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Palynofacies Studies of Sedimentary Succession in Ogbabu-1 well, Anambra Basin, Nigeria.

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ABSTRACT: Palynofacies studies of sedimentary succession in Ogbabu-1 well was carried out on ninety (90) ditch cutting samples retrieved from Ogbabu-1 well in Anambra Basin, Lower Benue trough, Nigeria with the aim of giving a detailed palynofacies study of the Ogbabu-1 Well, Anambra Basin using sedimentology and palynology as geologic tools. This was achieved by identifying the various palynological materials present and recognition of the various groups by taking counts of each specie, which aided in source rock evaluation as well as knowing the kerogen type. The identified minerals obtained from the sedimentological analysis were used to argument data from palynological analysis to carryout paleoenvironmental reconstruction. The samples ranged in depths 1000ft - 6830ft (305m - 2080m). The samples were subjected to sedimentological and palynofacies analysis. The hydrocarbon bearing formation and the spore colour index was noted. The sedimentological analysis of the ditch-cuttings was used to identify seven (7) palynofacies zones. The bulk of the lithologies encountered are shale, sand, sandy shale and shaly sand. In each palynofacies zone, most of the minerals identified include feldspar, iron oxide and mica. Two main environment of deposition delineated from palynofacies analysis are: shelfal and shallow marine environments. The shelfal environment is characterized by the occurrence of terrestrial woody plant/debris and relatively abundant of miospores. The shallow marine environment is characterized by occurrence of dinoflagellate cysts and foraminifer's test- lining. The palynofacies analysis suggest there is relatively higher frequency of the land phytoclast, amorphous and miospores compared to marine palynomorphs abundance, which suggests a shelfal/ shallow marine environment. The spore colour index of the source rock is 4.5 which is immature to generate hydrocarbon and the kerogen suggested for this Well section is type III. ©JASEM

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***Keywords*:** Palynofacies, Kerogen, Sedimentology, Phytoclast, Palynomorph and Anambra Basin.

The science of palynology introduced by coal petrologist in the 19th century has grown over the years and is widely used in the oil industry today (Hopping, 1967). The science started modestly with detailed studies of ancient pollen grains and spores but today has expanded to include detailed particulate organic matter investigation for palynofacies analysis.

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

Palynofacies is a relatively new aspect of palynology. The term connotes the global microscopic image of the organic constituents of the rock after proper carrying out of maceration and mounting under standard conditions of preparation. In other words, palynofacies involves the examination of the total acid insoluble component of sedimentary samples (outcrops, cores or ditch cuttings) with focus on the constituent elements, their proportions, diversity of palynomorph types, sorting and size characteristics and evidence for biological and physical degradation.

Palynofacies investigations have been carried out in many sedimentary basins in different parts of the world to improve on the quality of information and to ease exploration problems. Much has been done in the Anambra Basin of Nigeria. Its application is chiefly directed towards paleoenvironmental and biostratigraphic investigations but it is also usefully applied as an organic maturation tool (Bustin, 1988; Oyede, 1992).

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.

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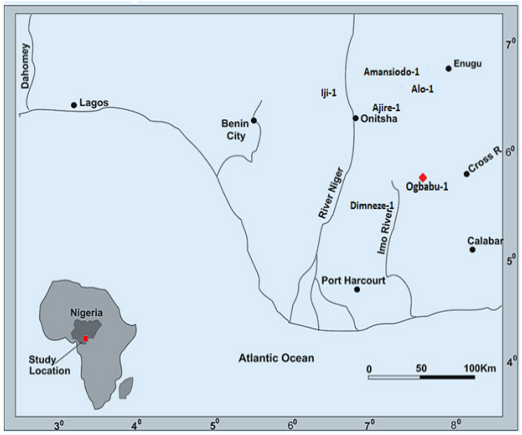


Fig 1: Map showing Ogbabu-1 well, Anambra Basin.

MATERIALS AND METHOD

Thirty-five (35) ditch cutting samples collected from Ogbabu-1 well were prepared and labeled to indicating the depth in the well. The materials used for carrying out this research work include:

Ditch cutting sample, electric hot plate with temperature control, binocular microscope with camera, aluminum pie dishes, glass beakers, iron mortar, steel block and hammer for crushing, glass bottles, slides labels, a transmitted light microscope, bunsen burner, tripod and ring stand, petri ditches, picking pin, striker and beaker tongs, plastic and glass stirring rods, polyethylene bags for sample storage, pipette and eye droppers, rubber gloves, pencil glass marker, glass coverslips, relevant reference material/literature.

