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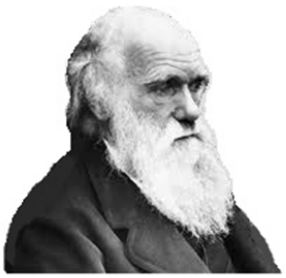

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Palynological Study of the Campano-Maastrichtian Nkporo Group of Anambra Basin, Southeastern, Nigeria

K. C. Chiadikobi[1], **O. I. Chiaghanam**[1], **O. C. Onyemesili** and **A. O. Omoboriowo**[2]

[1]Department of Geology, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria

[2]Department of Geology, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria

*E-mail address: kinsomino@yahoo.com

ABSTRACT

Palynological assemblages were used in the determination of the age and paleoenvironment of the Nkporo and Enugu Formations of the Anambra Basin, Southeastern Nigeria. Palynological analysis carried out in over twenty-five samples (25) yielded spores, pollens and marine species. The main diagnostic species of spores and pollen recovered includes; Foveotriletes margaritae, Distaverrusporites simplex, Cingulatisporites ornatus, Echitriporites trianguliformis, Longapertites marginatus, Proteacidites segali, Monocolpites marginatus, Constructipollenites ineffectus, Buttinia andreevi, and Retidiporites which were dated to Late Campanian to Earliest Maastrichtian. Also, other sporomorphs includes; Longapertites marginatus (overwhelming abundance), Longapertites microfoveolatus, Longapertites vaneedenburgi, Spinizonocolpites baculatus, Foveotriletes margaritae, Distaverrusporites simplex, Cingulatisporites ornatus, Matonisporites equiexinus, Azolla marsulae, Mauritidiites crassibaculatus, Constructipollenites ineffectus, Echitriporites trianguliformis, Foveotriletes margaritae, and Leiotriletes minor were assigned to Early Maastrichtian. From the palynological analysis, the age-diagnostic index palynomorphs reveal that the Nkporo Group is within Late Campanian to Early Maastrichtian and the depositional environment is mostly marginal marine to marine.

***Keywords*:** Palynology, Campano-Maastrichtian, Nkporo Formation, Palynomorphs and Anambra Basin

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1. INTRODUCTION

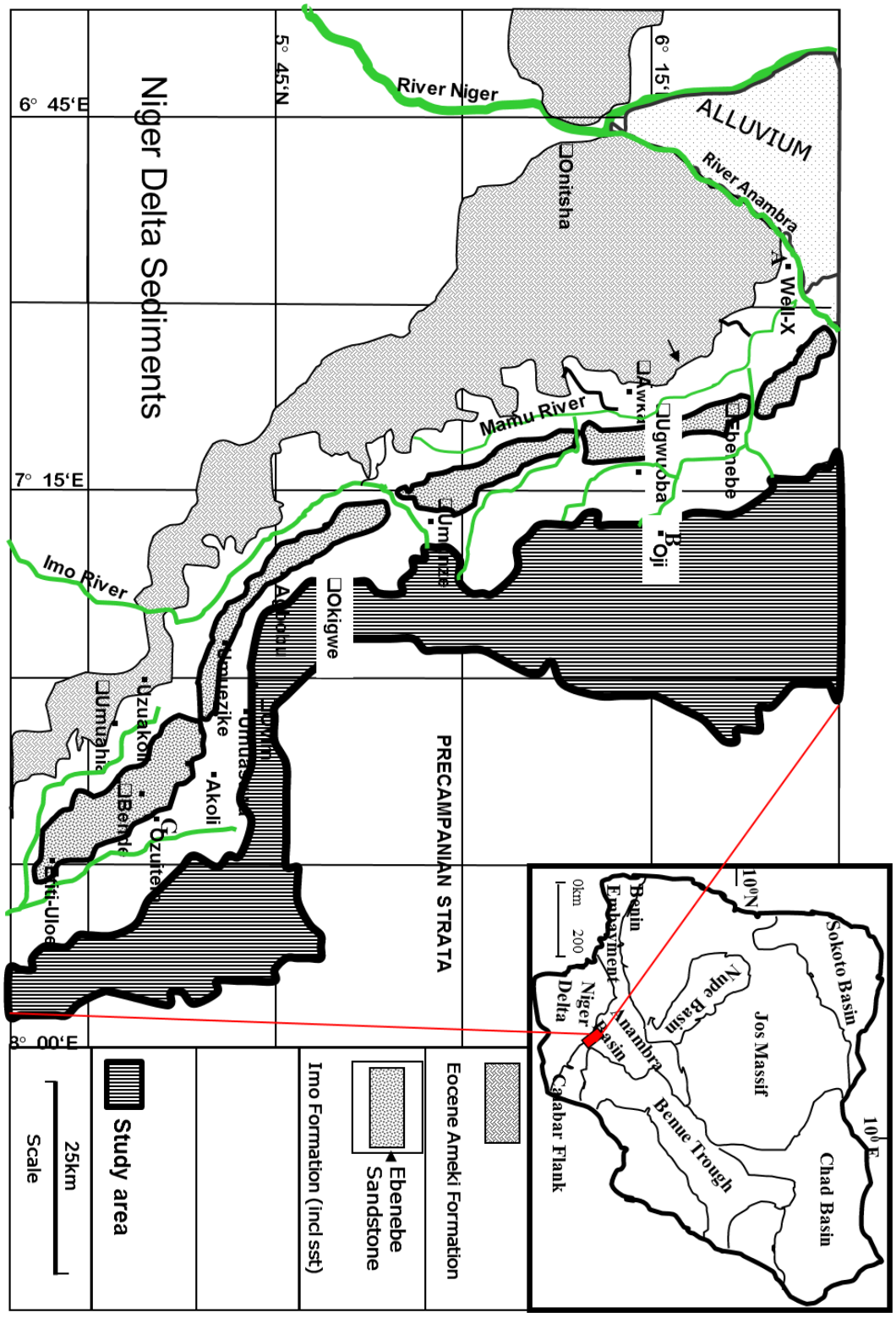


Fig. 1. Geologic Map showing the Study Area

Many researchers have studied the lithofacies, palynology age and paleoenvironments of the Campanian-Maastrichtian sedimentary fill of Anambra Basin, these researchers includes Nwajide and Reijers, 1996; Obaje et al, 1999; Umeji, 2006; Ogala et al, 2009; Onyekuru and Iwagwu, 2010; Anakwuba and Onyekwelu, 2010; Onuigbo et al 2012a; Onuigbo et al 2012b Soronnadi- Ononiwu et al, 2012; Chiaghanam et al 2013a; Chiaghanam et al 2013b). Onuigbo et al 2012a and Ogala et al (2009) used palynological data in the study of the Middle - Upper Maastrichtian Mamu coal facies. Onuigbo et al (2012b) studied the palynology, paleoenvironment and sequence stratigraphy of the Campanian-Maastrichtian deposits in the Anambra Basin.

