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PALYNOLOGICAL STUDIES OF UPPER CRETACEOUS SUCCESSION OF HERWA-1 WELL, CENTRAL CHAD BASIN, NIGERIA

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Abstract: The Late Cretaceous succession penetrated by Herwa-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 Herwa-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, Herwa-1 Well, Cretaceous, Chad Basin, Biostratigraphy

I INTRODUCTION

High Resolution Palynology was carried out On Herwa-1 Well drilled by the Nigerian National Petroleum Corporation (NNPC) in the Nigerian sector of the Chad Basin as exploratory well and this well was drilled to a total depth 4700meters respectively. 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.

Keywords: Herwa-1 well, Palynology, Chad Basin, Cretaceous

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 Herwa-1 were studied out of the twenty three wells drilled.

A. Vegetation

The vegetation found in the Chad Basin is the savanna type. A serious constraint is placed on the growth of plants due to the limited amount of rainfall and shortness of the rainy seasons. Also, the great heat of the region gives rise to high rate of evaporation and transpiration. The vegetation consists of a mixture of trees and grasses. The trees are smaller than those of the rainforest, while most of them are deciduous. The grasses range from one to five metres in height. The savanna vegetation becomes progressively poorer with increase in the length of dry season. During the rainy season, the vegetation wears a green look. But during the dry season, the environment looks bare and brown, except along water courses and depressions.The typical trees are acacia, silk cotton tree, baobao, locust bean tree, shea butter tree, oil bean tree, and reeds along watercourses. The grasses include Cenchrus biflorus, Aritida stipoidea, and Schienfeldia gracilis.

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B. Geology of the Chad Basin

The Chad Basin is the largest intracratonic basin in Africa. Some Researchers wrote that the basin is the largest area of inland drainage in Africa, occupying about 2,330,000km^2 in the Central Sahara and Southern Sudan with a diameter of 1000km [7]. In Nigeria, only 10 percent of South-West corner of the basin is situated in the North-East part of the country where the western limit is formed by the water divide between the Niger and the Chad drainage systems and the southern limit by the divide between the Chad and Benue systems (Barber, 1965).The Chad Basin resulted from plate divergence along the West Africa continental margin [6] 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. See Table 1.

III. AIM AND OBJECTIVE OF THE STUDY

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

TABLE I
STRATIGRAPHIC SEQUENCE IN THE CHAD BASIN, N-E (AFTER MATHEIS, 1976)

Age	Formation	Enviroment
Pleistocene	Chad Formation	Continental to Deltaic
Paleocene	Kerrikerri Formation	Continental
Maastrtcthian	Gombe Formation	Eustarine-Deltaic
Turonian to Santonian	Fika Shale Gongila Formation	Marine Marine – Estuarine
Cenomanian	Bima Formation	Continental

IV. MATERIAL AND METHODS

A total of one hundred and seventy ditch cuttings samples from 480ft – 4700ft depth intervals of Herwa-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. See Plate 1 and 2 for the photomicrograph of the palynomorphs

V. PRESENTATION OF RESULT

A. 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 (1965) and modified by Matheis in their work on the Chad Basin [4], For this well, the lithologic sequence of the studied interval covered a depth range of 480m – 4700m, having a total thickness of 4220m . The interval of 480m – 780m consists of yellow to brown, calcareous clay of 300m thick, passing into a 160m thick interval (800m-960m) of brown, non calcareous clayey sandstone. Between the interval of 980m – 1280m, a 300m thick brown to grey, calcareous clay was encountered. The interval between 4300m – 4520m consists of 220m thick grey, calcareous shally siltstone. The basal unit is composed of 160m thick grey, calcareous sandstone within the interval 4540m – 4700m. Based on the lithologic description, it can be inferred that the lithologic sequence penetrated from top to base can be divided into four broad lithologic types viz: cley/clayey sand unit, shale unit, sandstone-shale hybrid interval and sandstone unit. See fig. 1

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B. Palynological Result.

