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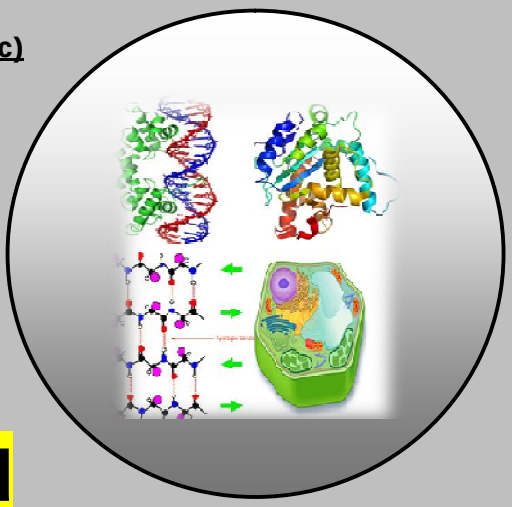

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Palynological Stratigraphy of the Upper Cenomanian – Turonian Eze-Aku Formation in Anambra Basin, South-Eastern Nigeria

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ABSTRCT

Palynology has increasingly become an important tool in evaluating biostrigraphy of sedimentary deposits. The research study was necessitated based on the fact that Eze-Aku Formation has not been dated using palynology as stratigraphic tool. However, its usage has further buttresses the argument that pre-Santonian sediments are contained in the subsurface of the basin. Its application in determining the relative age of Eze Aku Formation through point counts of pollen spores and dinoflagellates have helped in dating the formation as Upper Cenomanian to Turonian. Maximum development of Cretacaeiporate pollen such as Cretaceiporites mulleri, C. Scabratus, C. Polygonalis,, and C. infrabaculatus; in association with Triorites africaensis served as basis of recognizing Cretaceiporites spp acme zone. The main sedimentological sequence is dark shale, while the dominant paleoenvironment of deposition is marginal marine, deltaic in nature and characterized by prevalence of peridinaceans in association with scoledont, microforaminiferal wall lining and Forma T.

Key Words: Biostraigraphy, Dinoflagellate, Peridinacean, Organic-walled, Marginal marine.

INTRODUCTION

The geological investigation of Anambra Basin started with mapping of the sedimentary basin (Wilson and Bain, 1928, Tattan, 1944 and Simson, 1957). Oil exploration through the use of geophysical methods in search of both oil and gas started in the area in 1938 by Shell BP. This led to the drilling of deep well test at Ihuo, few kilometres northeast of Owerri. These efforts to the present have led to discovery of hydrocarbon in the area.

However, there is continuous need for the study of the stratigraphy of the region which is usually ambiguous and erratic in nature.

Thus, study of one of the deepest exploration wells in the basin revealed the relative age of the Eze Aku Formation to be pre Santonian unlike blanket believe that there was no deposition of pre Santonian age sediments in the Anambra Basin. Thus, the importance of this study to knowledge is that here, pollen and spores along with dinoflagellates have brought to light palynological evidence of older sediments' presence (Pre-Santonian) in the Anambra Basin.

Most of the early works in dating the sediments were based on fossils of ammonite, pelecypods, gastropods, echinoids, fish fragments, foraminiferal and dinoflagellates. This study geared towards evaluating the relative age of Eze Aku Formation principally on the basis of pollen and spores, while the associated dinoflagellates and other important forms present were used for paleoenvironmental deductions.

Geological Setting and Stratigraphy

There is a general believe that Anambra Basin evolved from the separation of Africa and South America during Mesozoic (Carter et al, 1963; Burke et al, 1972; Nwachukwu, 1972; Murat, 1972 and Wright, 1972). Structural units were distinguished in the Lower Benue Trough comprising of Anambra Basin and Abakaliki Anticlinorium which comprise of lithologic piles such as shales, siltstones and limestones deposited in shallow marine environment during Albian time. The shale is the dominant lithology in the subsurface of the northern part of the Anambra Basin.

Nwachukwu, (1972) and other workers attributed the tectonism due to separation of Gondwana land being the major controlling factor responsible for the geologic history of southern Nigeria. The major tectonic phases which resulted in the displacement of the axis of the Benin-Abakaliki, though, which gave rise to three successive basins- Anambra, Afikpo Syncline and Niger Delta.

The first phase (Albian) was characterized by movement along the major NE-SW trending fault resulting in thr formation of the rift-like trending fault resulting in the formation of the rift-like Abakaliki-Benue Trough. To the NW, the limit of the basin was the Benin-Benue hinge line (fault zone) beyond which there is no Pre- Upper Cenomanian sediment that has been reported.

