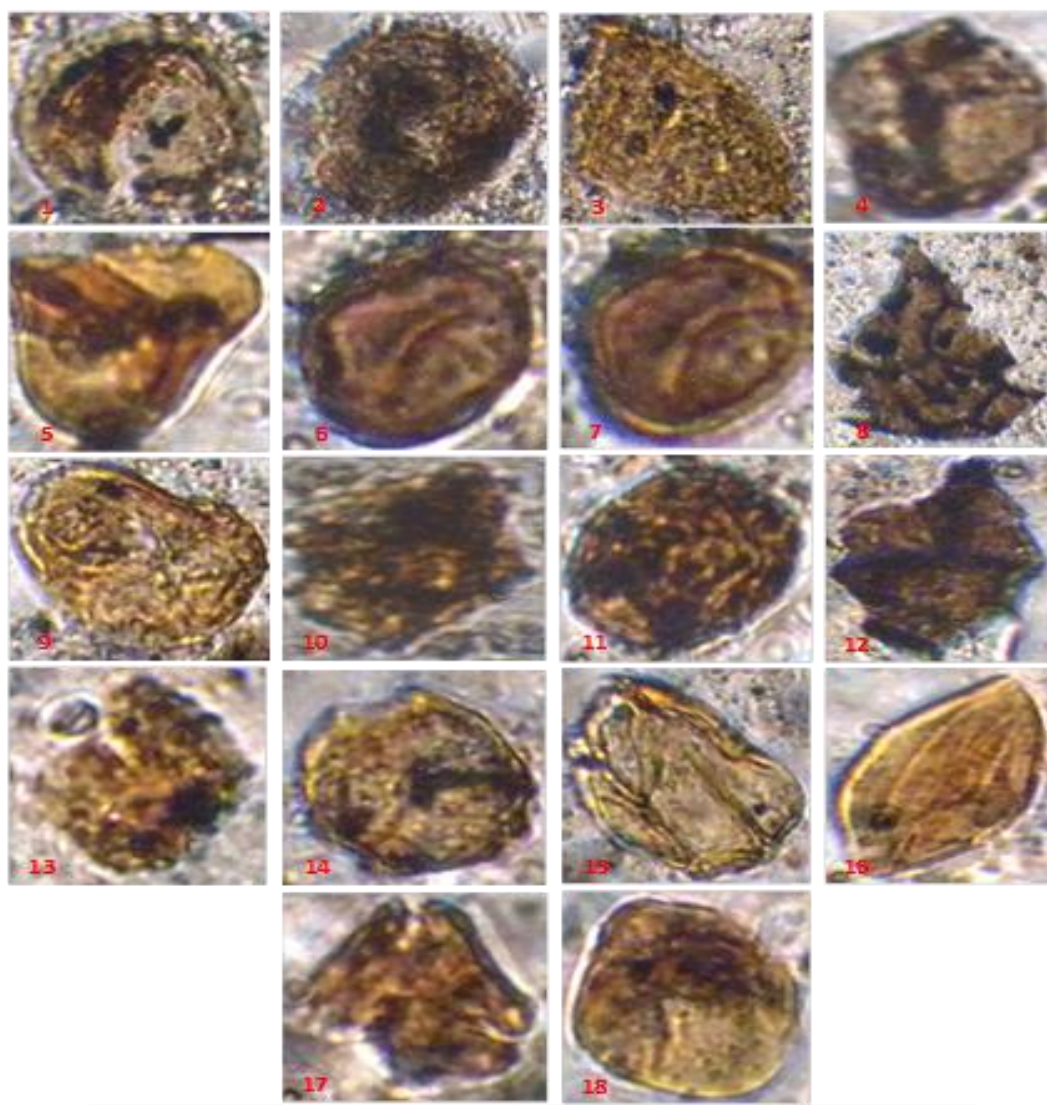


PLATE 2

- 1 *Constructipollenites ineffectus* Van Hoeken-Klinkenberg, 1964
- 2 *Milfordia jardinei* Hochuli, 1979
- 3 *Longapertites vaneendenburgi* Germeraad et al, 1968
- 4 *Monosulcites* sp
- 5 *Laevigatosporites* sp Wilson and Webster, 1946
- 6,7 *Monocolpites marginatus* Van der Hammen, 1954
- 8 Indeterminate
- 9 *Verrucatosporites* sp
- 10 *Auriculidites* sp 1 Lawal, 1982
- 11 *Milfordia* sp Ola-Buralmo and Akaegbobi, 2013b
- 12 *Botryococcus braunii*
- 13 *Senegalinium* sp
- 14 *Triporites* sp
- 15 *Laevigatosporites* sp
- 16 *Tricolpites* sp
- 17 *Tricolpites* sp
- 18 *Phelodinium boloniense* Rlegel, 1974; Rlegel and Sarjeant, 1982

Figure 5: Photomicrograph of some palynomorphs recovered from Akukwa-2 well, Plate 2

