Oil Shale, 2010, Vol. 27, No. 2, pp. 99–125 ISSN 0208-189X
doi: 10.3176/oil.2010.2.02

BIOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT OF THE OIL SHALE DEPOSIT IN THE ABAKALIKI FOLD BELT, SOUTHEASTERN NIGERIA

O. A. EHINOLA*

Energy and Environmental Research Group (EERG)
Department of Geology
University of Ibadan
Ibadan-Nigeria

The oil shale deposit in the Abakaliki anticlinorium has not been demarcated. The present study focused on the age, correlation and depositional environment of the oil shale using abundance, planktonic/benthonic ratio and species diversity of foraminiferal and ostracod assemblages. The result shows that three prominent peaks or biozones namely 1st, 2nd and 3rd were recognized. The 1st biozone showed that Praeglobotrucana *and* Guembelitria *are the dominant species and ranged from Albian to Mid-Cenomanian (96–108 my). The 2nd biozone indicated that* Hedbergella and Heterohelix *are the dominant species, and ranged from Upper Cenomanian to Early Turonian (92–95 my). The 3rd biozone showed that* Heterohelicids *are the dominant species and ranged from Middle Turonian to Coniacian (82–91 my). The 1st, 2nd, and 3rd biozones correspond to the deposition of Asu River Group (Abakaliki Shale), Eze-Aku Formation and Awgu Formation respectively. The 2nd peak is bimodal and has the highest frequency and this supports the maximum transgression occurring at the Cenomanian-Turonian boundary event (ocean anoxic event). The oil shale is deposited in outer shelf to bathyal environment and ranged from Upper Cenomanian to Early Turonian age and belongs to the Eze-Aku Formation.*

Introduction

The succession of the Cretaceous to recent sediments in the Benue Trough of Nigeria has attracted the attention of paleontologists who have used ammonites, foraminifera and ostracod to delineate the various zones in the Benue Trough [1–11]. The Abakaliki anticlinorium, which is one of the

* Corresponding author: e-mail *ehinola01@yahoo.com* or *oa.ehinola@mail.ui.edu.ng*

depocenters in the lower Benue Trough, contains approximately 3600 m thick sediments.

The preliminary studies on the lithostragraphy and depositional environment of the oil shale deposits of the Abakaliki fold belt indicated that three lithostratigraphic units, namely: Abakaliki, Eze-Aku and Awgu shales of Albian to Coniacian ages are present. The Abakaliki unit contains light brown to dark grey massive shales and forms part of the Asu River Group. The Eze-Aku shale is dark-grey to black, calcareous, platy and thinly laminated with inoceramus moulds between the laminae and alternates with marl units to form cyclotherms. The Awgu shale is dark-grey, well bedded with limestone interbeds [12]. Oil smell and concentric nodules with pyritic nuclei are common attributes of the oil shale.

The mineralogical analyses of the oil shale revealed that the principal mineral components are quartz, calcite, kaolinite and pyrite with feldspars, muscovite and illite as secondary components [13]. Geochemical analysis indicates high values for the SiO_2, CaO and Fe_2O_3. The high content of CaO indicates calcareous shale with marine condition prevailing [13].

An assessment, based on organic facies characteristics, has been carried out on the Middle Cretaceous black shales, in order to determine their hydrocarbon source potential, thermal maturity, and depositional environments [14]. The results show that the Abakaliki shale is characterized by average values of <0.5 wt% TOC, 26.7 mg/g SOM/TOC, <150 mg HC/g TOC HI, 465 °C T_{max} and is rich in inertinite. Average values typical of the Eze-Aku shale are 4.5 wt% TOC, 148 mg/g SOM/TOC, >200 mg HC/g TOC HI, 435 °C T_{max} and it is rich in liptinite. Average values typical of the Awgu shale are 1.5 wt% TOC, 66.4 mg/g SOM/TOC, <100 mg HC/g TOC HI, 427 °C T_{max} [14].

An extensive geological mapping and geochemical studies of the oil shale deposit in the Abakaliki anticlinorium were carried out to determine the areal extent, reserve estimate, recovery techniques and possible environmental impacts [15]. An areal extent of 72.7 km^2, reserve estimate of $5.76 \cdot 10^9$ tonnes and recoverable hydrocarbon reserve estimate of $1.7 \cdot 10^9$ barrels have been calculated for the oil shale [15]. Low concentration of sulphur (between 0.33 to 0.74%) and trace elements such as Ba, Cd, Cu, Cr, Ni, Pb and Zn supports the economic viability of the oil shale as refinery feedstock. Retorting recovery method was suggested for the oil shale, because of shallow upper soil and relatively cheap cost of establishments [15].

The stratigraphy of the Abakaliki fold belt is similar to that of the Southern Benue Trough, and paleoenvironmental interpretations in the lower Benue Trough are also valid here. However, pioneering study of the Abakaliki fold belt seems to be handicapped by the lack of core sections. The Albian to Coniacian sediments have not been adequately studied except on ammonite zonations, lithostratigraphy and organic geochemistry. The previous work done on microfossils in the study area has failed to address the Albian-Coniacian sediments but centered on Campanian to Maastrichtian sediments [5, 16–18]. This paper therefore focuses on Albian-Coniacian sediments in order to determine the age, depositional environment and correlation of the oil shale deposit in the Abakaliki fold belt using foraminiferal and ostracod assemblages.

Regional and stratigraphic setting

Before the Santonian, the Abakaliki region was one of the most important depocentres in the lower Benue Trough with marine sediments, ranging in age from Albian to Coniacian, which were deposited in the proximity of the proto-Gulf of Guinea [17]. The principal governing factors of the dynamic evolution in the Abakaliki basin during these epochs were regional tectonics, subsidence, and eustatism [17]. The three main subsidence tendencies in the region were described as high (Albian), low (Cenomanian) and high (Turonian – Coniacian).

The Benue Trough was subjected to four main depositional cycles, each of which was associated with transgression and regression of the sea [8, 9]. The first sedimentary cycle lasted from the Middle Albian to Late Albian and is thought to have been initiated by the opening of the South Atlantic Ocean. This is associated with the deposition of the Asu River Group, which is a lateral equivalent of the Bima Sandstones in the Upper Benue Trough, and Awe/Arufu/Uomba Formations in the middle Benue Trough. The Asu River Group is represented in the study area by the 500 m thick seam of Abakaliki shale, which occupies the core of the Abakaliki Anticlinorium (Fig. 1).

The second sedimentary phase occurred between the Upper Cenomanian and Middle Turonian and was associated with the deposition of Eze-Aku shale. Its lateral equivalents are the Amasiri and Makurdi sandstones in the Afikpo basin and middle Benue Trough respectively, while Gongila, Jessu and Dukul Formations are its lateral equivalents in the upper Benue Trough. This is approximately 1 km in thickness.

The third sedimentary cycle ranged from the Upper Turonian to the Lower Santonian. It is associated with the deposition of the Awgu shale and Agbani sandstones, which are lateral equivalents of the Fika/Sekunle shale in the upper Benue Trough. The Turonian transgression, which marked the start of this cycle, is believed to have commenced from the Gulf of Guinea through the Anambra basin to the Benue Trough [17]. Most of the deposits of this cycle have been eroded as a result of the Late Cretaceous tectonic activity [10, 11]. It is approximately 920 m in thickness.

The fourth sedimentary cycle was marked by deposition of the Nkporo shales, Owelli sandstones, Afikpo sandstones and Enugu shales during the Campanian-Maastricutian transgressive phase. This cycle also marked the deposition of the coal measures including: the Mamu Formation, Ajali sandstones and Nsukka Formation. Its lateral equivalents are the Numanha shale, and Gombe sandstone in the upper Benue Trough [1–3, 15].

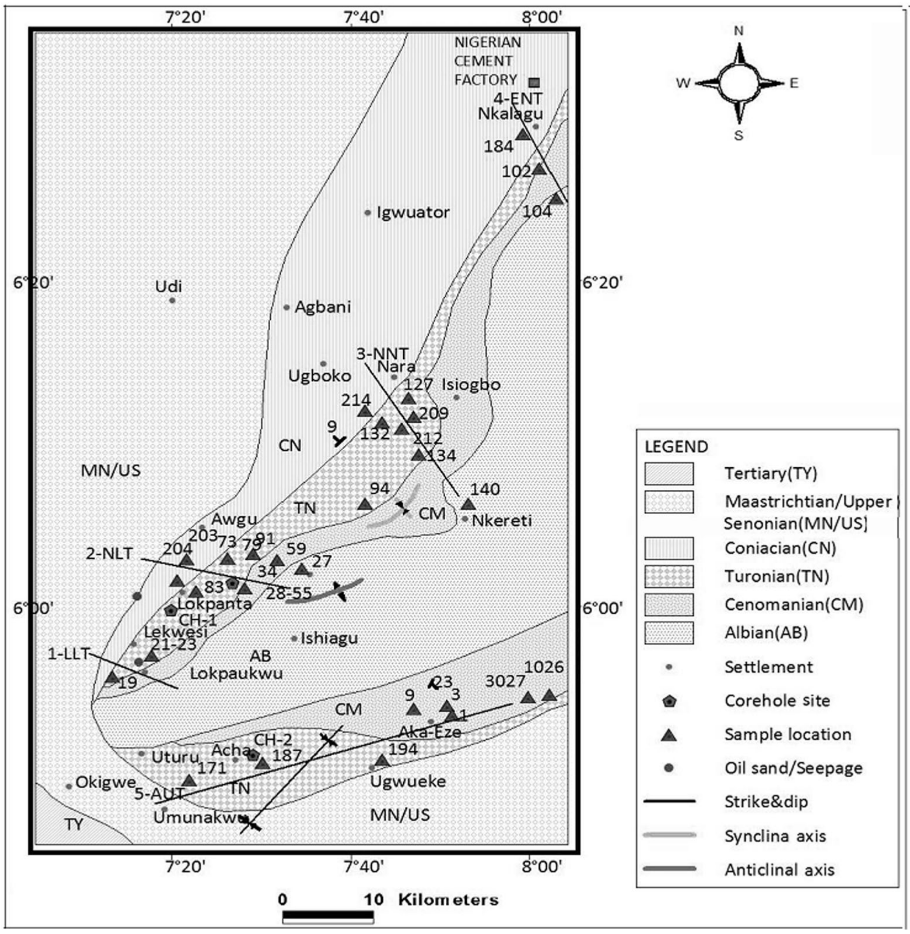


Fig. 1. Geological map of the lower Benue Trough, SE Nigeria (Modified from Ehinola, [36]).

