Minna Journal of Geosciences (MJG) Volume 1 Number 1, 2017
Pages 165 – 178

Palynological Evidence of a Campanian-Maastrichtian Age of the Northern Bida Basin, Nigeria: Implication for Paleoenvironment, Paleoclimate and Hydrocarbon Prospectivity

[1*]Onoduku, U.S., [1]Okosun, E.A., [2]Obaje, N. G., [1]Goro, A.I. [1]Salihu, H.D. and Chukwuma-Orji, J.N.

[1]Department of Geology, Federal University of Technology, Minna, Nigeria
[1]Department of Geology and Mining, Ibrahim Badamasi University, Lapai, Niger State
[*]Correspondence Author: onoduku.usman@futminna.edu.ng

Abstract

The result of this study hereby documented is probably the first of its kind in terms of the source of the samples (ditch cutting) used for palynological analysis. Studies related to ascertaining paleoenvironment, paleoclimate and hydrocarbon prospectivity status are yet to be conducted using subsurface samples within the Bida Basin. Consequently, ditch cuttings obtained from two pilot exploratory wells located at Kudu and Agaie (K and Y wells respectively) areas of the Northern Bida Basin were analysed for the purpose of studying the paleoenvironment, paleoclimate and hydrocarbon prospectivity status of the Basin. The K-well was drilled to a depth of 75 m and the Y-well to a depth of 70 m and the K well was sampled at 1 metre interval while well Y was sampled at 2 m interval, giving a total of 105 ditch cuttings. The studied samples are mainly sandstones, mudstones and shales, implying lithological samples from the Bida formation. The aim of the study is to use the results of the palynological analysis to infer the Palynostratigraphy, paleoenvironment, paleoclimate and possible hydrocarbon prospect within the Bida basin. Palynological analyses were performed on the 105 samples obtained from the two exploratory wells using the conventional acid method of palynological preparation technique and the microscopic analysis of the palynoslides. Well K is very rich in palynomorphs both in terms of taxonomical species and quantity and has afforded a clear interpretation of the paleoenvironment, paleoclimate and hydrocarbon prospectivity of the section of the basin penetrated. Palynomorphs identified include *Monocolpites* sp, *Proteacidites sigalii, Psilatricolporites* sp, *Tricolporopollenites* sp, *Acrostichum aureum, Cyathidites* sp, *Laevigatosporites* sp, *Rugulatisporites caperatus, and Verrucatosporites* sp. Two (2) palynostratigraphic zones from Late Campanian to Early Maastrichtian are proposed. The zones, in stratigraphically ascending order, are as follows: *Selaginella myosus – Classopollis* sp taxon range zone (Late Campanian) and the *Proteacidites sigalii – Psilotricolporites* sp taxon range zone (Early Maastrichtian). The vertical distribution of the palynoforms and the few presence of dinoflagellates show only one major paleodepositional environment: the terrestrial to nearshore type characterized by dominant terrestrial spores and pollen that were occasionally inundated by marine incursion. The inferred paleoclimate ranges from savanna to rainforest as evidenced from the diagnostic palynoforms. In addition, the paleoclimate, paleoenvironment and age of the penetrated strata suggest a considerable potential for natural gas accumulation within the basin.

Keywords: Palynomorph, Kudu, Agaie, Palynoslides, Campanian, Maastrichtian, Paleoenvironment, Paleoclimate.

Introduction

Palynological studies have become valuable tools and universally practiced methods of evaluating the stratigraphy, paleoenvironment, paleoclimate, age and analysis of sedimentary basins for hydrocarbons potentialities (Onoduku, 2013). Gutjahr (1960) wrote on the applications of palynology in petroleum exploration and concluded that palynology appears next in rank to Rock-Eval in petroleum exploration studies. Palynology deals with the study of plant remains in the sedimentary successions and their applications in biostratigraphy. Palynological zonation is the characterization and subdivision of sedimentary strata on the basis of palynomorph content. This differentiation allows small scale units to be delineated, dated, correlated and interpreted within a precise framework of geologic time (Odedede *et al*., 2016). The Bida Basin is a NW-SE trending bow-shaped intracratonic sedimentary basin bounded in the north by Kotangora town in the present Niger State and in the south by basement rocks around the rivers Benue-Niger confluence near Lokoja town (Figures 1and 2).

