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Palynostratigraphy of Ben 001well located at OML 40 Niger Delta Southern Nigeria

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ABSTRACT

This study applies an integrated palynological and lithological approach to determine the stratigraphic age of the Ben 001 exploratory well, situated within Oil Mining Lease (OML) 40 of the Niger Delta Basin, Southern Nigeria. The well lies at coordinates 6°57'56.757"E and 3°46'11.547"N, with a drilled depth interval ranging from 5,540 ft to 8,751 ft. Positioned offshore, the study analyzed ninety-seven (97) ditch cutting samples at 60 ft intervals. Lithologic examination revealed that the well penetrated the heterolithic Agbada Formation, composed primarily of interbedded shale and sandstone units. A refined palynological preparation method was employed, eliminating the use of strong acids and fume cupboards common in conventional techniques. Instead, mild reagents such as sodium hexametaphosphate and zinc bromide were utilized to isolate palynomorphs. Microscopic analysis yielded well-preserved miospores, with ninety-five taxa (sixty-one pollen and twenty-four spores) identified. Ten miospore biozones were established to define the well's chronostratigraphic framework, indicating an age range from the Lower to Upper Miocene. These biozones—Magnastriatites howardii (Zone I), Zonocostites ramonae (Zone II), Retibrevitricolporites obodensis (Zone III), Crassoretitriletes vanraadshoveni (Zone IV), Pachydermites diederixii (Zone V), Stereisporites sp. (Zone VI), Retitriporites heterobrochatii (Zone VII), Racemonocolpites hians (Zone VIII), Multiareolites formosus (Zone IX), and Nymphaepollis clarus (Zone X)—were correlated with the Magnastriatites howardii, Crassoretitriletes vanraadshoveni, and Echitricolporites spinosus zones of the Germeraad et al. (1968) Pantropical Scheme and the P670–P860 zones of the Evamy et al. (1978) framework. The results confirm the well's depositional sequence spans the Lower to Upper Miocene epochs.

1. INTRODUCTION

Since the 1958 discovery of crude oil at Oloibiri, Bayelsa State, exploration within the Cenozoic Niger Delta Basin has intensified, resulting in the drilling of more than 7,000 wells. The Niger Delta Basin, serving as Nigeria's most prolific hydrocarbon province, contributes over 83% of the nation's foreign exchange earnings. Growing global demand for petroleum, coupled with depletion of existing reserves, has heightened the need for advanced

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exploration technologies that extend beyond conventional geophysical methods. High-resolution biostratigraphy, therefore, has become indispensable in improving precision and reliability in stratigraphic interpretation. The confidentiality surrounding oil exploration data within the basin, due to limited corporate disclosure, has restricted the availability of detailed geological information. Nevertheless, biostratigraphic and biosequence stratigraphic methods remain essential tools for resolving depositional complexities arising from multiple interacting geological processes. This research aims to enhance understanding of the Niger Delta's stratigraphic framework through the application of palynological and lithological analyses.

1.1 Location of the Study Area.

The study area lies within the southern region of Nigeria, West Africa, specifically in the Niger Delta Basin. The Ben 001 well is situated in Oil Mining Lease (OML) 40, at geographic coordinates 6°57′56.757″E and 3°46′11.547″N.

