ISSN 0376-5156
Geophytology 50(1&2): 73–94
May 2022

Palynology of the Rockly Bay Formation (mid-Pliocene), Tobago, West Indies

Arun Kumar

Carleton Climate and Environment Research Group (CCERG), Department of Earth Sciences, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario, K1S 5B6, Canada. E-mail: arunkumarlko@hotmail.com

Manuscript received: 03 January 2022
Accepted for publication: 14 February 2022

ABSTRACT

Kumar A. 2022. Palynology of the Rockly Bay Formation (mid-Pliocene), Tobago, West Indies. Geophytology 50(1&2): 73–94.

Four samples from the upper section of the Rockly Bay Formation (mid-Pliocene) of Tobago were studied for their palynomorph contents with the objective to carry out a palynological investigation since it was described as unfossiliferous. This study demonstrates that the upper section of the Rockly Bay Formation is fossiliferous because it contains palynomorphs. Preservation of palynomorphs is generally fair to good and exhibit diverse affinities. They are, angiosperm pollen, spores, and non-pollen palynomorphs (NPP) such as dinoflagellate cysts, acritarchs, algal cysts and fungal, crustacean, annelid and arcellinidan palynomorphs. Ascidian spicules are calcareous mineral microfossils; they are reported here because they occur in the same palynological slides. Generally, palynomorphs are of terrestrial origin, but a few are of marine origin as well suggesting that the upper section of the Rockly Bay Formation was deposited under supratidal environment, where lakes and ponds existed in which a variety of algal forms thrived. This environment was periodically influenced by high tides and cyclones. These assemblages indicate tropical climate as also evident from the tropical location of Tobago during mid-Pliocene times. Most non-pollen palynomorphs, observed in this study, have a cosmopolitan distribution.

Keywords: Spores-pollen, Non-pollen palynomorphs (NPP), Ascidian spicules, *Balanaus* Beds, Rockly Bay Formation, Middle Pliocene, Tobago, West Indies.

INTRODUCTION

Tobago, a small island, is part of Trinidad and Tobago in the southeastern corner of the Caribbean Sea (Figure 1). Geologically, Tobago represents a fragment of the Antillean Cretaceous Island arc (Frost & Snoke 1989, Jackson & Donovan 1994) and a detailed geological map of the island was provided by Snoke et al. (1988). Most of the island is covered with igneous and metamorphic rocks (Jackson et al. 1988) except for a small region in the southwestern part of the island that is covered by sedimentary rocks unconformably overlying the Cretaceous volcanics. The mid-Pliocene Rockly Bay Formation and the overlying coral limestone (Pleistocene raised reef probably formed during the last interglacial age Sangamonian) are parts of the sedimentary succession (Donovan 1989). Maxwell (1948) provided an early account of the geology of Tobago. Later, Jackson and Donovan (1994) provided a modified and detailed geological description of the island. There are reports on the presence of invertebrate fossils and foraminifera, but no published palynological report from this formation is available. The objective of this paper is to demonstrate presence of palynomorph assemblages from this formation and to discuss their palaeoenvironmental significance.

