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Full Length Research Paper

Neogene dinoflagellate cyst assemblages of the late miocene-pliocene Ogwashi-Asaba sediment in umuna-1 well, Anambra basin, southeastern Nigeria

[1*]Ola-Buraimo AO and Akaegbobi IM[2]

[1]Department of Earth Sciences, Ladoke Akintola University of Technology, Ogbomoso, Nigeria
[2]Department of Geology, University of Ibadan, Ibadan, Nigeria

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Ditch cutting samples of interval 24-354m from Umuna -1 well were analyzed for palynomorphs. The interval yielded diverse abundance of dinoflagellates and diagnostic miospores. The marker dinocysts present are *Selenopemphix nephroides, Multispinula quanta, Tuberculodinium vancampoae, Polysphaeridium zoharyi, Impagidinium spp, Oligosphaeridium sp,* and *Thalassiphora sp* which are mainly of Late Miocene to Pliocene age. Presence of diagnostic pollen such as *Nymphae lotus, Elaeis guineensis, Cyperacaepollis sp, Podocarpus millanjianus, Retistephanocolpites gracilis, Arecipites sp* and *Echitricolporites spinosus* serve as control for age dating of the sediments. The paleoenviroment of deposition varies from inner neritic, characterized by *Selenopemphix nephroides*; inner neritic to outer neritic, defined by *Operculodinium spp, Polysphaeridium zoharyi, Tuberculodinium vancampoae*; while the outer to oceanic setting is marked by *Impagidinium sp,* and *Operculodinium centrocarpum*. Lithologic inference is mainly shale coupled with abundance of dinoflagellate cysts, microforaminiferal wall linings, and the predominant marine environments of deposition substantiate the fact that the formation is Ogwashi-Asaba not Benin Formation. This segment of the formation is suggested to be laterally equivalent both lithologically and age to upper part of the Agbada Formation in the adjacent Niger Delta. Evidence of reworked dinocysts and miospores is apparent in the analyzed samples which may suggest that the sediments are admixture of fresh and reworked materials of preexisting older rock probably Oligocene in age. A hiatus is thought to exist between the Late Miocene and the overlying younger Pliocene sediments.

Keywords: Dinoflagellate cysts, hiatus, reworked dinocysts and dichronous.

INTRODUCTION

This is the first time that dinoflagellate study is purely carried out on Tertiary Anambra Basin. Though, pollen and spores have been moderately studied in the basin when compared to the adjoining Niger Delta basin. Well documented work on dinocyst is uncommon on Nigeria sedimentary basins except few ones like that of Oloto (1987), Lawal, (1982) and Jan du Chene and Adediran (1984). Other researchers sparsely dwell on the occurrence of dinoflagellate cysts in sedimentary units only to be used mainly for paleoenvironment of deposition; such as the works of Umeji and Edet, (2006) on the Nsukka Formation of a type locality in Anambra Basin; Umeji and Nwajide, (2007) indicating marine conditions that prevailed across the K/T boundary into the Paleocene; Edet and Nyong, (1993), Ogala et al (2009); Ola-Buraimo and Adeleye (2010).

However, this study intent to use the relative abundance of dinoflagellate cysts present in the well section to date the sediments, determine the paleoenvironment of deposition and suggest the effect of reworked dinocyst which may be responsible for local unconformities. Thus, this paper serves to document the stratigraphic distribution of the dinocysts from cuttings obtained from the Late Miocene through Pliocene of the Ogwashi- Asaba Formation present in Umuna-1 well of Anambra Basin, southeastern Nigeria of which no previous information has been published.