The second phase (Santonian) was characterized by compressional movement along the established NE-SW trend and resulted in the uplift of the Abakaliki fold belt contemporaneously with the Anambra platform which subsided and the axis of the basin was displaced to a position SW of the Benue fold belt and NW of the Abakaliki uplift.

The third tectonic phase occurred towards the end of the Eocene. Large areas in the eastern part of the Niger Delta down dip of the Abakaliki plunged out of the Calabar Flank and show repeated periods of erosion and non-deposition during the Middle and Upper Eocene; whereas a large deltaic complex was deposited in the down dip Anambra Basin. This positive movement of blocks bounded by NE-SW and NW–SE trending fault preceded the subsidence of the Oligocene younger Niger Delta along the NW–SE fault trend (Figure 1).

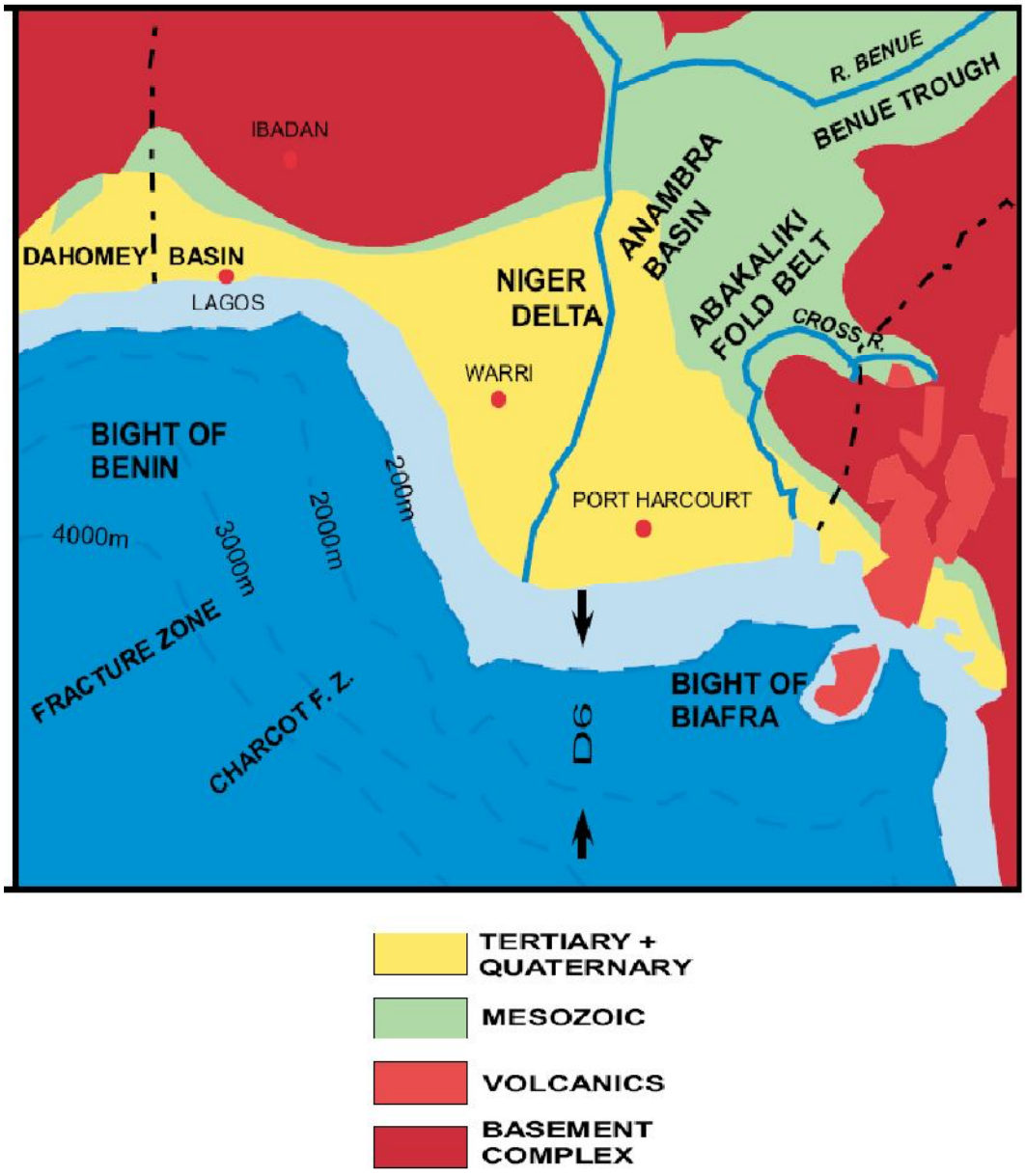


Figure 1. Index map of Niger Delta and offshore Nigeria showing the Anambra Basin and Abakaliki Fold belt (After Doust and Omatsola, 1989).