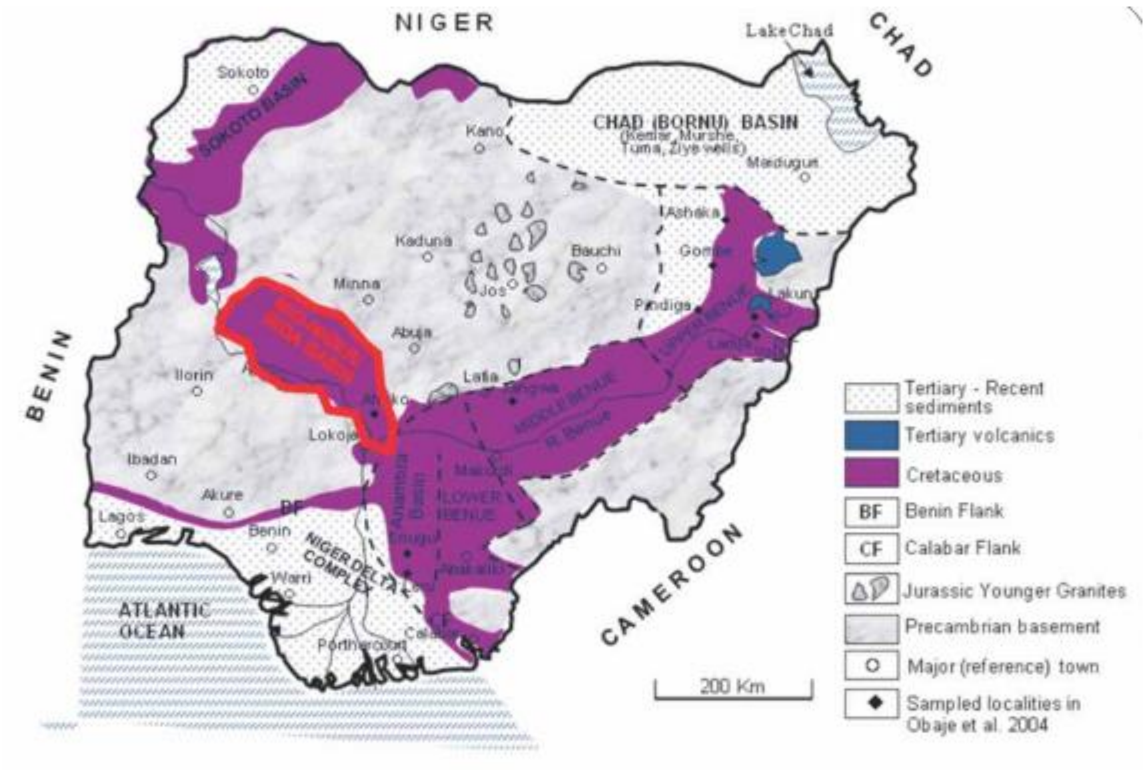


Figure1: Sketch geological map of Nigeria showing location of Bida Basin (After Obaje *et al*., 2011)

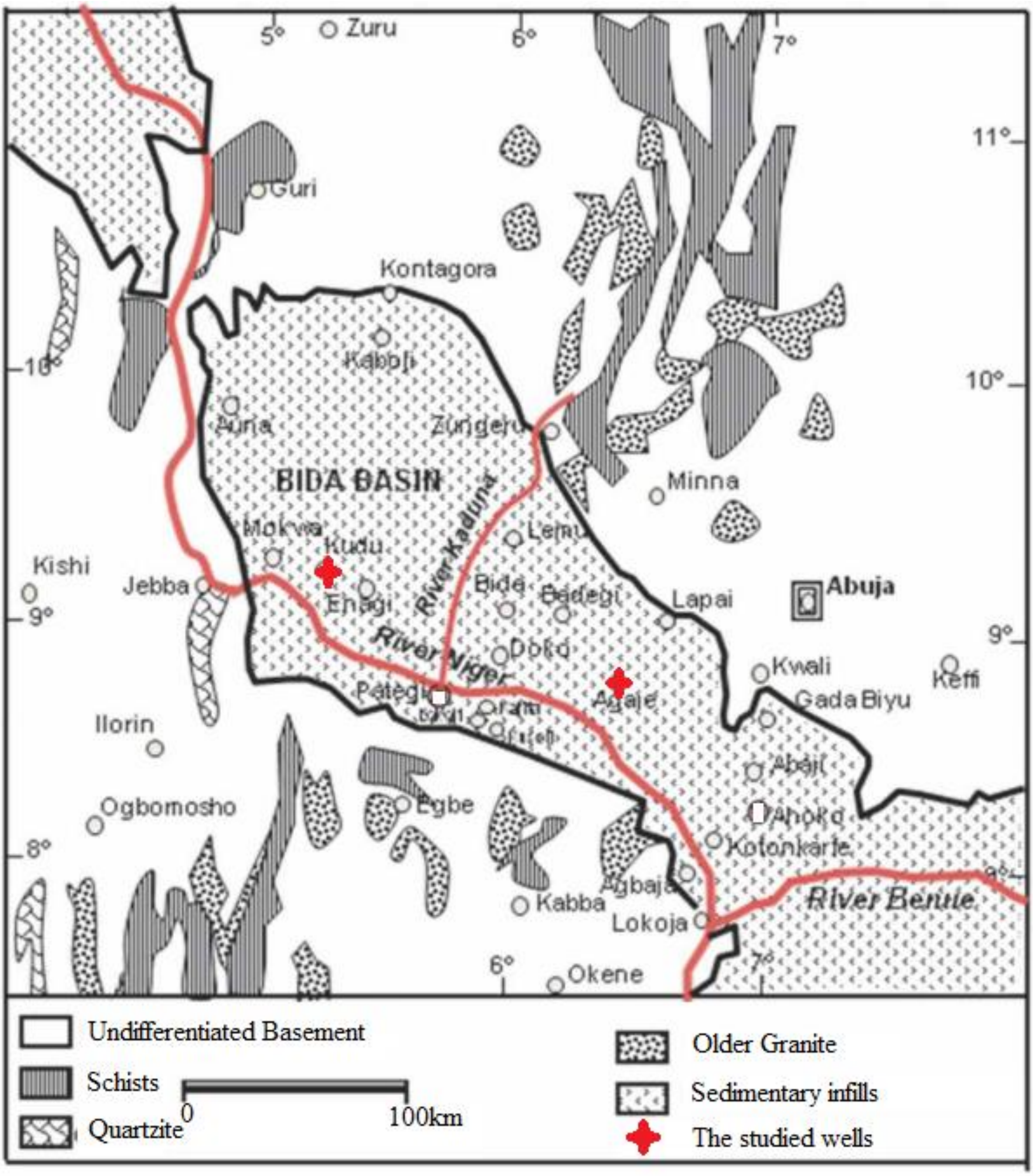


Figure 2: Geology and location of the Bida Basin showing the studied wells (Modified after Obaje *et al*., 2011).

The policy of the Federal Government of Nigeria to extend petroleum exploration to the inland basins which are hitherto unexplored, coupled with the petroleum-like seepages observed along the bed of River Niger within the basin, necessitated this research. The petroleum-like seepages occurred at three points directly opposite Pategi village, about 200 metres north of old Muregi village in January 1998. A team of Geologists (including the leading author of this paper) has visited the site for on spot investigations. Some previous workers have carried out palynological studies on surface samples and samples from road-cuts from various parts of the basin and their results documented (Akande *et al*., 2005; Ojo and Akande, 2006; Ojo, 2009; Obaje *et al*., 2011). The results of this study in which well cuttings (sub-surface samples) were used for the palynological analysis are expected to be more accurate and reliable in terms of paleoenvironment deductions for the basin because of the use of subsurface samples as against the use of surface samples in the previous studies. The use of surface samples will not provide the true status of a basin in terms of paleoenvironment, paleoclimate and petroleum prospect but can only give a semblance of these attributes of a basin. The aim of this study is therefore to determine the palynomorph composition, establish the palynostratigraphy, paleoenvironment, paleoclimate and date the sections penetrated by the two wells within the basin and on the bases of the above, assess the hydrocarbon prospects of the basin.