This study has shed more light on the dichronous age

*Corresponding Author Email:rolaburaimo@yahoo.com

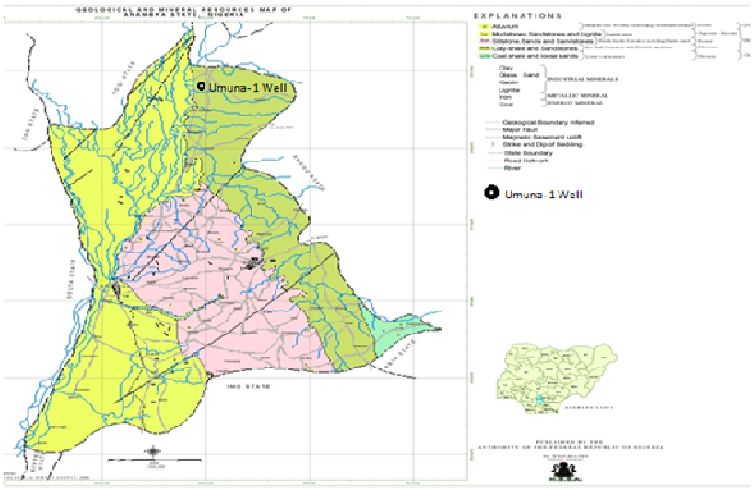

Figure 1. Geological map of Anambra state showing location of Umuna-1 well

of the Ogwashi-Asaba Formation which was supposedly reported to range from Oligocene to Pliocene. Studies carried out by the author on the same formation on another well located in the basin did not indicate Oligocene age as described by Nwajide (1990) and other workers; but rather corroborate the result obtained in this study to have ranged from Late Miocene to Pliocene in age (Figure 1)

Geological Setting

The geology of Anambra Basin is based on the fact that sedimentation did not commence in the basin until post-Santonian tectonic event. It is generally believed that pre-Santonian sediments were deposited in the Abakaliki syncline which contains Asu River Group, Eze Aku and Awgu Formations. The unfolded post-Santonian sediments started deposition in the Anambra Basin during the Campanian with Nkporo Shale at the bottom, sequencially overlain by Mamu, Ajali, Nsuka, Imo, Ameki and Ogwashi-Asaba Formations (Reyment, 1972; Nwachukwu, 1972; Nwajide. 1990). However, recent research studies by the author on some deep wells located in the basin have proved otherwise that there is indeed non-reworked Albian-Coniacian sediments present in the Anambra Basin (In Press). Stratigraphy of the basin is well documented in the work of Nwajide (1990) while the summary is presented is Figure 2.

METHODOLOGY

Analysis was carried out on the selected samples for both lithological and palynomorph contents. The lithological analysis involved observation of the samples under scientific binocular microscope. Features such as lithology type, color, grain size, sorting, fossil content and post depositional diagenetic effect were noted if present in the samples. Information obtained was logged.

Palynological preparation involved maceration of the samples with 60% grade hydrofluoric acid (HF); sieved with 5µm mesh in order to eliminate clay size particles, non-oxidized; separated in heavy liquid of Zn_2Cl_4 before finally mounted on glass slides with DPX mountant. Photographs of important dinoflagellate cysts, microforam lining, algae and miospores were taken with Nikon Coolpix P6000 digital camera.

Previous Studies

Most of the documented palynological studies are based on pollen and spores for stratigraphic age dating in Nigeria sedimentary basins. Few published dinoflagellate cyst studies known are within and outside the basin but Cretaceous in age. The only known dinocyst study on Anambra Basin is the work of Oloto, (1987) on Nkporo Shale (Maastrichtian age) located on the flank of Niger Delta; others are the works of Lawal, (1982) on Benue Trough and that of Jan du Chene and Adediran, (1984) on Dahomey Basin, Nigeria. Other researchers used dinoflagellage cyst assemblages for paleoenvironmental reconstruction. This paper is a research work on dinoflagellates from Tertiary Anambra Basin and specifically from Neogene sediments of the basin.

Nevertheless, outside the shore of Nigeria are Late Cenozoic dinocyst studies from Bering Sea (Bujak, 1984), British Isles (Reid, 1974, 1977), Caribbean Sea (Wall, 1967), Denmark (Piasecki, 1980), Northern Italy (Habib, 1971, Powel, 1986), Japan (Matsuoka, 1974, 1983, 1985), eastern Meditarranian Sea (Rossignol, 1964), North Atlantic Ocean (Brown and Downie, 1984; Coasta and Downie, 1979; Edwards, 1984; Harland,