The stratigraphic history of the southern Nigeria region is characterized by three sedimentary phases (Short and Stauble, 1967 and Murat, 1972), during which the axis of the sedimentary basin shifted. These three phases are: (I) the Abakaliki-Benue phase (Aptian-Santonian), (II) the Anambra-Benin phase (Campanian-Mid Eocene), and (III) the Niger Delta phase (Paleocene-Recent).

The second sedimentary phase resulted from the Santonian folding and upliftment of the Abakaliki region and dislocation of the depocenter into the Anambra platform and Afikpo region (Figure 1). The resulting succession comprises the Nkporo Group, Mamu Formation, Ajali Sandstone, Nsukka Formation, Imo Formation, Ameki Group and Ogwashi Asaba Formation (Table 1). The third sedimentary phase is credited for the formation of petroliferous Niger Delta which commenced in the Paleocene as a result of a major earth movement that structurally inverted the Abakaliki region and displaced the depositional axis further to the south of Anambra Basin.

Many lithostratigraphic units were proposed by Reyment, (1965) which marked the first detailed study of the stratigraphy of the southern Nigerian sedimentary basin. Paleogene time was represented by a sedimentary succession that is thicker than 3500m; Imo Formation (~1000m), Ameki Group (~1900m) and Ogwashi-Asaba Formation (~250m) (Jan du Chene et al, 1978; Nwajide, 1979; Arua, 1986; Anyanwu and Arua, 1990). (See Table 1)

Table 1. Correlation Chart for Early Cretaceous strata in southeastern Nigeria (After Nwajide, 1990).

<table>
<tr><td>AGE</td><td></td><td colspan="2">ABAKALIKI-ANAMBRA BASIN</td><td>AFKPO BASIN</td></tr>
<tr><td>M.Y
30</td><td>Oligocene</td><td colspan="2">Ogwashi-Asaba formation</td><td>Ogwashi-Asaba formation</td></tr>
<tr><td>54.9</td><td>Eocene</td><td colspan="2">Ameki/Nanka formation/
Nsugbe sandstone(Ameki group)</td><td>Ameki formation</td></tr>
<tr><td>65</td><td>Paleocene</td><td colspan="2">Imo formation
Nsukka formation</td><td>Imo formation
Nsukka formation</td></tr>
<tr><td>73</td><td>Maastrichtian</td><td colspan="2">Ajali formation
Mamu formation</td><td>Ajali formation
Mamu formation</td></tr>
<tr><td>83</td><td>Campanian</td><td colspan="2" rowspan="2">Npkoro Oweli formation/Enugu shale</td><td rowspan="2">Npkoro shale/Afikpo sandstone</td></tr>
<tr><td>87.5</td><td>Santonian</td></tr>
<tr><td>88.5</td><td>Coniacian</td><td colspan="2" rowspan="2">Agbani sandstone/ Awgu shale</td><td>Non-deposition/erosion</td></tr>
<tr><td></td><td>Turonian</td><td colspan="2">Eze Aku Group</td><td>Eze Aku Group
(include Amasiri sandstone)</td></tr>
<tr><td>93
100</td><td>Cenomanian-Albian</td><td colspan="2">Asu River Group</td><td>Asu River Group</td></tr>
<tr><td>119</td><td>Aptian
Barremian
Hauterivian</td><td colspan="3">Unnamed Group</td></tr>
<tr><td colspan="2">PRECAMBRIAN</td><td colspan="3">BASEMENT COMPLEX</td></tr>
</table>

MATERIAL AND METHODS

The method of analysis employed is the basic processes of preparing palynological slides for petrographic observation. Ten samples ranging in depth from 2878-3125m were processed for palynological content. The first stage of the laboratory analysis was lithological sample description. The samples were described under the microscope by considering the colour, textural features of the grains, fossil content and post deposition diagenetic effects.

Palynological slide preparation involved initial decarbonisation of the samples in dilute Hydrochloric acid (Hcl); followed by digestion in 60% grade Hydroflouric acis (HF) overnight. The samples were later sieved with 5 µm mesh in order to remove the clay size particles that might obsure clearity of the slides. Other stages involved include oxidation of the samples and heavy liquid separation of the macerals before they were finally mounted on glass slides with DPX mountant.

Counts of the pollen, spores, dinoflagellates, algae, fungi and other stratigraphically important forms present were made to determine the relative frequency of each species in the sample; upon which diagnostic species photographs were taken.

