https://dx.doi.org/10.4314/gjgs.v19i1.11

GLOBAL JOURNAL OF GEOLOGICAL SCIENCES VOL. 19, 2021: 133-143
COPYRIGHT© BACHUDO SCIENCE CO. LTD PRINTED IN NIGERIA ISSN 1596-6798
www.globaljournalseries.com, Email: globaljournalseries@gmail.com

OCCURRENCE OF SOME CAMPANIAN-MAASTRICHTIAN ORGANIC-WALLED MICROFOSSILS FROM ENUGU SHALE, ANAMBRA BASIN, SOUTHEASTERN NIGERIA: IMPLICATIONS FOR AGE AND PALEOENVIRONMENTS

IKEGWUONU, OKECHUKWU NICODEMUS, CHIAGHANAM, OSITA IGWEBUIKE, NWAKOBY, NNAMDI ENOCH, ANIWETALU, EMMANUEL UDE, AND CHIADIKOBI, KINGSLEY CHUKWUEBUKA,

(Received 19 July 2021; Revision Accepted 30 August 2021)

ABSTRACT

Detailed geological field mapping and sampling of the Enugu Formation in the Anambra Basin has been carried out in order to re-examine the age of sediments and reconstruct their paleoenvironments of deposition. A total of ten (10) outcrop samples of shale were subjected to palynological laboratory examination, using conventional method of acid demineralization and maceration techniques for recovering acid-insoluble organic-walled microfossils from sediments. Two main lithological units were distinguished: - carbonaceous fissile shale and siltstone. A late Campanian - Earliest Maastrichtian age was assigned based on index palynomorphs marker taxa *Longapertites marginatus* (overwhelming abundance), *Monocolpites marginatus, Zlivisporis blanensis,* and *Echitriporites trianguliformis*. The age designation was strengthened by the occurrence of a well-known stratigraphic age-diagnostic organic-walled microplankton *Coronifera tubulosa*, *Senegalinium* spp. and *Andalusiella polymorpha.* Palynomorphs of environmental value include *Cyathidites minor*, (a tree fern of wet, forested, tropical to temperate regions, usually most developed in mountainous / highland terrains under moist and equable climate); *Spinizonocolpites baculatus/echinatus, Longapertites marginatus, Mauritidites crassibaculatus* and *Moncolpites marginatus*, which are palm pollen that inhabit similar brackish water as the mangrove. A non-marine to marginal marine depositional setting has therefore been proposed for the Enugu Formation.

KEYWORDS: Palynoflora, Anambra Basin, Cretaceous, Spore/ Pollen grain, Microplankton,

1. INTRODUCTION

The Anambra Basin of southeastern Nigeria is a funnel-shaped, concave south structure which was filled with sediments of Campanian-Maastrichtian age (Murat, 1975; Umeji, 2000) (Fig. 1). The basin overlies the folded beds of the southern Benue Trough and is overlain by the deposits of Cenozoic Niger Delta Basin. The Nkporo Group (Nwajide, 2006) forms the oldest unit in Anambra Basin, to which the Enugu Formation belongs. The sediments of the Enugu Formation accumulated in ''the concave inward'' (Reijers, 1996) shaped coastline of the Campanian sea.

Previous workers have described the shales exposed in stream channels around Enugu (e.g. Umeji, 2000). Simpson (1954, p.34) described the soft grey-blue shale in the channels of Asata and the Ogbete Rivers, and noted that although very thin lenses of ''vitrinite'' may occur in dark shales, an unusual 2.5cm band of coal crops out near the top of the formation. Reyment (1965, p.58) observed that occasional beds of white sandstone and striped sandy shale are interlayered with the shale. Ladipo et al. (1992) reports that the facies of the Nkporo Group are inferred to be pro-delta to delta front environments. They noted that the shaly aspects of the group, with their mixed arenaceous and planktonic

Ikegwuonu, Okechukwu Nicodemus, Department of Geology, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State
Chiaghanam, Osita Igwebuike, Department of Geology, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State
Nwakoby, Nnamdi Enoch, Department of Microbiology, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State
Aniwetalu, Emmanuel Ude, Department of Geophysics, Nnamdi Azikiwe Federal University, Awka, Anambra State
Chiadikobi, Kingsley Chukwuebuka, Department of Geology, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State

© 2021 Bachudo Science co. Ltd. This work is licensed Under Creative Commons Attribution 4.0 international license.

foraminiferal suites, represent the prodelta facies of the Campano-Maastrichtian marine incursion. Petters (1995) interpreted the Enugu Shale as the product of processes in delta flood plains (overbank sheet floods, swamps and channels). He remarked that this interpretation is supported by the presence of sparse marsh arenaceous foraminifera *Miliammina* spp. and *Ammodiscus* spp.

Several studies have been carried out in respect to the age and depositional environments of the formation, of which most of the results and conclusions were drawn based on macrofossils, sedimentological and stratigraphic position of the Nkporo / Enugu Shales (Avbovbo and Ayoola, 1981; Whiteman, 1982; Nwajide, 2006). However, very few workers have demonstrated in detail the use of palynological suites for determining the age and environments of deposition of the formation. The present study therefore aims at re-evaluating the age of the Enugu Formation and reconstructing the depositional setting, using organic-walled microfossils.