Chemical reagents, acetic glacial acid (conc.) (CH_3COOH), acetic anhydride [$(CH_3CO)_2O$], acetone [$(CH_3)_2CO$], ammonium hydroxide (conc.) (NH_4OH), zinc Bromide (ZnBr), glycerin ($C_3H_8O_3$), hydrochloric acid (HCl), hydrofluoric acid (HF), sulfuric acid (H_2SO_4), nitric acid (HNO_3), potassium hydroxide (KOH), safranin ($C_{20}H_{19}ClN_4$) and bismark Brown ($C_{21}H_{24}N_8$).

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 palynofacie slides.

Palynofacies Sample Preparation: The sample preparation was carried out following the international standards given below:
10g of crushed samples was collected and tested for limestone ($CaC0_3$) using HCl, while effervescence was produced, the limestone was eliminated by further 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 matters 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

Ogbabu-1 well, is 6830ft deep and available ditch cuttings extend from 1000ft to 6830ft. The stratigraphic succession penetrated by this well is made up of siliciclastic sediments which is largely composed of shale. Figure 2 shows the lithostratigraphic succession of the part of Anambra basin as encountered by the Ogbabu-1 well.

The oldest sediment encountered by this well is composed of fine fissile sandy shale and it extends from 6530 to 6830 ft. This group of sandy fissile shales show alternation of colour between light grey and dark grey, this change in colour is as a result of changes in the oxidation level at the time of deposition. This is overlain by brown fine fissile shale extending from 6380ft to 6530ft; this suggests

that there was a drop in the energy of deposition as indicated by a decrease in grain size. An increase in the energy of deposition then led to the deposition of fine fissile sandy shale which extends from 6030ft to 6380ft. A further increase in the energy of deposition resulted in the deposition of an intercalation of dark fine fissile shale and fine to medium grained shaly sand, this extends from 5350ft and 6030ft. This is then overlain by dark fine fissile shale which extends from 2780ft to 5330ft showing a decrease in the energy of deposition, this is overlain by an intercalation of fine fissile shale and fine fissile sandy shale this extends from 2080ft to 2850ft. A further increase in the energy of deposition led to the deposition of an intercalation of medium to coarse shaly sand and it extends from 1380ft to 2040ft. The youngest sediments composed of sandy shale extends from 1000ft to 1380ft.

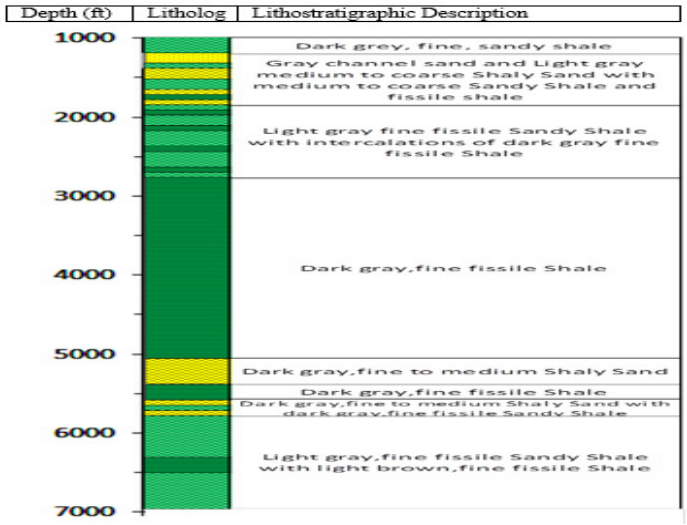


Fig 2: Lithologic Log of Ogbabu-1 well.

Palynofacies Description and Distribution: The palynofacies constituents identified from the 35 analysed samples can be classified according to their biological origin. Continental fragments constitute the allochthonous fraction and they include: miospores (pollen grains and spores), amorphous (resins and microbial mats) and phytoclasts (cuticles, membrane, biostructured, non-biostructured and fungal hyphae). The marine palynomorphs represent the anthochthonous fraction and these are dinoflagellates cysts and foraminiferal test-linings.

Examination of the total palynofacies characteristics produces an estimate of the relative proportion of the various components of the particulate organic matter present.

The well was divided into seven Palynofacies zones based on the textural properties of the sediments. A relative proportion of the particulate organic constituent was analysed and the results are displayed as follows:

Palynofacies Zone 1
Reference Depth: 1000ft – 1840ft
This zone is the youngest and the distribution of organic matter identified is shown below.

Table 1: Distribution of Organic Matter in Palynofacie Zone 1.

	Amorphous Organic Matter			Phytoclasts					Palynomorphs				
Depth (ft.)	Amorphous	Resins	Microbial mat	Phytoclasts	Cuticles	Membrane	Biostructured	Non-biostructured	Palynomorphs	Spores	Pollen	Dinocysts	Foraminiferal test-lining
1000	24	2	4	9	2	0	3	4	18	2	7	9	0
1260	120	6	8	209	18	0	16	175	57	3	47	6	1
1560	33	8	1	43	4	0	9	30	30	8	19	3	0
1840	101	23	2	125	13	1	13	98	36	0	25	11	0

Table 2: A classification of the palynomorphs in palynofacies zone 1, to the terrestrial sourced (Spores and Pollens) and marine source (Dinocysts) showing percentage distribution.