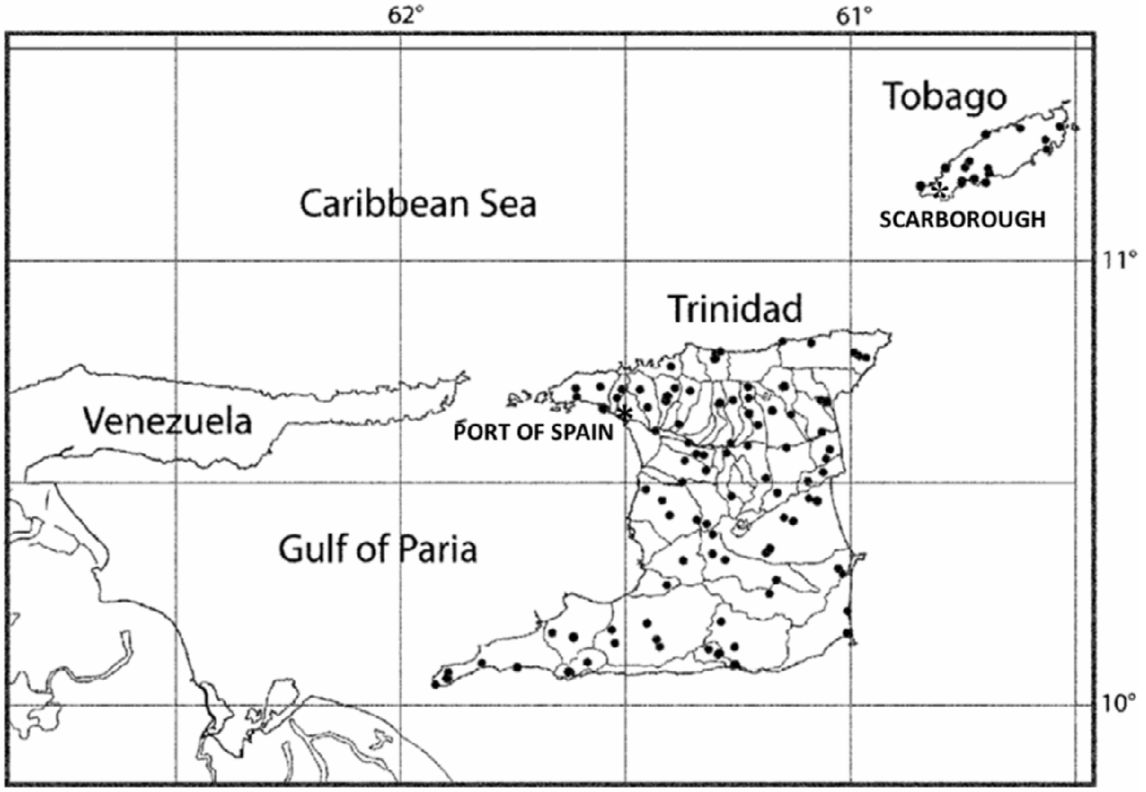

Figure 1. The map of Trinidad and Tobago showing location of Scarborough (Lat. 11.187215° N, Long. 60.730778° E) in Tobago. The Rockly Bay Formation is exposed around this town from where the samples for this study were collected.

During the past six decades extensive palynological research has been published from different parts of the Caribbean and the surrounding regions (Kuyl et al. 1955, Muller 1959, Jaramillo et al. 2014, 2020). Morphological and taxonomic studies of fossil pollen and spores have described many new taxa from this region (Germeraad et al. 1968, Jaramillo & Dilcher 2001). Palynological studies of late Quaternary marine and terrestrial sediments from mountain slopes, lakes, bogs, and other wetlands have provided significant information about environmental and climatic changes, vegetation, and floral history of the region useful to archeological studies (Brenner & Binford 1988, Islebe et al. 1996, Medeanic et al. 2008, Ramcharan 2004, 2005, Ramcharan & McAndrews 2006, Urquhart 2009, González et al. 2010, Peros et al. 2015, Pohl et al. 2017). Various palynomorph groups, including the non-pollen palynomorphs (NPP), have been used as proxies for palaeoenvironmental, palaeoecological and biostratigraphic studies with an emphasis on hydrocarbon exploration (Traverse & Ginsburg 1966, Burney et al. 1994, Cárdenas et al. 2020). Additionally, palynology has been used as a tool for oceanographic, palaeoceanographic and palaeoproductivity of phytoplankton studies (Boonstra et al. 2015, Bringué et al. 2019). There are few publications on source rock palynology and geochemistry identifying stratigraphic units with potential for hydrocarbon generation (Kuyl et al. 1955, Rull 2002).

Although Trinidad and Tobago is a major hydrocarbon producing country, there are only a few published papers on palynological studies. The present author studied palynology of the Pitch Lake in Trinidad and reported a diverse palynomorph assemblage which was obtained by developing a novel maceration technique used to isolate palynomorphs from solid hydrocarbon. The assemblage suggested that the pitch was sourced from the Miocene reservoir rocks underlying the Pitch Lake (Kumar 1979, 1981). Lamy (1985) published on the Plio-Pleistocene palynology along with visual kerogen studies in Trinidad. Payne (1991) discussed the palynological zonation system developed by A.E. González Guzmán for post-Middle Miocene sediments of offshore Trinidad which showed some consistency with seismic correlation and was applied on a broad basis for correlating formations and seismic events in time across major fault boundaries.

ROCKLY BAY FORMATION

Rockly Bay Formation (mid-Pliocene) of Tobago is primarily a siliciclastic succession composed of barnacles that were deposited in intertidal to subtidal environments. Donovan (1989) provided a detailed description of the geology and palaeontology of this formation in historical perspective. In its type locality, this formation is poorly consolidated clay horizons with occasional well indurated beds with calcium carbonate cement. This formation has two distinct lithologies. The lower part is about 3 m thick "*Balanus* Beds" which is about 75% *Balanus* fragments in brown clay matrix, with occasional mollusks and a few pebble beds. The upper part is about 2 m thick "unfossiliferous, thin bedded, grey and brown clay and sandy clay". This section is based on the strip log of Maxwell (1948) measured in the southwestern part of the type section (Donovan 1989).

The invertebrate fauna of the *Balanus* beds is dominated by the balanid barnacle *Megabalanus tintinnabulum* (Linnaeus), oysters, pectinaceans, gastropods, bryozoans, regular echinoids, and rare crabs and sharks (Donovan 1989). Based on foraminifera, Saunders and Muller-Merz (1985) assigned a mid-Pliocene age to this formation. This formation is now recognized to be a transgressive unit, unconformably overlying Mesozoic basalts, and appears to have formed in response to the mid-Pliocene rise in sea level (Donovan 1989).

