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Depositional Environment and Paleoclimatic Characterization of Ben 002 Well Located at OML 126, Niger Delta Southern Nigeria

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ABSTRACT

This research explores the use of Palynological Biostratigraphy and lithological data to characterize the depositional environment and Paleo climate of an exploratory well Ben 002 well. The well is located at 126 which has a longitude and latitude of 5°0'50.604"E and 5°57'48.196"N. The depth range interval of the well is between 350ft to 11256ft and it is an onshore well. The study was carried out on 335 samples. The lithology of the well penetrated the Heterolithic Agbada formation which is an interaction of shale and sand. The primary data used for this research were ditch cutting samples. Lithologic 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. 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 The samples were analyzed using the standard palynological sample preparation methods and analysis yielded well preserved miospores which one hundred and two miospore (eighty pollen and twenty-two spores) were identified in the well to characterize the age the well as Oligocene to Upper Miocene. Parameters like the palynological groupings of miospores present in the well and the palynomorph marine index was used to characterize the paleoenvironment of the well. The Paleoenvironment of the well was Continental Mangrove based on the high occurrences of the Mangrove pollen Psilatricolporites crassus and Zonocostites ramonae. The Paleoclimate of the well is Wet climate due to the high occurrences of the mangrove pollen Psilatricolporites crassus and Zonocostites ramonae.

1. INTRODUCTION

The 1956 discovery of petroleum by Shell-BP in Oloibiri marked a major milestone in the evolution of the Niger Delta Basin, establishing it as a region of immense economic importance due to its abundant hydrocarbon resources. This discovery shifted the area's economic base from agriculture to a petroleum-dominated economy. Today, oil and gas exports account for roughly 85% of Nigeria's foreign exchange earnings. However, as exploration activities progressed, locating new petroleum reserves became increasingly difficult,

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prompting the adoption of advanced technologies such as petrophysical analysis.

According to Reijers (2011), extensive exploration efforts following the initial discovery have resulted in the drilling of more than 7,000 wells across the Niger Delta. Despite this, access to detailed geological data remains limited, as oil companies operating in the region often regard such information as proprietary and confidential.

High-resolution biostratigraphic and bio-sequence stratigraphic techniques have become essential in overcoming exploration challenges by enhancing the accuracy and reliability of stratigraphic interpretations in the Niger Delta Basin. The advancement of biostratigraphy, in particular, has significantly reduced the uncertainties associated with subsurface correlation. As a sub-discipline of stratigraphy, biostratigraphy relies on fossil content to correlate rock layers within and between basins, thereby determining their relative ages. When fossil assemblages in separate sedimentary layers are similar, it implies synchronous deposition and allows for paleoenvironmental reconstruction. These fossils—whether macrofossils or microfossils—serve as valuable tools for correlating rock formations and establishing their geological age. As stated by Bryce and Levin (2020), biostratigraphy is the study of stratified rock sequences based on their fossil content.

1.1 *Location of the study Area*

The area under study is located in the southern part of Nigeria West Africa in the Niger delta basin. The latitude and longitude of Ben 002 well is 5°0'50.604"E and 5°57'48.196"N located in OML 126.

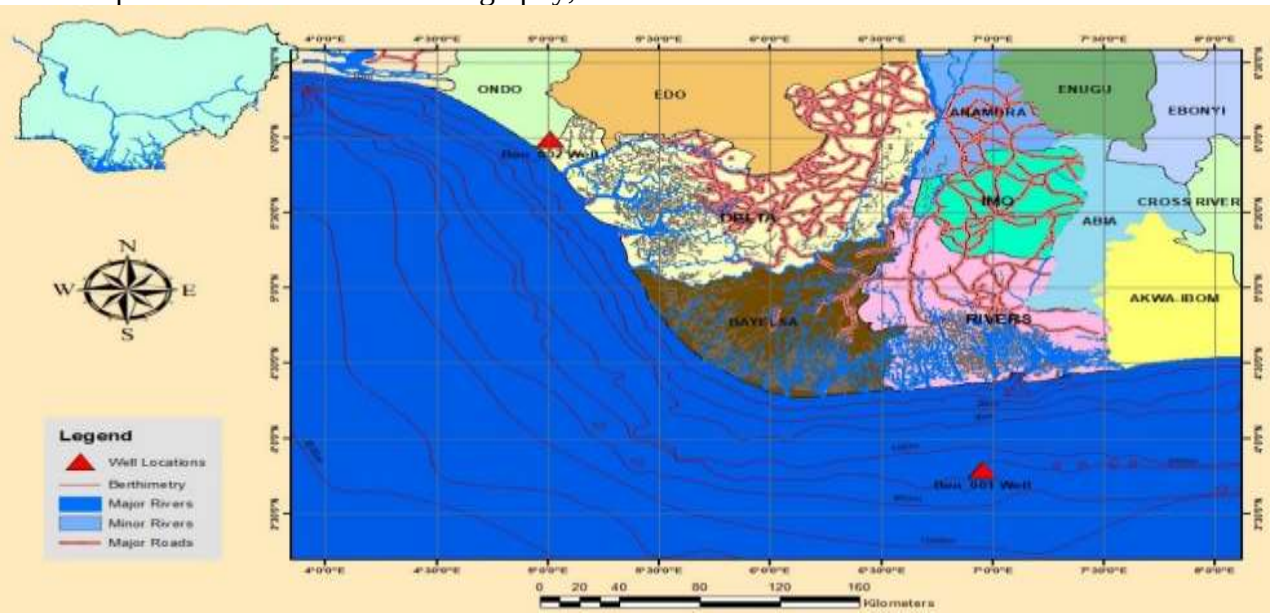


Figure 1: showing the location of the well

1.2 Geology of the Niger Delta

Whiteman (1982) and Obaje (2009) noted that the Tertiary Niger Delta occupies a structural junction between the South Atlantic Ocean and the Benue Trough, where a triple junction developed during the Late Jurassic as the South American and African plates diverged. The Niger Delta Basin is bordered by other basins formed through comparable tectonic processes. According to

Michele, Ronald, and Michael (1999), the Niger Delta represents one of Africa's largest subaerial basins, covering an estimated area of about 8,000 square kilometers. It comprises a regressive clastic sequence reaching a maximum thickness of approximately 12 kilometers (Orife and Avbovbo, 1982). Globally, the basin ranks among the most prolific hydrocarbon provinces (Corredor, Shaw, and Bilotti, 2005), with the Tertiary Akata–Agbada petroleum system serving as its principal hydrocarbon source. The stratigraphic framework of the Niger Delta is established through correlations based on palynomorph and foraminiferal assemblages (Obaje, 2009). The basin's stratigraphy is composed of three major lithostratigraphic formations: the continental sandstones of the Benin Formation, the transitional coastal marine sands and shales of the Agbada Formation, and the basal marine shales of the Akata Formation.

