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Lithofacies, Palynology and Paleoenvironmental Study of Campanian to Late Maastrichtian Deposits of Ogbabu-1 well Anambra Basin, South Eastern Nigeria

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ABSTRACT: Lithofacies, Palynology and Paleoenvironmental Study of Campanian to Late Maastrichtian Deposits of Ogbabu-1 well Anambra Basin was carried out using ninety (90) ditch cutting samples ranging in depths 1000ft - 6830ft (305m - 2080m), with the aim of giving a detailed palynological analysis of the formations penetrated by Ogbabu-1 Well in Anambra Basin using sedimentology and palynology as geologic tools. This was achieved by identifying the different species of palynomorphs present as well as their range, the lithologic unit, age, different biozones and paleoenvironment of deposition. The sedimentological analysis was used to define Lithofacies zones and identify minerals. The main lithologies encountered in the well consist of shaly sands; sandy shales, shales and sand. Fourteen (14) Lithofacies zones were established. Minerals identified include feldspar, iron oxide and mica. Six hundred and sixty one (661) palynomorphs species were recovered. Five hundred and eighty five (585) were Miospore (pollen and spore) and seventy six (76) Dinocysts. The identified minerals obtained from the sedimentological analysis was used to argument data from palynological analysis to establish paleoenvironmental events. The absence of Danian diagnostic dinocysts especially *Damasadinium californicum* and *Carpatella cornatus* respectively suggest a Maastrichtian age for the well section between 1000ft-6600ft. The age of the well penetrated was inferred to range from Campanian to Late Maastrichtian. Late Maastrichtian age (1000-3550ft), top of this zone is undefined because of absence of data but the base of the zone is defined by the last appearance datum of *Cingulatisporites ornatus* (3550ft). Middle Maastrichtian age (4050ft-5080ft) established based on top of the zone is marked by the base of preceding zone. The zone is also marked by last appearance datum of *Classopollis spp.* (4930ft). Early Maastrichtian age (5240ft-6600ft) established based on the last appearance datum of *Ctenolophonidites costatus* (6600ft) and the base is defined by the first appearance datum of *Constructipollenites ineffectus* (6600ft). Campanian age (6700-6830ft) established based on the last appearance datum of *Triorites africaensis* (6700ft). The formations likely penetrated by the well section are the Nkporo shale (Campanian) and the Ajali Sandstone (Maastrichtian age). The well section (1000ft – 6380ft) was delineated to be shallow marine environment.
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Keywords: Lithozones; Campanian-Late Maastrichtian; Anambra Basin; Palynomorphs; Formation.

The Anambra Basin is a synclinal structure consisting of more than 5,000m thick of Upper Cretaceous to Recent sediments representing the third phase of marine sedimentation in the Benue Trough (Akande and Erdtmann, 1998). The rich and economically viable hydrocarbon deposits of Anambra Basin has attracted lots of attention lately.

The Anambra Basin has a total sediment thickness of about 9km, and presents an economically viable hydrocarbon deposits. It is characterized by enormous lithologic heterogeneity in both lateral and vertical extension derived from a range of paleoenvironmental settings ranging from Campanian to Recent (Nwajide, 2005).

The Anambra Basin is a Cretaceous/Tertiary basin, which is the structural link between the Cretaceous Benue Trough and the Tertiary Niger Delta basin (Lucas and Ishiekwene, 2010). This sedimentary phase was initiated by the Santonian folding and uplift of the Abakaliki anticlinorium along the NE-SW axis, and the consequent dislocation of the depocenter into the Anambra Basin on the Northwest and the Afikpo syncline on the Southeast (Short and Stauble, 1967; Murat, 1972). The resulting succession comprises the Nkporo group, Mamu formation, Ajali sandstone, Nsukka formation, Imo formation and Ameki group. Hydrocarbon exploration in the Anambra Basin has been dependent on the abundant Maastrichtian coal deposits. The Anambra Basin was for long

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abandoned due to its fruitless and unrewarding effort for the exploration of petroleum.

The sedimentary rocks comprise ancient Cretaceous deltas, somewhat similar to that of the Niger Delta. The stratigraphic succession of the Anambra Basin comprises of the Campanian to Maastrichtian Enugu/Nkporo/Owelli formations (lateral equivalents). This is succeeded by the Maastrichtian Mamu and Ajali formations. The sequence is capped by the tertiary Nsukka formation and Imo Shale. The detailed stratigraphic description is available in several publications (Agagu, *et al*., 1985; Reijers, 1996).

The studied location Ogbabu-1 well lies on the right side of the Imo River in Southeastern Nigeria. The coordinates are approximately Longitude 007^0 40" E and Latitude 05^0 45" N.

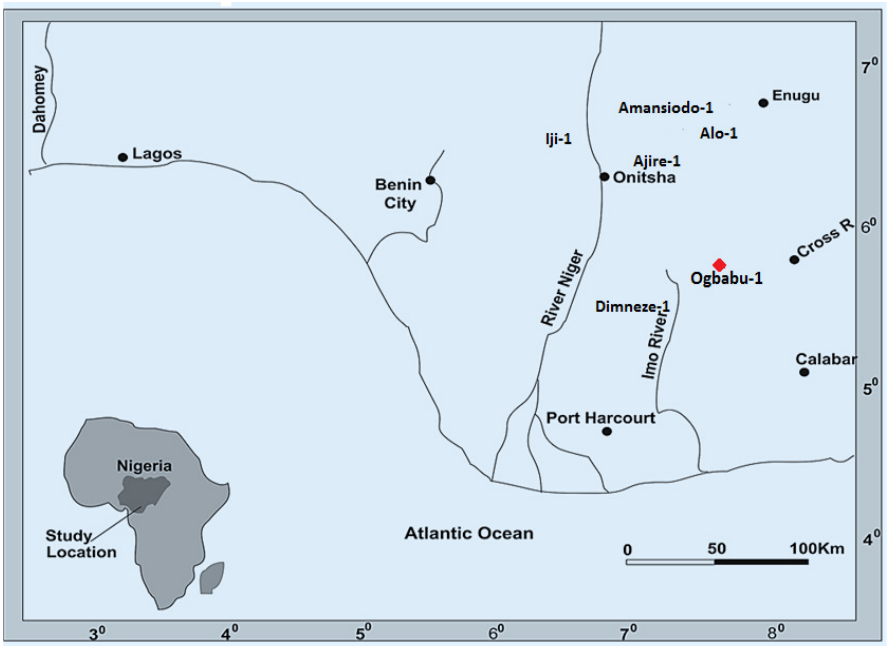

Fig 1: Map showing Ogbabu-1 well, Anambra Basin

Stratigraphy: *Nkporo Shale (Campanian – Maastrichtian):* The Nkporo shale is the basal sedimentary unit that was deposited following the Santonian folding and inversion in Southeastern Nigeria and indicates a late Campanian age, based on the presence of Afrobolivina afra (Reyment, 1965).