2. REGIONAL GEOLOGY AND STRATIGRAPHY

The Anambra Basin is the southern part of the regionally extensive northeast-southwest trending Benue Trough (Fig. 1). The basin is one of the seven sedimentary domains of Nigeria (Nwajide, 2006). The lithic fill of the Anambra Basin originated as a result of the depression of the area

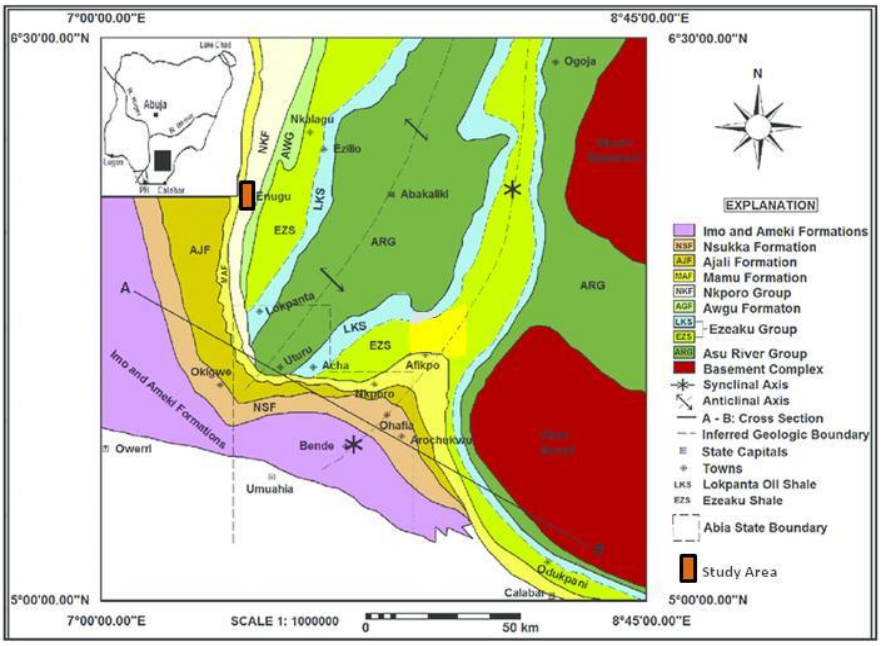

Fig. 1: Regional geologic map of southeastern Nigeria (modified after Murat, 1972)

Age	Basin	Stratigraphic Units					Group
Thanetian	Niger Delta	Imo Formation					
Danian	Anambra Basin	Nsukka Formation					Coal Measure Group
Maastrichtian		Ajali Formation					
		Mamu Formation					
Campanian		Nkporo Formation	Enugu Formation	Owelli Sandstone	Afikpo Sandstone	Lafia Sandstone	Nkporo Group
Coniacian - Santonian	Southern Benue Trough	Awgu Formation					

Fig. 2: Regional stratigraphy of the Anambra Basin (modified after Nwajide, 2006)

around the southern Benue Trough contemporaneous with folding of the latter in the Santonian. The basin became filled with two lithological groups – the Nkporo Group and the Coal Measures Group, following one major transgression and one major regression.The Nkporo Group forms the basal part of the basin and consists of the Nkporo Formation, the Enugu Shale, the Owelli Sandstone, and the Afikpo Sandstone (Nwajide, 2006) (Fig. 2). The Coal Measure Group forms the upper part of the Anambra Basin and of the Mamu Formation overlain by the Ajali Sandstone topped by the Nsukka Formations.

The study area is delimited by longitudes 7^{o} 28^{l} - 7^{o} 35^{l} E and latitude 6^{o} 19^{l} - 6^{o} 30^{l} N and falls within the Anambra Basin (Fig. 3). It is bounded in the east by Emene town, in the north by

Abakpa, and toward the west by Trans Ekulu, and to the south by Agbogugu - Owelli town. Major road includes the Ogui – Abakaliki road, which traverses the study area in an east – west direction, and serves as the take-off of the Enugu Port Harcourt express.

