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Foraminiferal Biostratigraphic Analysis of the Late Cenomanian – Turonian Eze-Aku Shale in the Afikpo Synclinorium, Lower Benue Trough, Nigeria

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Abstract
The Eze-Aku Shale represents the basal unit of the Eze-Aku Group and unconformably overlies the Asu River Group in the Afikpo Synclinorium. Foramineferal biostratigraphic analysis of the shale facies was carried out to re-evaluate the age, paleoecology and paleoenvironment of the shale unit. Field studies show that the shales are flaggy, dark grey to black, calcareous, thinly laminated with pelecypod moulds, gypsum efflouresence between the laminae and mudstone interbeds. The biostratigraphic study shows that the shales contain both planktonic and benthonic foraminiferal assemblages. The planktonic forms include species of *Hedbergellids, Heterohellicids, Whitenella* and *Archeogloberina blowi.* Benthonic forms are mainly species of *Ammobaculites, Haplophragmoides, Lenticulina, Gavelinella, Globigerinelloides.* Late Cenomanian to Turonian age was assigned to the Eze-Aku Shale facies based on the planktonic foraminiferal assemblages of *Hedbergellids* and *Heterohellicids.* The foraminiferal assemblages suggest middle neritic to deeper water, normal salinity environment with prevailing anoxic conditions. This explains the paucity of biofacies and mixture of both shallow and deep water microfauna were attributed to mass mortalities due to reduced salinities, anoxic/successive deepening of the depositional environmental setting.

1. Introduction

A major global marine transgression which characterized the Turonian time resulted in a remarkable establishment of Epeiric Sea in the Benue Trough Nigeria. This resulted in the deposition of Eze-Aku facies in a wide range of environment from brackish water to open, shallow sea with depths up to 100m with storm event as the depositional process [47]-[3]-[4]. Reference [38] working on the ammonite fauna of southeastern Nigeria regarded the Eze-Aku Shale facies as Turonian based on the rich faunas of *Vascoceratid* ammonites. He further suggested that the concentration of ammonites in these rocks marked posthumously dispersed materials. However, collective assignment of the age of the Eze-Aku facies showed Late Cenomanian to early Turonian based mainly on the ammonites, ostracods and foraminiferal contents of the various facies of the group [38]-[43]-[48]. The shale and limestone facies contain five families of ammonites which range from Cenomanian to Campanian. Reference [48] assigned the genera associated with

Eze-Aku facies to upper Cenomanian to Coniacian but genera predominantly occur within the upper Cenomanian to lower Turonian. Reference [45] correlated the Nkalagu Limestone of the Eze-Aku Group with the Wadatta Limestone member of the Markurdi Formation in the Central Benue Trough.

Reference [34] documented that the Eze-Aku Shale facies outcropping 24.8 km from Calabar on the Calabar – Itu highway comprises mostly species of *Ammobaculites, Heterohelix, Hedbergella, Guembelitria, Praebulimina.* The microflora from the Eze-Aku facies near Calabar which include *Triorites africaensis* and *Classopollis* indicate a Cenomanian to Turonian age. More so the cocolith found in vicinity, north of Calabar support a late Cenomanian to Turonian age for the rocks [32]. Reference [13] identified two calcareous nannofossil zones from Eze-Aku shales facies in Nkalagu quarry section in western flank: *Eiffelithus eximius* zone (middle Turonian to early late Turonian and *Marthasterites furcatus*zone (late Turonian to Coniacian).