RESULT AND DISCUSSION

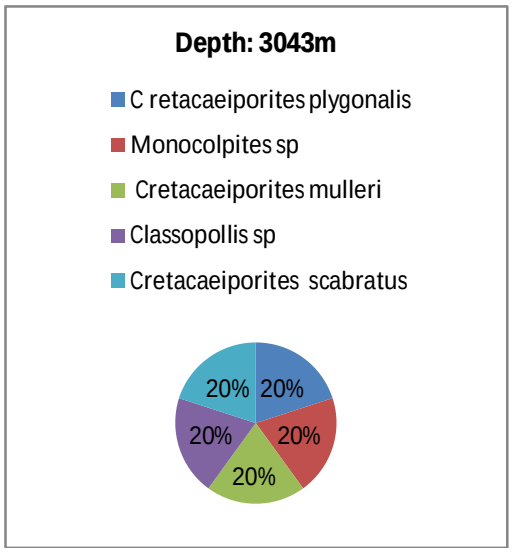
Lithostratigraphy of the well section

About seventy ditch cutting samples were described for the well section analyzed. The result shows that the entire stratigraphic succession is mainly of dark grey shale with mild to strong effervescence on acid test (Figure 2). This suggests that the sediments were mainly deposited in marine environment under a reducing condition.

Depth(m)	Litholog	Description
2906	_-__-_--_--	
	_--_--_--_--	
	_--_--_--_-_-	
	__-__----_---	
	_---__---	
	___---_---_--	
	___----___--	
	-___--_--__-	**Dark grey fissile shale, mild to strong effervescence on acid test**
	-___---__--	
	___--_____---	
	___--___---	
	____---	
	____---___--	
3125	-__--___----	
	___----___--	
	-__----___---	

Figure 2. The lithology log of the analyzed section (2906-3125m) of Well- N, southeastern Nigeria.

Palynology Result:
ZONE: Cretacaeiporites spp. Acme Zone
INTERVAL: 2906-3125m
AGE: Upper Cenomanian – Turonian
CHARACTERISTICS: The base of this zone coincides with the top of the underlying Zone 1 of *Forma PO 304 Lawal*. It is characterized by the last occurrence of *Forma PO 304 Lawal*, *Afropollis jardinus, Hexaporotricolpites emelianovi, Steevesipollinites sp* and maximum development of *Cretacaeiporites polygonalis.* The near base, at 3070m, the interval is marked by the occurrence of *Triorites africaensis.*
The near base of the zone (3043m) is defined by the last appearance of *Classopollis brasiliensis* and second appearance of *Odontochitina costata*. New dinoflagellate cysts appeared in this zone, including Forma E and Forma F. There is continuous occurrence of *Punctioratipollis krutzschi, Cretacaeiporites infrabaculatus, C. mulleri and Monocolpites sp.* The species of periporate pollen (Cretacaeiporate) which occurred sparsely in the lower Zone 1 is more common in this zone and similar to Lawal and Moullade, (1986) observation in the Kumo-6 borehole of the Upper Benue Trough, Nigeria. However, *Gnetaceaepollenites sp 1, G. diversus, Hexaporotricolpites emelianovi* and *Galeacornea clavis* are not observed in the samples analysed within this interval (3043 – 3125m) for this zone in contrary to what was observed in Triorites africaensis zone by Lawal and Moullade, (1986).



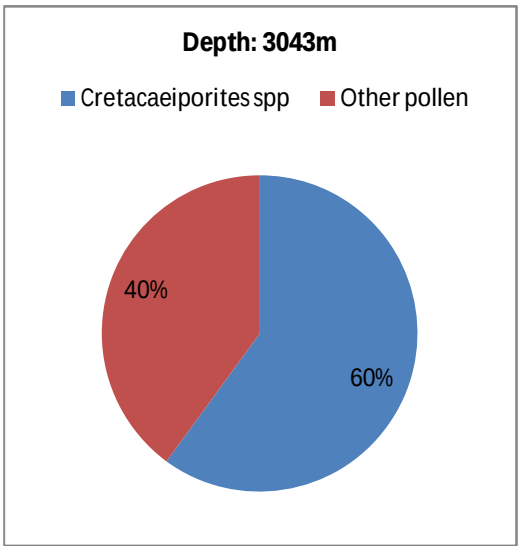
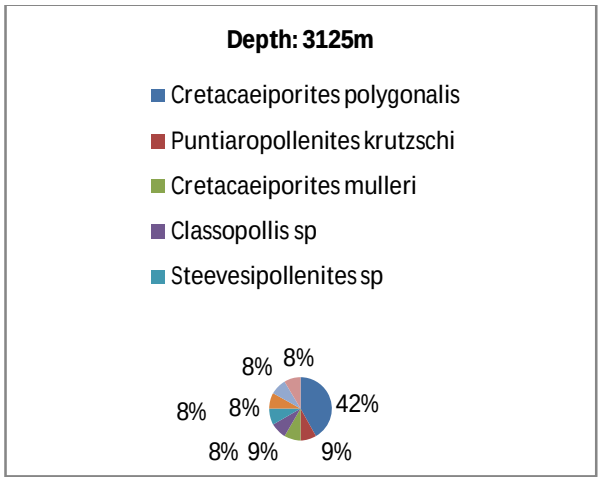


Figure. 3 **Figure. 4**

Fig. 3. Percetage of different forms of Cretacaeporate Cretacaeiporites spp to other pollen. Fig. 4. Relative Percentage of pollen and other pollen at depth 3043m. at depth 3043m.