The Akata Formation, which underlies the entire delta sequence, consists predominantly of marine shales, silts, and clays, with occasional thin sandstone interbeds near its contact with the overlying Agbada Formation (Doust and Omatsola, 1990). In the central part of the delta, this formation may attain a thickness of up to 21,000 feet (Doust and Omatsola, 1989). Its lithology is characterized by dark gray shales and silts, with minor sand lenses likely deposited by turbidity currents. The microfauna is dominated by planktonic foraminifera, reflecting a shallow marine shelf depositional environment. The Akata Formation spans from the Paleocene to the present (Doust and Omatsola, 1989) and has been interpreted by Stacher (1995) as comprising deep-water lowstand deposits.

The Agbada Formation**,** which conformably overlies the Akata Formation, consists mainly of paralic siliciclastic sediments and forms the principal deltaic sequence that hosts most of the economically significant hydrocarbon reservoirs. Biostratigraphic evidence from this formation indicates the presence of several miospore taxa, suggesting deposition during the Middle to Late Miocene. The Agbada Formation ranges in thickness from about 3,000 to 8,000 feet below sea level and exhibits a coarsening-upward succession, signifying deltaic progradation and regression. Its thickness increases toward the offshore depocenter (Short and Stauble, 1967).

The Benin Formation represents the fluvial and upper coastal plain unit, deposited from the Oligocene to the present. Extending across the entire delta, it consists mainly of unconsolidated sands and minor shales, reaching up to 2,000 meters in thickness in certain regions. The type section of this formation is located at the Elele-1 Well near Port Harcourt. Its upper sections are non-marine, having been deposited in alluvial and upper coastal plain environments during successive phases of delta advancement. The Benin Formation is dated from the Oligocene to Recent (Short and Stauble, 1967).

2. LITERATURE REVIEW

Between 1938 and 1957, Shell D'Arcy—now known as the Shell Petroleum Development Company of Nigeria—conducted geological exploration for oil across southern Nigeria. This exploration led to the historic discovery of petroleum in the Niger Delta at Oloibiri in 1957.

Germeraad et al. (1968) and Evamy et al. (1978) conducted extensive studies on the palynology of Tertiary sediments from tropical regions such as South America, West Africa (particularly Nigeria), and parts of Asia. They described and illustrated forty-nine biostratigraphically significant

miospores, from which they developed seven pantropical biozones. These zones were instrumental in defining geological boundaries ranging from the Maastrichtian to the Pleistocene epochs.

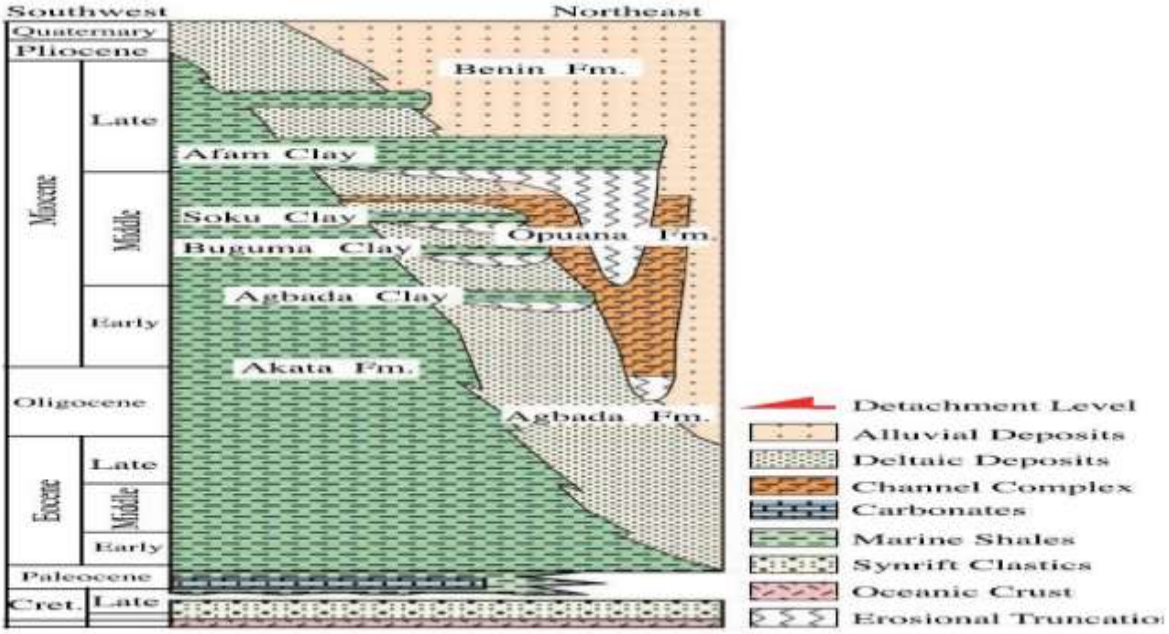


Figure 2: Depicting the Niger Delta Regional Stratigraphy (Lawrence, Munday and Bray 2002)

Adegoke (1969) investigated the stratigraphy of the Imo Shale and described it as comprising distinct beds of light greenish-gray to dark clay shales, with an average thickness of approximately 1,300 feet. He also noted the absence of biogenic limestone facies in the lower offshore portion of the Imo Shale.

