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Palynological study of some Afowo bituminous sediments in parts of Southwestern Nigeria

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Abstract

The tar sand and shale sequences of the Afowo Formation exposed at Lore, Shagbon, and Gbegude areas in parts of southwestern Nigeria has been palynologically investigated to unravel the depositional history. The lithofacies assemblage of the studied section comprising of shale, siltstone, claystone, lignites and ferruginised facies and their peculiar sedimentological features indicate low energy quiet setting, ranging from fresh water to nearshore marine swamps. Recovered palynomorph assemblage include marine dinoflagellate cyst such as *Paleocystodinium golzowenses, Lycopodium* spp. of Maastrichtian age. The pollen and spore (*Retidiporites magdalenensis, Echimonocolpites, Echitriporites trianguliformis and C-cristatus*) indicate terrestrial fresh water environment. The abundance of palmea pollen (*Echitriporites and Longapertites*) and the pteridophyte suggest that the vegetation developed under a predominant humid climate.

Keywords: Bituminous; Palynomorphs; Foraminifers; Ostracods

1. Introduction

The Dahomey Basin is a grouping of inland / coastal / offshore basin that expanses from southeastern Ghana through Togo and the Republic of Benin to southwestern Nigeria (Obaje, 2009). It is separated from the Niger Delta by a subsurface basement high referred to as the Okitipupa Ridge (Okosun, 1990). Its offshore extent is poorly defined. Sediment deposition follows an east-west trend. The heavy oil reservoir in Nigeria occur only in Dahomey basin and is approximately 120km long and 4-6km wide, starting from the boundary of Edo covering Ondo to Ogun state (Enu,1987).

A palynological study of tarsands alongside the oil shale is inevitable as it gives an insight into the environment of deposition of the shale and the sand (Afowo sand). Biostratigraphy study of the tarsands has been done in the past but not much has been done in terms of palynological studies (use of pollen and spores) to carry out the paleoenvironmental reconstruction. Considerable work had been carried out in the eastern branch of the Dahomey Basin. Reyment (1966a, 1966, Bolaji et al., 2020) recorded some species of foraminifera and nautiloids. Most of the information on palynology were obtained from the borehole samples. A fairly rich and diversified microflora was identified from the tar sands and the bituminous sandy clays associated with them. The palynomorphs include Dinoflagellates like; *Coronifera oceanica, Svelardella australlina, Palmichia* sp and *Deflandrea* sp. Pollens and spores like *Proteacidites dehanni, Buttinia andreevi, Aquillapollenites minimus, Spinozonocolpites baculatus, Echitriporites trianguliformis* and *Longapertites vaneendenburgi, Distaverrusporite simplex.*

The age of the bituminous horizon is determined based on the presence of the palynomorphs identified above and placed them in the Maastrichtian age as they are mostly Maastrichtian index fossils. (Jardine and Magloire 1965,

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Germeraad, Hoping and Muller 1968). Adegoke 1980 revealed that the environment of deposition of the bituminous horizon is indicative of continental to near shore environment. This claim is supported by the presence of perispores and pollens like *Monocolpites marginatus, M. humbertoides* and *Ephedripites regularis*. Observing the relation of the microfauna present, (planktonic foraminifers, Ostracodes) the bituminous bed was thus likely to have been effected in deltaic through shallow coastal waters to deeper marine environment.

1.1. Structural and Tectonic and Evolution of the Dahomey Basin.

The study area lies within sheet 282 Okitipupa South-west and sheet 281 of Ijebu Ife South –west. The study area covers a fairly large area extent. The study area extends from Ijebu –East local government of Ogun state to Gbegude and Sagbon in Okitipupa Local Government of Ondo state, (fig. 1). Samples were collected across the tar sand belt in locations like Ogbere, Gbegude. The Dahomey Basin constitutes part of a system of West Africa peri-cratonic basins (marginal sag) (Kingston *et al*, 1983) developed during the commencement of rifting, associated with the opening of the Gulf of Guinea in the Early Cretaceous to Late Jurassic (Burke *et al*, 1972; Whiteman, 1982). The evolution of Dahomey basin is attributed to the transcurrent movements on the oceanic fracture systems especially the Chain, and Charcot fractures during thee drifting stages of separation of South America and Africa in the Campanian to Tertiary. The separation of the African and South American landmasses as a result of the continental drift led to the subsequent opening of the Atlantic Ocean during the Mesozoic Era (Storey, 1995; Mpanda, 1997, Ola, 1991).

