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### Foraminifera Microfauna from Pindiga Formation and their Paleocological Interpretations, Gongola Basin, Northern Benue Trough, Nigeria

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#### ABSTRACT

Nineteen (19) shale samples were taken from the Pindiga formation for foraminiferal analysis. About fourteen species of mostly arenaceous foraminifera belonging to seven genera were recovered. *Bathysipon foliformis*, *Bathysipon sp*, *Haplophragmoides pindigensis* and *Ammobaculites pindigensis* are the most abundant species recovered occurring in most of the sampled shale while *Bathysipon argentus*, *Haplophragmoides sp*, *Ammobaculites gombensis*, *Ammobaculites bauchensis*, *Heterohelix globulosa*, *Heterohelix reussi*, *Milliamina pindigensis* occur sparsely within the formation. The distribution, abundance and diversity of these foraminifera species is used to interpret the paleoecological and paleoenvironmental conditions that prevailed during the deposition of these shale. Recovery of predominantly deep dwelling *Bathysipon* species amounting to about 81% of the total recovered foraminifera within the formation indicates it was deposited in a shallow to deep marine environment under saline water conditions allowing for the crystallization of gypsum within the shale. *Heterohelix* species recovered were used alongside previous work done on ostracods and other fossils to establish the age of the Pindiga Formation to be Turonian-Coniacian. It was discovered that the Pindiga shale was deposited under anoxic conditions making it rich in organic matter and also a potential source rock for hydrocarbon generation.

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#### INTRODUCTION

The knowledge and studies of the Gongola sub-basin part of the now Northern Benue Trough dated back to the Mid to late 20th century (Petters, 1982, Carter et al., 1963, etc). The sediments of the Pindiga Formation were described as a sequence of marine shales and limestones which overlie the sediments of the Yolde Formation. (Gerhardt, 1997).

The Pindiga Formation is one in a series of calcareous marine unit deposited in the Benue trough during the Mid-Cretaceous worldwide transgression (Obaje et al., 2000). According to (Carter et al., 1963), the type locality of the Pindiga formation is situated in the Pindiga river section southwest of Pindiga village in Gombe State,

although exposed outcrops of Pindiga Formation have been reported in the Arawa, Wurobirji and Pantami stream channels in Gombe town etc. Foraminifera studies have over time become a very useful tool in the interpretation of biostratigraphy, sequence stratigraphy, paleoecology, paleogeography and petroleum study of sedimentary strata. Information obtained from such studies are important to the understanding of the economic potentials of the sedimentary basin (Obaje et al., 2001). For example, an increase in oceanic influence corresponds to an increase in planktonic/benthonic ratio. Maximum oceanic influence will mean maximum diversity and abundance of foraminifera in relation to the maximum flooding surface.

A paucity of benthic foraminifera and preponderance of planktonic forms is attributed to oceanic anoxia (Demaison and Moore, 1980).

The area of this study falls within the Benue Trough which is geographically divided into three; The Northern, Central and Southern Benue Troughs. The geology and stratigraphy of the three sub-basin segments have been well described and documented (e.g. Obaje *et al.*, 2006, Zaborski *et al.*, 1997).

The Northern Benue Trough is made up of two major sub-basins; the North-South trending Gongola sub-basin and the East-West trending Yola Sub-basin. The study area falls within the Gongola Sub-basin of the Northern Benue Trough (Figure 1).

The study area (Figures 1) is located at Pindiga and Pantami streams within the Gongola Basin of the Northern Benue Trough which lies geographically within Gombe State, Nigeria. It is bounded by latitudes 009°N and 12°N and longitudes 10°E and 12°E (Figure 1). The shale samples used for the analyses were collected from the Kanawa Member of the Pindiga Formation from localities such as Pantami stream in Gombe town and Pindiga stream channel, Southwest of Pindiga village. The study areas are accessible through major roads such as Bauchi-Gombe, and Gombe-Kashere Roads.

This work is aimed at studying and reevaluating the foraminiferal biostratigraphy and paleoecology of Pindiga Formation (both Fika and Kanawa members) in the Gongola sub-basin of the Northern Benue Trough and can be achieved through these objectives:

1. to extracting and identifying the foraminiferal species present in the shales of the study area and to establish their biostratigraphy
2. to determination of the foraminiferal abundance and diversity.
3. to analyze and interpret the biostratigraphy.
4. to get information such as; paleoenvironmental reconstructions, dating, petroleum potentials, paleoecology etc.

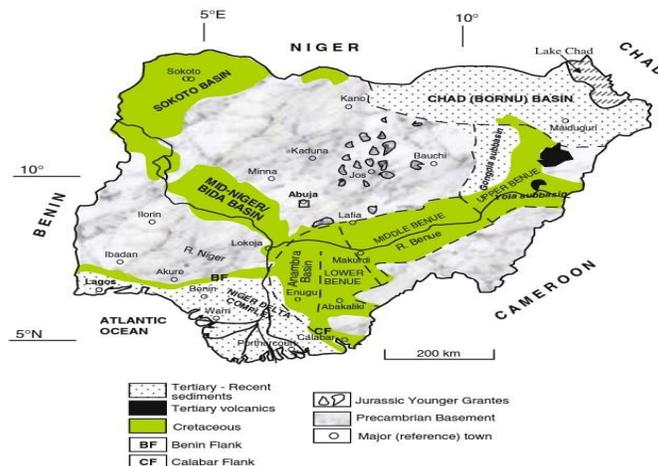


Figure 1: Map of Nigeria showing the location of the study area (Obaje., 2009)

## 2. GEOLOGICAL SETTING AND STRATIGRAPHY OF THE BENUE TROUGH

The Benue Trough is considered most important and hence, the most studied of all the Cretaceous sedimentary basins in Nigeria probably due to its peculiar formational history and its potentiality for hydrocarbon generation, ranking second to the oil prolific Niger Delta (Obaje *et al.*, 1994). At its northeastern end which conforms to the segment commonly known as the Northern Benue Trough, it bifurcates into an E-W trending Yola arm and an N-S trending Gongola arm (Figure 1). The Benue Trough is geographically divided into three; The Northern, Central and Southern Benue Troughs. The geology and stratigraphy of the three sub-basin segments have been well described and documented by several authors (e.g. Obaje *et al.*, 2006, Zaborski *et al.*, 1997).

