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HIGH RESOLUTION PALYNOLOGICAL STUDIES OF UPPER CRETACEOUS SUCCESSION OF MBEJI-1 WELL, CHAD BASIN, NIGERIA

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Abstract The Late Cretaceous succession penetrated by Mbeji-1well in the Central Chad Basin, North East Nigeria was investigated for its palynological content. This investigation produced biostratigraphically significant Pollen, Spore and dinoflagellate cyst. The studied interval penetrated a sequence of clay, sandstone, shale, shally sandstone, sandy shale and sandstone, occuriing at different intervals in all the wells. Based on the stratigraphic distribution of the palynomorphs from the Mbeji-1 –well. Twelve informal assemblage palynozones and six dinoflagellate assemblage biozones spanning the Upper Cretaceous were identified in the Chad Basin, Nigeria. The zones are: Assemblage Zones I-IV (Cenomanian); Assemblage Zone V (Turonian); Assemblage Zone VI,VII,VIII, and IX (Coniacian-Santonian); and Assemblage Zones X,XI, XII, and XIII (Campanian-Maastrichtian) for the Pollen/Spore biozones.. The age determinations are based on the known stratigraphic ranges of pollen, spores and dinoflagellate and their relative stratigraphic positions. Data from the studied well revealed that generally in the basin, there is relatively higher frequency of the land derived pollen and spores compared to marine palynomorph abundance, which suggests a paralic condition of continental to shallow marine environment. The shallow marginal marine environment is further supported by the presence high diversity of dinoflagellate species and foram test linings at some depths which are indicative of marine paleoenvironment i.e. neritic environment.
Keywords: Palynology, Chad Basin, Nigeria, Cretaceous, Mbeji -1 Well

I. INTRODUCTION

High Resolution Palynology was carried out On Mbeji-1 Well drilled by the Nigerian National Petroleum Corporation (NNPC) in the Nigerian sector of the Chad Basin as exploratory wells and this well was drilled to a total depth of 3720meters,.The well was selected for this work based on its depth of penetration, distribution along the structural Sub Basin i.e. Maiduguri in the South, Gubio in the West and Lake Chad in the North and along the basin deposition fault controlled axis. Sampling was done at 10-20 metres interval and ditch cutting samples were heavily relied upon for the analysis as there were no logs and core data available, coupled with the lack of outcrop exposure in the area.

II. LOCATION OF THE STUDY AREA.

The study area is located within latitudes 13^0N and 12^0N and longitudes 14^0E and 13^0E, north of Maiduguri near Gajigana where Mbeji-1 was studied out of the twenty three wells drilled .

*A. Geology of The Chad Basin***.**

Several workers have come up with different stratigraphic schemes for the Chad basin, with the earlier workers basing their stratigraphic interpretations on extrapolation from adjoining basins, others on seismic sections and the more recent once on the combination of seismic and well cuttings, which gave a more accurate lithostratigraphic description.*Bima Formation* This unit forms the basal sequence of sediments in the Chad Basin. It is of late Albian to early Turonian age, with thickness of between 100m to over 3000m of poorly sorted and thickly bedded feldsparthic sandstone, unconformably overlying the Precambrian crystalline basement. Outcrops of the formation have been found in both Chad and Benue Basins. However, the thickness of the formation is reduced along the Zambuk ridge separating both basins. *Gongila Formation* This formation is a transition between the continental Bima Sandstone that underlies it and the marine Fika Shale, which overlies it.

It is of Turonian age and shows a maximum thickness of 500m . The formation is mainly composed of intercalation of sand, shale and limestone. The base of the sequence is defined by the first appearance of marine limestone above the Bima Sandstone. The basal limestone is about 3m thick and consists of non-fossilferous and shelly variety as well as Ammonites of Lower Turonian age.[3]

1. Fika shale Overlying the Gongila Formation is the marine Fika Shale. The Fika Shale is late Turonian to Senonian in age and it is composed of blue-black shale, occasionally gypsiferous with thin limestone intercalations.The unit outcrops in a narrow belt-trending north from Tilde and Tongo villages in the south until it disappears beneath the Chad Formation to the north east of Fika.

2.*Gombe Formation* This unit forms an almost continuous and generally north trending belt some 250km long and 20km wide. It is a sequence of estuarine and deltaic sedimentation consisting of sandstones, shale, siltstone and ironstone. The sequence is best developed in the southwestern portion of the basin where it attains a thickness of about 350m.