Several hypotheses have been developed as to the origin / evolution of basin. The Rift Hypothesis is widely supported, in the basis of several salient features characterizing the basin. During the rifting stage in the Lower Jurassic Early Cretaceous, there was basement fracturing and initial separation between the Africa and South American landmasses. At this time, several marginal basins developed consequent to block faulting, fragmentation and subsidence on the central Paleozoic basement rock (Omatsola and Adegoke, 1981). The early movements were in the Lower Cretaceous when there was drifting (pulling apart) of the African and South American landmasses. Consequent to the opening of the South Atlantic Ocean, there was landward extensional and trantensional movement (drift stage) during the upper Cretaceous to Tertiary. Horizontal movements along the oceanic fracture zones were translated to vertical movements leading to block faulting and subsequent developments of horst and graben (Omatsola and Adegoke, 1981).

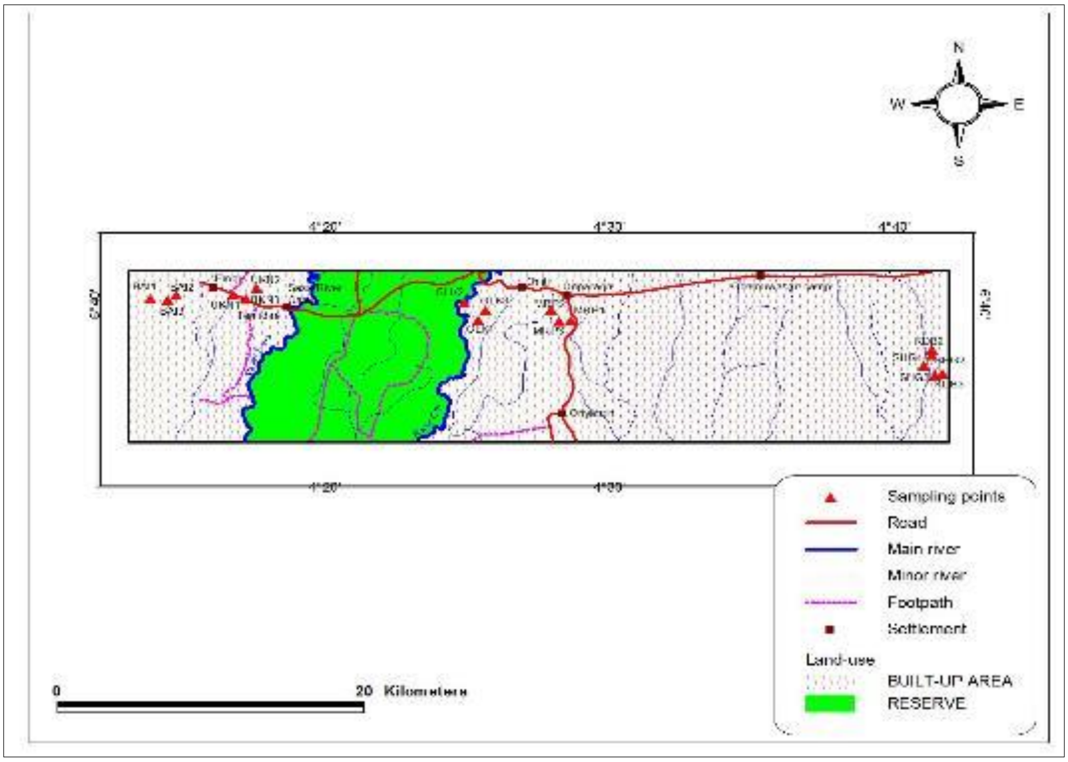

Figure 1 Location map of the study area showing sampling points.

Deposition was initiated in fault-controlled depression on the crystalline Basement complex. The depressions were as a result of rift-generated basement subsidence during the Early Cretaceous (Neocomian). The subsidence gave rise to the deposition of a very thick sequence of continental grits and pebbly sands over the entire basin (Lehner and Ruiter, 1977). Over 1.4km of these sediments are preserved in coastal areas in Nigeria and offshore in Benin Republic (Omatsola and Adegoke 1981; Billman, 1992).