Methodology and sample preparation

Field and laboratory techniques were utilized in the present study. The field study involved measurements and description of different rock outcrops and collection of core samples for laboratory analyses. The field mapping exercise in the Abakaliki fold belt covered an area of 1,105 km^2, which lies between latitudes 5°45' N and 6°35' N and longitudes 7°20' E and 7°50' E (Fig. 1). Spot sampling of outcrop and core sections was employed for sample collection. Five traverses cutting across Albian-Coniacian sediments were taken with the aim of locating and delineating geological contacts or boundaries. Fresh outcrop samples were obtained from stream and river channels, major road cuttings and minor paths, and quarries that exist in the area. At the western limb of the Abakaliki anticlinorium, the following traverses were undertaken (Fig. 1):

Lokpaukwu-Lekwesi Traverse (LLT) (1)
Ndeaboh-Lokpanta Traverse (NLT) (2)
Nkerefi-Nara Traverse (NNT) (3)
Ezillo-Nkalagu Traverse (ENT) (4)

At the eastern limb of the Abakaliki anticlinorium a traverse was covered, namely

Akaeze-Umunekwu Traverse (AUT) (5).

The lithologic disposition and number of samples collected are indicated in Figures 2 and 3. Three coreholes sited in the study area were carefully sampled and studied. These include Lokpanta (LKC), Acha (ACC) and Onoli-Awgu coreholes (OAC). The locations of the coreholes and depth of sampling are shown in Figures 1, 2 and 3 respectively.

Fifty-six (56) samples were used for biostratigraphic studies involving foraminiferal and ostracod assemblages. Standard recovery methods were adopted for this work [4, 11, 16–24]. Outcrop and core samples including calcareous shales, black shales and marls were analyzed for their foraminiferal assemblages. Ostracod samples were fragmented inside thick polythene bags using a geological hammer. Hammering was avoided wherever possible to minimize damage to fossils. Fragments were dried at 60 °C overnight, and disaggregated on hot plate using 15% of hydrogen peroxide. Larger undisaggregated pieces were separated using a 3 mm sieve and discarded. The mud-sized component was removed by washing through a 63-micron sieve. Breakdown at this stage was aided by gently rubbing the residue against the mesh with fingertips.

Various methods have been used for paleo-environmental analyses [3, 18, 23–25], which include foraminiferal abundance, planktonic/benthonic ratios and species diversity. Also, the correlation between the Cenozoic stable isotope record and number of planktonic foraminiferal species suggests that simple diversity registers change in global circulation [24, 26]. Therefore, species abundance, planktonic/benthonic ratio, and species diversity are used to characterize the paleo-oceanographic conditions based on the foraminiferal and ostracod fauna recovered.

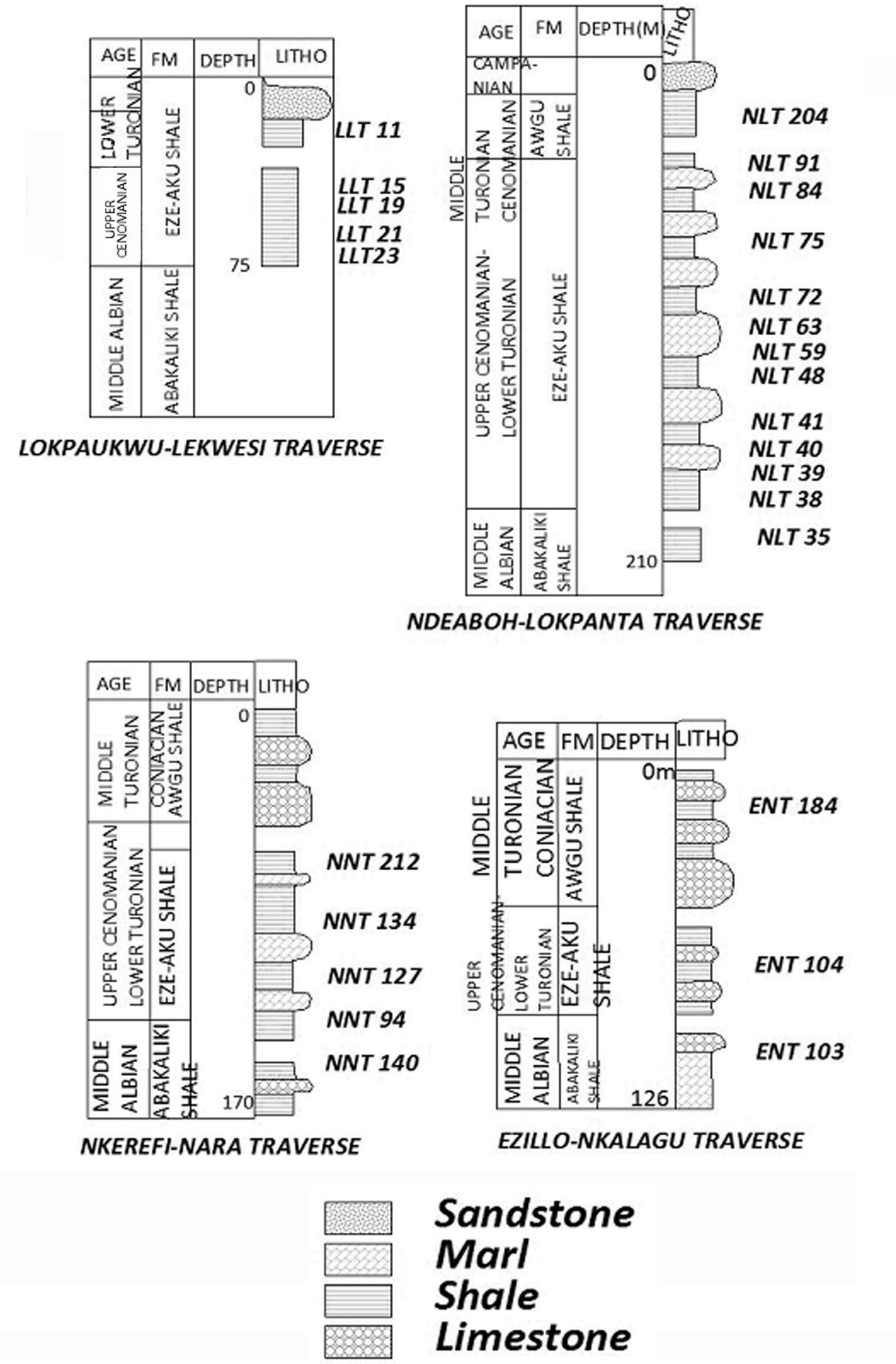


Fig. 2. Lithological description and sampling interval of outcrop sections (LLT, NLT, NNT & ENT) [36, 37].

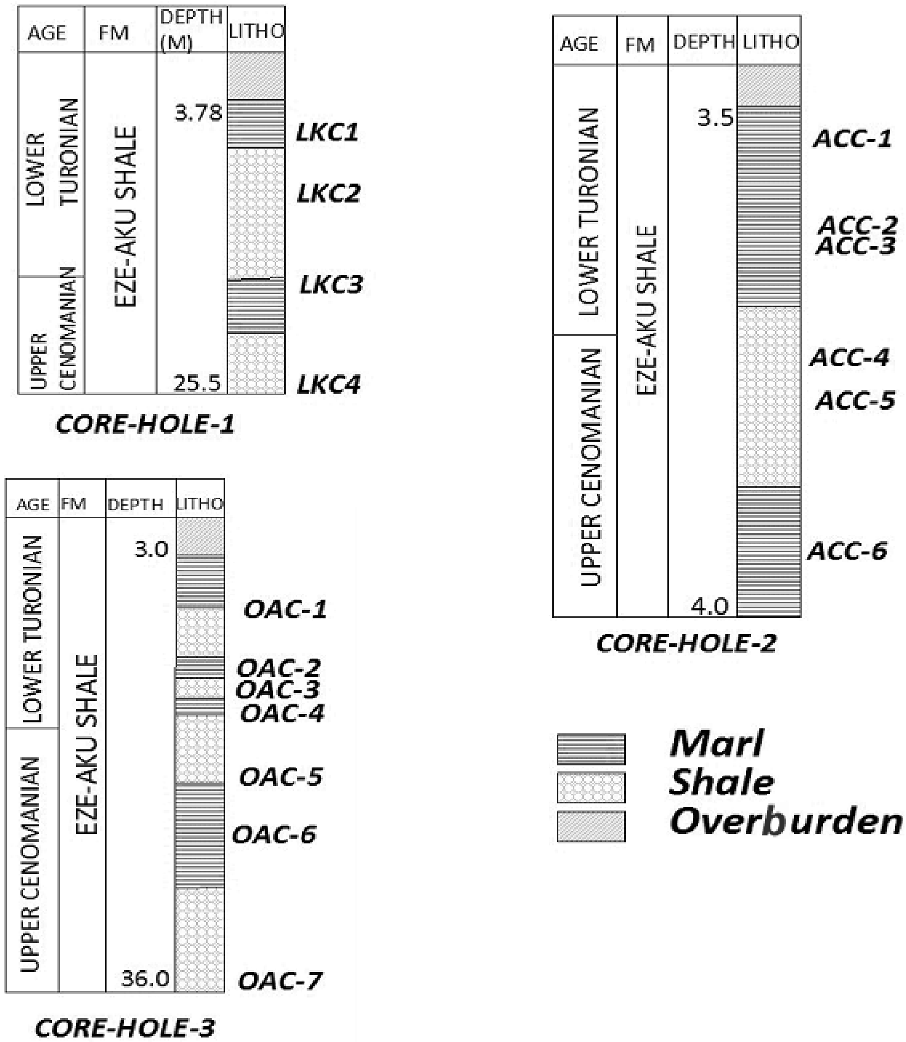


Fig. 3. Lithological description and sampling interval of corehole sections [36, 37].