The palynomorphs assemblage encountered in the study is composed of Pollen, Spores, Dinoflagellates, Foraminifera Test Lining, Algae and Diatom. The results of the palynological analyses of the wells are indicated in Plate 1and 2. The percentage occurrence of pollen is about 33.5%, spores, 44.7%, Dinoflagellates 2.2%, Foraminifera test lining 0.1%, Algae 23.5% and Diatom 3.0%.Interval 500m is devoid of any palynomorphs i.e. is barren, while interval 580m – 585m is composed of 100% algae palynomophs, reducing to 0% within interval 700m – 720m, in this interval pollen constitute about 10.0%, spore palynomorphs constitute 5.0% of the forms, and Diatom makes up about 85.0%, while the interval is devoid of other palynomorphs. Interval 760m – 780m, is composed of 11.0% pollen, 60.0% spore, 26.0% algae and 3.0% diatom. Interval 800m – 820m is composed of 3.0% to 10.0% algae and 90.0% to 97.0% diatom. Interval 840m – 1000m contain 1.0% to 28.0% pollen, 16.0% to 95.0% spores and 2.0% to 96.0% algae. Interval 1020m – 1040m is composed of 25.0% to 85.0% spore and 15.0% to 75.0% algae. Within interval 1060m to 1620m, there exist basically pollen, spore, algae and some rare occurrence of dinoflagellate, foram test linings and diatom. The pollen palynomorphs range in percentage from as low as 0.5% at 1280m increasing to 70.0% in interval 1600m. The spore palynomorph within this interval ranges from 2.0% in interval 1180 increasing to 95.0% in interval 1280m. The algae palynomorph ranges from 1.0% in interval 1260m, increasing to 98.0% in interval 1240m. The percentage occurrence of dinoflagellate within the interval is 3.0% at depth 1060m, 4.0% at depth 1200m and 5.0% at depth 1580m, while 0.5% and 12.0% occurrence of foram test lining is observed at intervals 1280m and 1620m respectively. Similarly, 13.0%, 18.0%, 29.0% and 6.5% of diatom was encountered at depths 1160m, 1180m, 1569m and 1600m respectively. The percentage occurrence of dinoflagelatte became consistent between intervals 1640m to 1980m, with percentage range of 1.0% at depth 1760m to 12.0% at depth 1660m.