1.2. Stratigraphy of the Eastern Dahomey Basin.

The sedimentary rock sequences in the Dahomey basin were derived from different sources and the final deposition which were of varied sediments, were placed under a number of varying basinal controls in many different operations. A profound mechanical and chemical sorting of the parent materials occurs, which could be described as sedimentary differentiation (Adegoke et al. 1981). This provides reasonable basis for classification of the sediments. Various workers including Jones and Hockey, (1964), Reyment (1965); Omatsola and Adegoke, (1981), and Agagu, (1985), had pieced together the stratigraphy of the Eastern Dahomey Basin from surface as well as sub-surface data (Table 1). In most part of the basin, the stratigraphy is dominated by monotony of sand and shale alternation with minor proportions of limestones and clays, (Agagu 1985).

Table 1 Regional Stratigraphic Setting of the Eastern Dahomey Basin (adapted from Adekeye et al 2019).

<table>
<tr><th></th><th>Age</th><th colspan="3">Formation</th><th>Lithology</th></tr>
<tr><td rowspan="5">Tertiary</td><td></td><td>Ako Et Al, 1980</td><td colspan="2">Omatsola And Adegoke, 1981</td><td></td></tr>
<tr><td>Eocene</td><td>Ilaro Formation</td><td colspan="2">Ilaro Formation</td><td>Sandstone</td></tr>
<tr><td rowspan="3">Paleocene</td><td>Oshosun Formation</td><td colspan="2">Oshosun Formation</td><td>Shale</td></tr>
<tr><td>AKINBO FORMATION</td><td colspan="2">AKINBO FORMATION</td><td></td></tr>
<tr><td>EWEKORO FORMATION</td><td colspan="2">EWEKORO FORMATION</td><td>LIMESTONE</td></tr>
<tr><td rowspan="3">Cretaceous</td><td>Maastrichtian</td><td>Abeokuta Formation</td><td rowspan="3">Abeokuta Group</td><td>Araromi Formation</td><td></td></tr>
<tr><td>Turonian</td><td rowspan="2"></td><td>Afowo Formation</td><td>Sandstone & Shale</td></tr>
<tr><td>Barremian</td><td>Ise Formation</td><td>Sandstone</td></tr>
</table>

2. Materials and methods.

A total number of 20 tar sand and oil shale samples were collected at different localities in the study area. Each sample collected were packed in well labeled polythene bag and tied to prevent mixing up of samples. The samples were systematically collected at outcrop zones and along river channels in the tar sand belt. After careful observation of the samples, a total number of seven (7) samples were selected (Tar sand and shale) for palynological study. For each sample, the prepared slides were scanned for visual assessment which was carried out with the aid of a Lietz Wetzler microscope.

3. Result and Discussion.

Most of the samples analyzed were productive as they yielded well preserved palynomorphs. Seven samples were processed for palynological investigation out of which six yielded dinocyst algae, pollens and spores. The barren sample (Sample 1) is located at the upper part where weathering and other activities has affected the palynomorph preservation. Palynomorph are rare in oxidized sediments. Most palynomorphs were obtained from reduced sediments. The pollen and spore assemblages include angiosperms, gymnosperms and pteridophytic spores belonging to more than 25 genera. The angiosperms constitute about 55% and are essentially monocolpate species. The pteridophyte (dominated by the triletes) and the gymnosperm pollen constitute about 28% and 2% respectively of the total population. Other microplankton includes the Spiniferates, microforaminiferal test lining and algae.

The lithologic assemblage which are largely dominated by argillaceous strata (shale, siltstone and claystone) in the study area suggests deposition processes dominated by suspension settling mode in a distal, quiet and low energy setting, probably swamps and flood plains (Miall, 1990). The ironstone/ferruginised siltstones are perhaps the diagenetic product of iron rich mud deposited in shallow marine condition. The abundance of woody and vegetal materials, which are land derived, in the shales and siltstones and kaolinite rich claystone in the sample (sample 7) indicate prevalence of fresh water conditions (Aturamu and Ojo 2015). The existence of non-marine swamp at a stage is strongly supported by peculiar lithologic association of lignite and coaly siltstones in certain part of the study area. The swamp may be sub environment of proximal deltaic plain (Umeji, 2002, Aturamu 2023)