Results and discussion

Foraminiferal biofacies

A total of fifteen planktonic foraminiferal species belonging to seven genera were recovered and presented in Tables 1 and 2. The planktonic genera include ***Rotalipora, Heterohelix, Hedbergella, Whiteinella, Guembelitria, Pseudotextularia*** and ***Praeglobotruncana.*** Three planktonic foraminiferal biofacies were proposed and found to correlate with the zonal schemes proposed by earlier workers [3, 25–29] (Table 3, Fig. 4). Most of the zones are interval zones defined by short and long range species rather than the first appearance datum (FAD) and last appearance datum (LAD) (Table 4).

The foraminiferal biofacies and the corresponding zonal schemes are discussed as follows from base to top (the oldest to the youngest):

Table 1. **Distribution and abundances of planktonic foraminiferal species from the outcrop samples [36]**

Sample No.	Formation	Praeglobotruncana stephani	Hedbergella planispira	Hedbergella delrioensis	Heterohelix globulosa	Whiteinella sp.	Rotalipora sp.	Heterohelix reussi	Guembelitria harrisi	Heterohelix moremani	Heterohelix pulchra	Whiteinella baltica	Heterohelix pseudoglobosa	Whiteinella inornata	Seudotextularia elegans	Hedbergella sp.	Total planktonic species	Total benthonic species	Planktonic/benthonic ratio	Species diversity
AUT-3	AK		5	2	6		4			3							20	5	80	5
AUT-6	AK		3	10	5					3							21	2	91	4
AUT-9	AK		5		15			6					3				29	2	78	4
AUT-171	AK														1	1	2	–	–	2
AUT-187	AK							2									2	–	–	2
AUT-3026	AK	5			10	10		3	12						3		43	1	100	4
LLT-11	EZ				2												2	5	29	1
LLT-15	EZ		2		2												4	2	67	2
LLT-19	EZ		4	12	8	15		4		6							49	19	72	6
LLT-21	EZ		5	5	8	4		5					2				29	18	62	6
LLT-23	EZ				2												2	1	67	1
NLT-35	AK				2												2	31	6	1
NLT-38	AK		10	3	15			6								2	36	5	95	5
NLT-39	AK		15		12			6								3	36	6	80	4
NLT-40	AK		4		8			4									16	20	44	3
NLT-41	AK				10			3									13	6	68	2
NLT-48	AK		2		4												6	10	38	2
NLT-59	EZ		8					6			8				10	12	44	11	80	5
NLT-63	EZ		10	11	12											6	39	3	95	2
NLT-72	EZ		6		4												10	11	71	2
NLT-75	EZ	2		8	25		3	7		5	6		12	4	10		85	3	97	11
NLT-84	EZ		10	8	20					8	7				8	10	71	9	87	8
NLT-91	EZ		4		22			10			8						44	5	94	4
NLT-203	AW			8								8				3	19	–	–	3
NLT-204	AW			15								8					23	–	–	2
NNT-140	EZ		5	8	20			7		4	6			8			58	7	89	7
NNT-94	EZ		13	6	8												27	8	79	3
NNT-127	EZ				18			8			10				8		44	7	90	4
NNT-134	EZ		8					8			8			10	15		49	7	88	5
NNT-212	EZ		10		16			8			10						44	4	92	4
ENT-184	EZ		1							1							2	3	22	2
ENT-104	EZ			1												1	2	1	67	2
ENT-103	AS				1					1							2	2	50	2

Legend: AS – Abakaliki shale, AK – Akaeze shale, EZ – Eze-Aku shale, AW – Awgu shale

Table 2. **Distribution and abundances of planktonic foraminiferal species from the core samples [36]**

Sample No.	Depth, m	Formation	Praeglobotruncana stephani	Hedbergella planispira	Hedbergella delrioensis	Heterohelix globulosa	Whiteinella sp.	Rotalipora sp.	Heterohelix reussi	Guembelitria harrisi	Heterohelix moremani	Heterohelix pulchra	Heterohelix pseudoglobosa	Whiteinella inornata	Pseudotextularia elegans	Hedbergella sp.	Total planktonic species	Total benthonic species	Planktonic/benthonic ratio	Species diversity
LKC-1	3.5	EZ		8	10	18	8		5	1	4	5					59	4	96	8
LKC-2	5.5	EZ	8	8		15			8		6	6					51	7	88	6
LKC-3	10	EZ	10	3	5	15			10		10	8					76	4	95	8
LKC-4	18	AK	6		2	12		3	7		5	4	4				43	10	81	8
LKC-5	25	AK															–	5	–	–
ACC-1	6	EZ		3		3	4		4	2	2						18	3	86	6
ACC-2	12	EZ		6	5		4										15	1	94	3
ACC-3	14	EZ		3	2	5											10	4	67	3
ACC-4	23	AK				6				2		2	1				11	18	42	4
ACC-5	27	AK				2			1								3	2	60	2
ACC-6	39	AK				3											3	6	33	9
OAC-1	7	EZ				6			2								8	16	81	2
OAC-2	11	EZ		3	4	10			5		3						25	6	86	5
OAC-3	13	EZ	28	18	5	20		5	5		8		9	3		12	113	18	85	12
OAC-4	15	EZ	25	12		10		4	8		5				8	8	80	14	79	8
OAC-5	20	AK	9	11	8	15	7		7	2	5		8			12	84	23	76	11
OAC-6	24	AK	15	3	5	15			9		4		3				54	17	41	7
OAC-7	28	AK		3		6			4		3						16	23	70	4
OAC-8	36	AK				7			4		3						14	6	2	3

Legend: AK – Akaeze shale, EZ – Eze-Aku shale

Praeglobotruncana Sp. Zone (1st Peak)

Praeglobotruncana stephani, Hedbergella delrioensis, H. planispira and ***Guembelitria harrisi*** characterize this zone. This could be assigned to Albian to Middle Cenomanian Age. Occurrence has been noted in the Aka-Eze and Ndeaboh areas (Figs. 4 and 5, Table 1). This interval is in agreement with the findings of earlier workers [17, 27, 29–31].

Beckmann et al. [30] introduced the ***Praeglobotruncana stephani*** zone to describe the oldest Cenomanian zone in the northern part of the Western Desert and the Gulf of Suez area, Egypt. Robaszynski and Caron [31] defined the present zone as the interval from the FAD of ***Praeglobotruncana stephani*** to the FAD of ***Rotalipora reicheli*.** The rarity of ***R. reicheli*** (keeled morphotype) in the present study may be related to paleoecological factors on the shallow shelf sea [18, 24]. The Asu River Group (Abakaliki shale) has been assigned to this biozone.

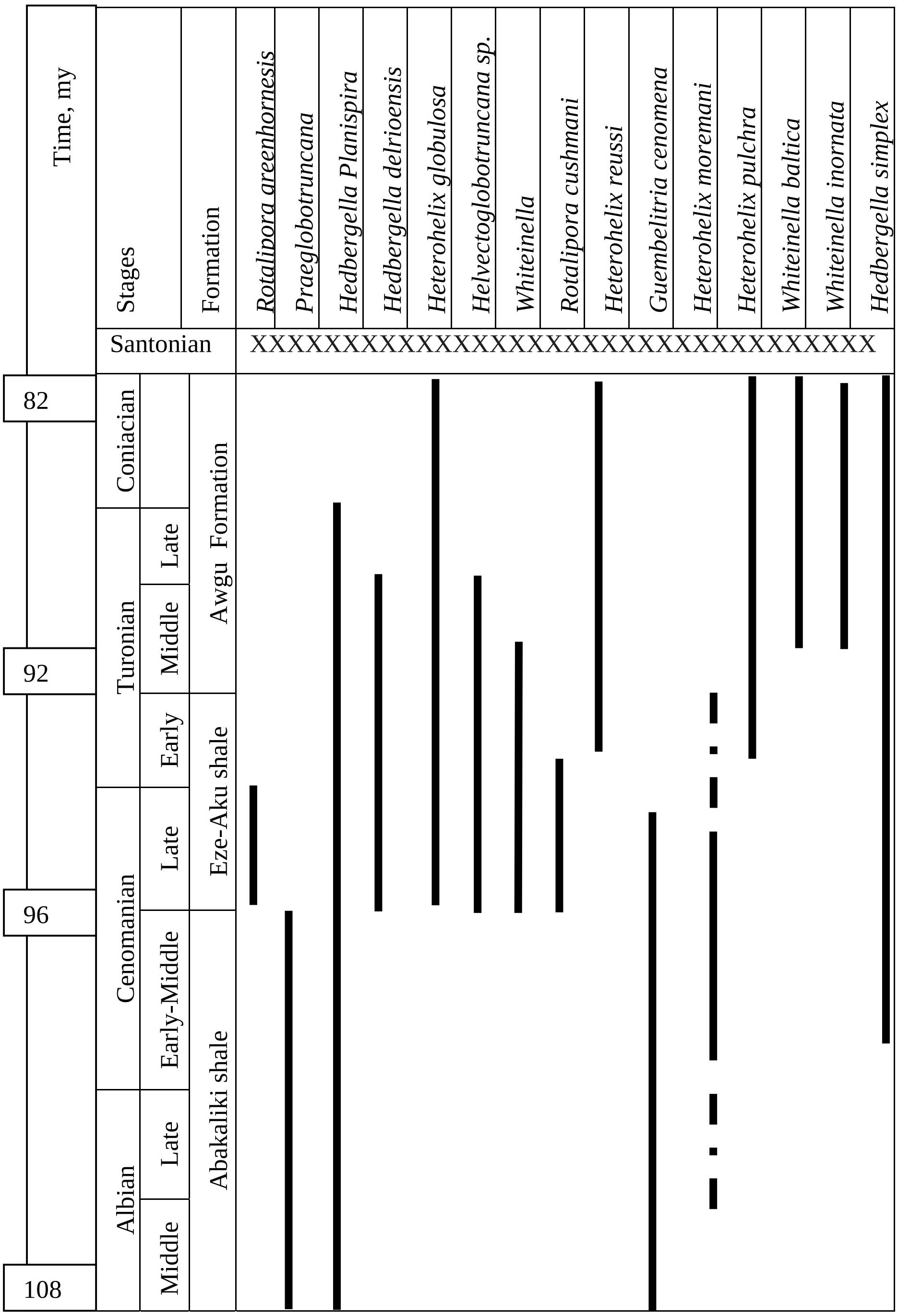
Hedbergella –Heterohelix Sp. Zone (2nd Peak)