Depth	Terrestrial		Marine	Total	%Terrestrial	%Marine
	Spores	Pollen	Dinocysts			
1000	2	7	9	18	50%	50%
1260	3	47	6	56	90%	10%
1560	8	19	3	30	69%	31%
1840	0	25	11	36	67%	33%
Total	13	98	29	140	79%	21%

Palynofacies Zone 2

Reference Depth: 2080ft -2750ft

Table 3: Distribution of Organic Matter in Palynofacie Zone 2

Depth (ft)	Amorphous Organic Matter			Phytoclasts					Palynomorphs				
	Amorphous	Resins	Microbial mat	Phytoclasts	Cuticles	Membrane	Biostructured	Non-biostructured	Palynomorphs	Spores	Pollen	Dinocysts	Foraminiferal test-lining
2080	9	1	0	11	0	1	2	8	9	1	5	3	0
2240	13	1	0	58	3	1	8	46	22	2	15	5	0
2300	11	3	0	52	0	0	0	52	16	2	11	3	0
2480	13	5	1	107	2	0	12	93	44	4	35	5	0
2620	13	5	1	93	16	0	10	67	38	2	35	1	0
2750	63	6	0	145	7	0	11	127	66	10	55	1	0

Table 4: A classification of the palynomorphs in palynofacies zone 2, to the terrestrial sourced (Spores and Pollens) and marine source (Dinocysts) showing percentage distribution

Depth	Terrestrial		Marine	Total	%Terrestrial	%Marine
	Spores	Pollen	Dinocysts			
2080	1	5	3	9	77%	23%
2240	2	15	5	22	81%	19%
2300	2	11	3	16	89%	11%
2480	4	35	5	44	97%	3%
2620	2	35	1	38	98%	2%
2750	10	55	1	66	100%	0%
Total	21	156	18	195	91%	9%

Palynofacies Zone 3

Reference Depth: 2850ft -5240ft

Table 5: Distribution of Organic Matter in Palynofacie Zone 3

Depth(ft)	Amorphous Organic Matter			Phytoclasts					Palynomorphs				
	Amorphous	Resins	Microbial mat	Phytoclasts	Cuticles	Membrane	Biostructured	Non-biostructured	Palynomorphs	Spores	Pollen	Dinocysts	Foraminiferal test-lining
2850	19	1	0	50	0	0	5	45	25	0	25	0	0
3050	49	5	0	113	5	0	9	99	60	9	46	5	0
3250	32	1	0	96	1	0	8	87	42	5	32	5	0
3550	35	5	0	67	0	0	7	60	35	4	25	6	0
4050	20	6	1	15	0	0	2	13	24	1	17	6	0
4230	10	3	0	22	1	0	2	19	16	1	15	0	0

4350	21	3	0	56	1	0	1	54	32	4	20	8	0
4630	22	8	0	22	0	0	0	22	24	0	21	3	0
4750	36	13	0	39	1	0	0	38	31	0	25	6	0
4930	38	5	0	47	2	0	3	42	34	2	28	4	0
5080	4	0	0	3	0	0	1	2	11	2	8	1	0
5240	2	0	0	10	0	0	0	10	12	2	8	2	0

Table 6: A classification of the palynomorphs in palynofacies zone 3, to the terrestrial sourced (Spores and Pollens) and marine source (Dinocysts) showing percentage distribution

Depth	Terrestrial		Marine	Total	%Terrestrial	%Marine
	Spores	Pollen	Dinocysts			
2850	0	25	0	25	92%	8%
3050	9	46	5	60	88%	12%
3250	5	32	5	42	83%	17%
3550	4	25	6	35	75%	25%
4050	1	17	6	24	100%	0%
4230	1	15	0	16	75%	25%
4350	4	20	8	32	88%	13%
4630	0	21	3	24	81%	19%
4750	0	25	6	31	88%	12%
4930	2	28	4	34	91%	9%
5080	2	8	1	11	83%	17%
5240	2	8	2	12	80%	20%
Total	35	270	46	351	87%	13%

Palynofacies Zone 4

Reference Depth: 5650ft -5930ft

Table 7: Distribution of Organic Matter in Palynofacie Zone 4

Depth(ft)	Amorphous Organic Matter			Phytoclasts					Palynomorphs				
	Amorphous	Resins	Microbial mat	Phytoclasts	Cuticles	Membrane	Biostructured	Non-biostructured	Palynomorphs	Spores	Pollen	Dinocysts	Foraminiferal test-lining
5650	5	2	0	9	0	0	0	9	10	0	8	2	0
5730	14	4	0	28	0	0	3	25	32	2	29	1	0
5750	19	7	0	34	0	0	2	32	23	3	15	5	0
5930	17	8	0	18	0	0	1	17	14	2	10	2	0

