Microfossil Assemblages of the Subsurface Parts of the Enugu Formation: Proxies to Depositional Environment and Age of the Formation

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Abstract
Two boreholes sunk into Enugu Formation within Enugu Metropolis were logged from the base to the top and samples collected were analyzed for palynomorphs and foraminifera in order to interpret the paleoenvironment and assign age to the formation. Four lithofacies identified include; dark fissile shale lithofacies, heterolithic lithofacies, sand laminated shale lithofacies and greyish shale lithofacies. Palynomorphs recovered consist of pteridophytic spores, angiosperm pollen, fungal spores and Botryoccocus braunii. *Echitriporites trianguliformis, Cythidites sps,. Retitricolporite sp., Retidiporite magdalenensis, Laevigatosporites sp., Zlivisporites blanensis* among others were recorded. Five genera of arenaceous benthic foraminifera (Ammobaculites sps., Haplophragmoides sp.,, Trochamina sp., Ammotium sp. and Saccamina sp.) dominated by Ammobaculites sps. were also recovered. The coarsening upwards of the lithofacies succession from basal shale to sand laminated greyish shale lithofacies and the heterolithic lithofacies observed in borehole 1 is an attribute typical of a prograding sea. Evidences from the lithofacies and association, palynomorphs and foraminiferal assemblages showed sediment deposition in a marginal marine setting. Low abundance and diversity of the arenaceous foraminiferal species with the predominance of Ammobaculites sps. is characteristics seen in almost all the samples analyzed. These are suggestive of stressful environment due to low water salinity, rapid sedimentation with influx from terrestrial environment which resulted to stagnant and restricted low oxygen bottom water condition.
Keywords: Palynomorphs, Lithofacies, Foraminifera, Environment, Deposition, Shale

1. Introduction

The Enugu Formation in Anambra Basin of southeastern Nigeria is the basal stratigraphic unit of the basin deposited after the Santonian tectonic event which led to the development of the basin (Reyment, 1965; Nwajide, 2005). Different research work on sedimentology, stratigraphy, palynology, sequence stratigraphy, ichnology and paleoecology (e.g Nwajide and Reijers, 1996; Onuigbo et al., 2012a and b, 2014, 2015; Omoboriowo et al., 2012; Nwajide, 2013) have been carried out on the outcrop sections of this formation but the subsurface part has been given little or no attention in these aspects.

Although surface exposures are considered representatives of the subsurface, the exposures however, must have been affected to some extent by sedimentary processes of weathering. This invariably must have altered the preservative states and abundance of the microfossils as well as posing limitations to the recognition and identification of their morphological features. Subsurface no doubt are more likely to preserve these fossils in their original state as climatic and weathering effects have not had much impact on them.

In this paper, lithofacies and biofacies (palynomorphs and foraminifera) of the subsurface part of the Enugu Formation will be evaluated in order to interpret the paleoenvironment and assign age to the formation. For a better and systematic evaluation of the microfossil contents and more coherent data that will aid higher resolution stratigraphic interpretation, borehole samples have been utilized in the study.
Figure 1 is the geologic map showing the Enugu Formation studied.