The Northern Benue Trough is made up of two major sub-basins; the North-South trending Gongola sub-basin and the East-West trending Yola Sub-basin (Figure 2). The Gongola arm is made up formations such as the Bima, Yolde, Pindiga, Gombe and Keri-Keri Formations while the Yola arm consist of formations such as Dukul, Jessu, Sekuliye, Numanha and Lamja Formations.

The Pindiga Formation falls within the Gongola Sub-basin of the Northern Benue Trough. The lithostratigraphic successions for the Gongola basin have been established, well described and documented (e.g. Obaje *et al.*, 2006, Zaborski *et al.*, 1997).

For the purpose of this study, the stratigraphy of the Gongola sub-basin that hosts the Pindiga Formation will be discussed and this is adopted from the work of Zaborski *et al.* (1997), Carter *et al.* (1963) and Popoff *et al.* (1986). The lithostratigraphic successions for the Gongola basin have been established by these workers. Their schemes are as shown in Figure 3.

The name Pindiga Formation was proposed by Carter *et al.* (1963) for the “Cretaceous beds” and “clay shales” previously described by Barber *et al.* (1954). Its type locality is in the Pindiga stream, to the southwest of Gombe (Zaborski *et al.*, 1997).

The Fika member is equivalent of the Fika shales of Barber *et al.* (1954), the Dumbulwa has equivalent of Gongila Formation of Carter *et al.* (1963), the Deba Fulani unit equivalent of previously unrecognized unit, the Gulani member being the equivalent of the “Gulani sandstone” of Barber *et al.* (1963) and Kanawa member being the equivalent of “Kanawa Formation” of Thompson (1958). The Gulani, Deba Fulani and Dumbulwa members are lateral lithofacies equivalents occurring in the middle part of the Pindiga Formation.

The Kanawa member is made of shales and intercalated lime stones. Its best outcrops are located at Pindiga stream and Ashaka Quarry. It was dated late Cenomanian to early Turanian. Its age equivalent is the Dukul Formation in the Yola arm. The Dumbulwa member has been correlated with the Gongila Formation and concluded to be coeval in age based on lithostratigraphical study by Zaborski. (1997). The Gulani member was proposed by Carter *et al.* (1963). Its type localities are at Bara, Gulani and Balbaya.

The Deba Fulani member was proposed by Zaborski (1997) for the sandy beds occurring in the middle of the Pindiga Formation which was hitherto undifferentiated. The defunct Geological Survey of Nigeria had earlier mapped the unit as part of Gombe Formation and Gongila Formation. Its type locality is at Deba Fulani at Deba Fulani and Kumo.

The Fika member comprises the “Fika Shales” of Carter *et al.* (1963). The formation is topographically not too prominent and consists of shaly mud stones, lace macrofossils and contains irregular bands and lenses of

gypsum. It equally contains beds of lime stones, iron stones, sand stones and plant-rich shales.

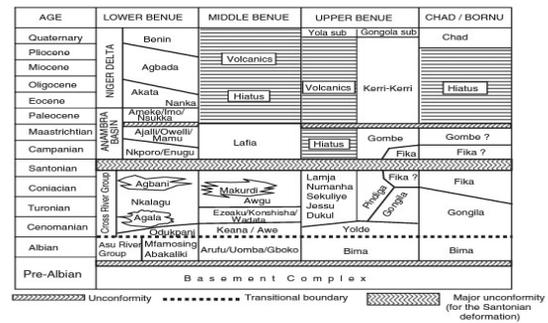


Figure 2: Stratigraphic sequence in the Gongola arm of the Northern Benue Trough (Obaje et al, 2009)

### 3. METHODOLOGY

19 shale samples were washed and prepared for foraminiferal analysis at the National Centre for Petroleum Research and Development (NCPRD), Bauchi of the Abubakar Tafawa Balewa University. Fresh shale samples were collected from Pindiga and Pantami river sections from the Pindiga Formation, Northern Benue Trough, with the aid of hand auger.

All the samples were crushed using pestles and mortar then put in a beaker and treated with 30% Hydrogen peroxide ( $H_2O_2$ ) for further disaggregation the treated samples are heated to boiling in Hydrogen peroxide ( $H_2O_2$ ) for some time then Sodium bicarbonate ( $NaHCO_3$ ) was added to the boiling sample to completely free and clean the forams present. The sample is then poured into a 63 $\mu$ m sieve, then washed under running water until all the mud is washed away and the fine grain sizes retained. The sieve was carefully cleaned with iron brush after each usage before it was used for another sample solution to avoid sample contamination. The residue of this sieve was then dried either by sunlight or using the oven, the now dried sample is mounted on the microscope for picking the fossils. The picked forams were put on a special foraminifera slide for further microscopic analysis. The slides were studied under the binocular paleontological microscope, moving north, south, east-west until the whole slide was studied and all fossil forams present were identified and counted.