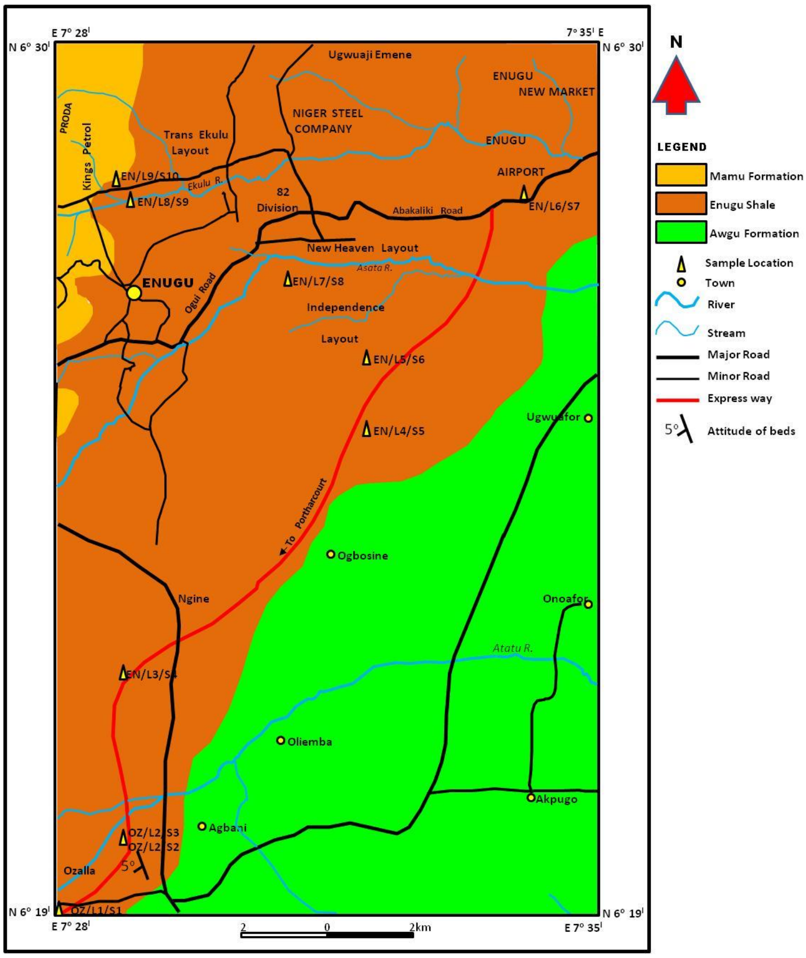

Fig. 3: Geologic map of study area.

3. MATERIALS AND METHODS

The materials for this study were obtained by sampling the shale intervals of the Enugu Formation. Exposures of the formation were systematically logged at different localities, such as Ozalla Junction at unit Loc. 1 in the southwest, along Enugu-Port Harcourt expressway, up to unit Loc. 9, near first flyover across the Enugu-Onitsha expressway, in the northern part of the study area (see Fig. 3).

Ten (10) shale samples were subjected to standard conventional method of acid demineralization and maceration for recovering acid-insoluble organic-walled microfossils. Each sample was thoroughly cleaned to remove field contaminants. 10 g of each shale sample was weighted out using weighing balance and gently crushed with agate mortar and piston. HCL acid treatment was unnecessary since the shale samples signaled non-calcareous. The crushed calcite-free sample was digested for 72 hours in 48 % hydrofluoric acid for removal of silicates. The samples were diluted with distil water to neutralize the acid, and then sieve-washed through 10 microns nylon mesh to enable the organic residue be free from mud and acid. The sieve-washed 10 g residue equivalent was partitioned into two parts, 5 g each, for oxidation and the other 5 g for kerogen studies. The 5 g acid-free organic residue extract from shale was oxidized for 30 minutes in 70% conc. nitric acid and 5 minutes in Schulze solution to render the fossils translucent for transmitted light microscopy. The oxidized residues were rinsed in 2% KOH solution to neutralize the acid. Heavy liquid separation using zinc chloride was employed to separate the palynomorphs, and remove resistant coarse mineral particles and undigested organic matter.

The palynomorph residues were collected on the sieve and stained with Safranin – O to increase the visibility for microscopic study. Aliquots were dispersed with polyvinyl alcohol, dried on cover-slips and mounted in petro-poxy resin. One slide was made from each sample for transmitted light microscopic study.

3. RESULTS

Table 1 shows the absolute occurrence and distribution of palynomorphs present in the samples from Loc. 1 to 9. The carbonaceous fissile shale samples generally yielded moderately rich palynomorph assemblage. Terrigenous species such as fern spores were the most abundant in almost all the examined samples, followed by pollen species of mangrove affinity. Marine species such as dinoflagellate cysts recorded very few presence.The peridiniacean species with a proximate cyst affinity predominates over the gonyaulacaceans.

Terrigenous species

Spores: Among the terrigenous species, spores were themost abundant and less diverse. Among the fern spores, *Laevigatosporitesovatus* was the most abundant (58 counts) in sample En/L9/S10, (Table 1) (Fig. 4). The samples from Loc. 1, 2a, 5, 7, and 8, recorded higher percentage frequency of spores (Table 3), with 45% count at Loc. 1, Loc. 2a (71 %), Loc. 5 (57 %), Loc. 7 (70 %), and 83 % at Loc. 8. Fresh water species, such as *Azolla cretacea,* were also recorded but in a very low numbers.

Pollen: Pollen gains were the second most abundant in all the samples but were the most diverse of the palynomorphs. Among the pollen grains, *Longapertites marginatus* produced the highest-counts (30) in sample En/L4/S5 (Fig. 4). The samples OZ/L3/S4 from Loc. 3 recorded higher percentage frequency of pollen count (71 %) followed by sample OZ/L2b/S3 (64 %) and EN/L4/S5 (49 %).

Marine species

Dinoflagellate cyst: Among the marine dinoflagellate species, the peridiniacean species *Andalusiella polymorpha* recorded the highest absolute count of (4) in sample EN/L4/S5. Other samples from locations such as, Loc. 2a, 2b, 4, 5, and 7, with (10 %, 5 %, 7 %, 9 %, and 2 %, respectively), relative percentage marine influence, were also recorded. Samples from Loc. 3, 6, 8, and 9, recorded no marine species.

5. DISCUSSIONS

5.1 AGE DETERMINATION AND CORRELATIONS

The abundance of stratigraphically significant miospore species as well as the presence of some marker taxa in the examined samples constitutes the basis for assigning an age to the Enugu Formation (see Table 1). The stratigraphic distribution of palynomorphs in the studied lithologic sections (Fig. 5) shows that the assemblage is similar to those of the Campanian-Maastrichtian interval of coeval tropical-subtropical Africa, South America and India (Van Hoekenklinkenberg, 1964, 1966; Jardine and Magloire, 1965; Herngreen, 1975; Jan du Chene et al., 1978, Salard-

Table 1: Absolute occurrence and distribution of palynomorphs present in the examined samples.