2. Geologic Setting

In lower Benue Trough (Fig. 1), sedimentation began in the early Cretaceous [46]-[7]-[31]-[17]-[47]. However, the lithostratigraphic succession in the Benue Trough consists mainly of Cretaceous sedimentary rocks with total thickness ranging 3500 m in northeast to over 7000 m in southwest [18]. The Ogoja Sandstone (Aptian) is the oldest Cretaceous unit in the basin. It consists of arkosic sandstone disconformably overlain by AlbianAsu River Group (Table 1) which was deposited as due to Albian marine transgression in the Abakaliki area. Asu River Group consists of Abakaliki Shale with volcanoclastis, sandstone and sandy limestone lenses [5]. This was followed by the deposition of marine, paralic and continental sediments of the Cenomanian Odukpani Formation in the Calabar Flank which consists of dark grey to black calcareous shale [38]. Further transgression and regression took place during Turonian period which deposited Eze-Aku Group and Awgu Shale (Coniacian) [46]. The Eze-Aku Group consists of flaggy grey or black shales with sandstones and surbodinate limestones which are rich in pelagic faunas, pelecypods and gastropods [38]-[1]-[34]. The Awgu Shale consists of dark and bluish-grey well bedded shales with abundant thin limestone and marl interbeds [38]. The tectonic event of the Santonian led to uplift, folding and widespread erosion in the sediment fill of the Benue Trough. Another transgression occurred in the Campanian-Maastrichtian resulting in deposition of marine sediments. Prior to the marine incursion in the early Campanian, the Abakaliki Basin in the southern sector of the Trough was folded into series of anticlines. Thus the Anambra Basin and Afikpo Syncline became the major depocentres for the Campanian-Maastrichtian sediments [46]. The Nkporo/Enugu Shale and Afikpo Sandstone member were deposited in these basins. The Abakaliki Anticlinorium formed the axis of the Santonian uplift and represent stable structural feature, which controlled the development of the associated basins (Anambra Basin and Afikpo Sub-Basin).Table 1 shows regional lithostratigraphic framework for southeastern Nigeria (lower Benue Trough)

