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

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## 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 the palynological analysis. The ditch cuttings analysed were sampled from the pilot exploratory well drilled at Kudu of the Central Bida Basin. The well was drilled to a depth of 71 m and sampled at 1 metre interval giving a total of 71 ditch cuttings. The studied samples are mainly sandstones, mudstones and coaly carbonaceous shales. Palynological analyses were performed on the 71 samples obtained from the well using the conventional acid method of palynological preparation technique and the microscopic analysis of the palynoslides. The well is very rich in palynomorphs both in terms of taxonomical species and quantity and has afforded a clear interpretation of the paleohistory of the section of the basin penetrated. Palynomorphs identified include *Monocolpites*sp, *Proteaciditessigalii*, *Psilatricolporites*sp, *Tricolporopollenites*sp, *Acrostichumaureum*, *Cyathidites*sp, *Laevigatosporites*sp, *Rugulatisporitescaperatus*, and *Verrucatosporites*sp. Three (3) palynostratigraphic zones from Late Campanian to Early Maastrichtian are proposed. The zones, in stratigraphically ascending order, are as follows:***Proteaciditessigalii – Psilotricolporites*sp interval range zone, *Longapertitesvandeburgii – Longapertitesmicrofoveolatus Concurrent range* zone and *Monocolpitesmarginatus - Inaperturopollenites sp. Interval range zone.*** 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 occasionally inundated by marine incursion. The inferred paleoclimate ranged from Savanna to Rainforest as evidenced from the diagnostic palynoforms. Also, the paleoclimate, paleoenvironment and age of the penetrated strata of the basin indicate a good hydrocarbon prospectivity potential for the basin though with prevalence of dry gas.

**Keywords:** Palynomorph, Kudu, Agaie, Palynoslides, Campanian, Maastrichtian, Paleoenvironment, Paleoclimate, Palynological Marine Index.

## 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

ock-Eval in petroleum exploration studies. Palynology deals with the study of plant remains in e sedimentary successions and their applications in biostratigraphy.Palynological zonation is e characterization and subdivision of sedimentary strata on the basis of palynomorphs content. is differentiation allows small scale units to be dated, correlated and interpreted within a ecise framework of geologic time (Odededeet *al.*, 2016). The Bida Basin is a NW-SE trending at-shaped intracratonic sedimentary basin bounded in the north by Kotangora town in Niger ate and in the south by basement rocks slightly beyond the rivers Benue-Niger confluence arLokoja town (Figures 1 and 2).