The paleoenvironment of the Afowo Formation was reconstructed based on the composition and relative proportions of different groups of palynomorphs. Environment changes are usually reflected in the palynologic assemblage (Oloto, 1989; Van Bergen et al, 1990; Ojo and Akande, 2004). The major group include pollen spores and dinoflagellates other associated element include foraminifera test linings. Among the significant terrestrially derived pollen and spores from the studied area are *Foveotriletes margaritae, Proteacidites* spp*., Cristauturites cristatus*. The occurrences of this land derived miospores indicate fresh water condition. Schrank (1984) suggested that palynomorph assemblage with higher content of large land derived miospore indicates terrestrial influence and vice versa.

The presence of some palmea pollen (*Longapertites, Spinizonocolpites and Echitriporites*) and the pteridophytes (dominated by trilete spores) suggests that the land was dominated by warm humid to tropical climate in the studied area (Herngreen, 1981; Schrank, 1984). Oloto, 1992 in his work on Early Eocene deposits in Nigeria considered the presence of *Paleocystodinium golzowenze* (Sample 2) as an indication of a restricted near shore marine environment. Chitinous foraminifera test linings composed of uniserial and coiled forms are present in the sample (Plate 1; Appendix 1). The linings were probably organic remains of benthonic foraminifera and are indicative of near shore shallow marine environment (Gebhardt, 1997; Koutoukos et al, 1990). Foraminiferal linings are the organic inner linings of juvenile foraminifers and they actually represent the chitinous inner tests. Although the lime skeleton is the sole character for identification of Foraminiferae, only the organic cast is preserved in the sediments, and as such it is difficult to ascertain their natural affinity such as genus or species for ecological and stratigraphical consideration.

The size of these fossils ranges from 10 to 100 mm, and may be even more. They are mostly elongated, unilocular. The frequent occurrence in palynological preparations suggests exclusively marine condition. Further, foraminifera chitinous inner tests show a distribution entirely different from the conventional palynomorphs (pollen and spores), presumably because the foraminifera fossils are thanatocoenosis, related primarily to factors encouraging the development of foraminifera populations. The descriptions of palynomorph groups and dispersed organic components as well as age and palaeoenvironmental deductions of the studied samples are represented in Tables 2 and 3 respectively.

Table 2 Descriptions of Palynomorph groups and dispersed organic components

Palynomorphs/ Organic debris	**Description**
Sporomorphs	Embryophytic spores and pollen grains derived from land plants
Fungal remains	Dark brown spores, filamentous hyphae, and mycelia (fruiting bodies of fungal origin)
Marine palynomorphs	Dinoflagellate cysts, acritarchs, and chitinous inner linings of foraminifera
Structured phytoclasts	Structured remains of land plants, including lath-shaped or blocky wood particles, parenchyma, and thin cuticle.
Unstructured phytoclasts	This category included highly degraded plant remains without much structure with colors ranging from yellow to dark brown and nearly black, comminuted brown debris with sizes <5 lm, and amber-colored, globular to angular particles of resin

Table 3 Summary of Age and Paleoenvironment for all the samples

Sample	Age	Paleoenvironment
1 Lore Tar Sand	Undiagnostic. This is due to non-recovery of age indicator species.	Swamp environment due to the presence of smooth monolete spore
2 Lore shale	Maastrichtian	Distal marine environment.
3 Gbegude Tar Sand	Late Maastrichtian to Paleocene	Coastal swamp environment.
4 Gbegude Shale	probably Paleocene	Swamp to marginal marine environment
5 Shogbon Tarsand	Indeterminate	Coastal Deltaic due to *Elaies guineenses, Inaperturopollinites* sp.
6 Shogbon Shale	Maastrichtian – Paleocene	Swamp environment

4. Conclusion

The lithofacies assemblage (Shale, siltstone, lignite, claystone, ferruginised siltstone and ironstones) and their peculiar sedimentological characteristics suggest that the investigated sections of the Afowo Formation were deposited in low energy, coastal, nearshore to non-marine swamp environments.