The formation is generally poorly exposed but has been described as coarsening upward deltaic Sequence of shale and interbed of sands and shale with occasional thin beds of limestone (Kogbe, 1974; Reyment, 1965; Whiteman, 1982; Ladipo, *et. al.*, 1992). The sediments here, includes dark shale and mudstone with occasional thin beds of sandy shale and sandstone and shaly limestone.

The Nkporo Shale documents the transgressive event that followed the Santonian deformation in the Anambra Basin (Murat, 1972; Obi and Okogbue, 2004). At the base of the Nkporo Shale, the coarse-grained sandstone is accounted for as a paleovalley because it visibly cuts erosionally into the older, genetically unrelated Awgu, Eze-Aku and Asu River Groups. The Nkporo shales of the Calaber flank, consists basically of alternating layers of black shale, usually brown to grayish limestones and siltstones.

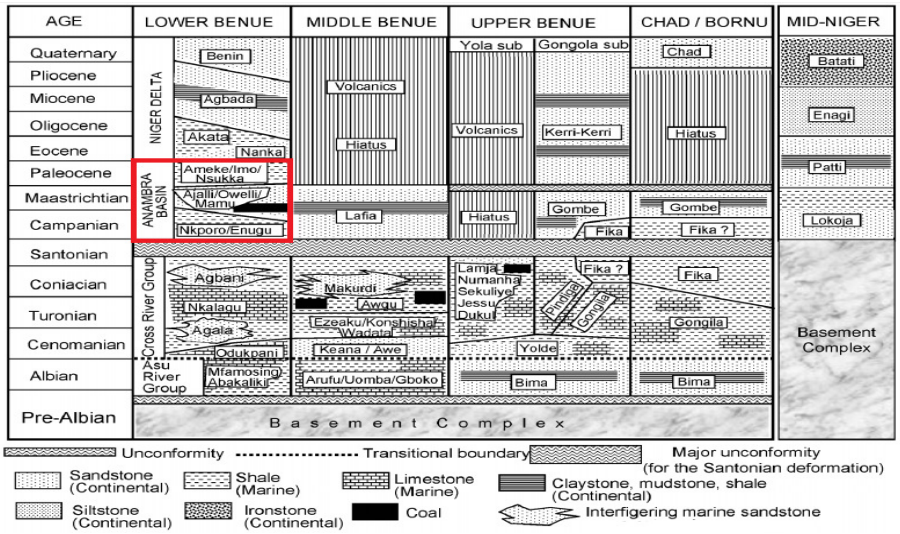

Fig 2: Stratigraphy of the Anambra basin in relation to the Benue trough complex (Obaje*, et.al.* 2006)

Mamu Formation (Lower Maastrichtian): The Mamu formation overlies the Enugu shale conformably and contains sandstone, shale mudstone, sandy-shale with coal seams in various horizons (Reyment, 1965). The sediment pile varies across the basin and ranges from 75m to over 1000m (Reyment, 1965; Ladipo, *et. al*., 1992). The possible environments of deposition are estuarine flood plain, Swamp and tidal flat flood plain. It is excellently exposed along the Enugu-Onitsha Road at the Miliken Hill and the outskirts of Enugu (Kogbe, 1974). The age of this formation is put at lower-middle Maastrichtian and has a significant thickness variation from about 100m in the south to as much as 100m in the central and northern part of the basin (Ladipo *et al*, 2001).

Ajali Sandstone (Middle-Upper Maastrichtian): The Ajali sandstone overlies the Mamu formation in the Anambra Basin and has a diachronous age from south to North (Middle-upper Maastrichtian) and exhibits significant thickness variation from less than 300m to over 1000m at the center of the basin (Ladipo, *et al*, 2001). Depositional characteristics are uniform for most parts of the basin, made up with textually mature sand facies i.e. mature quartz arenite intercalated with kaolinite beds. Dominant sedimentary structures are cross bedding associated with reactivation surfaces, mud drapes, tidal bundles, backflow ripples, channel cut and fills and lateral accretion surface (Ladipo, 1992).

Nsuk*ka Formation (Maastrichtian -Danian):* This formation overlies Ajali sandstone in the Anambra Basin. It was formally called Upper Coal Measure. It consists of an alternating succession of sandstone, dark grey shale with thin inter-beds of Coal seams. The basal part of the formation consists of sandstone up to 120m thick succeeded by shale with inter-beds. The formation is poorly fossiliferous and consists of some palynomorph species. Nsukka formation is Maastrichtian to Danian in age (Reyment, 1965). As the second post Santonian transgressive cycle was on, the Nsukka formation was deposited under parallic conditions which prevailed.

MATERIALS METHOD

Thirty-five (35) selected ditch cutting samples collected from Ogbabu-1 well situated in the Anambra Basin with depths ranging from 1000ft to 6830ft were utilized for lithofacies description and preparation of palynological slides. The slides were analyzed under the microscope for palynomorph content.

Palynological Sample Preparation: The sample preparation was carried out following the international standards given below:
The samples were crushed between aluminum pie dishes and 10g was collected and tested for limestone ($CaC0_3$) using HCl, while effervescence was produced, the limestone was eliminated by further addition treatment with concentrated HCl.

After two or three hours, the sample was decanted and the waste solution transferred to one special waste container bottle. The broken down mineral material and fossils were removed and centrifuged for about 1-2 minutes and decanted repeatedly until a neutral reaction was reached. Concentrated HNO_3 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. Sodium hypochlorite (Purex) as well as some drops of HCI was added, agitated and let for about 15 minutes. Two drops of Ammonium Hydroxide concentrate was added and diluted with water. At this stage, separation of these organic matter from the inorganic material (silica) was done by floatation using diluted zinc bromide (ZnBr).

The samples were transferred to a flexible plastic tubes, already prepared (cut and mount immersed into warm water); such plastic tubes are set into centrifuge tubes with water around them. Zinc bromide has a specific gravity of 2.2 thus, everything with a specific gravity of more than 2.2 will settle down. The process of centrifugation using zinc bromide took about 15 minutes. A small portion of the supernatant liquid was observed under the microscope. Then, a clip across the flexible plastic tube was inserted so that the supernatant liquid would be easy to take out by pipette decantation or eye dropper.

Microscopic view of the supernatant liquid decided how to clean, run acetolysis or stain. Add acetic anhydride and three of four drops of H_2SO_4 to take out the water, then immerse test tube in boiling water for about ten minutes. The sample was properly washed at each stage. Here, it was ready for cleaning and mounting; during this stage several views under the microscope accomplished with some attempt to get mainly fossil material was done.

RESULT AND DISCUSSION

Sedimentology: From the sedimentological analysis, four sedimentary units were deduced from Ogbabu-1 well. These lithofacie units are sandy shale, shale, shaly sand and sand. These was achieved by using the ditch cutting samples as they were analyzed for lithofacies, this follows standard laboratory procedure whereby the samples were observed under the binocular microscope by noting textural parameters such as grain size, roundness, sorting, and other features such as facies type, colour, fossil content and the effect of post depositional diagenetic effect such as haematite imparted on the sediments. This aided to establish the different litho-facies present within the formation.