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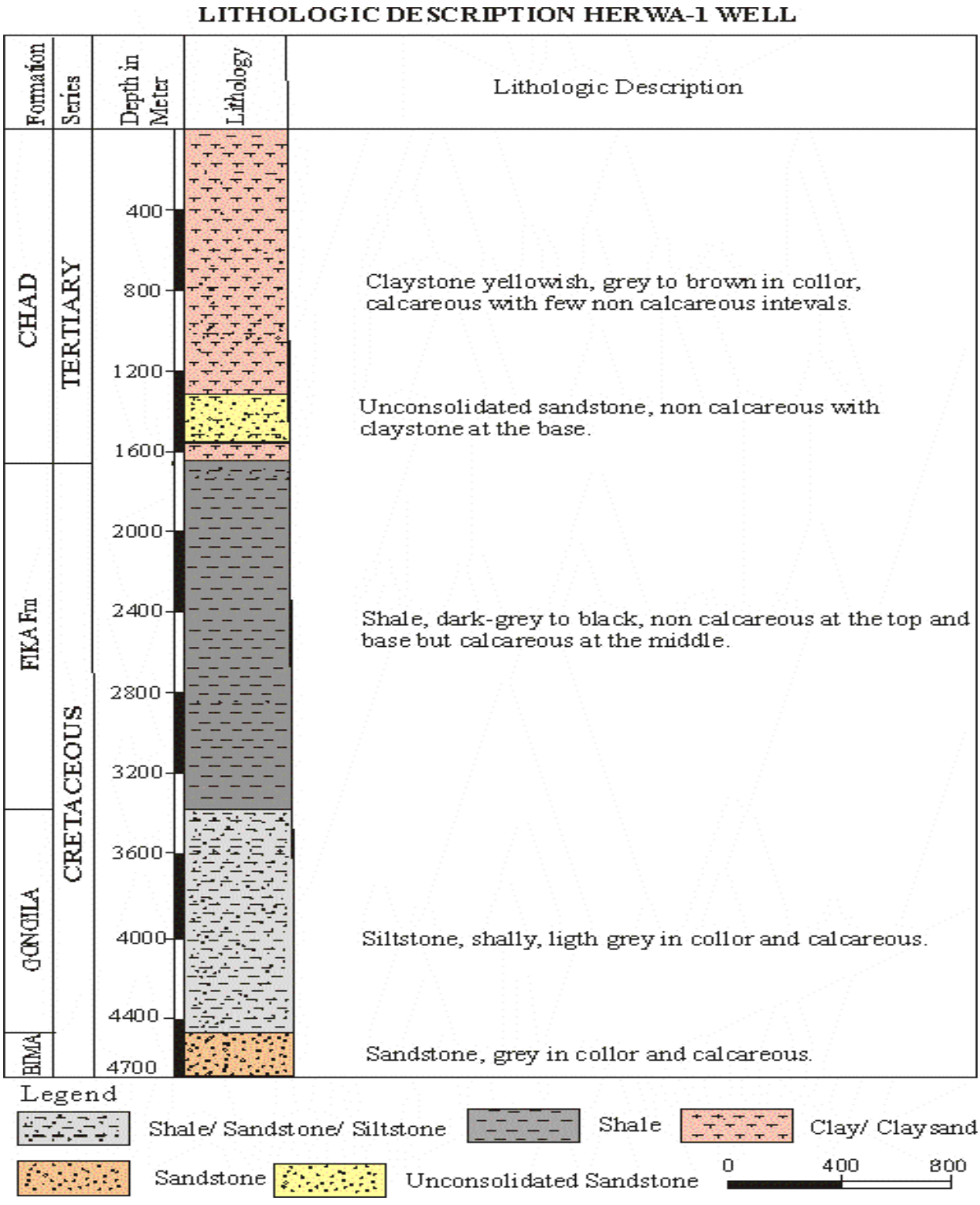

Figure 1. Lithologic description of Herwa-1 well

Also the pollen palynomorphs range from 3.0% to 69.0%, spore palynomorphs range from 16.0% to 61.0%, algae from 1.0% to 75.0% and diatom with 25.0% occurrence in interval 1880m only. Interval 1860m is devoid of palynomorphs. Pollen, spore and algae palynomorphs constitute majority of the forms within the interval 2000m to 2520m, with pollen palynomorph occurrence ranging from 9.0% to 75.0% at depth 2280m. Spore palynomorph range from 25.0% at depth 2000m to 100% at depth 2160m. Algae percentage occurrence range from 3.0% to 28.0% with the highest occurrence at depth 2200m, while few species of dinoflagellate, foram test linings and diatom were encountered at depths 2140m, 2180, 2120 and 2420 with 4.0%, 7.0%, 3.0% and 4.0% occurrence respectively.

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The percentage occurrence of pollen palynomorphs within intervals 2540m to 3060m range from 9.0% to 94.0% within intervals 2540m to 3040m. Interval 3060m is devoid of pollen microflora. Spore palynomorph occurrence range from 6.0% to 88.0%. Dinoflagellate occurred within intervals 2680m, 2900m, 2980m, 3000, and 3020m with percentage occurrence ranging from 4.0% to 10.0%. The entire interval is devoid of foraminifera test lining. Algea occurred within intervals 2700m to 2840m, 2920m to 3020m and 3060m with percentage occurrence ranging from 3.0% to 30.0%. Intervals 2540m to 3680m and 2860m to 2900m are devoid of algae palynomorphs. Also, the entire interval is devoid of diatom microflora.