Stratigraphy of the Bida Basin

The geological setting and stratigraphy of the Bida Basin have been described extensively by some previous authors, notably Adeleye (1974), Akande *et al*. (2005) and Obaje *et al.* (2011). The Bida basin is geographically divided into two sub-basins, namely; the Northern Bida sub-basin and the Southern Bida sub-basin. The two sub-basins are made up of distinct lithological units which depict lateral time and textural equivalents. These are shown in Figure 3.

Northern Bida Basin

The Bida Sandstone

The Bida Sandstone comprises of two members, the Doko Member and the Jima Member. The Doko Member is the basal unit and consists of very poorly sorted pebbly arkoses, sub-arkoses and quartzose sandstones. These are thought to have been deposited in a braided alluvial fan setting (Obaje *et al*., 2011). The Jima Member is dominated by cross-stratified quartzose sandstones, siltstones and claystones. Trace fossils comprising mainly Ophiomorpha burrows have been observed. These were also observed in the overlying Sakpe Ironstone, suggesting a possible shallow marine subtidal to intertidal influence during sedimentation. The Jima Sandstone Member is thus considered as the more distal equivalent of the upper part of the Lokoja Formation, where similar features also occur.

The Sakpe Ironstone

The Sakpe Ironstone comprises of oolitic and pisolitic ironstones with sandy claystones. The sandy claystones are found at the base of the formation, followed by oolitic ironstone at the top.

The Enagi Siltstone

According to Obaje *et al.* (2011), the Enagi Siltstone consists mainly of siltstones and correlate with the Patti Formation in the Southern Bida Sub-Basin. Other subsidiary lithologies include sandstone-siltstone admixture with some claystones. Fossil leaf impressions and rootlets have been found within the formation. The formation ranges in thickness of between 30 m and 60 m.

The Batati Formation

This formation constitutes the uppermost units in the sedimentary sequence of the Northern Bida Basin. The Batati Formation consists of argillaceous, oolitic and geothitic ironstones with ferruginous claystone and siltstone intercalations and shaley beds occurring in minor proportions, some of which have yielded near-shore shallow marine to freshwater fauna (Adeleye, 1974).

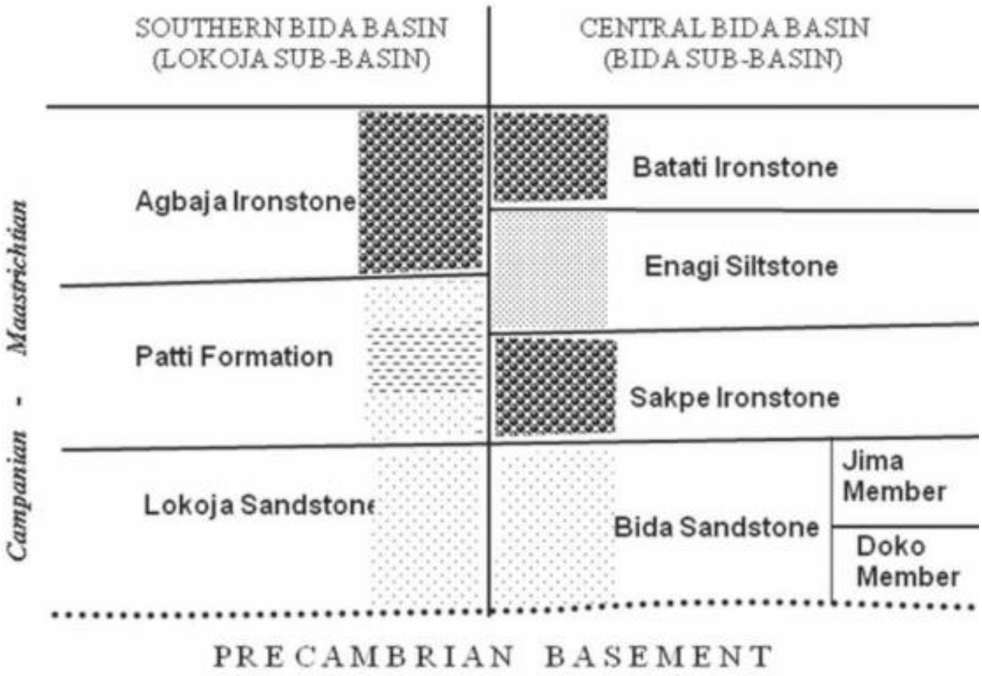


Figure 3: Stratigraphic succession of the Bida basin (After Obaje *et al.*, 2011).

Southern Bida Basin

The Lokoja Formation

Lithologic units in this formation range from conglomerates, coarse to fine grained sandstones, siltstone and claystones. Sub-angular to sub-rounded cobbles, pebbles and granule sized quartz grains in the units are frequently distributed in a clay matrix. Both grain supported and matrix supported conglomerates form recognizable beds at the base of distinct cycles at outcrops. The sandstone units are frequently cross-stratified, generally poorly sorted and composed mainly of quartz plus feldspar and are thus texturally and mineralogically immature. The general characteristics of this sequence especially the fining upward character, compositional and textural immaturity and unidirectional paleocurrent trends, suggest a fluvial depositional environment dominated by braided streams with sands deposited as channel bars consequent to fluctuating flow velocity. The fine grained sandstones, siltstones and clays represent floodplain over bank deposits.

The Patti Formation

Outcrops of the Patti Formation occur extensively on the Agbaja Plateau at Ahoko and Abaji on the Lokoja-Abuja expressway. This formation consists of sandstones, siltstones, claystones and shales interbedded with bioturbated ironstones. Argillaceous units predominate in the central parts of the basin. The siltstones of the Patti Formation are commonly parallel stratified with occasional soft deformational sedimentary structures (e.g. slumps), and other structures as wave ripples, convolute lamination sandload structures (Obaje *et al*., 2011). Trace fossils (especially Thallasinoides) are frequently preserved. Interbedded claystones are generally massive and kaolinitic, whereas the interbedded grey shales are frequently carbonaceous. The subsidiary sandstone units of the Patti Formation are more texturally and mineralogically mature compared with the Lokoja Formation sandstones.