Invertebrate fauna reported from this formation includes Echinoids (Lewis & Donovan 1991) and a shark tooth *Carcharhinus* sp. cf. *C. limbatus* (Donovan et al. 2001). Sum et al. (2015) reported an assemblage of benthic foraminifera from the Rockly Bay Formation consisting of *Bulimina exilis*, *Bulimina marginata*, *Cassidulina laevigata, Lenticulina rotulata, Brizalina subaenariensis* var. *mexicana, Brizalina transluscens* and *Eponides regularis*. They

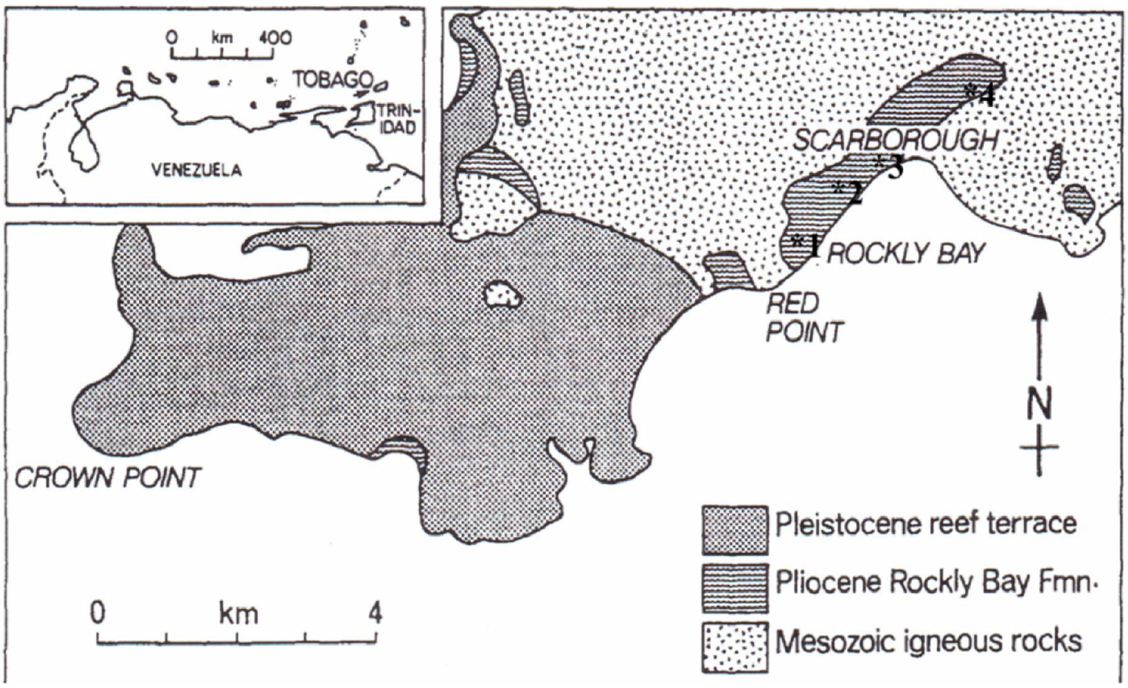

Figure 2. Simplified geological map of Tobago showing location of Scarborough town and outcrops of the Rockly Bay Formation. Sample locations are1 through 4. (modified after Scott et al. 2000).

suggested a Late Miocene or younger age and middle neritic (20–100 m) depositional environment.

MATERIAL AND METHODS

Four surface samples were collected from the cliff face outcrop of the Rockly Bay Formation at various places close to Scarborough (Lat. 11.187215° N, Long. 60.730778° E) (Figure 2). The outcrop surface is heavily weathered, thus the top 15 to 20 cm sediments were removed to get a fresh outcrop. Lithology of the samples varied between grey to greyish brown, finegrained sandy clays and clays. The samples collected for this study are from the upper part of the section described as "unfossiliferous, thin bedded, grey and brown clay and sandy clay" by Donovan (1989) based on information from Maxwell (1948).

Sediment samples were macerated using the standard maceration techniques. Five gram of each sample was used in the maceration process using the following method. (1) 10% HCl treatment for 15 minutes to remove carbonates. (2) Overnight cold HF (40%) treatment to remove silicate minerals. (3) Commercial grade HNO_3 (sp. gr. 1.35) treatment for two hours at 80°C for oxidation of organic matter to remove unwanted organic debris. (4) 10% KOH treatment for 15 minutes followed by rotation at 1,000 rpm for 5 minutes to remove humic matter. (5) Treatment of solution with 5% HCl to neutralize pH. (6) Residue sieved through 10 µm mesh size sieve to remove clay minerals. (7) Residue with fraction larger than 10 µm fraction mixed with 3 drops of polyvinyl alcohol, mixed thoroughly, and smeared over coverslip and dried at 60°C over hot plate. (8) Mounted with Canada Balsam and kept for 20 minutes over hot plate at 80°C. (9) Two slides of each sample were made.

The slides were studied under an OMAX Optical Microscope (MD827S30L Series) using transmitted light. Each slide was scanned under ×400 magnification and palynomorphs were photographed at ×400 and ×1,000 (oil immersion) using an inbuilt camera system in the microscope. Few large palynomorphs were photographed at ×100 magnification as well. Since palynomorph numbers are low, all palynomorphs in each slide were counted. All palynological slides are kept in the laboratory of Carleton Climate and Environment Research Group (CCERG), Department of Earth Sciences, Carleton University, Ottawa, Canada.