Table 8: A classification of the palynomorphs in palynofacies zone 4, to the terrestrial sourced (Spores and Pollens) and marine source (Dinocysts) showing percentage distribution

Depth	Terrestrial		Marine	Total	%Terrestrial	%Marine
	Spores	Pollen	Dinocysts			
5650	0	8	2	10	97%	3%
5730	2	29	1	32	78%	22%
5750	3	15	5	23	86%	14%
5930	2	10	2	14	65%	35%
Total	7	62	10	79	88%	12%

Palynofacies Zone 5

Reference Depth: 6030ft -6330ft

Table 9: Distribution of Organic Matter in Palynofacie Zone 5

Depth(ft)	Amorphous Organic Matter			Phytoclasts					Palynomorphs				
	Amorphous	Resins	Microbial mat	Phytoclasts	Cuticles	Membrane	Biostructured	Non-biostructured	Palynomorphs	Spores	Pollen	Dinocysts	Foraminiferal test-lining
6030	6	2	0	13	1	0	1	11	20	0	13	7	0
6210	5	1	0	10	0	0	0	10	9	1	7	1	0
6330	8	4	0	5	0	0	0	5	6	0	4	2	0

Table 10: A classification of the palynomorphs in zone 5, to the terrestrial sourced (Spores and Pollens) and marine source (Dinocysts) showing percentage distribution

Depth	Terrestrial		Marine	Total	%Terrestrial	%Marine
	Spores	Pollen	Dinocysts			
6030	0	13	7	20	89%	11%
6210	1	7	1	9	67%	33%
6330	0	4	2	6	100%	0%
Total	1	24	10	35	71%	29%

Palynofacies Zone 6

Reference Depth: 6380ft -6500ft

Table 11: Distribution of Organic Matter in Palynofacie Zone 6

Depth(ft)	Amorphous Organic Matter			Phytoclasts					Palynomorphs				
	Amorphous	Resins	Microbial mat	Phytoclasts	Cuticles	Membrane	Biostructured	Non-biostructured	Palynomorphs	Spores	Pollen	Dinocysts	Foraminiferal test-lining
6380	0	0	0	0	0	0	0	0	1	0	1	0	0
6500	1	0	0	0	0	0	0	0	8	0	8	0	0

Table 12: A classification of the palynomorphs in zone 6, to the terrestrial sourced (Spores and Pollens) and marine source (Dinocysts) showing percentage distribution

Depth	Terrestrial		Marine	Total	%Terrestrial	%Marine
	Spores	Pollen	Dinocysts			
6380	0	1	0	1	100%	0%
6500	0	8	0	8	93%	7%
Total	0	9	0	9	100%	0%

Palynofacies Zone 7
Reference Depth: 6600ft -6830ft
Table 13: Distribution of Organic Matter in Palynofacie Zone 7

Depth(ft)	Amorphous Organic Matter			Phytoclasts					Palynomorphs				
	Amorphous	Resins	Microbial mat	Phytoclasts	Cuticles	Membrane	Biostructured	Non-biostructured	Palynomorphs	Spores	Pollen	Dinocysts	Foraminiferal test-lining
6600	23	3	0	42	3	0	8	31	30	5	23	2	0
6700	0	0	0	0	0	0	0	0	1	0	1	0	0
6830	12	4	0	9	1	0	0	8	19	1	12	5	1

Table 14: A classification of the palynomorphs in zone 7, to the terrestrial sourced (Spores and Pollens) and marine source (Dinocysts) showing percentage distribution

Depth	Terrestrial		Marine	Total	%Terrestrial	%Marine
	Spores	Pollen	Dinocysts			
6600	5	23	2	30	100%	0%
6700	0	1	0	1	72%	28%
6830	1	12	5	18	72%	28%
Total	6	36	7	49	85%	14%

PLATE 1
Palynofacies zone 1 (1000ft-1840ft)

A- Amorphous organic matter = 34%
B- Phytoclasts = 48%
C- Miospores = 14%
D- Dinocysts= 4%

1. Miospores, biostructured phytoclast and woody cuticles
2. Amorphous organic materials
3. Foraminiferal test-lining
4. Biostructured phytoclast
5.