The presence of substantial proportion of shallow marine dinocyst represent period of marine flooding during the early Maastrichtian. The dramatic change in the palynomorph assemblage towards high proportion and exclusive terrestrially derived pollens/spores indicate fresh water swamp development towards the upper parts. Humid warm tropical climate also prevailed in the Dahomey basin during Maastrichtian.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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Appendix

Palynomorphs recovered

Lore Tarsand (sample 1)	
Species Recovered	No
Psilatricolporites sp	3
Indeterminate pollen	1
Diatom frustulum	8
Fungal spore	3
Smooth monolete spore	3
Fenestrites margeritae	2
Graminidites	1

Lore B Shale (sample 2)			
Species Recovered	No	Species Recovered	No
Arecipeties exilimuratus	2	*Diatum frustulum*	10
Perfotricolporites digitatus	2	*Fenestrites margaritae*	2
Proxapertites cursus	30	*Elaies guineensis*	1
? *Germatriporites* sp.	1	Long cell	11
Psilamonocolpites	18	*Spinizonocolpites echinatus*	8
Spore 34	1	*Psilatricolporites calabarensis*	2
Psilatricolporites sp.	42	*Proxapertites operculatus*	5
Striatricolporites catatumbus	1	*Echistephanoporites echinatus*	1
Smooth monolete spore	10	*Inaperturopollenites* sp	1
Indeterminate spore	2	*Palaeocystodinium golzowenses*	10
Proxapertites sp	1	Microforaminiferal test linings	3
Indeterminate pollen	2	Indeterminate dinoflagegelate cyst	8
Retidiporites magdalensis	4	Smooth trilete spore	3
Retimonocolpites obaensis	28	*Mauritiidites* crassiexinus	3
Ctenoponidites costatus	1	*Proteacidites* sp. (164 spdcw)	4
Pollen 104 (shell pb)	2	Pteris sp.	1
Psilamonocolpites marginatus	26	Pollen 302	3
Lycopodium sp	2	*Echitricolporites triangulatus*	2

Pollen 265 (shell pb)	11	*Ericipites* (205)	2
Chenopodipollis sp	1	*Ephedripites* sp.	1
Spore 11	8	Pollen 121	1
Incertae sedis	1	? *Droseridites senonicus*	1
Psilatriporites sp	4	*Verrucatosporites* sp	1
Monocolpopollenites spherioidites	12	*Retitricolporites* sp.	1

Gbegude Tarsand (sample 3)		Gbegude Shale (sample 4)	
Species Recovered	No	Species Recovered	No
Monoporites annulatus	3	*Graminidites*	12
Psilamonocolpites sp.	3	*Diatom frustulum*	7
Verrucatosporites sp.	4	*? Cyperaceae* sp	1
Psilatricolporites sp.	2	*Indeterminate pollen*	2
Incertae sedis	2	Smooth monolete spore	18
Zonocostites ramonae	1	*? Nymphaea lotus*	8
? Nymphaea lotus	9	*Fungal spore*	7
Proxapertites cursus	2	Smooth trilete spore	1
Indeterminate pollen	3	*Proxapertites cursus* (broken)	2
Inaperturopollenites sp.	5	*Retimonocolpites* sp.	1
Smooth monolete spore	17	*Psilatricolporites* sp.	3
Retimonocolpites obaensis	1	*Retimonocolpites obaensis*	1
Ephedripites sp.	1	*Retitricolporites* sp.	1
Spore 11 (spdcw)	2	*Verrucatosporites* sp.	1
Arecipites sp.	1	*Psilatricolporites crassus* (broken)	1
Diatom frustulum	1	*Monoporites annulatus*	3
Long cell	3	*Cf. Multiariolites formosus*	1
Lycopodium	1	*C costatus*	1
Smooth trilete spore	2	*Inaperturopollenites* sp.	6
Cf. 121	1	*Proxapertites operculatus*	1
Foveotriletes margaritae	1		