Sample No. / Palynomorphs species	OZ/L1/ S1	OZ/L2/ S2	OZ/L2/ S3	EN/L3/ S4	EN/L4/ S5	EN/L5/ S6	EN/L6/ S7	EN/L7/ S8	EN/L8/ S9	EN/L9/S 10
TERRESTRIAL SPECIES										
Spores										
Laevigatosporites ovatus	14	10	8	4	35	20	8	26	14	58
Cyathidites minor	-	-	-	-	-	-	-	-	3	-
Cyathidites austrialis	2	-	1	-	-	-	-	1	-	-
Leiotriletes adriennis	-	-	-	-	-	-	-	-	-	-
Lycopodiumsporites fastigides	-	-	-	-	7	1	-	-	-	-
Leiotriletes major	-	-	-	-	-	-	-	1	-	-
Verrucatosporites usmensis	-	-	3	-	1	2	1	2	-	-
Leiotriletes adriennis	1	-	-	-	-	-	-	6	2	-
Distaverrusporites simplex	1	-	1	-	1	-	-	-	-	-
Leiotriletes minor	-	2	-	-	-	-	-	-	-	-
Rugulatisporites capratus	-	-	-	-	-	-	-	1	-	-
Azolla cretacea	1	-	-	-	1	-	-	-	-	-
Zlivisporis blanensis	-	-	-	-	2	1	-	1	-	-
Pollen										
Longapertites vaneedenburgi	2	1	3	-	1	2	-	1	-	-
Scabratriporities simplformis	-	-	-	-	-	1	-	-	-	-
Proxapertites operculatus	1	-	1	1	10	3	1	1	1	1
Proxapertites anisoscuptus	-	-	-	1	1	-	-	-	-	-
Echitriporites trianguliformis	1	-	2	-	-	-	-	-	-	-
Retidiporites magdalenensis	1	-	-	-	3	1	-	-	-	2
Spinizonocolpites baculatus	-	-	2	1	1	-	-	-	-	-
Mauritidites crassibaculatus	2	-	1	1	-	-	-	-	-	-
Auriculitides reticulatus	-	-	-	-	1	-	-	-	-	-
Longapertites marginatus	3	1	12	3	30	-	6	-	2	4
Psilamonocolpites magnus	2	-	4	1	-	-	-	-	-	-

Monoporites annulatus	-	-	3	-	-	-	-	1	-	-
Cycadopites ovatus	-	-	-	2	2	4	2	9	1	6
Spinizonocolpites echinatus	-	-	-	-	-	-	-	1	-	-
Ephiedripites sp	-	-	-	-	-	-	-	-	-	1
Monocolpites marginatus	2	-	-	-	4	-	-	2	-	1
Mauritidiites crassibaculatus	-	-	-	-	1	-	-	-	-	-
Proxapertites cursus	1	-	-	-	-	-	-	-	-	2
Proteacidites miniporatus	1	-	-	-	-	-	-	-	-	-
Proteacidites dehaani	-	-	-	-	1	1	-	-	-	-
Psiltricolporites crassus	-	-	-	-	-	1	-	-	-	-
Echitriporites trianguliformis	-	-	-	-	-	1	-	-	-	-
Syncolpites marginatus	-	1	-	-	-	-	-	-	-	-
Retitricolpites irregularis	-	1	-	-	-	-	-	-	-	-
Psilatricolpites sp.	-	-	1	-	-	2	-	-	-	-
MARINE SPECIES										
Coronifera tubuloss	-	-	-	-	1	-	-	-	-	-
Andalusiella polymorpha	2	-	1	-	4	-	-	-	-	-
Dinogymnium sp.	1	-	-	-	3	-	-	-	-	-
Paleocystodiium sp	-	-	-	-	1	-	-	-	-	-
Phelodinium sp.	1	1	-	-	-	-	-	-	-	-
Cordosphaeridium deckoninki	-	-	1	-	2	2	-	1	-	-