Palynology: Palynomorphs that were stratigraphically significant and environmentally necessary were recovered in the analyzed samples and were plotted in order to interpret for the stratigraphy and zonal age of the interval (1000-6830ft). The pollen and spores were relatively moderate in abundance and diversity, moderately rich dinoflagellates cysts. Six hundred and sixty one (661) palynomorphs species were recovered. Five hundred and eighty five (585) were Miospore (pollen and spore) and seventy six (76) Dinocysts.
The palynomorph distribution with depth is shown on the table 3 below.

Table 1: Lithozones and their Lithologies

Reference depth (Ft)	Lithozones	Lithology
1000-1260	14	Sandy shale
1300	13	Sand
1380-1600	12	Shaly sand
1740-1840	11	Shaly sand
1920-2200	10	Sandy shale
2240-2550	9	Shale
2620-2780	8	Sandy shale
2850-5330	7	Shale
5350-5630	6	Shaly sand
5650-5730	5	Shale
5750-6010	4	Shaly sand
6030-6350	3	Sandy shale
6380-6430	2	Shale
6500-6830	1	Sandy shale

DEPTH(Ft.)	MINERALS	LITHOLOG	MUDLOG	SD-SH%	SEDIMENTOGICAL DESCRIPTION	LITHO-UNITS
1000	Mica, Iron oxide			10-90%	Dark grey,Fine Sandy Shale	14
1200	Mica, Iron oxide			10-90%		
1400	Mica			80-20&	light grey,angular-sub angular, poorly sorted, medium to coarse Sand	13
1600	Feldspar, mica, iron oxide			60-40%	Light grey,medium to coarse Shaly Sand	12
1800	Feldspar, Iron oxide			80-20%	Light grey,Medium to coarse Shaly Sand	11
2000	Feldspar			80-20%	Dark grey,Fine fissile Sandy Shale	10
2200	Feldspar, Mica			80-20%		
2400	Mica, Iron oxide			0-100%	Dark grey,Fine fissile Shale	9
2600	Mica, Iron oxide			5-95%	Dark grey,Fine fissile Sandy Shale	8
2800	Feldspar, Mica			0-100%		
3000	Feldspar, Mica			0-100%		
3200	Mica, Iron oxide			0-100%		
3400	Mica, Iron oxide			0-100%		
3600	Mica, Iron oxide			0-100%		
3800	Mica, Iron oxide			0-100%		
4000	Mica, Feldspar			0-100%	Dark grey,Fine fissile Shale	7
4200	Mica, Iron oxide			0-100%		
4400	Feldspar, Mica			0-100%		
4600	Feldspar, Mica			0-100%		
4800	Mica			0-100%		
5000	Mica			0-100%		
5200	Feldspar, Mica			0-100%		
5400	Feldspar, Mica			90-10%	Dark grey, subrounded, moderately sorted, Fine to medium Shaly Sand	6
5600	Feldspar, Mica			90-10%		
5800	Mica			0-100%	Dark grey,Fine fissile Shale	5
6000	Feldspar, Mica			80-20%	Dark grey,Fine to medium Shaly Sand	4
6200	Feldspar,Mica, Iron oxide			10-90%	Light grey,Fine fissile Sandy Shale	3
6400	Mica, Iron oxide			10-90%		2
6600	Mica, Iron oxide			0-100%	Light brown,Fine fissile Shale	1
6800	Mica, Iron oxide			20-80%	Light grey,Fine fissile Sandy Shale	

Fig 3: Lithologic Description of Ogbabu-1 well

Table 2: Occurrence and distribution of Miospores and Dinocysts in Ogbabu-1 well

S/N	DEPTH (ft)	DEPTH (m)	MIOSPORES	POLLENS	SPORES	DINOCYSTS	TOTAL PALYNOMORPS
1	1000	305	16	13	3	-	16
2	1260	384	17	15	2	-	17
3	1380	421	14	12	2	-	14
4	1560	476	9	7	2	2	11
5	1840	561	13	11	2	-	13
6	2080	634	12	11	1	-	12
7	2240	683	17	15	2	1	18
8	2300	701	16	15	1	1	17
9	2480	756	18	17	1	-	18
10	2620	799	19	18	1	1	20
11	2750	838	28	28	-	2	30
12	2850	869	15	15	-	-	15
13	3050	930	14	13	1	1	15
14	3250	991	21	20	1	1	22
15	3550	1082	41	41	-	4	45
16	4050	1234	13	13	-	5	18
17	4230	1289	12	11	1	-	12
18	4350	1326	19	18	1	5	24
19	4630	1411	23	21	2	4	27
20	4750	1448	12	11	1	1	13
21	4930	1503	24	24	-	2	26
22	5080	1548	17	16	1	3	20
23	5240	1597	44	41	3	6	50
24	5650	1722	28	27	1	4	32
25	5730	1747	43	43	-	1	44
26	5750	1753	3	3	4	4	7
27	5930	1808	15	11	4	3	18
28	6030	1838	4	2	2	3	7
29	6210	1893	8	8	-	1	9
30	6330	1929	8	7	1	9	17
31	6380	1945	1	-	1	-	1
32	6500	1981	10	10	-	1	11
33	6600	2012	12	10	2	1	13
34	6700	2042	5	4	1	4	9
35	6830	2082	14	13	1	6	20

Palynomorph Range Chart: A Palynomorph range chart has been established, each for the Miospore (pollen and spores) and the other for the Dinocysts. They were established based on the first appearance datum (last downhole occurrence) and last appearance datum (first downhole occurrence) of each palynomorph identified in the well section. The recovered palynomorph are as follows:

Miospores recovered are: Retidiporites magdalenensis, Syncolpites spp., Monoporites annulatus, Triorites spp., Ephedripites regularis, Syncolpites marginatus, Spinizonocolpites baculatus, Monosulcites spp., Echiperiporites trianguliformis, Longapertites marginatus, Sestrosporites pseudoalveolatus, Cyathides australis, Dictyophyllidits harrisii, Margocolpites sp., Laevigatosporites sp., Monocolpites marginatus, Cyperus sp., Milfordia jardinei, Retibrevitricolporites obodoensis, Leiotriletes adriennis, Periretisyncolpites sp., Proxapertites cursus, Dictyophyllidits spp., Cingulatisporites ornatus, Echitricolporites spinosus, Alchornea spp., Constructipollenites ineffectus, Trenocolpate pollen, Classopollis spp., Longapertites vaneedenburgi, Ctenolophonidites costatus, PO3, Tricolporate pollen, Gematricolpites scabratus, Triorites africaensis.

Dinocysts recovered are: Bitectatodinium tepikiense, Xenicodinium spp., Paleocystodinium golzowense, Fibrocysta ovalis, Paleocystodinium sp., Spiniferites Spp., Hystrichodinium cf. ramoides, Cerodinium

magnificum, Pareodinia sp., Homotryblium tenuispinosum, Lingulodinium machaerophorum, Kallosphaeridium spp., Senegalinium psilatum, Fibrocysta lappacea, Leiosphaeridia sp., Lingulodinium sp., Cerodinium spp., Dinogymnium acuminatum, Diphyes colligerum, Chytroeisphaeridia chytroeides, Paleohystrichophora infusoriodes, Caligodinium amiculum/ Senoniasphaera inornata, Hafniasphaera septata.