Within interval 3080m – 3140m, pollen palynomorph percentage occurrence range from 17.0% to 56.0% of the flora encounted in the samples, spore palynomorphs range from 22.0% in interval 3100m to 66.0% in interval 3080m,while algae microflora occurrence range from 17.0% to 22.0%. Dinoflagellate, foram test lining and diatom were not found in the interval.

On the basis of First Appearance Datum (FAD) or Last Downhole Occurrences (LDO) of three or more diagnostic species of palynomorphs forms; pollen/spore and dinoflagellate assemblage zones were defined and ages assigned to these zones. The biozones for each well are described below

VI. DISCUSSION OF RESULT

(A) Biozonation- Pollen and Spores Biozone

(1) Biozone I- Triorites tenuiexinus (4700m-4680m) The base of the zone is the base of the well It was difficult to ascertain which of the events occurred first or last but the species recorded here are: *Triorites tenuiexinus, Tricolpites clarensis, Podocarpidites multesimus, Monosulcites scaber, Clavatipollenites minutus, Alnipollenites verus, Verrucatosporites favus, Nyssapollenites pulvinus and Dicheiropollis etruscus.* The top of the zone is defined by the last downhole occurrence of *Classopollis obialosensis and Afropollis jardinus.*

(2) Biozone II- Classopollis obialosensis (4680m-4660m) The base of this zone is the same as the top of zone I. The event at the top of this zone is marked by the last downhole occurrence of *Syncolporites subtilis.* The base is marked by the last donwhole occurrence of *Classopollis obialosensis.* The species recorded in this zone are: *Classopollis obialosensi, Afropollis jardinus, Clavatipollenites rotundus, monocolpopollenites ovatus, Araucariacites australis* and *Psilatricolporites pachydermatus.*

(3) Biozone III- Syncolporites subtilis (4660m-4640m) The base of this zone is the same as the top of zone II. The top is characterized by the last downhole occurrence of *Inaperturopollenites cf. undulatus, Punctasporites sp, Longerpatites marginatus, Eucommiidites troedssonii, Cycadopites fragilis and Triorites africaensis.*

*(4) Biozone IV- Inaperturopollenites cf. undulatus (4640m-4600m)*The base of this zone is the same as the top of zone III. The events at the top are the last downhole occurrence of *Monocolpites marginatus, Ericaceiopollenites sp* and *Podocarpidites granulatus.*

(5) Biozone V-Monocolpites marginatus (4600m-4580m) The base of the zone is the same as the top of zone IV. The events marking the top of the zone are the last downhole occurrence of *corylus sp* and *Cyathidites sp.*

(6) Biozone VI-Corylus sp (4580m-4560m) The base of this zone is the same as the top of zone V. The events at the top are the last downhole occurrence of *Laevigatosporites catanejensis, Tricolporate sp* and *Liliacidites clavus.*

(7) Biozone VII-Laevigatisporites catanejensis (4560m-4540m) The base of the zone is the same as the top of zone VII. The top is defined by the last downhole occurrence of *Periretisyncolpites giganteus* and *Lycopodiumsporites fastiginoides.* Other species that characterize the zone are *Tricolporate sp* and *Liliacidites clavus.*

(8)Biozone VIII- Periretisyncolpites giganteus (4540m-4360m) The base of this zone is the same as the top of zone VII. The top of the zone is characterized by the last downhole occurrence of *Monocolpopollenites sphaeroidites, Eucommiidites sp and Syncolporites sp.* The other species that characterize this zone are *Cicatricosisporites dorogensis, Triporate sp, graminae sp, Syncolporites reymentii, Zliviporis blanensis, Tricolporate sp, Monocolpites medius* and *Tricolpopollenites sp.*