Soronnadi- Ononiwu et al (2012) and Chiaghanam et al (2013b) worked on the palynological and paleovironmental studies of the Mamu Formation. Onuigbo et al (2012a) and Chiaghanam et al 2013a applied lithofacies, palynology and facies association in the interpretation of paleogeography of the Enugu and Mamu Formations. Spores and pollens were used in the determination of age and paleonvironment of the study area.

2. GEOLOGIC SETTINGS

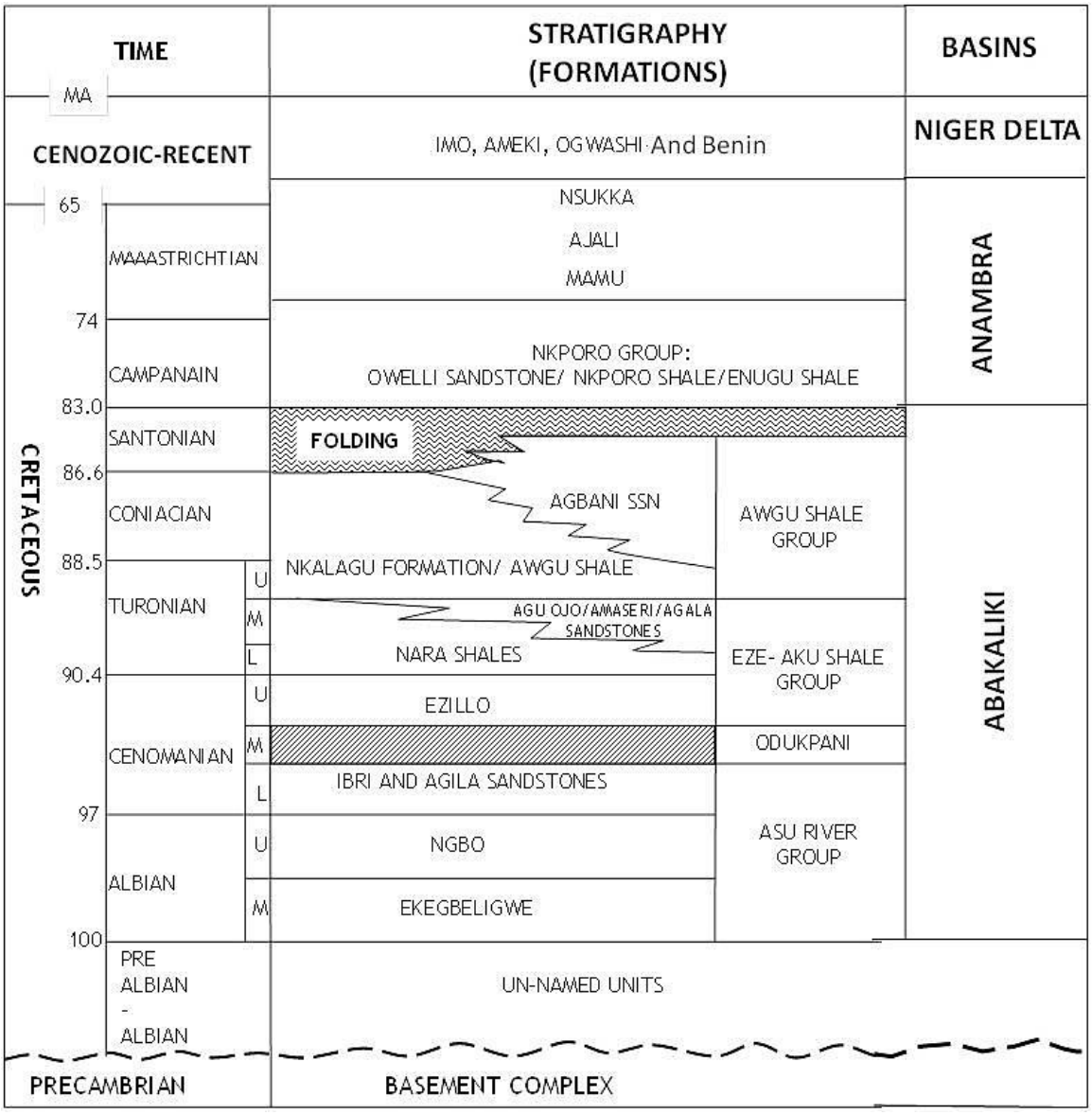
2. 1. Nkporo Formation

The Formation has its type locality at the Nkporo Town in Ohafia Local Government Area of Abia State. The Nkporo Formation is the basal sedimentary unit that was deposited following the Santonian folding in Southeastern Nigeria and indicates a Late Campanian, based on the presence of *Afrobolivina afra* (Reyment, 1965). The Nkporo Formation consists of dark shales and mudstones with subordinate sandstones, oolitic ironstone and shelly limestone with commonly burrows of *Skolithos isp, Ophiomorpha isp.* and *Thalassinoides isp.* (Nwajide, 2013). Deposition of the sediments of the Nkporo/Enugu Formations reflects a funnel-shaped shallow marine setting that graded into channeled low-energy marshes (Nwajide, 2013). The best exposure of the Nkporo Formation is at Leru, along the Enugu – Port Harcourt express road. It is also exposed in Abia and Akanu in Arochukwu LGA; Nkporo, Item, Amaiyi in Ohafia LGA all in Abia State; Owutu, Nguzu-Edda, Ekoji and Ebunwana in Afikpo South LGA of Ebonyi State.