#### 4. RESULTS AND DISCUSSION

##### Lithostratigraphy

Both sections logged are dominated by lithologies such as shale (80-90%), limestone (5-10%), mudstone (2%) associated with gypsum mineralization with estimated thicknesses in the proportion of about 20m for shale, limestone 4m and mudstone 0.5m in the Pindiga section (Figure 3) while the Pantami stream section (Figure 4) thicknesses ranges from about 19m for shale, 2m for limestone and about 0.6 for mudstone.

The shale changes in colour (from black to grey shale to brown) as you move from the Kanawa to the Fika member, texturally, the shale varies from sandy to fine grained and micaceous shale. Also, biological differences such as presence of fossiliferous and non-fossiliferous shale and chemical differences such as presence or absence of gypsum and other minerals within the shales is observed as you move from the bottom to the top of these stream sections (Kanawa to Fika members) plate I.



Plate I: showing different shale types within the Pindiga formation (a) dark fractured shale (b) brown micaceous shale with liasegang

Limestone is the second largest lithology within the Pindiga formation, it is relatively more abundant within the Kanawa member than the Fika although they all have limestone (figure 4 and 5).

As you move towards the middle of the Kanawa member, thick beds of fossiliferous limestone becomes abundant, this fossil-rich limestone sometimes occur as interbeds with thin beds of shale and sometime mudstones, the limestone beds becomes thinner and less fossiliferous as you navigate

towards the end of the Kanawa member. The Fika member are relatively thinner in beds (few centimeters) mostly buried in-between beds of shale and are also less fossiliferous compared to those of the Kanawa member (Figure 3,4; plate ii)

However, limestone of the Pantami stream channel (Fika member) are noticed to have two distinct properties that differentiate them from their older Kanawa counterparts, they are highly gypsiferous (have high gypsum content) and fibrous resembling (woody) in nature, the nature of the gypsum mineralization in this limestone is also interesting because it sometime form as liasegang (onion-like) mineralization within nodules of gypsum (plate II). This thin bed of limestone extends laterally across this member (Figure 3 and 4).



Plate II: showing different limestone types within the Pindiga formation (a) thin limestone bed within shale (b) fossiliferous limestone.

Aside the mineralization of gypsum within the shale and limestone, thin individual non-continuous lenses of gypsum mineralization occur within the formation, these beds often occur in between shale units. Although not usually common, anywhere these thin layers are found they mostly extend to about few meters before terminating; this type of mineralization is most common laterally within the Fika member of the Pindiga Formation with only few found within the Kanawa

Mudstone is also one of the lithology found within the Pindiga Formation although in a negligible proportion; thin beds of mudstones are found within the fossiliferous limestone beds of the Kanawa member, these beds measuring only few centimeters are most

times interbedded with the limestone and sometimes the shale bed of the Pindiga Formation

### Foraminiferal Distribution

The foraminifera microfauna are composed predominantly of poorly preserved arenaceous taxa with a few dwarfed hardly recognizable calcareous forms such as the *Heterohelids*. Most of the encountered species are similar to those described by Petters (1982) and Obaje (2000) from the same formation except for the abundant *Bathysipon* species recovered.

The foraminifera assemblage consist of 14 species (diversity) belonging to seven genera. *Bathysipon foliformis*, *Bathysipon sp*, *Haplophragmoides pindigensis* and *Ammobaculites pindigensis* are the most abundant species recovered occurring in most of the sampled shale while *Bathysipon argentus*, *Haplophragmoides sp*, *Ammobaculites gombensis*, *Ammobaculites bauchensis*, *Heterohelix globulosa*, *Heterohelix reussi*, *Milliamina pindigensis* occur sparsely within the formation (Table 1,2,3,4). The distribution, abundance and diversity of

these foraminifera species is used to interpret the paleoecological and paleoenvironmental conditions that prevailed during the deposition of the Pindiga Formation.



Plate III: showing different gypsum mineralization types within the Pindiga formation (a) mineralization within 'woody' limestone (b) mineralization as thin layers in between shale.