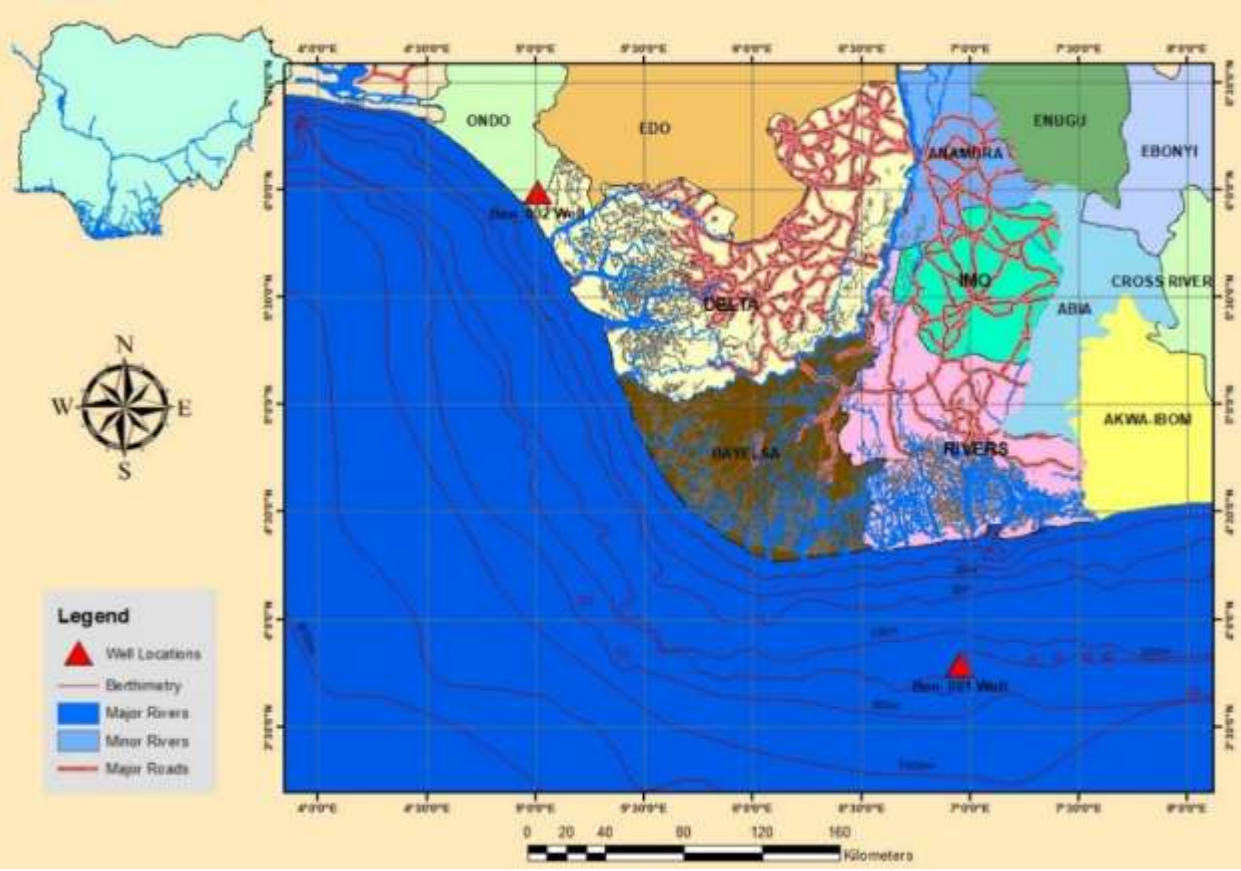


Figure 1: showing the location of the well

2. LITERATURE REVIEW

Palynological research in Nigeria has largely focused on the Tertiary sediments of the Niger Delta. Since the discovery of crude oil at Oloibiri in 1956, several studies have been conducted by different scholars; however, much of the detailed data remains confidential, as oil companies operating in the region often restrict access to such information. Despite this, significant palynological contributions have been made to understanding the basin (Odumodu, 2011).

Germeraad et al. (1968) and Evamy et al. (1978) developed an informal palynological zonation for the Niger Delta based on quantitative criteria. Asadu and Lucas (2010) established a dinoflagellate cyst biostratigraphic framework for the Maastrichtian–Lutetian succession in the Benin-1 Well, located on the western flank of the Anambra Basin, Southern Nigeria. Using the First Appearance Datum (FAD) and Last Appearance Datum (LAD) of sixty-seven key dinoflagellate cyst species, they defined sixteen tentative zones corresponding to five major geological boundaries.

Further studies by Asadu and Nkem (2020) on the Oshosun and Afowo Formations reported a moderately rich miospore assemblage, identifying seven subzones based on stratigraphic distribution and the first and last downhole occurrences of key taxa. Similarly, Asadu (2020) examined Well X-1 in OML 108, offshore Niger Delta, and recorded a diverse foraminiferal assemblage comprising twenty-four agglutinated benthic species, fifty-one calcareous benthic species, and twenty-seven planktonic species.

In another offshore Niger Delta study, Asadu and Ofuyah (2017) recovered sixty-one miospores (fifty-one pollen grains and ten spores) and delineated ten distinct miospore biozones. Likewise, Asadu and Oghotuoma (2023) analyzed the Ben 98 well, also offshore Niger Delta, revealing abundant and diverse palynomorphs in the upper section of the studied interval, while the lower section showed a decline in miospore abundance. Sixteen biozones were defined and correlated with the Evamy et al. (1978) scheme.

Ajaegwu et al. (2012) investigated the late Miocene to early Pliocene succession of the ANE-1 Well in the eastern Niger Delta, identifying 632 palynomorph species. Additionally, Aturamu and Ojo (2015) conducted an integrated foraminiferal and palynological analysis of the NEP-1 Well, located offshore in the eastern Niger Delta. Their biozonation recognized four benthic foraminiferal zones, two planktonic zones, and three palynological zones.

2.1 Geology of the Niger Delta

Reijers et al. (1997) described the Niger Delta Basin as being located along the West African continental margin, bordering Nigeria's coastline within the Gulf of Guinea. Obaje (2009) and Whiteman (1982) further explained that the Cenozoic Niger Delta occupies a structural intersection between the South Atlantic Ocean and the Benue Trough, a region where a triple junction developed during the Late Jurassic rifting that separated South America from Africa. The Niger Delta, situated in the Gulf of Guinea, began its formation during the Tertiary period, following an early Eocene regression that initiated the deposition of three principal lithostratigraphic units—namely, the basal Akata Formation, the intermediate Agbada Formation, and the overlying Benin Formation (Doust and Omatsola, 1990).

The Benin Formation, which overlies the Agbada Formation, represents the youngest unit within the Niger Delta sequence. It spans

from the Oligocene to the Recent epoch and, according to Asadu and Ikporukpo (2020), consists of more than 90% sandstone interbedded with thin shale layers. This formation extends laterally from the western margin of the Niger Delta across the basin and continues southward beyond the present coastline, reaching an estimated thickness of about 2,000 meters.

Beneath it lies the Agbada Formation, characterized by alternating shale and sandstone units that form a transitional sequence between the overlying continental deposits and the underlying marine shales. Asadu and Ikporukpo (2020) described the Agbada Formation as comprising three subunits: an upper subunit dominated by thick sand bodies containing 60–40% sand, a middle subunit with 50–30% sand, and a lower subunit with approximately 20% sand interbedded with undercompacted shale. The formation, deposited between the Eocene and Miocene epochs, reaches a thickness of approximately 3,000 meters.

The basal Akata Formation, as noted by Odumodu (2011), consists primarily of dark gray, overpressured marine shales interbedded with sandy turbidites and channel-fill deposits. Dating from the Paleocene epoch, it serves as a key source rock and potential reservoir, particularly in deep-water settings, with an estimated thickness of around 6,500 meters.