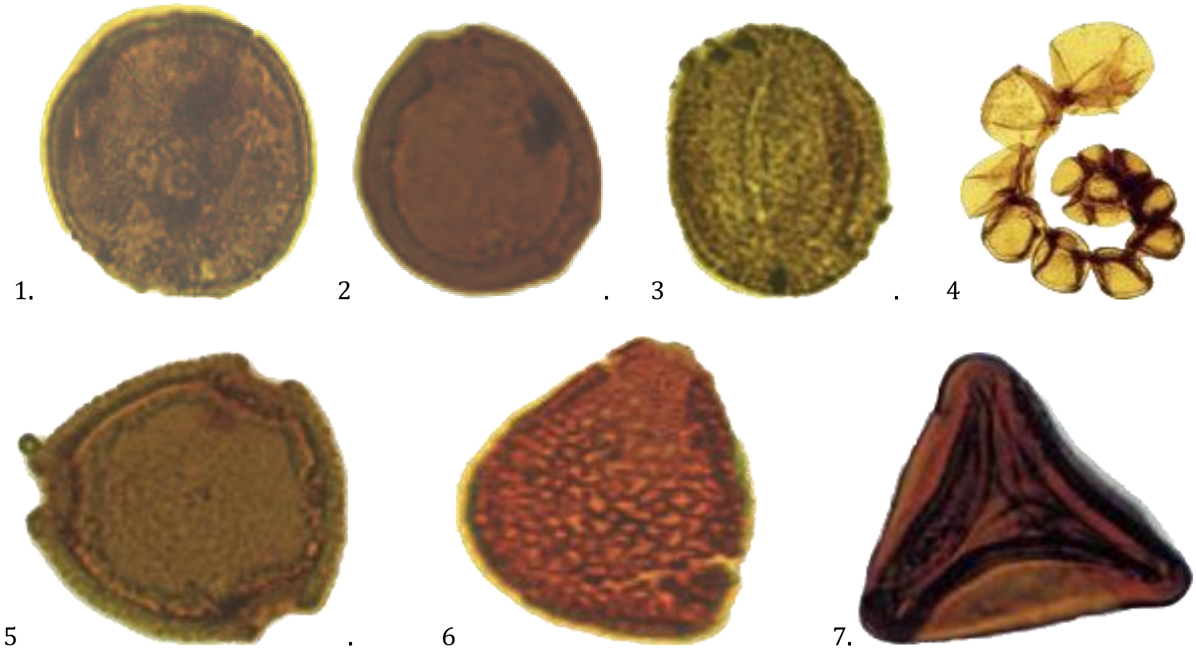
Shagbon Tarsand (sample 5)		Shagbon Shale E (sample 6)	
Species Recovered	No	Species Recovered	No
Fungal spore	9	*Retitricolporites* (tricolpites) sp.	1
Fruiting body	2	Smooth monolete spore	3
Diatum frustulum	2	*Spinizonocolpites echinatus*	2
Smooth monolete spore	2	*Psilamonocolpites* sp	1
Spore 11	6	Indeterminate dinoflagellate	1

Carya sp.	12	*Gleicheniidites* sp.	1
Elaies guineenses	17	Indeterminate pollen	1
Inapertuapollenites sp.	1	Smooth trilete spore	1
Psilatricolporites sp.	1	*Echimonocolpites* sp (pollen 104)	1
Psilamonocolpites sp.	1	Psilatricolporites sp.	2
		Proxapertites sp.	1
		Fungal spore	1

Lore Peat (sample 7)	
Smooth monolete spore	240
Smooth trilete spore	15
Graminidites	2
Verrucatosporites sp.	10
Chenopodipollis sp.	3
Psilamonocolpites sp	9
Arecipites sp.	6
Incertae sedis	2
Psilatricolporites sp.	7
Retimonocolpites sp.	3
Cyperaceae sp.	2
Elaies guineensis	60
Foveotricolporites margaritae	1
Retitricolporites irregularis	10
Lycopodium sp.	30
N. Clarus	8
Ephedripites sp.	1
Arecipites crassimuratus	4
? Zonocostites ramonae (tricolpites sp)	6
Psilamonocolpites marginatus	1
Psilatriccolpites sp.	1
Sapotaceae sp.	1
Concentricytes circulus	1
Gleicheniidites sp.	1
Arecipites exilimuratus	5
Proxapertites crassus	5
Indeterminate spore	1
Pteris	1