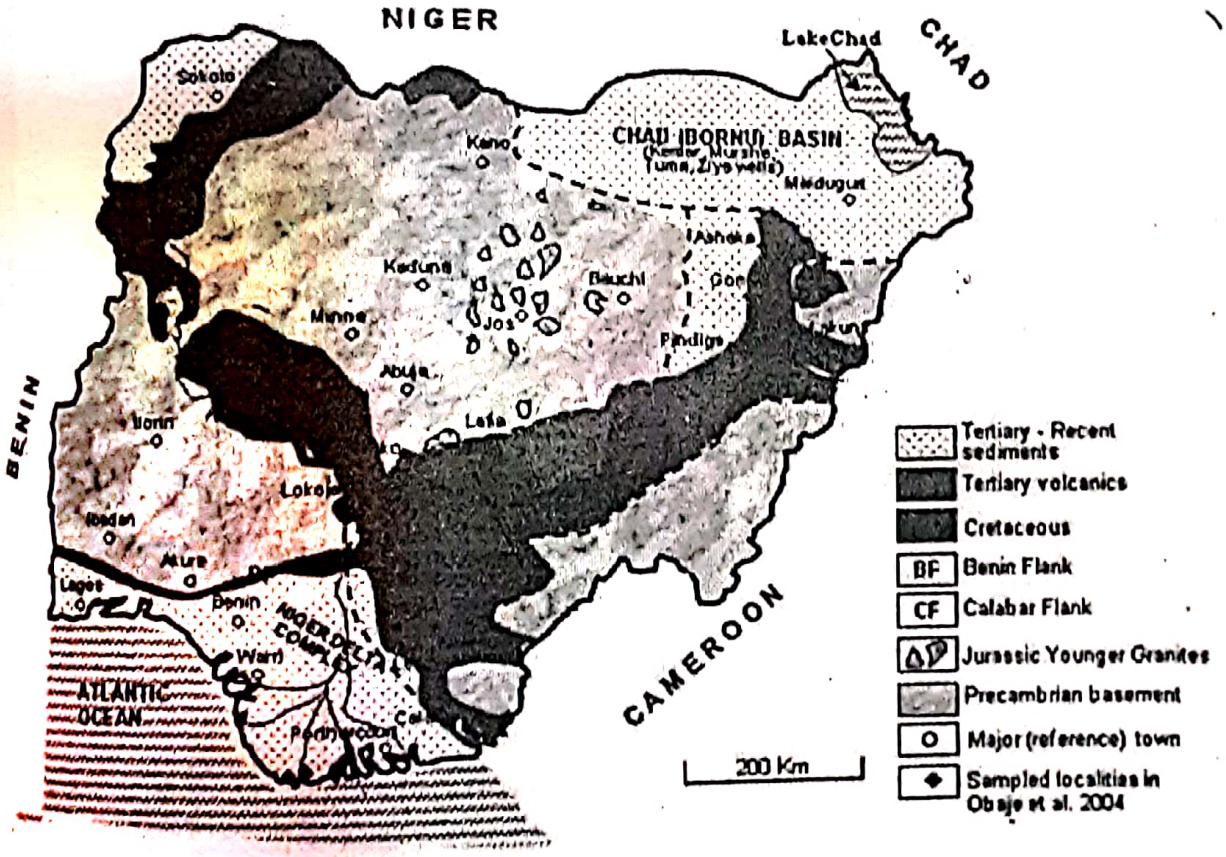



Figure 1:Sketch geological map of Nigeria showing location of Bida Basin (After Obaje*et al.*,2011).