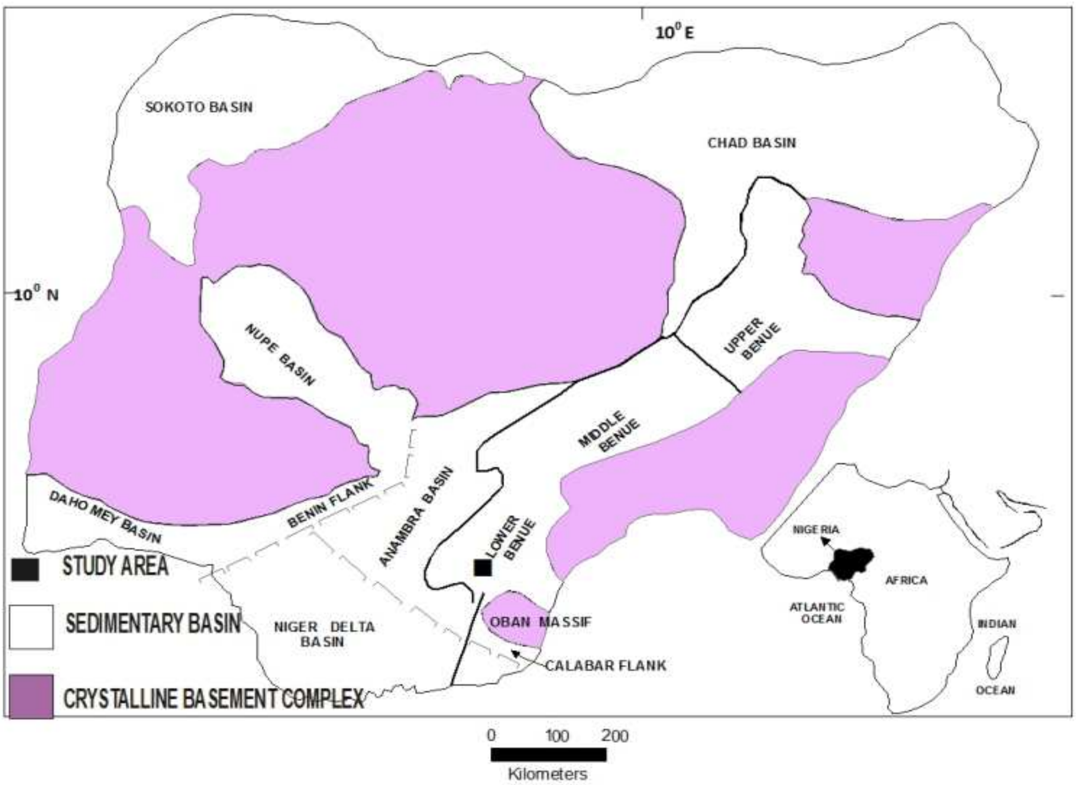

Fig. 1. *Geologic map of Nigeria showing the lower Benue Trough.*

Table 1. *Regional Lithostratigraphic Framework for Southeastern Nigeria (Modified from [46]-[17].*

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

3. Methodology

Shale samples of Eze-Aku Shale were collected from localities within the Afikpo Synclinorium (Table 2 and Fig. 2). A total of twenty two samples (22) of soft shale samples from Eze-Aku Shale were analyzed for microfauna. About 50 g of each fresh sample was broken into smaller fragment and dried. The processed samples were transferred into separate aluminum plates with covered lids for soaking. A significant quantity of household dishwashing liquid soap and a minimum amount of distilled water were added to the samples just to cover sample completely. The samples were thoroughly stirred with a glass rod and the soaked samples were allowed for 30 minutes. With the aid of a dispersing water spray nozzle (tap), the samples were washed thoroughly through 63-micron sieve until all the muds were completely removed. The washed samples were dried on a hot plate at 455 ^{O}F until sample was completely dry (45 to 60 minutes). Then, sample was removed from hot plate, kerosene, liquid soap and hot water enough were added enough to cover sample and allowed to stand for overnight for thorough digestion of the sample. The mud and disintegrated shale materials were washed the sieve leaving the residues containing the fossils. The microfossil concentrate (residues) were put in the plates and allowed to settle before the supernatant fluid were decanted. The sample concentrates (residues) were oven-dried and the dried sample kept in labeled bottles.

The sample residue was spread on a flat black picking tray and mounted on the microscope. The fossils were identified and named using comprehensive microfossil album and were picked with aid of picking brush.

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

Sample No	Formation	Town/location	Latitude/Longitude
EO/1-3	Eze-Aku Shale	Ohana/Boder Street	5^{O} 57′ 55.4″N/ 8^{O} 21′42.″E
EO/4a,b		Apiapum	6^{O} 00′4.2″ N/8^{O} 18′ 46.7″E
EO/5-6		Oyadama	5^{O} 56′27″N/8^{O}14′ 56″E
EO/7-8		Ntankpo	5^{O} 50′ 7.″N/8^{O} 05′ 43.1″E
EO/9-11		Usumutong	5^{O} 50′ 19.6″ N/8^{O} 05′ 54.″E
EO/12-14		Ediba	5^{O} 52′ 57.5″ N/8^{O} 02′ 08″E
EO/15-19		Abaomege	6^{O} 01′ 9.1″ N7^{O} 58′ 49.6″E
EO20		Akpoha	5^{O} 57′ 15.4″/7^{O} 56′ 47.7″E
EO21		Amasiri	5^{O} 55′ 45.5″ N/7^{O} 52′ 57.5″E
EO22		Adim	5^{O} 46′ N/8^{O} 3′E

4. Results

4.1. Lithostratigraphy/Field Relationship

The Eze-Aku Shale unit which represents the base of the Eze-Aku Group in the Afikpo Synclinorium has been described and established by earlier workers (*e.g.*[42]-[38]) with Eze-Aku River at Akaeze northeast of the studied area as the type locality. This extensive basal unit (Eze-Aku Shale) represents the lower boundary stratotypes of Eze-Aku Group in the Afikpo Synclinorium. It unconformably overlies the rocks of Asu River Group wherever it occurs in both flanks of the Abakaliki Anticlinorium. Apart from Akaeze where it has its type locality at Eze-Aku River., it overlies the Abakaliki Shale at Abaomege and the Mamfe Formation at Ohana. The shale facies of Eze-Aku Group which [29] established as Ezillo Formation outcropping in Ezillo and Ohana are still part of the Eze-Aku Shale (Eze-Aku Group) first described by [38] in Akaeze. This extensive unit also underlies Apiapum, Ediba, Adim localities adjoining the Oban Massif. Generally, the shales are flaggy, dark grey to black calcareous with pelecypod moulds of *Inoceramus* sp.