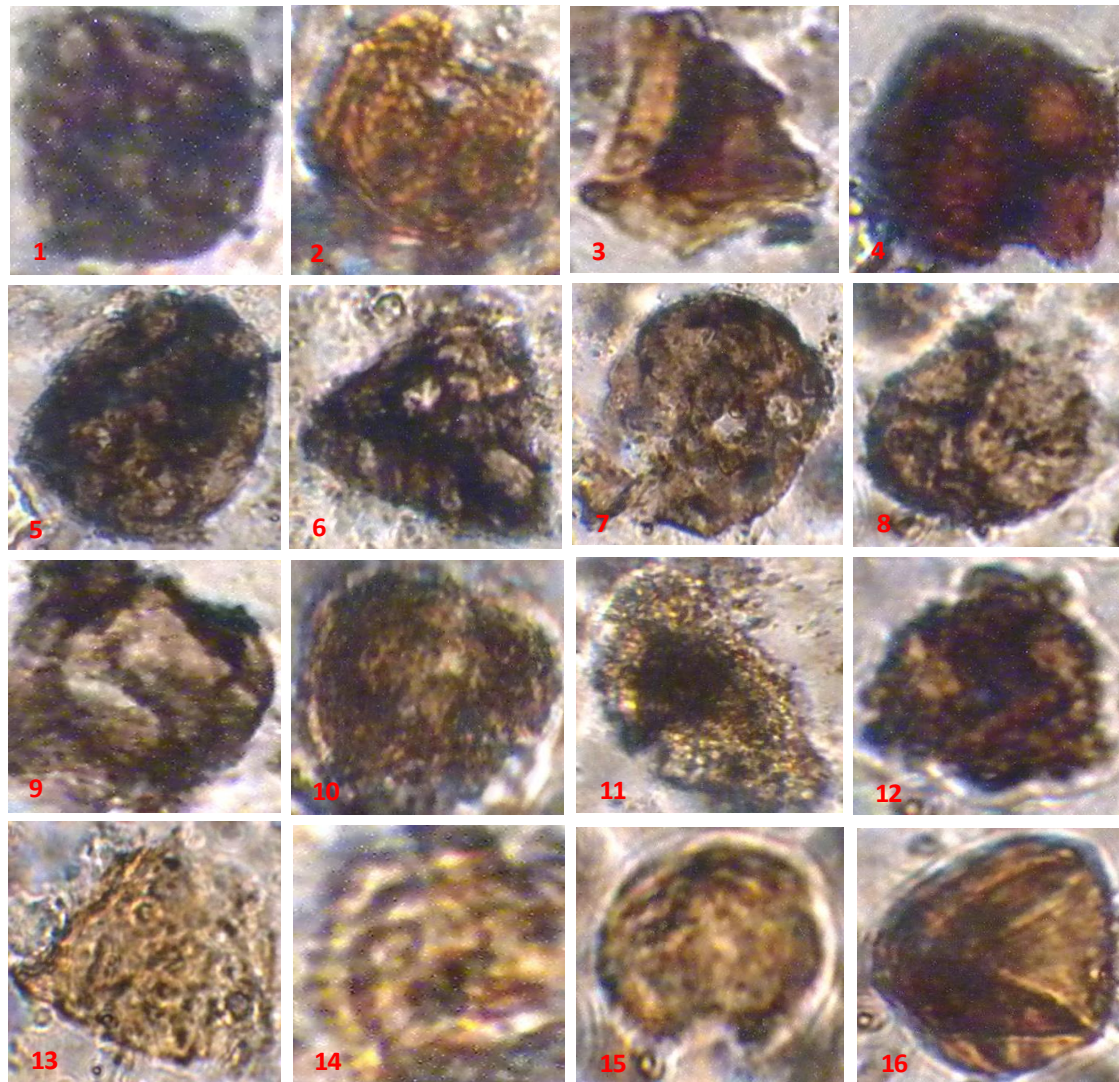


PLATE 3

- 1 *Stephanocolpites* sp
- 2 *Senegalinium* sp Lawal, 1982
- 3 *Syncolporites subtilis* Boltenhagen, 1976
- 4 *Senegalinium* sp 5 Lawal, 1982
- 5 *Andalusiella* sp Lawal, 1982
- 6 *Tricolporopollenites* sp. S. 152 Jardine and Magloire, 1965
- 7 *Isabelidium* sp Lawal, 1982
- 8 *Senegalinium* sp
- 9 *Dinocyst*
- 10 *Milfordia* sp Ola-Buraimo and Akaegbobi, 2013b
- 11 *Retimonocolpites* sp
- 12 *Tripolites* sp
- 13 *Proteacidites* sp. 5 Lawal, 1982
- 14 *Retidiporites magdalenensis* Van der Hammen and Garcia, 1966
- 15 Indeterminate pollen
- 16 *Graminidites* sp Jardine and Magloire, 1965

Figure 6: Photomicrograph of some palynomorphs recovered from Akukwa-2 well, Plate 3.