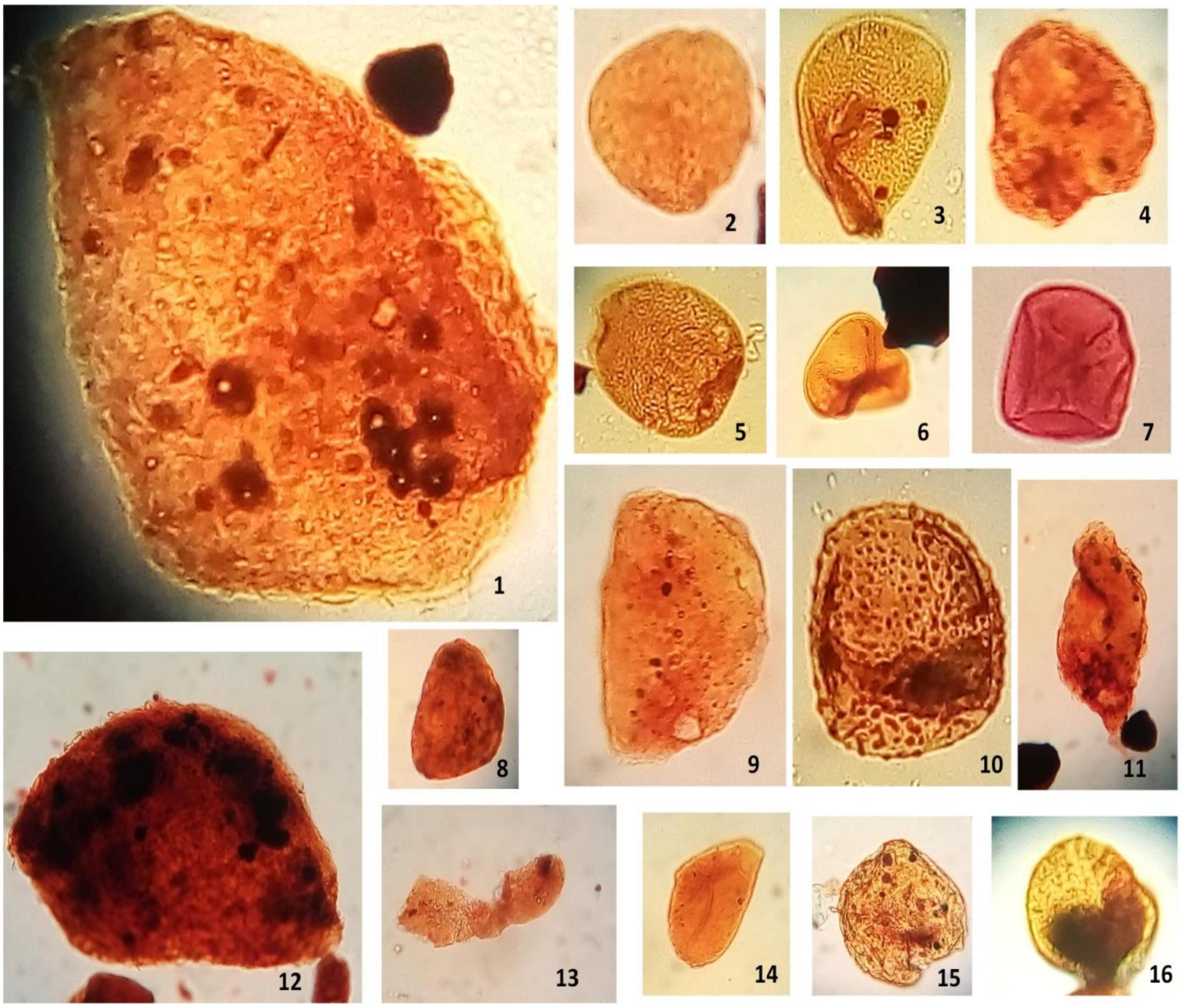

Fig. 4: Micrographs of some palynomorphs from the examined samples.

1.	*Longapertites vaneedenburgi*	9.	*Longapertites marginatus*
2.	*Leiotriletes adriennis*	10.	*Verrucatosporites usmensis*
3.	*Cyathidites minor*	11.	*Mauritidites crassibaculatus*
4.	*Proxapertites cursus*	12.	*Longapertites marginatus*
5.	*Retidiporites magdalensis*	13.	*Azolla cretacea*
6.	*Leiotriletes minor*	14.	*Laevigatosporites ovatus*
7.	*Laevigatosporites ovatus*	15.	*Retidiporites magdalensis*
8.	*Laevigatosporites ovatus*	16.	*Retitricolporites irregularis*

Cheboldaeff, 1979, Salami, 1983, 1988; Lawal and Moullade, 1986; Schrank, 1987; Edet and Nyong, 1994; Umeji, 2007). Based on palynological results, a late Campanian - Earliest Maastrichtian age was established for the formation based on the following index marker taxa: *Longapertites marginatus* (Overwhelming), *Monocolpites marginatus, Zlivisporis blanensis, Echitriporites trianguliformis*, and organic-walled microplanktons *Coronifera tubulosa*, *Senegalinium* spp. and *Andalusiella polymorpha,* (Schrank, 1987; Lawal and Moullade, 1986; Edet and Nyong, 1994) (Fig. 5). The species of *Coronifera tubulosa* and *Andalusiella polymorpha* have been reported from the Campanian of Egypt by Schrank (1987). Edet and Nyong (1994) identified the organic-walled microplanktons *Coronifera tubulosa, Senegalinium* spp. and *Andalusiella polymorpha* in the Nkporo Shale within the Calabar Flank, and remarked that in the tropical-subtropical regions, these species are mainly recorded from Campanian-Maastrichtian intervals (Herngreen, 1975b; Jain and Millepied, 1975; Salami, 1986, 1988; Schrank, 1986).

Edet and Nyong (1994) further reported that microfloral distribution within the Nkporo Shale in the Calabar Flank shows a frequent to common occurrence of stratigraphically significant miospore species typical of Campanian-Maastrichtian deposits of tropical-subtropical regions. The species include *Monocolpites marginatus, Longapertites marginatus, Longapertites* sp. 3 (Lawal and Moullade, 1986), *Echitriporites trianguliformis*, and *Dinogymnium acuminatum.* The presence of these species in the recovered assemblage from the examined samples in the study area thus supports a late Campanian-Earliest Maastrichtian age for the Enugu Formation. This age designation based on palynological result is in accord with the age indications of the ammonites and foraminifera. The age assignment correlates well with the late Campanian-Maastrichtian assemblage of (Chiaghanam et al., 2012), based on *Longapertitesmargintus*, *Echitriporites trianguliformis, Monocolpites marginatus,* and *Dinigymnium acuminatum* and *Andalusiella polymorpha.*

5.2 PALEOENVIRONMENTS OF DEPOSITION

Table 2 below shows the summary of palynomorphs percentage (%) frequency distribution and their paleoenvironmental inferences in the studied sections. The environments of deposition of the sediments of formation have been a subject of discussion in various published works (e.g. Chiaghanam et al., 2012). The authors suggested marginal marine environments for the shale of the Enugu Formation. Some other authors however recognized and reported certain non-marine sedimentological features in these sediments. The occurrence of well preserved terrestrial miospores from the shaly intervals of the formation in the study area, being recorded here, is therefore significant in elucidating the processes of sedimentation.