Colour code for Particulate Organic Matter:
Spore Colour Index = 4.5
Terrestrial Woody material = 10
All other Particulate organic matter = 4.5

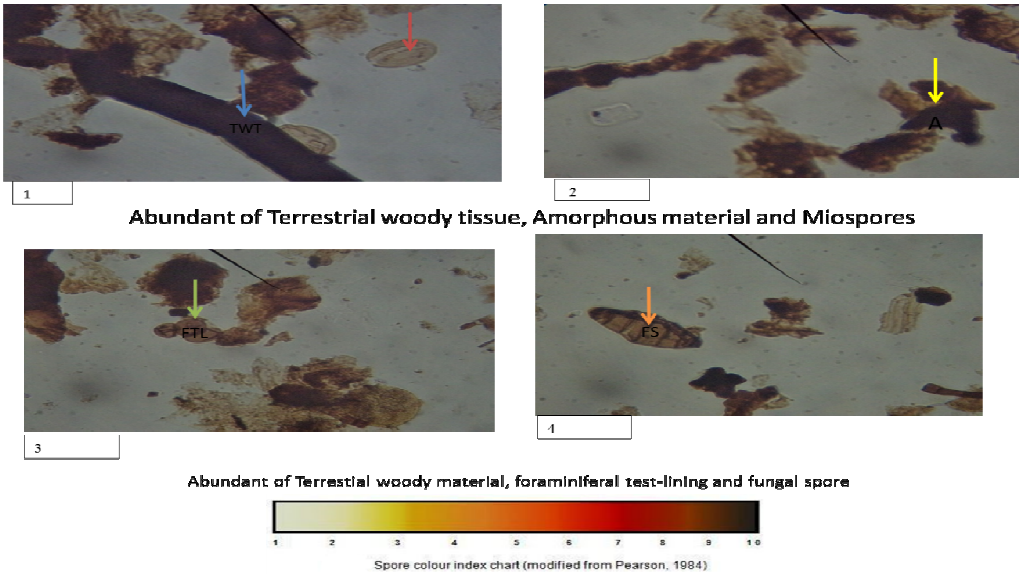


PLATE 2

Palynofacies zone 2 (2080ft-2750ft)

A- Amorphous organic matter = 16%
B- Phytoclasts = 60%
C- Miospores = 23%
D- Dinocysts= 2%

1. Miospores and biostructured phytoclast
2. Cuticles, miospores and biostructured phytoclast
3. Miospores, biostructured and non-biostructured phytoclast
4. Miospores, biostructured and non-biostructured phytoclast

Colour code for Particulate Organic Matter:

Spore colour index = 4.5
Woody material = 10
All other Particulate organic matter = 4.5

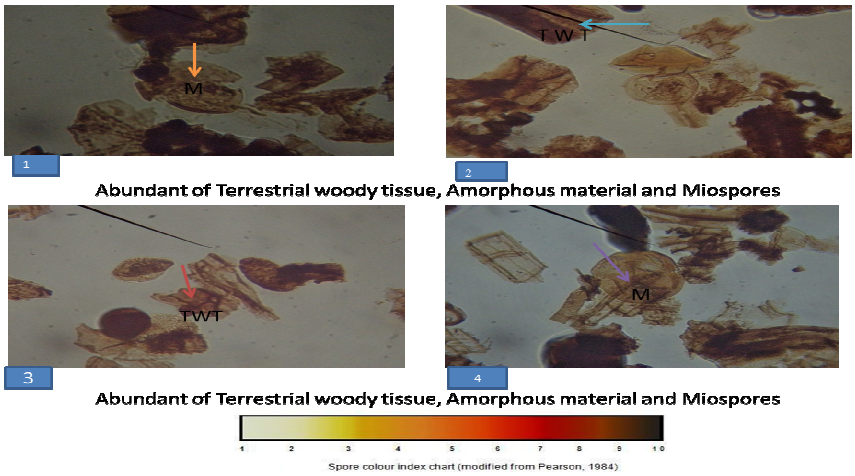


PLATE 3

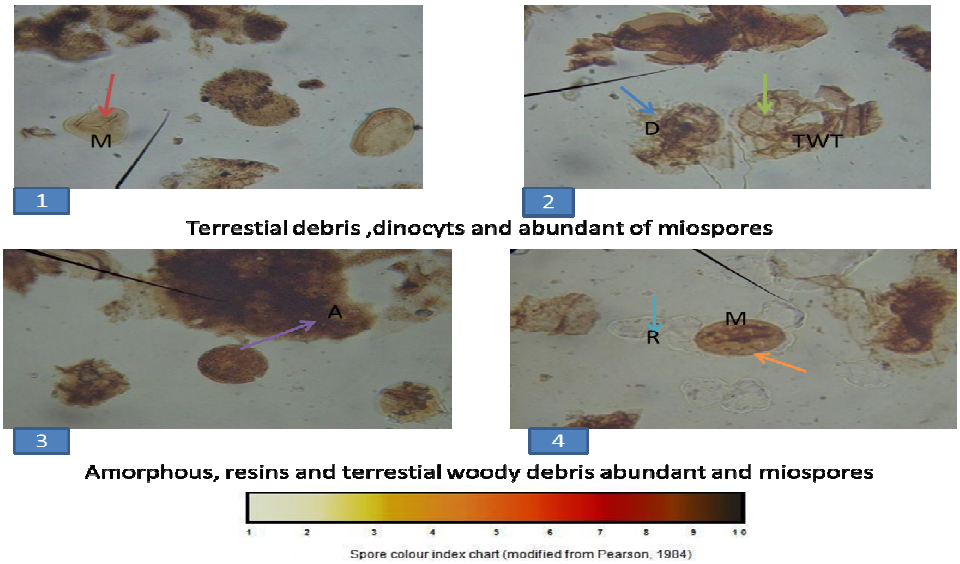
Palynofacies zone 3 (2850ft-5240ft)