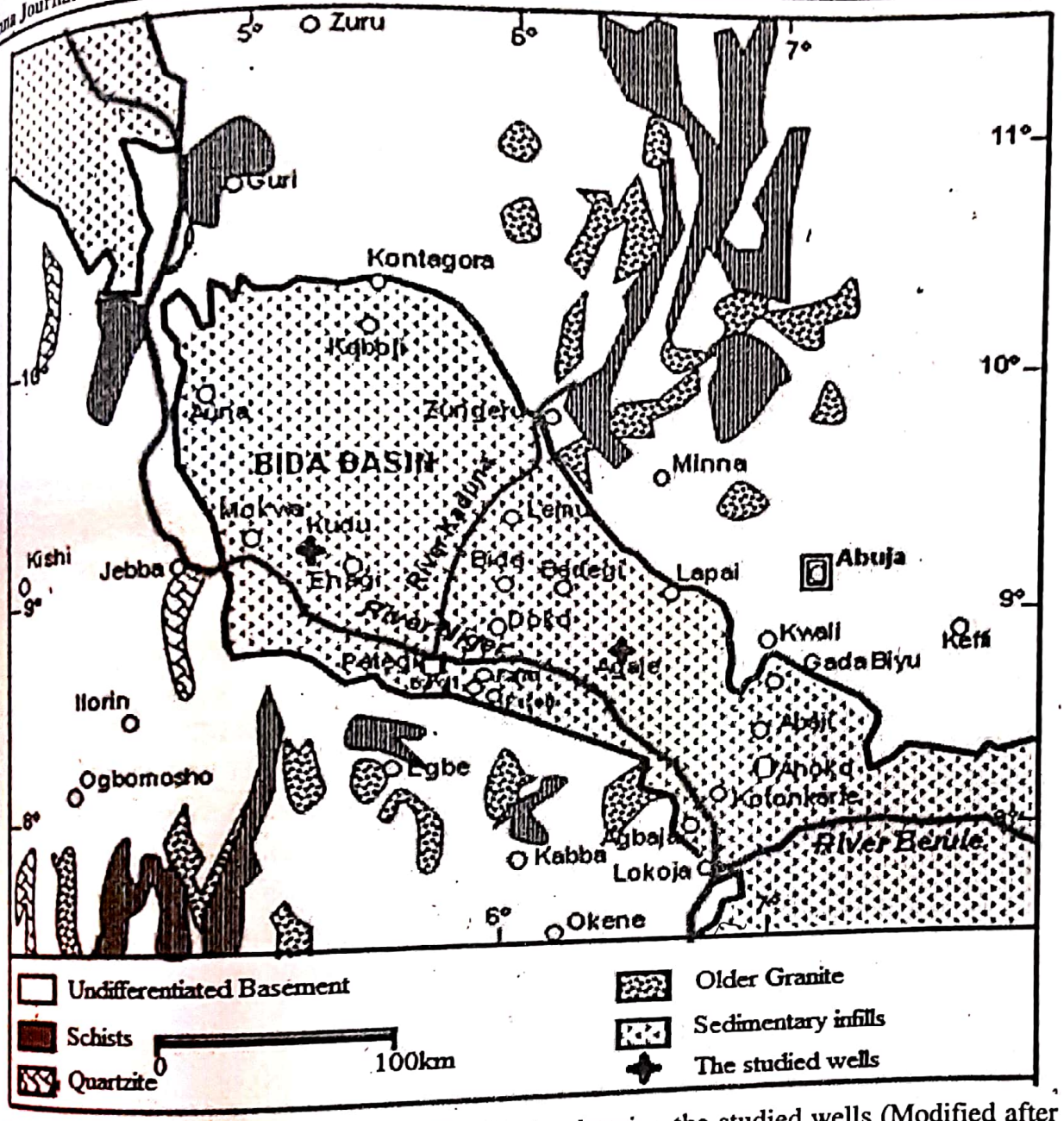



Figure 2: Geology and location of the Bida Basin showing the studied wells (Modified after Obajeet al., 2011).

The insistence of the Federal Government of Nigeria to extend the search for petroleum to the inland basins which are hitherto left unexplored, coupled with the emergence of petroleum-like substance seepages observed along the bed of river Nigerwithin the basin necessitated this research. The petroleum seepages occurred at three points directly opposite Pategi village, about 200 meters north of old Muregi village in January 1998 and a team of Geologists (including the lead author of this paper) 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 (Akandeet al., 2005;Ojo and Akande, 2006;Ojo, 2009;Obajeet al., 2011). However, the results of the previous studies notwithstanding, the results of this study in which well cuttings (sub-surface samples) were used for the palynological

ysis are believed to be more accurate and reliable in terms of palaeoenvironment deductions he basin. The aim of this study is to determine the Palynomorph composition, establish the nostratigraphy and date the sections penetrated by the two wells within the basin and on the s of the above, assess the hydrocarbon prospects of the basin.

## tigraphy of the Bida Basin

e geological setting and stratigraphy of the Bida basin have been described extensively by e previous authors, notablyAkande*et al.* (2005)and Obaje*et al.*(2011).The Bida basin is graphically divided into two sub-basins, namely; the Northern Bida sub-basin and the uthern Bida sub-basin. The two sub-basins are made up of distinct lithological units which ect lateral time and textural equivalents.

## rthern Bida Basin

### e Bida Sandstone

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

### e Sakpe Ironstone

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

### e Enagi Siltstone

cording to Obaje*et al.* (2011),theEnagi Siltstone consists mainly ofsiltstones and correlate h the Patti Formation in the Southern Bida Sub-Basin. Other subsidiary lithologies include dstone-siltstone admixture with some claystones. Fossil leafimpressions and rootlets have en found within the formation. The formation ranges in thickness ofbetween 30m and 60m.

### e Batati Formation

is formation constitutes the uppermost units in the sedimentary sequence of the Northern Bida sin. 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 fresh water fauna (Obajeet al.,2011).

