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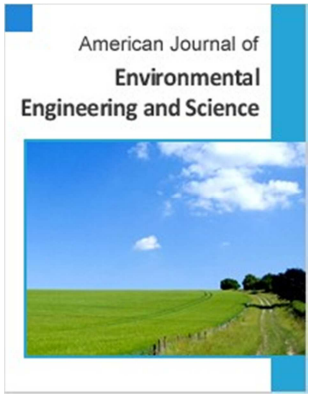

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Palynomorph Taxa Distribution in the Eze-Aku and Nkporo Shales within the Eastern Flank of Abakaliki Anticlinorium, Southeastern Nigeria

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Abstract
The Eze-Aku Shale represents the extensive basal unit of the Eze-Aku Group in the eastern flank of the Abakaliki Anticlinorium, southeastern Nigeria. The shale unit comprises of flaggy, dark-grey to black calcareous shales rich in pelagic faunas (pelecypods and gastropods) interbeded with mudstones. Palynological analysis of shale samples from selected surface outcrops of the unit yielded 20 palynomorph taxa comprising pollen, spores, and marine dinoflagellate cysts. The presence of palynomorph species *Elaterosporites* sp., *Perotriletes pannuceus* and *Steevesipollenites giganteus* suggest the shales outcropping in Ohana, Apiapum, Ntamkpo and Abaomege areas were deposited during the late Cenomanian-early Turonian. The lower age limit of late Cenomanian in this study is based on occurrence of *Elaterosporites* sp. and absence of the Albian palynoflora. Middle - late Turonian is assigned to shale outcropping in Oyadama and Ediba using palynomorph species: *Ephedripites* cf. *multicostatus, Monocolpopollenites spheroidites* and *Proteacidites dehaanii*. Samples collected from Usumutong and Ediba showed a mixture of Campanian - Maastrichtian palynoflora and Turonian palynomorphs and absence of the Coniacian - Santonian index pollen *Droseridites senonicus.* This supports absence of the Coniacian Awgu Formation in the eastern flank of Abakaliki Anticlinorium and overstepping of the Campano - Maastrichtian Nkporo Group onto the Eze-Aku units in the basin. The paleoenvironment has been interpreted as shallow, open marine to a slightly deeper water setting dominated by influence of waning flows typical of storm wave or turbidity current.

1. Introduction

The Eze-Aku shale unit which represents the basal part of the Eze-Aku Group in the basin [1] has been described and established to consist of flaggy or black shales with sandstones and surbordinate limestone which are rich in pelagic faunas, pelecypods and gastropods [2]-[3]-[4]. Palynological analysis has recently become essential tool in giving clues on biostratigraphy of sedimentary deposits in a basin. Most of the previous studies on the biostratigraphy of the Eze-Aku Shale were based on calcareous nannofossil and planktonic foraminifera from Eze-Aku Shale outcropping at Nkalagu area in the western flank of the Abakaliki Anticlinorium, which designated late Cenomanian - Coniacian age for the sediments [5]-[6]-[7]. More so, the biostratigraphic

zonal scheme based on ammonites presented by [2] is long overdue for a review. There is little or insufficient data regarding palynological results from previously un-investigated localities within the eastern flank. Most of the earlier works on the Eze-Aku Shale in the eastern flank were mainly for the interpretation of depositional environments and paleogeography as no attention was paid to palynological investigation of the shales except the studies conducted by earlier workers on foraminiferal and nannofossil assemblages within the western flank.

This study therefore is targeted on palynological analysis of surface shale outcrop samples from different localities in the eastern flank of Abakaliki Anticlinorium (Figure 3) for their palynomorph contents. The aim of the study is to present the palynological results from previously un-investigated localities and calibrate their ranges. An attempt is made at evaluating the age of the Eze-Aku Shale unit and its stratigraphic relationship with Nkporo Shale in the basin using recovered palynomorph taxa.

2. Geologic Setting

The installation of the Afikpo Synclinorium (eastern flank of Abakaliki Anticlinorium) resulted from the Santonian tectonism which caused the folding and uplift of the sediments of the first cycle in the southern Benue Trough of Nigeria [8]-[1]-[9]. The Benue Trough is a product of the failed arm of a trilate fracture system during the break-up of the Gondwana supercontinent and the opening up of the southern Atlantic and Indian oceans [30] - [10]–[11]-[12]-[13]-[1] and [14] equally added that the Benue rift is part of the West and Central African rift system which originated during the splitting apart of the Gondwana supercontinent. Reference [15] explained that a pre-Albian rifting of African shield prior to the opening of the South Atlantic gave rise to NE-SW trending Benue Trough. The southern Benue Trough is the southernmost of the three main Cretaceous downwarps forming the Benue Trough and has lateral extent of about 250 kilometers.

A major tectonic episode occurring in the mid-Santonian time deformed the Benue trough into folded belts accompanied by structural inversion [15]. These events led to the uplift of the Abakaliki Anticlinorium and the subsidence and formation of the Anambra Basin on its western flank and the Afikpo Synclinorium on its eastern flank [15] (Figure 2). Over 2000 m sediment thickness were eroded from the uplifted Abakaliki anticlinorium and deposited [15] as Campano-Maastrichtian sediments in the Anambra Basin and the Afikpo Sub-basin both of which are jointly called the Anambra-Afikpo Basin Complex [9]. Reference [16] regarded both the uplifted Abakaliki Anticlinorium together with the Benue trough as Abakaliki-Benue Trough. Sedimentation was generally controlled by transgressive and regressive cycles which actually led to the deposition of sediments in a wide variety of environments ranging from fluvial, fluvio-marine to marine environments [17]-[16]. Reference [16] documented three unconformity-bound trangressive – regressive cycles represented by the Albian – Cenomanian phase, Turonian – Coniacian phase and Campanian – Maastrichtian phase within the trough. The regional stratigraphy is shown in Figure 1 and Table 1.