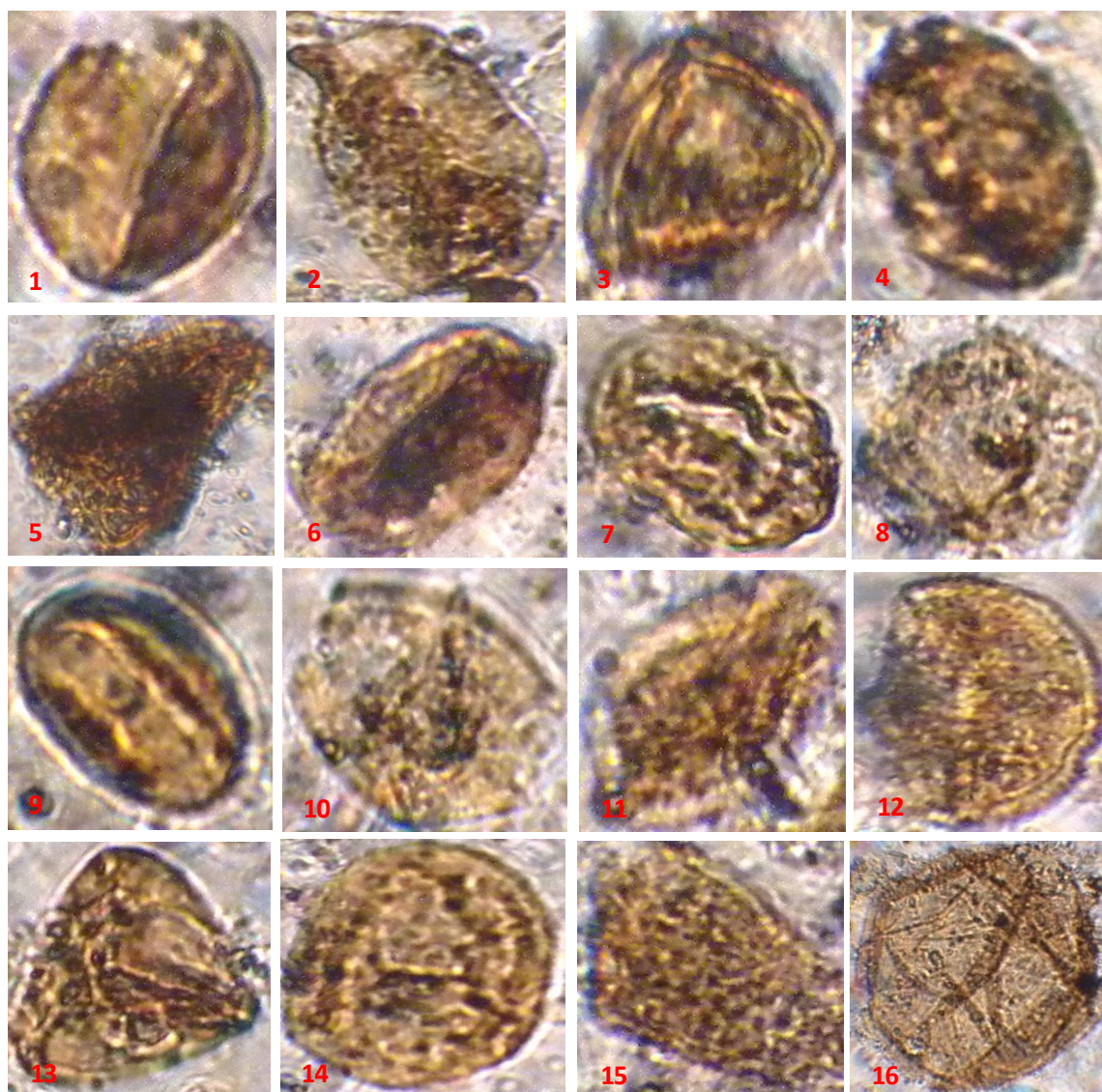


PLATE 4

- 1 *Monosulcites* sp 1 Lawal, 1982
- 2 *Longapertites marginatus* Van Hoeken-Klinkenberg, 1964
- 3,4 *Longapertites marginatus* Van Hoeken-Klinkenberg, 1964
- 5 *Periretisyncolpites* sp Ola-Buraimo and Akaegbobi, 2013b
- 6 *Monosulcites* sp
- 7 *Monocolpites marginatus* Van der Hammen, 1954
- 8 *Milfordia* sp Ola-Buraimo and Akaegbobi, 2013b
- 9 *Tricolpites* sp
- 10,15 *Retidiopores magdalenensis* Van der Hammen and Garcia, 1966
- 11,12 *Retimonocolpites* sp Lawal, 1982
- 13 *Cyathidites* sp
- 14 *Inaperturopollenites* sp Jardine and Magloire, 1965
- 16 *Batiacasphaera* sp in Lawal, 1982

Figure 7: Photomicrograph of some palynomorphs recovered from Akukwa-2 well, Plate 4.