(8) Biozone IX- Monocolpopollenites sphaeroidites (4360m-4260m) The base of this zone is the same as the top of zoneVIII. The top is defined by the last downhole occurrence of *Monoporites annulatus and Peripetipollis sp.* The other species that characterize the zone are *Eucommiidites sp, Syncolporites sp, Retitricolporites annulatus, Retitricolpites geranioides, Cingulatisporites ornatus, Retitriporate sp and Monocolporites sp.*

*(8) Biozone X- Monoporites annulatus (4260m-4240m)*The base of this zone is the same as the top of zone IX. The events at the top of this zone are the last downhole occurrence of *Baentritisporites sp, Proteacidites longispinosus,*

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Distaverrusporites simplex, Tricolporopollenites magadolium, Cyathidites minor and Chenopodipollis sp. The forms in this zone are *Monoporites annulatus and Peripetipollis sp.*

(9) Biozone XI- Distaverrusporites simplex (4240m-4140m) The base of this zone is the same as the top of zone X. The events marking the top of the zone are the last downhole occurrence of *Retimonocolpites pluribaculatus, Droseridites senonicus, Psilamonocolpites magnum* and *Retitricolporites crassicostatus.* The zone is characterized by the presence of *Baentritisporites sp, Proteacidites longispinosus, Distaverrusporites simplex, Tricolporopollenites megadolium, Cyathidites minor, Chenopodipollis sp, Verrutricolporites rotundiporus, Karyapollenites sp, Polypodiaceiosporites retirugatus* and *Psilastephanocolporites punctatus.*

(B) Age Characterization -Pollen and Spore Biozone

The erected biozones are compared with the palynoforal zonation schemes defined by various Authors[1,3,8].

(i) Assemblage zones I, II, III, IV, V, VI and VII of Herwa-1 Well, 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 (1990). 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 [1,3,8].

(ii) Palynomorph assemblage zones VIII, IX, X, XI, XII, XIII and XIV of Herwa-1 well, all 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 et al [1,3,8]. 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.

(iii) Assemblage zone XV of Herwa-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 (1990), Lawal and Moullade (1986), Eisawi and Schrank (2008) and Abubakar et al (2011). 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 (1986) and Abubakar et al (2011) which is aged Coniacian-Santonian.

(iv) Palynomorph assemblage zones XVI, XVII, XVIII, XIX, XX, XXI and XXII of Herwa-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 Tricolpites tienabaensis, Translutencipollenites reticulatus, Syncolpites corrugatus, Ephedripites zeklinskaiae, Rhoidipites scabratus* and *Graminidites annulatus* have been reported by in the Campanian-Maastrichtian by Salard-Cheboldaeff et al [1,5,8]. These palynozones based on the stratigraphic positions and the series of last downhole occurrence of key species corresponds to the *Proteacidites dehaani* zone of [1,3,,8,10] which is aged Campanian-Maastrichtian..

(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 [10,11]. 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 [9]. 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).