RESULTS

These samples yielded low numbers of palynomorphs having affinity with various biological groups. They are angiosperm pollen, spores, and non-pollen palynomorphs (NPP) such as dinoflagellate cysts, acritarchs and algal cysts, fungal palynomorphs, crustacean palynomorphs, annelid palynomorphs, and arcellinidan palynomorphs. Ascidian spicules are calcareous mineral microfossils thus cannot be considered as palynomorphs. However, they are reported here because they occur in the same palynological slides. Preservation of palynomorphs generally is fair to good. Few forms are difficult to identify even at the generic level; they are not illustrated but mentioned in the text, for example, 'monosulcate pollen (indet)' probably having a botanical affinity with the family *Arecaceae*, and 'inaperturate pollen (indet)' etc. Fungal palynomorphs are the most diverse group and numerically most common as well. Numerical distribution of palynomorphs is shown in Table 1.

PALYNOASSEMBLAGE

Palynomorphs and mineral microfossils are classified into three broad groups, as follows: 1. Pollen and spores; 2. Non-pollen palynomorphs (NPP); and 3. Ascidian spicules.

1. Pollen and Spores

Genus: *Ladakhipollenites* Y.K. Mathur & A.K. Jain 1980

Ladakhipollenites simplex (Gonz. Guzm.) C.A. Jaram. & Dilcher 2001
Figures 3.4–6

Size: 32.8 × 21.2 µm (Figure 3.4), 28 × 23 µm (Figure 3.5), 37.2 × 24.4 µm (Figure 3.6).

Comments: These are oblate subspherical, oval, circular to subcircular; tricolpate pollen, with long and broad colpi with generally pointed ends. Exine laevigate to faintly sculptured. Present specimens are similar to *Ladakhipollenites simplex* (Gonz. Guzm.) C.A.

Jaram. & Dilcher 2001, described from Palaeogene sediments of central Colombia but vary in their overall shape and size. Its botanical affinity is to *Angiospermae.*

Genus: *Monoporopollenites* B.L. Mey. 1956

***Monoporopollenites* sp.**

Figure 3.16

Size: 37 × 34.5 µm.

Comments: It is a monoporate, mid-sized pollen grain, pore slightly protruding, having psilate exine. Present specimen is an almost spherical monoporate pollen with a protruding pore and psilate exine. Its botanical affinity is to the family *Poaceae.*

Genus: *Palmaepollenites* R. Potonié 1958

***Palmaepollenites* sp.**

Figure 3.2, 15

Size: 38.3 × 21 µm (Figure 3.2) and 35.6 × 19 µm (Figure 3.15).

Comments: These are monosulcate pollen grains with a smooth exine. Sulcus is narrow with ends widening in a club shaped or circular manner. Thus, broadening of the sulcus at the end is an important morphological feature of this genus. The present specimen looks like *Palmaepollenites eocenicus* (B. Biswas) S.C.D. Sah & S.K. Dutta (1966) described from Eocene of Assam, India and Neogene of Kerala, India (Rao & Ramanujam 1978). Its botanical affinity is to the family *Arecaceae.*

Genus: *Proxapertites* Hammen 1956, emend. R.Y. Singh 1975

cf. *Proxapertites psilatus* G.A. Sarmiento 1992

Figure 3.10

Size: 56 × 50 µm.

Comments: These are zonosulcate pollen. *Proxapertites psilatus* G.A. Sarmiento 1992 is 25-37 µm in size whereas the present specimen is larger. This species is described from the Middle Palaeogene sediments of Central Colombia (Jaramillo & Dilcher 2001). Its botanical affinity is to the family *Arecaceae.*

Proxapertites verrucatus G.A. Sarmiento 1992

Figures 3.12, 4.2, 4, 8

Size: 45 × 40 µm (Figure 3.12); 33 × 30 µm (Figure 4.2); 32.2 × 29.4 µm (Figure 4.4); 48 × 42 µm (Figure 4.8)

Comments: This species was reported from the Middle Palaeogene sediments of Central Colombia (Jaramillo & Dilcher 2001). Its botanical affinity is to the family *Arecaceae.*

Genus: *Psilastephanocolpites* Leidelmey. 1966

***Psilastephanocolpites* sp.**

Figure 3.17

Size: 32 × 28 µm.

Comments: It is a mid-sized stephanocolpate psilate pollen. The present specimen is rounded and has four colpi seen in its equatorial view. Similar forms are reported from Neogene tropical sediments (Kumar & Takahashi 1991; Kumar 1994). Its botanical affinity is to *Angiospermae.*

Genus: *Dacrydium* Lamb. 1806

***Dacrydium* type** (*Podocarpaceae*)

Figure 4.19

Size: 35 µm (diameter); wall thickness 2.5–3.5 µm.

Alete spore

Figure 3.7

Size: 45 × 40 µm.

Comments: Such alete spores without any distinct laesura are similar to bryophytic spores *Polytrichum* sp. (Moss, *Polytrichaceae*) and also spores of *Equisetum* without elaters.

Genus: *Cicatricososporites* Pflug & P.W. Thomson in P.W. Thomson & Pflug 1953

***Cicatricososporites* sp.**

Figure 3.14

Size: 34.6 × 17 µm.