The paleoenvironments of the Enugu Formation may be reconstructed by evaluating its palynological attributes. The environmental changes are reflected in the palynological assemblages and are especially noticeable in the composition and relative proportion of different classes of palynomorphs, (Oloto, 1989; Ikegwuonu et al. 2020). The major components include spores and pollen grains. The associated elements include dinoflagellate cysts. Palynological data have been found useful as a paleoenvironmental synthesis tool (Oloto, 1989; Petters and Edet, 1996; Ojo, 1999, 2009). In these studies, the interpretation is based on the ratio of land derived miospores to marine dinoflagellates and also the morphology of the dinocysts, (Ojo, 2009). Schrank (1984) suggests that a palynomorph assemblage with higher content of land derived miospores indicates terrestrial influence and vice versa.

In this study, the palynomorphs of environmental value include: *Cyathidites minor*, a tree fern which inhabits a wet, forested, tropical to temperate regions, usually most developed in mountainous / highland localities under moist and equable climate; *Spinizonocolpites baculatus/echinatus, Longapertites marginatus, Mauritidites baculatus* and *Moncolpites marginatus* are palm pollen which inhabit similar brackish waters as the mangrove (Umeji and Nwajide, 2014; Ikegwuonu and Umeji, 2016). The overwhelming occurrence of well-known terrestrial miospores such as, *Laevigatisporites ovatus*, *Longapertites marginatus*, *Monocolpites marginatus,* and with few marine dinoflagellates of peridinioid affinity such as *Andaluseilla*spp., *Dinogymnium* spp., and *Senegalinium* spp., generallyindicate strong terrestrial conditions, with minor marine flooding. This is evident from the high dominance of miospore pollen with abundance fresh water fern spores over the marine microplankton in almost the entire samples. The samples OZ/L1/S1, OZ/L2/S2, OZ/L2/S3, EN/L4/S5, EN/L5/S6 and EN/L7/S8, recorded higher percentage frequency of miospore species, especially the fresh water fern spores *Laevigatosporites ovatus* and pollen grain of palmae *Longapertites marginatus*, than the marine species, indicating deposition in a marginal marine/ or brackish water condition probably in a proximal estuarine environment, whereas samples EN/L3/S4, EN/L6/S7, EN/L8/S9 and EN/L9/S10 documented only

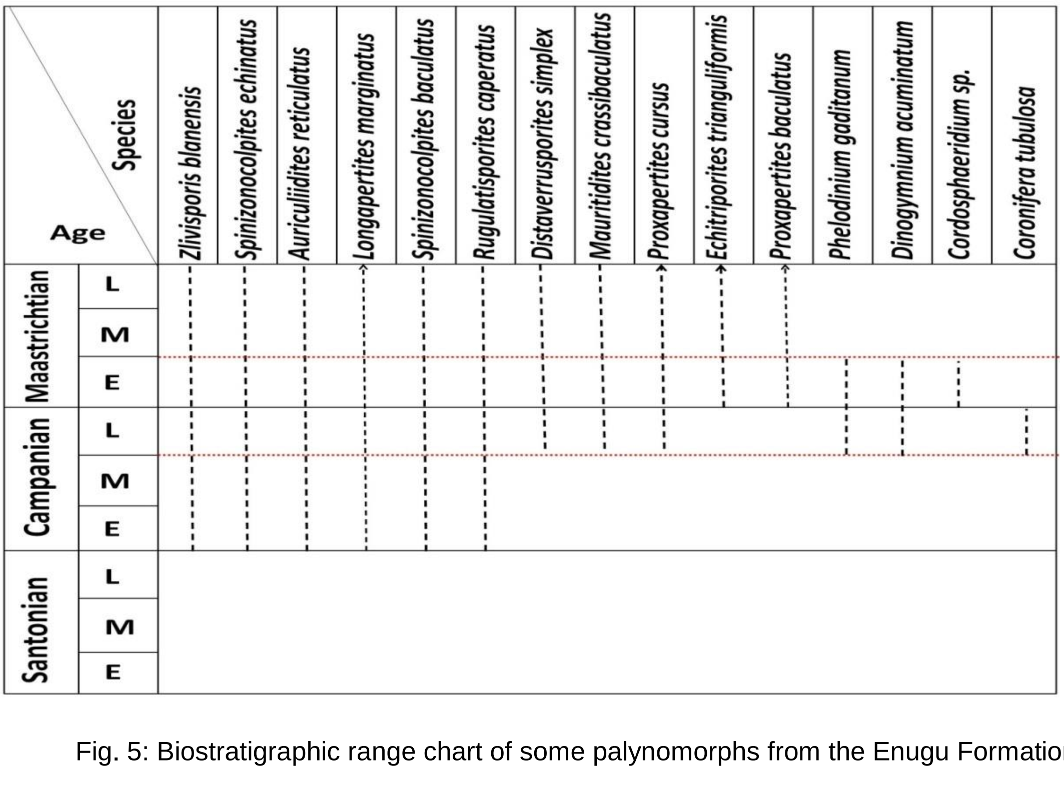

Fig. 5: Biostratigraphic range chart of some palynomorphs from the Enugu Formation.

Table 2: Summary of palynomorphs % frequency distribution and their paleoenvironmental indications.