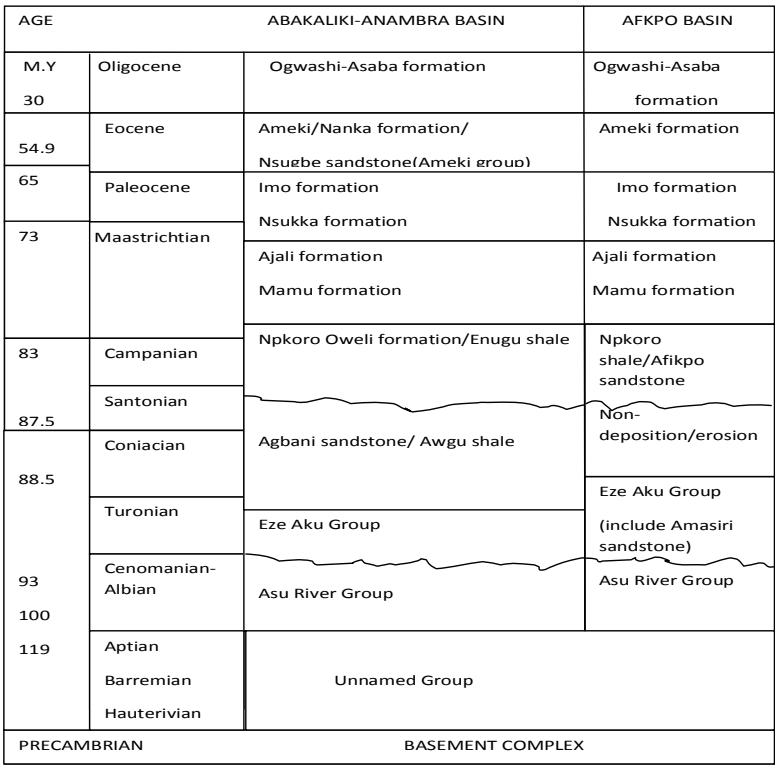

Figure 2. Correlation Chart for Early Cretaceous strata in southeastern Nigeria (After Nwajide, 1990)

1979), Gulf of Mexico (Wrenn and Kokinos, 1986; Duffield and Stein, 1986), Spain (Jan du Chene, 1977), Persian Gulf (Bradford, 1975) and Norwagian Sea (Manum, 1976).

Williams and Bujak (1985) was able to erect biostratigraphic zones based on dinoflagellates which is applicable on local geology of different regions. One of the difficulties encountered in applying dinoflagellate cysts zonation of different authors is the inconsistence of the establishment of bottoms and tops of diagnostic markers. However, the range chart of Williams and Bujak (1985) seems correlable to Anambra Basin in the case of Tuberculodinium vancampoae which falls within the range of Early Miocene to Recent.

Duffield and Stein (1986) uphold that poor recovery of dinoflagellates in the Early and Middle Miocene sediments prevented characterization of dinoflagellates zonation in their analyzed stratigraphic interval of the West Cameron area, offshore Louisiana; USA. Observations noted by earlier workers such as Bujak (1984); Wrenn and Kokinos, (1986) and Duffield and Stein, (1986) with respect to mixed assemblage of provincial and cosmopolitan forms in the Late Miocene sediments is also a characteristic feature of the analyzed section of Umuna-1 well. A concurrent range zone for the Late Miocene-Early Pliocene interval with prominent taxa of Impagidinium and Tuberculodinium vancampoae was established by Bujak (1984). Thus, the application of this zone is possible for this study because of the similarity in dinoflagellate assemblages.

RESULT AND INTERPRETATION

Sedimentology

The lithological description of the interval 24-329m in Umuna-1 well was carried out according to international standard of describing sediments. The information obtained is summarized in the litholog presented in Figure 3 below. Two main lithologic units were deduced from the analyzed stratigraphic interval- shale and shale with minor sand grains facies units.

The lithologic unit 1 is the dominant lithofacies present in the section, characterized by black fissile shale, slightly ferruginised and calcareous at the lower part of the interval. The upper segment is also black, fissile shale, slightly ferruginized but non-calcareous in nature (Figure 3).

Lithologic unit 2 is informally described to be sandy shale (shale with minor sand grains). At the middle part of the analyzed section is the occurrence of the facies. At depth 213m, the facies is a black fissile shale with minor coarse size sand grains (<8%); whereas at 128 m horizon

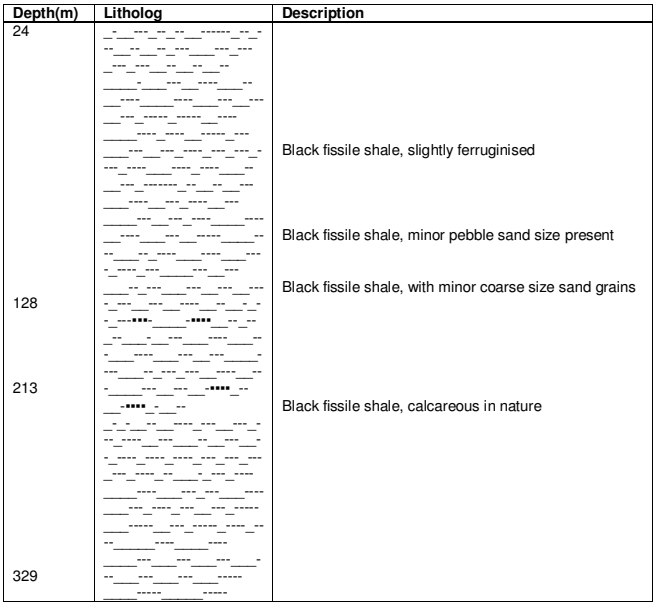

Figure 3. Litholog of Ogwashi-Asaba Formation in Umuna-1 well, Anambra Basin, Nigeria; (Figure not to scale)

the sand size is pebbly which may suggest evidence of erosional surfaces and sediment reworking (Figure 3).