The Agbaja Formation

This formation forms a persistent cap for the Campanian-Maastrichtian sediments in the Southern Bida Basin as a lateral equivalent of the Batati Formation on the northern side of the basin (Obaje *et al*., 2011). The Agbaja Formation is best exposed on the Agbaja Plateau where it overlies successively the Lokoja and Patti Formations. The Agbaja Formation consists of sandstone beds in this region.

Review of the Biostratigraphy of Bida Basin

Biostratigraphic and paleoecologic studies by Petters (1986) have revealed the occurrence of arenaceous foraminifers in the shales of the Patti Formation with an assemblage of *Ammobaculites, Milliamina* and *Trochaminaand Textularia*. Ojo (2009) reported the occurrence of some Maastrichtian marine dinoflagellates cysts and terrestrial pollen and spores from Upper Cretaceous sediment in Southeastern Bida Basin and used them to infer the ages and paleoenvironment of the Upper Cretaceous Patti Formation as Maastrichtian and continental with marine intervals respectively. He concluded that the palynomorph assemblages from the Patti Formation indicated a predominance of terrestrially derived pollen and spores and some significant marine dinoflagellates. Akande *et al*. (2005) studied the microfloral assemblage, age and paleoenvironment of the Upper Cretaceous Patti Formation, Southeastern Bida Basin and concluded that the abundance of Palmae pollen (*Echitriporites and Longapertites*) and the Pteridopytes suggest a humid climate and Maastrichtian ages for the formation. Other marker species identified by these authors include *Buttinia andreeve, Retidiporites magdalensis, Echimoncolpites, Echitriporites trianguliformis; Cristaeturites Cristatus* which support the Maastrichtian age of the formation.

Materials and Methods

Ditch cutting samples and lithological log from the drilled wells served as the materials used in this study. One hundred and five ditch cutting samples (70 from Y-well and 35 from K-well) were processed for the palynological studies. The standard palynological preparation and microscopic examination methods with modifications from procedures used at Mosunmolu Palynological Laboratory, Lagos were employed in this study.

Palynological Analysis

A constant weight (20 g) of each sample was treated with hot hydrochloric acid (HCl) to remove carbonates prior to complete digestion in hydrofluoric acid (HF) in a fume cupboard. Gentle agitation of the acid- mixture was carried out to aid digestion.

The sample was heated to boiling in HCl and wet sieved over a 5 micron mesh polypropylene sieve. The sieve was constantly cleaned with iron brush after each usage before it was used for another sample solution to avoid sample contamination. Branson sonifier 250 was routinely used during sieving to facilitate the complete removal of silt and clay particles. The sieved residue was given controlled oxidation by boiling briefly in concentrated nitric acid (HNO_3). The sample residue was then prepared for microscopic study in the form of strewn mount on glass slide. The mounting medium used was *LOCTITE (impruv)* manufactured by Loctite corporation, USA. Staining of the slide using infranin O was done in order to enhance the appearance of any dinoflagellates cysts under the microscope most of which are usually fairly transparent in routine (unstained) preparations. Two palynological slides were prepared for each sample (horizon) and analyzed microscopically in order to ensure a complete coverage of the palynomorphs present.

Microscopic Analysis

The Palynological slides were examined using transmitted light microscopes commonly under times forty (X 40) dry and times one hundred (X 100) oil immersion objective lenses. Accurate co-ordinates of individual Palynomorph on a slide were often given with the aid of either the graduated scale on the traversable slide table of a particular microscope or, preferably, by the use of England Finder co-ordinates. These co-ordinates were taken for marker species mostly during the microscopic work in this study. During the microscope studies, for taxonomy comprising more than 15% of the flora, only 20% of the first slide was examined and projected to 100%. All other taxas were counted completely until the slide is completely analyzed.

Results and Discussion

Palynology and Palynostratigraphy

Palynomorphs including spores, pollen and fungal spores were recovered from the two studied wells (Plate I). The quantitative values of these palynomorphs are shown in the form of distribution charts in Figures 4, 5, 6 and 7. A total of 1,789 palynomorph counts were recorded from the two studied wells. The two investigated wells are characterized by almost barren to very poor presence of palynomorphs with very few representations of some species at upper parts of the wells but become abundant in the lower parts of the wells. Abundance of palynomorphs begins from 30 m depth in well-K with scarce palynomorphs occurrence above this depth in the two wells. Palynostratigraphically, the studied wells can be zoned into two palyzones based on the recovered palynoforms. The studied depth is within the Bida Formation based on the observed lithologies.

***Selaginella myosurus-Classopollis* sp. taxon range zone.**

This zone occurs between 26 m – 70 m in Y-well and 30 m – 70 m in K-well. Diagnostic palynomorphs include *Inaperturopollenites* sp, *Proteacidites sigalii*, *Psilatricolporites* sp, *Tricolporopollenites* sp, *Acrostichum aureum*, *Cyathidites* sp, *Laevigatosporites* sp, *Verrucatosporites* sp, *and Rugulatisporites caperatus.* This zone is dated Late Campanian. This age agrees with Ojo and Akande (2006).

***Proteacidites sigalii – Psilotricolporites* sp taxon range zone.**
This zone occurs between 0 m – 26 m in Y-well and 0 m – 30 m in K-well. The characteristic palynomorphs include Polypodiaceoisporites sp, *Cyathidites* sp, *Tricolporites* sp, *Proteacidites sigalii*, *Psilatricolporites* sp, *Monoporites annulatus*, *Echitriporites trianguliformis*, *Ephedripites* sp, *Cingulatisporites* sp., *Acrostichum aureum*, *Verrucatosporites*, *Cyathidites* sp, *Cyathidites minor*, *Graminidites* and *Zonocostites ramonae.* The zone is dated Early Maastrichtian (cf Ojo and Akande, 2006).