The zone is characterized by the abundance of ***Hedbergella delrioensis*** and ***Heterohelix moremani*** [28]. ***Rotalipora cushmani*** zone was defined as the total range of the zonal marker [30] while this zone was defined as interval between the LAD of ***Rotalipora reicheli*** and the LAD of ***R. cushmani*** [31]. Originally, the present zone was named as zone of "Grandes Globigerines" in the Lower Turonian of North Africa [32, 33]. The ***Hedbergella-Heterohelix Sp.*** zone (Tables 3 and 4) was proposed to overlain the ***praeglobotruncana stephani*** zone, in the Lower Turonian of the Northern part of the Western Desert and Gulf of Suez area, Egypt [30]. Uppermost Cenomanian to Early Turonian age was suggested for this zone [30]. The Eze-Aku Formation has been ascribed to this zone (Table 4, Figs. 4 and 5).

Table 3. **Summary of planktonic foraminiferal zonation from different authors [36]**

Stages		Present work	Galal, 1999	Premoli Silva & Sliter, 1995	Robaszynski & Caron, 1995	Beckmann et al., 1969
Coniacian		Hetero helix sp.				
Turonian	Late					
	Middle					
	Early	Hedbergella Hetero helix	Whiteinella archaeo cretaceous	Whiteinella archaeo cretaceous	Whiteinella archaeo cretaceous	Hedbergella Heterohelix
Cenomanian	Late	Praeglo botruncana stephani	Rotalipora cushmani	Rotalipora Cushmani: Dicarinella algeriana Rotalipora greenhornesis	Rotalipora cushmani	Praeglo botruncana stephani
	Middle		Asterohed bergella sterispinosa	Rotalipora reicheli	Rotalipora reicheli	
	Early		Rotalipora globotrun-canoides	Rotalipora brotzeni	Rotalipora globotrun canoides	
Albian	Late					
	Middle		Rotalipora appenninica	Rotalipora appenninica	Rotalipora appenninica	

Table 4. **Planktonic foraminiferal stratigraphic range chart**



NB: XXXXX represents a period of non-deposition

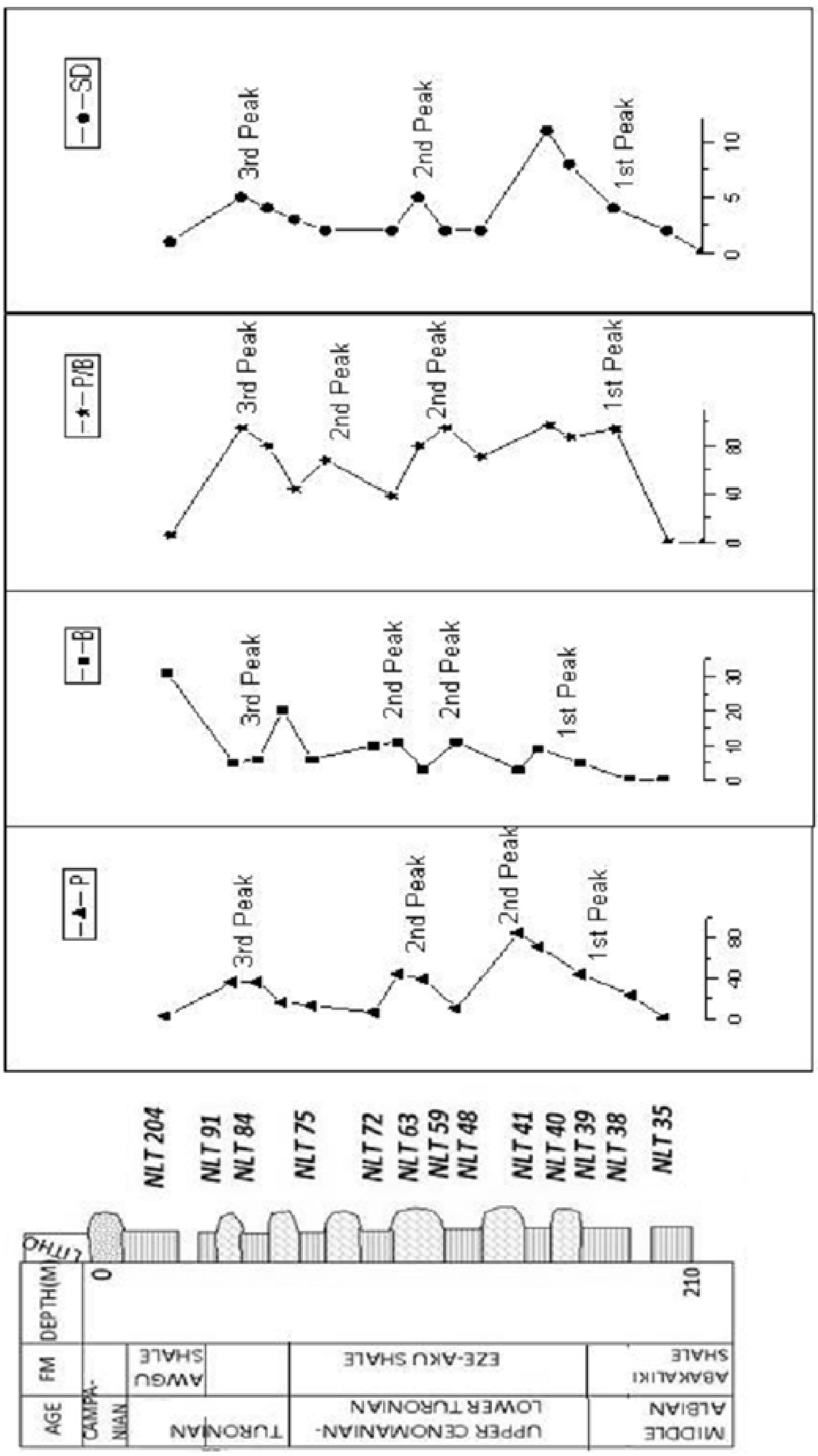


Fig. 4. Log plot of planktonic (P), benthonic (B), P/B, and species diversity (SD) for the Ndeaboh Lokpanta Traverse (NLT) section.

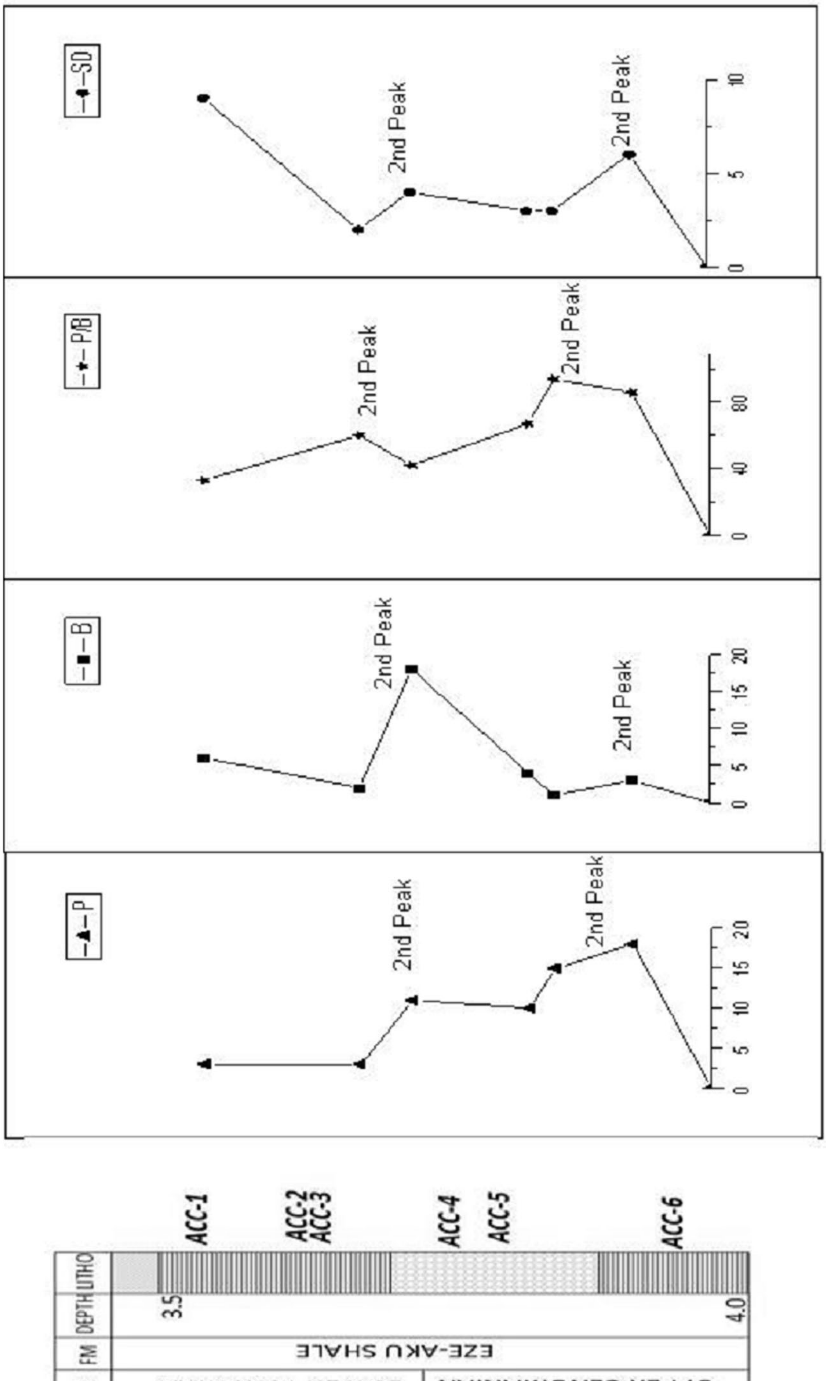


Fig. 5. Log plot of blanktonic (P), benthonic (B), P/B, and species diversity (SD) for the corehole 2 section.