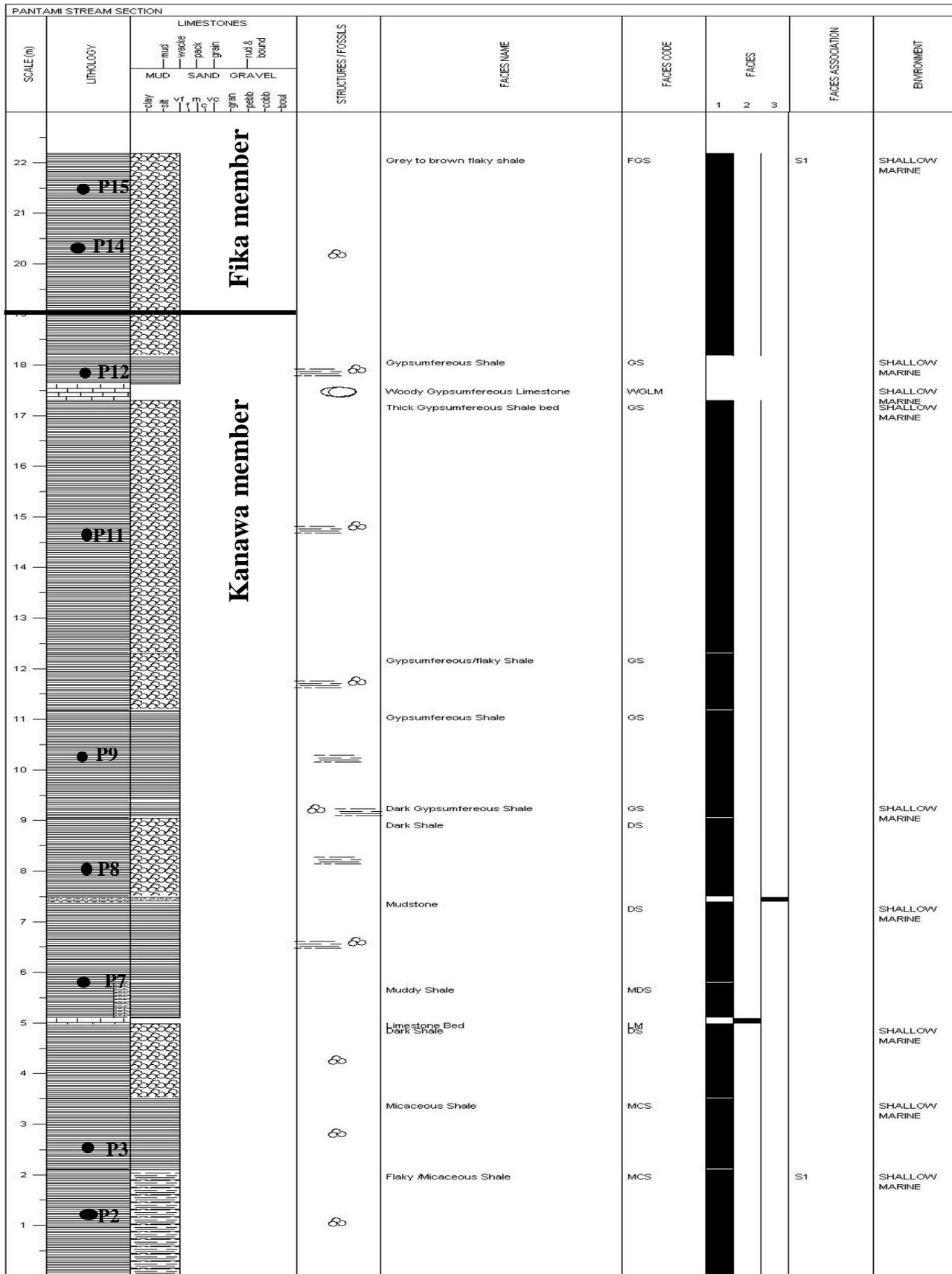


Figure 3: Lithology log of the Pantami stream section

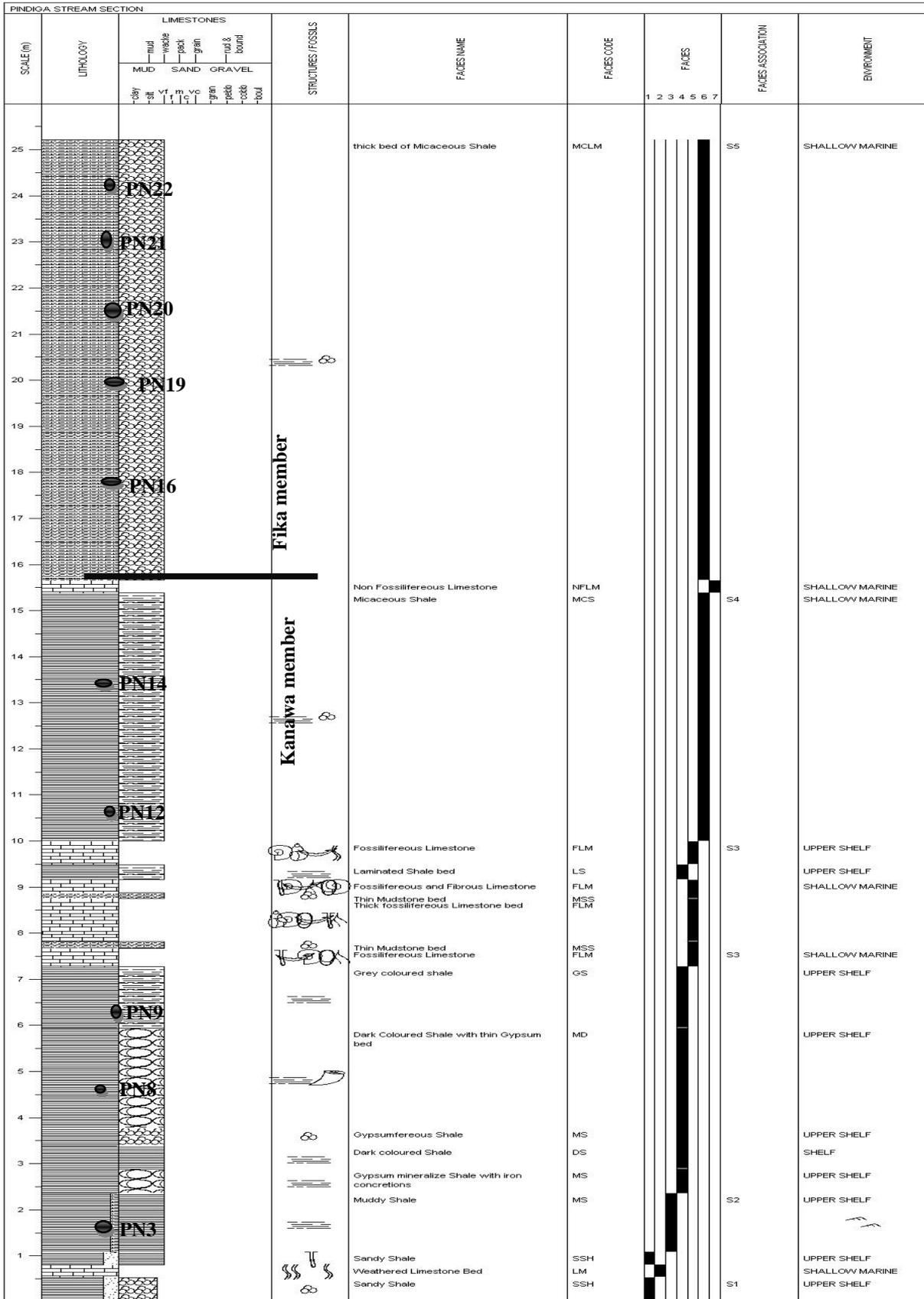


Figure 4: Lithology log of Pindiga stream section

Table 1: Logged section indicating foraminiferal distribution across Pindiga river section