Long cell	2
Psilatricolporites crassus	2
Croton type	1

Plate 1



1. Psilatricolpites crassus

2. *Pachydermites diederixii*

3. Perfotricolpites digitatu

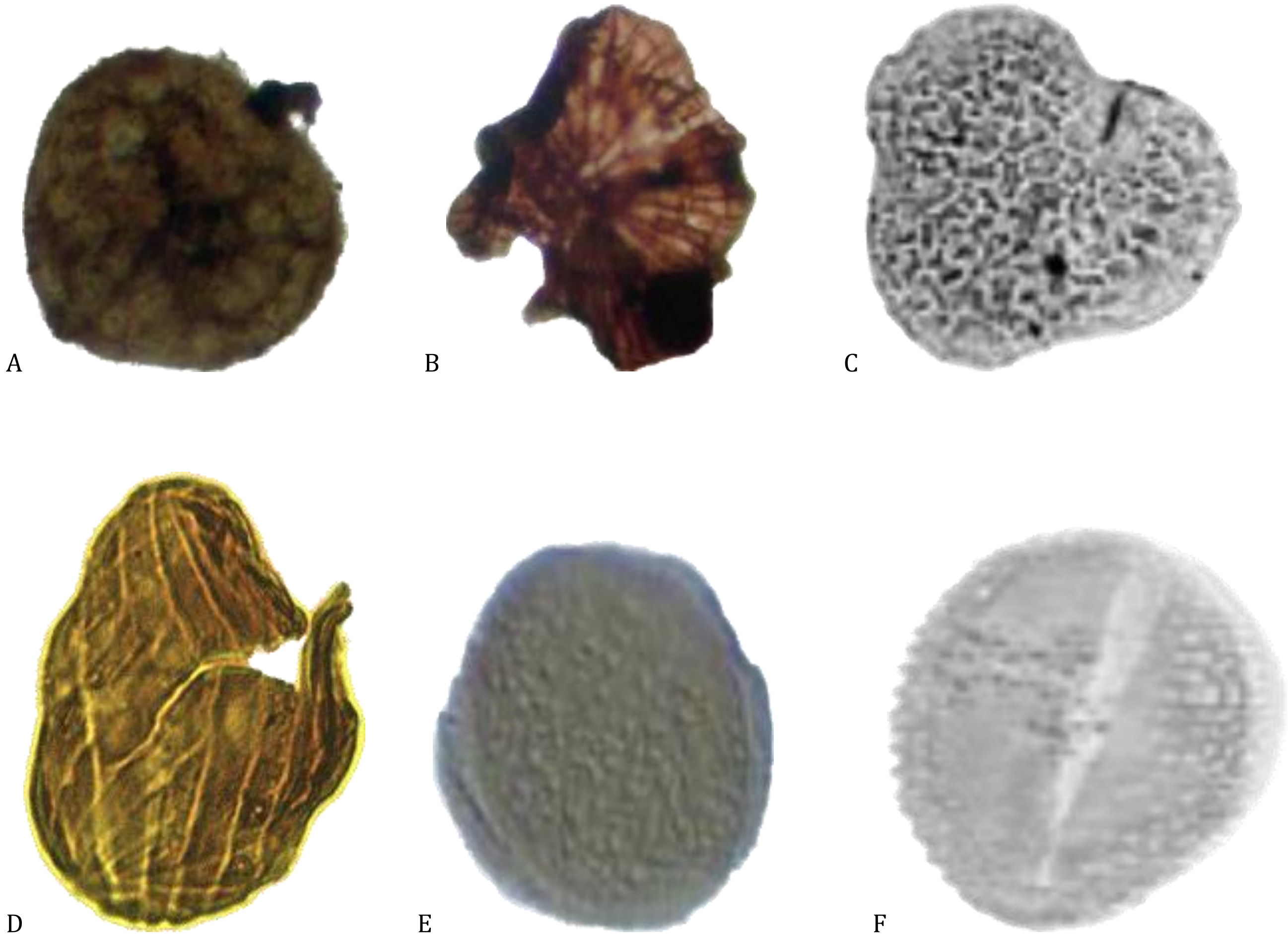
4. Foraminifera test lining

5. Retitriporites spp.

6. Longapertites proxapertitoides

7. Glaeichenidites spp.

PLATE 2



A. Trilete spore

B. Fungal fruiting body

C. *Retitricolpites* spp.

D. *Ephedripites* spp.

E. *Proxapertites* spp.