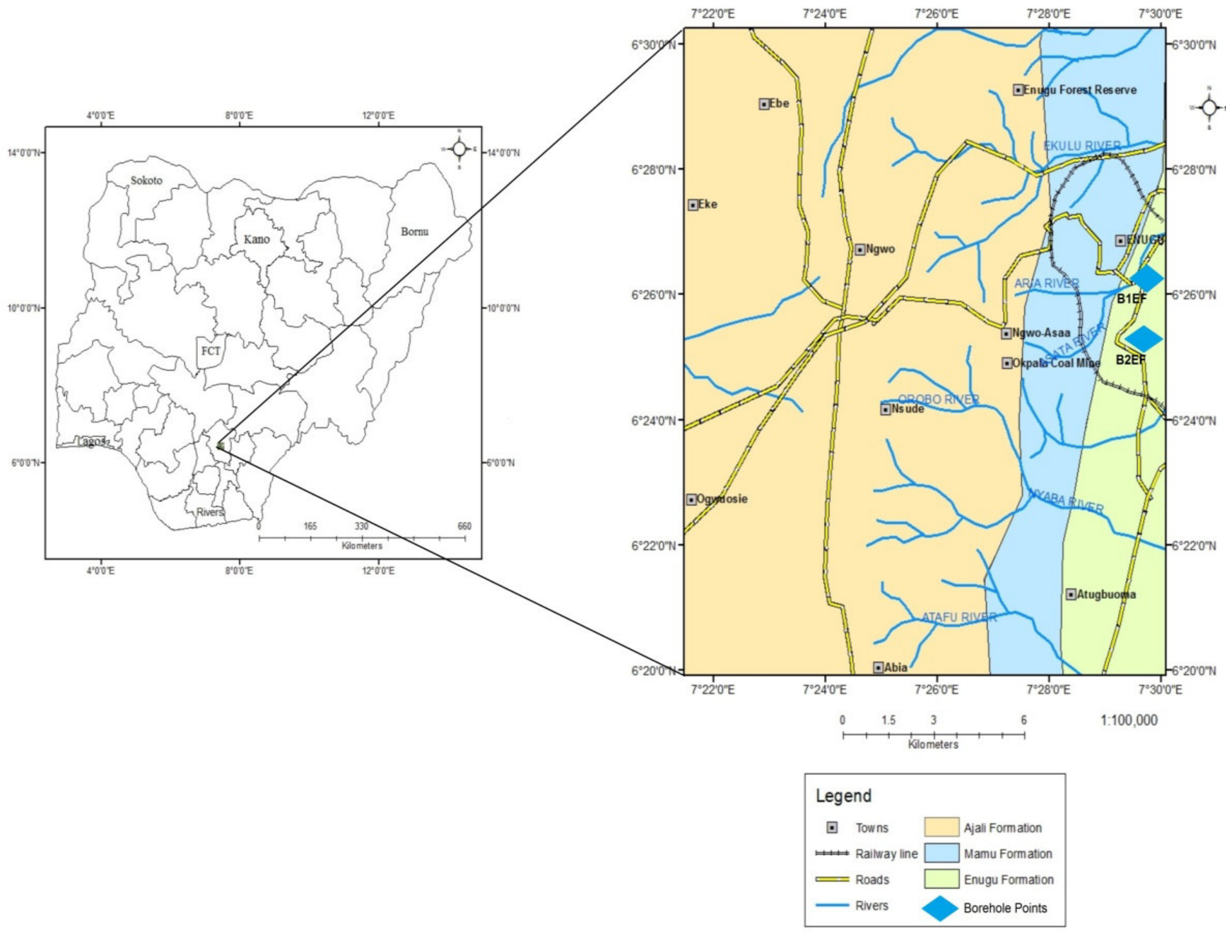


Fig. 1: Geologic map of the study area (modified from Geological Survey of Nigeria, 1957)

2. Regional Tectonics and Stratigraphic Setting

The tectonic origin of the Anambra Basin is intimately related to the development of the Benue Rift (Murat, 1972). The Benue Rift was installed as a failed arm of a tripartite rift system during the Cretaceous breakup of the Gondwana supercontinent and the opening of the South-Atlantic and Indian oceans in the Jurassic period (Nwajide and Reijers, 1996). The fault bounded Benue Trough is framed and floored by Precambrian granitic basement rocks of the continental crust (Aja and Igwe, 2015). The stratigraphic history of Southern Benue Trough is generally best described in terms of three tectono-sedimentary cycles as described by Murat (1972).

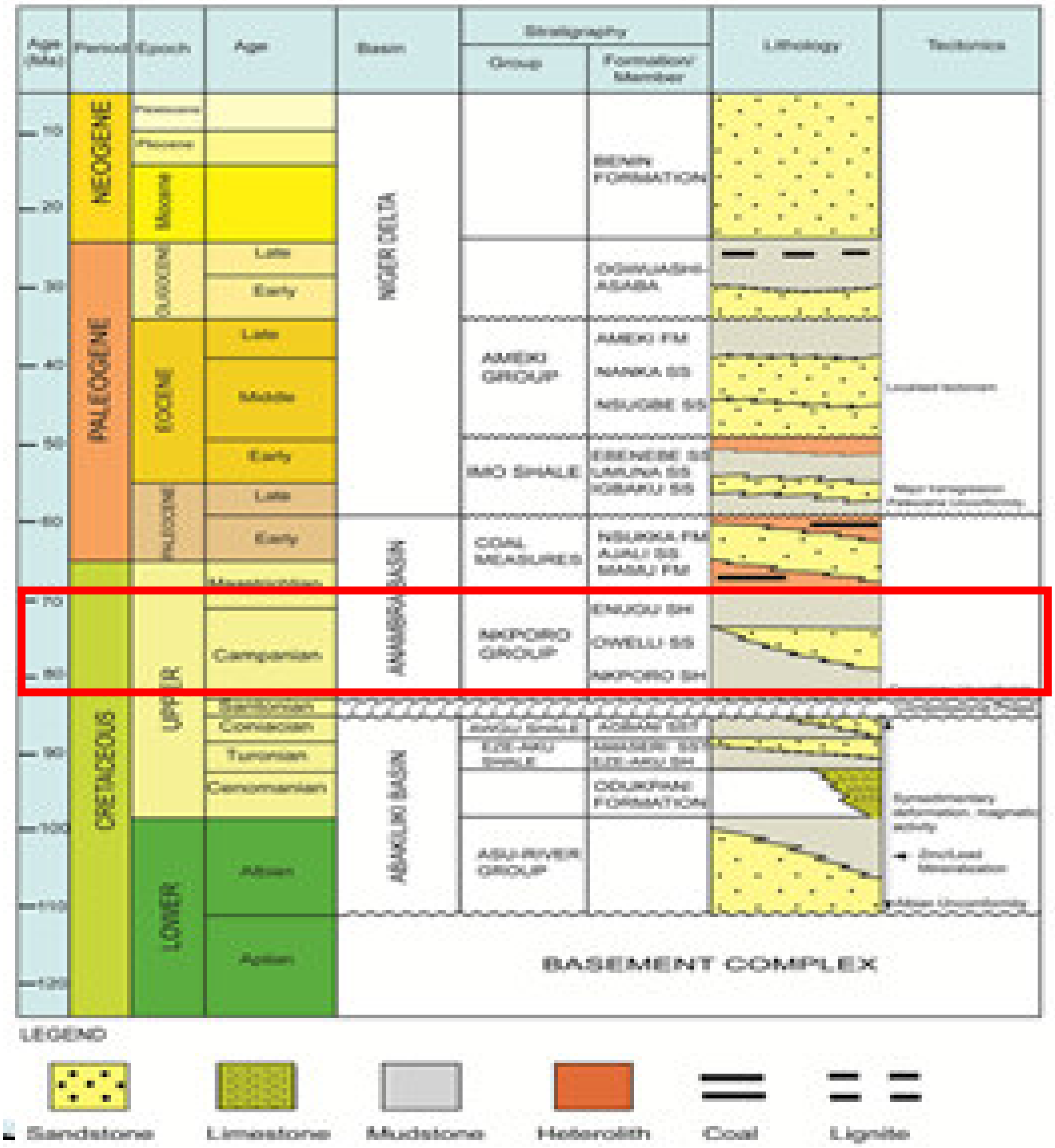
Sedimentation in the northwestern part of the subsided Abakaliki Anticlinorium is however, categorized by two sedimentary cycles. The first cycle which commenced in the lower Cretaceous was as a result of the post Aptian deposition of sediments in the trough. These sediments were subjected to the Santonian epeirogenic events (faulting, folding, and uplift) during the second cycle which led to the emergence of the Abakaliki Anticlinorium and the consequential basins flanking on both sides of the anticlinorium.