Lithology	Sample	Formation	AGE													Total foraminiferal count/diversity		
				<i>Haplophragmoides pindigensis</i>	<i>Haplophragmoides bauchensis</i>	<i>Ammobaculites pindigensis</i>	<i>Ammobaculites bauchensis</i>	<i>Ammobaculites gombensis</i>	<i>Bathysipon foliformis</i>	<i>Bathysipon sp</i>	<i>Bathysipon argentus</i>	<i>Heterohelix globulosa</i>	<i>Heterohelix reussi</i>	<i>Heterohelix moremani</i>	<i>Milliamina pindigensis</i>		<i>Reophax guineana</i>	
Kanawa member (Pindiga river PINDIGA FORMATION section)	PN22	PINDIGA FORMATION (Pindiga river section)	Turonian -Coniacian	5	1	1	2	1	5	2							17/7	
	PN21			2	7				71	12	1	1		1			95/7	
	PN20				1								2					3/2
	PN19			3	1			2	16	7	4	2				1	36/8	
	PN16				1				3								4/2	
	PN14					1											1/1	
	PN12			3	1	2	1	1	12	6	3				1		30/9	
	PN9					3	2										5/2	
	PN8									11	4						15/2	
	PN3							1									1/1	
Total				1 3	1 2	7	6	4	11 8	31	8	3	2	1	1	1		

Table 2: Foraminiferal species and their percentages within the Pindiga section

Species	Number of Specimen	Percentage%
<i>Bathysipon</i>	157	75.8
<i>Haplophragmoides</i>	25	12.1
<i>Ammobaculites</i>	17	8.2
<i>Heterohelix</i>	6	2.9
<i>Milliamina</i>	1	0.5
<i>Reophax</i>	1	0.5
Total	207	100

Table 3: Logged section indicating foraminiferal distribution across Pantami river section

Lithology	Sample	Formation	AGE	<i>Haplophragmoides pindigensis</i>	<i>Haplophragmoides bauchensis</i>	<i>Ammobaculites pindigensis</i>	<i>Ammobaculites bauchensis</i>	<i>Ammobaculites gombensis</i>	<i>Bathysipon foliformis</i>	<i>Bathysipon sp</i>	<i>Bathysipon argentus</i>	<i>Heterohelix globulosa</i>	<i>Heterohelix reussi</i>	<i>Milliamina pindigensis</i>	<i>Reophax guineana</i>	<i>Globogerina sp</i>	Total foraminiferal count/diversity		
	P15	PINDIGA FORMATION (Pantami river section)	Turonian -Coniacian						11							1	11/2		
	P14			2	1					8								11/3	
	P12					3	1	2						2					8/4
	P11			4	1		1			111	29	8							154/6
	P9				2		3					7							12/3
	P8			4						20	23				1	1			49/5
	P7					2										1			3/2
	P3			3	1					11	4			2					21/5
	P2				1									1	1				3/3
	Total			13	6	5	5	2	153	64	15	1	3	3	2	1			

Table 4: Foraminiferal species and their percentages within the Pantami section

Species	Number of Specimen	Percentage%
<i>Bathysipon</i>	232	85
<i>Haplophragmoides</i>	19	7
<i>Ammobaculites</i>	12	4.4
<i>Heterohelix</i>	4	1.5
<i>Milliamina</i>	3	1
<i>Reophax</i>	2	0.7
<i>globogerina</i>	1	0.4
Total	273	99.8

### Foraminiferal Paleoecology

The distribution of any particular fossil assemblage in any stratigraphic unit may be controlled either as a result of evolution or by paleoecological conditions prevailing during deposition (Hamza et al., 2002). Thus any change in fossil assemblage that corresponds with a change in lithology is more probably due to environmental tolerance of that particular fossil than to their evolution. Some fossils serve as paleo-environmental indicators and are used to interpret the paleo-depositional history of sediments. The distribution of both body and trace fossils can depend on environmental factors such as; temperature, pH, salinity, substrate and oxygen level etc that existed at the time that organism lived, died and was buried.

The low occurrence of calcareous taxa within the Pindiga shale maybe due to high alkalinity of the environment which dissolves calcium carbonate that would have otherwise form shells of such taxa (Murray, 1973). The deposition of limestone beds and the presence of

calcareous fossils in this limestone is a confirmation to this fact.

At some point in history, there was a rapid change in this pH level and possibly temperature within the sea leading to the deposition of limestone beds within thick layers of shale and mud.

The paleoecological interpretation is based on abundance of recorded foraminiferal assemblages within the formation.

The paleoenvironmental conditions are reconstructed using some paleoecologic parameters such as Bathymetry, oxygen and salinity.