Comments: It is a monolete, cicatricose spore having muri diagonal to laesura. It occurs widely in the Late Cretaceous-Tertiary sediments all over the world. Its botanical affinity is to the family *Schizaeaceae.*

Genus: *Clavatisporites* Kedves & Simoncs. 1964

Clavatisporites mutisii (Hammen) C.A. Jaram. & Dilcher 2001

Figure 3.9

Size: 38.7 × 26.5 µm.

Comments: These are trilete spores with clavate ornamentation. This species is described from the Middle Palaeogene sediments of Central Colombia (Jaramillo & Dilcher 2001). Its botanical affinity is to *Pteridopsida*.

2. Non-pollen palynomorphs (NPP)

2.1. Algal palynomorphs

Algal cysts

Figure 4.11–12, 21

Size: 21 × 18 µm (Figure 4.11); 16.4 µm (Figure 4.12); 21 µm, archaeopyle diameter 7 µm (Figure 4.21).

Comments: Algal cysts (Figure 4.11–12) with central body having large circular to subcircular opening. Endophragm is thicker than periphragm that is almost translucent, wrinkled and with irregular margin. These forms may be compared with genus *Halodinium* J.P. Bujak 1984 with large circular to subcircular pylomes. Algal cyst (Figure 4.21) shows a distinct archaeopyle; thus, it may be a dinoflagellate cyst.

Acritarch type

Figure 4.3

Size: 84 × 80µm

Comments: It is a thin walled spherical acritarch with an opening by cryptosuture.

Genus: *Ceratium* Schrank 1793

***Ceratium* cyst**

Figure 4.15–16

Size: 24.7 × 17 µm (Figure 4.15); 24.6 × 19 µm (Figure 4.16).

Comments: Present specimens are similar to the cyst of *Ceratium monoceras* K.N. Mert. et al. 2012 (supplementary material, figure S 19). This species is a freshwater dinoflagellate and its cysts are oval with an apical horn. Their length is 40–50 µm and width 30–40 µm. Present specimens are smaller in size.

cf. Dinoflagellate cyst

Figure 4.13

Size:47 × 33 µm, apical horn length 9 × 2.7 µm

Comments: This specimen has peridiniopsid affinity, having apical and antapical horns. But no other

Table 1. Distribution of palynomorphs in samples of the Rockly Bay Formation.

TAXA	SAMPLES			
	1	2	3	4
Pollen Grains				
Dacrydium type (*Podocarpaceae*)		1		3
Inaperturate pollen (indet)	3	1		
Ladakhipollenites simplex	3			
Monoporopollenites sp.	2	1		1
Monosulcate pollen (indet)	1	1		
Palmaepollenites sp.	3			1
Proxapertites psilatus	1			
cf. *Proxapertites psilatus*	1			
Proxapertites verrucatus	3			1
Psilastephanocolpites sp.				1
Spores				
Cicatricososporites sp.				1
Clavatisporites mutisii	1			
Alete spore			1	
Algal Palynomorphs				
Acritarch type	2			
Algal cysts			3	5
Ceratium cyst				2
cf. Dinoflagellate cyst			1	
Leiosphaeridia spp.	3	1		1
Micrhystridium sp.		1		
Ovoidites sp.	2			
Sigmopollis sp.	3			
Tasmanites sp.	1			1
Fungal Palynomorphs				
Asyregraamspora reticulata	2	1	2	3
Brachysporisporites ovoidus	3		2	
Brachysporisporites catinus	2			
cf. *Chaetosphaerites obscurus*				1
Dicellaesporites fusiformis				2
cf. *Dicellaesporites reniformis*	1			1
cf. *Dictyosporites fibrassi*	1			
Diporisporites sp.			1	
Dyadosporites sp. A		1		
Fungal fruit body	1	1	3	
Inapertisporites circularis				1
Inapertisporites sp. A				1
Inapertisporites sp. B	1			
Inapertisporites sp. C	2			
cf. *Milesites* sp.			1	
Multicellites granulatus	1			1
Palaeomycites bharwainensis	9	3	1	2
Palaeomycites sp. A	2			1
?*Palaeomycites* sp.	1			
Papulosporonites enormis	1			
Pluricellaesporites malayensis			1	
Crustacean Palynomorphs				
Crustacean exoskeleton	5			3
Crustacean wing	1			
Crustacean antennae		3	6	1
Crustacean sac		2		
Forma A	2			1
Ostracod jaw	1			
Annelid Palynomorphs				
Scolecodont type 1	1		1	
Scolecodont type 2			1	
Arcellinidan Palynomorphs				
Centropyxis aculeata			1	1
Centropyxis sp.			3	
?*Cyclopyxis* sp.			2	
Ascidian spicules		8		

features of a dinoflagellate cyst are visible. This specimen has a morphological affinity with the genus *Peridinium* Ehrenb. 1830, which is a cosmopolitan freshwater dinoflagellate that occurs in freshwater lakes, ponds, and brackish environments.