Heterohelix Sp. Zone (3 Peak)

The association of ***Heterohelix globulosa*** and ***Hedbergella planispira*** were used to identify this zone in the present study. The occurrence of these species was recorded from the Nkalagu quarry section (Fig. 2, ENT) [28]. The Awgu Formation has been assigned to this zone with thickness of 10 m (Fig. 2). However, the association of ***Marginotruncana sigalis, M. renzi*** and ***M. difformis*** was used to establish the Upper Turonian-Coniacian age in the Lower Benue Trough of Nigeria [29].

Benthonic foraminiferal assemblages

A total of thirty-five benthonic foraminiferal species, belonging to twenty-eight genera were recorded from the Albian to Coniacian exposed sections in the study area (Tables 5 and 6). These include ***Ammobaculites sp., Ramulina sp., Ammotium nkalagum, Coryphostoma crassumi, Gavelinella compressa, Textularia sp., Lenticulina secan, Sitella colonensis, Pallaimorphina yamaguchi, Bathysiphon robustus, Dentalina sp., Trochammina sp., Marssonella oxycona, Ammotium sp., Spiroplectammina semicomplanata, Gabonita sp., Ammobaculites bauchensis, Ammotium sp., Rheophax minuta, Haphlophragmoides sp., Textulariopsis sp.*** and ***Asterculus richteri.***

The benthonic associations have low diversity and are characterized by abundant agglutinated foraminiferids, all of which have calcareous rather than siliceous wall compositions. Species of ***Reophax, Haplophragmoids, Ammobaculites,*** and ***Trochammina*** are common (Tables 5 and 6, Fig. 6). Rotaliina forms include ***Leuticulina, Gavelinella*** and ***Lingulo-gavelinella. Marsonella, Spriroplectammina*** and ***Coryphostoma*** characterize the textulariina forms. Assemblages belonging to the benthonic association appear to be confined to carbonate-rich sediments such as calcareous shales, mudstones and limestones deposited in open seas bordering the continents [34].

Most of these species have been assumed to be of the Upper Albian to Middle Coniacian in age [6, 34–36]. Also, some of these fauna have been recognized from Western Central Sinai of Egypt, indicating possible connection between the Tethys Sea and the Atlantic end during the Cenomanian-Turonian times [14, 34].

Ostracod assemblages

The distribution of ostracod species of the investigated sections is presented in Table 7. The number of ostracod species is generally low; with a maximum of 2 species in a sample and 11 out of the 59 samples contain ostracod species. The low number of individuals and species or non-occurrence may be attributed to sample preparation or possible marine anoxic/dysoxic conditions [11, 28, 36]. The recovered ostracod species included ***Paracypris nigeriensis***, ***Ovocytheride symmetrical, reticulata, O. reniformis, O. ashakaenesis, Cytherella ovata, Cythereis vitiliginosa reticulata,*** and ***Hazena austinensis*** (Table 7, Fig. 6).

Table 5. **Distribution and abundances of benthonic foraminiferal species from the outcrop samples [36]**

Sample No.	Formation	Gavelinella compressa	Ammobaculites sp.	Textularia sp.	Ammotium sp.	Spiroplectammina semicomplanata	Trochammina sp.	Sitella colonensis	Osangularia alata	Rheophax minuta	Marsonella oxycona	Lagena stavensis	Lenticulina secan	Haplophgramoides sp.	Heterolepa minuta	Ammotium nkalagum	Ammobaculites bauchensis	Ramulina sp.	Bathysiphon robustus	Ammobaculite pindigensis	Asterculus richteri	Gabonita sp.	Praebulimina prolixa	Pallaimorphina yamaguchii	Coryphostoma crassum	Dentalina sp.	Marginulinopsis sp.	Total benthonic species
AUT-3	AK				1														2				2					5
AUT-6	AK												1						1									2
AUT-7	AK	1								1																		2
AUT-9	AK																						8					8
AUT-3026	AK																	1										1
LLT-11	EZ																			5								5
LLT-15	EZ										2																	2
LLT-19	EZ	1	1	6	2		1			1					1	2	4							1				19
LLT-21	EZ		2		2									8			3			1								18
LLT-23	EZ																								1			1
NLT-35	AK	2		21			4																			4		31
NLT-38	AK						3								1													5
NLT-39	AK						1		1	2	1														1			6
NLT-40	AK							4			4			1	2						2			2	5			20
NLT-41	AK						1												1	4								6
NLT-48	AK						1			1							1	2	2					2				10
NLT-59	EZ			8						1					2													11
NLT-63	EZ																2	1										3
NLT-72	EZ								1		1						1	1			1	6						11
NLT-75	EZ							1																1			1	3
NLT-84	EZ			1			2									1	1										3	9

Table 5 continued

Sample No.	Formation	Gavelinella compressa	Ammobaculites sp.	Textularia sp.	Ammotium sp.	Spiroplectammina semicomplanata	Trochammina sp.	Sitella colonensis	Osangularia alata	Rheophax minuta	Marsonella oxycona	Lagena stavensis	Lenticulina secan	Haplophgramoides sp.	Heterolepa minuta	Ammotium nkalagum	Ammobaculites bauchensis	Ramulina sp.	Bathysiphon robustus	Ammobaculite pindigensis	Asterculus richteri	Gabonita sp.	Praebulimina prolixa	Pallaimorphina vamaguchii	Coryphostoma crassum	Dentalina sp.	Marginulinopsis sp.	Total benthonic species
AUT-3	AK				1														2				2					5
AUT-6	AK												1						1									2
NLT-91	EZ		1	3		1																						5
NNT-140	EZ														1	5		2							1			7
NNT-94	EZ										4							1	1					1				8
NNT-127	EZ			2	1															1		2	1					7
NNT-134	EZ											1		1		4				2								7
NNT-212	EZ							1							2				1									4
ENT-103	EZ								1					1												1		3
ENT-104	AK															1												1
ENT-184	AW									1		1																2

Legend: AK – Akaeze shale, EZ – Eze-Aku shale, AW – Awgu shale

Table 6. **Distribution and abundances of benthonic foraminiferal species from the core samples**

Sample No.	Depth (m)	Formation	Gavelinella compressa	Ammobaculites sp.	Textularia sp.	Ammotium sp.	Spiroplectammina semicomplanata	Trochammina sp.	Sitella colonensis	Osangularia alata	Rheophax minuta	Marsonella oxycona	Lagena stavensis	Lenticulina secan	Haplophgramoides sp.	Heterolepa minuta	Ammotium nkalagum	Ammobaculites bauchensis	Ramulina sp.	Bathysiphon robustus	Asterculus richteri	Gabonita sp.	Praebulimina prolixa	Pallaimorphina yamaguchii	Coryphostoma crassum	Dentalina sp.	Total benthonic species
LKC-1	3.5	EZ				1												1	1	2							4
LKC-2	5.5	EZ			2					1																3	7
LKC-3	10	EZ			1															3							4
LKC-4	18	AK	2		3				2							2						1					10
LKC-5	25	AK		1			1											1				1	1				5
ACC-1	6	EZ				2					1																3
ACC-2	12	EZ																1									1
ACC-3	14	EZ				1						1					1							1			4
ACC-4	23	EZ				2						6									5		3	2			18
ACC-5	27	AK	1	1																							2
ACC-6	39	AK	2	1					1																		6
OAC-1	7	EZ		5	1	1					1	1						2		5							16
OAC-2	11	EZ		1	2	1														1		1					6
OAC-3	13	EZ			2																	6	10				18
OAC-4	15	AK	4	2	3								2	5													14
OAC-5	20	AK	1	4		3	2	1	1					1		2		3		2	1				1		23
OAC-6	24	AK							2	2	1									3	1			1	1		17
OAC-7	28	AK		4	3		5					1			1	2			3	4						1	23
OAC-8	36	AK						2									1						1		1		6