Table 1. *Regional Lithostratigraphic Framework for Southeastern Nigeria (Modified from Hoque, 1977, Whiteman, 1982).*

AGE		STRATIGRAPHIC UNIT		BASIN CYCLE
TERTIARY	Oligocene - Pliocene	Benin Formation		Niger Delta Basin
	Eocene	Ameki / Agbada Formation		
	Paleocene	Imo/Akata Formation		
	Danian	Nsukka Formation		Anambra Basin
	Maastrichtian	Ajali Sandstone Mamu Formation		
UPPER CRETACEOUS	Campanian	Nkporo Group	AfikpoSS/Nkporo Sh/ Owelli SS /Enugu Fm.	
	Santonian	Unconformity	(Erosion and Non-deposition)	Tectonic Uplift and Folding
	Coniacian	Awgu Formation		
	Turonian	Eze- Aku Group	Eze- Aku Sh / Amasiri SS	Abakaliki Basin
	Cenomanian	Odukpani Formation		
LOWER CRETACEOUS	Albian Aptian	Asu River Group	Abakaliki Formation Mamfe Formation	
PRECAMBRIAN		BASEMENT COMPLEX		

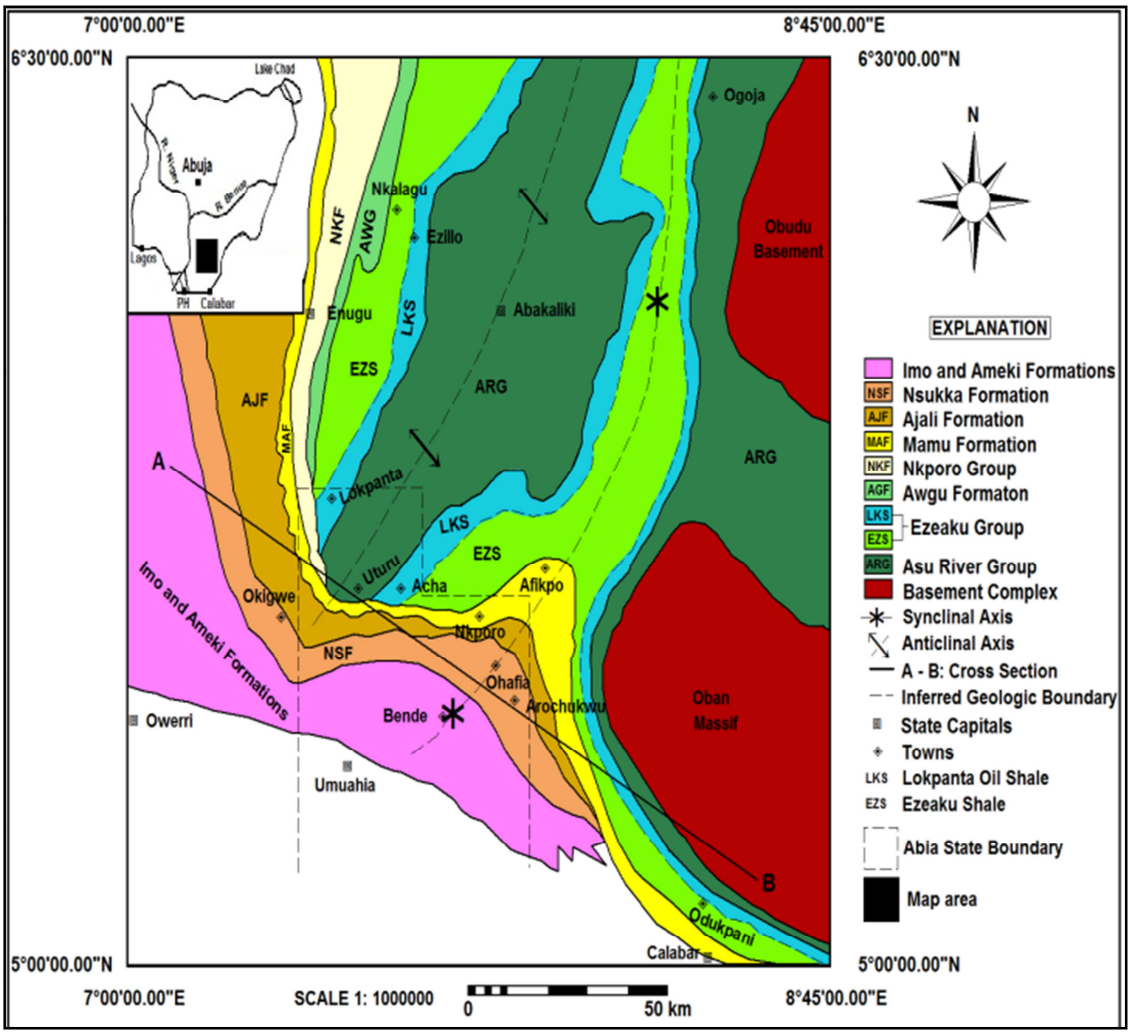

Figure 1. *Geologic map of southeastern Nigeria showing the Study area and the stratigraphic position of Eze-Aku Group relative to other formation.(After [36]).*