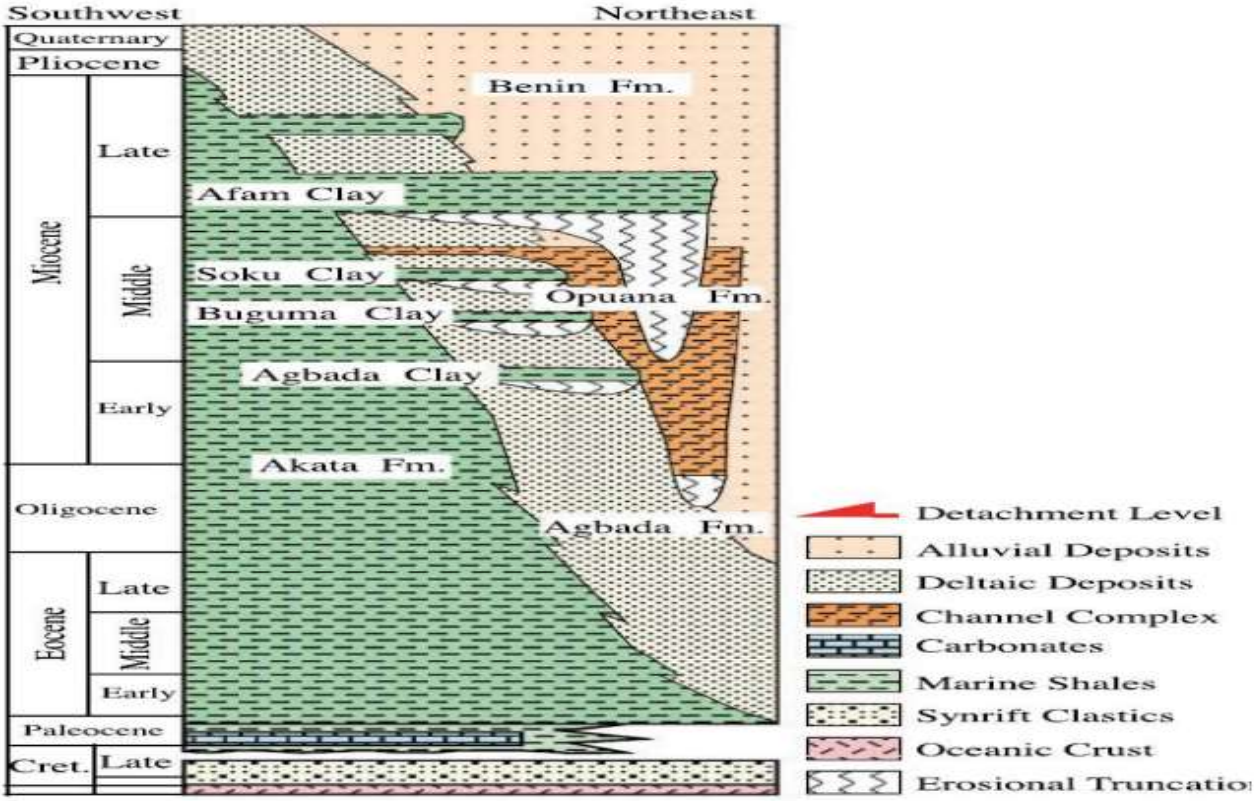


Figure Figure 2: Depicting the Niger Delta Regional Stratigraphy (Lawrence, Munday and Bray 2002)

3. METHODOLOGY

Primary data used for this research were ditch cutting samples. Lithology analysis was carried out to establish the description of rock texture and structures in order to establish the formation penetrated by the well. Sampling was done at 60ft interval. Palynological analysis was carried out on 97 samples in the well. The processing of the slides was done with the most recent technique which was without the use of strong acids and fume cupboard as done in the conventional methods. The method used was simpler and more effective which involved the use of mild salts like sodium hexametaphosphate and zinc bromide to isolate the palynomorphs from the sediments.

Sodium hexametaphosphate was used to digest the sediment and a mixture of zinc bromide and hydrochloric acid was used to separate the miospore from the sediment. The miospores obtained was washed with a 5 micron sieve, spotted and mounted on a glass slide with the aid of a norland adhesive optical glue after which it was ready for examination. A transmitted reflected electronic light microscope and the SPDC palynomorph photo album was used to identify the miospore to their species level based on their morphological features for their biostratigraphic significance.

4. RESULTS AND DISCUSSION

4.1 Lithostratigraphy

The well's rock facies consist mainly of alternating sand and shale layers of varying thicknesses, with sand grain sizes ranging from fine to medium and coarse. The lithologic sequence shows a consistent alternation between sandy and shaly sand units.