Synthesis of the works of several authors (Murat, 1972; Nwachukwu, 1972, Nwajide and Reijers, 1996; Mode and Onuoha, 2001) reveal that the Santonian epeirogenic movements characterized by compressional tectonics dating back to about 84 Ma was accompanied by wide spread magmatism, folding, faulting and uplifting of sediments deposited in the trough. This Santonian tectonics caused the Abakaliki area to become flexurally inverted to form Abakaliki Anticlinorium with simultaneous formation of depressions on its two flanks (displacement of depocentres by tectonic forces): the small Afikpo Syncline and the wider Anambra Basin to the southeast and northwest of the trough respectively.

The Anambra Basin is thus generally considered as an Upper Cretaceous descendant of Southern Benue Trough which was the site of deposition of sediments derived from the erosion of Abakaliki Anticlinorium (Akaegbobi and Schmitt, 1998, Akaegbobi and Boboye, 1999). Other provenance areas for texturally matured sediments which found its way into Anambra Basin include Southwestern Nigeria Craton, crystalline basement areas of the Oban Massif and Cameroon basement granites which had undergone prolonged chemical weathering (Hoque and Ezepue, 1977, Nwajide and Reijers, 1996, Akaegbobi and Schmitt, 1998).

The stratigraphic sequence of the Anambra Basin (Table 1) started with the deposition of the marginal-shallow marine Nkporo Group which constitutes the basal and the oldest sediments of the lithostratigraphic unit of the Late Campanian-Maastrichtian transgressive successions of the Anambra Basin. Nkporo Group comprises of the Nkporo Shale and its lateral equivalents the Enugu Formation and Owelli Sandstone. The broad shallow sea gradually become shallower because of gradual subsidence, initiating a regressive phase during Maastrichtian that deposited deltaic forests and flood plain sediments of the Mamu Formation (Lower Coal Measure). The Mamu Formation is overlain by the continental beds of Ajali Sandstone (False bedded Sandstone) which was followed by a return to partially paralic conditions and the deposition of the Nsukka Formation.

Table 1: Summarized Stratigraphy of the Benue Trough and Anambra Basin (after Reyment, 1965; Short and Stauble, 1967 and Nwajide, 2005).



3. Methodology

Two boreholes sunk at Ibagwa- Nike and Liberty Estate in Enugu Metropolis were logged from the top to the depth of 22 m and 18 m in boreholes 1 and 2 respectively. Samples of shales and heteroliths were collected at the intervals of 4 m depth in each of the boreholes and were analyzed for palynomorphs and foraminiferal contents.

For palynological analysis, samples were prepared according to the standard methods of acid maceration, alkali treatment and staining. The palynomorphs recovered were studied under transmitted light microscopy. In order to determine the relative frequency of each species in each sample, counts were made and the total counts were taken since the grains were less than 200.

Foraminifera was washed out of the shale samples using the routine techniques of washing the sample with hydrogen perioxide (H_2O_2) and deionized water. The identification was carried out under the binocular microscope.

The lithofacies, palynomorphs and foraminiferal data were employed in the interpretation of the depositional environment. Index palynomorphs and foraminifera formed bases for the dating of the sediments.

4. Results and Interpretation

4.1 Facies Description

Borehole 1

Four lithofacies identified from the base to the top of the borehole at Ibeagwa- Nike include; grayish fissile shale lithofacies, laminated grayish shale lithofacies, heterolithic (shale/fine sandstone) lithofacies and dark fissile shale lithofacies (Fig. 2). There is coarsening upward of succession from the basal shale lithofacies to the heterolithic lithofacies at the middle part of the borehole. The lithofacies and their fossil contents are described below;