Salami (1990) analyzed palynomorph taxa from the Lower Coal Measures of Campanian–Maastrichtian age within the Anambra Basin. He identified forty-six species of palynomorphs, including eleven spores, twenty-six pollen types, several dinocysts, and three *incertae sedis* species. Based on these findings, he concluded that the Lower Coal Measures were deposited in a freshwater swamp environment intermittently influenced by short-lived marine or brackish incursions.

Oloto (1994) reviewed dinoflagellate cyst and miospore biozonation models for Maastrichtian to Pleistocene successions across Nigerian sedimentary basins. She proposed nineteen dinocyst zones and corresponding miospore zones that aligned with the pantropical zonation scheme of Germeraad et al. (1968).

Asadu and Onifade (2020) identified the Akata, Agbada, and Benin Formations as the three principal lithostratigraphic units of the Niger Delta, reflecting a complex interplay of fluvial, deltaic, littoral, and marine depositional environments. The primary distinguishing feature among these formations is their varying sand-to-shale ratio. Asadu and Ikporukpo (2020) further detailed that the Agbada Formation comprises alternating shale and sandstone layers and can be divided into three subunits: an upper unit containing 60–40% sand, a middle unit with 50–30% sand, and a lower

unit containing roughly 20% sand interbedded with undercompacted shale.

In another study, Asadu and Odumoso (2020) recovered forty-three pollen types, seven spores, and one dinoflagellate cyst, from which they established four subzones based on distinctive palynofloral assemblages of marker species. Similarly, Asadu and Oghotuoma (2023), in their study of the Ben 98 offshore Niger Delta well, reported an abundance and moderate diversity of palynomorphs, particularly in the upper interval of the analyzed section. However, a decline in miospore abundance characterized the lower part of the well. They delineated sixteen miospore biozones, which were employed to determine the age, paleoenvironmental conditions, and paleoclimatic evolution of the well.

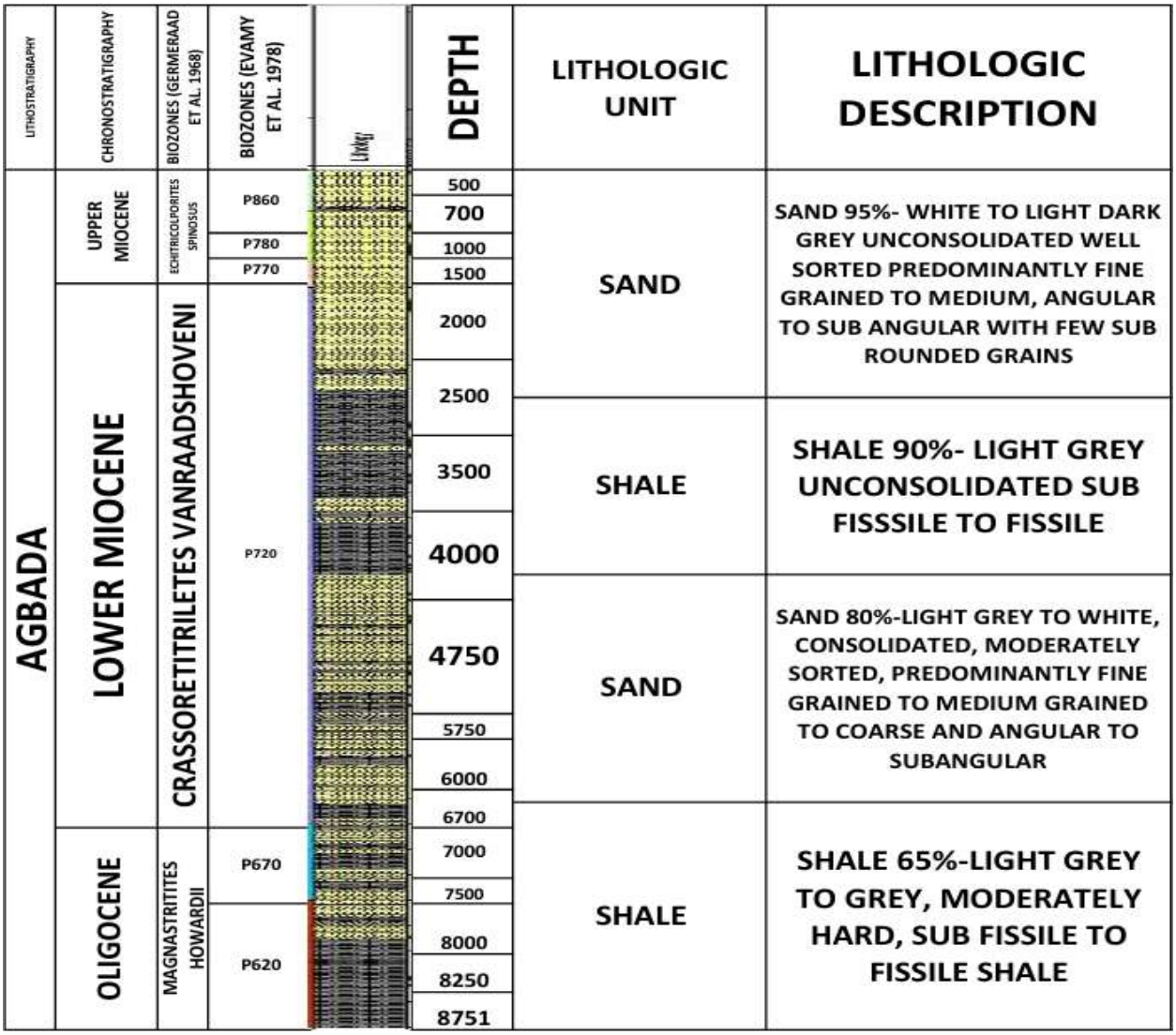


Figure 3: Lithologic description of Ben 002 well

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 335 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. The procedures are stated below:

1)Weighing and labelling of ditch cutting samples. Beakers and other apparatus

2)Addition of Sodium hexametaphoshate and distilled water to the sample to digest the sediments

3)Addition of a mixture of Zinc bromide and Hcl to the samples and centrifuging to separate the miospores from the sediment.