Genus: *Leiosphaeridia* Eisenack1958

***Leiosphaeridia* spp.**
Figures 3.8, 4.5

Size: 42 µm (Figure 3.8); 63 × 61 µm (Figure 4.5)

Comments: These acritarch forms have a simple spherical test with a single smooth wall. Their size ranges widely and have biological affinity with modern planktic green alga *Halosphaera* (Tschudy & Scott 1969). They represent shallow-water environments. Specimen (Figure 3.8) is damaged; part of it has been removed. Another specimen (Figure 4.5) is damaged and has a folded wall.

Genus: *Ovoidites* R. Potonié 1951 ex Krutzsch 1959

***Ovoidites* sp.**
Figures 3.1, 3

Size: 35.8 × 20.3 µm (Figure 3.1); 44 × 32.4 µm (Figure 3.3).

Comments: These are ovoid zygospores or aplanospores of the filamentous green algae of family *Zygnemataceae*. Their known geological record goes back to Cretaceous. These zygospores have a close association with freshwater peats and related pollen assemblages (Rich et al. 1982). This form has been associated with shallow, stagnant, oxygen-rich, open fresh waters, lake margins and marsh habitats (Rich et al. 1982, van Geel & van der Hammen 1978).

Genus: *Sigmopollis* R.W. Hedl. 1965

***Sigmopollis* sp.**
Figure 4.1, 6–7

Size: 36.3 × 29.6 µm (Figure 4.1); 28.4 × 27.3 µm (Figure 4.6); 59 × 46 µm (Figure 4.7).

Comments: This genus is a freshwater Cyanophyte alga (Krutzsch & Pacltová 1985) that prefers meso- to eutrophic, stagnant or slowly flowing shallow waters. It has been reported widely in the Quaternary sediments from various parts of the world.

Genus: *Tasmanites* E.T. Newton 1875

***Tasmanites* sp.**
Figure 3.11

Size: 48.5 µm (diameter); wall thickness 3–3.5 µm.

Comments: *Tasmanites* occurs in marine environments and its age ranges from Ordovician to Recent (Tschudy & Scott 1969). According to Wall (1962) modern algal genus *Pachysphaera* is very similar to or may be same as *Tasmanites* E.T. Newton 1875. The affinities of *Tasmanites* with the modern prasinophycean algae *Pachysphaera, Halosphaera*, and *Pterosphaera* are reported by Guy-Ohlson (1988).

2.2. Fungal palynomorphs

Genus: *Asyregraamspora* Sal.-Cheb. & Locq.1980

Asyregraamspora reticulata Sal.-Cheb. & Locq. 1980
Figure 3.13

Size: Diameter of three specimens range between 28.6 and 15.7 µm.

Comments: These are dark brown, small (20 × 15 µm), inaperturate, reticulate fungal spores. This species was described from the Early Miocene of the coast of Equatorial Africa, Gulf of Guinea, Cameroon (Salard-Cheboldaeff & Locquin 1980).

Genus: *Brachysporisporites* R.T. Lange & P.H. Sm. 1971

Brachysporisporites catinus (Elsik & Janson.) Kalgutkar & Janson. 2000
Figure 5.11, 15

Size: 36–39.7 × 20.3–20.6 µm.

Comments: Present specimens conform with the description of Elsik and Jansonius (1974) who described this species as *Granatisporites catinus* from Mackenzie River Delta, N.W.T., Canada but was later transferred to the genus *Brachysporisporites* by Kalgutkar and Jansonius (2000).

Brachysporisporites ovoidus Z.-C. Song & Liu Cao 1994
Figure 5.8, 10

Size: 41–41.5 × 19–23.7 µm.

Comments: Present specimens conform with the descriptions of Song and Cao (1994). However, their specimens do not show any curvature at the proximal end and were described from Late Cretaceous of Antarctica.

Genus: *Chaetosphaerites* Felix 1894

cf. *Chaetosphaerites obscurus* (P. Ke & Z.Y. Shi) Kalgutkar & Janson. 2000
Figure 5.22

Size: 43 × 19 µm, wall thickness 2.0 µm, thickness of the middle septa 3.5 µm, thickness of terminal septa 1.5 µm.

Comments: The present specimen conforms to the description of this species described from Eocene-Oligocene of China. However, the Chinese specimens are larger in size (63 × 31.5 µm).

Genus: *Dicellaesporites* Elsik 1968

Dicellaesporites fusiformis Sheffy & Dilcher 1971
Figure 4.18

Size: 34.4 × 15.2 µm.

Comments: The present specimen conforms with the description of this species given by Sheffy and Dilcher (1971), reported from the Middle Eocene of Tennessee, U.S.A., except for its smaller size (8.7 × 17.4 µm).

cf. *Dicellaesporites reniformis* Zhong Y. Zhang 1980
Figure 5.6

Size: 35.5 × 15.3 µm.

Comments: This species was originally described from Oligocene of China, and its reniform shape and large size (87.3 × 28.6 µm) are its identifying characters. The present specimen is smaller in size.

Genus: *Dictyosporites* Felix 1894 emend. Kalgutkar & Janson. 2000

cf. *Dictyosporites fibrassi* (Hammen) Kalgutkar & Janson. 2000
Figure 5.13

Size: Spore diameter 11.6 × 10.6 µm (largest) 8.4 × 8.0 µm (smallest).