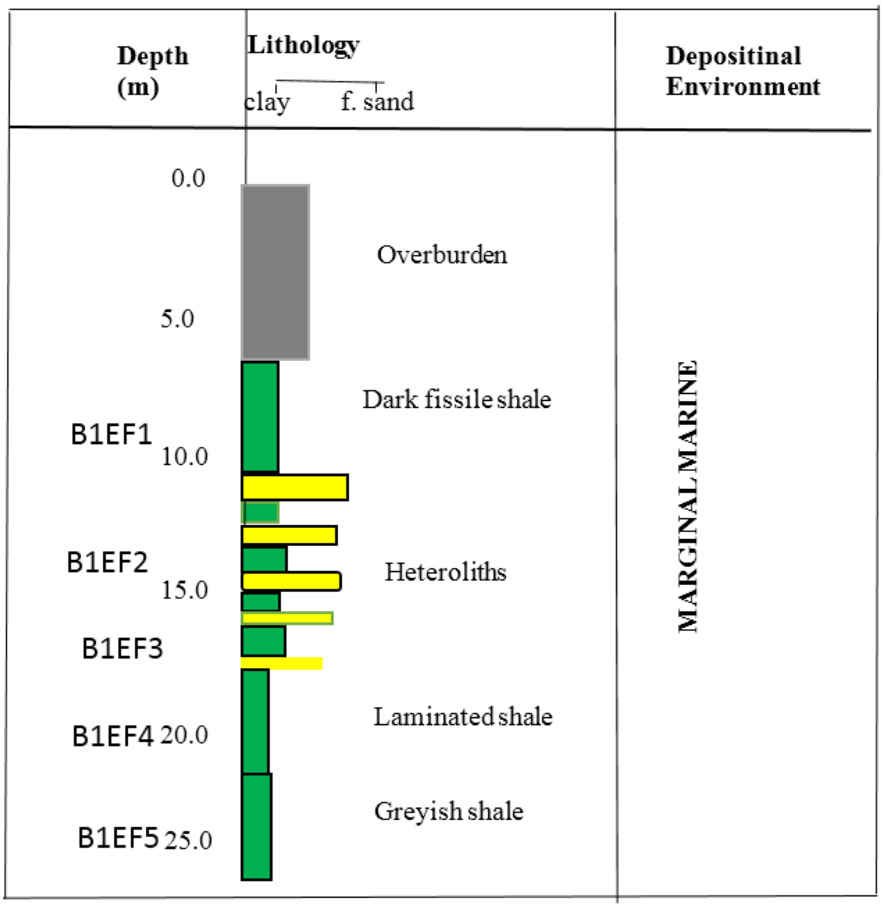


Fig. 2: The lithologic section across borehole one; B_1EF (Ibagwa-Nike)

Greyish Shale Lithofacies (A)

This is at the base between the intervals of 22 – 26 m depth and consists of very fissile grayish shale. Sample collected from the unit is labelled B_1EF_5. Palynomorphs recovered at this depth comprise of pollen and spores which show low abundance but moderate diversity. These include *Echitriporites trianguliformis, Zlivisporites blanensis, Rugulatisporites caperatus, Constructipollenites ineffectus, Longapertites sp. and Proteacidites longispinosum* (Table 2a). The only foraminifera at this depth is the *Ammotium nkalagun.*

The facies is interpreted to be deposited within coastal swamp to lagoonal setting.

Laminated Greyish Shale Lithofacies (B)

This lithofacies is overlain by the heterolithic lithofacies. It lies at a depth interval of about 18- 22 m and denoted as B_1EF_4. The lithofacies consists of laminated light grey shale with thin bands of whitish fine sandstone which constitute the laminae. *Ammobaculites* was the only genera recovered which also documented very low abundance and diversity.

The shale also recorded low abundance and diversity of pollen and spores assemblages notably; *Cyathidites australis, Echitriporite trianguliformis, Retitriporites sp.* among *others.* The depositional environment is interpreted as coastal swamp to lagoonal/estuarine setting.

Heterolithic lithofacies (C)

The lithofacies lies below the dark fissile shale facies at the depth interval of between 10 -18 m. The two samples collected within the interval are labelled B_1EF_2 and B_1EF_3. It consists of laminated grayish shale interbedded with thin beds of whitish fine sandstone. The unit becomes sandier upwards (Fig. 2). Foraminifera recovered from the heteroliths comprises of only *Ammobaculites* which documented very low abundance and diversity of species. Two species of the genera recovered include *Ammobaculite bauchiensis* and *Ammobaculites amabensis* (Table 3).

Palynological analysis yielded very low abundance but high diversity of pollen and spores among which are Cingulatisporites ornatus, Monocolpites marginatus, Echitriporites trianguliformis, Constructipollenites ineffectus, Rugulatisporites caperatus, Monocolpites annulatus, Psiltricolporites sp., Auriculiidites sp., Retimonocolpites sp., Gleicheniidites sp, etc (Table 2 and Fig. 4). Coastal swamp and marshes to estuarine/lagoonal depositional setting is assigned to the sediment.

Dark Fissile Shale Lithofacies (D)

This lithofacies is at the topmost part of the borehole at a depth intervals of between 6 – 10 m and denoted by B_1EF_1. It consists of dark fissile shale. Palynomorphs recovered from the intervals are only pollen and spores of plants which documented low abundance but high diversity. *Proteacidites longispinosus, Acrostichum aureum, Psilatricolporites sp., Polypodiaceoisporites sp., Retidiporites magdalenensis, Gemmamonoporites sp., Retitricolporites sp., Ephedripites sp., Foveolatus margaritae, Echitriporites trianguliformis, Cyathidites australis, Laevigatosporites sp.,* among others were recovered (Table 2a).

Coastal swamp depositional setting is assigned to the facies.

Borehole 2

The borehole is located at Liberty Estate, Enugu. The lithofacies of the borehole consist of the basal laminated shale lithofacies followed upwards by greyish shale lithofacies and dark fissile shale lithofacies at the topmost part of the borehole (Fig. 3).