4)Washing the residue containing the miospores with a 5 micron sieve

5)Drying and spotting of residue containing the palynomorphs on a hot plate

6)Mounting the cover slid on a glass slide with the aid of norland optical glue.

7)Then the glass slide are ready for study under a light transmitted microscope and the SPDC palynomorph photo album 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 rock facies consist of alternating sand and shale layers, with both lithologies occurring in nearly equal proportions. The sand grains range from angular to sub-rounded and rounded in shape, and their sizes vary from fine to medium and coarse. The shale, on the other hand, is characterized by a fissile to sub-fissile texture.

4.2 Paleoclimatic interpretation of Ben 002 well

Paleoclimatic interpretation of the well, based on ditch cutting samples from depths of 500 to 8,750 ft, was conducted using ecologically and climatically significant palynomorphs recovered from the analyzed interval. The diagnostic species identified include *Zonocostites ramonae*, *Psilatricolporites crassus*, *Monoporites annulatus*, *Proteacidites cooksonii*, *Foraminiferal test linings*, and *Callimothallus pertusus*.

As illustrated in Figure 3, the mangrove species *Psilatricolporites crassus* exhibits the highest abundance peak, suggesting a predominantly humid climatic condition throughout the studied section. Similarly, the mangrove pollen *Zonocostites ramonae* shows moderate peaks, further supporting evidence of a wet climate. In contrast, the savannah indicators *Proteacidites cooksonii* and *Monoporites annulatus* display very low or absent peaks, reinforcing the interpretation of a persistently humid environment due to the scarcity of these dry-climate taxa. Additionally, marine *Foraminiferal test linings* record minimal occurrences, consistent with limited marine influence under prevailing wet climatic conditions.

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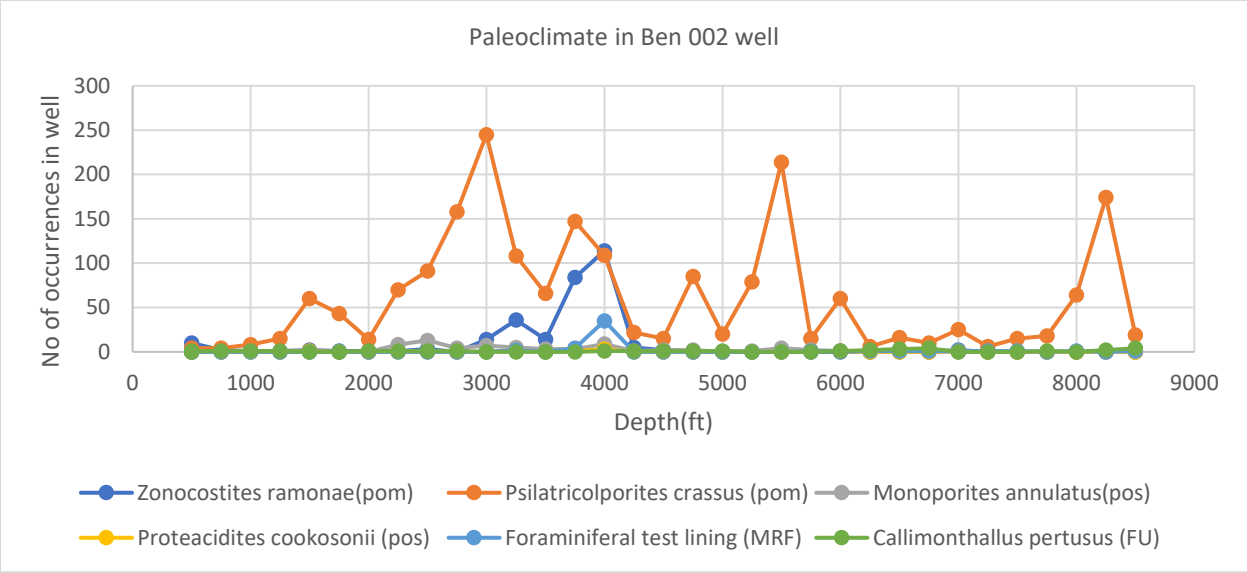


Figure 4: Paleoclimate in Ben 002 well

4.3 Environment of deposition for Ben 002 well

The integration of sedimentological wireline log data and palynological evidence facilitated the interpretation of the varying depositional environments across the analyzed interval (350 ft to 8,751 ft). This paleoenvironmental reconstruction is based on the relative abundance and diversity of specific ecological groups of palynomorphs, combined with lithofacies characteristics. The results suggest that the well was deposited within a continental mangrove paleoenvironment, as indicated by the dominance and high percentage of mangrove palynomorphs throughout the studied section.

