Biostratigraphy And Paleoenvironment Of The Coniacian Awgu Formation In Nzam-1 Well, Anambra Basin, Southeastern Nigeria.

Ola-Buraimo A. Olatunji

ABSTRACT : - Ditch cutting samples from an exploratory Nzam-1 well located in the northwestern part of Anambra Basin were subjected to lithological description and palynomorph enrichment and analysis through digestion with Hydrofluoric acid (HF) and floatation with Zinc Bromide (Zn_2Br_4). The study was intended to determine the relative geologic age and paleoenvironment of deposition of Awgu Formation through the application of palynologic tool. The lithostratigraphy of Awgu Shale is mainly shaley in nature and diagenized at different degrees within various stratigraphic levels. Palynological study revealed that the sequence is dominated by angiosperm pollen such as *Monocolpites sp, Tricolpites sp and Retimonocolpites sp*. Other diagnostic forms that characterize the formation include *Zlivisporites blanensis, Peromonolites perireticulatus* and *Odontochitina sp*. Thus, the Awgu Shale is dated Coniacian age. However, new forms of dinoflagellates appeared in the sediments that are suggestive of transitional environment of deposition.

Key words: - Lithostratigrapy, Biostratigraphy, Palynology, Dinoflagellate, Transitional environment.

INTRODUCTION

The stratigraphic study of the Anambra Basin continues to attract attention because it is imperative to understand the stratigraphic complexity of the basin. Though, one would have expected that it is only the eastern part of the basin (Abakaliki Syncline) that should contain Pre-Santanian sediments according to literature (Nwachukwu, 1972, Nwajide, 1990). However, the northwestern part of it in which the Nzam-1 well analyzed belongs; it is found to also contain Pre-Santonian facies. This observation been noted in the work of Ola-Buraimo and Akaegbobi, (2012a); Ola-Buraimo, (2013) for the same area of the basin. Thus, Awgu Shale which has been dated by other means is here investigated using palynological tool for the first time in order to determine relative geological age, compare palynomorph assemblages contained in it to other older formations based on the assemblage of forms that are distinctively different from the adjacent formations and finally to determine the paleoenvironment of deposition of sediments deposited within the formation.

- Ola-Buraimo A. Olatunji
- Department of Chemical and Geolocal Scinces, College of Natural Sciences, Al-Hikmah University, Ilorin, Nigeria.
- Email: rolaburaimo@yahoo.com