Comments: These are inaperturate, multicellate, rounded to subrounded fungal spores. This species was described from Maastrichtian of Magdelena Valley, Colombia and its spore size ranges between 33–34 µm. Present specimens are significantly smaller.

Genus: *Diporisporites* Hammen 1954

***Diporisporites* sp.**

Comments: Slide Tob 3/A # 45. Not photographed due to poor preservation.

Genus: *Dyadosporites* Hammen ex R.T. Clarke 1965

***Dyadosporites* sp. A**
Figure 5.18

Size: 61 × 27 µm.

Comments: Present specimen is an elliptical, bilocular, fungal spore with a septum that divides the spore into two unequal parts in an approximately 65:35

⟶

Figure 3. All photographs ×400 unless otherwise mentioned.
1. *Ovoidites* sp. (*Zygnemataceae*); slide Tob-1a; 128.7 × 5.5; size 35.8 × 20.3 µm. **2.** *Palmaepollenites* sp. (*Arecaceae*); slide Tob-1a; 129.8 × 7.4; size 38.3 × 21 µm. **3.** *Ovoidites* sp.(*Zygnemataceae*); slide Tob-1b; 136 × 6.5; size 44 × 32.4 µm. **4.** *Ladakhipollenites simplex* (Gonz. Guzm.) C.A. Jaram. & Dilcher 2001; slide Tob-1b; 136.6 × 17.8; size 32.8 × 21.2 µm. **5.** *Ladakhipollenites simplex* (Gonz. Guzm.) C.A. Jaram. & Dilcher 2001; slide Tob-1b; 129 × 15.8; size 28 × 23 µm. **6.** *Ladakhipollenites simplex* (Gonz. Guzm.) C.A. Jaram. & Dilcher 2001; slide Tob-1b; 135.8 × 19; size 37.2 × 24.4 µm. **7.** Alete spore; slide Tob-3a; 143.8 × 9; size 45 × 40 µm. **8.** *Leiospheridia* sp.; slide Tob-4a; 129.6 × 4.6; size 42 µm (diameter). **9.** *Clavatisporites mutisii* (Hammen) C.A. Jaram. & Dilcher 2001; slide Tob-1a; 136 × 9.8; size 38.7 × 26.5 µm. **10.** cf. *Proxapertites psilatus* G.A. Sarmiento 1992 slide Tob-1a; 130 × 9.8; size 56 × 50 µm. **11.** *Tasmanites* sp. (mid focus); slide Tob-4a; 134.8 × 5.5; size 48.5 µm (diameter); wall thickness 3.5-3 µm. **12.** *Proxapertites verrucatus* G.A. Sarmiento 1992; slide Tob-4a; 131.8 × 7.8; size 45 × 40 µm. **13.** *Asyregraamspora reticulata* Sal.-Cheb. & Locq. 1980; slide Tob-4a; 136.5 × 8.5; size diameter range 28.6-15.7 µm. **14.** *Cicatricososporites* sp. (*Schizaeaceae*); slide Tob-4a; 135 × 9.6; size 34.6 × 17 µm. **15.** *Palmaepollenites* sp. (*Arecaceae*); slide Tob-4a; 133 × 11; size 35.6 × 19 µm. **16.** *Monoporopollenites* sp. (*Poaceae*); slide Tob-4b; 141 × 10; size 37 × 34.5 µm. **17.** *Psilastephanocolpites* sp.; slide Tob-4b; 143.2 × 14.5; size 32 × 28 µm. **18.** Ascidian spicule; slide Tob-2b; 143.2 × 15.5; size 22.7 µm. **19.** Ascidian spicules; slide Tob-2b; 128 × 19.8; size 21 µm (19a) and 16 µm (19b). **20.** Cuticle; slide Tob-1b; 139.6 × 14.6; size 99.6 × 36.8 µm. **21.** Ascidian spicules; slide Tob-2b; 136 × 21.5; size 25 × 20 µm (21a) and 10 × 9 µm (21b).