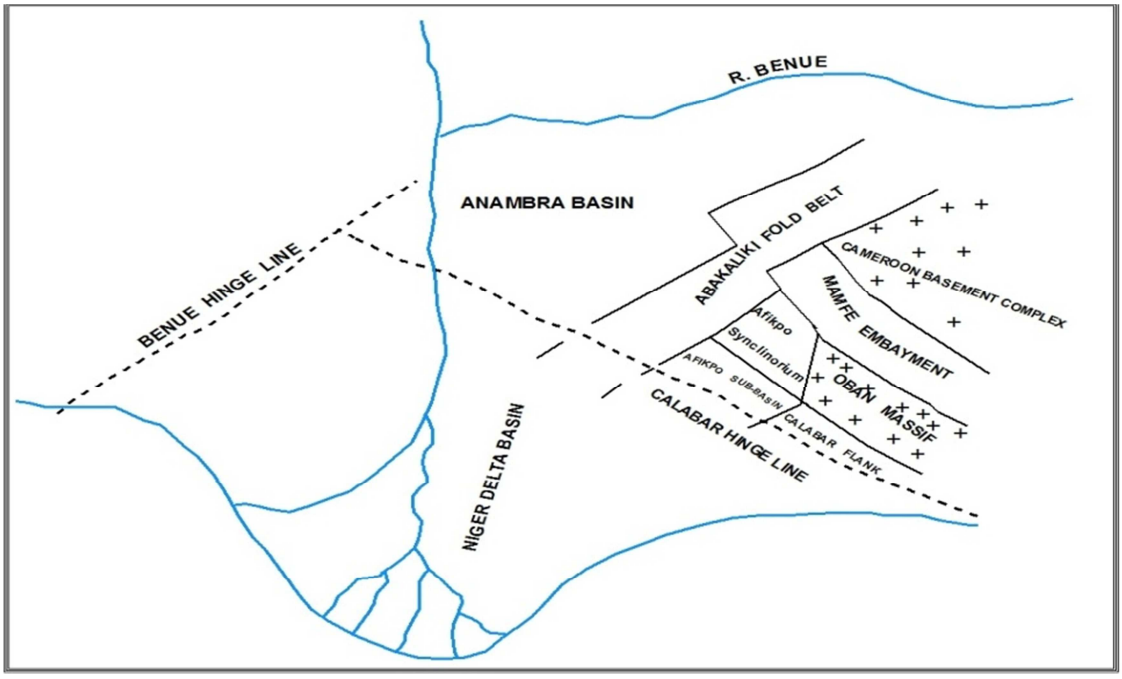

Figure 2. *Tectonic Elements map of the Southern Benue Trough (Modified after [16] cited in [37]).*

3. Methodology

The study involves field mapping and palynological analysis of surface samples of Eze-Aku and Nkporo Shales outcropping in the eastern flank of Abakaliki Anticlinorium. A total of twenty two representative shale samples were collected from different localities within the basin and analyzed for palynomorphs (Table 2 and Figure 3). About 50 g of each shale sample was pulverized using pestle and mortar and put inside labeled plastic beakers for acid treatment. The palynological slide preparation involved initial removal of carbonates from the samples using 35% hydrochloric acid (HCl) up to an hour. HF was added to the sample after neutralization of HCl acid. The sample was washed with water and potassium chlorate ($KClO_3$) was added into the mixtureto clean the slides or buffer the effect of silicon fluoride gel produced from the reaction of HF and silicate which reduces the quality of the slides

The next phase involved addition of about 70% nitric acid to oxidize the organic content of the residue in order to clean the palynomorphs. About 10% KOH was added to neutralize the HF, followed by using water to wash the sample through the 10µm sieve. The liquid portion of the samples were then transferred into test tubes and then loaded in the centrifuge machine maintaining 2500 r.p.m for about 3 minutes and were then decanted. To separate the organic from the inorganic substances, 2.20 specific gravity zinc chloride ($ZnCl_2$) was added in a quantity that is 2.5 times greater than the sample and centrifuged for the third time for 5 minutes. The organic matters suspended on the surface of the mixture were carefully separated and transferred into another labeled test tube. The acidification of the residue was done again by adding 2 ml of 0.5 mole HCl, centrifuged and decanted. Water was then added to neutralize the acid, centrifuged to remove the water. The actual pre-organic residue/palynomorphs used were transfered into plastic vials. Cleaning and labeling of the slides were done followed by spotting of the specimen on the slide after staining or spotting the cover slips before they were finally mounted on glass slides using Norland brand adhesives resin. The palynomorphs were then studied under transmitted light microscope with objective magnification of 25 and 40 respectively. The photomicrographics were done using a photomicroscope. From each of the samples, counts of pollen, spores and dinoflagellate cysts were done and recorded. The recovered species were identified with the references of many other relevant works [18]