A sedimentological relationship with the palynological content shows that the interval 128-213 m contains reworked dinocysts of older ages such as *Deflandrea sp, Wetzeliela sp, Senegalinium sp, Lejeunecysta diversiforma, Wetzeliela gochtill, Distatodinium craterum* and *Paleocysytodinium golzowense* as a result of input of sediments from older rocks and deposition along with freshly weathered materials into the basin (See Figure 4). The effect of the erosion is manifested by the presence of coarse to pebbly sand grains and admixture of older dinocysts (Oligocene age) with relatively younger dinoflagellate cysts of Late Miocene to Pliocene age.

Palynology

The base of the analyzed interval placed at 329 m is characterized by diagnostic assemblages of *Selenopemphix nephroides, Tuberculodinium vancampoae, Polysphaeridium zoharyi, Impagidinium sp, Multispinula quanta* and *Spiniferites mirabilis*. Other dinocysts present are *Oligosphaeridium sp* and *Cometodinium sp* (Figures 4 and 5). All the dinocysts present at this level are marker fossils of Late to Pliocene age sediments (Bujak, 1984; Wrenn and Kokinos, 1986; Duffield and Stein, 1986). The overlying horizon (311m) is as well rich in palynomorph abundance and diversity like the underlying segment. New dinoflagellates that evolved are *Cyclonephelium sp 3* (Lawal, 1982), *Subtilisphaera aff. deformane* and *Paleocystodinium golzowense*. These forms are long ranging in age, older and non-diagnostic of age. They are likely to have been eroded from pre-existing older sedimentary rock (reworked).

Depth 213 m contains important dinoflagellates such as *Nematosphaeropsis sp, Selenopemphix nephroides, Operculodinium centrocarpum, Spiniferites pachyderma, Multispinula quanta, Spiniferites sp, Impagidinium sp, Spiniferites membranaceus, Polysphaeridium sp, Histrichokolpoma sp* and *Oligosphaeridium sp* (Figure 5). Most of the forms in the assemblage have been used by Bujak,(1984); Wrenn and Kokinos, (1986); Duffield and stein, (1986) to date forms Bering Sea and Northern North Pacific area, De Sato Canyon, Gulf of Mexico; and West Cameron are offshore Louisiana, USA respectively. The analyzed depth is rich in dinoflagellates and miospores. It is also characterized by reworked forms of Oligocene age such *Distatodinium craterum, Wetzeliela sp,* and *Paleocystodinium golzowense.*

The overlying stratigraphic horizon (195m) contains similar assemblage of older age but with new appearances like *Wetzeliela gochtil, Forma D1, D2, Distatodinium sp, Trinovantidiniumsp,* and *Lejeunecysta diversiforma*. Some of the older forms have been well described by Powel, (1986) for the Earliest Paleogene Lemme Section, northwest Italy. The only new form that appeared at depth 171m is *Thalassiphora sp* which is diagnostic of Late Miocene to Pliocene age (Wrenn and Kokinos, 1986).

Interval 85-137m is relatively rich in palynomorphs compared to the overlying interval. The interval is marked by the admixture of old and new dinocysts such as