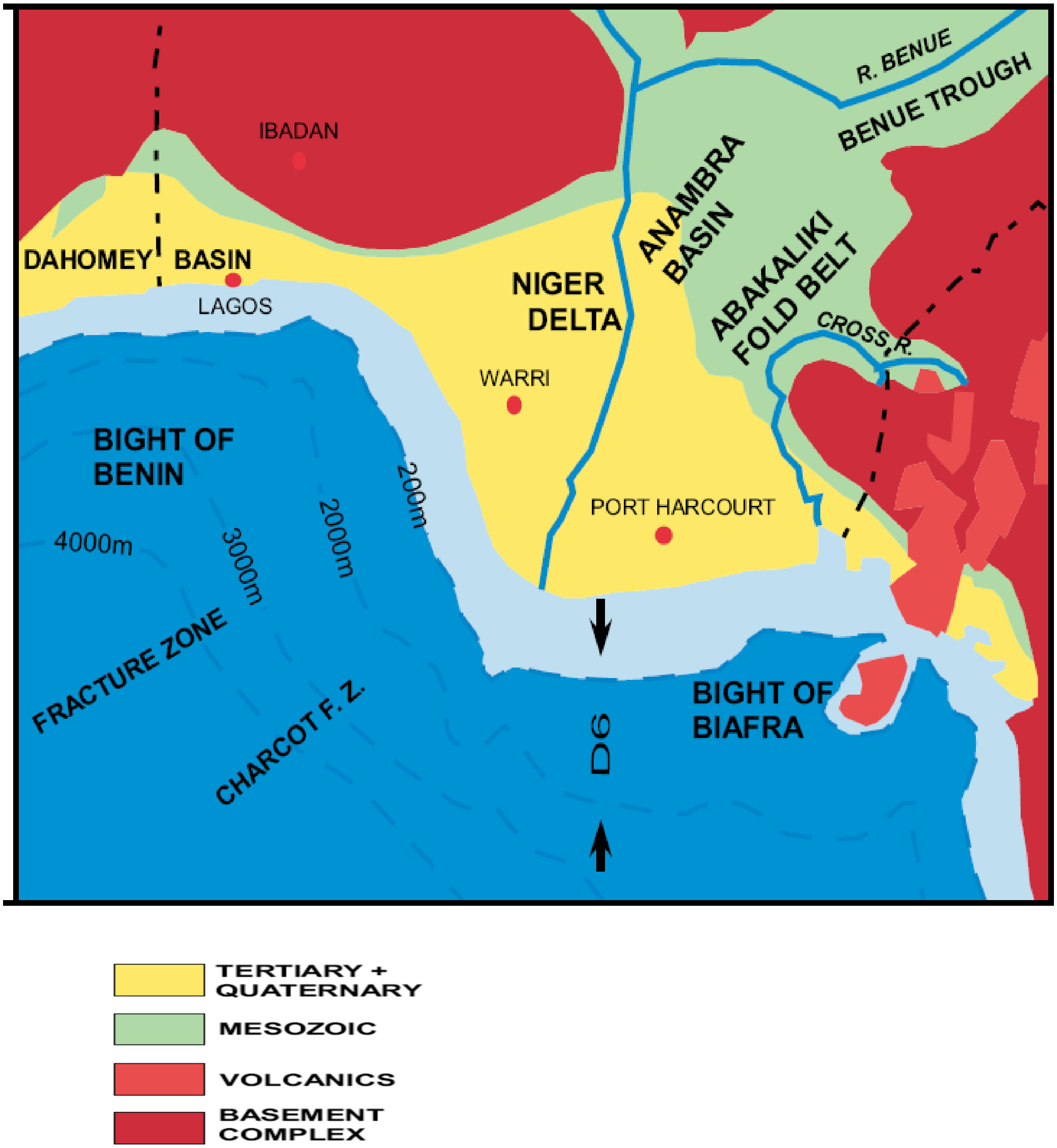


Figure 1: Index map of Niger Delta and offshore Nigeria showing the Anambra Basin and Abakaliki Fold belt (After Doust and Omatsola, 1989).

Geologic setting and stratigraphy

The geology of the Anambra Basin has been well studied and documented. Earlier work began with the investigation of tectonism in the southern Nigeria. This was said to have evolved probably in the Early Cretaceous time with the separation of Africa plate from the South America plate due to the opening of the Atlantic Ocean (Burke et al, 1972; Murat, 1972 and Nwachukwu, 1972). The geologic history of the Southern Nigeria was attributed to three tectonic phases resulting into the displacement of the axis of the Benin-Abakalika Trough thereby resulting to three successive basins- Anambra Basin, Afikpo Syncline and Niger Delta (Murat, 1972). Murat, (1972) described the first phase to be characterized by movement along the major NE-SW trending faults 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 it as described to contain no Pre-Upper Cenomanian sediments. However, Albian-Lower Cenomanian sediment deposits have been reported in the northern part and close to the Benin Hinge Line of the Anambra Basin (Ola-Buraimo and Akaegbobi, 2012a; Ola-Buraimo, 2013) 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 folded belt and NW of the Abakaliki uplift. To the west of the Benin Hinge line, an older structural unit, the relatively shallow Dahomey embayment existed dated Neocomian in age (Omatsola and Adegoke, 1981; in-house, Mosunmolu Limited, 1992; Jan du Chene, 2000). Towards the end of the Eocene, the third tectonic occurred in which the eastern part of Niger Delta down dip of the Abakaliki plunged out of the Calabar Flank and show repeated periods of erosion or non-deposition during the Middle and Upper Eocene. However, a large deltaic complex was developed in the down dip of Anambra Basin. Thus, 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 (See Figure 2).