Plate IV: Some recovered foraminifera from the Pindiga formation(1-5,9 *Bathysiponfoliformis*; 6-8 *Bathysipon Argentus*)

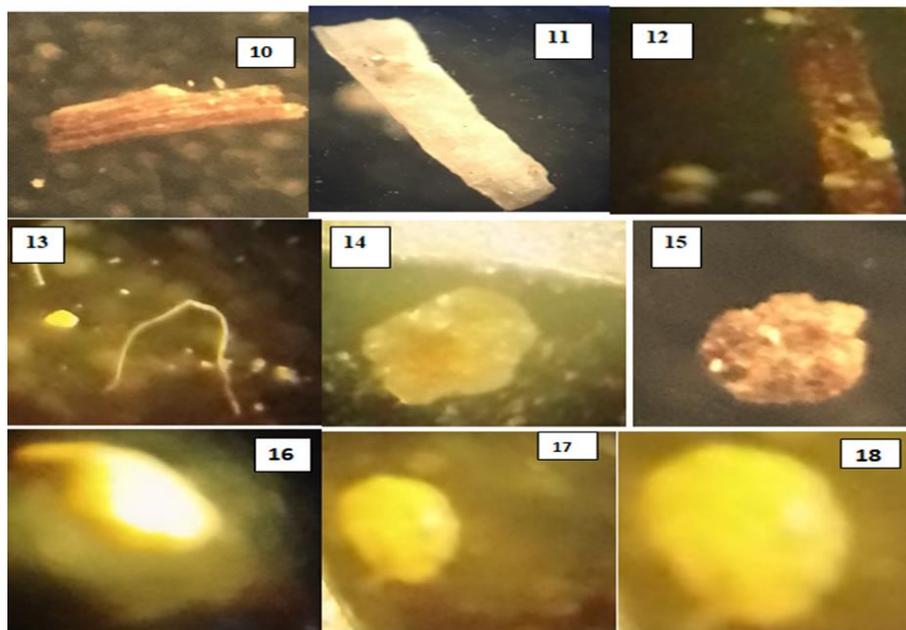


Plate V: Somerecoveredforaminifera from the Pindiga formation(10-11 *Bathysipon foliformis*; 12 *Bathysipon Argentus*; 13 *Bathysipon sp*;14, *Haplophragmoides pindigensis*; 15-16 *Haplophragmoides bauchensis*;17,18 *Ammobaculites* ).

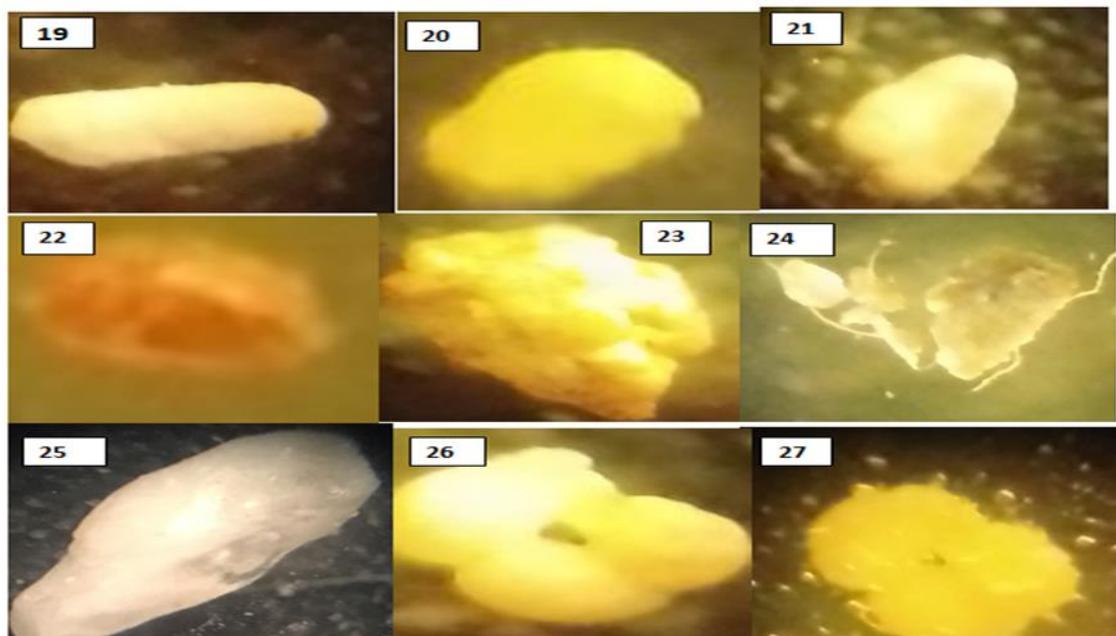
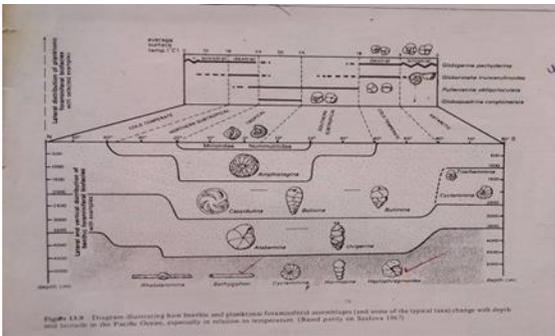


Plate VI: Some recovered foraminifera from the Pindiga Formation (19,20 *Ammobaculites gombensis*; 21 *Heterohelix reussi*; 22 *Milliamina pindigensis*;23 *Heterohelix moremani*;24 *Heterohelix globulosa* ;25 *Reophax guineana*;26-27 *Globergirina sp*)

## Paleobathymetry

Planktonic foraminifera are less common in near-shore shallow marine than in the deep ocean (Dodd and Station, 1981). Only two genera of planktonic foraminifera (*Heterohelix* and *Globogerina*) are recovered from the Pindiga Formation and their populations and diversities were very low. According to Petters, (1978b), abundant benthonic species are greater in shallow water where food on the seafloor was abundant available. However most benthonic foraminifera e.g *Ammobaculites* and *Haplophragmoides* genera are known to cover almost all ecologic niches in modern seas (Culver and Buzas,1981).