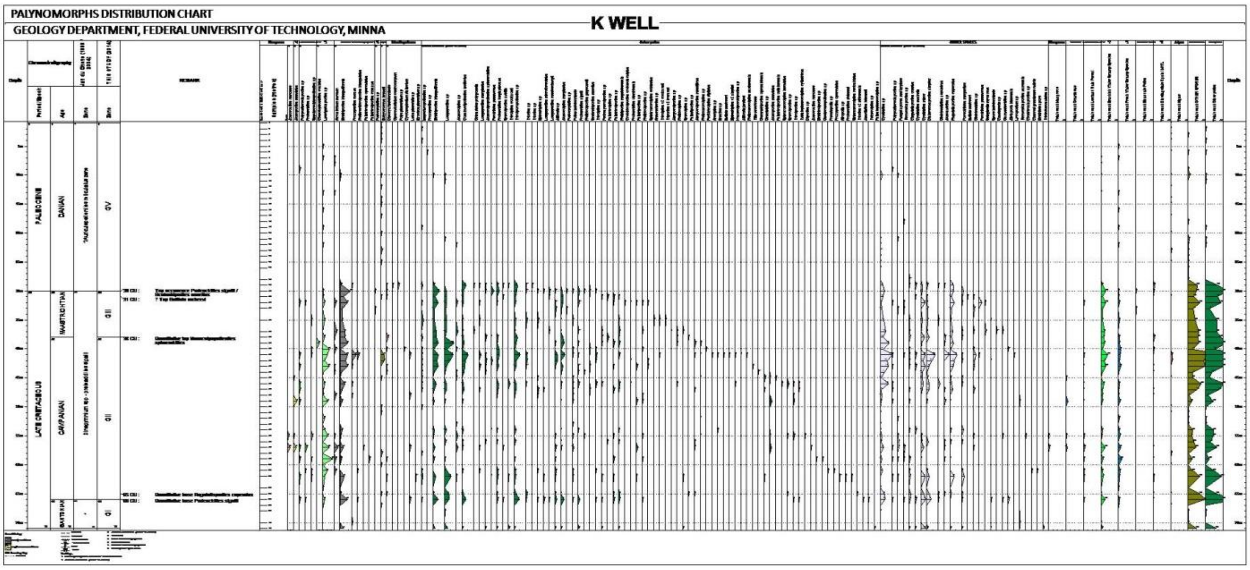


Figure 4: Palynomorph distribution chart for well-K.

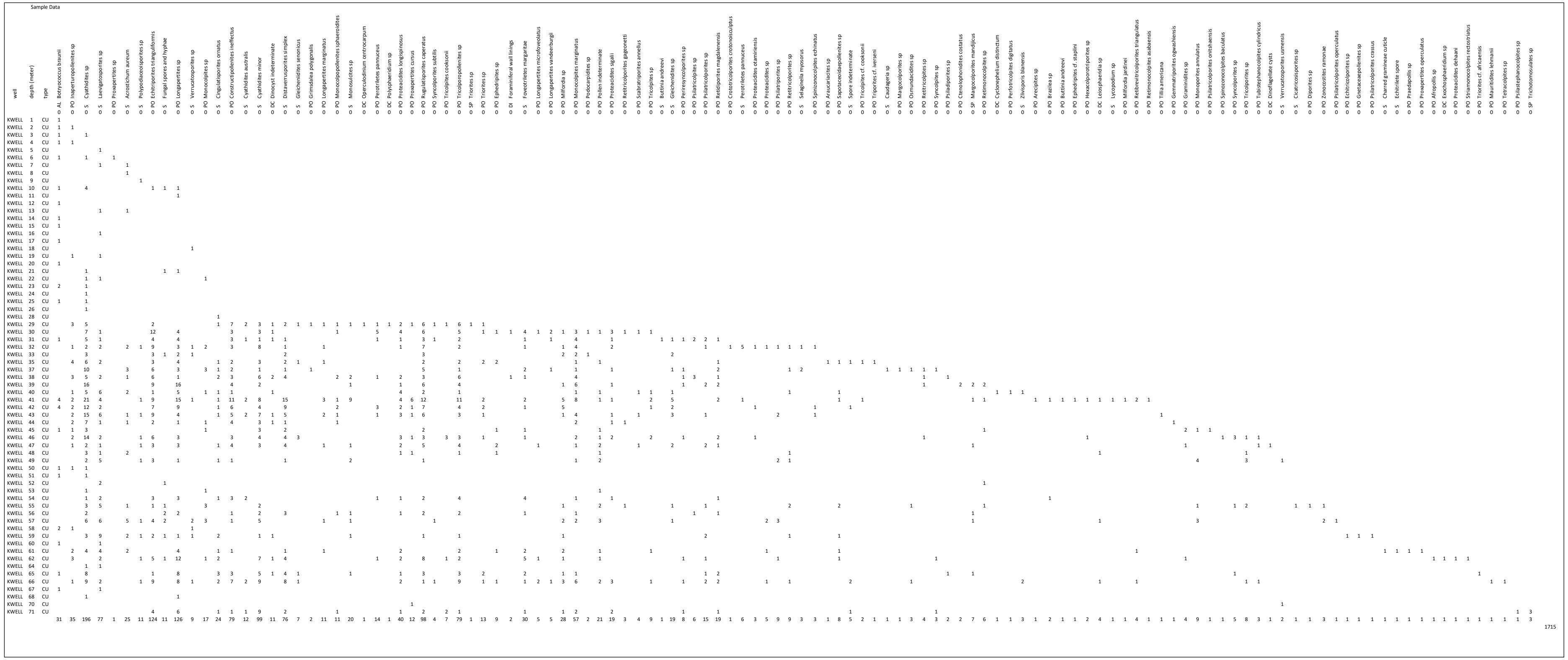


Figure 5: Palynomorph distribution chart of well K.