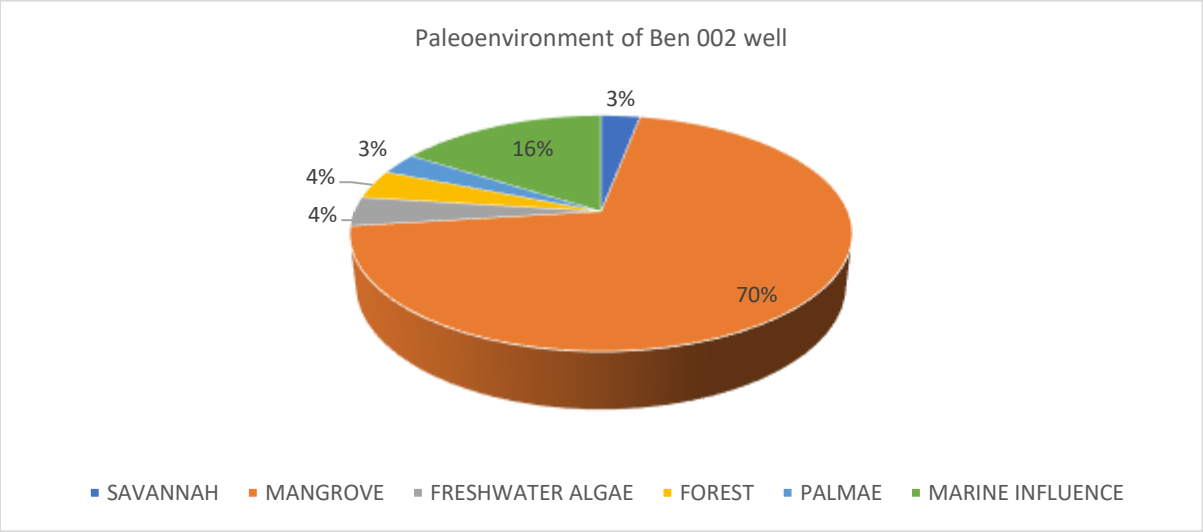


Figure 5: Pie-chart showing the paleoenvironmental distribution in Ben 002 well

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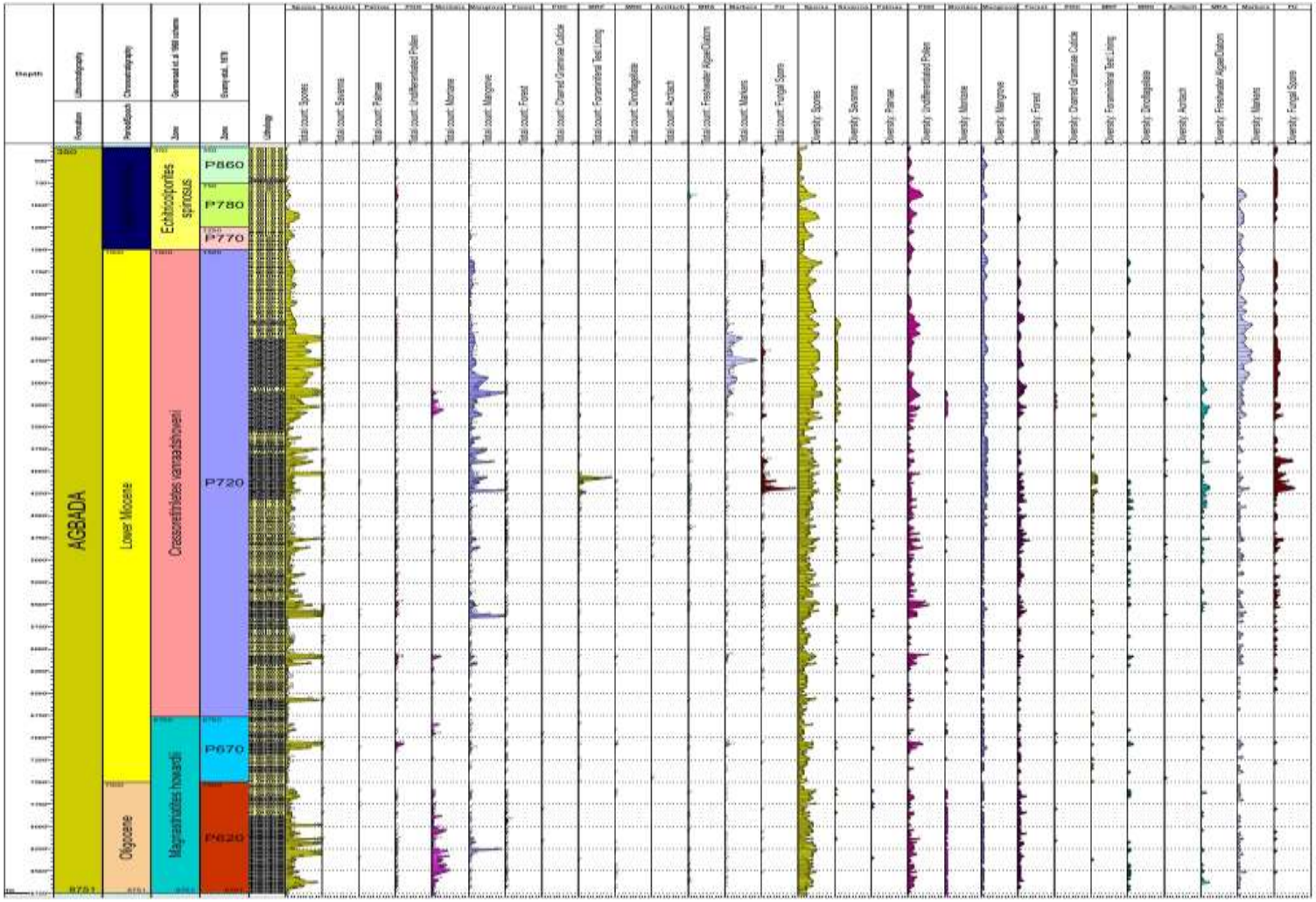


Figure 6: Paleoenvironmental chart for Ben 002 well

Two other methods was also used in deciphering the paleoenvironment of Both wells. They were: Palynological groupings and Palynomorph Marine index.

4.4 Palynological groupings of Ben 002 well

In the well, the mangrove miospores of the Terrestrial groups predominated depicting the environment as a continental mangrove paleo-environment. The figure 5 below shows this information.