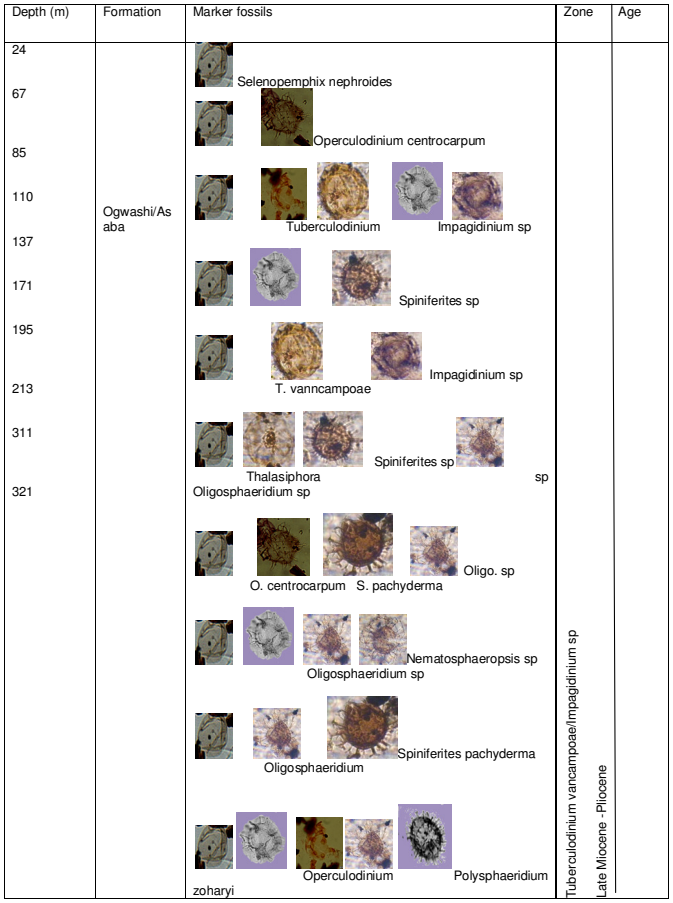

Figure 4. Palynolog of marker forms appearances with deth in Tuberculodinium vancampoae assemblage zone of interval 24-321m, Umuna-1 well, Anambra Basin, Nigeria

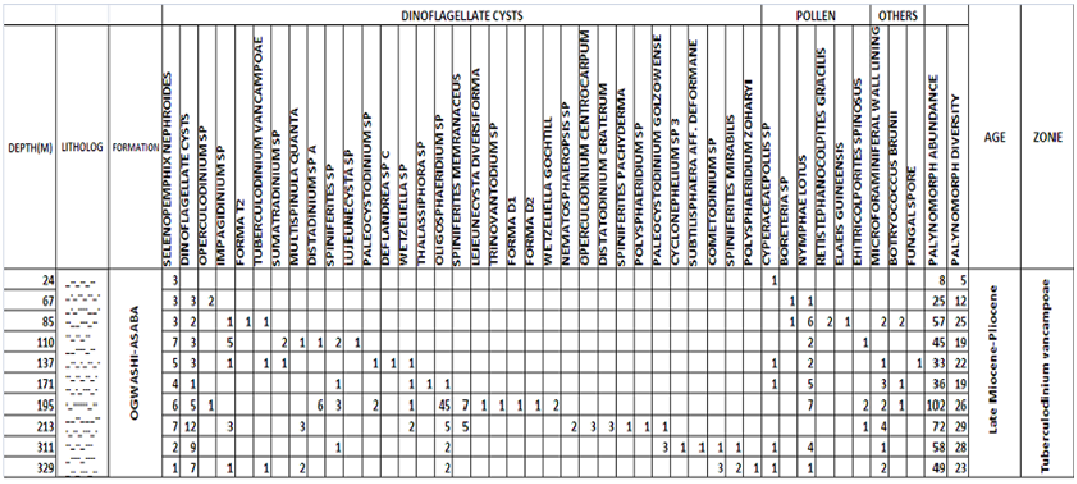

Figure 5. Distribution chart of important dinoflagellates and miospores of interval 24-329m in Ogwashi-Asaba Formation, Anambra Basin southeastern Nigeria

Wetzeliela sp, Paleocystodinium sp, Defladrea sp C, Summatradinium sp, Tuberculodinium vancampoae, are Multispinula quanta, Impagidinium sp and *Spiniferites sp* (Figure 5).

The uppermost interval (24-67 m) is relatively poor in *Impagidinium sp, and Selenopemphix nephroides. Others*

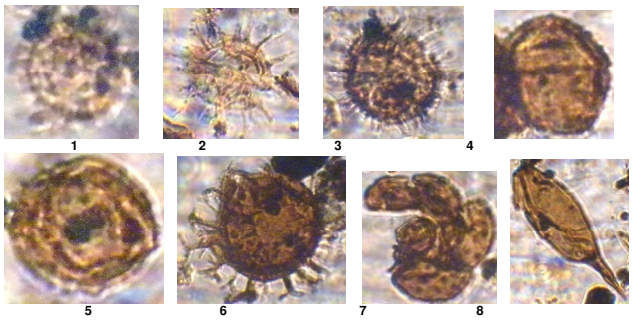

Plate 1. Magnification at ×400
1 Spiniferites sp
2 Polysphaeridium zoharyi
3 Spiniferites sp
4 Canningia sp
5 Nymphae lotus
6 Spiniferites pachyderma Wrenn and Kokinos, (1986)
7 Microforaminiferal wall lining
8 Paleocystodinium golzowense