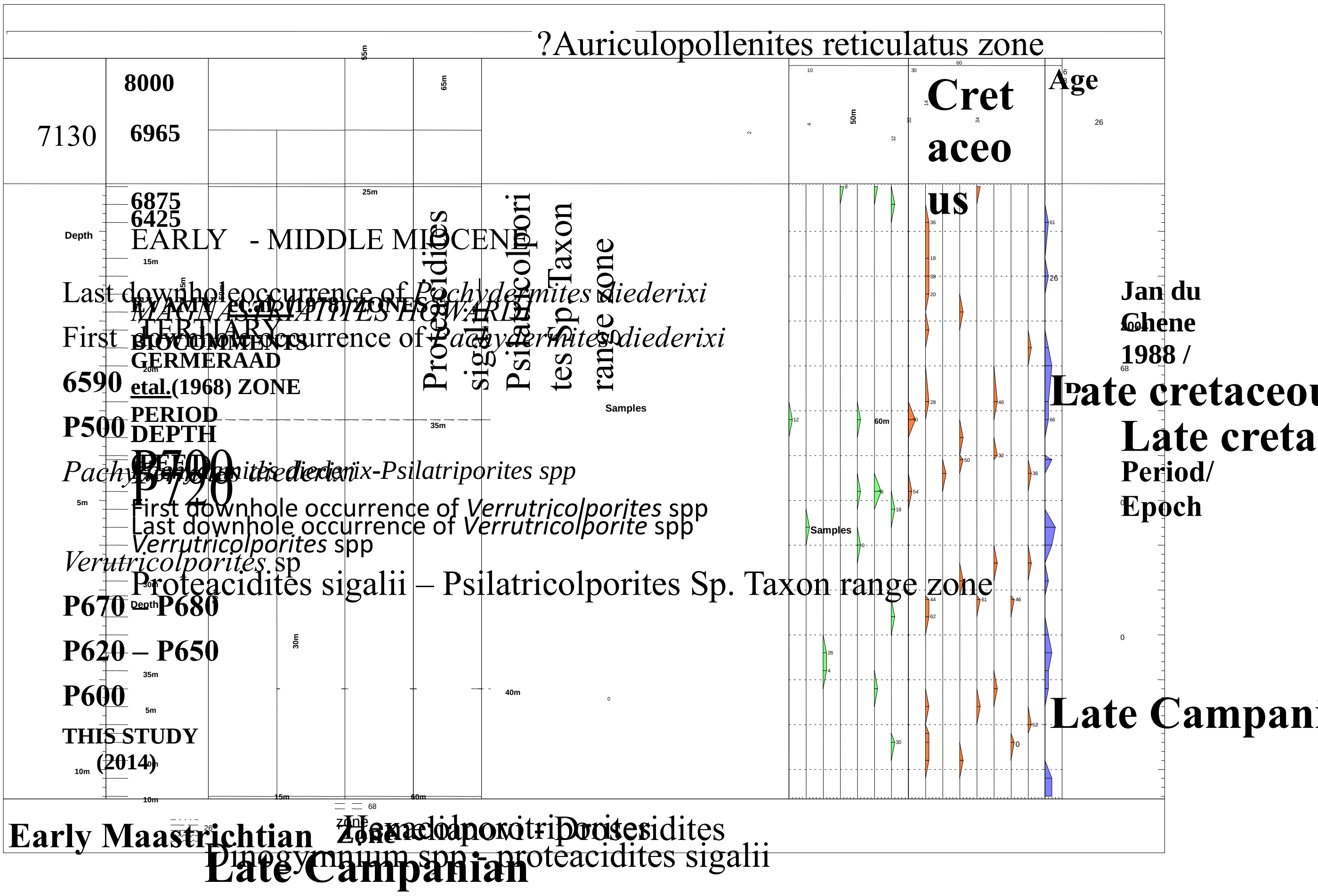
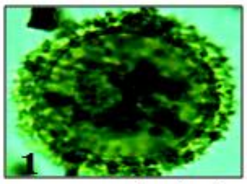


Figure 6: Palynomorph distribution chart for well-Y.

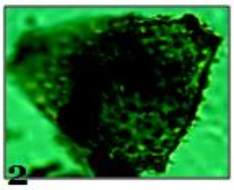
Sample Data

well	depth	type	Pollen indeterminate	Polypodiaceoisporites sp	Psilatricolporites sp	Tricolporopollenites sp.	Botryococcus braunii	Cyathidites sp	Laevigatosporites sp	Verrucatosporites sp	Rugulatisporites caperatus	?Classopollis sp	Acrostichum aureum	Proteacidites sigalii	Fungal spores and hyphae	Inaperturopollenites sp	Selaginella myosurus	Monocolpites sp
			PO	S	PO	SP	AL	S	S	S	S	PO	S	PO	S	PO	S	PO
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YWELL	0	CU	1	1	1													
YWELL	2	CU				1												
YWELL	4	CU					1	1										
YWELL	8	CU						1										
YWELL	10	CU					1	1										
YWELL	12	CU						1										
YWELL	14	CU							1									
YWELL	16	CU						1										
YWELL	18	CU					1			1								
YWELL	20	CU					2											
YWELL	24	CU					1	1			1							
YWELL	26	CU					1					1	2	1				
YWELL	28	CU							1									
YWELL	30	CU									1							
YWELL	30.5	CU					2		1									
YWELL	32	CU								1					1			
YWELL	34	CU			2								1	1				
YWELL	36	CU				1												
YWELL	38	CU					3									1		
YWELL	40	CU					2							1				
YWELL	42	CU								1	1							
YWELL	44	CU					1		1									
YWELL	45.7	CU																
YWELL	46	CU		1				1									1	
YWELL	48	CU				1		1										
YWELL	50	CU					1											
YWELL	52	CU					2											1
YWELL	54	CU					1											1
YWELL	56	CU			1		1				1							
YWELL	58	CU		1				1										
YWELL	60	CU								1								
YWELL	61	CU						1										
YWELL	62	CU				1		1									1	
YWELL	64	CU						1	1									
YWELL	66	CU					2											
YWELL	68	CU					2											
			1	3	4	4	24	12	5	4	4	1	3	3	1	1	2	2
																		74

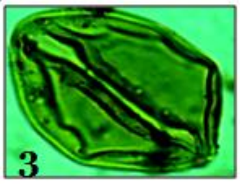
Figure 7: Palynomorph distribution chart of Y well.