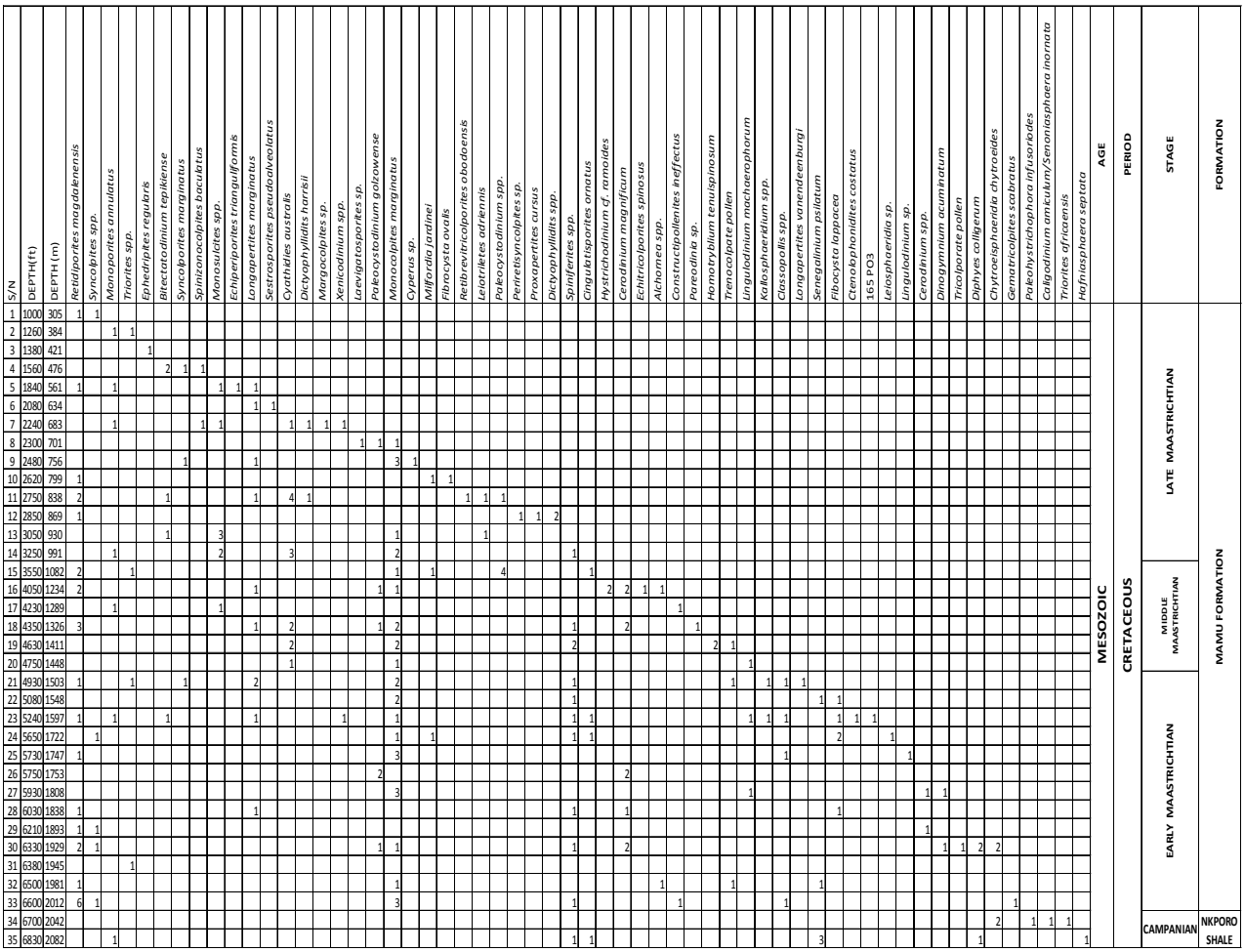

Fig 4: Range Chart of recovered Palynomorphs

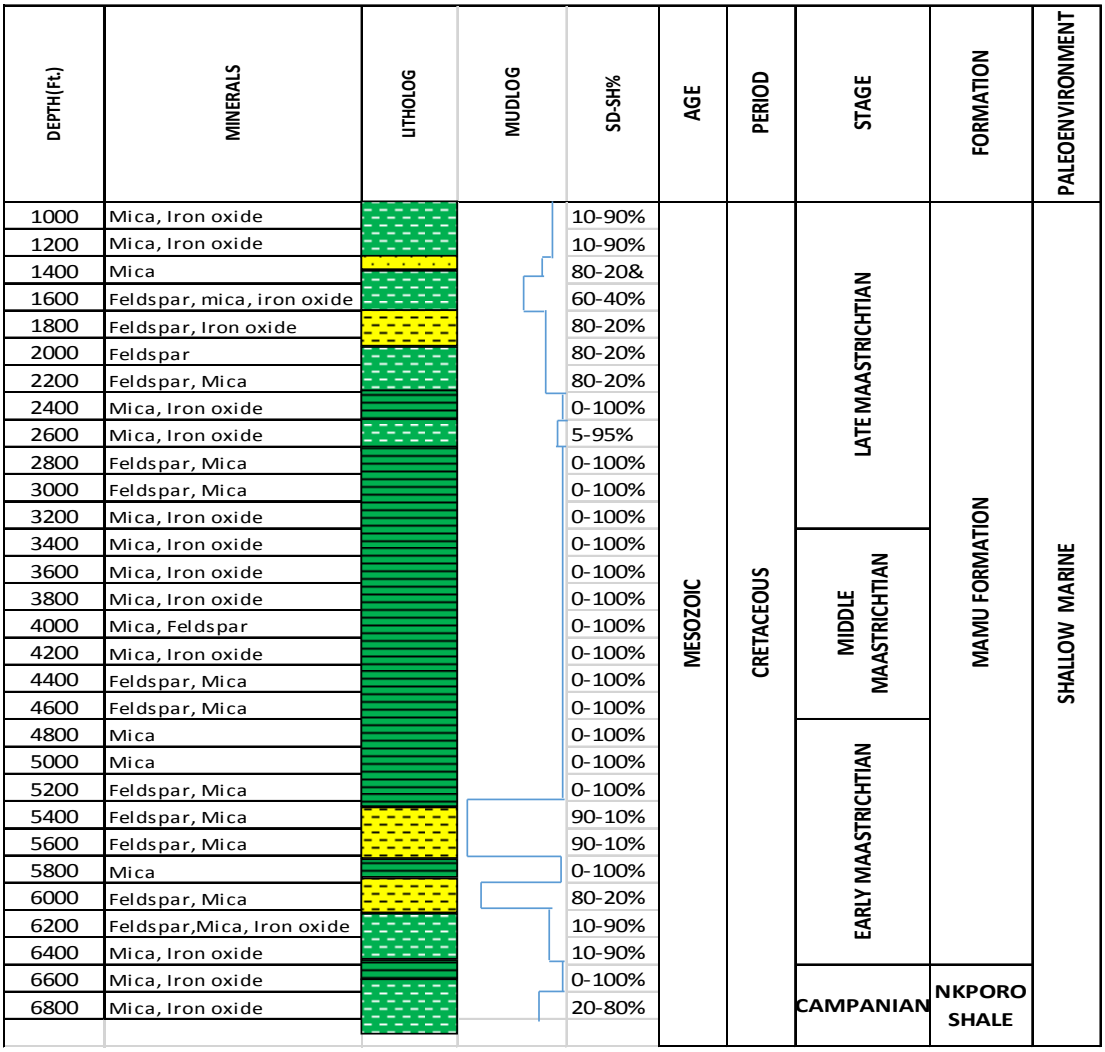

Fig 5: Lithologic description showing Age, Period, Stage, Formations and Paleoenvironment