2. 2. Enugu Shale

The Enugu Formation consists of grey, blue or dark shale, occasional white sandstones and striped sandy shale beds (Nwajide, 2013) (Table 1). The Formation has its type locality at the Enugu Municipality, with an area coverage that stretches north to Ikem- Ihandiagu area, and southwards to Awgu area (Nwajide, 2013). The formation consists mainly of shales, with two distinguishable sandstone bodies- the Otobi and the Okpaya Sandstones- which are regarded as members of the Formation (Nwajide, 2013). The Formation is restricted to the central and northern parts of the Anambra Basin, with a thickness of about 300ft. The Enugu shale was assigned Campanian to Lower Maastrichtian, based on the diagenetic species of palynomorphs such as *Cingulatisporites onatos* and *Tricolpites tienebaensis* (Reyment 1965; Whiteman 1982 and Soronnadi- Ononiwu et al (2012). Burrows of ichnogenous Thalassinoides, have been observed in the Formation (Nwajide, 2013).

Table 1. Stratigraphy of the Southeastern Nigeria
(modified after Reyment, 1965 and Ojoh, 1992)



3. METHODOLOGY

This palynological analysis is sometimes called shale analysis. Palynology studies the fossil palynomorphs – including pollen and spores – present in a rock sample. This analysis helps in determining the age of the rock. Twenty-five (25) shale samples gotten from the study area were done on this basis to determine the terrestrial species (spores and pollen) and marine species. The samples have a definite processing schedule, and thus, before any mechanical or chemical treatment, each sample should be properly registered under the laboratory register book and sample number assigned. Care must be taken to record data such

as lithologic type, geographic location, collector's name, geologic formation, and code number. All of these data as well as processing schedules are necessary details in order to keep good permanent records of each processed sample.

Sample preparation was done using the conventional maceration technique for recovering acid insoluble organic- walled microfossil from sediments. Each sample was digested for 30 minutes in 40% hydrochloric acid to remove traces of carbonate and 72 hours in 40% hydrofluoric acid for removal of silicate. The extracts were sieve- washed through 10 microns nylon mesh. The sieve- washed residues were oxidized for 30 minutes in 70% HNO_3 and 5 minutes in Schulze solution to render the fossils translucent for transmitted light microscopy; rinsed in 2% KOH solution to neutralize the acid; swirled to sediment resistant coarse mineral particles and organic matter; and stained with Safranin- O to increase the constract for study and photography (Umeji and Nwajide, 2007; Umeji, 2011; Chiaghanam *et al.*, 2013b).

4. RESULTS AND DISCUSSION

Combaz, 1964 introduced the term *palynofacies* to describe the total organic content of a palynological assemblage (e.g., tracheids, woody tissue, microplankton, microforaminiferal linings). Palynofacies is a powerful analytical tool when used in conjunction with geological and geophysical information. Palynofacies data can be combined with ancillary biostratigraphic information in a sequence-stratigraphic framework to help recognize reservoir–source rock relationship.

4. 1. Age Determination

The age determination of the examined samples was based on selected key age-diagnostic palynomorph assemblages encountered. They are summarized as follow:

From the tables below, samples NKP/09/002, NKP/07/001, NKP/13/001, NKP/12/001, NKP/03/002, NKP/04/001, NKP/06/001, NKP/10/001, NKP/08/001, NKP/01/001, and NKP/15/001, NKP/16/002, ENU/23/001, ENU/24/001, ENU/25/001and ENU/27/001, were dated Late Campanian to Earliest Maastrichtian with the following sporomorphs assemblage: *Foveotriletes margaritae, Distaverrusporites simplex, Cingulatisporites ornatus, Echitriporites trianguliformis, Longapertites marginatus, Proteacidites segali, Monocolpites marginatus, Constructipollenites ineffectus, Buttinia andreevi, and Retidiporites magdalenensis,* (Lawal and Moullade, 1986; Umeji, 2007, 2011; and Chiaghanam *et al,* 2012) (Table 2). The age was further confirmed by the presence of the typical West African Campano-Maastrichtian Dinocysts assemblage such as, *Dinogymnium* sp., *Andalusiella polymorpha, Andalusiella manthei, Senegalinium* sp., *Ceratiopsis diebeli,* and *Paleocystodinium austrialinium*, (Lentin and Williams, 1980; May, 1991).

Meanwhile, samples NKP/LST/05/001, and NKP/14/001 lack adequate marker palynomorph assemblages required for proper age assessment. However, based on some few important palynomorphs species recovered, sample NKP/14/001 has tentatively been assigned Late Campanian age whereas NKP/LST/05/001 were probably assigned Late Campaniam – Earliest Maastrichtian, (Table 3a-d).

However, samples NKP/16/004, NKP/16/008, NKP/17/001, NKP/17/003, ENU/20/001, ENU/21/003, and ENU/22/001, were assigned to Early Maastrichtian based on *Longapertites*

marginatus (overwhelming abundance), *Longapertites microfoveolatus, Longapertites vaneedenburgi, Spinizonocolpites baculatus, Foveotriletes margaritae, Distaverrusporites simplex, Cingulatisporites ornatus, Matonisporites equiexinus, Azolla marsulae, Mauritidiites crassibaculatus, Constructipollenites ineffectus, Echitriporites trianguliformis, Foveotriletes margaritae,* and *Leiotriletes minor* (Lawal and Moullade, 1968; Umeji and Nwajide, 2007, Umeji, 2011; Ogalla, 2009; and Chiaghanam *et al*, 2012) (Tables 3a-d).