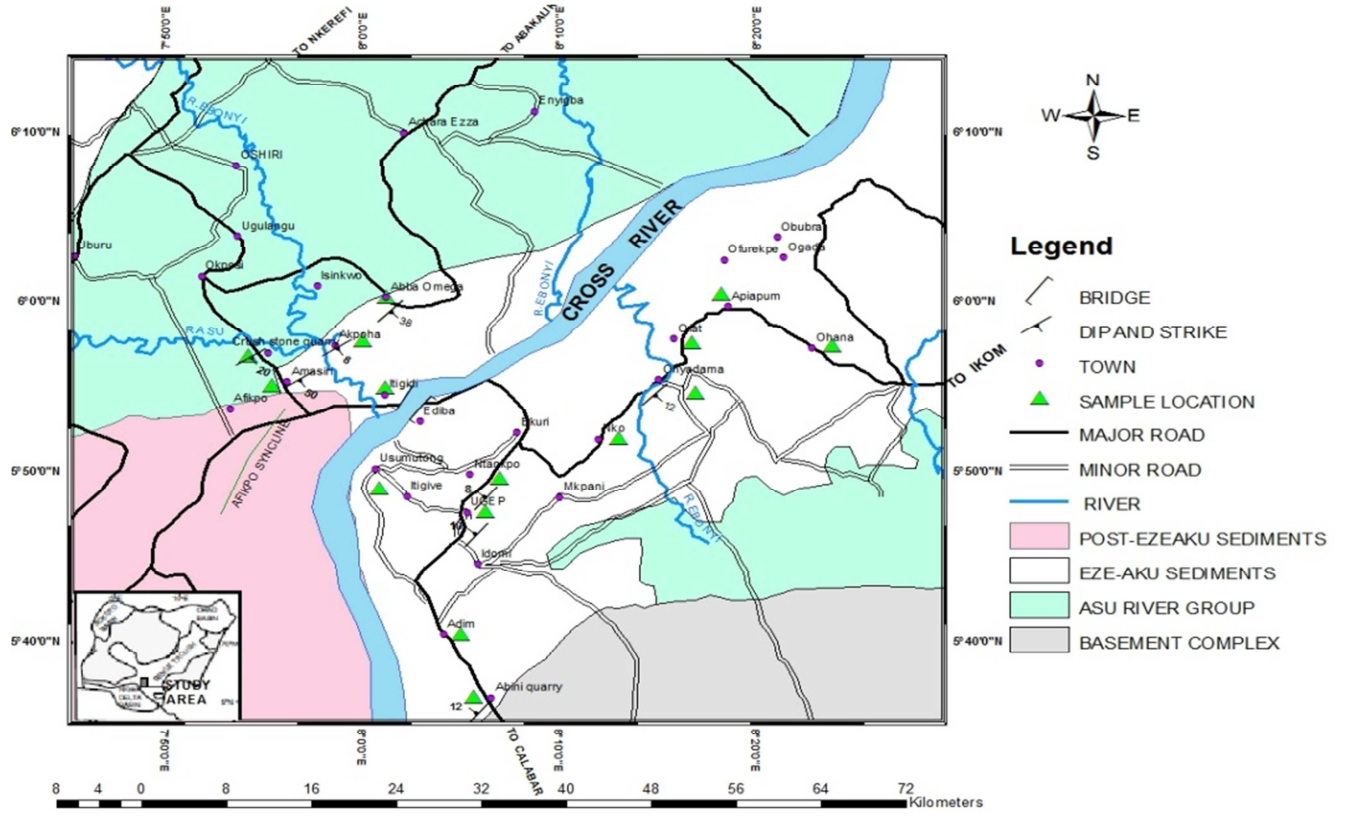

Figure 3. *Geological map of parts of eastern flank of Abakaliki Antclinorium showing the studied Eze-Aku and Nkporo units [37].*

4. Results

4.1. Field Characteristics

The Eze-Aku Shale facies unconformably overlies the sediments of Asu River Group wherever it occurs in both flanks of the Abakaliki Anticlinorium and underlies the Nkporo Shale in the Afikpo Syncline. Apart from Akaeze where it has its type locality at Eze-Aku River., it overlies the Abakaliki Shale (Asu River Group) at Abaomege and the Mamfe Formation at Ohana in the study area.

Field study and sedimentological observations show that

the unit comprises of dark grey to black laminated shales, interbedded with thin beds of mudstones (Figure 4). There is occurrence of gypsum efflorescence within the shale laminae. The unit consists of over 90% mudrocks with less than 3% admixture of siltsone or sandstone in Sematec quarry, Itigidi and road cut section along Adadama – Itigive Road and Akpoha River. In the Ediba –Usumutong outcrop (Figure 5), the outcropping Nkporo shale is highly fossiliferous, evident by small numerous pelecypods moulds (*Inoceramus* sp) and juvenile gastropods, while ammonites occur inside the geodes. Concretions and cm-scale nodules mostly elliptical in shape occur as nodular beds and dispersed nodules within the laminations/bedding planes in the Eze-Aku Shale outcrop at Oyadama. The shale facies also outcrop at Apiapum Border Street, Ohana green pond, Ntamkpo, road cut near Julius Berger quarry, Ebonyi River channel, Akpoha, Marlum Quarry along Amasiri Road and Okaria village Abaomege.

Table 2. *Sample Numbers and Location of Sampling Points.*

Sample Code	Formation	Town/location	Latitude/Longitude
EO/1-3	Eze-Aku Shale	Ohana/broder street	5°57′ 55.4″N/ 8°21′42.″E
EO/4a,b		Apiapum	6°00′4.2″ N/ 8°18′ 46.7″E
EO/5-6		Oyadama	5°56′27″N/ 8°14′ 56″E
EO/7-8		Ntankpo	5°50′ 7.″N/ 8°05′ 43.1″E
EO/9-11		Usumutong	5°50′ 19.6″ N/ 8°05′ 54.″E
EO/12-14		Ediba	5°52′ 57.5″ N/ 8°02′ 08″E
EO/15-19		Abaomege	6°01′ 9.1″ N7°58′ 49.6″E
EO20		Akpoha	5°57′ 15.4″/ 7°56′ 47.7″E
EO21		Amasiri	5°55′ 45.5″ N/ 7°52′ 57.5″E
EO22		Adim	5°46′ N/8°3′E

Figure 4. *Parallel Laminated Shale interbedding with Mudstone at Ebonyi River, Akpoha.*

Figure 5. *Parallel Laminated Shale and Mudstone Lithofacies at Ediba.*

4.2. Palynological Investigation

Palynological analysis was conducted on 22 selected fresh samples of shale. The analysed shale samples yielded 20 palynomorph taxa comprising of pollen, spores and marine dinoflagellate cysts. The distribution chart for the palynomorphs species and species abundance are shown in Tables 3 and 4. The photomicrographs of the identified palynormorphs are shown in Figures 6a-c. The recovered pollen taxa include: *Ephedripites* cf. *multicostatus*, *Monocolpollenites sphaeroidites*, *Araucariacites* cf. *australis*, *Steevespollenites giganteus*, *Elaterosporites* sp., *Tricolporopollenites* sp., *Ephedripites* sp., *Syncolporites* sp., *Retitricolporites* sp., *Retimonocolpites* sp., *Gnetaceaepollenites* sp., *Inaperturopollenites* sp., *Charred graminae curticle, Perotriletes pannuceus, Constructipollenites inffectus, Longapertites* sp. among others. Those of the spore taxa include *Cyathidites minor, Osmundacidites* sp., *Laevigatosporites* sp., *Polypodiaceoisporites* sp., *Gleicheniidites* sp., fungal spore, *Cyathidites* sp. e.t.c. Dinocysts are represented by *Lejunecysta* sp., *Polysphaeridium* sp. and *Dinogymnium euclaensis*. These and others are shown in Table 3. The palynological result is presented based on the localities (Table 2).

4.2.1. Ohana Locality (EO/1-3)

Palynological analysis of the shale from this locality yielded terrestrial species which include *Tricolporopollenites* sp., *Araucariacites* cf. *australis*, *Laevigatosporites* sp., *Inapperturopollenites* sp., *Cyathidites minor* and *Gleicheniidites* sp. Marine dinoflagellate cysts were absent.

4.2.2. Apiapum locality (EO/4a and b)

Marine species is totally absent in the prepared sample. Terrestrial species which occur in low diversity include: *Proteacidites sigali*, *Monosulcites* sp., *Proteacidites dehanni*, *Ephedripites* sp., *Polypodiaceoisporites* sp., *Araucariacites* cf. *australis*, *Laevigatosporites* sp. and charred graminae cuticle.