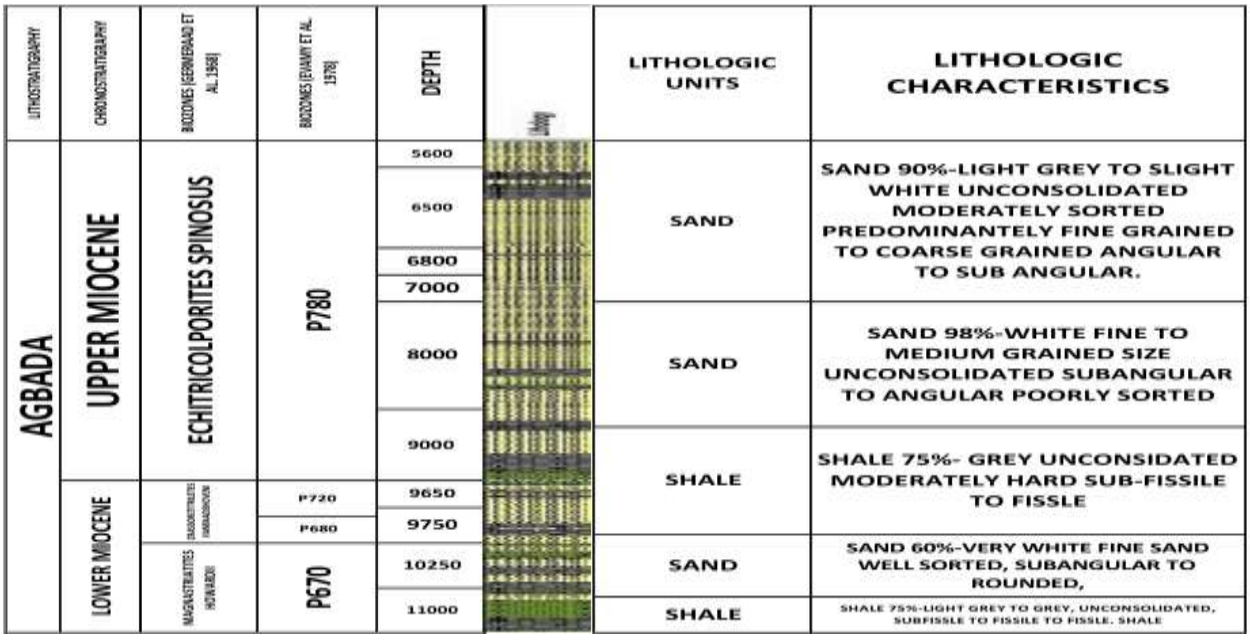


Figure 3 Lithologic description of Ben 001 well

4.2 Biozonation and Age

A total of ninety-seven (97) samples from the Ben 001 well were examined in this study. Lithological analysis revealed that the well penetrated the heterolithic Agbada Formation, characterized by alternating layers of shale and sandstone. The samples were processed following standard palynological preparation techniques, which yielded well-preserved miospores. Ninety-five (95) miospore taxa were identified in total, comprising sixty-one (61) pollen grains and twenty-four (24) spores. Based on their distribution, ten (10) distinct miospore biozones were established, which were instrumental in dating the well sequence to the Lower–Upper Miocene. The recognized biozones are: Magnastriatites howardii Zone (Zone I), Zonocostites ramonae Zone (Zone II), Retibrevitricolporites obodensis Zone (Zone III), Crassoretitriletes vanraadshoveni Zone (Zone IV), Pachydermites diederixii Zone (Zone V), Stereisporites sp. Zone (Zone VI), Retitriporites heterobrochatii Zone (Zone VII), Racemonocolpites hians Zone (Zone VIII), Multiareolites formosus Zone (Zone IX), and Nymphaepollis clarus Zone (Zone X). The characteristics of each zone are summarized below:

Zone I – Magnastriatites howardii (Lower Miocene)

This zone extends from 11,250 ft (base) to 10,750 ft (top) and is defined by the last downhole occurrences of *Monoporites annulatus*, *Multiareolites formosus*, *Verrucatosporites alienus*, *Pachydermites diederixii*, *Verrucatosporites tenellis*, and *Bombacacidites cieba*. The top of this zone corresponds to the base of Zone II.

Zone II – Zonocostites ramonae (Lower Miocene)

Ranging between 10,750 ft and 10,250 ft, this zone is marked by the presence of *Magnastriatites howardii*, *Polypediaceoisporites sp.*, *Verrucatosporites alienus*, *Monoporites annulatus*, *Psilatricolporites sp.*, and *Fusiformisporites sp.*

Zone III – Retibrevitricolporites obodensis (Lower Miocene)

This zone is from 10,350 ft to 9,850 ft, this zone is characterized by the last downhole occurrences of *Retitricolporites heterobrochatii* and *Canthiumidites sp.*, along with the continued presence of *Monoporites annulatus*, *Verrucatosporites alienus*, and *Zonocostites ramonae*.

Zone IV – Crassoretitriletes vanraadshoveni (Lower Miocene)

This zone extends from 9,850 ft to 9,500 ft and is identified by *Verrucatosporites tenellis*, *Verrucatosporites alienus*, *Monoporites annulatus*, *Zonocostites ramonae*, *Magnastriatites howardii*, and *Psilatricolporites crassus*. The *Crassoretitriletes vanraadshoveni* Zone marks the upper boundary of the Lower Miocene interval.

Zone V – Pachydermites diederixii (Upper Miocene)

Located between 9,500 ft and 8,750 ft, this zone is characterized by the occurrences of *Polypediaceoisporites sp.*, *Verrucatosporites alienus*, *Monoporites annulatus*, *Psilatricolporites sp.*, *Verrucatosporites*

tenellis, *Zonocostites ramonae*, and *Canthiumidites sp.*

Zone VI – Stereisporites sp. (Upper Miocene)

This zone, ranging from 8,750 ft to 7,200 ft, is marked by the continuous presence of *Zonocostites ramonae*, *Monoporites annulatus*, *Verrucatosporites tenellis*, *Verrucatosporites alienus*, and *Polypediaceoisporites sp.*

Zone VII – Retitricolporites heterobrochatii (Upper Miocene)

Extending from 7,200 ft to 6,900 ft, this zone is characterized by the occurrences of *Pachydermites diederixii*, *Verrucatosporites alienus*, *Verrucatosporites tenellis*, *Polypediaceoisporites sp.*, and *Zonocostites ramonae.*

Zone VIII – Racemonocolpites hians (Upper Miocene)

This zone, extending from 6,900 ft to 6,750 ft, is defined by *Polypediaceoisporites sp.*, *Verrucatosporites alienus*, *Monoporites annulatus*, *Zonocostites ramonae*, *Verrucatosporites tenellis*, *Multiareolites formosus*, *Psilatricolporites sp.*, and *Pachydermites diederixii.*

Zone IX – Multiareolites formosus (Upper Miocene)

This zone is from 6,750 ft to 5,800 ft, this zone is defined by the occurrences of *Polypediaceoisporites sp.*, *Verrucatosporites tenellis*, *Monoporites annulatus*, *Verrucatosporites alienus*, *Zonocostites ramonae*, *Racemonocolpites hians*, *Psilatricolporites crassus*, and *Pachydermites diederixii*.

Zone X – Nymphaepollis clarus (Upper Miocene)

The uppermost biozone, extending from 5,800 ft to 5,540 ft (the top of the well), is characterized by the first downhole appearances of *Pachydermites diederixii*, *Zonocostites ramonae*, *Racemonocolpites hians*, *Psilatricolporites crassus*, *Verrucatosporites alienus*, *Verrucatosporites tenellis*, and *Polypediaceoisporites sp.*

Collectively, these ten miospore biozones delineate the stratigraphic succession of the Ben 001 well and confirm that its depositional sequence spans from the Lower to Upper Miocene.

Correlation of the well with Germeraad et al. 1968 pantropical scheme and Evamy et al. 1978 scheme.