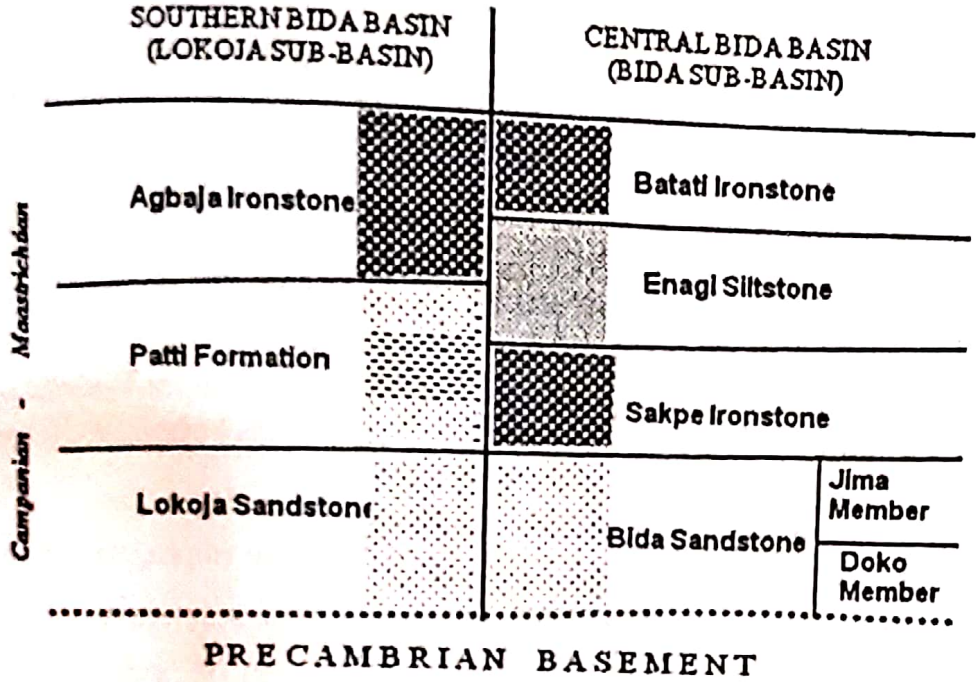



Figure 3: Stratigraphic succession of the Bida basin (After Obajeet al., 2011).

## 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 ofthis sequence especially the fining upward character, compositional and textural immaturity and unidirectional paleocurrent trends, suggest afluvial 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 Abajion the Lokoja-Abuja expressway. This formation consists of sandstones, siltstones, claystones and shalesinterbedded 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 (Obajeet al., 2011). Trace fossils (especially Thallasinoides) are frequently preserved. Interbeddedclaystones are generally massive and kaolinitic, whereas the interbedded grey shales are frequently carbonaceous. The subsidiary sandstone units ofthe 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 ofthe Batati Formation on the northern side ofthe basin. 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 Biostrtigraphy 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*TrochaminaandTextularia.* Ojo(2009) reported the occurrence of some Maastrichtian marine dinoflagellates cysts and terrestrial pollen and spores from Upper Cretaceous sediment in SoutheasternBida 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.Akandeet al. (2005) studied the microfloral assemblage, age and paleoenvironment of the Upper Cretaceous Patti Formation, SoutheasternBida Basin and concluded that the abundance of Palmae pollen (*Echitriporites and Longapertites*) and the Peridopytes suggest a humid climate and Maastrichtian ages for the Formation. Other marker species identified by these authors include*Buttiniaandreeve, Retidiporitesmagdalensis, Echimoncolpites, Echitriporitestrianguliformis;CristaeturitesCristatus*which support the Maastrichtian age of the formation.

## Material and Methods

Ditch cutting samples and lithological log from the drilled wells served as the materials used in this study.Seventy-One ditch cutting samples were processed for the palynological studies. The standard palynological preparation and microscopic examination methods with modifications from procedures used at MosunmoluPalynological Laboratory, Lagos were employed in this study.

**PalynologicalAnalysis**

A constant weight (20 g) of each sample was treated with hot hydrochloric acid 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 hydrochloric acid (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 studied well. The quantitative values of these palynomorphs are shown in the form of distribution charts in Figures 4.A total of 1,715palynomorph counts were recorded from the studied well.

The investigated well is characterized by almost barren to very poor presence of palynomorphs with very few representations of some palynomorphs species at upper parts of the well.Abundance of palynomorphsbegins from 30 m depth in the studied well with scarce palynomorphsoccurrence above this depth in the well. Palynostratigraphically, the studied well can be zoned into threepalyzones based on the recovered palynoforms. These are:

### *Proteaciditessigalii* – *Psilastenocolpites* sp. Interval Range Zone

This zone occurs between 66 m – 70 m in the studied well. The zone is characterized by the first downhole occurrence (FDO) of *Proteaciditessigalii* while the base is marked by the last downhole occurrence (LDO) of *Psilastenocolpites*sp. Other characteristics palynomorphs of this zone include *Echitriporitestrianguliformis*, *Proxapertitescursus*, *Longapertites*sp,*Constructipollenitesineffectus*, *Monocolpopollenitessphaeroidites*, *Tricolpitescooksonii* and *Syncolpites*sp. The zone is dated Santonian (?) based on the presence of the *Psilastenocolpites*sp.