At Akpoha, Oyadama and Usumutong outcrops, the shale is dark-grey to black, parallel laminated, fossiliferous interbedded with mudstones (Figs 3 & 4). The shale exhibits flaggy fissility. It contains gypsum efflorescence within the laminae and abundant carbonaceous materials. The high fissility of the shale is as a result of weathering as it decreases in the fresher samples. Varying shapes of nodules/concretions occur in the shale. The body fossils in shale are mainly pelecypods and gastropods while some occur in geodes.

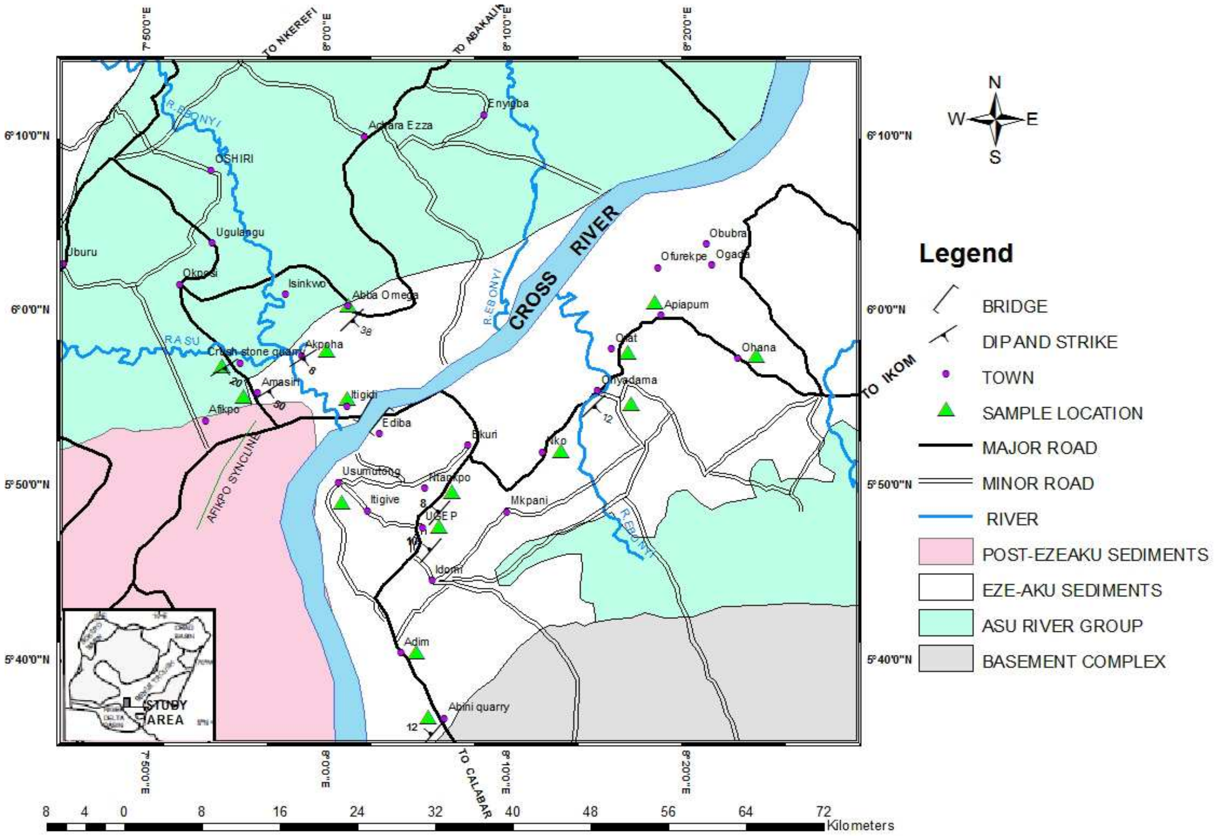

Fig. 2. Geological Map of Parts of the Afikpo Synclinorium within the Lower Benue Trough.