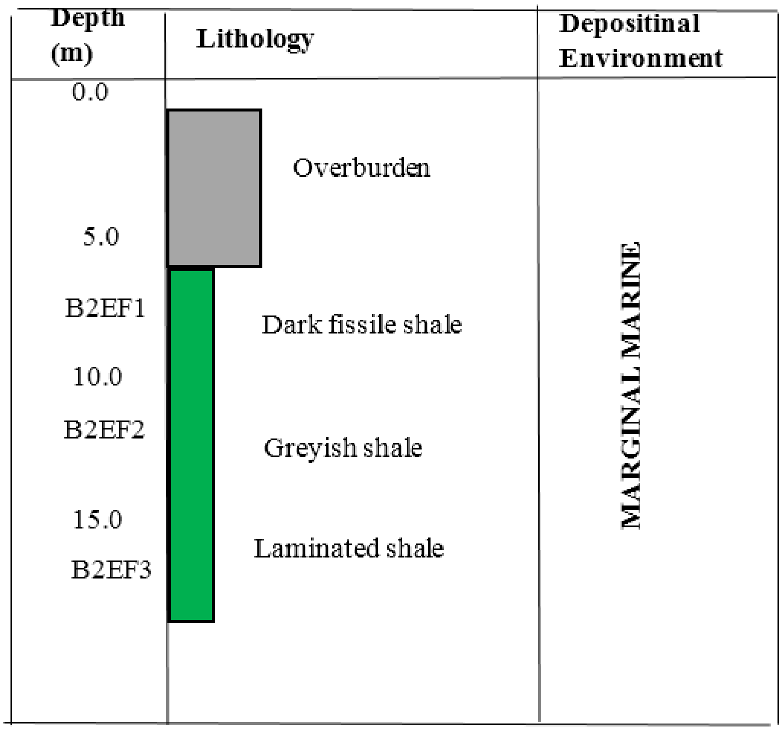


Fig. 3: The lithologic section across borehole two, B_2EF (Liberty Estate)

Greyish Shale Lithofacies (A)

This lithofacies underlies the dark fissile shale lithofacies and is found between the intervals of 10- 14 m depth. It is represented as B_2EF_2. Palynomorphs recovered from this lithofacies include: *Tricolporopollenites sp, Echitriporites trianguliformis, Cingulatisporites ornatus, Rugulatisporites caperatus* and *Proteacidites longispinosus.* It documented high abundance of arenaceous benthic foraminifera which is predominated by the species of *Ammobaculites* (about 96%). They include *Ammobaculite bauchiensis, A. jessenses, A. bennensis and A. stratheanensis.* Other genera recorded are *Haplophragmoides* sp. and *Saccamina* sp. (Table 3). The depositional environment is interpreted to show range from coastal swamp to lagoonal./estuarine.

Laminated Shale Lithofacies (B)

This unit is at the base between the depth intervals of 14-18 m and denoted as B_2EF_3. It is made up of laminated shale which is grayish in color. The palynomorphs recovered from this unit consist of *Monosulcites sp., Cingulatisporites ornatus, Cyathidites sp., Psilatricolporites sp., Laevigatosporites sp. and Foveotriletes* *margaritae*. Micropaleontological analysis yielded low abundance of benthic foraminifera which are of arenaceous type. The assemblage is also predominated by species of *Ammobaculites*. However, *Haplophragmoides sp.* and *Trochamina sp.* were also recovered.

Coastal swamp to lagoonal/estuarine environments is assigned.

Dark Fissile Shale Lithofacies (D)

This lithofacies is between the intervals of 6 -10 m depth and at the topmost part of the borehole. Sample collected from the shale is labelled B_2EF_1. It consists of dark shale which is very fissile (Fig. 3). The palynomorphs recovered from the facies are only pollen and spores with low abundance. *Foveotriletes margaritae, Cyathidites sp., Milfordia sp.,* and *Echitriporites trianguliformis* were recovered along with the bacteria *Botryococcus braunii* (Table 2b),

There is general absence of foraminiferal assemblages. Coastal swamp depositional setting is assigned to the facies.

Table 2a: Chart of pollen and spore assemblages recovered from the borehole at Ibagwa-Nike (B_1EF)