SAMPLE NO.	PALYNOMORPHS % FREQUENCY			PALEO-SALINITY	PALEOENVIRONMENTS OF DEPOSITION
	Spores	Pollen	Marine Species		
OZ/L1/S1	49%	41%	10%	Brackishwater	Marginal marine (Proximal estuary)
OZ/L2/S2	71%	24%	5%	Brackishwater	Marginal marine (Proximal estuary)
OZ/L2/S3	29%	64%	7%	Brackishwater	Marginal marine(Proximal estuary)
EN/L3/S4	29%	71%	0%	Freshwater	Non-marine (Mangrove)
EN/L4/S5	42%	49%	9%	Brackishwater	Marginal marine (proximal estuary)
EN/L5/S6	57%	38%	5%	Brackishwater	Margin al marine (proximal estuary)
EN/L6/S7	50%	50%	0%	Freshwater	Non-marine (Mangrove/Lake)
EN/L7/S8	70%	28%	2%	Brackishwater	Marginal marine (proximal estuary)
EN/L8/S9	83%	17%	0%	Freshwater	Non-marine (Mangrove)
EN/L9/S10	76%	24%	0%	Freshwater	Non-marine (Mangrove)

the terrestrial miospore species with no marine species, indicating deposition in a non-marine/ fresh water condition probably in a mangrove swamp setting (see table 2). In general, following these observations, the depositional paleoenvironment of the Enugu Formation ranged from non-marine to marginal marine settings.

5. CONCLUSIONS

Detailed palynological studies of the Enugu Formation based on the occurrence of both miospores and dinoflagellate cysts have been undertaken within Enugu and environs. The recovered palynofloral assemblage essentially demonstrates the typical features of the Senonian Palmae province comprising mostly of Campano-Maastrichtian taxa reported from tropical-subtropical regions of South America, India and Africa.

Based on the result obtained from this study, a Late Campanian - Earliest Maastrichtian age interval was assigned for the formation following the stratigraphically significant age marker palynomorph taxa recovered. Environmentally significant palynomorph species encountered were equally utilized in delineating the environments of deposition of the sediments, which ranged from non-marine to marginal marine within the upper to lower deltaic setting.

REFERENCES

Avbovbo, A. A. and Ayoola, O., 1981. Petroleum prospects of southern Nigeria's Anambr Basin. Oil and Gas Journal, May 4, 1981

Chiaghanam O. I., Ikegwuonu O. N., Chiadikobi K. C., Nwozor K. K., Ofoma A. E and Omoboriowo A. O., 2012. Sequence Stratigraphy and Palynolgical Analysis of the Late Campanian to Maastrichtian Sediments in the Upper-Cretaceous, Anambra Basin (A Case Study of the Okigwe and its Environs, South-Eastern Nigeria). Pelagia Research Library (Advances in Applied Science Research) Journal 3(2): 962-979.

Edet, J. J and Nyong, E. E., 1993. Depositional environments, sea-level history and palaeobiography of the late Campanian-Maastrichtian on the Calabar Flank, SE Nigeria.

Germeraad, J. H., Hopping, C. A., Muller, J., 1968. Palynology of Tertiary sediments from tropical areas. Rev. Paleobot. Palynol. 6: 189-343.

Harland, R., 1978. Dinoflagellate cysts and achritarchs from the Bearpaw Formation (Upper Campanian) of southern Alberta, Canada. Paleontology, 16: 665-706.

Herngreen, G. F. W., 1975. Palynology of Middle and Upper Cretaceous strata in Brazil. Meded. Ryks Geol. Dienst n.s. 26: 39-91

Ikegwuonu, O. N. and Umeji, O. P., 2016. Palynological age and paleoenvironment of deposition of Mid-Cenozoic sediments around Umuahia Niger Delta, southeastern Nigeria. Journal of African Earth Sciences, 117 (29): 160-170.

Ikegwuonu, O. N. and Umeji, O. P., Chiaghanam, O. I., Nwozor, K. K., Ndukwe, O. S., and Chiadikobi, K. C., 2020. Palynomorph assemblage biozonation of Paleogene strata in Bende-Umuahia area, Niger Delta Basin, southeastern Nigeria. Journal of Palaeogeography, 9: p. 1-13.

Jain, K. P. and Millipied, P., 1975. Createaceous Microplankton from Senegal basin, W. Africa II, Systematics and biostratigraph. Geophytology, 5: 125-171.

Jan du Chene, R. E., and Salami, M. B., 1978. Palynology and micropaleontology of the upper Eocene of the well Nsukwa-I, Niger Delta. Nigeria, 13 centuries Recherches des séances SPHN Geneve, pp: 5-9.

Jan du Chene, R. E., Onyike, M. S and Sowunmi, M. A., 1978c. Some new Eocene pollen of the Ogwashi-Asaba Formation ,south-eastern Nigeria. Rev. Esp Micropaleontol., 10 (2): 285-322.

Jardine, S. and Magloire, L., 1965. Palynologie et stratigrapie du Cretace des Bassins du Senegal et de Cote d' Ivoire. Mem. B.R.G.M. 32 Coll. Micropal: 187-222.

Ladipo K. O., 1988. Paleogeography, Sedimentation and Tectonics of the Upper Cretaceous Anambra Basin, Southeastern Nigeria. Journal of African Earth Sciences, **7:** 815-821.

Lawal, O and Moullade, M., 1986. Palynological biostratigraphy of the Createaceous sediments in the Upper Benue Basin. N.E Nigeria. Rev. Micropaleontol., 29(1): 61-83.