Fig. 3. Parallel Laminated Shale and Mudstone interbeds at Ebonyi River, Akpoha.

Fig. 4. Outcrop of Fossiliferous and Parallel Laminated Shale at Oyadama alongIkom – Calabar Road.

4.2. Foraminiferal Biostratigraphy

A total of twenty two (22) shale samples from seven localities in the studied area were analyzed for microfauna. The result shows paucity of foraminifera in the samples probably as a result of the nature of the shale, preservation problem or difficulty in extracting the specimen. Out of the twenty two (22) samples analyzed, only nine (9) sampled yielded foraminifera species indicating poor recovery. A total of 21 foraminifera species were recoverd comprising 10 planktonics and 11 benthonics. The sediment from Akpoha and Amasiri are completely barren. The localities where microfaunas were identified are described as below while localities with barren samples are not presented. Table 3 shows the distribution of the foraminifera.

4.2.1. Ntamkpo Locality (EO7-8)

The samples of laminated black shale collected from Ntamkpo (EO7) yielded *Heterohellicids* and *Hedbergellids* as dominant microfauna. They are represented by occurrence of *Heterohelixglobulosa, Heterohelix reussi, Hedbergella planispira, Hedbergella portdownensis* and *Hedbergella sp*. *Globigerinelloides sp* is the only benthonic foram recovered from this sample.

4.2.2. Adim Locality

The sample of the dark grey to black shale collected from the Assemblies of God Church, Adim yielded only benthonic forms dominated by *Ammobaculites amabensis*. Others include *Amobaculites coprolithiformis*, *Haplophragmoids sp* and *Haplophragmoids talokaense*.

Table 3. *Distribution of Planktonic and Benthonic Foraminifera in the Eze-Aku Group in the Afikpo Synclinorium.*

Sample No	EO-1	EO-2	EO-4	EO-7	EO-12	EO-14	EO-15	EO-17	EO-22
Planktonics									
Heterohelix globulosa				nd(63)			nd(2)		
Heterohelix reussi				nd(2)			nd(6)		
Hedbergella delrioensis				nd(7)					
Hedbergella planispira				nd(11)					
Hedbergella portsdowensis				nd(18)					
Archeogloberina blowi								nd(1)	
Whitenellasp			nd(1)						
Whitenella baltica			nd(3)						
Benthonics									
Ammobaculites bauchensis						Nd(32)			
Ammobaculites coprolithiformis									3(7)
Ammobaculites amabensis									87(215)
Haplophragmiods talokaense									6(15)
Haplophragmoids sp									4(11)
Globigerinelloides sp					nd (4)				
Trochammina sp						nd(2)			
Gavelinella devotensis	nd(1)								
Lenticulina taylorensis		nd(2)							
Globigerinelloides multispinatus				nd(2)					
No individual picked	1	2	4	103	4	34	8	1	248
Total benthonic species	1	1	1	1	1	2	0	0	4
Total planktonic species	0	0	2	5	0	0	2	1	0

4.2.3. Ohana Locality (EO1-3)

Three (3) samples from Ohana were analyzed. There was poor recovery of microfauna**.** Samples EO1 and EO2 yielded *Gavelinella davoterisis* and *Lenticulina taylorensis* respectively. Planktonic foraminifera did not occur in these samples.

4.2.4. Apiapum Locality (EO4a & 4b)

The black shale collected at Border Street, Apiapum yielded only *Whitnella sp*, few calcareous indeterminate foraminifera and micromulluscan shells.