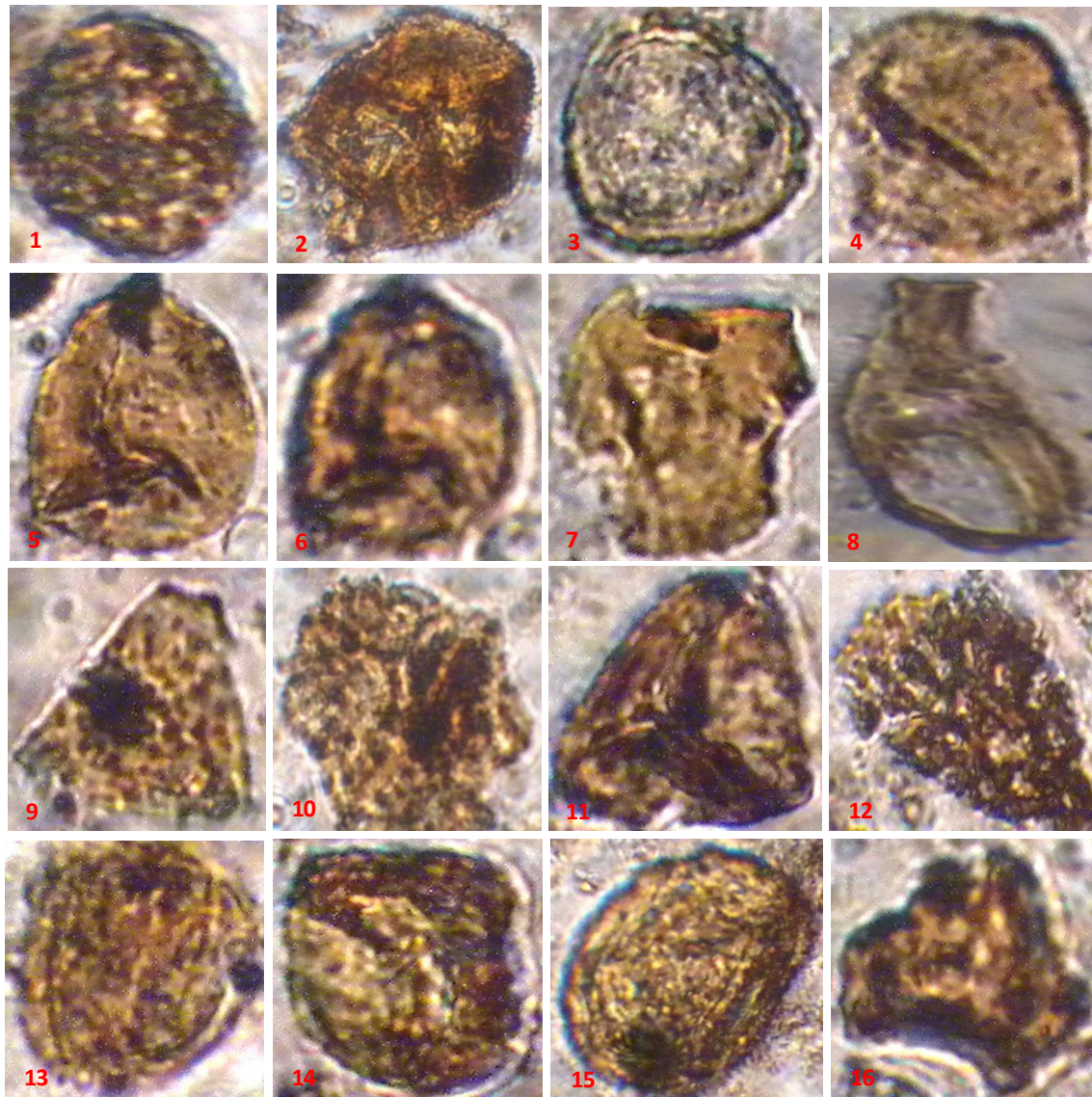


PLATE 5

- 1 *Monocolpites* sp 3 Lawal, 1982
- 2 *Buttinia andreevi* Boltenhagen, 1967
- 3 *Retitricolporites* sp
- 4 *Monocolpites marginatus* Van der Hammen, 1954
- 5,6 *Syncolporites* sp
- 7 *Tricolpites* sp
- 8 *Monoporites* sp
- 9 *Echitriporites trianguliformis* Van Hoeken-Klinkenberg, 1964
- 10 *Zlivisporites blanensis* Pacltova, 1961
- 11 *Leiotriletes* sp
- 12 *Periretisyncolpites magnosagenatus* Kieser and Jan du Chene, 1979
- 13 *Longapertites vaneendenburgi* Germeraad et al, 1968
- 14 *Milfordia jardinei* Hochuli, 1979
- 15 *Verrucatosporites* sp
- 16 *Tricolporites* sp

Figure 8: Photomicrograph of some palynomorphs recovered from Akukwa-2 well, Plate 5.