4.2.3. Oyadama Outcrop (EO/5-6)

The samples were collected from outcrop 3 along the Ikom – Calabar Road, Oyadama. The palynomorphs encountered

in this locality outcrop include *Ephedripites* sp. which is the most abundant form. Other terrestrial species noted in the samples include: *Monosulcites* sp., *Gnetaceaepollenites* sp., *Monocolpopollenites sphaeroidites*, *Cyathides* sp., *Retimonocolpites* sp., *Retitricolpites* sp., *Araucariacites* sp., *Inapperturopollenites* sp., *Tricolporopollenites* sp. and pollen indeterminate.

4.2.4. Ntamkpo Locality (EO/7-10)

The sample was collected from a hand dug well behind the Okori Memorial College. The result of the palynological analysis shows that sample EO7 is barren (practically no palynormorphs). EO8 recorded the occurrence of terrestrial species. Dinoflagellate cysts are rare. The palynomorphs recorded in the samples are *Ephedripites* sp., *Ephedripites procerus*, *Ephedripites multicostatus*, *Ephedripites americana*, *Ephedripites jansonii*, *Steevesipollenites giganteus*, *Retitricolporites* sp., *Acostichum aureum* and microforaminiferal linings.

4.2.5. Usumutong Locality (EO/9-11)

Palynomorphs in this area include both marine and terrestrial species. Dinoflagellate cysts at this locality include: *Dinogymnium euclaense* and Dinocyst indeterminate. *Acostischum aureum*, *Longapertites* sp., *Proteacidites sigali* and *Retitricolpollenites* sp. are most frequently occurring terrestrial species at these samples. Others include: *Retimonocolpites* sp., *Proteacidites longispinosus*, *Longapertites microfoveolatus*, *Laevigatosporites* sp., *Cyathidites* minor, *Retitricolporites* sp., *Syncolporites subtilis*, *Tubistephanocolporites cylindricus*, *Constructipollenites infectus*, *Psilatricolporites* sp. among others.

Table 3. *Distribution Chart of Palynomorphs Species in the Study Area.*

Sample No.	Age	*Araucariacites cf. australis*	*Tricolporopollenites sp*	*Gleichenidites sp*	*Laevigatosporites sp*	*Cyathidites minor*	*Ephedripites sp*	*Polypodiaceoisporites sp*	*Proteacidites dehanni*	*Monosulcites sp*	*Proteacidites sigali*	*Inaperturopollenites sp*	*Charred gramineae cutille*	*Ephedripites procerus*	*Ephedripites cf. multicostatus*	*Ephedripites Americana*	*E. jansonii*	*Steevesipollenites giganteus*	*Steevesipollenites sp*	*Syncolporites sp*	*Fungal spore*	*Longapertites sp*	*Leoisphaeridia sp*	*Perotriletes pannuceus*	*Proteacidites sp*	*Cyathidites sp*	*Retimonocolpites sp*	*Monocolpopollenite sphaeroidites*	*Araucariacites sp*	*Cuparieidites reticularis*	*Elaterosporites sp*	*Gneataceaepollenites sp*	*Pollen indeterminate*
E O11																																
EO10																					2											
EO9																					2					1						
EO14						3	1		1			1									1											
EO13					1																1	1										
EO12					1					1	2	2									3			1	4							1
EO6			1			1						1			7					1									1			
EO5			1				7			4														1	1	1	1	1	1		2	
EO22																																
EO20																					1											
EO19												1													1							
EO18												1									1			1								
EO15		1										1												1								
EO17		1																					1									
EO16		1			2					1											1											
EO8							7							10	4	1	1	1	1	1										1		
EO4b												1	1																			
EO4a		2				1	1	1	1	1	1																					
EO2			2		2	1																										
EO1		2	1	1																												

Campanian – early Maastrichtian / *Turonian* / *Late Cenomanian- Early Turonian*

Table 3. *Continued.*

Sample No.	Age	*Monocolpites sp*	*Cupariecdites reticularis*	*Foraminifera wall lining*	*Constructipollenites infectus*	*Periretisyncolpites sp*	*Tricolpites sp*	*Syncolporites subtilis*	*Gemmamonoporites sp*	*Monocolpite margintis*	*Monoporites annulatus*	*Polyshaenidium sp*	*Scabratriporites annellus*	*Psilatriporites sp*	*Acrosticchum aureum*	*Retritricolporites sp*	*Psilatriporites sp*	*Longapertites microtoveolatus*	*Acritarch sp*	*Petrospermella sp*	*Zonocostites ramonae*	*Selaginella myosurus*	*Indeterminate dinocyst*	*Zlivisporis blanensis*	*Spinzonocopite sp*	*Dinogymnium euclaense*	*Ariadnaesporites sp*	*Converrucosisporites proxigranulatus*
E O11	*Campanian – early Maastrichtian*														3								2				1	1
EO10															1									1	1	1		
EO9														1	2			2	1									
EO14		4							1	1	1	1	1															
EO13																												
EO12		2		1	1	1	1	1																				
EO6																												
EO5																												
EO22	*Turonian*																			1								
EO20																					4	3	1					
EO19																												
EO18																												
EO15																												
EO17	*Late Cenomanian- Early Turonian*																											
EO16																												
EO8				1										1	1	1	1											
EO4b																												
EO4a																												
EO2																												
EO1																												

4.2.6. Ediba Locality (EO/12-14)

The palynological analysis for this locality shows that the only dinoflagellate cyst and sporomorph in the samples are *polysphaeridium* sp. and *Cyathidites minor* respectively. The dominance of terrestrial species in this locality reflects the carbonaceous nature of the shale. The recovered pollens are *Monocolpites* sp., *Constructipollenites infectus*, *Inapperturopollenites* sp., *Longapertites* sp., *Ephedripites* sp., *Tricolpites* sp., *Syncolporites subtilis*, *Gemmamonocoporites* sp. among other pollen. There is also occurrence of microforaminiferal linings and other indeterminate palynomorphs.