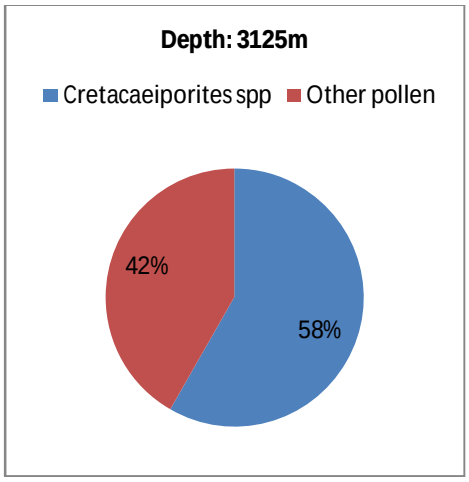
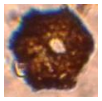
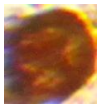
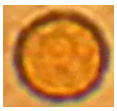
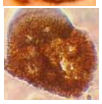
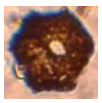
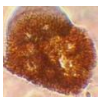
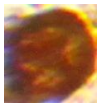


Figure. 5 **Figure. 6**

Fig. 5. Percetage of different forms of Cretacaeporate Cretacaeiporites spp to other pollen
Fig. 6. Relative Percentage of pollen and other pollen at depth 3125m. at depth 3125m.

Table 2. Palyno-log, evolutionary and maximum development of Cretacaeiporate pollen in the Well N-1 section.

Depth	Lithology	Formation	Marker fossil evolution	Age
2906 3012 3043 3070 3098 3125m		Eze-Aku	 Steevesipollenites sp  Cretacaeiporites mulleri C. polygonalis C. mulleri Cretacaeiporites scabratus     Triorites africaensis Punctiarotipolliskruzsci infrabaculatus Cretacaeiporites   C. polygonalis P. Kruzschi C. mulleri   	Upper Cenomanian To Turonian

The pollen-*Triorites africaensis* has been described by many workers. It is generally, believed that it depicts Late Cenomanian age. Jardine and Magloire, (1965) used this form to characterize both Senegal and Code de I'voire sediments as Cenomanian age, belonging to sequence VII. The sequence VII was further characterized by the presence of *Elaterocolpites* and *Galeacornea* types which are absent in this well (Nzam -I). But, the disappearance of *Afropollis jardinus* in Sequence VII conforms to observation made in this research work for Zone 2.

Therefore, the Zone 2 of this well is equivalent in part to sequence VII of Jardine and Magloire, (1965); dated late Cenomanian age. Other workers that have reported the presence of *Triorites africaensis* and *Classopolis brasiliensis* are Herngreen, (1973, 1975); Moussavou, (1980); and Boltenhagen, (1980). They described the two pollens to have appeared in older sediments but also described them to mark Late Cenomanian deposits.

The first appearance of *Odontochitina costata* is suggested to mark Late Cenomanian, but its continuous occurrence in stratigraphy mark the base of Turonian age deposits. Williams and Bujak, (1990), ranged the occurrence of *Odontochitina costata* to vary from Cenomanian to Santonian. Therefore, the lower part of this zone is equivalent to *Triorites africaensis* Assemblage Zone II of Lawal and Moulade, (1986) dated Late Cenomanian. The lower part of this zone is characterized by the occurrence of *Triorites africaensis,* and *Classopollis brasiliensis;* first appearance of *Odontochitina costata*, Forma E and Forma F. The lower part of the zone is further dominated by the varieties of *Cretacaeiporate* pollens such as *Cretacaeiporites infrabaculatus,* (Boltenhagen, 1975), *Cretacaeiporites polygonalis*, *C. mulleri, C. scrbratus* and *Punctioratipollis krutzsch.* The *Cretacaeiporites mulleri* is moderately developed at depth 3012m (See Figures 3-6 and Table 2).