In the well, Zone I (Magnastriatites howardii) and Zone II (Zonocostites ramonae) correlate with the Magnastriatites howardii Zone of the Germeraad et al. (1968) Pantropical scheme and the P670 Zone of the Evamy et al. (1978) framework, corresponding to the Lower Miocene epoch. Similarly, Zone III (Retibrevitricolporites obodensis) and Zone IV (Crassoretitriletes vanraadshoveni) align with the Crassoretitriletes vanraadshoveni Zone of the Germeraad et al. (1968) scheme and the P720 and P680 Zones of the Evamy et al. (1978) scheme, also indicating a Lower Miocene age. Furthermore, Zones V through X—namely Pachydermites diederixii, Stereisporites sp., Retitriporites heterobrochatii, Racemonocolpites hians, Multiareolites formosus, and Nymphaepollis

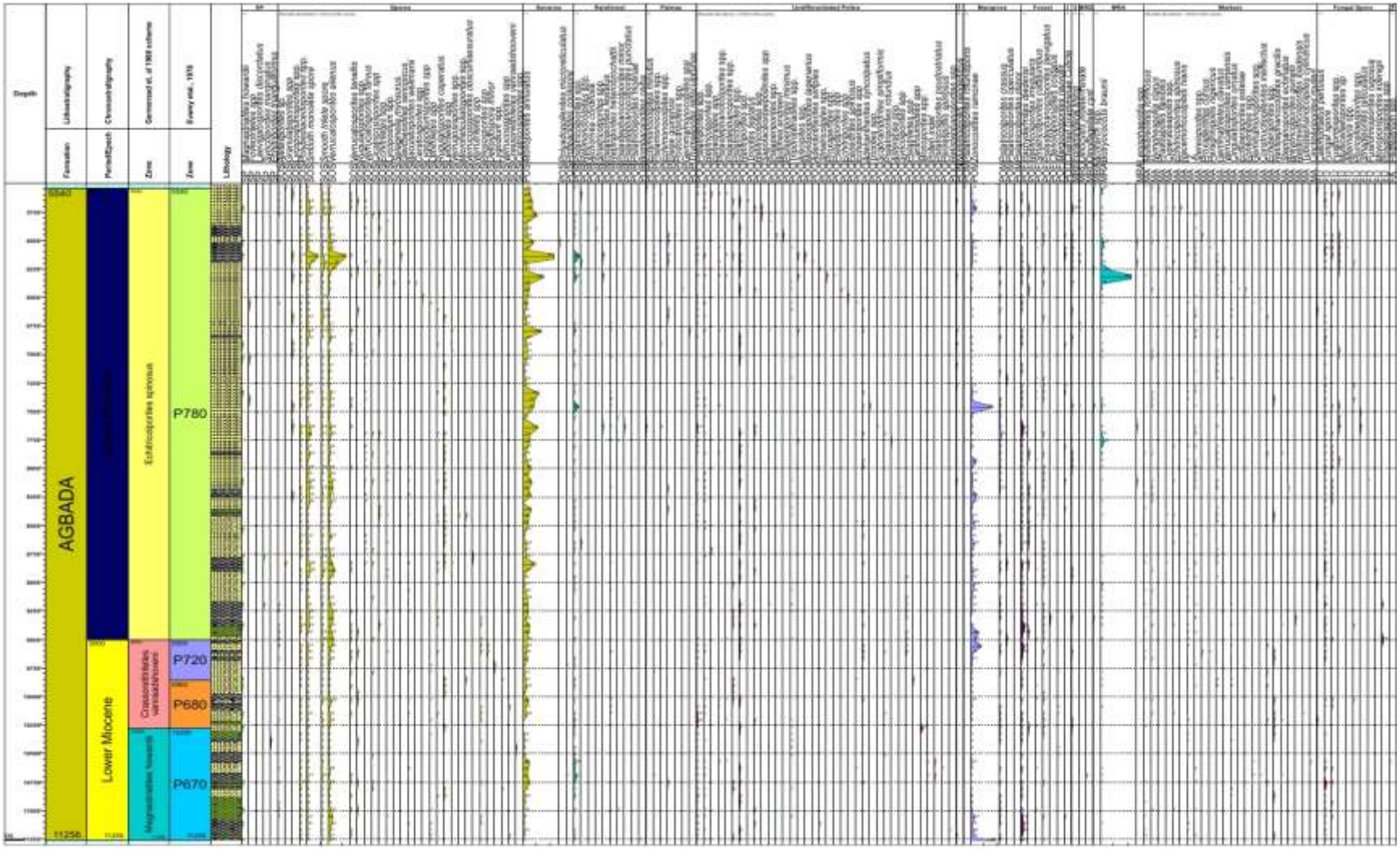