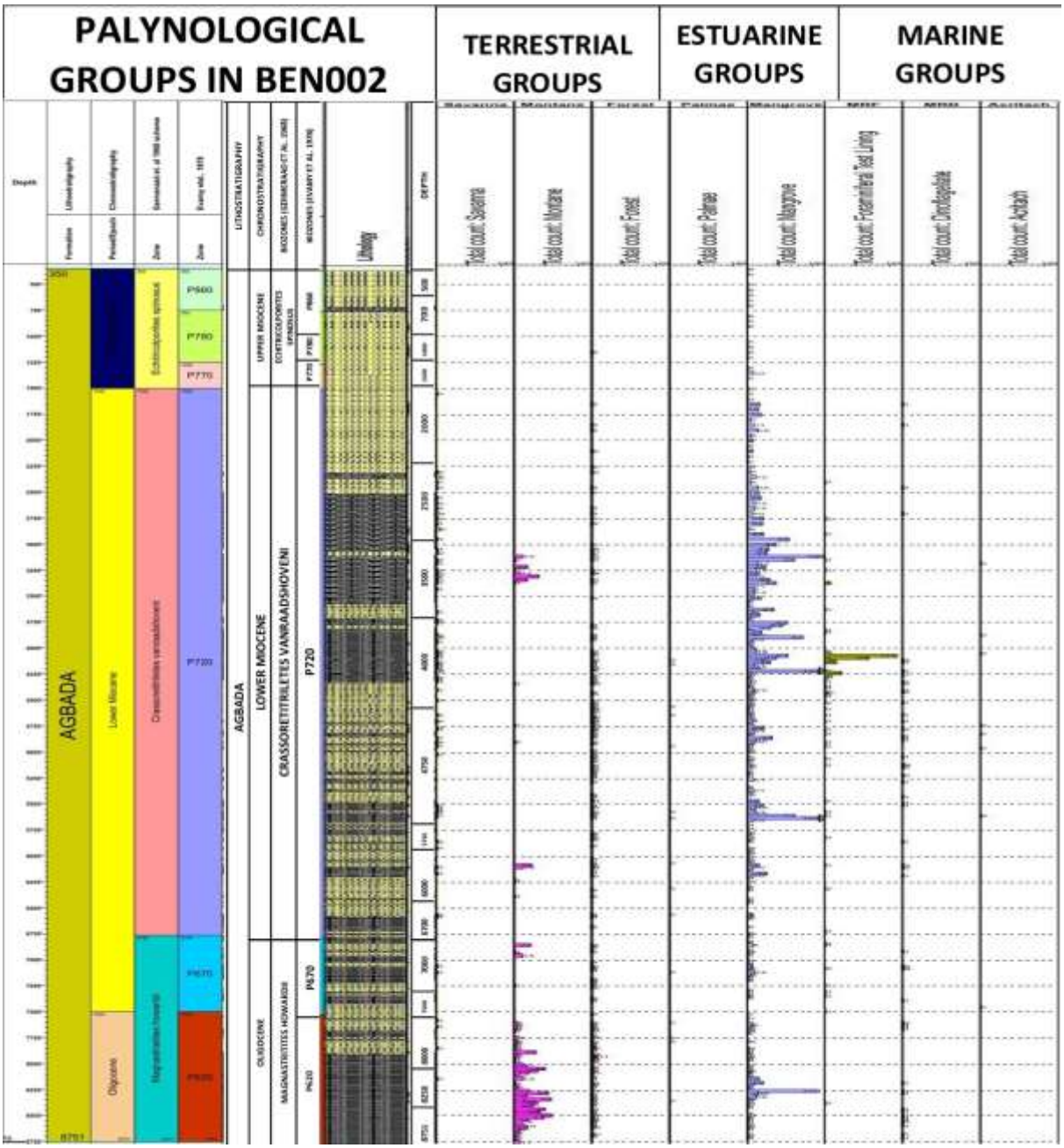


Figure 7: Palynological group in Ben 002 well

4.5 Palynomorph Marine index for Ben 002 well

In the well, a single prominent peak was observed at a depth of approximately 4,000 ft, while the remaining peaks were relatively low. The high peak suggests a period of marine influence, whereas the low peaks are indicative of mangrove depositional conditions within the corresponding depth intervals. Overall, these observations support the interpretation of a predominantly continental mangrove environment for the well. This interpretation is further illustrated in Table 1 and Figure 6 below.

Table 1: Palynomorph Marine index (PMI) of Ben 002 well

DEPTH (FT)	**MARINE MIOSPORE**	**TERRESTRIAL MIOSPORE**	**BEN 002 WELL**					
	MRD	MRF	POS	POM	POF/POR	Total Marine Miospore	Total terrestrial Miospore	Palynomorph marine index
350	1	0	1	4	0	1	5	0.2
500	1	0	1	14	0	1	15	0.06
750	2	0	2	5	0	2	7	0.28
1000	1	0	1	8	0	1	9	0.11
1250	1	0	1	16	2	1	19	0.053
1500	2	0	3	62	1	2	65	0.03
1750	4	0	1	44	3	4	47	0.021
2000	1	0	1	15	5	1	21	0.047
2250	2	0	1	71	1	2	74	0.027
2500	3	0	1	94	4	3	100	0.03
2750	0	0	1	158	2	0	161	0
3000	4	0	1	259	4	4	264	0.015
3250	5	2	5	144	1	7	150	0.02
3500	3	0	1	80	0	3	81	0.037
3750	1	4	2	231	2	5	235	0.0212
4000	1	35	4	223	0	36	227	0.15
4250	4	0	1	27	0	4	28	4

4500	3	0	1	17	1	3	19	3
4750	4	0	1	85	5	4	91	0.04
5000	2	0	1	20	1	2	22	0.09
5250	3	0	1	79	0	3	80	0.04
5500	2	0	1	215	3	2	219	0.01
5750	2	1	2	15	0	3	17	0.17
6000	2	1	2	60	1	3	63	0.04
6250	1	1	1	6	0	2	7	0.07
6500	1	1	1	16	2	2	19	0.11
6750	2	1	1	10	3	3	14	0.21
7000	2	1	2	26	0	3	28	0.11
7250	1	1	1	6	1	2	8	0.25
7500	4	1	1	15	4	6	19	0.32
7750	5	1	1	18	0	6	19	0.32
8000	2	1	1	64	5	3	60	0.04
8250	4	0	1	174	0	4	175	0.02
8500	3	1	1	19	1	4	21	0.19