**Figure 5: diagram showing benthic and planktonic foraminifera abundance (Braisier, 19..)**

Sliter and Baker (1972) stated that reliable bathymetric interpretations can be made using benthonic foraminifera at least as far back as the Cretaceous time and possibly into the Jurassic. The recovered foraminifera on the bases of percentages E.g *Bathysiphon* (81%) *Haplophragmoides* (9%) *Ammobaculites* (6%), *Heterohelix* (2%) and others (2%) that makes up the total recovered species. The high percentage of *Bathysiphon* and *Haplophragmoides* species recovered are both of the deeper marine environment i.e the shelf and lower bathyal niche (fig 4). This also correspondence to the results of the ratio of planktonic/benthonic foraminifera recovered from the Pindiga Formation by (Obaje et'al,2000).

The presence of other foraminifera species such as the *Ammobaculites*, *Milliamina*, *Reophax* and *Globogerina* however are suggestive of a shallow marine environment

although some of these species are known to also thrive under anoxic conditions.

These facts are suggestive that the Pindiga Formation was deposited in a shallow to deep marine (the shelf to upper bathyal ) environment.

The planktonic/benthonic ratio (P/B) technique has been used by many workers to determine the water depth in marine environments. The percentage of the planktonic foraminifera in the Pindiga Formation is about 2.2% with only four species ( *Heterohelix globulosa*, *Heterohelix reussi*, *Heterohelix moremani* and *Globogerina sp*) recovered throughout the formation, the planktonic/benthonic ratio do not display any trend that could be used to study the bathymetric history of the Pindiga Formation. However, the planktonic/benthonic ratio is so low and therefore suggestive of a shallow to deep marine environment.

## Salinity:

Salinity is one of the predominant factors controlling the distribution of foraminifera and marine microfossils (Boltovoskoy and Wright, 1979). Under low salinity conditions of brackish water environments, usually low fauna occur (Murray,1999) as found in the Pindiga shale. Planktonic foraminifera are intolerant to wide ranges of salinity (Douglas,1979),this factor may be responsible for their near absence in the Pindiga Formation shales because of their high salinity variation. Seven (7) genera of Foraminifera are recovered from the Pindiga Formation, some of the predominant genera are *Bathysiphon* (81%), *Haplophragmoides* (9%), *Heterohelix* (2%) and *Ammobaculites* (6%), these make up the bulk of the recovered species (98%) of the Pindiga Formation.

The high population of *Bathysiphon*, *Haplophragmoides* and *Ammobaculites* indicate and overall saline water environment. Interpretation using modern analogies (e.g Gibson, 1989;Gebhardt,1997; Murray,1991;Obaje et al 2000) points to the same fact.

Also the presence of gypsum mineralization within the Pindiga Formation suggests some degree of hypersalinity of the ancient sea (Oti,1990). Therefore, based on the nature, species and abundance of the foraminifera recovered, the Pindiga shale is suggested to represent an open to deep marine environment of deposition.

## Oxygen

Gebhardt, 1997, reported that the predominance of arenaceous foraminifera shows low oxygen concentration in basins. The dominance of arenaceous benthonic foraminifera and the rarity of planktonic foraminifera shows that the oxygen levels were only sufficient for arenaceous benthonic foraminifera to survive and thrive. *Ammobaculites* and *Haplophragmoides* are known to be low oxygen level tolerant (Koutsoukos et al., 1990). The occurrence of simple chambered arenaceous foraminifera species such as *Ammobaculites* and *Haplophragmoides* and rod-like species like the *Bathysiphon* also suggest poor oxygen circulation. Murray (1994) also suggested that the dominance of agglutinated benthonic foraminifera indicates significant anoxia and bottom water restriction, these anoxic conditions allow for the preservation of organic rich sediments which normally form good source rocks for hydrocarbon.

Based on the occurrence of low oxygen tolerant species of foraminifera (*Bathysiphon*, *Ammobaculites* and *Haplophragmoides*) in the Pindiga shale, it is suggested to be deposited under anoxic conditions. The recently reported discovery of hydrocarbon in the Kolmani River 2 of the Northern Benue Trough is a confirmation to this fact.

The above conditions also go to support the fact that the Pindiga shale was deposited in a deep marine environment, where the depleted oxygen levels cause anoxia.

## Age

From the two studied sections (the Pantami and Pindiga stream channels) about four species of planktonic foraminifera (*Heterohelix globulosa*, *Heterohelix moremani*, *Heterohelix reussi* and *Globogerina*) were observed in both the two sections. Planktonic foraminifera are generally used for age determination in sediments mostly because of their short life span (Gebhardt, 1997; Opeloye, 2013) and as such will be used here to determine the age of the Pindiga Formation.

Obaje et al. (2000) in his work on the sequence stratigraphic and paleoenvironmental interpretation of Heterohelids from the Pindiga Formation proposed that

the formation is deposited during the mid-Cretaceous (Cenomanian-Turonian-Coniacian).

Abubakar and Obaje (2001) were in agreement with the work of Petters (1979) which dated the sediments of the Gongila Formation using the *Heterohelix reussi* to be Turonian-Coniacian in age. Several of these species and other Heterohelids were recovered from the Gongila Formation (Abubakar and Obaje, 2001).