Figure 4: Palynomorph Distribution chart for Ben 001 well

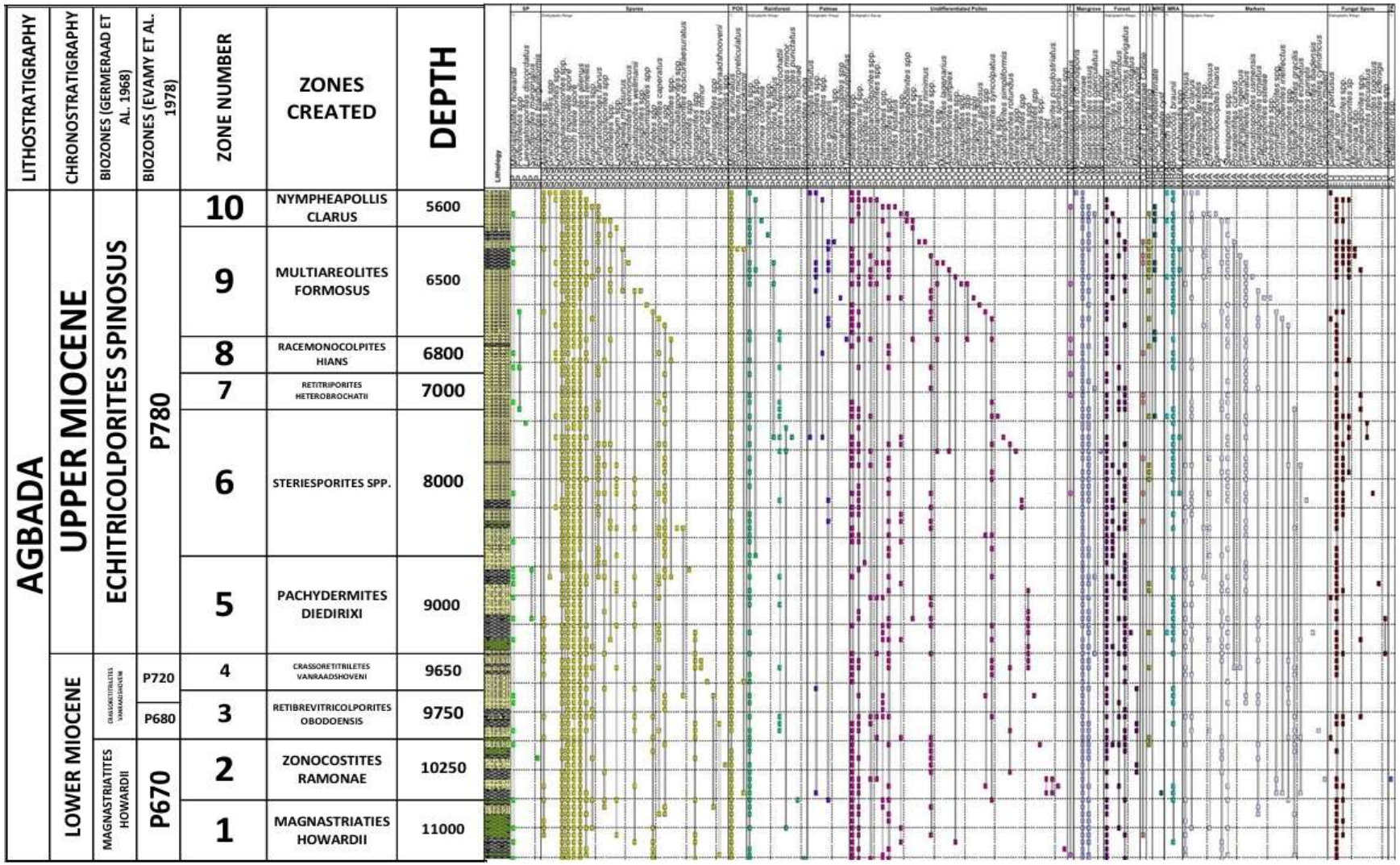


Figure 5: Miospore range chart and Biozonation of Ben 001 well

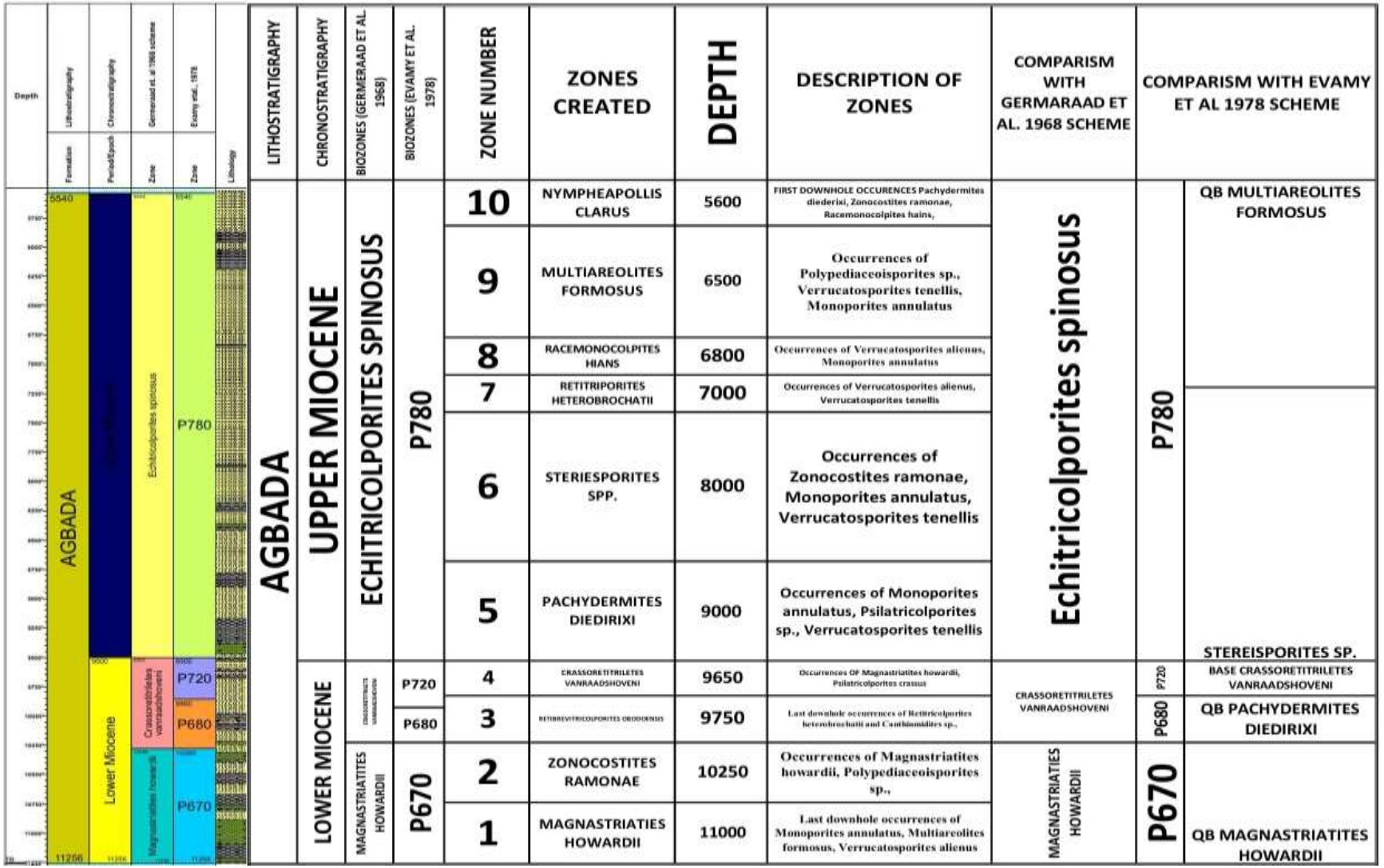


Figure 6 Miospore Biozonation of Ben 001 well

Plate 1

1) Botryococcus braunii
2) Callimothallus pertusus
3) Monoporites annulatus
4) Monoporites annulatus
5) Monoporites annulatus
6) Zonocostites ramonae
7) Zonocostites ramonae
8) Zonocostites ramonae
9) Zonocostites ramonae
10) Zonocostites ramonae
11) Zonocostites ramonae
12) Zonocostites ramonae
13) Zonocostites ramonae
14) Zonocostites ramonae
15) Zonocostites ramonae
16) Zonocostites ramonae
17) Zonocostites ramonae
18) Echimonocolpites minutus
19) Multiareolites formosus
20) Dinocyst sp.,