S/N	DEPTH(ft)	DEPTH (m)	*Retidiporites magdalenensis*	*Syncolpites spp.*	*Monoporites annulatus*	*Triorites spp.*	*Ephedripites regularis*	*Bitectatodinium tepikiense*	*Syncolporites marginatus*	*Spinizonocolpites baculatus*	*Monosulcites spp.*	*Echiperiporites trianguliformis*	*Longapertites marginatus*	*Sestrosporites pseudoalveolatus*	*Cyathidies australis*	*Dictyophyllidits harrisii*	*Margocolpites sp.*	*Xenicodinium spp.*	*Laevigatosporites sp.*	*Paleocystodinium golzowense*	*Monocolpites marginatus*	*Cyperus sp.*
1	1000	305	1	1																		
2	1260	384			1	1																
3	1380	421					1															
4	1560	476						2	1	1												
5	1840	561	1		1						1	1	1									
6	2080	634											1	1								
7	2240	683			1					1	1				1	1	1	1				
8	2300	701																	1	1	1	
9	2480	756							1				1								3	1
10	2620	799	1																			
11	2750	838	2					1					1		4	1						
12	2850	869	1																			
13	3050	930						1			3										1	
14	3250	991			1						2				3						2	
15	3550	1082	2			1															1	
16	4050	1234	2										1							1	1	
17	4230	1289			1						1											
18	4350	1326	3										1		2					1	2	
19	4630	1411													2						2	
20	4750	1448													1						1	
21	4930	1503	1			1			1				2								2	
22	5080	1548																			2	
23	5240	1597	1		1			1					1					1			1	
24	5650	1722		1																	1	
25	5730	1747	1																		3	
26	5750	1753																		2		
27	5930	1808																			3	
28	6030	1838	1										1									
29	6210	1893	1	1																		
30	6330	1929	2	1																1	1	
31	6380	1945				1																
32	6500	1981	1																		1	
33	6600	2012	6	1																	3	
34	6700	2042																				
35	6830	2082			1																	

S/N	*Milfordia jardinei*	*Fibrocysta ovalis*	*Retibrevitricolporites obodoensis*	*Leiotriletes adriennis*	*Paleocystodinium spp.*	*Periretisyncolpites sp.*	*Proxapertites cursus*	*Dictyophyllidits spp.*	*Spiniferites spp.*	*Cingulatisporites ornatus*	*Hystrichodinium cf. ramoides*	*Cerodinium magnificum*	*Echitricolporites spinosus*	*Alchornea spp.*	*Constructipollenites ineffectus*	*Pareodinia sp.*	*Homotryblium tenuispinosum*	*Trenocolpate pollen*	*Lingulodinium machaerophorum*	*Kallosphaeridium spp.*
1																				
2																				
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6																				
7																				
8																				
9																				
10	1	1																		
11			1	1	1															
12						1	1	2												
13				1																
14									1											
15	1				4					1										
16											2	2	1	1						
17															1					
18									1			2				1				
19									2								2	1		
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30									1			2								
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32														1				1		
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35									1	1										

S/N	*Classopollis spp.*	*Longapertites vanendeenburgi*	*Senegalinium psilatum*	*Fibocysta lappacea*	*Ctenolophonidites costatus*	165 PO3	*Leiosphaeridia sp.*	*Lingulodinium sp.*	*Cerodinium spp.*	*Dinogymnium acuminatum*	*Tricolporate pollen*	*Diphyes colligerum*	*Chytroeisphaeridia chytroeides*	*Gematricolpites scabratus*	*Paleohystrichophora infusoriodes*	*Caligodinium amiculum/Senoniasphaera inornata*	*Triorites africaensis*	*Hafniasphaera septata*	AGE	PERIOD	STAGE	FORMATION	PALEOENVIRONMENT
1																			MESOZOIC	CRETACEOUS	LATE MAASTRICHTIAN	MAMU FORMATION	SHALLOW MARINE
2																							
3																							
4																							
5																							
6																							
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15																					MIDDLE MAASTRICHTIAN		
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20																							
21	1	1																			EARLY MAASTRICHTIAN		
22			1	1																			
23	1			1	1	1																	
24				2			1																
25	1							1															
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27									1	1													
28				1																			
29									1														
30										1	1	2	2										
31																							
32			1																				
33	1													1									
34													2		1	1	1				CAMPANIAN	NKPORO SHALE	
35			3									1						1					

Fig 6: Range Chat showing Age, Period, Stage, Formations and Paleoenvironment

Sedimentology: Samples ranging in depths 1000ft - 6830ft (305m - 2080m) were used for Sedimentological description of Ogbabu-1 well in the Anambra Basin. The information derived aided in the construction of the lithologic log of the well section. This has provided a basis for understanding the Lithostratigraphy of the well section. The bulk of the lithologies encountered are shale, sandy shale, shaly sand and sand. Fourteen (14) lithologic zones was established. In each Lithologic zone, minerals were identified, this include: feldspar, mica and iron oxide. The Lithozones with reference depth are discussed below.

Lithozone 1
Reference Depth: 6500ft-6830ft
This zone is sandy shale, light grey coloured and fissile. The sand is brown coloured, friable, fine-medium grained, sub angular-sub rounded, poorly sorted and non-calcareous. There is little presences of carbonaceous material. Its thickness is 330ft. Minerals present within this zone are mica and iron oxide.

Lithozone 2
Reference Depth: 6380ft-6430ft
This zone is shale. The shales are light brown-dark grey coloured, fine and fissile. There is no sand here. Its thickness is 50ft. The minerals found within this zone is mica and iron oxide.
Lithozone 3

Reference Depth: 6030ft-6350ft
This zone is sandy shale, light grey coloured and fissile. The sand is brown coloured, friable, fine-medium grained, sub angular-sub rounded, poorly sorted and non-calcareous. There is little presences of carbonaceous material. Its thickness is 320ft. Minerals present within this zone are feldspar, mica and iron oxide.
Lithozone 4

Reference Depth: 5750ft-6010ft
This zone is shaly sand. The shales are dark grey coloured and fissile. The sand is friable, brown coloured, fine-medium grained, sub angular-sub rounded, moderately sorted and non-calcareous. The thickness is about 260ft. Minerals present in the zone are feldspar and mica.