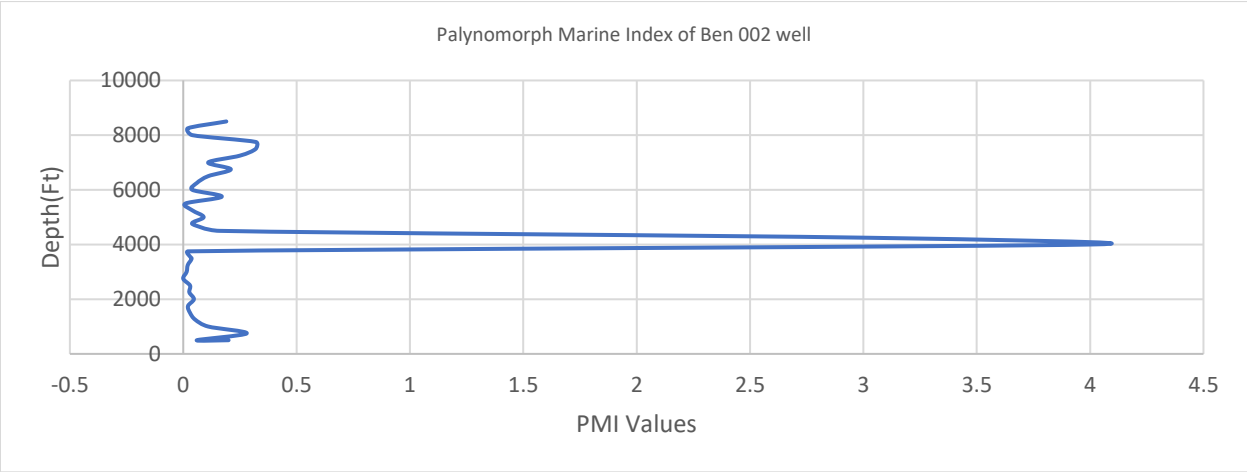


Figure 8: Palynomorph marine index in Ben 002 well

5. CONCLUSION

This study investigates the application of palynological biostratigraphy and lithological data to interpret the depositional environment and paleoclimate of the exploratory Ben 002 Well**.** The well, located at coordinates 5°0′50.604″E and 5°57′48.196″N within location 126, extends from a depth of 350 ft to 11,256 ft and is classified as an onshore well**.** A total of 335 ditch cutting samples were analyzed. Lithological examination revealed that the well penetrated the heterolithic Agbada Formation**,** composed of alternating shale and sand sequences. The lithologic analysis was conducted to describe the rock textures and structures, thereby confirming the formation encountered by the well. Sampling was performed at 60 ft intervals**.** Palynological slide preparation employed an improved modern technique that excluded the use of strong acids and fume cupboards, which are typical in conventional methods. Instead, mild reagents such as sodium hexametaphosphate and zinc bromide were used to isolate palynomorphs from the sediments, offering a safer and more efficient approach. Standard palynological preparation and analytical procedures were followed, resulting in the recovery of well-preserved miospores**.** A total of one hundred and two (102) miospores—comprising eighty (80) pollen grains and twenty-two (22) spores—were identified from the well, enabling the determination of its stratigraphic age as Oligocene to Upper Miocene. Paleoenvironmental interpretation was based on the palynological groupings of miospores and the palynomorph marine index (PMI)**.** The results indicate that the well was deposited in a continental mangrove environment**,** supported by the high abundance of mangrove pollen such as *Psilatricolporites crassus* and *Zonocostites ramonae*. The paleoclimatic reconstruction suggests a humid (wet) climate**,** also inferred from the dominance of these mangrove pollen species.

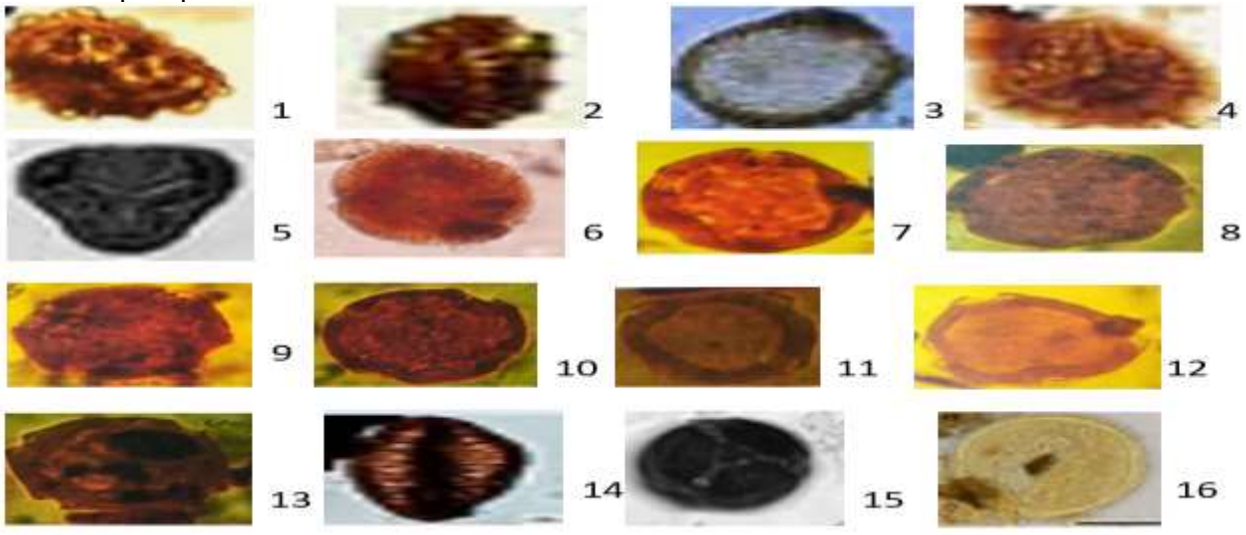


Plate 1: 1. Verrucatosporites alienus, 2. Echimonocolporites sp, 3. Fungal spore, 4. Multicellaesporites sp., 5. Pachydermites diederixi, 6. Pachydermites diederixi, 7. Pachydermites diederixi, 8. Pachydermites diederixi, 9. Pachydermites diederixi, 10. Pachydermites diederixi, 11. Pachydermites diederixi, 12. Pachydermites diederixi, 13. Pachydermites diederixi, 14. Ephedripites sp., 15. Psilastephanoporites sp., 16. Retimonocolpites sp.