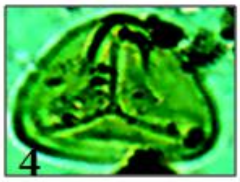
1.Constructipollenites ineffectus K30



2. Proteacidites Longispinosus K30

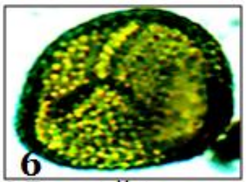


3. Monocolpites marginatus (K30)

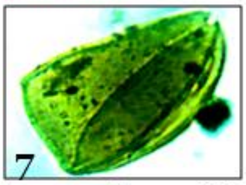


4. Gleicheniidites senonicus(K30)

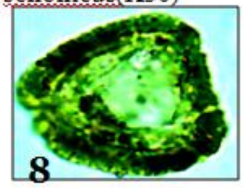
5. Ephedripites sp. (K30)



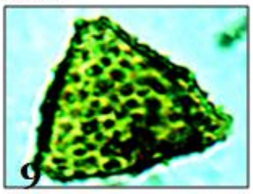
6. Foveotriletes margaritae(K30)



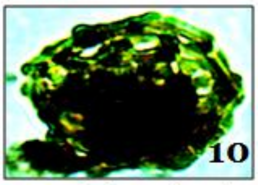
7. Longapertites sp. (K30)



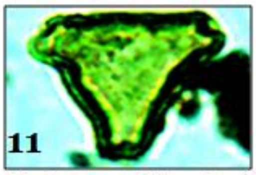
8. Distaverrusporites simplex K30)



9. Echitriporites trianguliformis (K30)

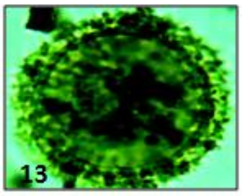


10.Buttinia andreevii (K30)

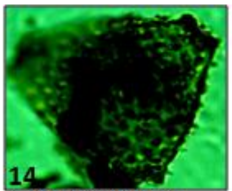


11. Proteacidites sigalii (K30)

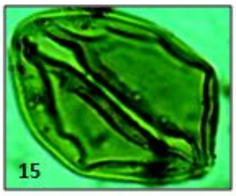
12. Ephedripites sp. (k30)



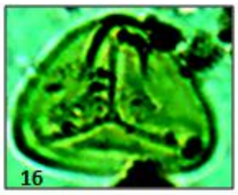
1.Constructipollenites ineffectus K30



2. Proteacidites Longispinosus K30

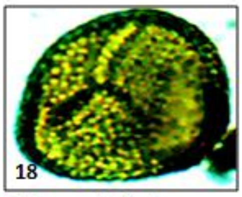


3. Monocolpites marginatus (K30)



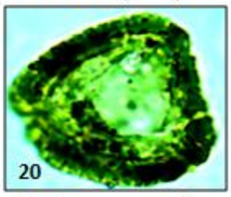
4. Gleicheniidites Senonicus (K30)

5. Ephedripites sp. (K30)

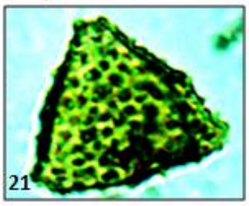


6. Foveotriletes Margaritae (K30)

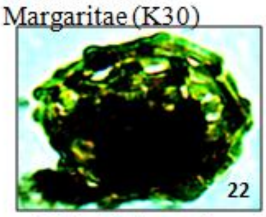
7. Longapertites sp. (K30)



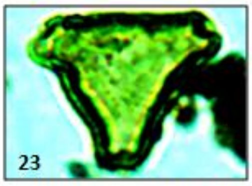
8. Distaverrusporites simplex (K30)



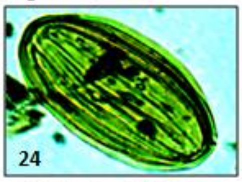
9. Echitriporites trianguliformis (K30)



10.Buttinia andreevii (K30)