A- Amorphous organic matter = 26%
B- Phytoclasts = 48%
C- Miospores = 23%
D- Dinocysts= 3%

1. Miospores and amorphous organic matter
2. Dinocyst, miospores, non-biostructured and biostructured phytoclast
3. Miospores and amorphous organic matter
4. Resin, miospores and non-biostructured phytoclast

Colour code for Particulate Organic Matter:

Spore colour index = 4.5
Woody material = 10
All other Particulate organic matter = 4.5



The studied area Ogbabu-1 Well can be classified into seven (7) major palynofacies zones types on the basis of the abundance (Particulate Organic Matter) groups .They include from oldest to youngest as follow:

Palynofacies Zone 7: 6600ft-6840ft (Phytoclast, AOM and Palynomorphs) This zone is the oldest one ranging from depth 6600ft-6840ft which is at the base of the well section in the study area. It is characterized by frequent phytoclast materials, frequent amorphous organic matter (AOM) and frequent to rare palynomorphs. The phytoclast consist mostly of moderately to well preserve biostructured to non-biostructured terrestrial plant fragments with dark to brown colour (e.g., tracheids, xylem tissues and cuticles). Tracheids are the most common structured phytoclast constituents usually in the form of elongate lath-shaped particles.

Kerogen Type 111: Based on the presence of high frequent of dark to brown phytoclast and frequent of amorphous organic matter (AOM) and yellow to yellowish colouration of palynomorphs, a gas-prone material is suggested for this zone.

Palynofacies Zone 6: 6380ft-6500ft (Palynomorphs) This palynofacies zone ranges from depth 6380ft-6500ft and overlies the oldest palynofacies zone which is at the base of the well section in the study area. It is characterized by common to rare palynomorphs.

Kerogen Type 111: Based on the presence of common to rare miospores (pollen) of yellow colouration, a gas-prone material is suggested for this zone.

Palynofacies Zone 5: 6030ft-6330ft (Phytoclast, AOM and Palynomorphs) This palynofacies zone ranges from depth 6030ft-6330ft and overlies palynofacies zone 6 which is at the well section in the study area. It is characterized by common to rare phytoclast, amorphous organic matter and palynomorphs.

Kerogen Type 111: Based on the presence of common to rare phytoclast, AOM of dark to brown and palynomorphs of yellow to yellowish colouration, a gas-prone material is suggested for this zone.

Palynofacies Zone 4: 5650ft-5930ft (Phytoclast, AOM and Palynomorphs) This palynofacies zone ranges from depth 5650ft-5930ft and overlies palynofacies zone 5 which is at the well section in the study area. It is characterized by frequent phytoclast, AOM and palynomorphs. The phytoclasts consist mostly of moderately to well preserve biostructured to non-biostructured terrestrial plant fragments with dark to brown colour (e.g., tracheids, xylem tissues and cuticles). Tracheids are the most common structured phytoclast constituents usually in the form of elongate lath-shaped particles.

Kerogen Type 111: Based on the presence of phytoclast, AOM of dark to brown and palynomorphs of yellow to yellowish colouration, a gas-prone material is suggested for this zone.

Palynofacies Zone 3: 2850ft-5240ft (Phytoclast, AOM and Palynomorphs) This palynofacies zone ranges from depth 2850ft-5240ft and overlies palynofacies zone 4 which is at the well section in the study area. It is characterized by frequent phytoclast, AOM and palynomorphs. . The phytoclasts consist mostly of moderately to well preserve biostructured to non-biostructured terrestrial plant fragments with dark to brown colour (e.g., tracheids, xylem tissues and cuticles). Tracheids are the most common structured phytoclast constituents usually in the form of elongate lath-shaped particles.

Kerogen Type 111: Based on the presence of phytoclast, AOM of dark to brown and palynomorphs of yellow to yellowish colouration, a gas-prone material is suggested for this zone.