4.2.5. Abaomege (EO15-17)

The shale samples were collected from hand dug well at Okaria village and Nduide River, Abaomege. The shales from these locations are hard/indurated similar to the shales at Ebonyi River, Akpoha. Sample EO17 yielded only *Archeoglobigerina blowi*

5. Discussion

5.1. Age Dating

Planktonic foraminifera and palynormorphs species were used in the determination of stratigraphy of the studied rocks. Seven (7) common and biostratigraphically important planktonic foraminifera species from the samples investigated were used to build the foraminiferal stratigraphic range chart (Table 3 & 4). They include: *Heterohelix globulosa* (Ehrenberg) – Turonian., *Heterohelix reussi* (Cushman) – Turonian to Coniacian., *Hedbergella delrioensis* (Carsey) – Late Cenomanian to middle Turonian., *Hedbergella planispira* (Tappan) – Late Cenomanian to middle Turonian., *Herdbergella portsdownensis* (Williams-Mitchell) – Middle Turonian to Coniacian., *Whitnellasp* (Douglas and Rankin) – Late Cenomanian to middle Turonian. Age determination on the stage level is possible using the occurrence of *Heterohelicids* and *Hedbergellids* and palynormorphs [20]-[24]-[36]-[25]-[6].*Lenticulina taylorensis* and *Gavelinella sp* are the only two index benthonic forms in the analyzed samples exclusively indicative of the Turonian stages. *Gavelinella sp* range from Turonian to Maastrichtian while *Lenticulina taylorensis* extends from Turonian to Santonian. References [34]-[35] reported that these benthonic forms have long stratigraphic ranges hence could not be used for age dating [11].

5.1.1. Late Cenomanian –Early Turonian

The Cenomanian stage has been established in the lower part of quarry section at Nkalagu Cement Factory [37] (*i.e*western flank of Abakaliki Anticlinorium) based on the co-occurrence of *Rotalipora balenaensis* and *Globigerinelloides casey*[19]. These index fauna were not recovered from the analyzed samples. The existence of the Cenomanian age in the Afikpo Synclinorim (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 synclinorium and Anambra Basin [33]-[2]. Notwithstanding, the existence of Cenomanian age was recorded in the sediments collected from some parts of lower Benue Trough (*e.g.* Nara, Ngbanocha, Ezillo, Akaeze) using palynological studies [29]. The determination of Late Cenomanian to Early Turonian age in this present study was achieved using some planktonic foraminifera (Table 4).

Some planktonic species such as *Hedbergella delrioensis* and *Hedbergella sp* which [10] initially described from late Cenomanian sediments in the Ituk – 2 well were recorded in the shales collected from Ntamkpo locality. This interpretation is corroborated by palynological result. The planktonic species associated with early Turonian in this study are *Whitnella sp*, and *Heterohelix reussi*[40]. This interpretation is supported by the occurrence of *Inoceramus*, an index marker for Early Turonian [19]at Ediba locality. *Heterohelix reussi* has been recovered from sediments from parts of Mexico, Egypt, and Texas. They are interpreted to range from Turonian to Masstrichtian.

5.1.2. Middle –Late Turonian

This stage was established using a few planktonic forms recorded in some samples. *Heterohelix globulosa* and *Heterohelix planispira* which [19] used to establish the middle Turonian to Coniacian age in the southern Benue Trough were recorded in the sediments within the study area. These species which occur in the samples from Abaomege and Ntamkpo suggest middle Turonian stage. Bassey (1991) had earlier identified these planktonic foraminifera on the subsurface samples from Calabar flank.