Table 2. The occurrence and distribution of palynomorphs species in the examined samples and their Age

Samples	Sporomorphs	Age
NKP/09/002, NKP/07/001, NKP/13/001, NKP/12/001, NKP/03/002, NKP/04/001, NKP/06/001, NKP/10/001, NKP/08/001, NKP/01/001, NKP/15/001, NKP/16/002, ENU/23/001, ENU/24/001, ENU/25/001 and ENU/27/001	*Foveotriletes margaritae, Distaverrusporites simplex, Cingulatisporites ornatus, Echitriporites trianguliformis, Longapertites marginatus, Proteacidites segali, Monocolpites marginatus, Constructipollenites ineffectus, Buttinia andreevi, and Retidiporites*	Late Campanian to Earliest Maastrichtian
NKP/14/001	lack adequate marker palynomorph	Late Campanian
NKP/16/004, NKP/16/008, NKP/17/001, NKP/17/003, ENU/20/001, ENU/21/003, and ENU/22/001,	*Longapertites marginatus* (overwhelming abundance), *Longapertites microfoveolatus, Longapertites vaneedenburgi, Spinizonocolpites baculatus, Foveotriletes margaritae, Distaverrusporites simplex, Cingulatisporites ornatus, Matonisporites equiexinus, Azolla marsulae, Mauritidiites crassibaculatus, Constructipollenites ineffectus, Echitriporites trianguliformis, Foveotriletes margaritae, and Leiotriletes minor*	Early Maastrichtian

Below are the micrograph pictures of some key palynomorphs species recovered from the analyzed samples (Fig. 2) and their botanical names (Table 4).

Table 3a. The occurrence and distribution of palynomorphs species in the examined samples

Sample No. / **Palynomorphs species**	NKP/01/003	NKP/03/002	NKP/04/001	NKP/LST/05	NKP/06/001	NKP/07/001	NKP/08/001
TERRESTRIAL SPECIES							
Spores							
Foveotriletes margaritae	-	1	-	-	2	1	-
Laevigatosporites ovatus	9	13	9	3	8	6	13
Cyathidites minor	4	-	2	-	1	-	-
Cyathidites austrialis	-	8	4	2	2	3	-
Leiotriletes adriennis	2	3	-	-	-	5	-
Verrucatosporites usmensis	-	4	1	-	3	-	-
Cingulatisporites ornatus	2	4	2	-	5	3	4
Distaverrusporites simplex	1	1	3	-	-	1	-
Leiotriletes minor	3	-	2	2	3	-	-
Schizosporis parvus	-	-	-	-	-	-	-
Pollen							
Buttinia andreevi	3	-	-	-	-	-	2
Proxapertites operculatus	-	2	1	-	3	1	2
Echitriporites trianguliformis	4	3	2	-	5	3	2
Retidiporites magdalenensis	2	-	-	-	1	1	4
Spinizonocolpites baculatus	-	-	1	-	-	3	2
Grimsdalea polygonalis	-	-	-	-	-	-	-

Longapertites marginatus	8	6	4	3	7	5	12
Constructipollenites ineffectus	2	-	1	-	-	1	6
Monoporites annulatus	2	7	3	2	5	3	8
Spinizonocolpites echinatus	3	5	3	-	1	1	4
Monocolpites marginatus	-	2	-	-	-	-	-
Mauritidiites crassibaculatus	2	1	-	-	-	2	-
Proxapertites cursus	-	-	1	-	2	-	-
Proteacidites segali	-	1	2	-	-	-	-
Psiltricolporites crassus	-	3	4	-	2	-	4
Psilatricolporites operculatus	2	1	-	-	3	-	-
Echitriporites trianguliformis	1	-	2	-	4	2	-
Pachydermites diederixi	-	-	-	-	-	-	2
Echiperiporites icacinoides	2	4	2	2	-	-	-
Zlivisporis blanensis	-	-	-	-	-	-	-
MARINE SPECIES							
Andalusiella polymorpha	2	-	1	-	-	5	2
Ceratiopsis diebeli	-	-	2	1	1	7	-
Senegaliniun sp.	4	-	-	-	2	14	-
Fibrocysta sp.	-	-	-	-	-	6	-
Phelodinium sp.	2	1	-	-	4	11	-
Cordosphaeridium sp.	-	-	2	-	2	4	-
Paleocystodinium austrialinium	6	-	-	2	-	6	4
Dinogymnium acuminatum	2	-	-	-	-	4	6

Spiniferites sp.	-	5	3	-	1	-	-
Oligosphaeridium complex	-	-	1	-	-	4	2
Andalusiella manthei	2	-	-	2	-	1	-
Senoniasphaera inornata	-	-	-	-	-	-	-
Glaphyrocysta ordinate	-	-	-	-	-	-	-

Table 3b. The occurrence and distribution of palynomorphs species in the examined samples

Sample No. / **Palynomorphs species**	NKP/09/002	NKP/10/001	NKP/12/001	NKP/13/001	NKP/14/001	NKP/15/001
TERRESTRIAL SPECIES						
Spores						
Foveotriletes margaritae	2	-	-	-	-	1
Laevigatosporites ovatus	4	6	11	16	8	7
Cyathidites minor	2	6	4	4	-	-
Cyathidites austrialis	-	-	-	-	-	2
Leiotriletes adriennis	8	2	2	-	-	-
Verrucatosporites usmensis	-	-	-	-	-	-
Cingulatisporites ornatus	2	12	-	-	2	-
Distaverrusporites simplex	-	6	-	-	-	-
Leiotriletes minor	-	-	4	-	-	4
Schizosporis parvus	-	-	3	-	-	-
Pollen						

Buttinia andreevi	-	-	-	2	-	-
Proxapertites operculatus	2	-	2	2	-	-
Echitriporites trianguliformis	2	-	4	-	-	1
Retidiporites magdalenensis	4	-	-	-	-	-
Spinizonocolpites baculatus	6	-	2	2	-	-
Grimsdalea polygonalis	2	-	-	-	-	-
Longapertites marginatus	6	3	8	6	4	4
Constructipollenites ineffectus	2	-	-	1	-	-
Monoporites annulatus	2	-	2	-	-	3
Spinizonocolpites echinatus	2	2	-	-	-	-
Monocolpites marginatus	2	2	-	-	2	2
Mauritidiites crassibaculatus	4	-	2	-	-	-
Proxapertites cursus	-	-	2	-	-	2
Proteacidites segali	-	-	2	-	2	-
Psiltricolporites crassus	-	2	-	-	2	1
Psilatricolporites operculatus	-	2	-	-	-	-
Echitricolporites spinosus	-	2	-	-	-	1
Pachydermites diederixi	-	-	-	-	-	-
Echiperiporites icacinoides	-	-	-	2	-	4
Zlivisporis blanensis	-	-	1	-	-	1
MARINE SPECIES						
Andalusiella polymorpha	8	4	-	4	-	-
Ceratiopsis diebeli	14	-	-	-	-	-