Table 3: Akukwa -2 Well Chart

DEPTH(M)	LITHOLOGY	FORMATION	POLLEN AND SPORES		DINOFLAGELLATE CYST OTHERS										PALYNOLOGICAL ZONES	CHARACTERISTICS	AGE	PALEOENVIRONMENT			
3.297		NKPORO SHALE	EHITRIPORITES TRIANGULIFORMIS	1	1	1	2	1	1	5	1							The zone is characterized by quantitative occurrence of <i>Milfordia</i> sp. <i>Milfordia jardinei</i> in association with continuous occurrence of <i>Auriculidites</i> sp., <i>Auriculidites reticulatus</i> , <i>Longapertites vaneenburgi</i> ; restricted within the zone are <i>Echitriporites trianguliformis</i> , <i>Longapertites vaneenburgi</i> and quantitative occurrence of <i>Syncolporites</i> spp. The top of the zone is marked by quantitative abundance of palynomorphs	CAMPANIAN TO EARLY MAASTRICHTIAN	MARINE	
3.314									4	1											
3.346																					
3.369					1	1															
3.412					1	1	1	2	1	4	2	1									
3.474					1	1	1	3			1	1	1	3							
3.481					2	1	1				1	2	1								
3.514					1	1	1	2			1	2									
3.543					1		1	2	3												
3.558					3		1	1	1		1										
3.576							2														
3.591											1		1								
3.619							1	1			1	1									
3.647			NKPORO SHALE		1						1										
3.689																					
3.704											1										
3.866		NKPORO SHALE		1																	
3.793				1		2															
3.809				1	2																

Table 4: Summary - Akukwa-2 well Palynozones

Sample No	Depth (m)	Palynozones	Age	Paleo-Environment
AKU 1 – AKU 14	3,296 – 3,647	<i>Milfordia spp</i> Acme Zone 3	Campanian to Early Maastrichtian	Marine
AKU 15 – AKU 16	3,689 – 3,704	<i>Droseridites Senonicus</i> Assemblage Zone 2	Coniacian	Marginal Marine
AKU 17 – AKU 20	3,866 – 3,850	<i>Triorites Africaensis</i> Assemblage Zone 1	Turonian	Marginal Marine

CONCLUSION

Twenty samples collected from a shale sequence in an upward order are composed mainly of dark grey to black silty shale facies with intercalated mudstone and sandstone. Palynological analysis indicates that the samples contain a relatively high abundance and diversity of palynomorphs. The entire sequence is dated Campanian to Maastrichtian based on the maximum development of *Botryococcus braunii*; thus, the sequence belongs to *Milfordia spp* acme zone characterized by strong development of *Indeterminate pollen*, *Monosulcite sp.* *Milfordia sp.* *Longapertites marginatus* and *Tricolporopollenites sp.* based on distinctive palynomorph assemblages in particular and sedimentation pattern in relation to sea level changes.

The lower part of the studied Nkporo Shale is characterized by relative quantitative occurrence of indeterminate pollen, associated with rare occurrence of *Botryococcus braunii*, *Monosulcites sp.*, *Senegaliun sp.*, *batiasphaera sp.* deposited in marginal marine setting. The samples (15-20) with interval 3,689-3,863m are suggested to belong to Campanian age.

The middle section (samples 8-14) is characterized by moderate abundance and continuous occurrence of *Botryococcus braunii*, *Monosulcites sp.* and *Milfordia sp.* compared with the underlying section dated Campanian. Other forms present are *Perireisyncolpites sp.*, *Syncolporites subtilis*, *Tricolpites sp.* And *indeterminate pollen* different forms of dinocysts and *microforaminiferal wall lining*. The sedimentation pattern is mainly deposited in marginal marine environment, therefore suggested to belong to Late Campanian age.

The upper section (samples 1-7) dated Campanian to early Maastrichtian is based on high abundance and diversity of palynomorphs; marked by maximum development of *Botryococcus braunii*, *Milfordia sp.* moderate frequency of *indeterminate pollen* and *Tricolpites*. It is further characterized by a deepening marine paleo-environmental setting, within which is the location of maximum flooding surface.

References

- [1] Giwa G. O., et al. *Advances in the Application of Biostratigraphy to Petroleum Exploration and Production*. Adapted from presentation and AAPG International Conference, Paris, France 2005, September 11-14.
- [2] Valenti, Rull. *High-impact palynology in petroleum geology: Applications from Venezuela (northern South America)*: AAPG Bulletin 2002, v. 86, p. 279-300.