Plate 1

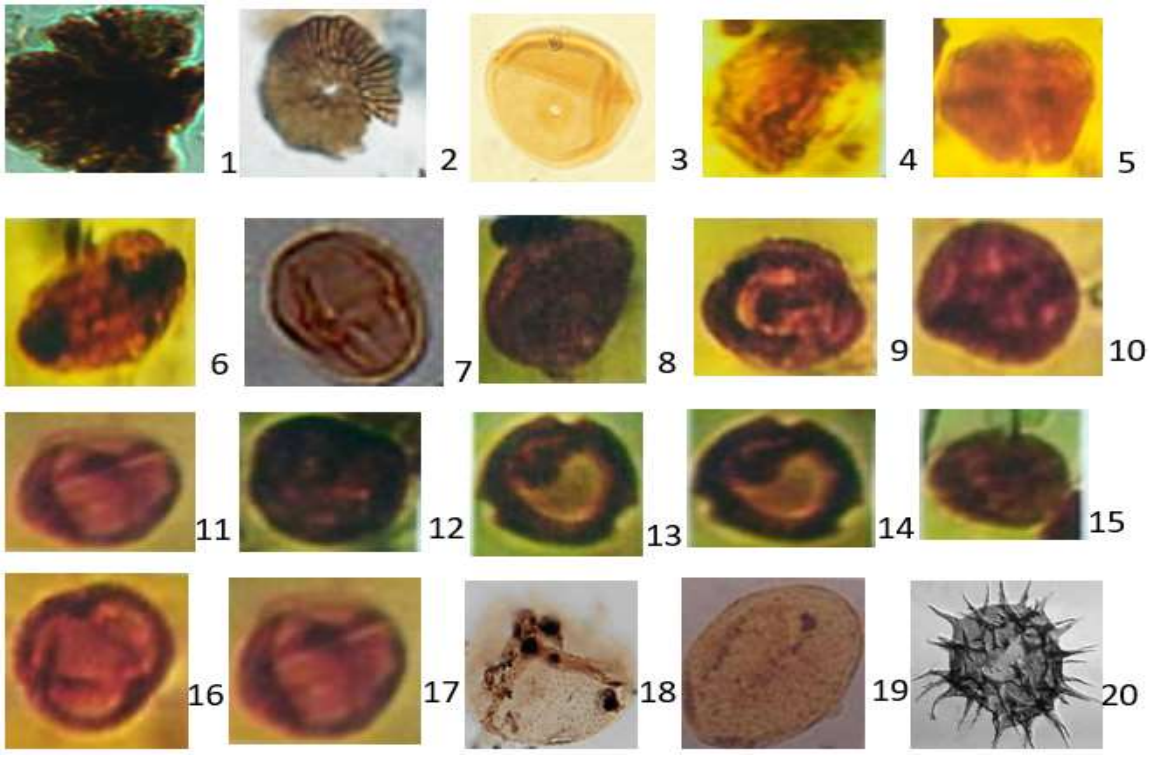


Plate 2

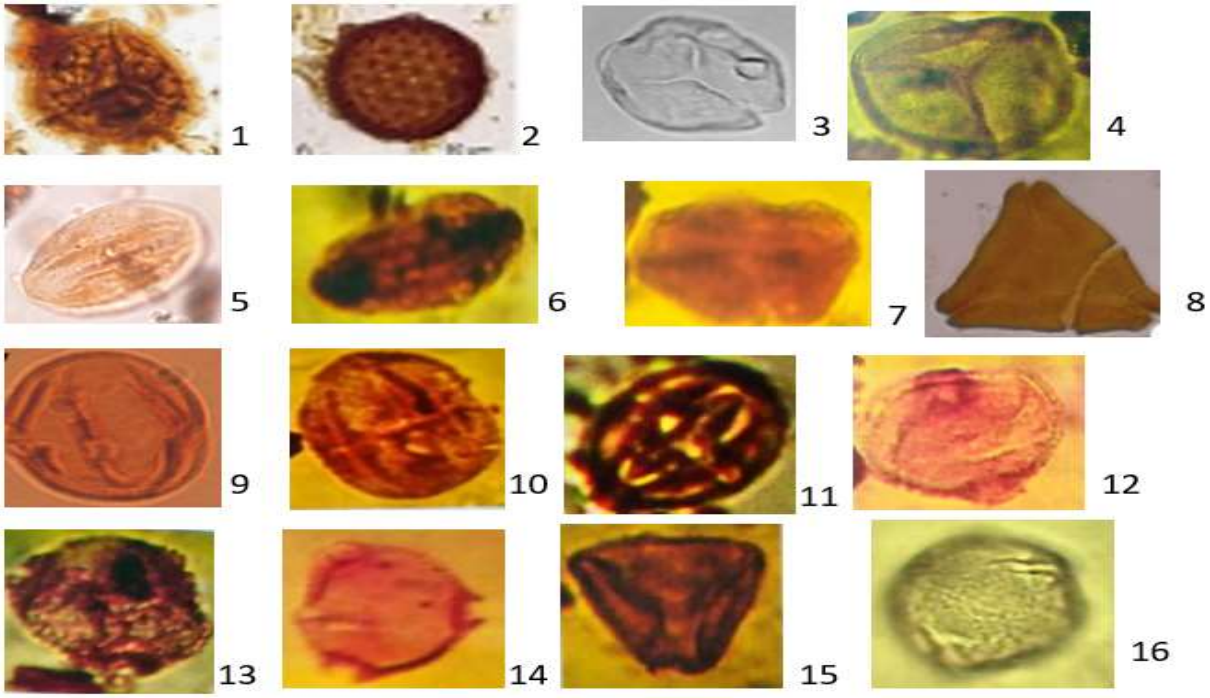


Plate 2

1) Echitriletes sp.,
2) Psilaperiporites sp.,
3) Stereisporites sp.,
4) Steriesporites sp.,
5) Striatricolpites catatumbus
6) Striatricolpites catatumbus
7) Striatricolpites catatumbus
8) Retitricolporites sp.,
9) Sapotaceoidaepollinites sp.,
10) Sapotaceoidaepollinites sp.,
11) Sapotaceoidaepollinites sp.,
12) Retibrevitricolporites triangulatus
13) Retibrevitricolporites triangulatus
14) Retibrevitricolporites triangulatus
15) Elaesis guineansis
16) Alchornea cordifolia