Senegaliniun sp.	22	-	-	6	-	2
Fibrocysta sp.	12	-	9	-	-	-
Phelodinium sp.	22	-	2	4	-	4
Cordosphaeridium sp.	6	-	17	-	-	2
Paleocystodinium austrialinium	4	-	-	2	-	-
Dinogymnium acuminatum	6	-	-	-	-	-
Spiniferites sp.	2	2	-	-	-	2
Oligosphaeridium complex	6	2	-	-	-	-
Andalusiella manthei	2	-	-	-	-	2
Senoniasphaera inornata	-	-	2	-	-	-
Glaphyrocysta ordinate	-	-	4	-	2	3
Aleorigera senoniensis	-	-	-		2	-
Achomosphaera ramulifera	-	2	-		-	1
Cyclonepheliun deckonincki	-	2	-		-	-
Kallosphaeridium brevibarbatum	-	1	-		-	-

Table 3c. The occurrence and distribution of palynomorphs species in the examined samples

Sample No. / **Palynomorphs species**	NKP/16/002	NKP/16/004	NKP/16/008	NKP/17/001	NKP/17/003
TERRESTRIAL SPECIES					
Spores					
Foveotriletes margaritae	-	-	-	-	2

Laevigatosporites ovatus	16	11	26	10	16
Cyathidites minor	2	-	-	2	2
Cyathidites austrialis	-	3	-	2	-
Leiotriletes adriennis	-	1	2	-	-
Verrucatosporites usmensis	-	-	-	-	2
Cingulatisporites ornatus	1	1	2	2	-
Distaverrusporites simplex	2	-	-	-	-
Leiotriletes minor	-	3	-	1	-
Azolla marsulae	-	-	2	-	-
Matonisporites equiexinus	-	-	-	-	2
Pollen					
Buttinia andreevi	2	-	-	2	-
Proxapertites operculatus	-	-	2	-	-
Echitriporites trianguliformis	2	1	-	2	4
Retidiporites magdalenensis	2	1	4	-	2
Spinizonocolpites baculatus	-	-	-	-	2
Longapertites microfoveolatus	-	-	-	-	-
Longapertites marginatus	11	9	18	10	16
Constructipollenites ineffectus	-	2	-	2	-
Monoporites annulatus	3	-	2	2	6
Spinizonocolpites echinatus	-	-	-	-	-
Monocolpites marginatus	-	3	2	4	-
Mauritidiites crassibaculatus	1	-	-	1	-
Proxapertites cursus	-	-	-	-	-

Proteacidites segali	-	2	-	1	-
Psiltricolporites crassus	2	-	-	-	-
Psilatricolporites operculatus	-	2	-	2	-
Echiperiporites icacinoides	-	1	-	-	-
Auriculidites reticulatus	-	-	2	-	-
Longapertites vaneedenburgi	-	-	-	-	-
MARINE SPECIES					
Andalusiella polymorpha	-	2	2	-	-
Ceratiopsis diebeli	2	-	-	2	-
Senegaliniun sp.	1	1	-	-	-
Fibrocysta sp.	-	-	-	-	-
Phelodinium sp.	2	1	-	-	-
Cordosphaeridium sp.	-	-	-	-	-
Paleocystodinium austrialinium	1	2	2	-	-
Dinogymnium acuminatum	2	2	4	2	-
Spiniferites sp.	-	-	-	-	-
Oligosphaeridium complex	-	-	-	2	-
Andalusiella manthei	1	-	-	1	-
Cyclonephelium sp.	-	-	-	-	2
Achomosphaera sp.	-	-	-	2	6

Table 3d. The occurrence and distribution of palynomorphs species in the examined samples

Sample No. / **Palynomorphs species**	ENU/20/001	ENU/21/003	ENU/22/001	ENU/23/001	ENU/24/001	ENU/25/001	ENU/27/001
TERRESTRIAL SPECIES							
Spores							
Foveotriletes margaritae	-	-	-	-	-	-	-
Laevigatosporites ovatus	21	11	26	9	13	8	10
Cyathidites minor	4	4	6	2	-	2	-
Cyathidites austrialis	-	-	-	2	4	-	-
Leiotriletes adriennis	2	-	2	-	-	4	-
Verrucatosporites usmensis	-	-	-	-	-	-	2
Cingulatisporites ornatus	1	1	2	-	2	-	-
Distaverrusporites simplex	-	-	-	1	-	1	2
Leiotriletes minor	2	-	1	4	4	1	-
Azolla marsulae	-	-	-	-	-	-	-
Matonisporites equiexinus	-	-	-	-	-	-	-
Pollen							
Buttinia andreevi	-	-	-	1	-	2	-
Proxapertites operculatus	-	-	-	-	1	2	-
Echitriporites trianguliformis	2	3	2	2	-	2	-
Retidiporites magdalenensis	-	-	-	2	1	-	-
Spinizonocolpites baculatus	-	-	-	-	-	-	-

Longapertites microfoveolatus	1	2	2	-	-	-	-
Longapertites marginatus	6	5	-	4	6	5	2
Constructipollenites ineffectus	2	-	1	-	-	-	-
Monoporites annulatus	-	4	2	2	-	3	-
Spinizonocolpites echinatus	1	-	-	1	-	-	1
Monocolpites marginatus	-	2	3	-	4	1	-
Mauritidiites crassibaculatus	-	-	-	-	1	-	-
Proxapertites cursus	-	-	-	-	-	1	-
Proteacidites segali.	2	-	-	1	2	-	-
Psiltricolporites crassus	-	1	-	2	-	-	2
Psilatricolporites operculatus	-	-	2	-	2	-	-
Echiperiporites icacinoides	-	-	-	-	-	-	-
Auriculidites reticulatus	-	-	-	-	-	-	-
Longapertites vaneedenburgi	2	-	4	-	-	-	-
MARINE SPECIES							
Andalusiella polymorpha	1	1	2	-	-	1	-
Ceratiopsis diebeli	-	-	-	-	2	-	-
Senegaliniun sp.	-	-	-	1	1	2	-
Fibrocysta sp.	-	-	-	-	-	-	-
Phelodinium sp.	-	-	-	-	-	-	-
Cordosphaeridium sp.	-	2	-	-	-	2	-
Paleocystodinium austrialinium	2	1	3	2	-	3	-
Dinogymnium acuminatum	2	2	4	2	1	4	-