However, Opeloye (2013) assigned the Numanha shales (the equivalent of Pindiga Formation) to be Turonian-Coniacian in age based on the occurrence of *Heterohelix* species, which are unsurprisingly the same species recovered by Obaje et al. (2000) and also the same species of Heterohelids were recovered in the course of this study. Also, Petters (1978b) dated the Pindiga, Jessu and Numanha Formations to be Late Turonian to Santonian in age using molluscan evidence. These three studies are closely related in terms of the age proposed.

However, the most related to this study is the work of Opeloye (2013) which agrees with the Turonian-Coniacian age except for the fact that he only worked on the Numanha Shales and not the whole equivalent of the Pindiga Formation (Lamja, Numanha, Sekule, Jessu and Dukul Formation). However, Uzoegbu et al. (2013) and Akande et al. (1998) also assigned the Turonian-Coniacian age for the Gongila/Pindiga/Dukul Formation based on geochemical and fossil evidence from their study of Dukul and Pindiga Formations respectively.

Based on the facts of this study, it is therefore convenient to assign the Pindiga Shales from the two stream channels to Turonian-Coniacian age.

## Implication for Hydrocarbon Exploration

The association of anoxic conditions with the accumulation of carbon-rich sediments, is generally a proof that anoxia inhibits decay of organic matter and is therefore important in the preservation of organic carbon in sediments (Curtis, 1980; Demaison and Moore, 1980).

Since the Pindiga shale is suggested to be deposited under anoxic conditions, we can also further suggest that the anoxia aided the preservation of carbon-rich organic matter in the Pindiga shales and thus could in

turn be a potential source rock. Also the review of Geochemical analysis data from the Pindiga Formation shows that it has a TOC ranging from about 0.4-2.4wt% and averaging about 0.75wt% hence possess fair to good source rock generative potential (Akande et al.,1998) since it surpasses the minimum TOC of 0.5% required for Hydrocarbon generation according to Demaison and Moore (1980).

It is therefore suggestive that the Pindiga shales could be a potential source rock for oil and gas within the Northern Benue Trough especially where it has attained optimum maturity.

The already reported success in the exploration of oil and gas in the Northern Benue Trough is a confirmation to this fact.

## CONCLUSION

The Turonian-Coniacian Pindiga Formation of the Northern Benue Trough is studied within the Pindiga and Pantami river channels. Both sections logged are dominated by lithologies such as shale, limestone, mudstone associated with gypsum mineralization.

The Pindiga stream section is estimated to contain thicknesses in the proportion of about 20m for shale (Figure 4), limestone 4m and mudstone 0.5 m while the Pantami stream section thicknesses ranges from about 19m for shale,1m for limestone and about 0.6 for mudstone (Figure 3).

The detailed study of the recovered foraminifera species within the Pindiga Formation indicates that the Pindiga shale were deposited in a shallow to deep marine environment under saline water conditions. Also, the Pindiga Formation was deposited under anoxic (oxygen depleted) conditions which favours the preservation of rich- organic matters which could serve as a potential source rock for hydrocarbon generation if maturity is reached.

## REFERENCE

Akande S.O and ERDTMANN,B.D. 1988.Burial metamorphism (thermal maturation) in cretaceous sediments of the Southern Benue trough and Anambra basin,Nigeria.AAPG Bulletin 82(6),pp.1191-1206

Benkhelil, J. (1989). The origin and evolution of the Cretaceous Benue Trough, Nigeria. *Journal of African Earth Sciences*, 8: 251 – 282.

Carter, J.D.,Barber, S.W. Tait, E.A. and Jones, G.P. (1963). The Geology of Part of Adamawa, Bauchi and Borno provinces in North- eastern Nigeria. *Bulletin of the Geological Survey of Nigeria*, 30: 1 – 108.

Demaison,G.J and Moore,G.1980. Anoxic Environments and oil source bed Genesis.AAPG Bulletin 64(8),pp.1179-1209.

Gebhardt,H.1997. Cenomanian to Turonian foraminifera from Ashaka (NE Nigeria) Quantitative analysis and Paleoenvironmental interpretation. *Cretaceous research* 18,pp.17-36.

Guiraud, M. (1993). Late Jurassic rifting – Early Cretaceous rifting and Late Cretaceous transpressional inversion in the Upper Benue Basin (N. E Nigeria).*Bulletin des Centres des Recherches Exploration-Production Elf-Aquitaine*, 17: 371 – 383.

Obaje,N.G;Olu, O.K; and Petters, S.W 1999a. Biostratigraphy and Geochemical controls of Hydrocarbon prospect in the Benue Trough and Anambra Basin,Nigeria, NAPE Bulletin 14 (1),pp 18-25

Obaje,N.G; Olu, O.K; Maigari, S..A and Abubakar,M.B 2000. Sequence stratigraphy and Paleoenvironmental interpretations of Heterohellicids from the Pindiga formation, North Eastern Benue Trough,Nigeria. *Journal of Mining and Geology* 36 (2),pp 191-198.

Petters,S.W. 1982 Central west African Cretaceous to Tertiary Benthic Foraminifera and Stratigraphy. *Paleontographica A*.179, pp.1-104.

Petters,S.W. 1983 Lithoral and Anoxic Facies in the Benue Trough. *Bulletin des centres de recherches Exploration Production ELF-Aquintain* 7, pp.361-365.

Zaborski, P.M. (1998). A review of the Cretaceous System in Nigeria. *Africa Geoscience Review*, 5: 385 – 483.

Zaborski, P.M., Ugoduluwa, F., Idornigie, A., Nnabo, P. and Ibe, K. (1997). Stratigraphy and structure of the Cretaceous Gongola Basin, north eastern Nigeria.*Bulletin des Centres des Recherches Exploration–Production Elf-Aquitaine*, 21: 153