Legend: AK – Akaeze shale, EZ – Eze-Aku shale

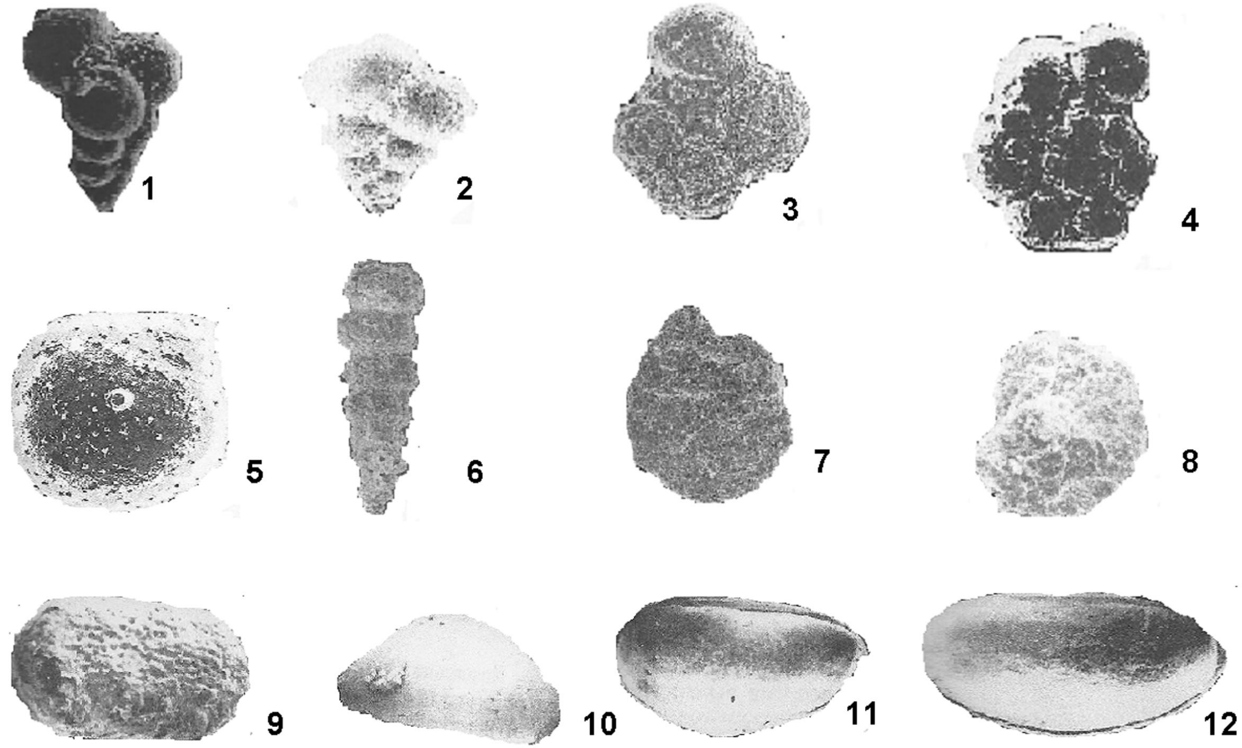


Fig. 6. Planktonic (1 to 4), Benthonic (5 to 8) and Ostracod (9 to 12) species from the Abakakliki fold belt. 1. *Heterohelix moremani*, 2. *Heterohelix globulosa*, 3. *Whiteneilla baltica*, 4. *Hedbergella planispira*, 5. *Ramulina sp*., 6. *Reophax minuta*, 7. *Ammotium nkalagu*, 8. *Haplophragmoides sp*., 9. *Cytherella sp*., 10. *Paracypris nigeriensis*, 11. *Clithrocytheridea senegali*, 12. *Ovocytheridea reniformis*

Table 7. **Distribution and abundances of ostracod species from outcrop and core samples**

Sample No.	Formation	Paracypris nigeriensis	Ovocytherídea symmetrica	Ovocytherídea reniformis	Cythereis vitiliginosa reticulata	Ovocytherídea ashakaensis	Clithrocytherídea senegali	Bracythere sapucariensis	Cytherella sp.	Bracythere ekpo	Hazelina austinensis
LLT-19	EZ					1					
NLT-41	AK			1	1		1				
NLT-59	EZ		1	1							
NLT-204	AW										1
NNT-140	EZ							1			
ENT-103	AK					2	1				
OAC-1	EZ		1								
OAC-2	EZ	2								1	
OAC-6	AK					1					
LKC-1	EZ					1					
LKC-3	EZ								1		

Legend: AK – Akaeze shale, EZ – Eze-Aku shale, AW – Awgu shale

Based on this study and the previous ostracod studies in Nkalagu borehole (GSN 1037) of the study area [11], it has been demonstrated that Cenomanian-Turonian boundary is exposed at the Abakaliki fold belt. The occurrence of some of the species found in this study in strata of equivalent ages in Egypt [30, 36] further confirms the suggestion of a union between the Tethys and the South Atlantic arms of the Late Cretaceous epicontinental trans-Saharan transgression in Africa.

Biostratigraphy

Heterohelix and ***Hedbergella*** species are the most abundant planktonic genera in all the section studied while ***Rotalipora; Praeglobotruncana*** and W***hiteinella*** species are scarce to common (Tables 1 and 2). The dominance of long-ranging heterohelicid and hedbergellid planktonic foraminifera in the study area permit better biostratigraphic resolution only at stage level (Table 4) [7].

The Abakaliki shales of the Asu River Group, which are the oldest sediment in the study area, are totally devoid of benthonic and relatively low planktonic foraminifera (may be due to preservation problem or alteration). Albian age has been assigned to this section based on ammonite [1]. The outcrop and core sections yield diverse foraminiferal assemblages, which enable recognition of the Middle-Cretaceous stages discussed below.

Middle Albian-Early Cenomanian (108-96 my)

The Cenomanian stage was established in the lower part of the Nkalagu Formation based on the co-occurrence of ***Rotalipora balenaensis*** and ***Globigerinelloides caseyi*** [28]. However, the planktonic species such as ***Guembelitria harrisi, Heterohelix moremani*** and benthonic species which include, ***Quinqueloculina sandiegoensis, Gavelinella cenomanica, Rheophax sp., Ammobaculite sp., Orbitolinacea str. sp.*** and ***Haplophragmoides platus*** have been used to date rocks of Cenomanian age in Iraq, Brazil, Egypt and along the Gulf Coast of the United States [37–42].

The existence of Cenomanian age in the study area has been a sort of controversy. Some authors suggested a period of non-deposition (hiatus) for this time interval in the Anambra basin and Afikpo syncline [43, 44]. However, the existence of Cenomanian sediments was recorded from four locations in the study area; Aka-Eze, Ezillo, Ngbanocha and Nara using palynological studies [17]. In the present study, the Cenomanian sediments have been collected at the town of Aka-Eze (Fig. 1) beside the bridge over the Eze-Aku River.

Late Cenomanian to Early Turonian (95-92 my)

The Late Cenomanian to Early Turonian was characterized by the appearance of ***Rotalipora cushmani*** and ***Dicarinella algeriana*** [21, 23–25] while the Early Turonian was clearly defined by the first occurrence of ***Whiteinella archaeocretacea***[27, 30, 31, 34]. Other planktonic species that are recorded in Early Turonian include ***Praeglobotruncana stephani, Heterohelix pulchra*** and ***Heterohelix reussi*** (Table 4, Fig. 6). ***Whiteinella archaeocretacea*** was found in association with the bivalve ***Inoceramus labiatus*** and is considered a good marker for the Early Turonian [28]. This interval corresponds to the time of deposition of the oil shale facies in the Abakaliki fold belt [45]. Biostratigraphic records from Texas, Arkansa, Mississippi, Bohemia, Mexico and Egypt indicate that water circulation in the area was in open communication with the world ocean [33, 37–42].

The Late Cretaceous benthonic species noted in the study area include: ***Gavelinella compressa, Ammobaculites sp. Coryphostoma crassum, Spiroplectammina semicomplanata, Rheophax minuta, Lenticulina secan*** and ***Dentalina sp.*** The Early Turonian species include ***Ammobaculite nkalagum, Marsonella oxycona, Heterolepa minuta, Ramulina sp., Bathysiphon robustus*** and ***Gabonita sp.*** [14, 28, 36].

Middle Turonian to Coniacian (91-82my)

The association of ***Marginotruncana sigalis, M. renzi*** and ***M. difformis*** was used to establish the Middle Turonian to Coniacian age in the lower Benue Trough [29]. None of these planktonic species was recorded in this interval. Rather association of ***Whiteinella inornata, Heterohelix globulosa*** and ***H.***

planispira has been used to assign a Middle Turonian to Coniacian age (Table 4).

Correlation

Five outcrop and three core sections have been correlated based on lithology, and palaeontologic data. A correlation of the different sections along the Abakaliki fold belt of the Albian to Coniacian sediments appears feasible (Fig. 7). The cross sections show that alternations of shale and marl are restricted to the tip of the Abakaliki anticlinorium (Fig. 7). Laterally, the facies grades into a shale and limestone sequence with reduction in oil shale thickness and increase in limestone in a northeastward direction. The oil shale facies yields dominantly planktonic with few benthonic foraminiferal assemblages indicating fairly shallow marine environments. The bedding of the oil shale is highly significant because it shows lamination couplets each consisting of a light grey marl layer of about 10 m thick on average and a dark to black shale layer about 5 m in thickness [45] (Fig. 3). The ratio of the average thickness of shale/marl sequences in the three core-holes studied at Lokpanta, Onoli-Agwu and Acha town is 3/8, 3.6/2.8 and 10/7.5 m respectively (Fig. 3). The differential thickness of the shale and marl layers may be due to variable suspension input to the basin. Restriction of shale/marl sequence to the tip of Abakaliki anticlinorium could be as a result of cyclic variation of water depth with time and may further support the relatively shallow-marine environment of these portions of the Abakaliki fold belt.

Depositional environment and palaeogeographic reconstruction

Foraminiferal abundance/diversity (p+b)

Simple diversity is the number of species found in a sample [39, 40–42] and may also be termed foraminiferal numbers [39]. In the present work, all samples have relatively low foraminiferal numbers (Tables 1, 2, 5, 6). It shows an overall increase from Albian through the Lower Turonian (Figs. 4 and 5). Its upward increase may be interpreted as a gradual shift to more stable/quiet environment and an increase in water depth [25, 46] and may represent the Mid-Cretaceous transgression, which reached its maximum at the Cenomanian-Turonian boundary [7].

Three peaks in the Albian to Coniacian sediments indicating three cycles of deposition are well demonstrated in the Ndeaboh-Lokpanta (NLT) and Acha core (ACC) sections (Figs. 4 and 5). The 1^{st}, 2^{nd} and 3^{rd} peaks (biozones) correspond to the Middle Albian-Early Cenomanian, Late Cenomanian-Early Turonian and Middle Turonian-Coniacian cycles respectively. The 2^{nd} peak is bimodal and has the highest frequency in all the sections made. This coincides with the maximum transgression occurring at the Cenomanian-Turonian boundary.