Murat, R. C., 1972. Stratigraphy and Paleogeography of the Cretaceous and Lower Tertiary in Southern Nigeria. In Dessauvigie, T.F.J and Whiteman, A. J., (Eds.), African Geology, University of Ibadan Press, P. 251-266.

Nwajide C. S. 1990. Cretaceous Sedimentation and Paleogrography of the Central Benue Trough. In: The Benue Trough Structure and Evolution, edited by Ofoegbu CO, Braunschwelig and Wiesbaden, Germany, Vieweg and Shne Verlag, 19-38.

Nwajide S. C., 2006. Anambra Basin of Nigeria: Synoptic basin analysis as a basis for evaluating its hydrocarbon prospectivity. In: Okogbue, C. O (ed.) Hydrocarbon potential of the Anambra Basin: Geology, geochemistry and geohistory perspectives. Proceedings of the first seminar organized by the Petroleum Technology Development Fund (PTDF) Chair in Geology University of Nigeria, Nsukka, May 12-12, 2005, pp. 1-46.

Nwajide S. C., 2013. Geology of Nigeria's Sedimentary Basin (CSS Bookshops) 277-518.

Odunze, S. O. and Obi, G. C., 2013. Sedimentology and Sequence Stratigraphy of the Nkporo Group (Campanian to Maastrichtian) Anambra Basin, Nigeria. Journal of Paleogeography, 2: 192-208

Oloto, I. N., 1984. A palynological study of the late Createaceous and Tertiary boreholes from Southern Nigeria sedimentary basins. PH.D .thesis, Univ. of Scheffield (unpublished), 180 pp.

Oloto, I. N., 1989. Maastrichtian dinoflagellate cyst assemblage from Nkporo Shale on the Benin Flank of the Niger Delta. Review of palaeobotany and palynology, 57: 173-186.

Ojo O. J., 2009. Occurrence of some Maastrichtian dinoflagellate cysts from the Upper Cretaceous sediments in southern Bida Basin, Nigeria: Implications for age and paleoenvironments. Ozean Journal of Applied Sciences, 2 (3): pp. 291-305.

Reijers T. J. A., 1996. Selected Chapters in Geology, Shell Petroleum Development Company (Nigeria) publication, 197 p

Petters, S. W., 1978. Stratigraphic Evolution of the Benue Trough and its implications for the Upper Cretaceous Paleogeography of West Africa. Journal of Geology, 86: 311-322.

Petters S. W., 1995. South-eastern Benue Trough and Ikom-Mamfe Embayment. Excursion Guide, 31st Annual Conference of the Nigerian Mining and Geosciences Society, p. 54.

Petters, S. W. and Edet, J. J., 1996. Shallow shelf and anoxic facies in the Late Campanian-Early Maastrichtian of S. E Nigeria. Geologie de l' Afrique et de l' Atlantique Sud: Actes Colloques Angers, pp. 219-233.

Reyment, R. A., 1965. Aspects of the Geology of Nigeria: the stratigraphy of the Cretaceous and Cenozoic deposits Ibadan University Press, 145p.

Salard-Cheboldaeff, M., 1979. Palynologie Maastrichtienne et Tertiaire du Cameroun. Etude Qualitative et Repartition verticals des principales especes. *Review of Palaeobotany and Palynology,* **28**: 365–388.

Salami, M. B., 1983. Some Late Createaceous and Early Tertiary pteridophytic spores from the southern Nigeria sedimentary basin. Rev Esp. Micropaleontol. 15(2): 252-272

Salami, M. B., 1986. Some diniflagellate cysts and acritarchs from the late Cretaceous and Paleogene sediments of the Benin (ex Dahomey) Embayment in southwestern Nigeria. Ife J. Sci., 1(1): 11-12

Salami, M. B., 1988. Petrology and palynoogy of the Upper Maastrichtian Abiokuta Formation of southwestern Nigeria. Niger. J. Sci., 22 (1/2): 127-142

Schrank, E., 1984. Organic-Geochemical and palynological studies of a Darkhla Shale profile (Late Createceous) in southeast Egypt. Part A: Succession of microfloras and depostional environment. Berl. Geowiss. Abh. (A), 50: 189-207.

Simpson, A., 1954. The Nigerian Coalfield: The geology of part of Owerri and Benue provinces. Bulletin Geological Survey Nigeria, 24: 1-85.

Umeji, A. C., 2000. Evolution of the Abakaliki and the Anambra Basin Sedimentary basins, southeastern Nigeria. A report submitted to the Shell Petroleum Development Company, Nigeria Limited. 155 p

Umeji, O. P., 2007 Late Albian to Campanian palynostratigraphy of southeastern Nigerian sedimentary basins. Unpublished PhD thesis, Department of Geology, University of Nigeria, Nsukka, 280 p.

Umeji, O. P. and Nwajide, C. S., 2014. Record of warm temperate pollen from the Palaeogene – Neogene lignite of southeast Nigeria: Consequences of regional palaeoclimatic changes or tectonics? Quaternary International, **338**: 2–13

Whiteman, A. J., 1982. Nigeria: Its Petroleum Geology, Resources, and Potential. Graham and Trottan, London, 394p.

Van Hoeken-Klinkenberg. P. M. J., 1964. A palynological investigation of some Upper Createaceous sediments in Nigeria. Polen et spores, 6 (1): 209-231

Van Hoeken-Klinkenberg. P. M. J., 1966. Maastrichtian Paleocene and Eocene pollen amd spores from Nigeria. Geologische Mededelingen, 38: 37-48.