4.2.7. Abaomege Locality (EO/13-19)

This locality shows a poor recovery of palynomorphs. The recovered marine dinoflagellate cysts are *Lejeunecysta* sp. and *Leoispharidia* sp. The pollen include: *Inaperturopollenites* sp., *Proteacidites* sp. and *Araucariacites* cf. *australis*. The spores include: *Cyathidites* sp., *Laevigatosporites* sp. and fungal spore.

4.2.8. Akpoha Locality (EO/20)

The samples were collected from the Ebonyi River Akpoha. There is low abundance of palynormorphs species in this locality samples. Acritarch species which does not represent a formal taxon is present in the samples. The occurrence of few other palynomorphs is represented by *Zonocostites ramonae*, *Selaginella mysorus*, fungal spore and Dinocyst indeterminate.

The result of the palynological analysis shows that sample

EO7 is barren (practically no palynormorphs). EO8 recorded the occurrence of terrestrial species. Dinoflagellate cysts are rare. The palynomorphs recorded in the samples are *Acostichum aureum, Ephedripites* sp., *E. americana*, *E. jansonii*, *E. multicostatus*, *E. procerus*, *Retitricolporites* sp., *Steevesipollenites giganteus*, and microforaminiferal linings.

Table 4. *Distribution and Abundance Percentage of the Recovered Palynomorph Taxa.*

Sample Code	Species Diversity			Total	Species Abundance			Total	Percentage (%)		
	Terrestrial		Marine		Terrestrial		Marine		Terrestrial		Marine
	Pollen	Spore	Dynocyst		Pollen	Spore	Dynocyst		Pollen	Spore	Dynocyst
EO1	2	1	-	3	3	1	-	4	75	25	-
EO2	1	2	-	3	2	3	-	5	40	60	-
EO49	4	2	-	6	6	2	-	8	75	25	-
EO45	2	-	-	2	2	-	-	2	100	-	-
EO5	10	1	-	11	21	1	-	22	95	5	-
EO6	7	1	-	8	13	1	-	14	93	7	-
EO8	7	-	-	7	35	-	-	35	100	-	-
EO9	6	-	1	7	11	-	4	15	73	-	27
EO10	12	2	3	17	28	6	8	42	67	14	19
EO11	8	-	4	12	28	4	9	41	68	10	22
EO12	10	2	-	12	14	5	-	19	74	26	-
EO13	2	1	-	3	2	1	-	3	67	33	-
EO14	9	1	1	11	12	3	1	16	75	19	7
EO15	3	-	-	3	3	-	-	3	100	-	-
EO16	2	1	1	4	2	3	-	5	40	60	-
EO17	2	-	1	3	2	-	1	3	67	-	33
EO18	2	1	-	3	2	1	-	3	67	33	-
EO20	3	1	2	6	5	1	41	47	11	2	87
EO22	1	-	1	2	1	-	40	41	2	-	98
Total	94	16	14		187	32	104				

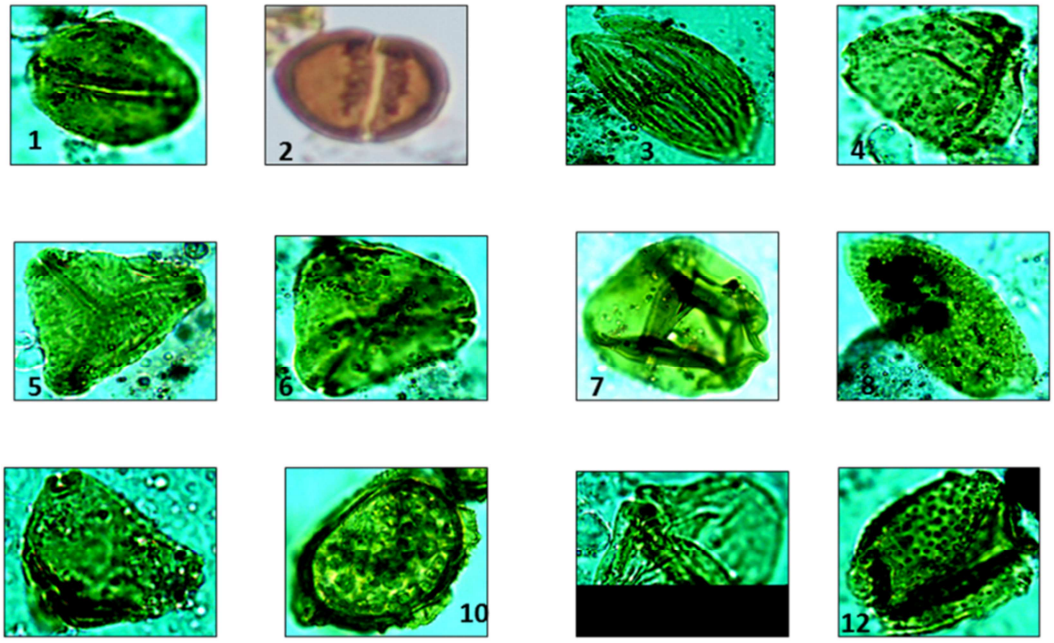

Figure 6a. *Photomicrographs of Palynomorphs Species.*

1. *Monocolpopollenites sphaeroidites* (x400)
2. *Monocolpopollenites sphaeroidites* (x400)
3. *Ephedripites sp*. 4 Hernegreen, 1973 (x400)
4. *Proteacidites dehanni* (x400)
5. *Cupanieidites reticularis* (x400)
6. *Syncolporites subtilis* (x400)
7. Araucariacites sp (x400)
8. *Longapertites* sp (x400)
9. *Scabratriporites annellus* (x400)
10. *Perotriletes pannuceus* (x400)
11. Dinogymnium sp (x400)
12. *Proteacidites sigalii* (x400)