Lithozone 5
Reference Depth: 5650ft-5730ft
This zone is shale. The shales are dark grey coloured, fine and fissile. There is no sand here. Its thickness is 80ft. The mineral found within this zone is mica. Carbonaceous materials are present.

Lithozone 6
Reference Depth: 5350ft-5630ft
This zone is shaly sand. The shales are dark grey coloured and fissile. The sand is friable, brown coloured, fine-medium grained, sub angular-sub rounded, moderately sorted and non-calcareous. The thickness is about 280ft. Minerals present in the zone are feldspar and mica.

Lithozone 7
Reference Depth: 2850ft-5330ft
This zone is shale. The shales are dark grey coloured, fine and fissile. There is no sand here. Its thickness is 2480ft. Carbonaceous materials are present. Minerals present within this zone are feldspar, mica.

Lithozone 8
Reference Depth: 2620ft-2780ft
This zone is sandy shale. The shales are dark grey coloured and fissile. The sand is milky white in color, friable medium-coarse grained, sub angular-angular, poorly sorted and non-calcareous. There is the presence of carbonaceous material. Its thickness is about 160ft. Minerals present within this zone are mica and iron oxide.

Lithozone 9
Reference Depth: 2240ft-2550ft
This zone is shale. The shales are dark grey coloured, fine and fissile. There is no sand here. Its thickness is 310ft. The minerals found within this zone is mica and iron oxide.
Lithozone 10

Reference Depth: 1920ft-2200ft
This zone is sandy shale, dark grey coloured and fissile. The sand is brown coloured, friable, fine-medium grained, sub angular-sub rounded, poorly sorted and non-calcareous. There is little presences of carbonaceous material. Its thickness is 280ft. Minerals present within this zone are feldspar and mica.

Lithozone 11
Reference Depth: 1740ft-1840ft
This zone is shaly sand. The shales are light grey coloured and fissile. The sand is friable, brown coloured, medium-coarse grained, sub angular-sub rounded, moderately sorted and non-calcareous. Its thickness is 100ft. Minerals present in the zone are feldspar and iron oxide.

Lithozone 12
Reference Depth: 1380ft-1600ft

This zone is shaly sand. The shales are light grey coloured and fissile. The sand are brown coloured, friable, medium-coarse grained, sub rounded, moderately sorted and calcareous. Its thickness is 220ft. Minerals present in this zone are mainly feldspar, mica and iron oxide.

Lithozone 13
Reference Depth: 1300ft
This zone is mainly sand, light grey coloured, friable, medium-coarse grained, angular -sub rounded, moderately - well sorted and is calcareous. The mineral present is mica. The thickness is about 40ft. From the physical characteristics (grain size, sorting and shape) of this sand body, the porosity tends to be relatively high. The presence of carbonate cement in this sand body can inhibit porosity. Depending on geochemical conditions of the sand body, secondary porosity can be generated by partial dissolving of the carbonate cements and some of the clastic components of the sand. Permeability decrease with decreasing particle size (owing to the decrease in pore diameters and increase in capillary pressures) and decreasing sorting. From the above description of this sand reservoir body, it may not allow the flow of fluid unless there is secondary porosity which will enhance permeability.

Lithozone 14
Reference Depth: 1000ft-1260ft
This zone is sandy shale. The shales are dark grey coloured and fissile. The sand are milky white, friable, medium grain, sub angular-sub rounded, poorly sorted and is non- Calcareous. Its thickness is 260ft. The minerals found within this zone is mica and iron oxide.

Palynostratigraphy: *Biozonation:* The biozonation by Ogbabu-1 well has been zoned using age diagnostic marker palynomorphs species of the recovered palynomorphs. Biozonation of the well section was established using zones defined by the first and last occurrences of two or more species. In defining the assemblage zones, well-known species was used as the principal characteristic element. Though some less well known forms with precise stratigraphic ranges in the sequence studied were also used where appropriate.

Age Division
Late Maastrichtian age (1000-3550ft) top of this zone is undefined because of absence of data but the base of the zone is defined by the last appearance datum of *Cingulatisporites ornatus* (3550ft).

Middle Maastrichtian age (4050ft-5080ft) established based on top of the zone and is marked by the base of preceding zone. The zone is also marked last appearance datum of *Classopollis spp.* (4930ft).

Early Maastrichtian age (5240ft-6600ft) established based on the last appearance datum of *Ctenolophonidites costatus* (6600ft) and the base is defined by the first appearance datum of *Constructipollenites ineffectus* (6600ft).
The absence of Danian diagnostic dinocysts especially *Damasadinium californicum* and *Carpatella cornatus* respectively suggest a Maastrichtian age for the well section between 1000ft-6600ft.

Campanian age (6700-6830ft) established based on the last appearance datum of *Triorites africaensis* (6700ft).
The formations likely penetrated by the well section is the Nkporo shale (Campanian) and the Mamu formation (Maastrichtian age).

Miospore Assemblage Zones: The miospore assemblage zones start from bottom to top of the section of the well studied and they have been defined based on the first and last occurrences of two or more pollen and spore.

The *Cingulatisporites ornatus* Assemblage Zone
Reference section: 1000ft- 3550ft
Age: Late Maastrichtian
Definition
The top of this zone is undefined because of absence of data but the base of the zone is defined by the last appearance datum of *Cingulatisporites ornatus* (3550ft). Events within this zone includes the occurrence of *Retidiporites magdalenensis, Syncolpites spp., Monoporites annulatus, Triorites spp., Ephedripites regularis, Syncolpites marginatus, Spinizonocolpites baculatus, Monosulcites spp., Echiperiporites trianguliformis, Longapertites marginatus, Sestrosporites pseudoalveolatus, Cyathides australis, Dictyophyllidits harrisii, Margocolpites sp., Laevigatosporites sp., Monocolpites marginatus, Cyperus sp., Milfordia jardinei, Retibrevitricolporites obodoensis, Leiotriletes adriennis, Periretisyncolpites sp., Proxapertites cursus, Dictyophyllidits spp.*

The *Classopollis spp.* Assemblage Zone
Reference Depth: 4050ft-5080ft
Age: Middle Maastrichtian

Definition: Top of the zone is marked by the base of preceding zone. The zone is also marked last appearance datum of *Classopollis spp.* (4930ft). Events within this zone includes *Retidiporites magdalenensis, Monoporites annulatus, Triorites spp., Syncolpites marginatus, Monosulcites spp., Longapertites marginatus, Cyathides australis, Trenocolpate pollen, Monocolpites marginatus, Echitricolporites spinosus, Alchornea spp., Constructipollenites ineffectus.*

The *Ctenolophonidites costatus* Assemblage Zone
Reference Depth: 5240ft-6600ft
Age: Early Maastrichtian