11. Proteacidites sigalii (K30)



12. Ephedripites sp. F35/3 (k30)

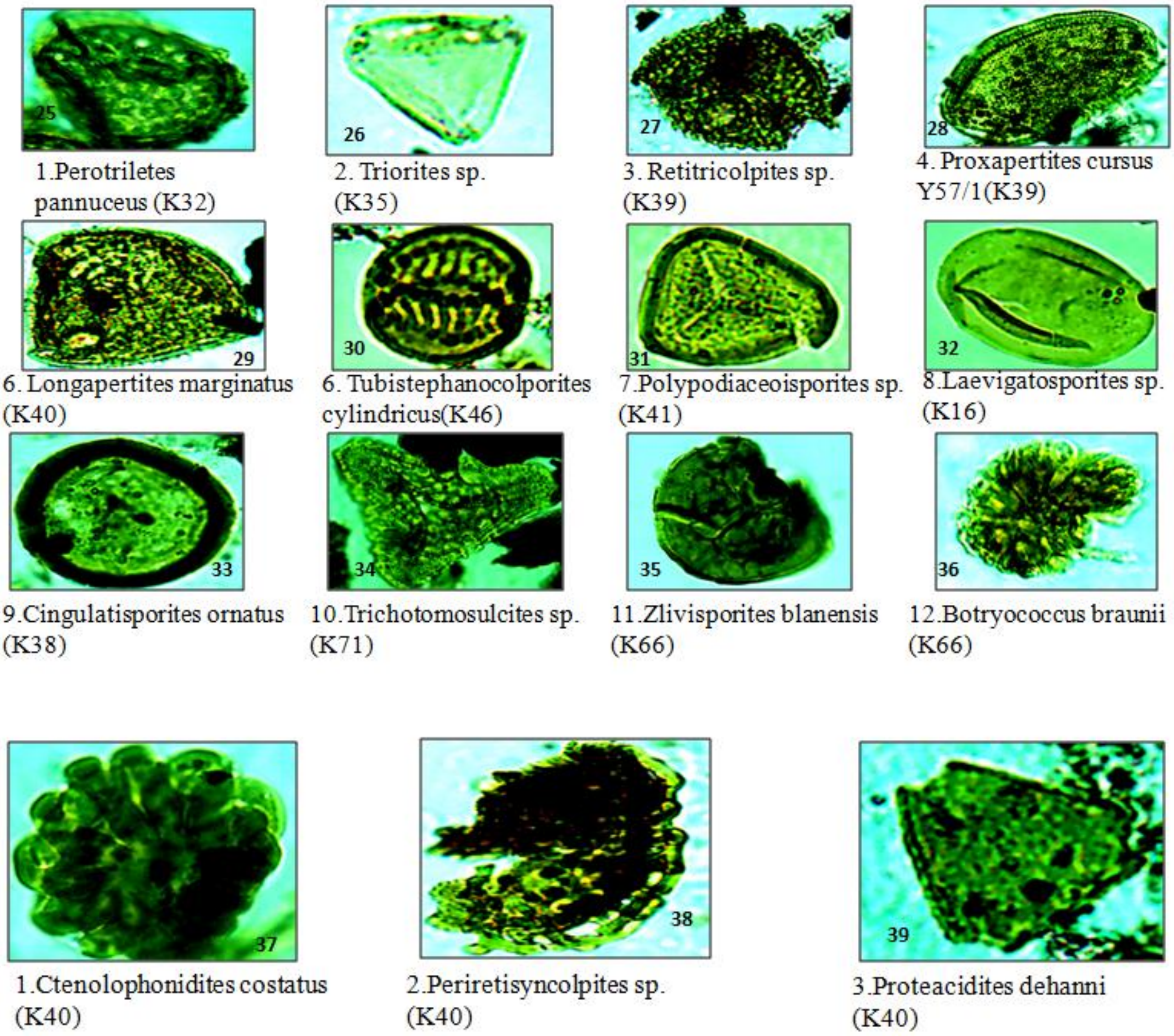


Plate 1: Photomicrographs of palynomorphs.

Paleoclimate, Paleoenvironment and Age

The vertical distribution of the palynoforms coupled with the few occurrences of dinoflagellates is an indication of one major paleodepositional environment; the terrestrial to nearshore environment inundated by marine incursion characterized by dominant terrestrial spores and pollen. Presence of *Acrostichum aureum*, *Verrucatosporites*, *Cyathidites* sp, *Cyathidites minor*, *Graminidites* and *Zonocostites ramonae are* indication of humid tropical climates. The inferred paleoclimate ranges from savanna to rainforest as evidenced from the diagnostic palynoforms.The inferred age for the studied sections of the Bida Basin is late Campanian – early Maastrichtian and this agrees with Obaje and Akande (2006).

Hydrocarbons Prospectivity Leads

Lithostratigraphically, the carbonaceous shale facies can serve as the source rocks while the sandstones serve as reservoir rocks for petroleum accumulation within the studied basin. Inferred non-marine environment is an indication of terrestrial/fluvial dominated environment prone to generate dry gas. Most pollen and spores show terrestrial paleoenvironment (indication of Type I or II kerogen which is an indication of gas prone environment. However, petroleum-like seepages observed along Muregi-Pategi axis along the River Niger bed calls for a follow-up investigation for possible large quantity of oil.

Conclusions and Recommendations

The studied sections of the Bida basin are zoned into two biozonation, dated Late Campanian – Early Maastrichtian based on the observed palynomorphs. Paleoenvironment was inferred to be terrestrial to near shore environment with marine incursions. Paleoclimate ranged from Savanna to Rainforest as evidenced from the diagnostic palynoforms and possibility of gas prone environment with little wet oil.

On the basis of the above observations from the study, the following recommendations were made:

(i). Drilling of deeper wells to obtain samples for more analyses.

(ii). Detailed geochemical analyses should be performed on the ditch cuttings for more reliable appraisal of the petroleum potentials of the basin.

(iii). Correlation of the studied wells with some productive wells in other inland basins, such as the Bornu basin for better understanding of the Bida basin.

References

Adeleye, D.R. (1974). Sedimentology of the Fluvial Bida Sandstone (Cretaceous), Nigeria. *Sedimentary Geology*, vol. 12, issue 1, p. 1-24.

Akande, S. O., Ojo, O. J., Erdtmann, B. D. and Hetenyi, M. (2005). Paleoenvironments, Organic Petrology and Rock-Eval studies on source rock facies of the Lower Maastrichtian Patti Formation, Southern Bida Basin, Nigeria. *Journal of African Earth Sciences,* 41, 394 – 406.

Gutjahr, C. C. M. (1960). Palynology and its application in petroleum exploration. *Gulf Coast Association Geological Society Trans*., 10, 175 - 187.

Obaje, N.G., Moumouni,A., Goki, N.G. and Chaanda, M.S. (2011). Stratigraphy, Paleogeography and Hydrocarbon Resource Potentials of the Bida Basin in North-Central Nigeria. *Journal of Mining and Geology*, vol. 47(2), p 97-114.

Odedede, O., Ogala, J.E. and Ugbe, F.C. (2016). Palynological Zonations and Saquence Stratigraphic Analysis of Sediments in Benin West-1, Anambra Basin, Nigeria. *J. Sci. Res.,* 8 (2), pp. 171-179.

Ojo, O. J. (2009). Occurrence of some Maastrichtian Dinoflagellate Cysts from the Upper

Cretaceous Sediments in Southeastern Bida Basin, Nigeria: Implications for Age and Paleoenvironments. *Ozean Journal of Applied Sciences*, 2 (3), 291 – 305.

Ojo, O. J. and Akande, S. O. (2006). Sedimentological and Palynological studies of the Patti Formation, South Eastern Bida Basin, Nigeria: Implications for Paleoenvironments and Paleogeography. *Nigerian Association of Petroleum Explorationist Bulletin,* 19 (1), 61 – 77.

Onoduku, U.S. (2013). The Geochemistry, Palynology and Palynofacies characteristics of Maiganga Coal deposit, Upper Benue Trough, Northeastern Nigeria. An unpublished PhD Thesis. Federal University of Technology, Minna, Nigeria. pp 179.

Peters, K. E. (1986). Guidelines for Evaluating Petroleum Source Rock Using Programmed Pyrolysis. *The American Association of Petroleum Geologists Bulletin,* 70 (3), 318 - 329.