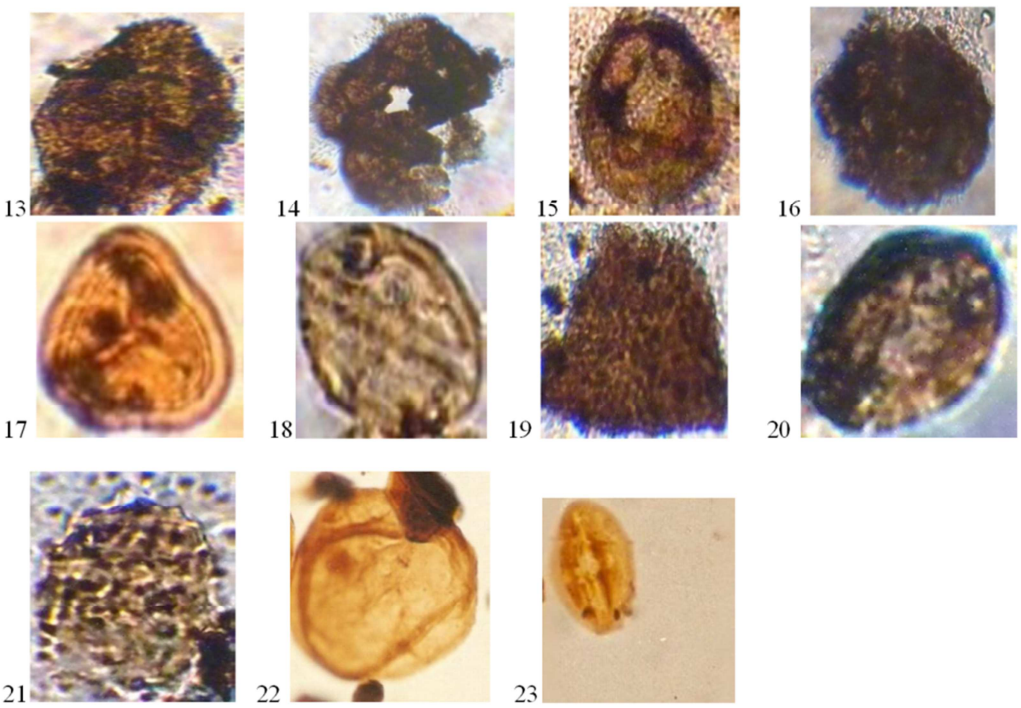

Figure 6b. *Photomicrographs of Palynomorphs Species continued.*

13. *Retimonocolpites* sp =? *Liliacidites variegatus* in Brenner, 1968 (x400)
14. Microforaminiferal wall lining (Spiral) (x800)
15. *Araucariacites australis* Cookson, 1947 (x400)
16. Fungal spore (x400)
17. *Cyathidites* sp (x400)
18. *Monocolpites* sp (x400)
19. *Longapertites* sp 3 Lawal, 1982 (x400).
20. *Monocolpopollenites sphaeroidites*
21. *Dinogymnium* sp
22. *Inaperturopollenites* sp (x800)
23. Tricolporopollenites sp

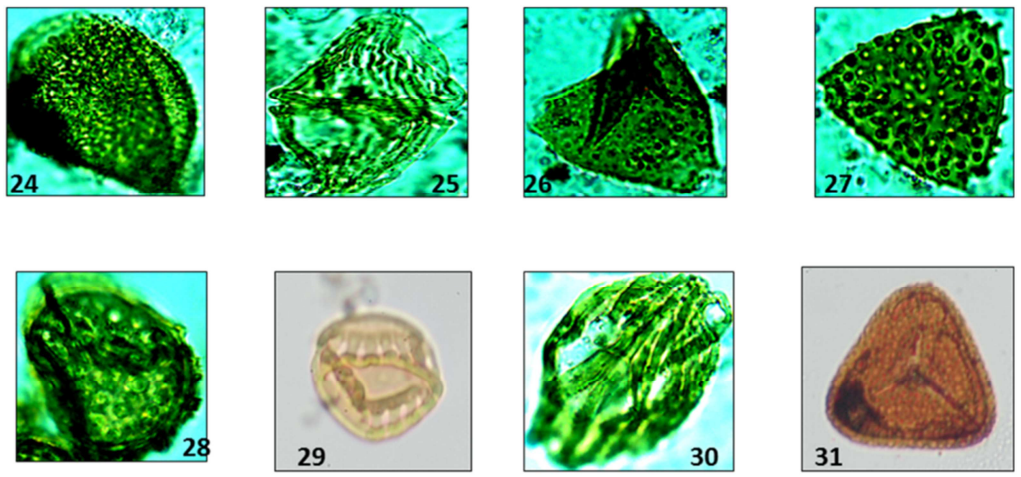

Figure 6c. *Photomicrographs of Palynormorphs continued. All magnification x400.*

24. *Longapertites marginatus*.
25. *Dinogymnium euclaensis*.
26. *Proteacidites sigalii*
27. *Proteacidites longispinosus*.
28. *Perotriletes pannuceus*.
29. *Tubistephanocolporites cylindricus*.
30. *Gnetaceaepollenites* sp.
31. *Foveotriletes margaritae*

5. Discussion

5.1. Stratigraphic Range Calibration

Generally, there is low abundance of palynomorphs, in the samples analyzed. This is probably attributed to general belief of unstable ecologic conditions in the Benue Trough and Gongola Rift during Late Cenomanian/Early Turonian times [20]. High run off from land probably carried much terrestrial organic matter into the Benue Trough and caused hyposalinity and oxygen depletion for period of time [19]-[20]- [5]. Some of the recovered palynomorphs occur in the Cenomanian to Turonian age. They include: *Elaterosporites* sp, *Perotriletes pannuceus Ephedripites cf. multicostatus*, *Monocolpollenites sphaeroidites*, *Araucariacites cf. australis*, *Steevespollenites giganteus*, *Tricolproropollenites* sp [21]-[22]-[18]-[23]. The scenario which [28] identified on the Turonian/Campanian boundary at Leru probably played out also in the study area. For instance, In Ediba/Usumutong, the plunge of the sediments of the southern Benue Trough in the area and subsequent erosion may have caused the Campano – Maastrichtian Nkporo Shale at the base of Afikpo Sub-Basin to overstep onto the Late Cenomanian to Turonian Eze-Aku Shale at Ediba/Usumutong locality with the Coniacian – Santonian Awgu Shale abruptly missing. The Campanian/Turonian boundary within which reworked Turonian palynomorphs are mixed up with the Campanian flora is represented by *Constructipollenites infectus, Longapertites microfoveolatus, Monocolpites marginatus.*

The palynomorphs used for stratigraphic range chart (Table 5) and age determination include: *Araucariacites cf. australis, Perotriloletes pannuceus, Steevesipollenites giganteus, Elaterosporites* sp*, Tricolporopollenites* sp, *Ephedripites cf. multicostatus, Monocolpollenites sphaeroidites, Longapertites* sp, *Cupanieidites reticularis.* Age determination on the stage level is possible using the occurrence of palynomorphs [21]-[22]-[18]-[23].