The top of the zone is characterized by the last appearance of *Cretacaeiporites mulleri* (2933m) and *Triorites africaensis* (2906m). The upper part of the zone is dominated by dinoflagellate cysts, also, dominated by continuous occurrence of *Odontochitina costata.* The dinoflagellate cysts that define the zone with new appearances are *Polysphaeridium sp,* Forma G, Forma H (*?Scoledont*); Forma I (peridinacae); Forma J (*Subtilisphaera sp 1),* Forma K (*Senegalinium macrocysta)*; *Palaeocystodinium australinum* and Forma L. The dinoflagellate cysts present constitute over 80% while, pollen and spore is less than 20%. The zone is further characterized by relatively high abundance of *Andalusiella polymorpha* (2933m). Other dinocysts present are Forma B2, *Gochtodinium sp* 1 (Forma C-3), *Senegalinium sp*, *Andalusiella sp* 1; microforaminiferal wall lining and relative abundance of *Botryococcus brunii* (algae) at the top of the zone.

The *Cretacaeiporites spp* Acme Zone is here dated Upper Cenomanisan to Turonian age (Figures 3-6 and Table 2). This zone is similar to *Cretacaeiporites scrabratus* acme Zone III of Lawal and Moullade, (1986). The Cretacaeiporites *spp* Acme Zone 2 is dated Upper Cenomanian at the base and Turonian age for most part of the interval at the upper part of the section on the basis of co-occurrence of *Triorites africaensis* and diverse occurrence of *Cretacaeiporites spp,* such as *Cretacaeiporites scrabratus*, *Cretacaeiporites mulleri*, *Cretacaeiporites polygonalis, Cretacaeiporites infrabaculatus* and *Punctioratipollenites krutzschi.* The zone is further characterized by good development and continuous occurrence of *Odontochitina costata* and high frequencies of dinoflagellates at the upper part of the zone than pollens and spores.

PALEOENVIRONMENT

The paleornvironmental deduction was based on the relative frequency of fossils present such as pollen, spores, dinoflagellates and other important forms (Harland, 1973; Fredericksen, 1985; Ojo and Akande, 2001; Ola-Buraimo and Adeleye, 2010). The lower part of the stratigraphic section is composed of miospores, dinoflagellates and scoledonts. The dinoflagellates are dominated by peridinacean forms such as *Phelodinium sp, Andalusiella polymorpha* and kite-like structured dinocyst *(Forma T)*, *Calcium oxalate crystals* (Ruta et al, 2007) and *Forma B (Odontochitina sp).* The assemblage of these forms is suggestive shallow marine environment.

The middle part of the section is dominated by organic-walled organisms of about 80% such as *Polysphaeridium sp, Senegalinium sp, Andalusiella sp, Andalusiella polymorpha, Subtilisphaera sp 1, Senegalinium macrocysta, Forma C, Forma E* and *Paleocystodinium australinum.* This is also a marginal marine setting probably in a deeper marginal environment tending towards an open marine kind. The uppermost sediments have similar assemblage of dinoflagellates but characterized by *Scoledont*, algae (*Botryoccus braunii)* and microforaminiferal wall lining. The suggested paleoenvironment of deposition is marginal marine setting with fluviatile influence, depicting a kind of deltaic depositional setting.

CONCLUSION

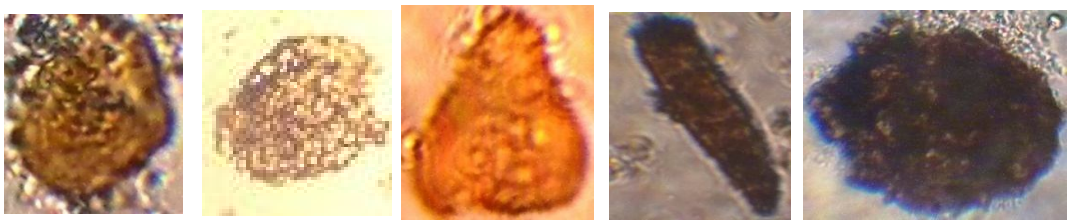
This research has fulfilled the task of revealing the geology of Anambra Basin. Within the main part of the basin in the northern section of it is the location of the Well N-1 from which ditch cutting samples were prepared for this study. Pre-Santonian sediments are now found within the basin unlike popular notion that believes that only Post-Santonian sediments are present. The Cratacaeipotites spp acme zone established here is based on the maximum development of Cretacaeiporatepollen such as Crtacaeiporites mulleri, C. Scbratus, S. Polygonalis, C. Infrabaculatus, in association with Triorites africaensis which are characteristically restricted to the interval. It is on this basis that an Upper Cenomanian-Turonian age is suggested for the formation.The interval is characterized by co-occurrence of Cretacaeporate pollen, Triorites africansis, Classopollis brasiliensis, and Puntioratipollenites krutzchi. Among the new dinoflagellate cysts present are Forma G, Forma H, Forma I, Forma J and Forma K.