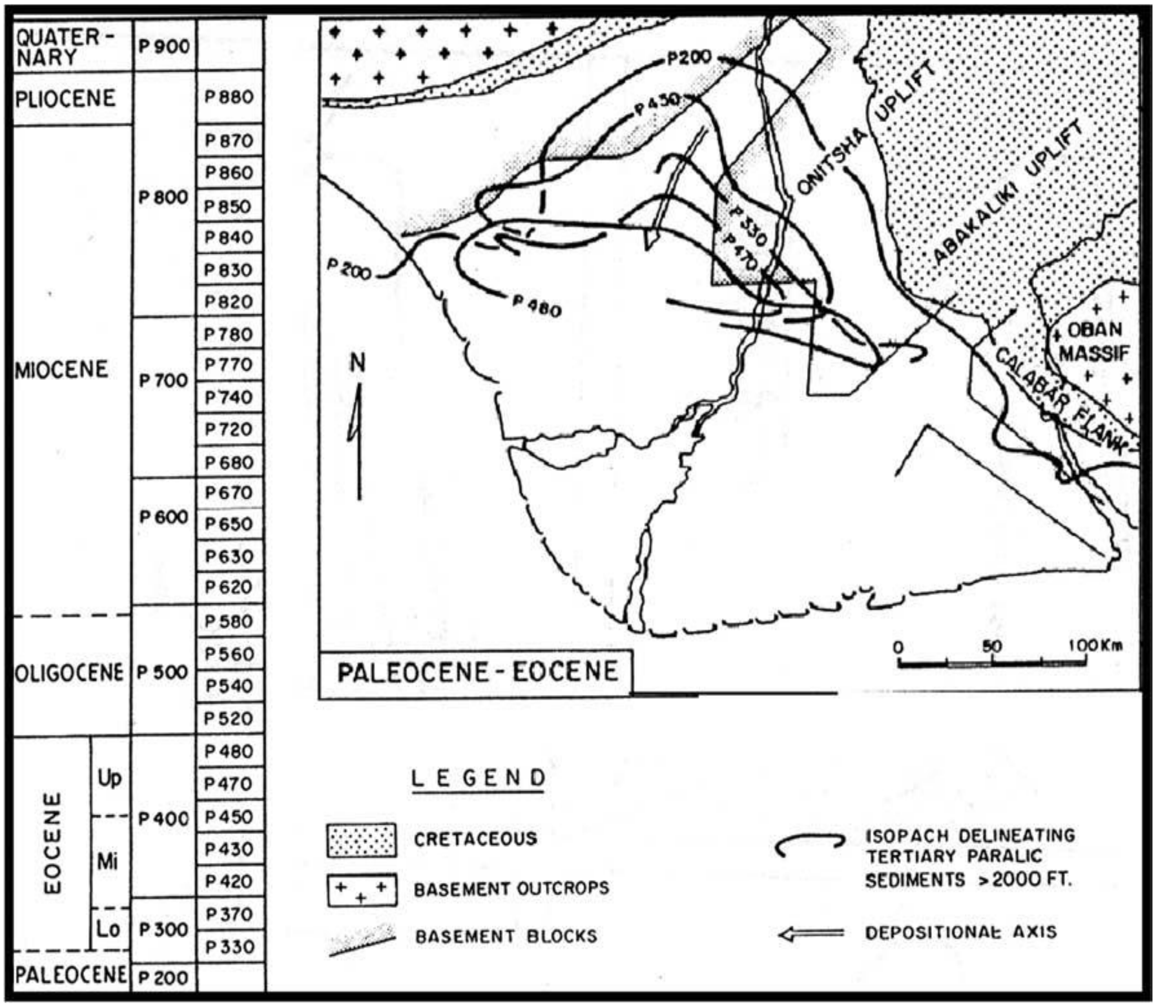


Figure 2: Tectonic evolution of some important basins in Nigeria (After Evamy et al, 1978).

The stratigraphic history of the southern Nigeria has been widely described to be characterized by three sedimentary episodes (Short and Stauble, 1967; Murat, 1972). The axis of the basin shifted during the period whereby the three phases formed are referred to as-(I) Abakaliki-Benue phase (Aptian-Santonian), (II) the Anambra-Benin phase (Campanian-Mid Eocene), and (III) the Niger Delta phase (Paleocene-Recent). The sedimentary pile of over 300 meters belong to the Asu-River Group, Eze-Aku and Awgu Formations deposited during the first phase of the Abakaliki-Benue Basin, the Benue Valley and Calabar Flank. The second sedimentary episode developed from the Santonian folding and upliftment of the Abakaliki region and dislocation of the depocenter into the Anambra platform and Afikpo region (Figure 3). Therefore, successive sedimentation encompasses of Nkporo Formation, Mamu Formation, Ajali Sandstone, Nsuka Formation, Imo Formation and Ameki Group, Ogwashi /Asaba dated Late Miocene-Pliocene (Ola-Buraimo and Akaegbobi, 2012b) (Table 1). The third sedimentary phase development resulted in the formation of petriferous Niger Delta which started in the Paleocene as a result of tectonic movement which structurally inverted the Abakaliki region and displaced the depositional axis further to the south of Anambra Basin. Among the earlier works on the study of the stratigraphy of Anambra Basin include Reyment, (1965); Petters and Ekweozor, (1982); Nwajide, (1990); Nwajide and Reijers, (1997); Ogala et al, (2009); Ola-Buraimo and Akaegbobi, (2012a, 2012b) and Ola-Buraimo, (2012, 2013). The detail stratigraphy of the basin is given below (See Table 1).