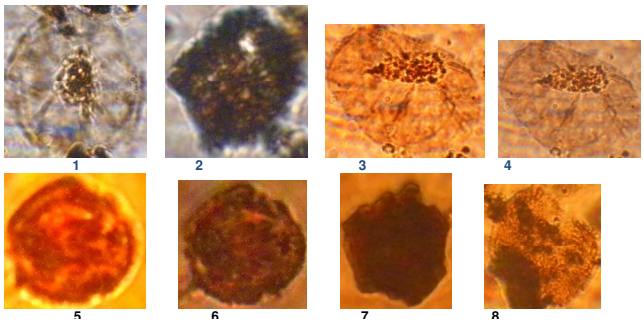

Plate 2. Magnification at ×400
1 Thallasiphora sp
2 Indeterminate
3,4 Invertocysta tabulate Edwards, 1984
5,6 Triporites sp
7 Forma R
8 Indeterminate

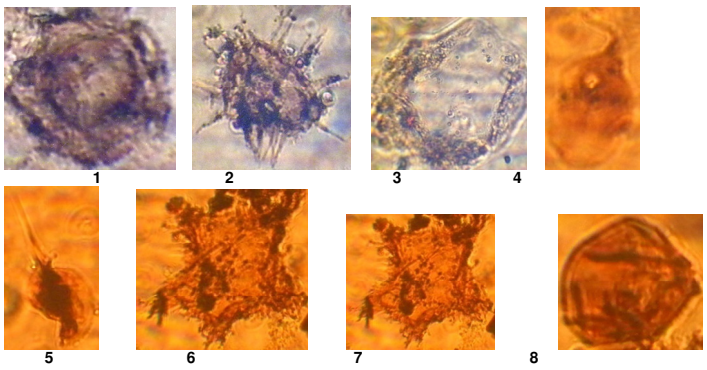

Plate 3. Magnification at ×400
1 Impagidinium striata
2 Echitricolporites spinosus
3 Indeterminata (Forma)
4 Forma D1
5 Forma D2
6,7 Wetzeliella sp B
8 Phelodinium sp

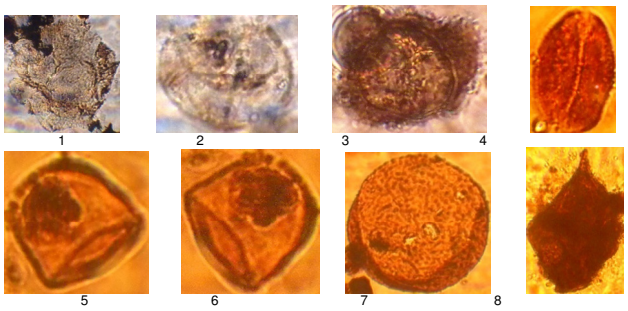

Plate 4. Magnification at ×400
1 Cf Calcium oxalate crystal Ruta et al., 2007
2 Invertocyster tabulate
3 Indeterminate
4 Retimonocolpites sp
5,6 Cyperaceaepollis sp
7 Indeterminate
8 Cribroperidinium sp

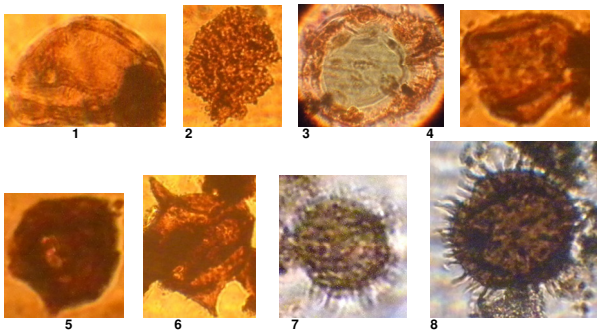

Plate 5. Magnification at ×400
1 Longapertites marginatus
2 Indeterminate cyst
3 Indeterminate Forma T4
4 Cyperaceaepollis sp
5 Forma T3
6 Deflandrea sp
7 Operculodinium sp
8 Echiperiporites estalae

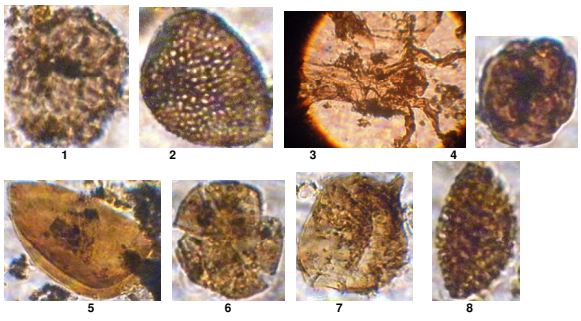

Plate 6. Magnification at ×400
1 Forma P
2 Arecipites sp
3 Distatidinium sp
4 Retistephanocolpites gracilis
5 Longapertites microfoveolatus
6 Stephanocolpites sp
7 Forma T2
8 Retimonocolpites sp