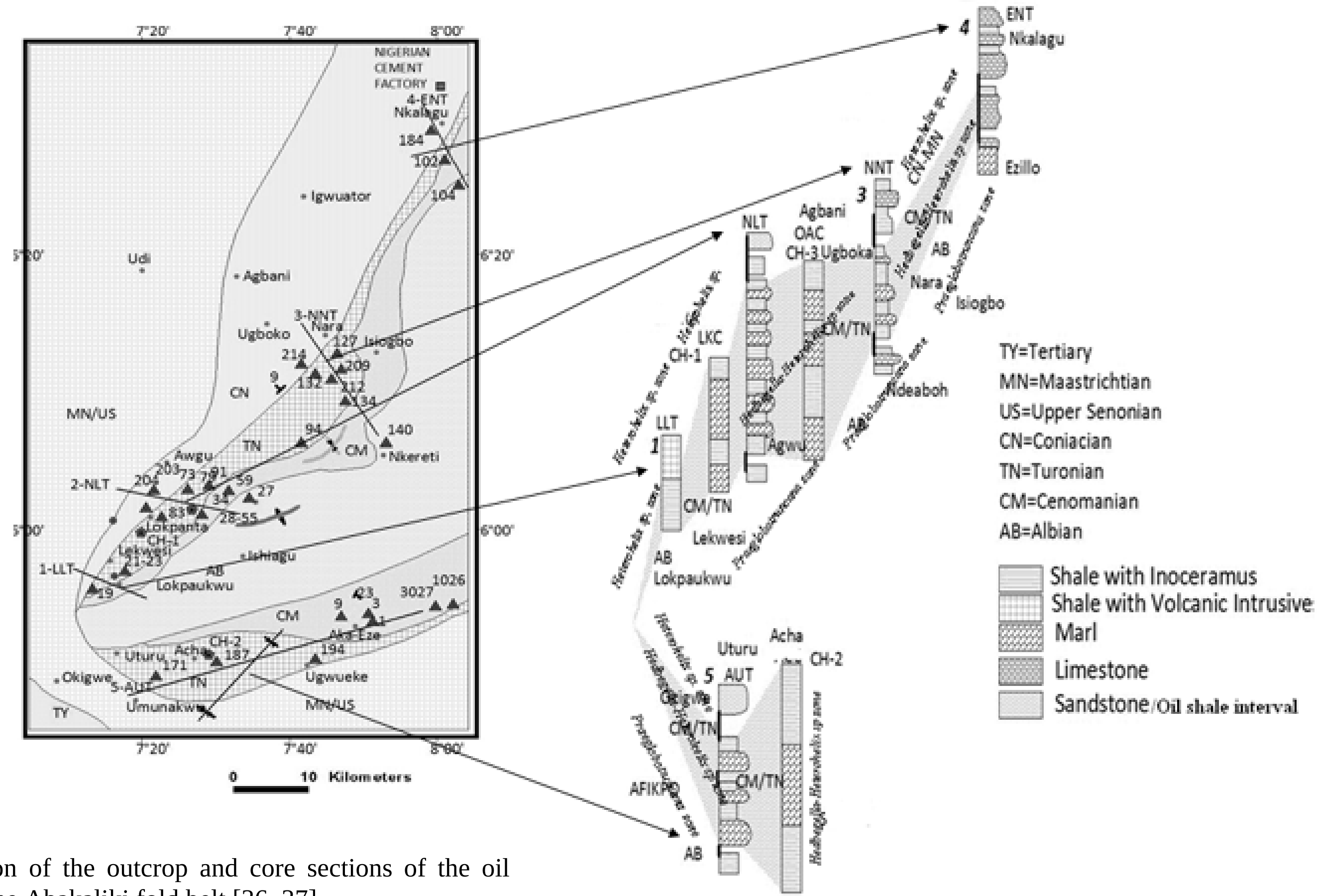


Fig. 7. Correlation of the outcrop and core sections of the oil shale interval in the Abakaliki fold belt [36, 37].

Planktonic/benthonic ratios (P/B = p/(p+b)·100%)

Planktonic/benthonic ratios in some intervals probably suggest restricted shelf environments [39, 41]. This trend suggests that waters were relatively shallow during deposition of the oil shale in the Abakaliki fold belt.

The benthonic genera present in the study area include ***Ammobaculitiеs, Textularia, Haplophragmoides, Osangularia, Rheophax and Trochammina.***

Ammobaculites is an infaunal deposit feeder that lives in muddy sediments with brackish to normal-marine salinities from marsh to bathyal environments [22] and it also tolerates low oxygen levels. ***Textularia*** species inhabit normal marine environments ranging from lagoonal to bathyal and live epifaunally on hard substrates, muddy silts and sands [41]. Some Cenomanian-Turonian textulariids seem to resist reduced salinities [42]. ***Trochammina*** settles as an infaunal or epifaunal deposit and plant feeder in a wide range of environments and water depth [42]. ***Trochamminids*** are also tolerant of low oxygen values [18]. ***Rheophax*** is an infaunal deposit feeder in muds and sands of lagoons, shelves and bathyal regions [38]. ***Rheophax*** is mainly a marine genus, but has also been reported from brackish lagoons and estuaries [42]. ***Osangularia*** species live in modern oceans from outer neritic to bathyal environments with normal marine salinities and prefer muddy sediments [42]. This suggests that the oil shale may possibly be deposited in outer shelf to bathyal environments.

Another explanation for the high planktonic-benthonic ratios might be the oxygen content of the water. The palaeo-oxygen content can be made using the low occurrence of ostracod fauna. Since the demand for oxygen in ostracods was higher than that of some foraminifera species such as calcareous oxygen deficiency-adapted specialists [18, 25], the few ostracod species (Cythereis and Ovocytheridae species) recovered from the Abakaliki fold belt might be more tolerant of reduced oxygen and salt contents. This mechanism was used to explain high planktonic-benthonic ratios in the Cenomanian of the Western Interior using the recent example of the Arabian Sea [42]. A depth as shallow as 76 m was proposed as an oxygen minimum level in the Western Interior [42], and if the depth is valid, the planktonic-benthonic ratios that were observed in the Abakaliki fold belt would indicate outer shelf or upper bathyal depths with minimum depth of about 100 m.

Species diversity (SD)

There are three peaks of species diversity as could be observed from Ndeaboh-Lokpanta (NLT) and only the 2nd peak was observed at Acha corehole (Figs. 4 and 5). The 1st peak corresponds to ***Praeglobotruncana stephani*** zone, which may be a result of rapid increase in water depth at this time. The 2nd peak coincides with ***Hedbergella-Heterohelix Sp.*** zones. The peak shows an increase in foraminiferal and ostracod assemblages and may be related to a major transgression in the Abakaliki fold belt. The 3rd peak corresponds to the ***Hetrohelix Sp.*** zone.

Peaks in foraminiferal numbers are similar to the peaks in planktonic-benthonic (P/B) ratios and to peak in species diversity (SD) (Figs. 4 and 5). The major peaks also relate to diversification of the genus ***Hedbergella*** and ***heterohelicids*** within the study area, which include thin tri-and biserial heterohelicids (***Guembelitria*** and ***Heterohelix sp.***). The intermediate morphotypes include ***Whiteinella*** and ***Praeglobotruncana sp.*** while the complex morphotypes include ***Rotalipora sp***.

Conclusions

The number of species within the various genera of planktonic foraminifera present in each zone in the Abakaliki fold belt during the Albian to the Coniacian includes ***Hedbergella, Heterohelix, Praeglotruncana, Whitei-nella*** and ***Guembelitria.*** Three biofacies zone have been identified: ***Praeglo-botrucana stephani*** representing the 1st peak***, Hedbergella-Heterohelix*** representing the 2nd peak and ***Heterohelix sp.*** representing the 3rd peak**.** Albian to Coniacian sediments in the Abakaliki fold belt can thus be subdivided into three depositional cycles. The 1st peak is from Middle Albian to Middle Cenomanian (108–96 my) and the Asu River group (the Abakaliki Shale) belongs to this depositional cycle.

Hedbergella delrioensis, H. planispira, Heterohelix moremani and ***Heterohelix reussi*** characterize the 2nd peak which is from Late Cenomanian to Early Turonian (95–92 my)**.** The Eze-Aku shale (oil shale facies) was assigned to this depositional cycle. The occurrence of some Tethyan fauna (foraminifera and ostracod species) indicates possible connection between the Tethys Sea and the Atlantic Sea during this cycle. ***Heterohelix globulosa*** and ***Hedbergella planispira*** characterize the 3rd peak which ranges from Middle Turonian to Coniacian (91–82 my)**.** The Awgu shale is deposited during this time interval.

Acknowledgements

The author is grateful to Dr. R. O. Olugbemiro and Prof. H. P. Luterbacher for the assistance provided and Deutscher Akademischer Austauschdienst (DAAD) for providing the scholarship to undergo the study at the University of Tübingen, Germany as well as the anonymous reviewers.

REFERENCES

1. *Reyment, R. A.* Aspects of the Geology of Nigeria. – Nigeria: University of Ibadan Press, 1965. 145 p.