### *Longapertitesvandeburgii* – *Longapertitesmicrofoveolatus Concurrent Range* Zone

This zone occurs between 30 m – 66 m in the studied well.The zone is characterized by the concurrent appearance of *Longapertitesvandeburgii and Longapertitesmicrofoveolatus*within the above defined stratigraphic depth.Diagnostic palynomorphs include*Inaperturopollenites*sp, *Proteaciditessigalii*, *Psilatricolporites*sp, *Tricolporopollenites*sp, *Acrostichumaureum*, *Cyathidites*sp, *Laevigatosporites*sp, *Verrucatosporites*sp and*Rugulatisporitescaperatus*. This zone is datedCampanian based on the listed palynomorphs.This zone is equivalent of *Dinogymnium*spp-*proteaciditessigalii* of Jan Du Chene*et al.* (1978).

### *Monocolpitesmarginatus* – *Inaperturopollenites sp. Interval Range Zone*

This zone occurs between 0 m – 30 m in the studied well. The zone is defined by the first downhole occurrences (FDOs) of *Monocolpitesmarginatus* and*Inaperturopollenites*sp within the stated depth range above. The characteristic palynomorphsinclude Polypodiaceoisporitessp, *Cyathidites*Sp, *Tricolporites*sp, *Proteaciditessigalii*, *Psilatricolporites*Sp, *Monoporitesannulatus*, *Echitriporitestrianguliformis*, *Ephedripites*sp, *Cingulatisporites*sp., *Acrostichumaureum*, *Verrucatosporites*, *Cyathidites*sp, *Cyathidites minor*, *Graminidites*and*Zonocostitesramonae*.The zone is datedMaastrichtian and it is the equivalent of the Auriculopollenitesreticulatus zone of Jan Du Chene*et al.* (1978).