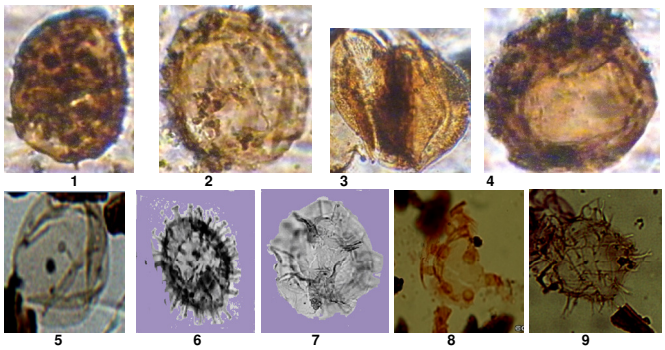

Plate 7. Magnification at ×400
1 Echiperiporites estalae
2,8 Tuberculodinium vancampoae
3 Perfotricolpites digitatus
4 Forma B2
5 Selenopemphix nephroides
6 polysphaeridium zoharyi
7 Impagidinium sp
9 Operculodinium centrocarpum

palynomorph recovery. The only dinocyst forms that appeared are *Selenopemphix nephroides* and *operculodinium sp*. Tappan and Loeblich, (1966) stated that relatively few extant dinoflagellate taxa produce preservable cysts which are suggested to be the case of the Neogene sediments of the Anambra Basin. However, if this statement is right, thus, the diverse and abundant dinocysts assemblages from this interval could suggest that the motile dinoflagellates, both cyst producers and non- producers are common in the Late Cenozoic of the Anambra Basin like the northeastern Gulf of Mexico (Wrenn and Kokinos, 1986).

Therefore, the analyzed stratigraphic interval- 24-329 m contains enough dinoflagellate cyst markers that belong to the Tuberculodinium vancampoae/Impagidinium sp assemblage zone of Bujak, (1986); also similar to dinoflagellate cyst assemblages reported by Wrenn and kokinos, (1986); Duffield and Stein, (1986) to date sediments from De Soto Canyon, Gulf of Mexico and Gulf of Mexico Shelf, offshore Louissiana, USA respectively for Neogene sediments. The high productivity of dinoflagellates in the uppermost part (analyzed section) of Umuna-1 well is suggested to be strongly influenced by upwelling currents, low turbidity, high temperature within the photic zone, relatively shallow to moderately deep water body, high nutrient, adequate Ph and eh. In the view of these the analyzed section is conveniently dated Late Miocene-Pliocene age (Neogene) based on the occurrence of diagnostic dinoflagellate cysts.

This research study aim at the use of dinoflagellates in deducing the stratigraphic age of the analyzed section but is here further corroborated by using the occurrence of marker pollen and spores present. The base of the interval in term of miospores is marked by the first uphole and continuous occurrence of *Nymphae lotus*; the base is further characterized by the assemblages of *Echiperiporites estalae, Perfotricolporites digitatus, Uapaca sp, Crassotriletes vanraadshooveni, Monoporites annulatus, Monosulcites sp, Striatricolpites catatumbus* and *Arecipites sp*. At depth 329m there is an increase in palynomorphs, where new miospores emerged such as *Elaeis guineensis, Cypereceaepollis sp*, *Sclerosrema sp, Retibrevitricolporites obodoensiss* and *Lycopodium phlegmaria*. New forms of pollen and spore that appeared are *Crototricolporites crotonoisculptu*s and *Pteris sp* (See Figure 5).

At depth 213m, new miospores emerged; they are *Sclerosrema sp, Tetradites sp, Echitricolporites spinosus, Zlivisporites neogenicus, Polyadopollenites sp,* and *Brevitricolpites guinetii*. Interval 85-171m is relatively moderate in palynomorph recovery in term of abundance and diversity. Diagnostic miospores continue to appear in the stratigraphy, including *Cyperaceaepollis sp, Nymphae lotus,* and *Arecipites sp;* others are *Retimonocolpites sp, Lycopodium phlegmaria, Perfotricolpites digitatus, Longapertites marginatus, Retistephanocolpites gracilis, Echitricolporites spinosus, Striamonocolpites rectostriatus, Elaeis guineensis* and *Borteria sp*.