Table 4. *Planktonic Foraminiferal Stratigraphic Range Chart.*

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**
								×	*Hedbergella delrioensis*
								×	*Hedbergella planispira*
								×	*Heterohelix reussi*
								×	*Heterohelix globulosa*
								×	*Hedbergella portsdowensis*
								×	*Whitnella sp*
								×	*Whitnella baltica*

5.2. Paleoecology and Paleoenvironment

5.2.1. Planktonic Foraminifera

Reference [34] believed that planktonic foraminiferal assemblages of the Benue Trough are not diverse. They are dominated by *heterohellicids* and *hedbergellids*. Keeled ones are however rare except in Coniacian deposits. The absence of fauna in the shales except the samples from Akpoha which recorded *Acrtitarch sp* may be as a result of anoxic conditions. Anoxic conditions (<0.5 ml/l oxygen) are characterized by complete absence of fauna [9]-[39] and the presence of well laminated rocks [11]. Some araneceous foraminifera may survive under dysoxic to anoxic conditions [44]-[22], but may not survive in greater anoxic conditions. These anoxic conditions may have been occasioned by organic productivity in deeper bottom and increase supply of organic matter to the oceans and epicontinental seas during the extensive middle Cretaceous transgression [41]-[27]. The large amount of organic matter supplied to Benue Trough possibly generated the anoxic bottom conditions for some parts of the basin due to reduced circulation and poor communication [34]. In some cases, infaunal species move upward in the illuminated upper water column or even exhume themselves to avoid anoxic conditions. This probable anoxic condition in this part of the basin is corroborated with turbidite deposits and Bouma Sequence reported by [30] in the area.

Reference [14] also established successive deepening conditions at the Nkalagu section (western flank of Abakaliki Anticlinorium) using foraminiferal assemblages. He noted that the Turonian deepening trend at Nkalagu is contrary to the worldwide sea level fall. The general deepening of the studied area is occasioned by a shift from inner shelf (Ohana through Itigidi areas) to the upper bathyal (Abaomege) during middle to late Turonian using foraminiferal assemblages. The planktonic foraminiferal species from Ntamkpo and Abaomege samples belong to the non – keeled *Heterohelicids* and *Hedbergellids* morphogroup. Non – keeled planktonic foraminifera are suggested to be shallow water dwellers [34]-[21]-[26]. However, *Heterohelicids* and *Hedbergellids* which are known to reproduce in shallow and/or dysoxic water [21], have deep water as preferred place for reproduction of certain species such as *Hedbergella delrioensis, Hedbergella planispira, Heterohelix globulosa* [16].

5.2.2. Benthonic Foraminifera Distribution (Bathymetric)

Water depth in exception of other ecological factor may not possibly be a major limiting factor in benthonic fauna distribution rather factors associated with water depth such as substrate or nutrient supply. Reference [42] opined that reliable bathymetric interpretations can be deduced using benthonic foraminifera from Cretaceous and possibly Jurassic Eras. Notwithstanding, not much is known about the paleoecology of Cretaceous benthonic species particularly for restricted, shallow Epeiric seas like that in the Benue Trough and adjoining Chad Basin [15]. The vast data collection of [28] is used as the basis for interpretation of the benthonic faunas at generic level rather than species level because modern sea species of Muray [28] did not occur in the study area. Though certain genera change their ecologic preferences through time, this approach will give reliable results in the interpretation of fossil - bearing shale facies in the area and in combination with other sedimentological data.

The genus *Ammobaculites* covers almost the entire ecological niches in modern seas [8] and is an infaunal deposit feeder [23]-[28]. They live in muddy sediments of brackish to normal marine salinity in marsh to upper bathyal environments [28]-[11]. The occurrence of *Ammobaculites coprolithiformis, A. amabensis* and *A. bauchensis* in shale samples collected from Adim and Ediba suggest their tolerance to low oxygen level. Previous workers reported the occurrence of *Ammobaculites* in some parts of Benue Trough. [34]-[23]-[11]. This primary infaunal marine genus is commonly found in muddy to sandy substrates in a range of marsh to bathyal environments [11]. However, several authors have recorded this genus in hypersaline lagoons and estauries[28]. *Haplophragmoids sp* and *H. talocaense* occur only in Adim.