3.Kerri-kerri Formation The Kerri-Kerri Formation is composed of continental sequence, which dips northeast beneath the Chad Formation and lies unconformably on the folded Cretaceous sedimentations. They contain alternating layers of clayey grit, grit and sandstone with well developed cross-bedding indicating lacustrine and deltaic environments respectively. The sequence is often capped by thin laterite, which may either be oolithic or vesicular in texture. The Kerri-Kerri Formation is similar to Bima Sandstone in terms of depositional conditions, but Bima Sandstone differs from the Kerri-Kerri Formation by the feldspathic nature of the sediment..

4. *Chad Formation* This formation is a variable sequence that includes all quaternary sediments of lacustrine origin underlying the surface deposit over a vast area in the chad basin. the chad formation unconformably overlies the fika shale in some parts of the basin due to non-wide spread occurrence of both the gombe sandstone and kerri-kerri formation which are mainly restricted to the southwest part of the basin. towards the center of the basin, lacustrine clays are predominant in the sequence, but near the margins, fluviatile sands, grits and gravels become more predominant.the chad basin resulted from plate divergence along the west africa continental margin. the basin is believed to be the vestige of the fragmentation and dispersal of gondwanaland, like other mesozoic - cenozoic sedimentary basins of central west Africa

III. REVIEW OF PREVIOUS BIOSTRATIGRAPHIC WORK

Only few published information on the biostatigraphy of the Chad Basin is available. Paleontological investigations were based mainly on ammonites, vertebrate, fish and reptile remains used to correlate and age date the formations.Bima Formation is thought to be of Upper Albian – Lower Turonian in age. Lateral equivalents contain Upper Albian Ammonites in the neighbouring Benue province and since Lower Turonian Ammonites occur in overlying sediments, the Upper Albian-Lower Turonian age is assumed.

Reyment assigned a Lower Turonian age to the Gongila Formation based on the presence of numerous ammonites of that age [13].

The Fika shale overlies the lower Turonian Gongila Formation and with this fact together with the presence of some vertebrate fossils (fish and reptile remains) suggests a Turonian to Maastrichtian age. Both the Gombe Sandstone and Kerri-Kerri Formation have been dated based on the palynological data as Upper Maastrichtian to Paleocene and Paleocene ages, respectively. The dating of the Chad Formation is based on vertebrate remains of lower Pleistocene and Diatoms, which are not older than the Pleistocene. Few species of foraminifera for the Turonian of the northeast part of the Benue Trough, which constitutes the southern fringe of the basin, were reported and published by Dessavaugie [4].

Obaje described the foraminiferal microfauna from the upper section of the Pindiga Formation. In his analysis, the top of the Pindiga Formation yielded an abundant entirely arenaceous assemblage [7]. The Numanha shales sampled at the type locality yielded monospecific arenaceous foraminiferal microfauna. The arenaceous assemblage includes *Ammoastuta, Haplophragmoides, Ammobaculites* and the poor presence of *Ammomarginulina, Spiroplectammina* and *Miliamina*. A hyposaline marshy depositional environment was suggested for the upper unit of the Pindiga Formation on the basis of low diversity and high dominance of hyposaline micro fauna, said to be comparable with those of tidal marshes discussed by Murat, base on the analogy with recent hyposaline marshes in parts of North America where *Miliammina* and *Ammoastuta* are the dominant taxa.

Ojo and Akande carried out an integrated study involving sedimentological, Palynological and organic geochemical analyses of the Cenomanian to Coniacian succession in the Gongola and Yola Basins of which lateral equivalents exist in the Chad Basin [8]. The palynoflora assemblage reflects a transition from a Cenomanian near shore marine to full development of marine water during the Turonian to Cenomanian times. Some Authors [5] carried out the only published sequence stratigraphic analysis using heterohelicids from Pindiga Formation. In their proposed scheme, the Pindiga Formation was divided into lower, middle and upper portion on the basis of the distribution of the heterohelicid foraminifera and they identified the maximum flooding surface within the middle Pindiga, which correspond to the maximum diversity and abundance of the planktonic heterohelicids.

From all the published work so far carried out on the Chad basin, none have studied the palynology of the basin from the Bima Formation up to the Chad Formation in a holistic manner, taking into consideration the whole palynological content of the sediments. The few works on the basin have restricted their findings to intervals/formations of interest.

IV. AIM OF THE STUDY

The aim of the present study is to establish the sedimentological and floral characteristics of the formations penetrated by Mbeji-1 Well, Chad Basin, Nigeria. These characteristics when established will be used in predicting the age, depositional characteristics and paleoenvironmental trends of the formation.