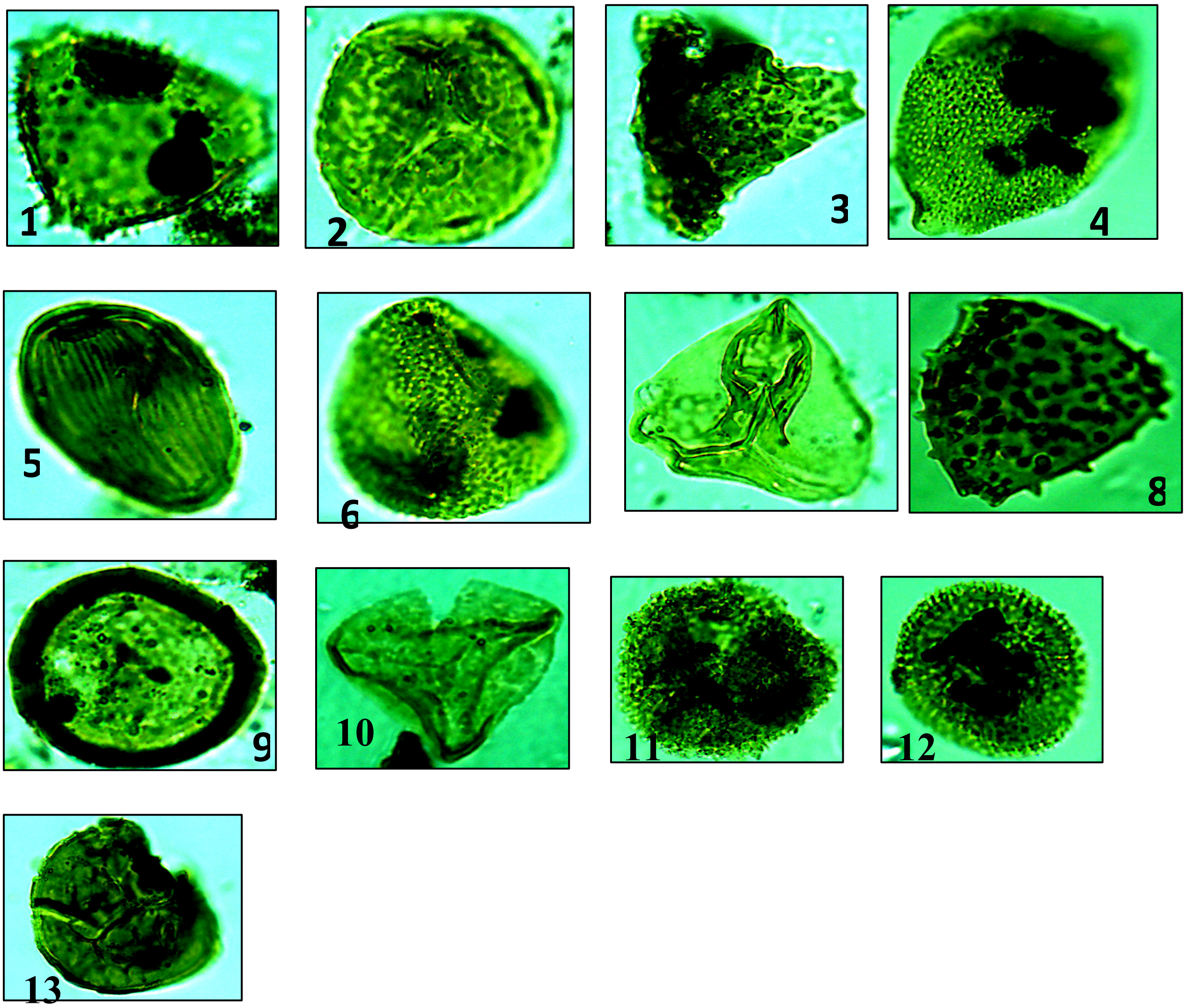
		POLLENS															SPORES								
Depth (m)	Taxa / Sample Name	*Constructipollenites ineffectus*	*Droseridites senonicus*	*Echitriporites trianguliformis*	*Inaperturate pollen*	*Longapertites sp.*	*Monocolpites marginatus*	*Monoporites annulatus*	*Monosulcites sp*	*Psilatricolporites sp*	*Retitricolporites sp.*		*Acrostichum aureum*	*Auriculiidites sp.*	*Cingulatisporites ornatus*	*Cyathidites australis*	*Cyathidites sp*	*Cyathidites minor*	*Gleicheniidites sp.*	*Laevigatosporites sp.*	*Polypodiaceoisporites sp.*	*Rugulatisporites caperatus*	*Retidiporites magdalenensis*	*Verrucatosporites sp*	*Zlivisporites blanensis*	SPECIES AMOUNT
22-26	B_1EF_5	1		2		1			1													2			1	8
18-22	B_1EF_4			1							1					1	1				1					5
14-18	B_1EF_3							1		1					3						1			1		7
10-14	B_1EF_2	1	1	1	1		2			1				1	2				1			1				12
6-10	B_1EF_1			1						1	1		2					3		1	1		1			11
	Total	2	1	5	1	1	2	1	1	3	2		2	1	5	1	1	3	1	1	3	3	1	1	1	43

Table 2b: Chart of palynomorph assemblages recovered from the borehole at Liberty Estate (B_2EF)

			POLLEN					SPORES						DINOFLA-GELLATES	
Depth (m)	**Taxa / Sample Name**	***Echitriporites trianguliformis***	***Milfordia sp.***	***Monosulcites sp***	***Proteacidites longispinosus***	***Psilatricolporites sp.***	**Tricolporopollenites sp**		***Cyathidites sp***	***Foveotriletes margaritae***	***Cingulatisporites ornatus***	***Laevigatosporites sp.***	***Rugulatisporites caperatus***	**Leoisphaeridia sp.**	**SPECIES AMOUNT**
14-18	**B_2EF_3**			**3**		**1**			**3**	**1**	**1**	**1**			**10**
10-14	**B_2EF_2**				**1**		**1**				**1**		**1**	**1**	**5**
6-10	**B_2EF_1**	**1**	**1**						**2**	**1**					**5**
	TOTAL	**1**	**1**	**3**	**1**	**1**	**1**		**5**	**2**	**2**	**1**	**1**	**1**	**20**

Table 3: The chart of Foraminifera recovered from the studied sections

Taxa / Sample Name	*Ammobaculites bauchensis*	*Ammobaculites sp.*	*Ammobaculite amabensis*	*Shell fragment*	*Ammotium nkalagum*	*Ammobaculites jessensis*	*Haplophragmoides spp.*	*Ammobaculites strathearnensis*	*Saccammia sp.*	*Ammobaculites bennensis*	*Trochammina spp.*	SPECIES AMOUNT
B_1EF_5		-			1							1
B_1EF_4		1		1								2
B_1EF_3		1	1									2
B_1EF_2	1											1
B_1EF_1	-	-	-	-	-	-	-	-	-	-	-	0
B_2EF_3	8					1	2				1	12
B_2EF_2	27	119				6	6	2	1	4		165
B_2EF_1	-	-	-	-	-	-	-	-	-	-	-	0
TOTAL	36	121	1	1	1	7	8	2	1	4	1	183



1. Echitriporites trianguliformis Van Hoeken- Klinkenberg, 1964
2. Rugulatisporites caperatus Van Hoeken- Klinkenberg, 1964

3. Proteacidites longispinosus
4. Retidiporites magdalenensis Germeraad et al., 1968
5. Ephedripites sp.
6. Foveotrilete margaritae Germeraad et al,. 1968
7. Cyathidites sp;
8. ?Proteacidites longispinosus
9. Cingulatisporites ornatus Van Hoeken- Klinkenberg, 1964
10. Gleicheniidites
11. ? Gemmatriporites ogwashiensis
12. Constructipollenite ineffectus Van Hoeken- Klinkenberg, 1964
13. Zliviporites blanensis Pacltova, 1961

Fig. 4: Pollen and spore assemblages from the Enugu Formation

4.2 Age of the Enugu Formation

The relative age assigned to the formation is based on the index palynomorphs (Table 4) as well as foraminifera recovered from the analyzed samples.