- [3] Cratchley C. R. and Jones G. P. *An interpretation of the Geology and Gravity Anomalies of the Benue Vally, Nigeria*, "Overseas Geological Surveys Geophysical Paper, vol. 1, H. M. Stationery Office, Norwich, 1965, pp. 1 – 26.
- [4] Wright J. B. *South Atlantic Continental Drift and the Benue Trough. Tectonophysics*, Vol. 6, Issue 4, 1968, page 301 – 310.
- [5] Grants, N. K.. *South Atlantic, Benue Trough and Gulf of Triple Junction*. Geological society of America Bulletin, 1971, 8:2295-2298.
- [6] Burke K. C., Dessauvage T. P. and Whiteman A. J. *Opening of the Gulf of Guinea and the Geological History of the Benue Depression and Niger Delta*. Nature Physical Science, 233, 51 – 55, 1971.
- [7] Burke K. C. and Whiteman A. J. *In: Implication of Continental Drift to the Earth Sciences* (Edited by D. H. Tarling and S. K. Runcom) 1973, pp. 735 – 755.
- [8] Nwachukwu, S. O. *The tectonic evolution of the southern portion of the Benue trough, Nigeria* . Geol, Mag. 1972, 109, 411-419.
- [9] Olade, M. A. *Evolution of Nigeria Benue Trough (Aulacogen): A tectonic model*. Geological magazine, 1975, vol.122, 575-583.
- [10] Akaegbobi I. M. *Sequence Stratigraphy of Anambra Basin: Journal of African Earth Sciences*, 2005, 42: 394 – 406.
- [11] Nwojiji C. *Palynostratigraphy and Age of the Sequence Penetrated by the Kolmani River 1 Well in the Gongola Basin, Northern Benue Trough, Nigeria*. Journal of Geosciences and Geomatics 1, no.1 (2013): 15 – 21.
- [12] Ola-Buraimo, A.O. et al. *Palynological characterization of the organic richness, kerogen type and thermal maturity of source rocks in interval 905e1360m of Kemar-1 well, Bornu Basin, northeastern Nigeria*. Journal of Biological and Chemical Research, 2015, 32(2).
- [13] Adeagbo O.A., et al. *Palynological and Palaeoenvironmental Study of Campano-Maastrichtian Nkporo Shales of Amasiodo-1 Well, Anambra Basin, Southeastern Nigeria*. *Science and Engineering Perspectives [SEP]*, Faculty of Science, The Polytechnic, Ibadan, Nigeria. 2018, Vol. 13, 2018.
- [14] Obaje, N.G. *Geology and Mineral Resources of Nigeria*. 2009, (221 p). Berlin: Springer.
- [15] Shirley O. Odunze and Gordion. *Sedimentology and sequence stratigraphy of the Nkporo Group (Companian –Maastrichtian), Anambra Basin, Nigeria*. Journal of Palaeogeography, 2013, 2(2): 192 – 208.
- [16] Hoque M. *Petrographic Differentiation of Techtonically Controlled Cretaceous Sedimentary Cycles, Southeastern Nigeria*. Sedimentary Geology, 1977, 17, 235 – 245.
- [17] Traverse A. *Palaeopalynology*. Unwin Hyman, London. 1988, 1- 600.
- [18] Faegri K. and Iversen J. *Textbook of Pollen Analysis*. 4th edn. New York, John Wiley and Sons, 1989.
- [19] Wood GD. et al. Palynological techniques-processing and microscopy. In: Jansonius J. McGregor V. editors. *Palynology: Principles and applications*. American Association of Stratigraphic Foundations, Dallas. 1996, 1: 29-50.