V. MATERIAL AND METHODS

A total of one hundred and seventy ditch cuttings samples from 550ft – 3720ft depth intervals of Mbeji-1 well were collected and sampled. From each depth-interval, about 5gm was weighed, thoroughly washed/cleaned. The pre-treatment of the samples with various Acid combinations include removal of unwanted carbonate material by washing with 10ml diluted hydrochloric acid as well as further treating the residue with 40% hydrofluoric acid and boiling hydrochloric acid to dissolve all silicates and silicofluoride gel respectively. The ultrasonic centrifuge machine further separated out the dissolved material from the organic matter residue for 2minutes. Subsequently, three drops of safarin'o dye solution dropped into the residue to stain the palynomorphs and left for few minutes to allow for proper mixing and then pipette into a cover slip glass slide on top of the hot plate until dryness and was used for palynological microscopic study. The Slide were properly labelled and observed under palynological microscope through which snapshot was taken. **Sees Plate 1** for the photomicrograph of the palynomorphs

VI. PRESENTATION OF RESULT

1. Lithostratigraphic Description

The lithologic description of the relevant sequence in these wells is based on physical inspection of the ditch cuttings from top to base and it compared favourably with the stratigraphic units outlined by Barber and Matheis [ ]in their work on the Chad Basin [ ]. The lithologic sequence of the studied interval covered a depth range of 550m – 3720m, having a total thickness of 3170m The upper 190m within the interval of 550m – 740m consists of yellow, non calcareous clay, passing into a 255m thick interval (740m-995m) of brown, non calcareous clayey sandstone. Between the interval of 1000m – 1630m, a 630m thick brown, non calcareous sandstone was encountered. **See figure 1**.

2. Palynological Result.

The occurrence of palynomorph assemblages are sporadic and vary from few in some depths to common in others. The intervals 2000m and 2740m have the highest number of species (34), while depths 860m, 1380m, 1740m, 2250m, 2480m, 2520m, 2740m, 2860m, 2900m, 2990m, 3120m and 3180m have highest number of individual, i.e. over 1000 forms with depth 2520m having 1875 forms with *smooth trilete spore* accounting for 1002 forms (See plate 1).
Intervals 550m, 620m, 740m, 1460m, 1500m, 2310m and 3720m contains between one to ten individual forms. Within interval 1540m – 2660m, the pollen palynomorphs range in percentage 10.0% to 97.0% interval 1540m. The spore palynomorph within this interval ranges from 2.4% to 88.0% in interval 2160m. Dinoflagellate ranges from 0.6% to 64.0%. The percentage occurrence of foram test linins within this interval is 0.9% in depth 1580m, 3.0% in depyh 2040m, 1.0% in depth 2500m and 3.0% in depth 2660m. Algae percentage occurrence is 7.0% in depth 1660m and 0.1% in depth 2250m, wwhile the percentage occurrence of diatom within the interval is 1.4% in depth 1580m and 1.0% in depth 2160m. The interval 2700m is composed of 98.0% pollen palynomorph and 2.0% dinoflagellate cyst.. The interval 2740m – 3520m is basically composed of pollen, spore, dinoflagellate and foram test linings, with some sporadic occurrence of algae and diatom .On the basis of First Appearance Datum (FAD) or Last Downhole Occurrences (LDO) of three or more diagnostic species of palynomorphs forms; pollenThe biozones for the well are described below

(A) Biozonation- pollen and spores biozone

*(i) Biozone I- Tricolpites clarensis (3660m-3720m)*The base of this zone is the same as the base of the well (appendix 9). The species encountered in this zone ar**e** *Tricolpites clarensis, Retimonocolpites pluribaculatus, Tricolporate sp, Exesipollenites sp and Ericaceae sp.*The top of the zone is defined by the last downhole occurrence of *Osmundacidites wellmanii, Ephedrites sp, Araucariacites australis and Ephedripites multicostatus.*

(ii) Biozone II- Ephedripites multicostatus (3640m-3660m) The base of this zone is the same as the top of zone I. The top is characterized by the last downhole occurrence of *Ephedripites ambiguus and Raistrickia obtusispina.* Species in this zone include *Osmundacidites wellmanii, Ephedrites sp, Araucariacites australis and Ephedripites multicostatus.*