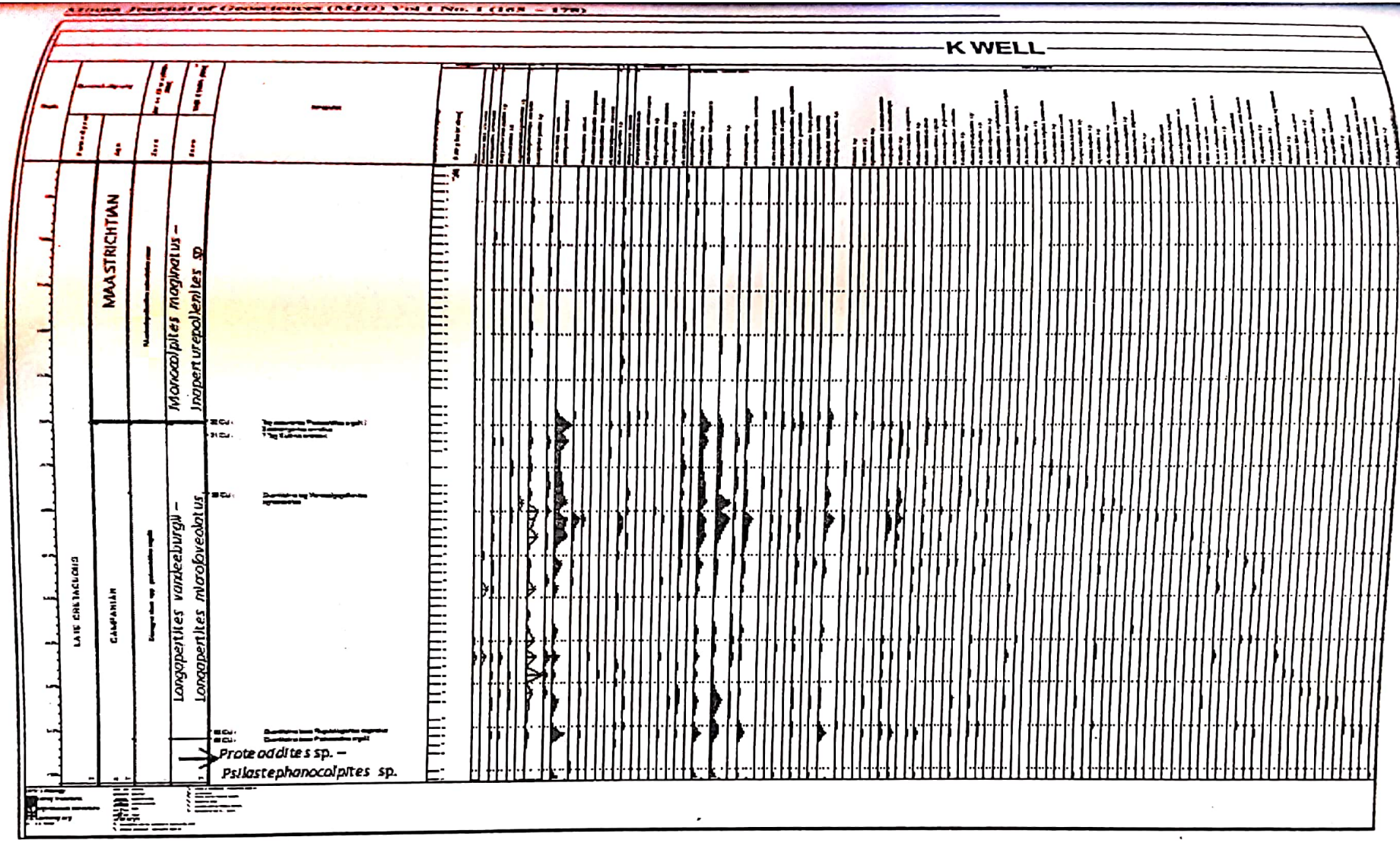



Figure 4: Palynomorph distribution chart for the studied well.