-
- [20] Ola-Buraimo A.O. and Adeleye M. *Palynological haracterization of the Late Maastrichtian Ute Coal measure deposit, Southwestern Nigeria. Science Focus. 2010, 15(2): 276-287.*
- [21] Ola-Buraimo AO. *Palynological stratigraphy of the Upper Cenomanian- Turonian Eze-Aku formation in Anambra Basin, Southeastern Nigeria.* Journal of Biological and Chemical Research. 2013a, 30(10):54-67.
- [22] Ola-Buraimo A. O. et al. *Appraisal of the Middle Cretaceous Sediments in Ubiaka-1 Well Through the Use of Palynology in Anambra Basin, Southeastern Nigeria.* British Journal of Applied science and Technology, 14(3): 1-11, 2016
- [23] Jardine S. Magloire I. *Palynologieet stratigraphic du Cretace des Basins du Senegal et de Cote d' Ivoire*ler Coll. Memoire du. Bureau Recherches GeologiquesetMinieres. 1965, 32:187-245.
- [24] Lawal O. and Moullade M. *Palynological biostratigraphy of the Creteceous sediments in the upper Benue Basin, N.E. Nigeria.* Revue micropaleontology. 1986, 29(1): 61-83.
- [25] Adebayo O. F., et. al. *Paleoenvironmental studies of Ahoko Shale, Southeastern Bida Basin, Nigeria.: Insight from Palynomorph Assemblage and Trace Metal Proxies.* International Journal of Scientific and Research Publications, 2015, Vol. 5, issue 10,pp.50.
- [26] Ola-Buraimo, A.O. & Akaegbobi, I.M. *Palynological evidence of the oldest (Albian)sediment in the Anambra Basin, southeastern Nigeria.* Journal of Biological and Chemical research, 2013b, vol. 30(2): 387-408.
- [27] Van Hoeken-Klinkenberg, P. M. J. *Palynological investigation of some UpperCretaceous sediments in Nigeria.* Pollen Spores, 1964, 6(1), pp. 209-231.
- [28] Elsik W. C. *A new sporomorph genus from Eastern Peru: Pollen et Spores*, 1964, v.6, no. 2.
- [29] Lawal, O. *Biostratigraphie palynologique es paleoenvironmens des formations Cretacee de la Haute-Benoue, Nigeria mord-oriental.* These- 3-cycle, University of Nice, 1982, 218p.
- [30] Hochuli,P. A. *The palaeoclimatic evolution in the late Palaeogene and the early Neogene*, Ann. Geol. Pays Hallen. 2: 515 – 523. 1979.
- [31] Germeraad, J. H., et al. *Palynology of Tertiary sediments of tropical areas.* Rev. Palaeobot. Palynol. 1968, 6, 189-348.
- [32] Wilson L. R. and Webster R. *.Plant microfassils from a Fort Union Coal of Montana.* Ann. J. Botany 33, 271 – 278, 1964
- [33] Van der Hammen, T. *El desarrollo de la flora Columbiaus en los perindos geologieos. Maestrichtiane basin Terciarin mas inferior.* Bol. Geol. Begata, 1954, Vol. 2,(1), pp. 49-106
- [34] Riegel W. *New form of organic-walled microplankton from an Upper Cretaceous assemblage in southern Spain.* Revista espanola de micropaleontologia, 1974, v.6, no. 3, p.347 – 366, pl. 1 – 3.
- [35] Riegel W. and Sargeant W. A. S. *Dinoflagellatecysts from the Upper Cretaceous of Southern Spain: new morphological and taxonomic observations.* Neues Jahrb. Geol. Palaeontol. Abh., 1982, 162: 286 – 303.
- [36] Boltenhagen E. *Pollen et spore Senoniens du Gabon.* Cashier Micropaleontology. 1976; 3: 3 – 21.
- [37] Van Der Hammen T. and Garcia C. *The Paleocene Pollen flora of Colombia.* Leidse Geologische Mededelingen, 1966, 35: 105 – 114.
- [38] Boltenhagen E. *Spore et Pollen du Cretace superior du Gabon.* Pollen et Spores. 1967; ix(2): 335 – 355.
-

- [39] Pacltová, B. *Některé rostlinné mikrofosilie ze sladkovodních uloženin svrchní křídy (senon) v jihočeských pánvích I. [Some plant micro-fossils from fresh-water sediments of the Late Cretaceous (Senonian) of the South Bohemian basins I.]*. **1961** – Sborník Ústředního ústavu geologického, 26: 47–102. (in Czech)
- [40] Kieser, G., and Jan Du Chêne, R. *Periretisyncolpites n. gen. and Terscissus Tschudy 1970. Grands pollen syncolpés du Maastrichtien du Sénégal et du Nigeria*. *Revista Española de Micropaleontología* 11, 321-334, 1979.