Spiniferites sp.	-	1	-	-	3	-	-
Oligosphaeridium complex	-	-	2	-	-	1	-
Andalusiella manthei	1	-	-	3	2	-	-
Cyclonephelium sp.	-	-	-	-	-	-	-
Achomosphaera sp.	-	-	1	-	1	-	-

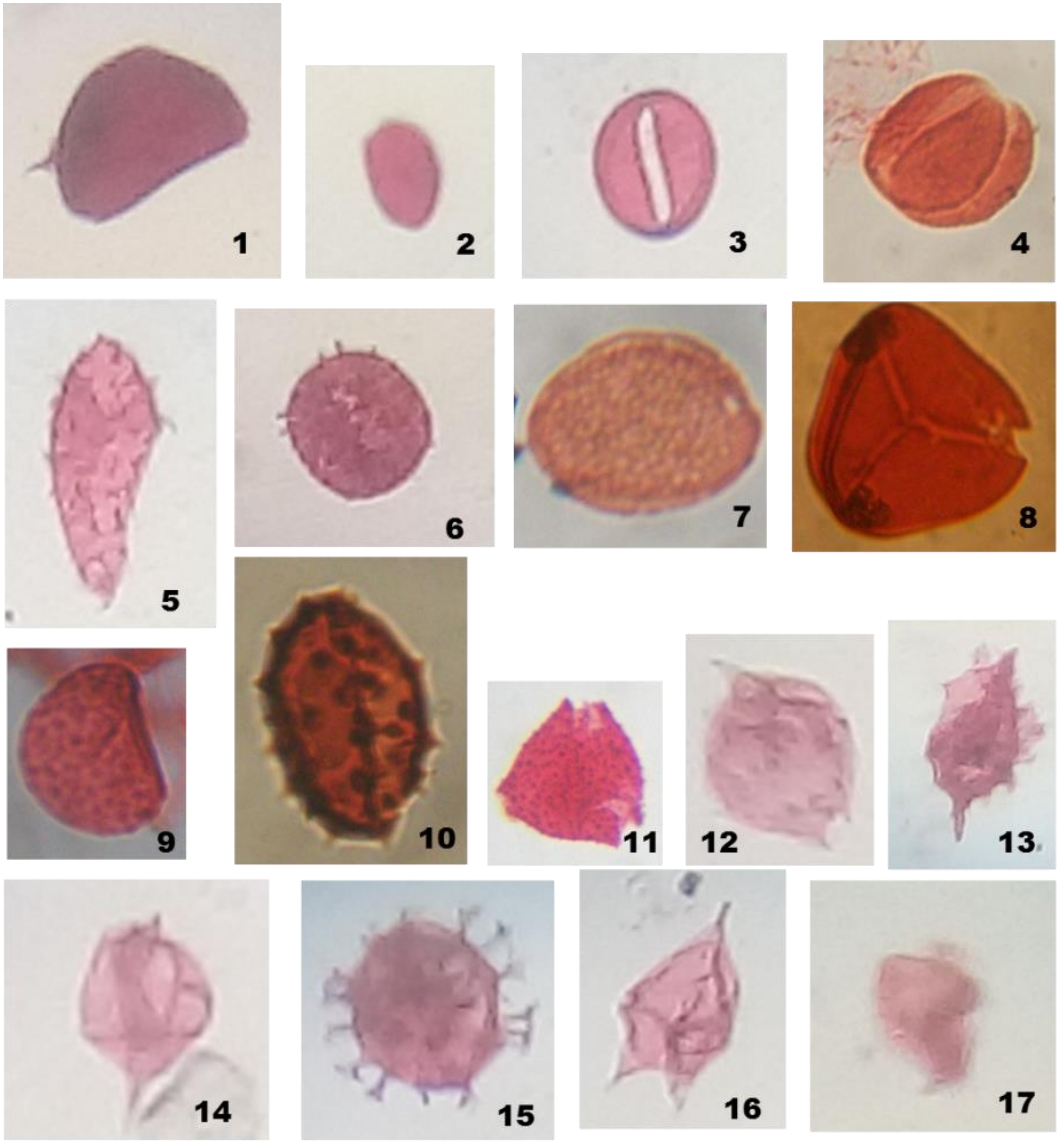


Fig. 2. Micrographs of some palynomorphs species recovered from the examined samples. Magnifications nos. 4 and 8 (X 100 oil immersion), others (X 40)

Table 4. Micrograph names of some palynomorph species recovered in the examined samples.

S/N	Palynomorh Species
1	*Longapertites marginatus*
2	*Retidiporites magdalensis*
3	*Monocolpites marginatus*
4	*Proxapertites operculatus*
5	*Mauritidiites crassibaculatus*
6	*Spinizonocolpites baculatus*
7	*Proxapertites cursus*
8	*Cyathidites austrialis*
9	*Verrucatosporites usmensis*
10	*Spinizonocolpites echinatus*
11	*Echitroporites trianguliformis*
12	*Andalusiella manthei*
13	*Fibrocysta* sp.
14	*Andalusiella polymorpha*
15	*Olygosphaeridium complex*
16	*Ceratiopsis diebeli*
17	*Dinogymnium* sp.

Palynomorphs species was classified on the basis of spores, pollens and marine species (Table 5a and b). The Nkporo Formation samples have average percent counts of spores of 35.28%, pollens is about 39.44% and marine species is 24.72% (Table 5a). This is confirmed by the histogram and area plots showing the abundance of various classes of palynomorphs species of Nkporo Formation samples (Figs. 3a and 3b). The paleosalinity of the Nkporo Formation is brackish water.