Definition: The top of this zone is defined by the last appearance datum of *Ctenolophonidites costatus (5240ft)* and the base is defined by the first appearance datum of *Constructipollenites ineffectus* (6600ft). Events within this zone are the occurrence of species such as *Longapertites marginatus, Milfordia jardinei, Monocolpites annulatus, Cingulatisporites ornatus, Monocolpites marginatus, Retidiporites magdalenensis, Triorites spp., Syncolpites spp.*

The *Triorites africaensis* Assemblage Zone
Reference Depth: 6700ft- 6830ft
Age: Campanian

Definition: The top of this zone is defined by the last appearance datum of *Triorites africaensis* (6700ft) and the base is defined by the first appearance datum of *Retidiporites magdalenensis* (6600ft). Other event within this zone is the occurrence of *Monocolpites annulatus* and *Cingulatisporites ornatus.*

DINOCYST ASSEMBLAGE ZONES
The *Paleocystodinium golzowense* Assemblage Zone
Reference Depth: 1560ft-3550ft

Definition: The top of this zone is not well defined due to lack of diagnostic dinocysts but the base of the zone is defined by the last appearance datum of *Paleocystodinium spp.* (3550ft). Other event within this zone is the occurrence of *Bitectatodinium tepikiense, Xenicodinium spp., Fibrocysta ovalis*, *Spiniferites Spp.*

The *Cerodinium magnificum* Zone
Reference Depth: 4050ft-4930ft

Defin*ition:* The top of this zone is defined by the last appearance datum of *Cerodinium magnificum* (4050ft) and the base of the zone is marked by the last appearance datum of *Kallosphaeridium spp.* (4930ft). Events within this zone include the occurrence of *Paleocystodinium golzowense, Spiniferites Spp., Hystrichodinium cf. ramoides, Pareodinia sp., Homotryblium tenuispinosum, Lingulodinium machaerophorum.*

The *Fibrocysta lappacea* Zone
Reference Depth: 5080ft-5750ft

Definition: The top of this zone is marked by the last appearance datum of *Fibrocysta lappacea* (5080ft). Events within this zone include the occurrence of *Bitectatodinium tepikiense, Xenicodinium spp., Paleocystodinium golzowense, Spiniferites Spp., Cerodinium magnificum, Lingulodinium machaerophorum, Kallosphaeridium spp., Leiosphaeridia sp., Lingulodinium sp.*

The *Dinogymnium acuminatum* Zone
Reference Depth: 5930ft-6830ft

Definition: The top of this zone is marked by the last appearance datum of *Dinogymnium acuminatum* (5930ft) and the base of the zone is marked by the first appearance datum of *Senegalinium psilatum* (6830ft). Events within this zone include the occurrence of *Paleocystodinium golzowense, Spiniferites Spp., Cerodinium magnificum, Lingulodinium machaerophorum, Fibrocysta lappacea, Cerodinium spp., Diphyes colligerum, Chytroeisphaeridia chytroeides, Paleohystrichophora infusoriodes, Caligodinium amiculum/ Senoniasphaera inornata, Hafniasphaera septata.*

Paleoenvironment: The use of palynomorph data has been used differently by various authors for paleoenvironment of deposition, these including the works of (Vadja-Santivanez, 1999; and Van Berger *et al*, 1990). However, relative abundance of terrestrially derived miospores compared to marine forms has been documented by Schrank, 1984; Ojo and Akande, (2001); Edet and Nyong, (1993, 1994); Lawal, 1982; and Ogala *et al*, (2009); Ola-Buraimo and Adeleye, (2010). Some Cretaceous sediments have been studied using dinoflagellates for the reconstruction of environments. The well section (1000ft – 6380ft) was delineated to be shallow marine environment. This environment is defined by a decrease in miospores (pollen and spores) abundances and an increase in Dinocysts abundance while moving down the well section. The litholog has mainly shale as its lithology, which is as a result of quite environmental conditions. The minerals

found with the well section are feldspar, mica and iron oxide.

Conclusion: The Palynological analysis of Ogbabu-well was used to determine the age and paleoenvironment of the studied section, it has indicated a shallow marine sedimentation in an Anambra basin of a Campanian to Late Maastrichtian sedimentary unit which is characterized with transgressive and regressive events as reflected from the abundance and diversity of Miospore (pollen and spores) and Dinoflagellates that was recorded.

Palynological slides analysis of Ogbabu-1 well yielded about six hundred and sixty one (661) palynomorphs species. Five hundred and eighty five (585) were Miospore (pollen and spore) and seventy six (76) Dinocysts.

Fourteen (14) lithologic zones was established. The bulk of the lithologies encountered are shale, sandy shale, shaly sand and sand. In each Lithologic zone, minerals were identified, this include: feldspar, mica, iron oxide. The identified minerals were used to argument the palynomorphs recovered to establish paleoenvironment.

Age division of the well section ranges from Campanian to Late Maastrichtian. Late Maastrichtian age (1000-3550ft) top of this zone is undefined because of absence of data but the base of the zone is defined by the last appearance datum of *Cingulatisporites ornatus* (3550ft). Middle Maastrichtian age (4050ft-5080ft) established based on top of the zone is marked by the base of preceding zone. The zone is also marked last appearance datum of *Classopollis spp.* (4930ft). Early Maastrichtian age (5240ft-6600ft) established based on the last appearance datum of *Ctenolophonidites costatus* (6600ft) and the base is defined by the first appearance datum of *Constructipollenites ineffectus* (6600ft). Campanian age (6700-6830ft) established based on the last appearance datum of *Triorites africaensis* (6700ft). The well section (1000ft – 6380ft) was delineated to be shallow marine environment.