*(iii) Biozone III- Ephedripites ambiguus (3600m-3640m).*The base of this zone is the same as the top of zone II. The events marking the top of the zone are the last downhole occurrence of *Verrutricolporites rotundiporus, Steevesipollenites sinuosus, Lycopodiumsporites fastiginoides and Classopollis brasillensis.* Forms in this zone include *Ephedripites ambiguus and Raistrickia obtusispina*

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(iv) Biozone IV- Verrutricolporites rotundiporus (3560m-3600m) The base of the zone is the same as the top of zone III. Events at the top are the last downhole occurrence of *Syncolpites sp, Hexacolpotriporites emalianovi, Droseridites senonicus and Afropollis jardinus.* Forms in this zone include *Verrutricolporites rotundiporus, Steevesipollenites sinuosus, Lycopodiumsporites fastiginoides, Classopollis brasillensis and Triorites tenuiexinus.*

(v) Biozone V- Droseridites senonicus (3320m-3560m) The base of this zone is the same as the top of zone IV. The top of the zone is characterized by the last downhole occurrence of *Tricolporopollenites megadolium and Longapertites reticulatus.* Species in this zone include *Syncolpites sp, Hexacolpotriporites emalianovi, Droseridites senonicus, Afropollis jardinus, Verrucatosporites favus, Gabonisporis vigourouxii, Droseridites sp, Cretacaeporites polygonalis, Cupanieidites reticularis and Hexopollenites chmurae.*

(vi) Biozone VI- Tricolporopollenites megadolium (3180m-3320m) The base of this zone is the same as the top of zone V. The top of the zone is defined by the last downhole occurrence of *Proteacidites sigalli, Foveotriletes margaritae, Syncolporites planiverrucatus, Inaperturopollenites cf. undulatus, Ephedripites regularis and Echitriporites triaguliformis.* The forms in the zone include *Tricolporopollenites megadolium, Longapertites reticulatus, Rugulatisporites sigalii, Monocolpopollenites ovatus, syncolporites subtilis and Trifossapollenites ruosei.*

(vii) Biozone VII- Proteacidites sigalli (2990m-3180m) The base of this zone is the same as the top of zone VI. The events marking the top are the last downhole occurrence of *Retimonocolpites obaensis, Ericaceaepollenites sp and Lygodium reticuliformis.* Forms in this zone include *Proteacidites sigalli, Foveotriletes margaritae, Syncolporites planiverrucatus, Inaperturopollenites cf. undulatus, Ephedripites regularis, Echitriporites triaguliformis, Syncolporites sowunmiae, Monocolpopollenites sphaeroidites, Monocolpites marginatus, Auriculicidites reticulatus, Proteacidites dehaani, Cingulatisporites ornatus, Echitriporites minor, Steevesipollenites multillineatus, Equisetosporites lawaii, Triporate sp and Granulatisporites tuberculatus.*