2. *Reyment, R. A., Tait, E. A.* Biostratigraphic dating of the early history of the South Atlantic Ocean // Phil. Trans. R. Soc. B. 1972. Vol. 264. P. 55–95.
3. *Petters, S. W.* Mid-Cretaceous palaeoenvironments and biostragraphy of the Benue Trough, Nigeria // Bull. Geol. Soc. Am. 1978. Vol. 89, No. 1. P. 151–154.
4. *Petters, S. W.* Stratigraphic evolution of the Benue Trough and its implications for the upper Cretaceous paleogeography of West Africa // J. Geol. 1978. Vol. 86. P. 311–322.
5. *Petters, S. W.* Biostratigraphy of upper Cretaceous foraminifera of the Benue Trough, Nigeria // J. Foramin. Res. 1980. Vol. 10, No. 3. P. 191–204.
6. *Petters, S. W.* Central West African Cretaceous-Tertiary benthic foraminifera and stratigraphy // Paleontographica A. 1982. Vol. 179. P. 1–104.
7. *Petters, S. W.* Gulf of Guinea planktonic foraminiferal biochronology and geological history of the South Atlantic // J. Foramin. Res. 1983. Vol. 13, No. 1. P. 32–59.
8. *Wozny, E., Kogbe, C. A.* Further evidence of marine Cenomanian, lower Turonian and Maastrichtian in the Upper Benue basin of Nigeria (West Africa) // Cretaceous Res. 1983. Vol. 4, No. 1. P. 95–99.
9. *Reyment, R. A., Dingle, R. V.* Palaeogeography of Africa during the Cretaceous period // Palaegeogr. Palaeoecol. 1987. Vol. 59. P. 93–116.
10. A*degoke, O. S.* Ancient seaways, sediments and their recorded history in Nigeria. – Inaugural lectures series 31, Nigeria, University of Ife Press, 1978. 43 pp.
11. *Okosun, E. A.* Ostracod biostatigraphy of Nkalagu area from the Lower Benue Trough // Geological Survey of Nigeria, Bulletin. 1987. Vol. 10. P. 18–29.
12. *Ehinola, O. A., Bassey, C. E., Ekweozor, C. M.* Preliminary studies of the lithostratigraphy and depositional environment of the oil shale deposits of Abakaliki anticlinorium, southeastern Nigeria // Journal of Mining and Geology. 2003. Vol. 39, No. 2. P. 85–94.
13. *Ehinola, O. A., Abimbola, A. F.* Preliminary assessment of major and trace elements content in the middle Cretaceous black shales of the Abakaliki fold belt, Southeastern Nigeria // Nafta. 2002. Vol. 53, No. 9. P. 323–326.
14. *Ehinola, O. A., Badejoko, T. A., Ekweozor, C. M., Adebowale, K. O.* Organic facies variations in the Middle Cretaceous black shales of the Abakaliki Fold Belt, Southeastern Nigeria // Nafta. 2004. Vol. 55, No. 12. P. 505–515.
15. *Ehinola, O. A., Sonibare, O. O., Akanbi, O. A.* Economic evaluation, recovery techniques and environmental implications of the oil shale deposit in the Abakaliki anticlinorium, Southeastern Nigeria // Oil Shale. 2005. Vol. 22, No. 1. P. 5–19.
16. *Mode, A. W.* Assemblage zones, age and paleoenvironment of the Nkporo Shale, Akanu Area, Ohafia, southeastern Nigeria // Journal of Mining and Geology. 1991. Vol. 27, No. 1. P. 107–114.
17. *Ojoh, K. A.* The Southern part of Benue Trough, Nigeria Cretaceous stratigraphy, Basin analysis, paleo-oceanography and the aerodynamic evolution of the Equatorial domain of the South Atlantic // NAPE Bulletin. 1992. Vol. 7, No. 2. P. 67–74.
18. *Gebhardt, H.* Benthic Foraminifera from the Maastrichtian lower Mamu Formation near Leru (Southern Nigeria): paleoecology and paleogeographic significance // J. Foramin. Res. 1998. Vol. 28, No. 1. P. 76–89.

19. *Loeblich, A. R. Jr, Tappan, H.* A revision of mid-Cretaceous Textularian foraminifers from Texas // J. Micropalaeontol. 1982. Vol. 1. P. 55–69.
20. *Loeblich, A. R. Jr, Tappan, H.* Suprageneric classification of the Foraminiferida (Protozoa) // Micropaleontology. 1984. Vol. 30, No. 1. P. 1–70.
21. *Hart, M. B., Bailey, H. W.* The distribution of planktonic Foraminiferida in the mid-Cretaceous of NW Europe // Aspekte der Kreide Europas / J. Wiedemann (ed.). Stuttgart: IUGS series A, 1979. Vol. 6. P. 527–542.
22. *Kaiho, K., Fujiwara, O., Motoyama, J.* Mid-Cretaceous faunal turnover of intermediate-water benthic foraminifera in the northwestern Pacific Ocean margin // Mar. Micropaleontol. 1993. Vol. 23. P. 13–49.
23. *Dupoint, G.* Main Planktonic Foraminifera of the Cretaceous of Gabon (Aptian to Early Campanian), Geologie de l`Afrique et de l`Atlantique Sud: Actes Colloques Angers. 1984. P. 83–121.
24. *Galal, G.* Albian-Turonian planktic foraminiferal zonation and evolutionary trends in the Gebel Musaba Salama Section, West Central Sinai, Egypt // N. Jb. Geol. Palaont. Abh. 1999. Vol. 213, No. 1. P. 57–101.
25. *Gebhardt, H.* Cenomanian to Turonian foraminifera from Ashaka (NE Nigeria): quantitative analysis and palaeoenvinronmental interpretation // Cretaceous Res. 1997. Vol. 18. P. 17–36.
26. *Caron, M.* Cretaceous planktonic foraminifera // H. M. Bolli, J. B. Saunders, K. Perch-Nielsen (eds.) / Plankton Stratigraphy. Cambridge: Cambridge University Press, 1985. P. 17–86.
27. *Premoli Silva, I., Sliter, W. V.* Cretaceous planktonic foraminiferal biostratigraphy and evolutionary trends from the Bottaccione section, Gubbio, Italy // Palaeontographia Italica. 1995. Vol. 82. P. 1–89.
28. *Fayose, E. A., De Klasz, I.* Microfossils of the Eze-Aku Formation (Turonian) at Nkalagu quarry, Eastern Nigeria // Journal of Mining and Geology. 1976. Vol. 13, No. 2. P. 51–61.
29. *Iwobi, O. C.* Foraminifera ages in the southern Benue Trough, Nigeria // NAPE Bulletin. 1991. Vol. 6, No. 1. P. 39–47.
30. *Beckmann, J. P., El Heiny, I., Kerdany, M. T., Said, R., Viotti, C.* Standard planktonic zones in Egypt // P. Bronnimann, H. Renz (eds.) / Proc. First Internat. Conf. Planktonic Microfossils, Geneva, 1969. Vol. 1. P. 92–103.
31. *Robaszynski, F., Caron, M.* Foraminifères planctoniques du Crétacé: Commentaire de la zonation Europe-Mediterrannée // Bull. Soc. Géol. France. 1995. Vol. 166, No. 6. P. 681–692.
32. *Sigal, J.* Notes micropaléontologiques nord-africaines. 1. Du Cénomanien au Santonien: zones et limites en faciés pélagiques // C.r. Somm. Soc. Geol. France. 1955. No. 8. P. 157–160.
33. *Haig, D. W.* Global distribution patterns for mid-Cretaceous foraminiferids / J. Foramin. Res. 1979. Vol. 9, No. 1. P. 29–40.
34. *Murray, J. W.* Ecology and Paleoecology of Benthic Foraminifera. – U.K.: Longman Scientific and Technical, 1991. 397 p.
35. *Rönnfeld, W.* Foraminiferen: ein Katalog typischer Formen. – Germany, Tübingen, 1999, 70 p.
36. *Abubakar, M. B., Obaje, N. G.* Preliminary biostratigraphic evaluation of the hydrocarbon potentials of the Cenomanian-Turonian horizon in the Gongila Formation, Upper Benue Trough, Nigeria // Journal of Mining and Geology. 2001. Vol. 37, No. 2. P. 121–128.

37. *Eicher, D. L.* Foraminifera from Belle Fourche Shale and equivalents, Wyoming and Montana // J. Paleontol. 1967. Vol. 41. P. 167–188.
38. *Frerichs, W. E.* Planktonic foraminifera from the Sage Breaks Shale, Centennial Valley, Wyoning // J. Foramin. Res. 1979. Vol. 9, No. 2. P. 159–184.
39. *Darmoian, S. A.* Planktonic foraminifera from the upper Cretaceous of southeastern Iraq; biostratigraphy and systematics of the Heterohelicidae // Micropaleontology. 1975. Vol. 21, No. 22. P. 185–214.
40. *Koutsoukos, E. A. M., Leary, P. N., Hart, M. B.* Latest Cenomanian - earliest Turonian low-oxygen tolerant benthonic foraminifera - a case study from the Sergipe Basin (N.E. Brazil) and the western Anglo-Paris Basin (southern England) // Palaeogeogr. Palaeoecol. 1990. Vol. 77, No. 2. P.145–177.
41. *Culver. S. J., Buzas, M. A.* Distribution of selected Recentbenthic Foraminiferal genera in the Western North Atlantic // Neale, J. W., Brazier, M. D. (eds.) / Microfossils from Recent Shelf Seas. British Micropalaeontological Society series. Ellis Horwood Limited, Chichester, England, 1981. P. 336–349.
42. *Frush, M. P., Eicher, D. L.* Cenomanian and Turonian foraminifera and palaeoenvironments in the Big Bend region of Texas and Mexico // Caldwell, W. G. E. (ed.) / The Cretaceous System in the Western Interior of North America. Geological Association of Canada Special Paper, 1975. No. 13. P. 277–301.
43. *Amajor, L. C.* The Cenomanian hiatus in the Southern Benue Trough, Nigeria // Geol. Mag. 1985. Vol. 122, No. 1. P. 39–50.
44. *Petters, S. W.* Paralic arenaceous foraminifera from the Upper Cretaceous of the Benue Trough, Nigeria // Acta Paleontol. Pol. 1979. Vol. 24, No. 4. P. 451–471.
45. *Ehinola, O. A.* Depositional Environment and Hydrocarbon Potential of the Oil Shale Deposit from the Abakaliki Fold Belt, Southeastern Nigeria. – Ph.D thesis, University of Ibadan, 2002, 240 p.
46. *Ottens, J. J.* Planktonic Foraminifera as Indicators of Ocean Environments in the Northeast Atlantic. – Ph.D thesis (unpublished), de Vrije Universiteit te Amsterdam, 1992, 189 p.

Presented by A. Raukas
Received June 27, 2009