The environment of deposition is marginal marine. The Enugu Shale samples have average percent counts of spores of 50.71%, pollens of 33% and the marine species is 16.29% (Table 5b). This is confirmed by the histogram and area plots showing the abundance of various classes of palynomorphs species of Enugu Shale samples (Figs. 3c and 3d).

The paleosalinity of the Enugu Shale is mostly brackish water. The environment of deposition is marginal marine.

Table 5a. Results of the palynomorphs species and their paloenvironments of deposistion of each examined sample of the Nkporo Formation.

SAMPLE NO.	PALYNOMORPHS % FREQUENCY			PALEO-SALINITY	PALEOENVIRONMENTS OF DEPOSITION
	Spores	Pollen	Marine Species		
NKP/01/001	30	44	26	Brackish water	Marginal marine (Intermediate estuary)
NKP/03/002	45	47	8	Brackish water	Marginal marine (proximal estuary)
NKP/04/001	40	45	15	Brackish water	Marginal marine (proximal estuary)
NKP/LST/05/001	37	37	26	Brackish water	Shallow marine
NKP/06/001	36	49	15	Brackish water	Marginal marine (proximal estuary)
NKP/07/002	19	21	60	Brackish water	Distal estuary – open marine
NKP/08/001	22	61	17	Brackish water	Marginal marine (proximal estuary)
NKP/09/002	13	25	62	Brackish water	Distal estuary – open marine
NKP/10/001	56	22	22	Brackish water	Marginal marine (Intermediate estuary)
NKP/12/001	29	30	41	Brackish water	Marginal marine (distal estuary)
NKP/13/001	39	29	32	Brackish water	Marginal marine (distal estuary)
NKP/14/002	42	42	16	Brackish water	Marginal marine (proximal estuary)
NKP/15/001	29	39	32	Brackish water	Marginal marine (distal estuary)
NKP/16/002	40	43	17	Brackish water	Marginal marine (proximal estuary)
NKP/16/004	40	45	15	Brackish water	Marginal marine (proximal estuary)
NKP/16/008	46	33	11	Brackish water	Marginal marine (proximal estuary)
NKP/17/001	33	50	17	Brackish water	Marginal marine (proximal estuary)
NKP/17/003	39	48	13	Brackish water	Marginal marine (proximal estuary)
AVERAGE	35.28	39.44	24.72		

Table 5b. Results of the palynomorphs species and their paloenvironments of deposistion of each examined sample of the Enugu Shale

SAMPLE NO.	PALYNOMORPHS % FREQUENCY			PALEO-SALINITY	PALEOENVIRONMENTS OF DEPOSITION
	Spores	Pollen	Marine Species		
ENU/20/001	58	31	11	Brackish water	Marginal marine (proximal estuary)
ENU/21/003	40	43	17	Brackish water	Marginal marine (proximal estuary)
ENU/22/001	57	25	18	Brackish water	Marginal marine (proximal estuary)
ENU/23/001	44	36	20	Brackish water	Marginal marine (proximal estuary)
ENU/24/001	46	34	20	Brackish water	Marginal marine (proximal estuary)
ENU/25/001	36	36	28	Brackish water	Marginal marine (Intermediate estuary)
ENU/27/001	74	26	0	Fresh water	Mangrove swamp
AVERAGE	50.71	33	16.29		

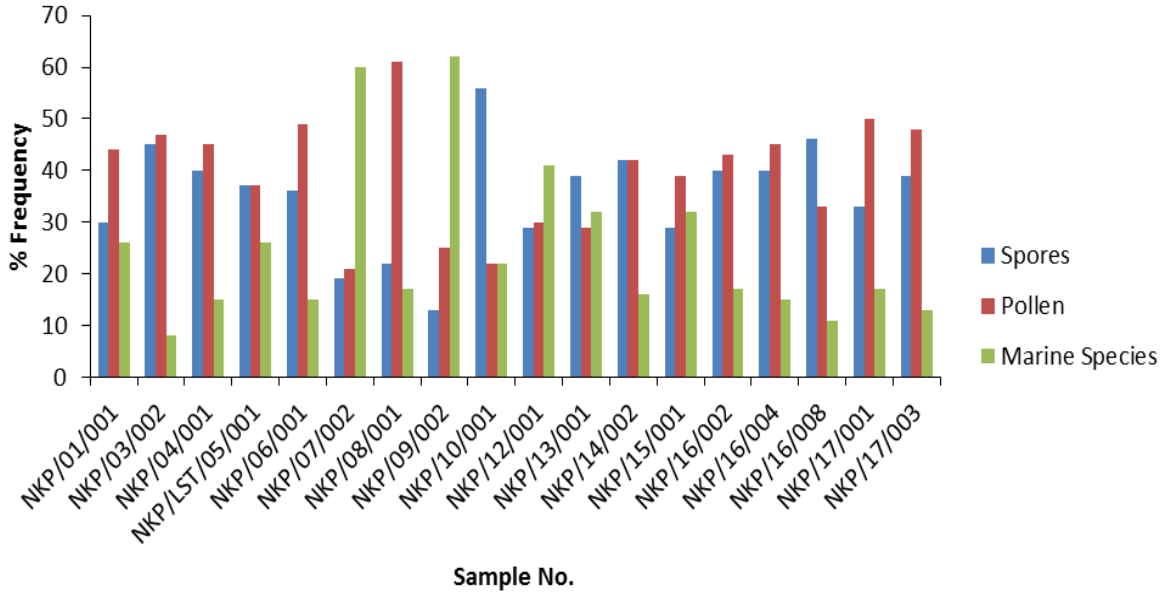


Fig. 3a. Histogram showing the % Frequency of Palynomorphs of the Nkporo Formation samples