Trochammina is both an infaunal and epifaunal deposit and a plant feeder. It covers very wide ranges of salinity (0 – 60 %) and water depth (0 - >6000 m) [28]-[11]. *Trochammina* is also tolerant of low oxygen level [23]. *Trochammina sp* is identified in the shales at Ediba. The benthonic forms identified in the Afikpo Synclinorium include araneceous species which cover a wide range of environment but also tolerant of oxygen fluctuations and low salinities. This group includes *Ammobaculites* and *Haplophragmoids*. Reference [11] reported that the occurrence of these araneceous foraminifera indicate deeper water bottom since low oxygen content of bottom may cause difficulties in occurrence of calcareous forms.

The *Ammobaculites* and *Haplophragmoids* occurring in the shales at Adim and Ediba areas suggest normal marine, inner shelf water depth (bathymetry) [15]. This is interpreted based on the absence of *Ammotium*, *Reophax* and *Saccammina* species which Gebhardt [11] used to indicate brackish conditions for Ashaka deposits. The recovered benthonic genera of foraminifera are restricted to normal salinities and total absence of brackish conditions for the localities. The palynological results show that the occurrence of terrestrially derived palynormorphs suggests deposition in a shallow, low salinity brackish and/or marginal marine deposition (Gemeraad, *et al* 1968) for such localities where they occur. However, the same cannot be said to be true of the studied area due to the absence of benthonic foraminifera such as *Ammotium*, *Reophax* and *Saccammina* associated with brackish and/or marginal marine conditions [11]. The high diversity of marine dinocyst in the shales at Abaomege suggest normal marine salinity and open marine environment [24]. Table 5 shows the integrated paleoecology of investigated shales at Nkalagu by [12] and its comparism with the present study.

Table 5. *The integrated paleoecology of sections investigated around Nkalagu by [15] and its comparism with the present study.*

Age	Water-depth	Oxygenation	Carbon-flux	Foraminiferal trends		Present study
				Benthonic	Planktonic(Gebhardt, 2004)	
Coniacian 88Ma	C. 600m	Low oxic Stable	High	Dominance of small calcareous species(turrilinids and gavelinellids)	63 -93% planktonic forams, heterohelicids dominating, up to 30% hedbergellids, considerable amount of keeled species	None
Late Turonian 89 Ma	Upper bathyal C. 250m	Low oxic Unstable(oxygen fluctuations)	Variable (generally high)	Strong fluctuations in dominance of small calcareous in- and epifauna and of arenaceous species	20 – 71% planktonic forams, heterohelicids dominating, keeled species very rare	Ntamkpo/Abaomege/Ohana
Middle Turonian	C. 600m				46 – 94% planktonic forams, heterohelicids dominating, up to 30% hedbergellids, considerable amount of keeled species	Akpoha-Suspected anoxic condition
LatestCenomanian 91Ma	Inner shelf 0 – 70m	Dysoxic	High	Strong dominance of arenaceous species (Ammobaculites sp)	Almost absence of planktonic forams	Adim

6. Conclusion

The biostratigraphic study shows that the shales contain both planktonic and benthonic foraminiferal assemblages. The paucity of biofacies is attributed to mass mortalities due to reduced salinities, anoxic/successive deepening of the depositional environmental setting. Late Cenomanian – Turonian age was assigned to the Eze-Aku Shale based on the index planktonic foraminiferal assemblages of *Hedbergellids* and *Heterohellicids*. The presence of *Hedbergellids* has used to deduce a late Cenomanian age. The recently documented Late Cenomanian – Turonian stage which is different from Turonian age only as earlier reported by [38] is affirmed in this study. The Turonian sediments in the area were recognized based on the diagnostic foraminifera forms which include *Heterohellicids, Whitenella sp* and *inoceramus* biomarker.The planktonic foraminiferal assemblages in the studied rock samples are dominated by *Heterohellicid s*and *Hedbergellids* while benthonic forms are dominated by *Ammobaculites* with and *Haplophragmoids*.

The foraminiferal assemblages indicate normal marine, inner shelf to upper bathyal depositional environments. This is in agreement with some portions of range of environments provided by the shale facies which is indicated by low abundance foraminiferal assemblage and/or anoxia and sedimentologic characteristics of the rocks.

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