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

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

METHODOLOGY

Twenty ditch cutting samples obtained from well – X situated in the Anambra Basin range in depth from 2743 to 3671m. The samples were utilized for lithofacies description and preparation of palynological slides; analyzed under the microscope for palynomorph content. In the case of lithologic description, 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. Palynological slide preparation involved selection of samples at 27.4m (90ft) interval where present. The sample preparation was carried out following the international standard. Lithified samples were crushed with the mortar and pestle in order to enhance maximum recovery of pollen and spores. The crushed samples along with the friable samples were initially treated with dilute hydrochloric acid (10%) in order to eliminate carbonate substance present in them. They were later soaked in 60% hydrofluoric acid for silica and silicates digestion. The samples were not oxidized in order to avoid corrosion; but were sieved with 5µm mesh in order to maximize concentration of miospore grains and to achieve clean slides for easy identification and photography. The recovered residues were mounted on glass slides with Deepex (D.P.X.). Total count of miospore grains present were noted and presented in the checklist for absolute representation of different important pollen and spores grains recovered, while photographs of diagnostic forms were taken.

RESULT AND DISCUSSION

ZONE: Zlivisporites blanensis Assemblage Zone
INTERVAL: 2716 – 2906m
AGE: Coniantian –? Santonian

CHARACTERISTIC: The lower part of the interval is characterized by the paucity of palynomorphs. It is further characterized by the extinction of *Cretacaeiporites spp* and break in the continuous appearance of *Odontochitina costata*. The zone is marked by dominance of monosulcate, tricolp(or)ate grains of angiosperms and continuous occurrence of *Zlivisporites blanensis* (Figures 3and 4). The top of the zone is relatively highly fossiliferous; characterized by new appearances of *Peromonolites peroreticulatus* and *Longapertites sp 3* (Lawal and Moullade, 1986). Microplankton grains that are rare and low in frequency at the lower part of the zone are more common at the upper part of the zone. Among the dinoflagellate cysts that are present are *Andusiella sp, Andalusiella polymorpha, Senegalinium sp, Odontochitina costata,* Forma M, Forma N, and Forma J (*Subtilisphaera sp 1*). The pollen and spore forms also present in the zone are *Tricolpites sp, Monosulcites sp, Retimonocolpites sp 2 = Liliacidites sp* (Lawal and Moullade, 1986), *Tricolporopollenites sp, Cyathidites sp*, *Araucariacites sp, Monocolpopollenites sphaeroidites*, *Inaperturopollenites sp* and *Peromonolites peroreticulatus*. *Cretacaeiporites spp* become extinct within this zone. The presence of *Cretacaeiporites spp* in the zone is in consonant with the work of Odebode, (1987) on the palynological age dating of Lamja Sandstone in Benue Trough, Nigeria.