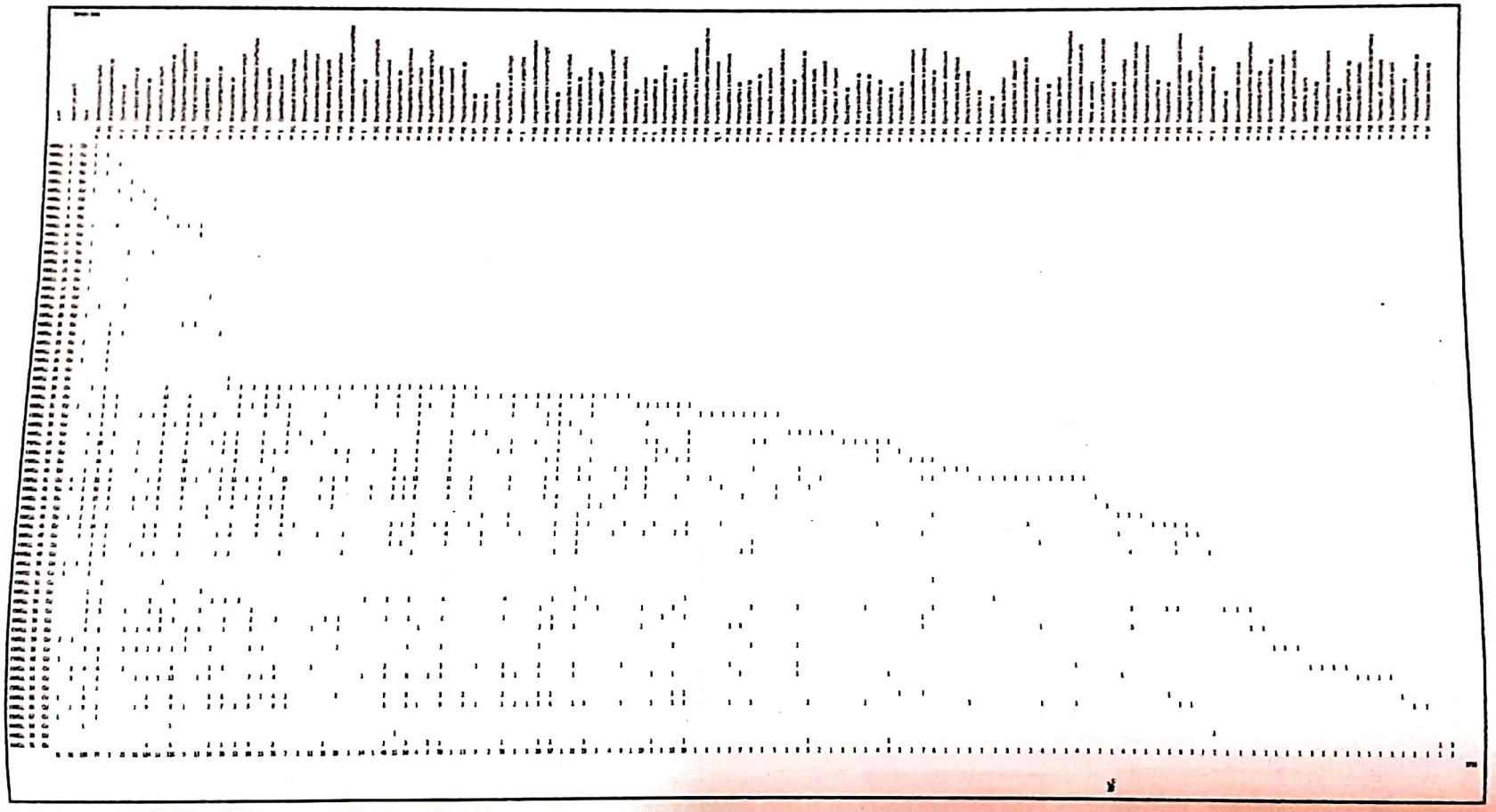


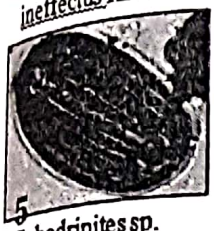
Figure 5: Palynomorph distribution chart of the studied well (Excel form).

1.Constructipollenites ineffectus K30

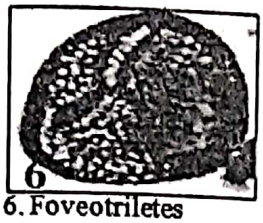
2. Proteacidites Longispinosus K30

3. Monocolpites marginatus (K30)

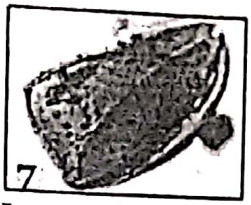
4. Gleicheniidites senonicus(K30)



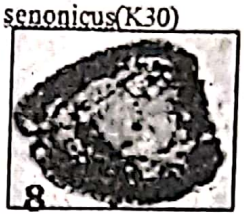
5. Ephedripites sp. (K30)



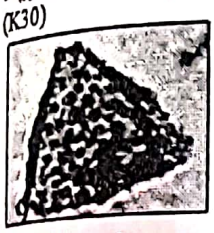
6. Foveotriletes margaritae(K30)



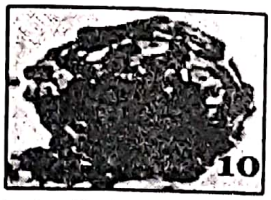
7. Longapertites sp. (K30)



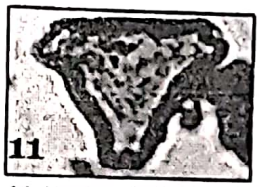
8. Distaverrusporites simplex K30)



9. Echitriporites trianguliformis(K30)



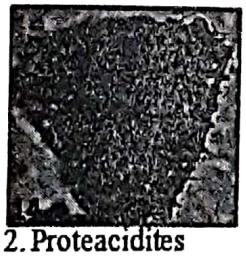
10.Buttinia andreevii (K30)



11. Proteacidites sigalii (K30)

12. Ephedripites sp. (k30)

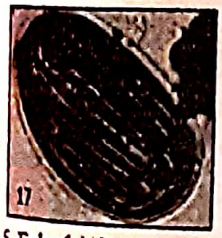
1.Constructipollenites ineffectus K30



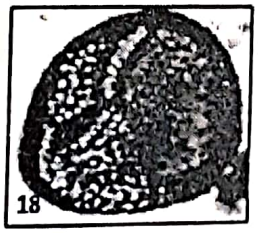
2. Proteacidites Longispinosus K30

3. Monocolpites marginatus (K30)

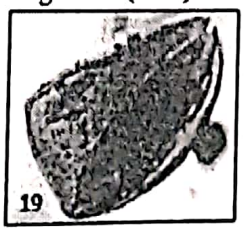
4. Gleicheniidites Senonicus (K30)