A monotonous shale sequence is present in the stratigraphic section (2706-3125m), containing minor calcite grains. Marginal marine environment was deduced for the analyzed section characterized by dominance of peridinaceans in association with Scoledont, microforaminiferal wall lining and Forma T. It is suggested that further study should be carried out using micropaleontologic approach in order to establish a concrete relative age of the formation.

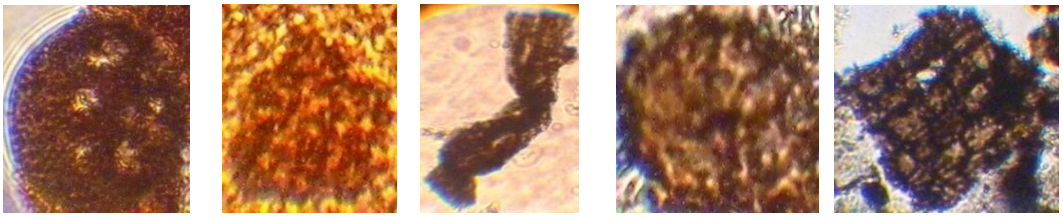
ACKNOWLEDGEMENT

The author appreciates the assistance of Palystrat Limited for both financial and moral support and in particular for granting the use of her facilities. I am as well indebted to the Geological Survey Agency of Nigeria for provision of ditch cutting samples.