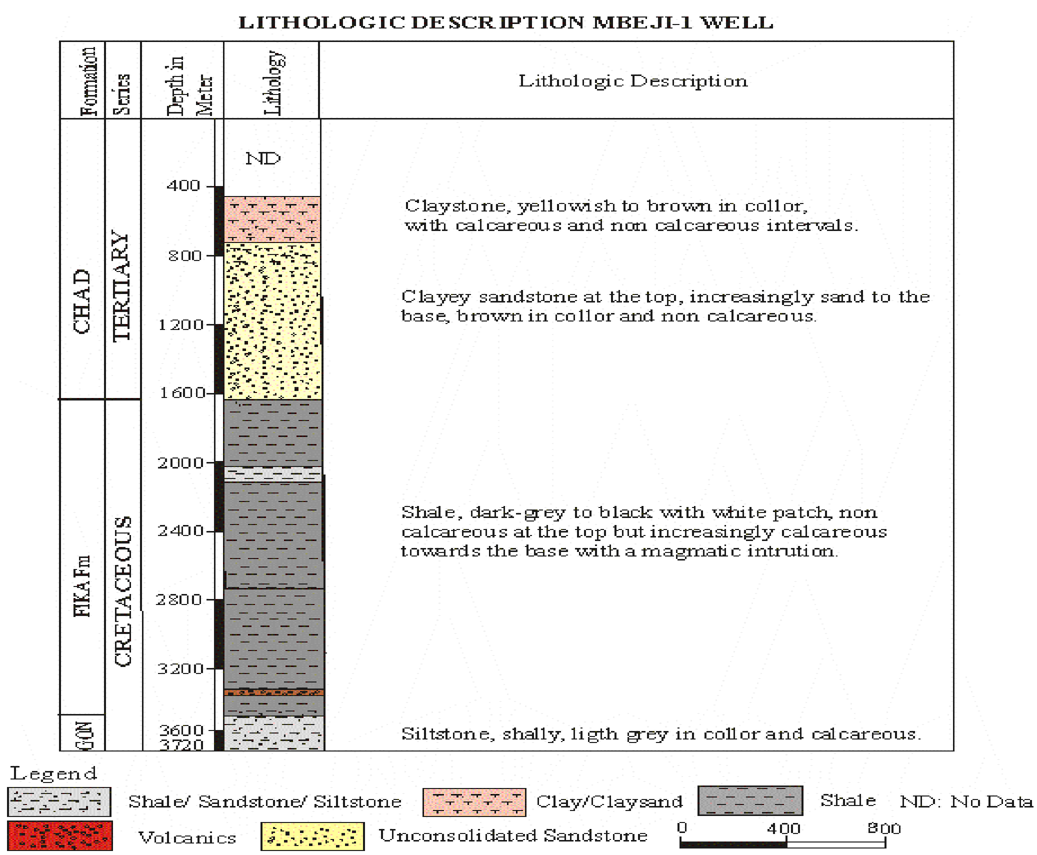

Figure 1: Lithographic Description of Mbeji-1 Well

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PLATE 1

1.Droseridites senonicus, 2.Psilatricolporites operculatus 3. Proteacidites sigalii 4. *Classopollis brasiliensis*

5. *Zlivisporis blanensis* 6. *Syncolporites subtilis* 7. *Tricolpites clarensis* 8. *Rugulatisporites caperatus*

9. *Araucariacites australis* *10. Cretacaeiporites polygonalis*

(B) Age characterization -pollen and spore biozone

-The erected biozones are compared with the palynoforal zonation schemes defined by Lawal and Moullade, Salard-Cheboldaeff , Eisawi and Schrank and Abubakar et. al [1,13,14and15].

(i) Assemblage zones I, II, III and IV of Mbeji-1Well-1 all falls within the Cenomanian age. The occurrence of *Triorites tenuiexinus, Classopollis obialosensis, Ephedripites costaliferous, Ephedripites ambiguus, Ephedripites multicostatus, Triorites africaensis* and the other forms constituting the biozones have been reported in Cenomanian

sediments by Salard-Cheboldaeff [13]. These palynozones based on the stratigraphic positions and the series of last downhole occurrence of key species corresponds to the *Triorites africaensis* zone of Lawal and Moullade and Abubakar et al which is aged Cenomanian. Palynomorph assemblage zones V of Mbeji-1 Well fall within the Turonian age. The occurrence of *Monocolpopollenites sphaeroidites, Distaverrusporites simplex, Retimonocolpites pluribaculatus, Tricolporites sp, Triporites iverseni, Periretisyncolpites giganteus, Monoporites annulatus, Distaverrusporites simplex, Exesipollenites tumulus* and *Droseridites senonicus* have been reported in Turonian sediments by Salard-Cheboldaeff, Lawal and Moullade and Abubakar et al [1,13,and 15]. These palynozones based on the stratigraphic positions and the series of last downhole occurrence of key species corresponds to the *Cretacaeiporites scabratus* zone of Lawal and Moullade and Abubakar et al which is aged Turonian.

(ii) Assemblage zones VI, VII, VIII and IX of Mbeji-1 well all fall within the Conacian-Santonian age. The occurrence of *Classopollis brasiliensis, Polypodiaceoisporites fossulatus, Echitricolporites trianguliformis, Tubistephanocolpites cylindricus, Deltoidospora africana, Tricolporopollenites megadolium, Proteacidites sigalli, Retimonocolpites obaensis* and *Tubistephanocolpites cylindricus* have been reported in the Coniacian-Santonian sediments by Salard-Cheboldaeff , Lawal and Moullade, Eisawi and Schrank and Abubakar et al . These palynozones based on the stratigraphic positions and the series of last downhole occurrence of key species corresponds to the *Droseridites senonicus* zone of Lawal and Moullade and Abubakar et al which is aged Coniacian-Santonian. [1,13and 15]