Palynofacies Zone 2: 2080ft-2750ft (Phytoclast, AOM and Palynomorphs) this palynofacies zone ranges from depth 2080ft-2750ft which is on top of palynofacies zone 3 at the well section in the study area. It is characterized by frequent phytoclast, AOM and palynomorphs. . The phytoclasts consist mostly of moderately to well preserve biostructured to non-biostructured terrestrial plant fragments with dark to brown colour (e.g., tracheids, xylem tissues and cuticles). Tracheids are the most common structured phytoclast constituents usually in the form of elongate lath-shaped particles.

Kerogen Type 111: Based on the presence of phytoclast, AOM of dark to brown and palynomorphs of yellow to yellowish colouration, a gas-prone material is suggested for this zone.

Palynofacies Zone 1: 1000ft-1840ft (Phytoclast, AOM and Palynomorphs) This palynofacies zone ranges from depth 1000ft-1840ft and overlies palynofacies zone 2, this zone is the youngest one which is at the top most part of the well section in the study area. It is characterized by frequent phytoclast, AOM and palynomorphs. . The phytoclasts consist mostly of moderately to well preserve biostructured to non-biostructured terrestrial plant fragments with dark to brown colour (e.g., tracheids, xylem tissues and cuticles). Tracheids are the most common structured phytoclast constituents usually in the form of elongate lath-shaped particles

Kerogen Type 111: Based on the presence of phytoclast, AOM of dark to brown and palynomorphs of yellow to yellowish colouration, a gas-prone material is suggested for this zone.

Paleoenvironmental Reconstruction: Lithologies penetrated by the well section were shale, sandy shale, shaly sand and sand. The minerals identified Mica, feldspar and iron oxide has been used to infer depositional environment. Two (2) main environments of deposition have been delineated based on palynofacies studies these are: Shelfal and Shallow marine environments.

Petroleum Potentials of the Basin: The different kerogen components and its distribution throughout the studied sequence starting from the oldest to youngest shows a normal terrestrially influenced organic matter down the well section to a high terrestrially dominant organic matter towards the top. However, the studied well section was subdivided and grouped into seven palynofacies zone based on these changes in organic facies constituents. Palynofacies zone 5, 6 and 7 constitutes the middle to lower parts of the section and is mainly composed of both biostructured and non biostructured phytoclasts, frequent amorphous organic matter (AOM). Marine and terrestrially derived palynomorphs were also observed and recorded for this zones. Palynofacies zone 1, 2, 3, and 4 characterizes the upper part of the well section and predominantly consists of dark to brown phytoclasts and amorphous organic matter. Terrestrial palynomorphs were also encountered as well as marine palynomorph was observed. Following the kerogen classification scheme of Tyson R.V 1993, a type 3 kerogen (gas-prone material) was interpreted for Palynofacies Zone 1 to 7. Spore colour index (Pearson 1984) spore/pollen colour standard calibration together with other thermal maturity parameters as documented by (Waples, 1985) was employed to theoretically estimate the vitrinite reflectance (Ro%) and thermal alteration index (TAI) values. The pollen colour observed generally ranged from pale yellow to yellowish colouration in palynofacies zone 1 to 7. Therefore, these correspond to TAI of 2.0 to 2.15 and vitrinite reflectance (Ro %) of 0.40 to 0.45 / 0.5 for all the palynofacies zones.

Finally, the studied sediments, therefore, contain particulate organic matter (POM) that is still immature to generate hydrocarbon but have the potential capacity to generate gas. This is reflected in Table 15.

Table 15: Generalized Correlation of Different Maturity Indices (Waples, 1985)**.**

Vitinite Reflectance (%R_0)	Spores Coloration Index (SCI)	Thermal Alteration Index (TAI)	Pyrolysis T_{max}(°C)	Generalized Hydrocarbon Zone
0.40	4.0	2.0	420	Immature
0.50	5.0	2.3	430	Immature
0.60	6.0	2.6	440	Oil
0.80	7.4	2.8	450	Oil
1.00	8.1	3.0	460	Oil
1.20	8.3	3.2	465	Oil and wet gas
1.35	8.5	3.4	470	Wet gas
1.50	8.7	3.5	480	Wet gas
2.00	9.2	3.8	500	Methane
3.00	10	4.0	500+	Methane
4.00	10+	4.0	500+	Over mature

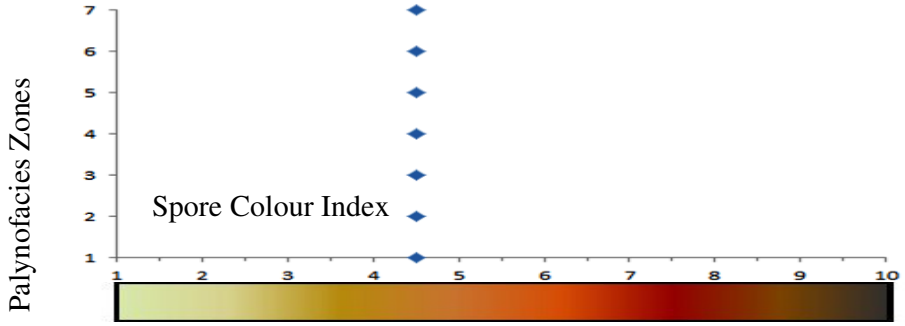


Fig 3: Spore colour index chart (modified from Pearson, 1984)