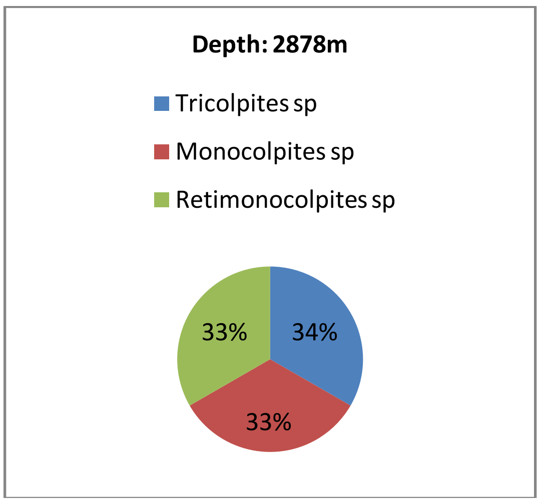


Fig. 3: Relative percentage of angiosperm forms at depth 2878m

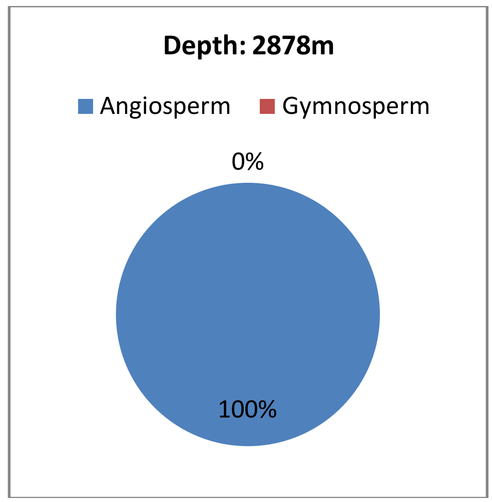


Fig. 4: Dominant percentage of angiosperm to gymnosperm pollen at depth 2878m

The peculiar pollen that characterize Senonian sediments such as *Droseridites senonicus, Syncolporites subtilis, Tricolpites gigantireticulatus and Bacutricolporites manifestus* are all not present in the samples analyzed. However, the palynolog of diagnostic forms appearances with depth in the zone is presented in Figure 5. The Zlivisporites blanensis Assemblage Zone is equivalent to Sequence VI – IV of Jardine and Magloire, (1965) for the Senegal Basin, dated Senonian. It is also similar in part to *Droseridites senonicus* Acme Zone IV of Lawal and Moullade, (1986). The *Subtilisphaera sp* present in this zone was also reported in the Coniacian sediments of the Upper Benue Trough, Nigeria (Ojo and Akande, 2001). The *Zlivisporites blanensis* Assemblage Zone is here dated Coniacian age. The presence of *Longapertites sp 3* (Lawal and Moullade, 1986) at the top of the zone marks the base of Campanian age. The Santonian sediment is unlikely to be present in the well analyzed, because, the interval do not contain diagnostic forms that depict Santonian deposit. Thus, the deposited Santonian sediments within the section might have been eroded; therefore, an unconformity exists between this interval and overlying younger interval probably due to combined tectonic activity and weathering. However, a conformable relationship exists within the stratigraphy because it is a monotonous facies of shale sequence. This observation is similar to the work of Umeji, (2006) for the Turonian /Campanian boundary between the Abakaliki and Anambra Basins, as exposed at Leru, Southeastern Nigeria. It is believed that the Anambra-Benin phase of Campanian-Middle Eocene is strongly contested that such phenomenon did not affect the whole part of Anambra Basin. Some parts of the basin has been found to contain Pre-Campanian sediments that are as old as Albian-Lower Cenomanian in the Ezu-River Group (Ola-Buraimo and Akaegbobi, 2012); Ola-Buraimo, (2012); in the case of Eze-Aku Formation dated Upper Cenomanian to Turonian in age based on palynomorph recovery; while the present study on Awgu Shale also located in the Anambra Basin is dated Coniacian age. Therefore, the phase 1 sedimentation described by Short and Stauble, (1967), and Murat, (1972) which resulted in the deposition of Asu-River Group, Eze-Aku and Awgu Formations were not restricted to the Abakaliki-Benue Basin, Benue Valley and Calabar Flank alone but also took place simultaneously in the Anambra Basin as evident in this study. This has made it clearly known that the structural style of the basin associated with deep faults (Graben nature) may be responsible for the blanket erroneous believe that the Anambra Basin does not contain Pre-Santonian deposits. Further palynological research works carried out on the northern part of the basin corroborate these findings (Ola-Buraimo, unpublished).

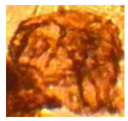
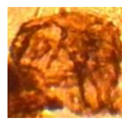
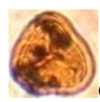
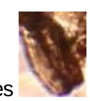
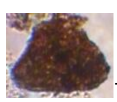
Depth (m)	Lithology	Formation	Marker forms	Age
2744 2771m 2799m 2823m 2851m 2878m 2906m		Awgu Formation	 Peromonolites peroreticulatus  Zlivisporites blanensis  Zlivisporites blanensis  Araucariacites sp  Retimonocolpites sp  ricolporites sp  Cyathidites sp  Monocolpites sp  Tricolpites   Triorites africaensis  Odontochitina sp	Coniacian To Santonian