The index palynomorphs recovered include late Campanian markers such as;

1. *Auriculiidites sp.* (Okoro *et al*., 2012; Ola-Buraimo and Akaegbobi, 2013)
2. *Ephedripites sp*. (Adebayo *et al*., 2015)
3. *Monocolpites marginatus,* (Umeji, 2006; Okoro *et al*., 2012; Chiaghanam *et al*., 2013; Aja and Igwe, 2015)
4. *Milfordia sp:* (Ola-Buraimo and Akaegbobi, 2013; Adebayo *et al*., 2015)
5. *Rugulatisporites caperatus* (Okoro *et al*., 2012)

The early Maastrichtian markers are as follow;

1. *Cingulatisporites ornatus,* (Soronnadi-Ononiwu *et al*., 2012; Chiaghanam *et al*., 2013; Ola-Buraimo and Akaegbobi, 2013)
2. *Constructipollenites ineffectus* (Soronnadi-Ononiwu *et al*., 2012; Chiaghanam *et al*., 2013)
3. *Cyathidites minor* (Nwojiji *et al*., 2012)
4. *Echitrisporites triaguliformis,* (Soronnadi-Ononiwu *et al*., 2012)
5. *Foveotriletes marginatus* (Okoro *et al*., 2012),
6. *Laevigatosporites sp.* (Lawal and Moullade, 1986; Umeji, 2006; Chiaghanam *et al*., 2013; Onuigbo *et al*., 2012a; Okoro *et al*., 2012; Aja and Igwe, 2015)
7. *Longapertites marginatus* (Lawal and Moullade, 1986; Umeji, 2006; Okoro *et al*., 2012; Chiaghanam *et al*., 2013; Aja and Igwe, 2015)
8. *Retidiporites magdalenesis,* (Soronnadi-Ononiwu *et al*.; 2012; Chiaghanam *et al*., 2013; Ola-Buraimo and Akaegbobi, 2013)

Late Campanian- Early Maastrichtian markers

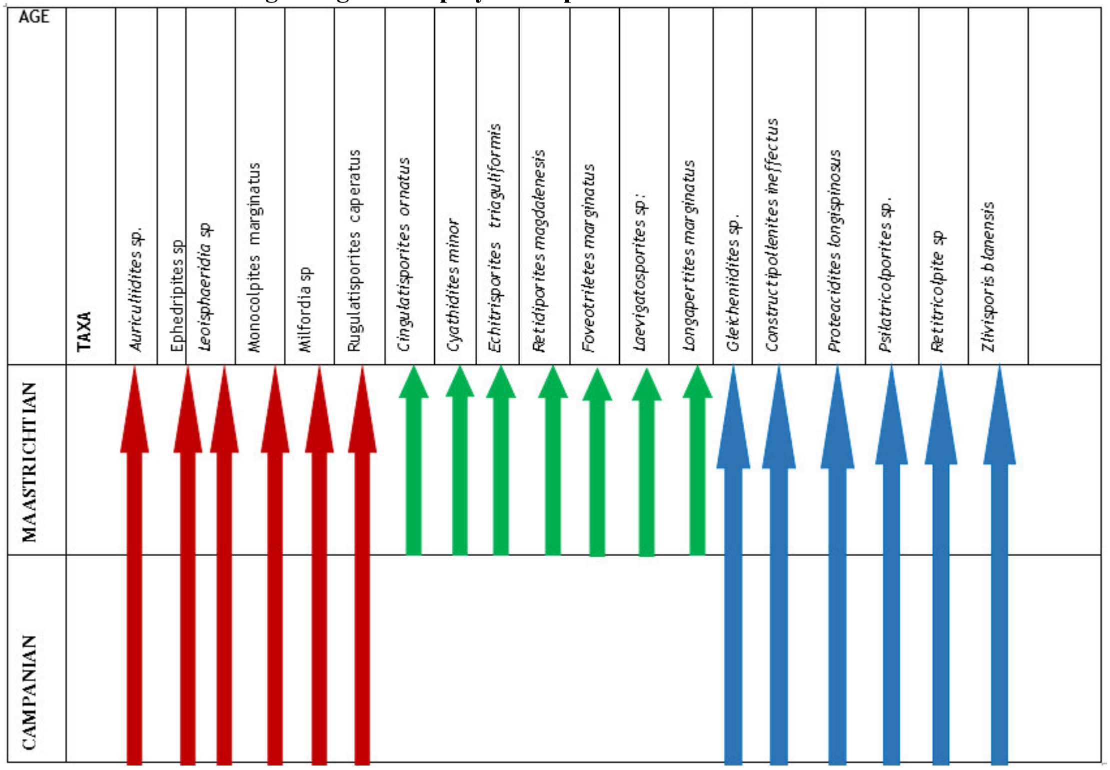
1. *Constructipollenites ineffectus,* (Nwojiji *et al*., 2013Aja and Igwe, 2015)
2. *Gleicheniidites sp.* (Aja and Igwe, 2015)
3. *Laevigatosporites,* (Onuigbo *et al*., 2012a)
4. *Longapertites sp. (*Aja and Igwe, 2015)
5. Monocolpites marginatus (Nwojiji *et al*., 2013; Aja and Igwe, 2015)
6. *Proteacidites longispinosus*, (Onuigbo *et al*., 2012a; Aja and Igwe, 2015)
7. *Psilatricolporites sp*. (Onuigbo *et al*., 2012a)
8. *Retitricolpite sp.* (Onuigbo *et al*., 2012)
9. *Zlivisporites blanensis* (Onuigbo *et al*., 2012a; Okoro *et al*., 2012),

Index Foraminifera

The foraminiferal assemblages consisting of *Ammobaculites sp, Ammotium nkalagum, Saccamina spp., Trochammina sp. and Haplophragmoides sp.* have been assigned Late Campanian to Early Maastrichtian age by Peters, (1979), Omoboriowo *et al*., (2012) and Aja and Igwe, (2015).