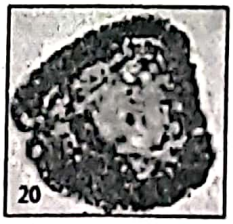
5. Ephedripites sp. (K30)



6. Foveotriletes Margaritae (K30)

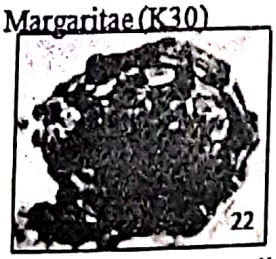


7. Longapertites sp. (K30)



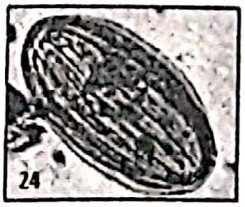
8. Distaverrusporites simplex (K30)

9. Echitriporites trianguliformis (K30)



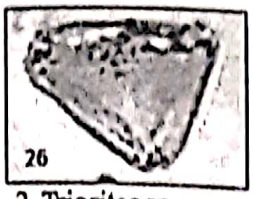
10.Buttinia andreevii (K30)

11. Proteacidites sigalii (K30)



12. Ephedripites sp. F35/3 (k30)


1.Perotriletes pannuceus (K32)



2. Triorites sp. (K35)

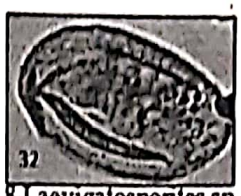
3. Retitricolpites sp. (K39)

4. Proxapertites cursus Y57/1(K39)

6 Longapertites marginatus (K40)

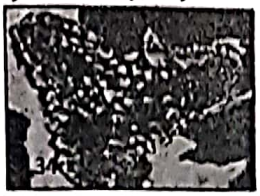
6. Tubistephanocolporites cylindricus(K46)

7.Polypodiaceoisporites sp. (K41)



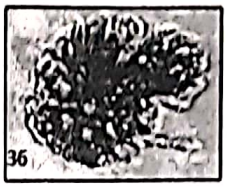
8.Laevigatosporites sp. (K16)

9 Cingulatisporites ornatus (K38)



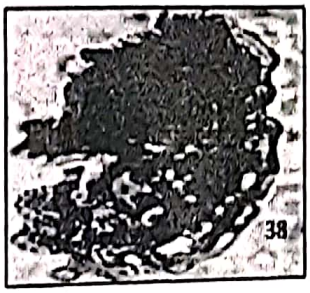
10.Trichotomosulcites sp. (K71)

11.Zlivisporites blanensis (K66)

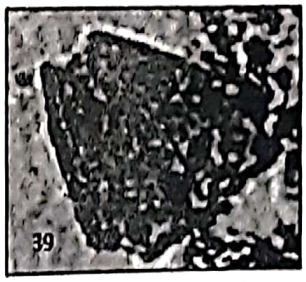


12.Botryococcus braunii (K66)


1.Ctenolophonidites costatus (K40)



2.Periretisyncolpites sp. (K40)



3.Proteacidites dehanni (K40)

**Plate I: 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 ranged from Savanna to Rainforest as evidenced from the diagnostic palynoforms. Age – Late Campanian – Early Maastrichtian.

Hydrocarbons Prospect

Litostratigraphically, the coal facies can serve as the source rocks while the sandstones serve as reservoir rocks. 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 1 or 2 kerogen which is an indication of gas prone environment. However, oil seepages observed along Muregi-Pategi axis along the River Niger bed calls for a follow-up investigation for possible large quantity of oil.

## Conclusion and Recommendations

The Studied sections of the Bida basin are zoned into two biozonation, dated Late Campanian – Early Maastrichtian with total of 1,715 palynomorphs for the well. 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;

(1) Drilling of deeper wells to obtain samples for more analyses;
(2) Detailed geochemical analyses should be performed on the ditch cuttings for more reliable appraisal of the petroleum potentials of the basin; and
(3) Correlation of the studied wells with some productive wells in other basins in the Country for better understanding of the Bida basin.

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