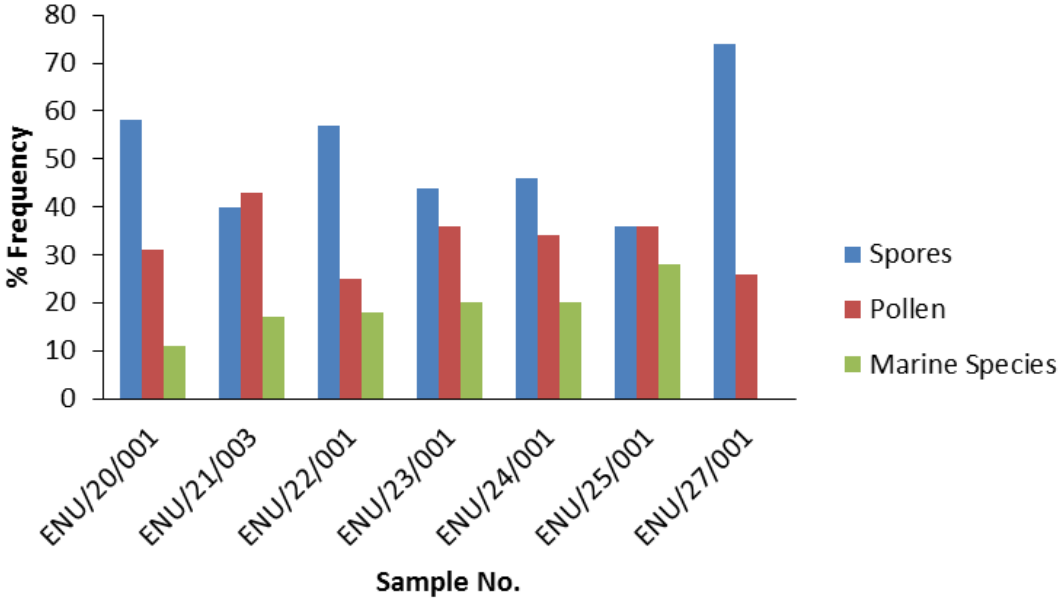


Fig. 3b. Histogram showing the % Frequency of Palynomorphs of the Enugu Shale samples

Fig. 3c. Area Chart showing the % Frequency of Palynomorphs of the Nkporo Formation samples

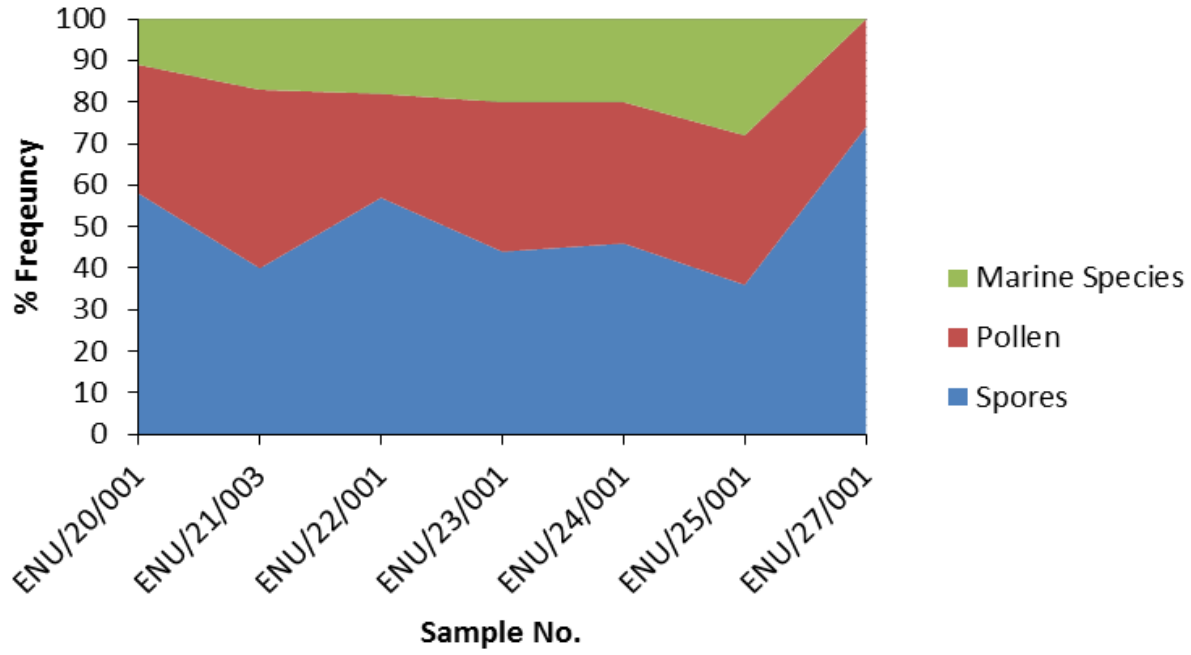


Fig. 3d. Area Chart showing the % Frequency of Palynomorphs of the Enugu Shale samples

5. CONCLUSIONS

Palynological study of the shale samples exposed in the study area has been undertaken. Twenty-five main lithological units were encountered. They included carbonaceous shales, sandstones, mudstones, and limestone. Age determination/ correlation was achieved on the basis of the stratigraphically significant age-diagnostic palynomorph assemblages recovered from the examined samples. Nkporo Formation was assigned Late Campanian to Early Maastrichtian while Enugu Shale was dated Early Maastrichtian Age. The age-diagnostic index palynomorphs reveal that the Nkporo Group is within Campano-Maastrichtian age bracket in the geologic time scale and the depositional environment is mostly marginal marine to marine.

Biography

Chiadikobi, K.C. is currently pursuing doctoral degree in Petroleum Geology at Nnamdi Azikiwe University, Awka, Nigeria. He is a Lecturer in Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria.
E-mail: kinsomino@yahoo.com

Chiaghanam, O.I. is a Ph.D holder in Stratigraphy/Sedimentary Geology in Nnamdi Azikiwe University, Awka, Nigeria. He is a Professor of Geology in Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria.
E-mail: oichiaghanam@yahoo.com

Onyemesili, O.C. is is a Ph.D holder in Organic Geochemistry in Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria. She is a Lecturer in Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria.
E-mail: co.oyemsili@gmail.com

Omoboriowo, A.O. is a Ph.D holder in Palynology/Biostratigraphy in the University of Port Harcourt, Choba-Port Harcourt, Nigeria. He is a Lecturer in Federal University of Petroleum Resources Effurun, Delta State, Nigeria
E-mail: adeboriowo@yahoo.com

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