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VII. CONCLUSION

Over 540 ditch cutting samples from four wells viz; Herwa-1, 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 and sequence stratigraphic 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 four wells, twenty two 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-VII (Cenomanian); Assemblage Zones VIII-XIV (Turonian); Assemblage Zone XV (Coniacian-Santonian); and Assemblage Zones XVI-XXII (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 four 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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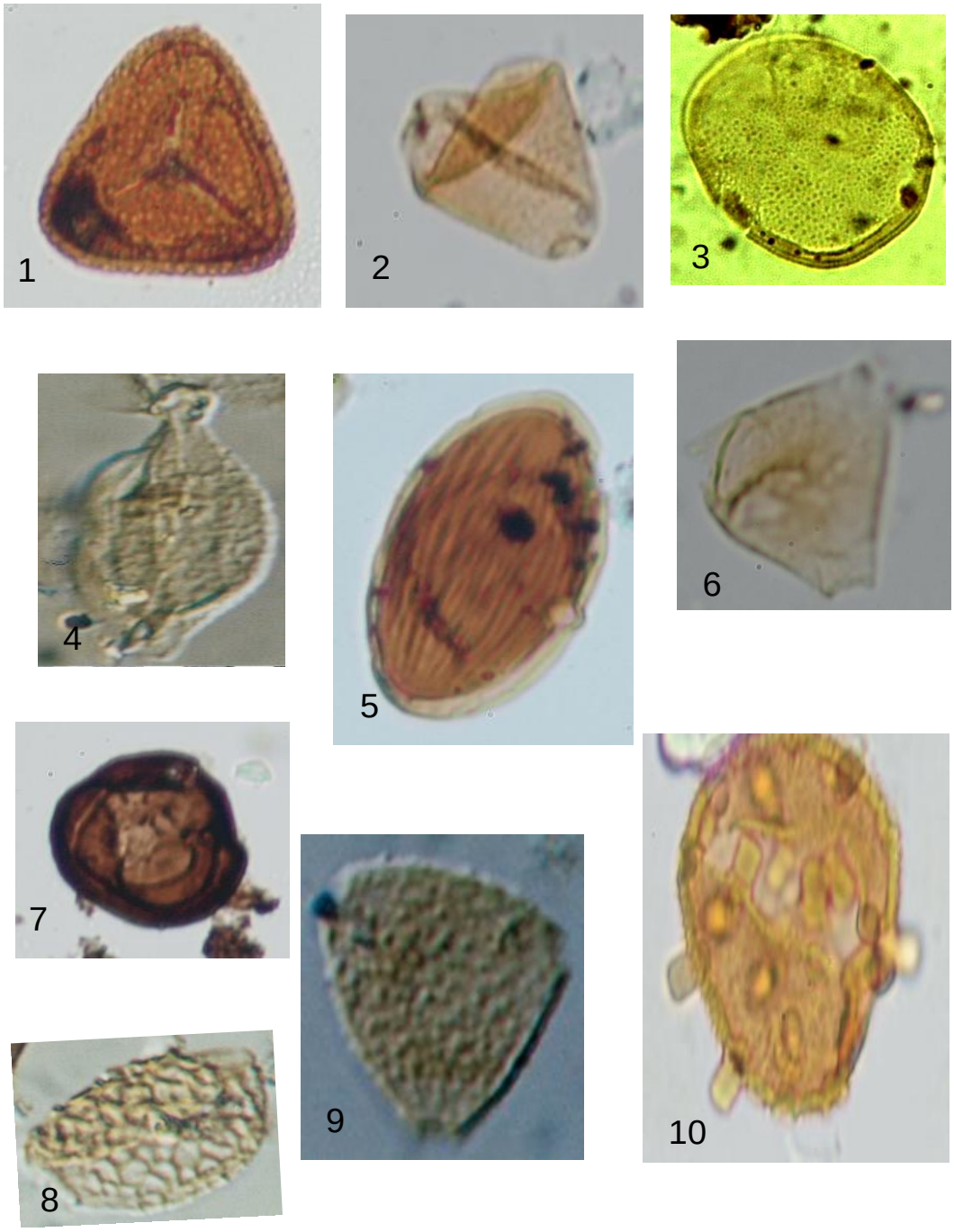
PLATE 1



1. *Foveotriletes margaritae, 2Triorites africaensis ,3Proxapertites cursus* 4.*Auriculopollenites reticulatus,* 5. *Ephedripites ambiguus* 6.*Proteacidites miniporatus* , 7. *Classopollis obialosensis,* 8 *Retimonocolpites pluribaculatus. 9. Proteacidites sigalii, 10. Grimsdalea magnaclavata*

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PLATE 2

1.Monocolpites marginatus 2, Peregrinipollis nigericus ,3 Hexpollenites chmurae , 4 Tricolporate sp. 5. Distaverrusporites simplex ,6 Zlivisporis blanensis, 7 Longapertites microfoveolatus ,8 Cingulatisporites ornatus 9. *Cretacaeiporites scabratus, 10 Graminidites annulatus*

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