Figure 5: Marker fossils appearaances with depth in Zlivisporites blanensis assemblage zone

PALEOENVIRONMENT

A number of workers have used palynomorph content to determine environment of deposition of sediments. Therefore, use of palynomorph data have been used in differently by various authors for paleoenvironment of deposition including the works of (Van Berger et al, 1990; and Vadja-Santivanez, 1998. However, relative abundance of terrestrially derived miospores compared to marine forms been documented Lawal, 1982; Schrank, 1984; Edet and Nyong, (1993, 1994); Ojo and Akande, (2001); and Ogala et al, (2009); Ola-Buraimo and Adeleye, (2010). Some Cretaceous age sediments have been studied using dinoflagellates for the reconstruction of environments; these include the works of Deflandre (1935, 1936, and 1937); Lejeune-Carpentier (1938, 1939); Clarke and Verdier (1967); Kjellstrom (1973) and Hansen (1977). However, in Newzealand- Wilson, (1976a, 1976b, 1983, and 1984) used microplanktons to determine paleoenvironment of deposition. Drugg (1967), Harland (1973), Williams (1975), Williams and Brideaux (1975), Mc Intype (1975), Benson (1976), Bujak and Williams (1978), May (1980), and

Wartney (1984) also used dinoflagellates for paleonenvironment reconstruction in North America. The basal part of the interval (2906m) is marked by open marine system based on the relative abundance of gonyaulacacean forms such as Paleocystodinium australinum, Forma B2, Forma E, Subtilisphaera sp, Gochtodinium sp (Forma C3) in association with micro-foraminiferal wall linings. However, interval 2851-2878m is devoid of dinoflagellate but contain recovered miospore of low frequency such as Tricolpites sp, Monosulcites so, and Retimonocolpites sp 2. This is overlain by a suggested open marine environment. The stratigraphic position of the continental setting in-between the open marine indicate a sharp break from terrestrial to open marine paleoenvironment. Such phenomenon of sharp paleobathymetry contact between the open marine and continental environment is suggestive of an unconformity sedimentary relation within the Awgu Formation. The overlying interval at the top (2716-2797m) indicate a marginal marine environment based on the recovery of peridinacean forms such as Andalusiella sp and Odontochitina costata over gonyaulacacean form such as Subtilisphaera sp (See Table 2)

Table 2: Paleoenvironment of deposition of interval 2744-2906 within Awgu Formation

Depth(m)	Lithology	Formation	Miospore Frequency	Dinoflagellate Frequency	Gonyaulacacean frequency	Peridinacean Frequency	G/P Ratio After Harland, 1983	Microfofaminiferal wall lining	Algal Frequency	Fungal Frequency	Paleo-Environment
2744			2	2	0	2	-2	0	0	0	Marginal Marine
2771			3	4	0	4	-4	0	0	0	
2799			1	0	0	0	0	0	0	1	
2823		AWGU SHALE	3	1	1	0	1	0	0	0	Open marine
2851			2	0	0	0	0	0	0	0	Continental
2878			3	0	0	0	0	0	0	0	
2906			2	7	5	2	2.5	1	1	0	Open marine

CONCLUSION

The lithofacies of the Awgu formation is mainly dark grey fissile shale. Relative age of the formation was determined using palynomorph content based on the distinctive abundance of angiosperm pollen such as *Monocolpites sp, Tricolpites sp,* and *Retimonocolpites sp.* Other forms that characterize it are co-occurrence of *Zlivisporites blanensis, Odontochitina sp* (dinoflagellate); interval disappearance of *Cretacaeiporites sp* and top occurrence of *Perimonolites perireticulatus.* The interval of study is dated Coniacian age belonging to Awgu Formation. The paleoenvironment of deposition vary from open marine at the base through continental to open marine system at the top. The sharp paleobathymetry between continental and open marine paleoenvironments could suggest presence of unconformity relation within the formation. Biostratigraphic study of this formation can be correlated to other parts of the basin on the basis of distinctive assemblage of miospore forms present. Furthermore, the Coniacian age interpreted for this interval and equivalent stratigraphically to Awgu Formation support the opinion that there are Pre-Santonian sediments deposited in the Anambra Basin of Nigeria.