(iii) Assemblage zones X, XI, XII and XIII of Mbeji-1 well all fall within the Campanian-Masstrichtian age. The occurrence of *Auriculiidites reticulatus, Praedapollis africanus, Lycopodiacidites caperatus, Echitricolporites manstellae, Spinizonocolpites echinatus, Ephedripites montanaensis, Rugulatisporites caperatus, Polypodiaceoisporites fossulatus, Psilamonocolpites magnum, Tricolpites tienabaensis, Translutencipollenites reticulatus, Syncolpites corrugatus, Ephedripites zeklinskaiae, Rhoidipites scabratus* and *Graminidites annulatus* have been reported by in the Campanian-Maastrichtian by Salard-Cheboldaeff , Lawal and Moullade , Eisawi and Schrank and Abubakar et. al. These palynozones based on the stratigraphic positions and the series of last downhole occurrence of key species corresponds to the *Proteacidites dehaani* zone of Lawal and Moullade and Abubakar et al and zones I, II and III of Eisawi and Schrank which is aged Campanian-Maastrichtian [2,9,10,11].

(C) Paleoenvironmental Interpretation

The distribution of any particular fossil assemblage in any stratigraphic section may be controlled either by palaeoecological factors or as a result of evolution. Any change in fossil assemblage that corresponds with a change in lithology is probably due to the environmental tolerance of the fossil species rather than to evolution. Some fossils serve as environmental indicators and are used to interprete ancient environments of deposition of the sediments. Also, the distribution of both body fossils and trace fossils depends on the environmental conditions that existed and the time organisms lived, died, or were buried. The application of palynological data to paleoenvironmental reconstruction has been attempted by several authors. In this study, the relative abundance of terrestrially derived pollen and spore and marine derived dinoflagellates and foram test linings are used to interprete the depositional environments of the studied wells. The pollen and spores decrease with distance from the shore. The palynofloral constituent of 0.0% - 35.0% reflects open marine; minimum of 35.0% to maximum of 60.0% reflects nearshore marine environment; while pollen and spore represented by a minimum of 80.0% to a maximum of 100% reflects continental conditions (i.e Fresh water to brackish water).

VII. DISCUSSION AND CONCLUSION

A total of 170 ditch cutting samples from Mbeji-1 well, located in Chad Basin Nigeria, were studied for their sedimentological and biostratigraphic (palynological) contents, from which palynological (pollen/spore and dinoflagellate) assemblage biozonation schemes were erected, paleoenvironmental analyses were made. The studied interval penetrated a sequence of clay, sandstone, shale, shally sandstone, sandy shale and sandstone, occuriing at different intervals in all the wells.

From the biostratigraphic result, over 300 species of Pollen, Spores and Dinoflagellate were encountered, and this yielded over 53,000 individual forms.The accessory microflora encountered are Fungal Spore, Pediastrum, Radiolaria, Foraminifera test lining and diatoms.

Based on the stratigraphic distribution of the palynomorphs from the Mbeji -1 well, Twelve informal assemblage palynozones and six dinoflagellate assemblage biozones spanning the Upper Cretaceous were identified in the Chad Basin, Nigeria. The zones are: Assemblage Zones I-IV (Cenomanian); Assemblage Zones V (Turonian); Assemblage Zone VI,VII, VIII and IX (Coniacian-Santonian); and Assemblage Zones X, XI, XII, and XIII (Campanian-Maastrichtian) for the Pollen/Spore biozones.. The age determinations are based on the known stratigraphic ranges of pollen, spores and dinoflagellate and their relative stratigraphic positions.

The usage of the pollen/spore against marine microflora plot served as an aid in the delineation of depositional environment. From the plot, the palynofloral (pollen and spore) constituent of 0.0% - 35.0% reflects open marine; 35.0%

to 60.0% reflects nearshore marine environment; while a minimum of 80.0% to a maximum of 100% reflects continental conditions (i.e. Fresh water to brackish water).

Data from the studied wells revealed that generally in the basin, there is relatively higher frequency of the land derived pollen and spores compared to marine palynomorph abundance, which suggests a paralic condition of continental to shallow marine environment. The shallow marginal marine environment is further supported by the presence high diversity of dinoflagellate species and foram test linings at some depths which are indicative of marine paleoenvironment i.e. neritic environment.

The upper part of the studied intervals showed an overall continental depositional environment as indicated by the very high percentage of terrestrially derived palynomorphs. The middle part of the studied intervals showed an overall near shore marine environment of deposition as indicated by the increase in the percentage of marine microflora.

The lower part of the studied interval revealed a sequence of deposition of both continental and marine influence as indicated by the overall high percentage of continental palynomorphs with intermittent incursion of near shore to open marine influence as seen in the percentages of these forms.

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