Table 5. *Stratigraphic Range Chart for the Palynomorphs.*

108		96	92			82	Time (my)	
Albian		Cenomanian	Turonian			Coniacian	Santonian	Stages
Middle	Late	Early -Middle	Late	Early	Middle	Late	Uplift + Folding	
Abakaliki shale			Eze-Aku Shale			Awgu Formation		Formation
							×	*Araucariacites cf. australis*
							×	*Perotriletes pannuceus*
							×	*Ephedripites sp*
							×	*Steevesipollenites giganteus*
							×	*Ephedripites cf. multicostatus*
							×	*Elaterosporites sp*
							×	*Tricolporopollenites sp*
							×	*Monocolpollenites shaeroidites*
							×	*Proteacidites dehanni*
							×	*Inaperturopollenites sp*
							×	*Araucariacites sp*
							×	*Syncolporites sp*

The existence of the Cenomanian age in the eastern flank of the Abakaliki Anticlinorium has been a subject of controversy. Most authors suggested a period of non – deposition (unconformity) for this time interval in the eastern flank (Afikpo Sub-basin) and Anambra Basin [24]-[25]. Notwithstanding, the existence of Cenomanian age was recorded in the sediments collected from some parts of lower Benue Trough (Nara, Ngbanocha, Ezillo, Akaeze) using palynological studies (Ojoh 1992). The determination of Late Cenomanian to Early Turonian age in this present study was achieved using some palynomorph taxa.

Palynofacies in shales collected from Ohana, Apiapum, Ntamkpo and Abaomege localities have been dated Late Cenomanian to Early Turonian based on palynomorph assemblages from samples EO1, EO2, EO4a, EO8, EO15 and EO17. *Araucariacites cf. australis, Perotriletes pannuceus, Steevesipollenites giganteus, Ephedripites* sp, *Tricolporopollenites* sp, *Elaterosporites* sp (Table 5) represent species used to identify the Late Cenomanian. These markers were used to date the Late Cenomanian to Early Turonian stage [21]-[22]-[23]. Reference [23] reported these species in some parts of the Chad (Bornu) Basin. The co-occurrence of *P. pannuceus* and *Araucariacites* sp in sample EO15 and admixture of *Araucariacites australis* and *Tricolporopollenites* sp strongly indicate this age. The lower age limit of Late Cenomanian in this study is based on the occurrence of index form, *Elaterosporites sp* and absence of the Albian microflora. Elatere bearing forms have been reported in Cenomanian of Brazil, Senegal, Ivory Coast and Nigeriaby a great genetic diversity [21].

The middle – late Turonian stage was established using palynomorphs recorded in some samples. A Turonian age is assigned to samples EO5 and EO6 from Oyadama and sample EO14 from Ediba basedon the significant palynomorph forms that were recorded in these samples. These forms include *Ephedripites cf. Multicostatus, Monocolpollenites sphaeroidites, Proteacidites dehanni, Inaperturopollenites sp, Araucariacites sp* and *Syncolporites sp* (Table 5). References [22]-[18]-[2012] used these species to date Turonian Stage. (Jardine and Malgoire, 1965,

Boltenhagen, 1965 documented the non-occurrence of *Syncolporites sp* in the Senonian.

The result of palynological analysis of samples collected from Usumutong and Ediba showed a mixture of Campanian to Maastrichtian flora and Turonian palynomorphs and absence of the Coniacian to Santonian index pollen *Droseridites Senonicus* of [18] This result confirms the absence of the Awgu Formation in the Synclinorium (eastern flank of Abakaliki Anticlinorium) and overstepping of the Campano – Maastrichtian Nkporo Formation onto the Eze-Aku Group. The Campanian/Turonian boundary within which reworked Turonian palynormorphs are mixed up with the Campanian flora is represented by *Constructipollenites infectus, Longapertites microfoveolatus and Monocolpites marginatus.* This was caused by the plunge of sediments of the southern Benue Trough and subsequent erosion [28] that accompanied the Santonian orogenic activities.

5.2. Paleoenvironment

The general low abundance of palynofacies in samples from different localities and complete absence of terrestrial species of palynomorphs in samples collected from Ebonyi River in Akpoha suggest deeper water, normal salinity and open marine environment [22]. Dark-grey to black parallel laminatated shale with mudstone interbeddings and interstratifications and pelecypods moulds suggest deposition in shallow, open marine to aslightly deep water setting [2]-[31]. The environment is typical of that dominated by influence of waning flows typical of storm wave or turbidity current [32] Beyond the shelf, the depositional environment for this kind of facies is probably distal submarine fan setting [33]-[34]-[35]. The depositional process is fairly low energy or low density turbidity. Generally, the range of environments for this shale facies is corroborated by the palynormorphs. The open marine setting in particular is corroborated by presence of pelecypods moulds and dinocysts [22]-[29].

6. Conclusion

Field studies show that the Eze-Aku facies represent the base of Eze-Aku Group in the studied basin and unconformably overlies the sediments of Asu River Group. The shale unit comprises of dark grey to black laminated shales interbedded with thin beds of mudstones with subordinate limestones. Palynological analysis show that shale samples yielded palynormorphs comprising dominantly terrestrial pollen and spores and marine dinoflagellates. The Cenomanian to Turonian stage for the Eze-Aku Shale unit in the basin were determined using the occurrence of *Elaterosporites sp*, *Perotriletes pannuceus Ephedripites cf. multicostatus*, *Monocolpollenites sphaeroidites*, *Araucariacites cf. australis*, *Steevespollenites giganteus*, *Tricolproropollenites sp.* The shales were deposited in shallow, open marine to deep water setting. The open marine setting in particular is corroborated by presence of pelecypod moulds and dinocysts.

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