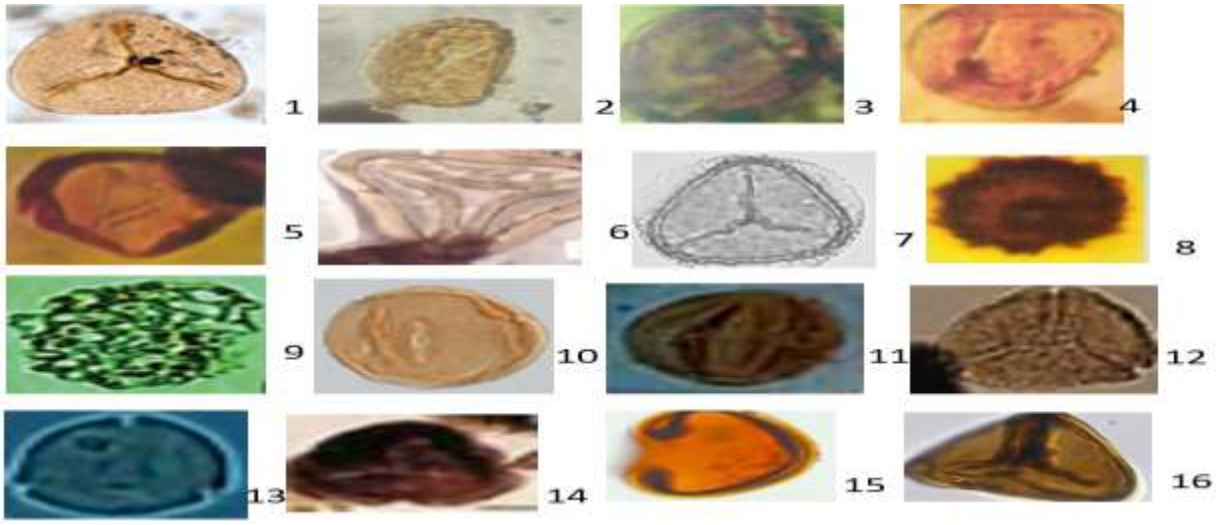


Plate 2: 1 Granulatisporites sp., 2. Nymphaepollis clarus, 3. Nymphaepollis clarus, 4. Nymphaepollis clarus, 5. Nymphaepollis clarus, 6. Aletesporites sp., 7. Lycopodiumsporites, 8. Cingulatisporites ornatus, 9. Praedapollis flexibilis, 10. Psilamonocolpites sp., 11. Psilatricolporites rotundiporis, 12. Psilatricolporites sp., 13. Psilatriporites sp., 14. Retitricolporites sp., 15. Smooth monolete spore, 16. Smooth trilete spore

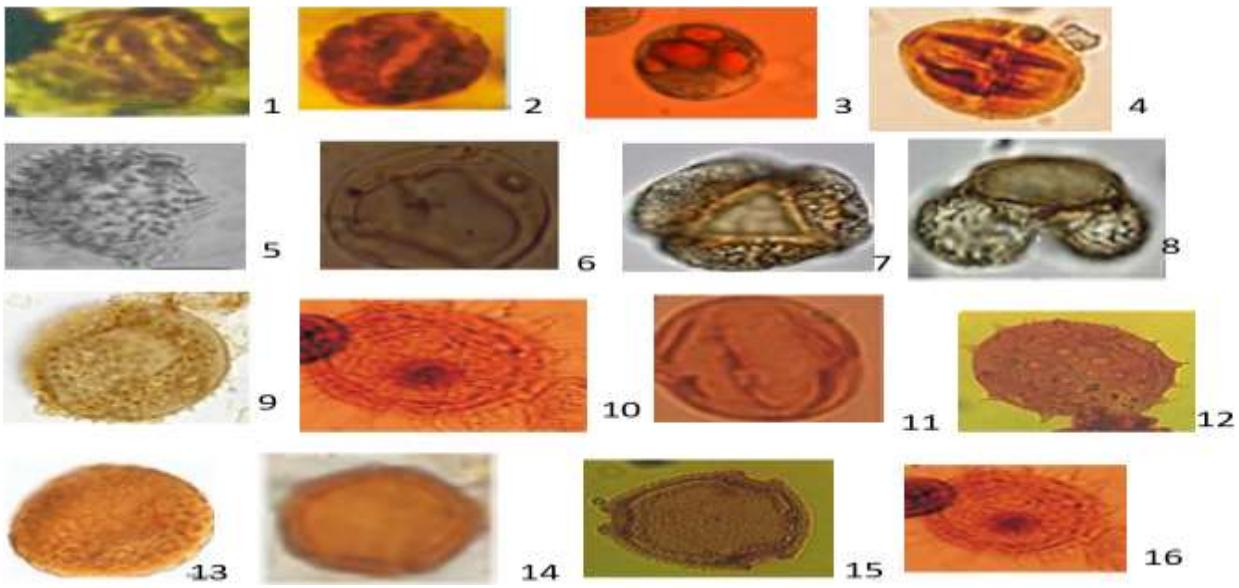


Plate 3: 1. Peregrinipollis nigericus, 2. Peregrinipollis nigericus, 3. Psilaperiporites sp., 4. Striatricolpites sp., 5. Bultinea andreevi, 6. Charred graminae cuticle, 7. Podocarpidites sp., 8. Podocarpidites sp., 9. Psilaperiporites minimus, 10. Psilastephanocolporites laevigatus, 11. Psilastephanocolporites laevigatus, 12. Echiperiporites stelae, 13. Verrutricolporites usmensis, 14. Verrutricolporites microporus, 15. Retitriporites heterobrochatii, 16. Psilastephanocolporites perforates

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