The presence of the above recovered index palynomorphs and foraminifera have been used to propose Late Campanian – Early Maastrichtian for the Enugu Formation (Table 4).

Table 4: The chart of age range of the palynomorphs



5. Discussion

5.1 Depositional Environment

The greyish shale lithofacies at the basal part of borehole 1 (22- 26 m depth interval) documented very low abundance of single species of the genera Ammotium. Ammotium is referred to as a genera typical of estuarine environment (Scott et al., 2004). It is an infauna deposit feeder restricted to shallow brackish water of tidal marshes, brackish lagoons and estuaries and enclosed brackish shelf sea (Murray, 1991). The high abundance and diversity of the arenaceous benthic forms which include Ammobaculites (constitutes almost 96% of the genera present), Haplophragmoides and Saccamina recorded by this lithofacies in borehole 2 at 10- 14 m depth intervals are also suggestive of estuarine condition (Aseez et al., 1974). High diversity and abundance of arenaceous species occur in estuaries in region of high nutrient availability due to organic matter input from the terrestrial environment. This is evidenced from the occurrence of fungal spores, *Botryococcus braunii,* and *Milfordia sp.* Marginal marine are usually areas of high organic productivity and relatively high environmental variability.

The thin sand laminae within the laminated shale lithofacies at the depth intervals of 18- 22 m in borehole one indicate shallowing/progradation of the sea. The low abundance and diversity of Ammobaculites as well as trilete spores and angiosperm pollen recorded by the lithofacies is also attributed to lagoonal/estuarine condition and the development of fresh water swamp and marshes as the sea progrades. The association of only arenaceous foraminifera notably Ammobaculites, Haplophragmoides and Trochamina seen in the lithofacies in borehole 2 at 14- 18 m depth interval suggests marginal marine condition (estuaries and hyposaline lagoons) characterized by low temperature, rapid sedimentation and stagnant bottom conditions (Nagy et al., 1988). Such association is also attributed to restricted low oxygen bottom water condition (Gebhardt, 1988; Scott et al., 2004; Nwojiji et al., 2014). This could be as a result of increasing input of organic matter from the fluvial system. Arenaceous foramaminifera tolerate conditions of high fresh water flux (high sediment and organic matter flux) and associated lowered oxygen availability which are characteristics of marginal marine environments. The low diversity and the dominance of the three genera also confirm marginal marine condition. The co- occurrence of the three arenaceous benthic foraminifera with the pteridophytic spores and angiosperm pollen suggest a marginal marine setting that ranges from coastal swamp and marshes to estuaries/lagoonal settings.

The heterolithic lithofacies at the depth interval of 10- 18 m in borehole 1, consisting of shale interbedded with thin beds of fine sandstone which becomes sandier upwards suggests parallic condition. The coarsening upwards of successision exhibited by the lithofacies from the basal greish shale lithofacies to the laminated shale lithofacies and the overlying heterolithic lithofacies also suggests shallowing of the sea. The occurrence of only Ammobaculites which exhibit low abundance and diversity may possibly be attributed to stressful condition due to low water salinity and rapid sedimentation with increased influx of sand and organic matter from the continental environment. It has been noted that Ammobaculites tolerate water salinity variations from 0.5°/oo to 23°/oo (Aseez et al., 1974) and are well developed in brackish water with moderate temperature such as coastal plain estuaries or lagoons (Scott et al., 2004) and tolerate low oxygen level. It however, show extreme dominance in estuaries with salinity range of 1- 15°/oo (Ellison and Nichols, 1970; Ellison, 1972). The co-occurrence of the Ammobaculite sp. with the Pteridophytic spores and angiosperm pollen in this lithofacies is suggestive of environmental setting that ranges from fresh water swamp and marshes to coastal plain estuaries/lagoons.

The dark fissile shale lithofacies at the top of the two boreholes exhibit the same characteristics of general absence of foraminifera. Palynomorphs comprising of pteridophytic spores (Cyathidites minor, Foveotrilete margaritae and laevigatosporites) together with angiosperm dominated by tricolporate (Psilatricolporites sp., and Retitricolporites sp.), diporate (Retidiporite magdalenensis) and monocolpate (Echitriporite trianguliformis) pollen group are suggestive of occurrence in fresh water swamp and marshes.

The dominance of the terrestrial pollen and spores over the marine species and general absence of the marine species documented by the lithofacies are indications of the withdrawal of the sea. The terrigenous species commonly increase during regressions.

6. Conclusion

Enugu Formation from the study of the two boreholes was deposited in a marginal marine setting which ranges from coastal swamp and marshes to estuarine/lagoonal. Lithofacies analysis of borehole 1 shows a coarsening upwards of lithofacies succession from the basal shale lithofacies to sand laminated shale lithofacies and heterolithic lithofacies. The succession is overlain by a shale lithofacies that consists entirely of terrestrially derived pollen and spores and generally lack marine species. This is an attribute of a prograding sea.

Late Campanian to early Maastrichtian age is proposed for the sediments based on the index palynomorphs and foraminifera recovered.

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