Conclusion: The sedimentological section of the studied well reveals the occurrence of shales and sands intercalation with shales. This sedimentological log was grouped into seven palynofacies zones. The minerals identified were mica, feldspar and iron oxide, these were used to infer depositional environment. Two environments of deposition were delineated based on palynofacies studies these are: Shelfal and Shallow marine environments.

Palynofacies analysis helped in the evaluation of source rock (kerogen types) using characteristics of palynomorphs present in the rock samples as well as the nature of the various organic constituents. The palynofacies zones reveals that the area under study is generally made of Type III Kerogen with an abundance of Terrestrial woody plant materials and abundance of miospores which is mainly from continental.

The well section under study also revealed that the sediments (shale) of the Upper Cretaceous in the Anambra Basin has pollen colours that ranged from yellow to yellowish brown which also corresponds to the thermal alteration index of 2.0 + to 2.15-2.3, with vitrinite reflectance (Ro %) of 0.4 to 0.45/0.5 for the palynofacies zone 1-7. The kerogen quality as identified from the phytoclast and amorphous organic matter dominant facies indicate that the studied area is of type III, meaning that they are gas prone. Based on the particulate organic matter, the thermal maturation of the studied section is still immature to generate hydrocarbon but has the potential of generating gas.

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REFERENCES

Bustin, RM (1988). Sedimentology and characteristics of dispersed organic matter in Tertiary Niger Delta: origin of source rocks in a deltaic environment. *AAPG* Bulletin. 72(3): 277-298.

Hopping, CA (1967). Palynology and Oil Industry. *Review of Paleobotany and Palynology*. 2: 23-48.

Kogbe, CA (1974). The Cretaceous and Paleogene Sediments of Southern Nigeria: In: Kogbe, CA

(Eds.), Geology of Nigeria. *Elizabethan Publ*., Lagos, Nigeria. 273-286.

Ladipo, KO; Nwajide, CS; Akande, SO (1992). Cretaceous and Paleogene Sequences in the Abakaliki and Anambra Basins, Southeastern Nigeria. A fields Guide. *Int. Symp. on Geology of Deltas*, Port Harcourt, Nigeria. 39p.

Ladipo, KO; Ekweozor, C; Nwajide, CS (2001). Geological Field Trip to the Anambra Basin and the Lokpanta Oil Shale, *NAPE Conference*, Port Harcourt.

Lucas, FA; Ishiekwene, E (2010). Miospore (Pollen and Spore) Biozonation Model for Late Cretaceous – Tertiary Succession of Gbekebo-l Well, Benin Flank, Anambra Basin, Nigeria. *World J. of Appl. Sci. and Technol*. 2(2): 303 – 308.

Obaje, NG; Attah, DO; Moumount, A (2006). Geochemical Evaluation of Hydrocarbon Prospects of Sedimentary Basins in Northern Nigeria. *Geochem. J*. 40: 227-243.

Obi, GC; Okogbue, CO (2004). Sedimentary Response to Tectonism in the Campanian-Maastrichtian Succession, Anambra Basin, Southeastern Nigerian. *J. of Afric. Earth Sci*. 38: 99-108.

Oyede, AC (1992). Palynofacies in Deltaic Stratigraphy, *Nig. Ass. of Petr. Expl. Bulletin*. 7(1): 10-16.

Pearson, DL (1984). Pollen/Spore Colour-Standard, Version 2. Phillips Petroleum Company privately distributed.

Reyment, RA (1965). Aspect of the Geology of Nigeria. *University of Ibadan Press*, Nigeria. 145p.

Short, KC; Stauble, AJ (1967). Outline of Geology of Niger Delta. *AAPG Bulletin*. 51(5): 761-779.

Tyson, RV (1995). Sedimentary Organic Matter. Organic facies and palynofacies. *Chapman and Hall*, London. 615p.

Vincent, AJ (1995). Palynofacies analysis of Middle Jurassic sediments from the Inner Hebrides. PhD Thesis, University of Newcastle upon Tyne. 475p.

Waples, DW (1985). Predicting Thermal Maturity. In: Geochemistry in Petroleum Exploration. *International Human Resources Development Corporation*. 217-232.

Whiteman, AJ (1982). Nigeria. Its Petroleum Geology, Resources and Potential. *Graham and Trotman*, London. 39p.