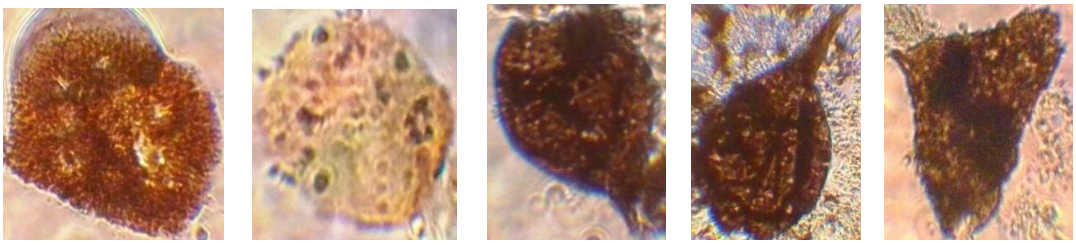
Plate 1



1 2 3 4 5



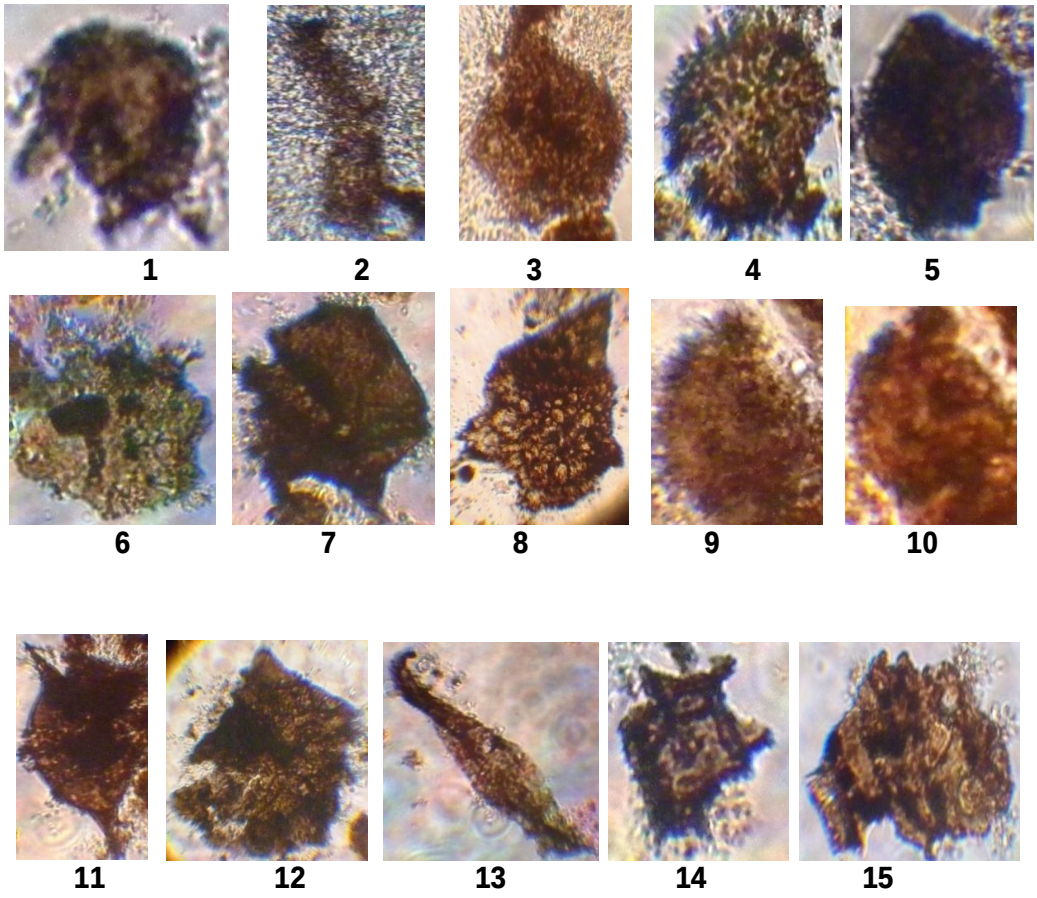
6 7 8 9 10



11 12 13 14 15

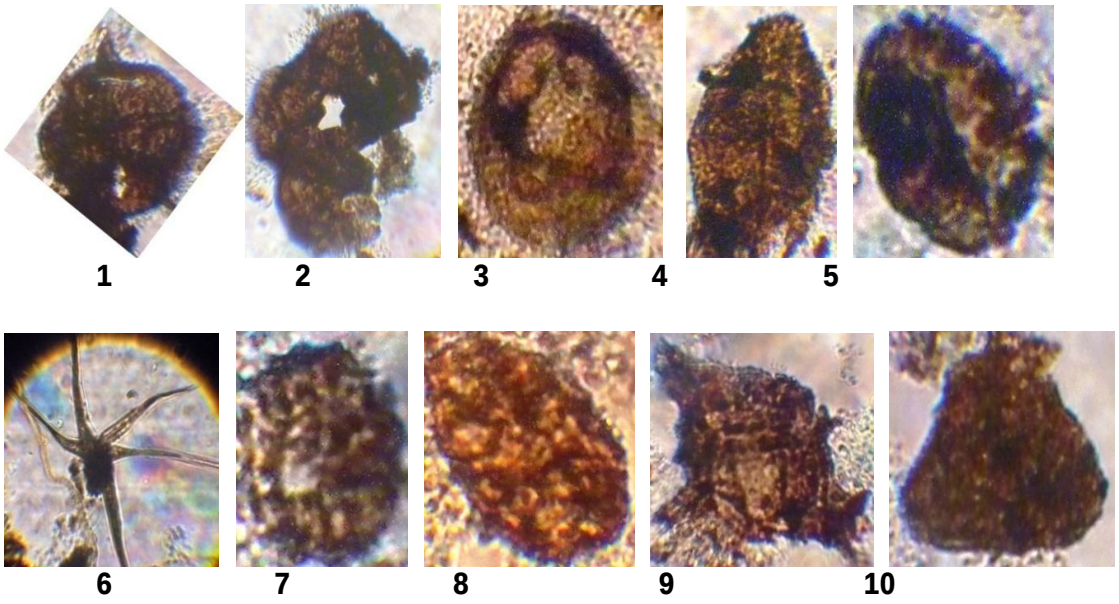
1 Phelodinium sp,
2 Triorites africaensis **Jardine and Magloire, 1965,**
3 Afropollis jardinus,
4 Cretacaeiporites mulleri **Boltenhagen, 1975,**
5 Fungi spore,
6, 11 Punctioratipollis kruzschi **Boltenhagen, 1975,**
7 Cretacaeiporites sp (corroded),
8 Forma B,
9 Cretacaeiporites infrabaculatus **Boltenhagen, 1975** ,
10 Calcium oxalate crystal **Ruta et al, 2007,**
12 Phelodinium bolonienae **Riegel, 1974,**
13, 14 Andalusiella polymorpha Malloy**, 1972,**
15 Forma T.

Plate 2



1 Classopollis brasiliensis,
2 Odontochitina costata,
3 Forma P,
4 Polysphaeridium sp,
5 Andalusiella polymorpha,
6 Forma N,
7 Peridinacea dinocyst (Forma I),
8 Subtilisphaera sp 1 (Forma J),
9, 10 Senegalinium macrocysta **in Oloto, 1987,**
11 Andalusiella polymorpha **Malloy, 1972,**
12 Forma C,
13 Palaeocystodinium australinum,
14 Forma.

Plate 3



1 ? Gonyaulacysta sp **Lawal, 1982,**
2 Microforaminiferal wall lining (Spiral),
3 Araucariacites australis **Cookson, 1947,**
4 Retimonocolpites sp =? Liliacidites variegatus in **Brenner, 1968,**
5 Retimonocolpites sp 2 =? Liliacidites variegatus in **Brenner, 1968,**
6 Trochome **Ruta et al, 2007,**
7 ? Peromonolites peroreticulatus **Brenner, 1963,**
8 Cretacaeiporites infrabaculatus **Boltenhagen, 1975,**
9 Andalusiella sp (Forma N),
10 Triorites africaensis.

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