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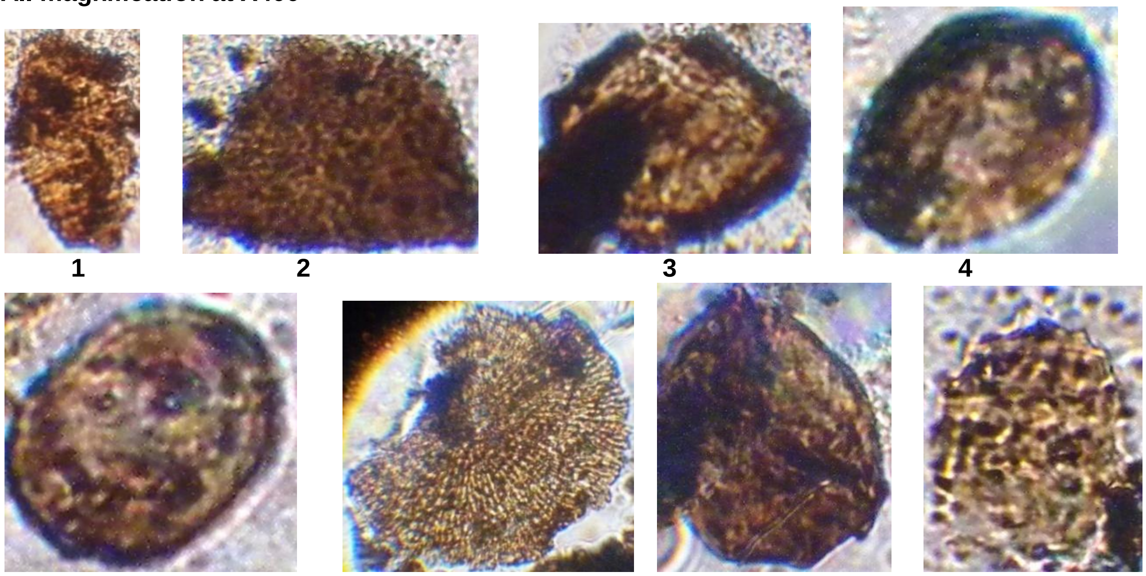
PLATE 1