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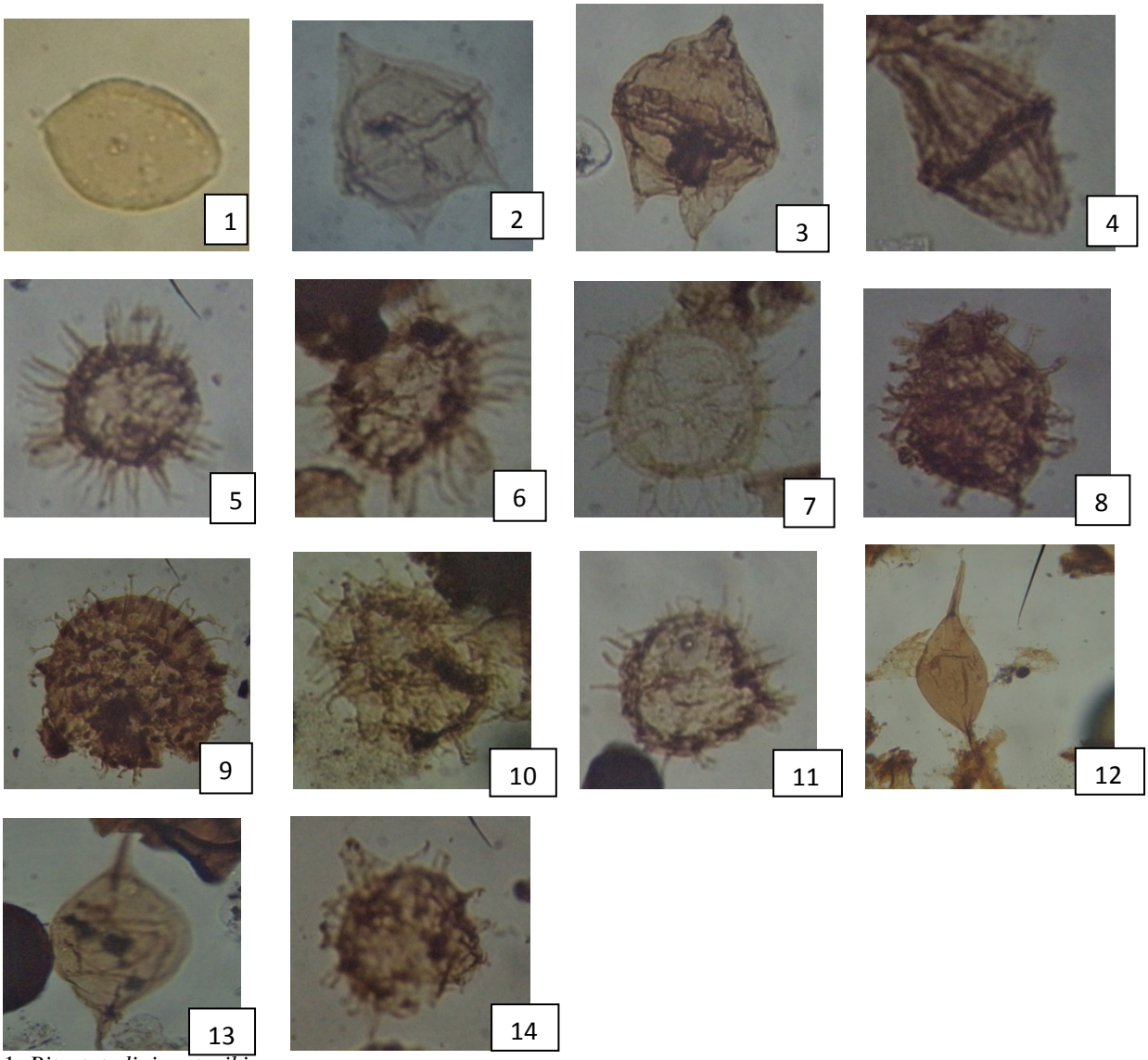
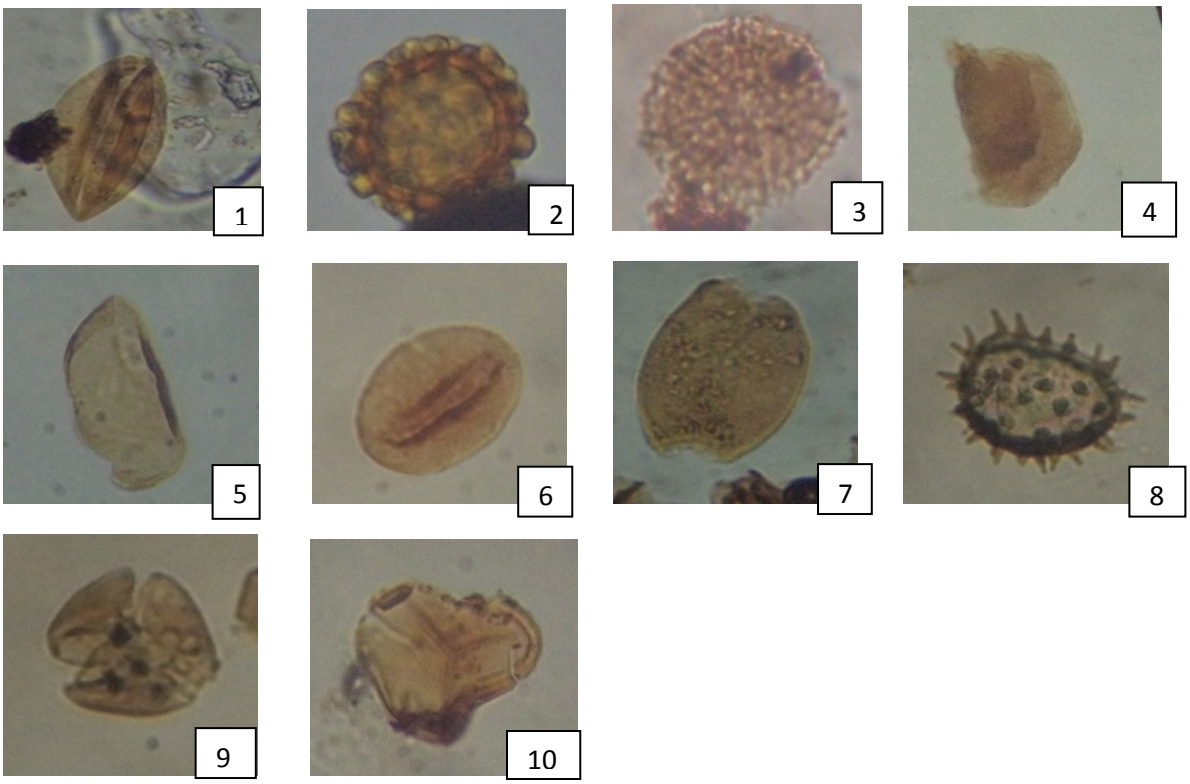
PLATE 1



1. *Bitectatodinium tepikiense*
2-3. *Cerodinium magnificum*
4. *Dinogymnium sp.*, Habib and Drugg, 1987
5-6. *Diphyes colligerium*, Deflandre and Cookson, 1955
7. *Fibrocysta ovalis*, Hansen, 1977
8. *Fibrocysta sp*., Stover and Evitt, 1978
9. *Hafniasphaera septata*, Cookson and Eisenack, 1967
10. *Homotryblium tenuispinosum*, Davey, *et al*., 1966
11. *Lingulodinium machaerophorum*, Deflandre and Cookson, 1955
12-13. *Paleocystodinium golzowense*, Alberti, 1961
14. *Spiniferites sp.*

(All magnification at X400)

PLATE 2:



1. *Alchornea sp*.
2. *Cingulatisporites ornatus*, Van Hoeken-Klinlenberg, 1964
3. *Constructipollenites ineffectus*, Van Hoeken-Klinkenberg, 1964
4. *Longapertites marginatus*, Van Hoeken-Klinkenberg, 1964
5. *Longapertites Vaneedenburgi*, Germeraad, Hopping and Muller, 1968.
6. *Monocolpites marginatus*, Van der Hammen, 1954
7. *Retidiporites magdalenensis*, Van der Hammen and Garcia de Mutis, 1966
8. *Spinizonocolpites baculatus*, Muller, 1968
9. *Syncolporites marginatus*
10. *Triorites africaensis*, Jardine and Magloire, 1965

(All magnification at X400)

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