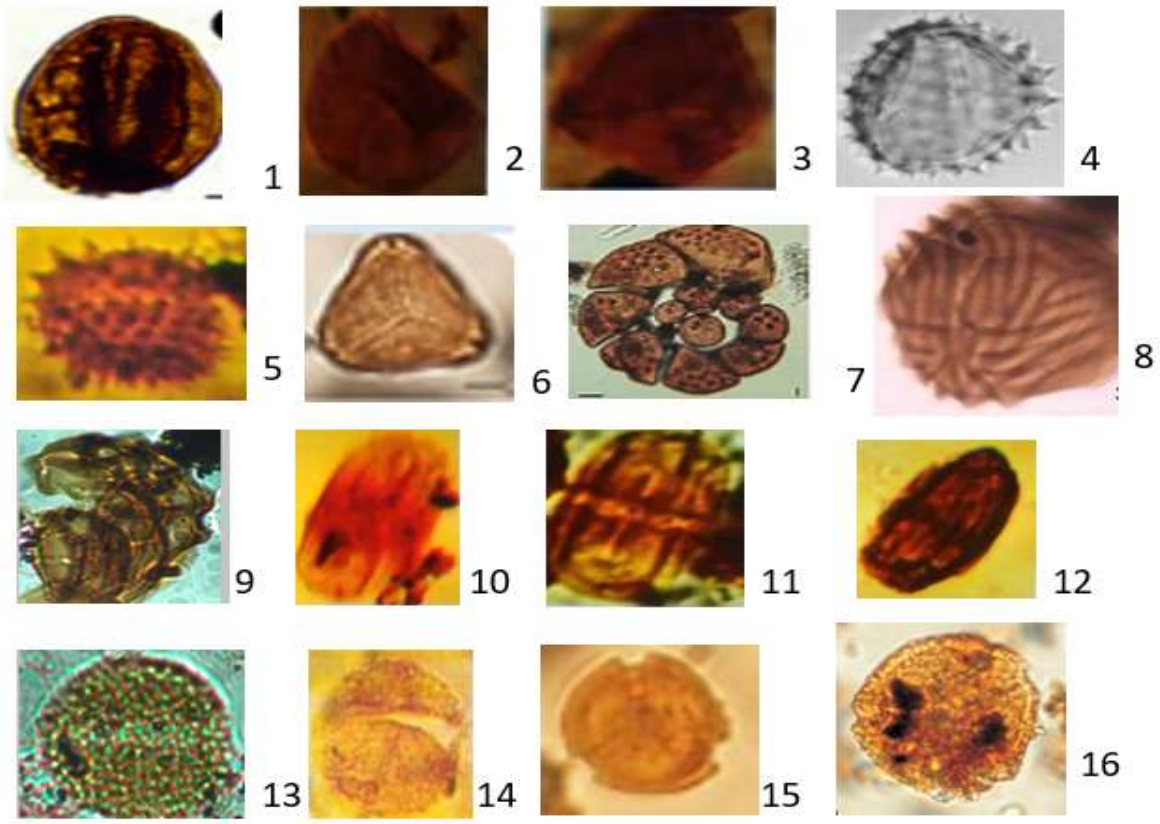


Plate 3

1) Cyperaceopollis sp.,
2) Cyperaceopollis sp.,
3) Cyperaceopollis sp.,
4) Echitricolporites spinosus
5) Echitricolporites spinosus
6) Psilatricolporites operculatus
7) Foraminiferal testling
8) Magnastriatites howardii
9) Magnastriatites howardii
10) Belskipollis elegans
11) Belskipollis elegans
12) Belskipollis elegans
13) Racemonocolpites hians
14) Racemonocolpites hians
15) Retitriporites irregularis
16) Retibrevitricolporites obodoensis

clarus—correspond to the Echitricolporites spinosus Zone of the Germeraad et al. (1968) framework and the P780 Zone of the Evamy et al. (1978) scheme, representing the Upper Miocene epoch.

5. CONCLUSION

This research focuses on the integration of palynological and lithological data to determine the age of the exploratory the well. The well is situated in Oil Mining Lease (OML) 40, at coordinates 6° 57′ 56.757″ E and 3° 46′ 11.547″ N, with a depth interval ranging from 5,540 ft to 8,751 ft. The well is an offshore well, and a total of 97 samples were analyzed. Lithological examination revealed that the well penetrated the heterolithic Agbada Formation, characterized by alternating shale and sand deposits. The primary data utilized in this study were ditch cutting samples, collected at 60 ft intervals. Sample processing employed a modernized palynological preparation technique that eliminates the use of strong

acids and fume cupboards commonly required in conventional methods. Instead, mild reagents such as sodium hexametaphosphate and zinc bromide were used to isolate palynomorphs from the sediment, providing a safer and more efficient approach. Standard palynological preparation and analysis techniques were applied, resulting in the recovery of well-preserved miospores. A total of ninety-five (95) taxa were identified—comprising sixty-one (61) pollen grains and twenty-four (24) spores. Ten (10) miospore biozones were established in the well, which were used to determine its stratigraphic age as Lower to Upper Miocene. These biozones include: Magnastriatites howardii (Zone I), Zonocostites ramonae (Zone II), Retibrevitricolporites obodensis (Zone III), Crassoretitriletes vanraadshoveni (Zone IV), Pachydermites diederixii (Zone V), Stereisporites sp. (Zone VI), Retitriporites heterobrochatii (Zone VII), Racemonocolpites hians (Zone VIII), Multiareolites formosus (Zone IX), and Nymphaepollis clarus (Zone X). Correlation of these biozones with the Magnastriatites howardii, Crassoretitriletes vanraadshoveni, and Echitricolporites spinosus zones of the Germeraad et al. (1968) Pantropical Scheme, as well as the P670–P860 zones of the Evamy et al. (1978) scheme, supports the relative age assignment of Lower Miocene to Upper Miocene for the well.

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