Interval 24-67m can be described to contain relatively low abundance and diversity of palynomorphs. There is a continuous reduction in abundance and diversity of dinoflagellates in relation to miospores present in the interval. The top of the interval is placed at 24m where the analysis stopped; characterized by paucity of palynomorphs, top occurrence of *Nymphae lotus, Cyperaceaepollis sp,* and *Arecipites sp*. The near top (67m) is marked by the occurrence of *Borteria sp* along with those miospores present in the upper depth (24m). Therefore, the interval 24-329m is dated Late Miocene to Pliocene age on the basis of co-occurrence of *Cyperaceaepollis sp, Nymphae lotus, Echitricolporites spinosus, Pteris sp,* and *Retistephanocolpites gracilis,*

Elaeis guineensis, and Podocarpus millajianus (Evamy et al., 1978).

The interval is equivalent stratigraphically to Ogwashi-Asaba Formation here dated Late Miocene–Pliocene (Neogene) age. The age deduced in this study is at variance to earlier workers such as Nwajide (1990) and Umeji (2006) who dated the formation to be Oligocene in age (See Figure 2). The age deduced by them may have been due to falsehood presence and admixture of older (Oligocene) and younger (Neogene) fossils present in the sediments.

Evidences of reworked dinocysts and miospores are observed in the analyzed section of Umuna-1 well which suggest that the sediments are admixtures of fresh and reworked materials of pre-existing older rock that is probably Oligocene in age. A detail chronostratigraphic study shows that a Late Miocene/Pliocene boundary cannot be established, therefore, a hiatus is suggested to exist between the Late Miocene and the overlying younger Pliocene sediments probably within the interval associated with reworked sediment. On the basis of lithology and fossil content the Ogwashi-Asaba Formation can be described to be laterally equivalent to the upper part of the Agbada Formation in the adjacent Niger Delta.

The deduction of paleoenvironment of deposition of the studied section follows the interpretation of paleoenvironment of sediments based on exclusive dinoflagellate cysts as proposed by Wrenn and Kokinos, (1986). Various environment of deposition are present in the stratigraphic section ranging from shallow to deep water setting. The inner neritic setting is characterized by *Selenopemphix nephroides*; inner neritic to outer neritic is defined by *Operculodinium spp, Polysphaeridium zoharyi* and *Tuberculodinium vancampoae*; while the outer to oceanic system is marked by *Impagidinium sp* and *Operculodinium centrocarpum*.

CONCLUSION

This is the first time that dinoflagellate cyst would be used exclusively for sediment age dating and paleoenvironmental deduction from Neogene well section of Umuna-1 well located in Anambra Basin, southeastern Nigeria. The attempt made in this study was to corroborate the result obtained from dinoflagellate cysts interpretation with miospores present in order to further substantiate the age of the Ogwashi-Asaba Formation.

The lithostratigraphy is mainly dominated by black fissile shale at the upper and lower portion of the analyzed interval. The middle part is characterized by sandy shale; sand size varies from coarse to pebble suggesting erosional surfaces responsible for the presence of hiatus within the stratigraphic section.

The interval 24-329 m was analyzed for palynomorph content; one dinoflagellate cyst zone of *Tuberculodinium vancampoae / Impagidinium sp* assemblage zone of Bujak, 1984 was established. The dinoflagellate cysts assemblage marker fossils are characterized by the co-occurrence of *Tuberculodinium vancampoae, Selenopemphix nephroides, Polysphaeridium zoharyi, Multispinula quanta, Impagidinium spp, Thalassiphora sp* and *Oligosphaeridium sp*. All the forms are known to be diagnostic of Late Miocene–Pliocene age sediments.

The result obtained was corroborated with the presence of Late Miocene–Pliocene age diagnostic miospores obtained from the samples such as *Elaies guineensis, Nymphae lotus, Cyperaceaepollis sp, Podocarpus millanjianus, Retistephanocolpites gracilis, Arecipites sp* and *Echitricolporites spinosus.*

The presence of admixture of old and young dinocyst assemblage such as *Distatodinium craterum, Wetzeliela sp, Paleocysytodinium golzowense, Wetzeliela gochtil, Distatodinium sp* and *Lejeunecysta diversiforma* which are Oligocene in age with younger Late Miocene to Pliocene forms might have been responsible for the earlier workers erroneous report of Oligocene age for the formation. Paleoenvironment of deposition varies from inner neritic through middle/outer neritic to oceanic setting represented by the occurrence of *Selenopemphix nephroides, Operculodinium spp, Polysphaeridium zoharyi, Tuberculodinium vancampoae* and *Impagidinium sp*.

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