All magnification at X400

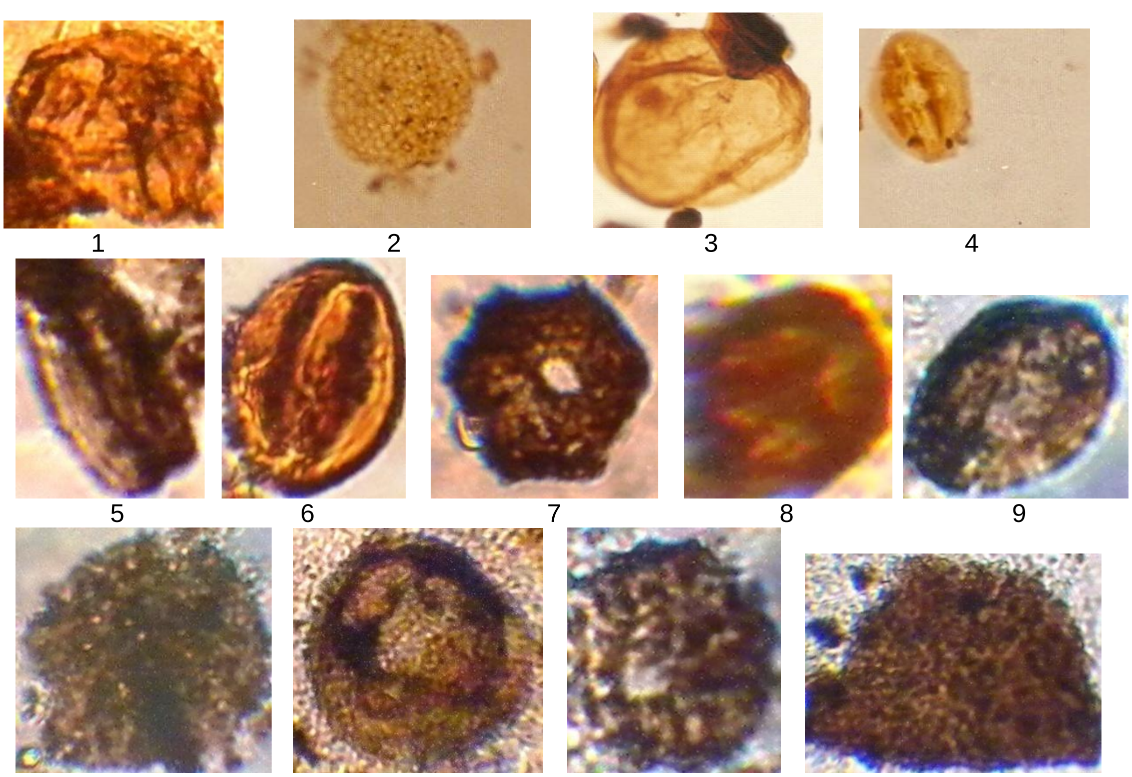


5 6 7 8

1 Monosulcites sp
2 Longapertites sp 3 **Lawal, 1982.**
3 Stephanocolporate pollen
4 Monocolpopollenites sphaeroidites
5 Milfordia sp
6 Trichothyrites sp (microthyriaceous fungal fruiting body) **Ruta et al, 2007.**
7 Andalusiella laevigata **Malloy, 1972.**
8 Dinogymnium sp

PLATE 2

All magnification at X400

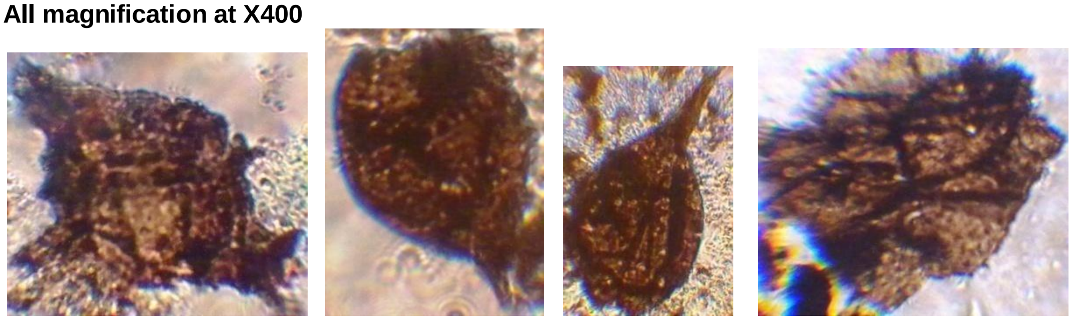


10 11 12 13

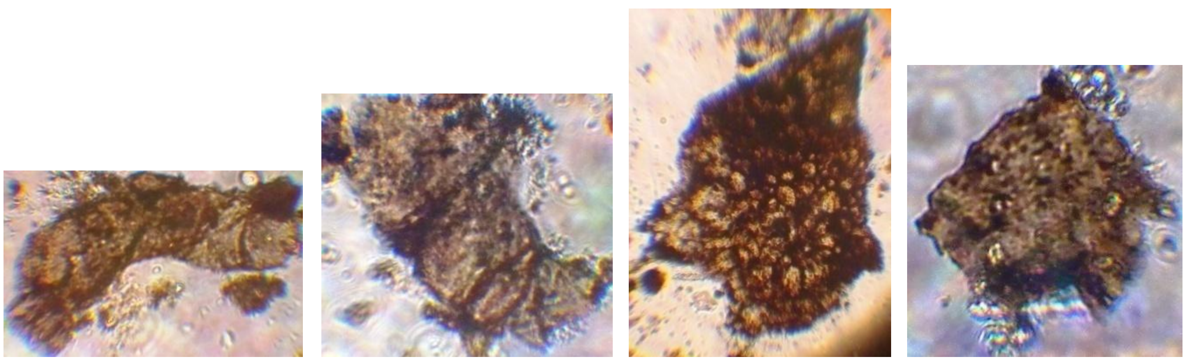
1 Zlivisporites blanensis
2 Retimonocolpites sp = Liliacidites sp
3 Inaperturopollenites sp
4 Tricolporopollenites sp
5 Monosulcites sp
6 Tricolpites sp
7 Cretacaeiporites polygonalis
8 Cretacaeiporites mulleri
9 Monocolpopollenites sphaeroidites
10 Tricolpites sp
11 Araucariasites sp
12 Peromonolites perireticulatus
13 Longapertites sp 3

PLATE 3

All magnification at X400



1 2 3 4



5 6 7 8

1 Forma N
2,3 Andalusiella polymorpha
4 Senegalinium sp
5.6 Odontochitina costata
7 Forma J (Subtilisphaera sp 1)
8 Senegalinium sp

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