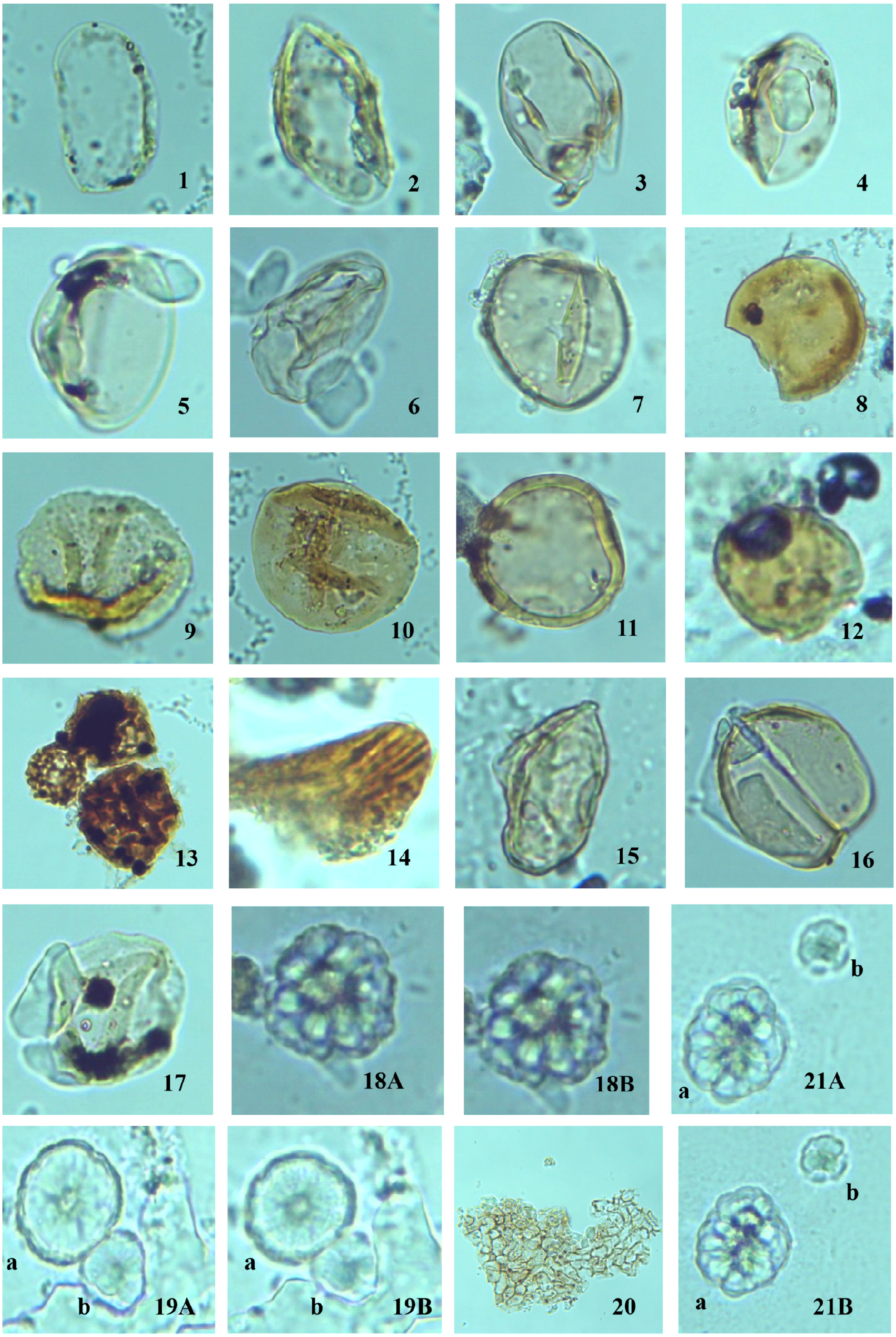
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18A
18B
a
b
21A
a
b
19A
a
b
19B
20
a
b
21B

Figure 3

ratio. Septum is tilted to one side. Cell wall psilate, having a pore at the apex of each cell. This is a new species of the genus *Dyadosporites*, but a new formal name is not assigned because only one specimen has been observed.

Genus: *Inapertisporites* Hammen 1954 emend. Elsik 1968

Inapertisporites circularis (Sheffy & Dilcher) Kalgutkar & Janson. 2000
Figure 5.23

Size: 13.2 µm (diameter).

Comments: It is a small, circular, inaperturate, single celled fungal spore with a psilate wall.

***Inapertisporites* sp. A**
Figure 4.20

Size: 81 × 74.5 µm.

Comments: This is an inaperturate, dark brown, spherical spore without any septa. Wall ~ 2.5 µm thick, folded, with unevenly distributed, faintly reticulate ornamentation. Its large size and wall structure separates this from any known species of this genus.

***Inapertisporites* sp. B**
Figure 5.3

Size: 28 × 24 µm, wall psilate ~1.5 µm thick.

Comments: It is a dark brown, planoconvex spore without any pores or furrow. This specimen looks like *Hypoxylonites curvatus* (Ramanujam & K.P. Rao) Elsik 1990 described from Miocene of Kerala, India but lacks pores at the opposite ends as noted by Ramanujam and Rao (1978). Elsik (1990) disputed the size of this species and noted the presence of a furrow between the aporate ends of the spore along the straight side.

***Inapertisporites* sp. C**
Figure 5.4, 16

Size: 33.3 × 11.5 µm and 38.3 × 34 µm.

Comments: These are dark brown, spherical to ovoidal forms, wall psilate; often irregularly damaged and broken. They appear to have been damaged during the maceration process of the sediments.

Genus: *Milesites* Ramanujam & Ramachar 1980

cf. *Milesites* sp.
Figure 5.20

Size: 46.5 × 26.8 µm.

Comments: A single celled fungal spore with triangular-obovoid shape; having a terminal pore. Wall is thin and scabrate. Such forms are known to be Urediniospores having varied shapes ranging from lanceolate, obovoid, pedicellate or of irregular configuration (Ramanujam & Ramachar 1980). The present specimen appears close to the description of *Milesites irregularis* (Ramanujam & Ramachar 1980) described from the Miocene sediments of Tamil Nadu, India. However, shape of the present specimen differs in being close to triangular-obovoid with a broad pore at one end and with a thin, scabrate wall.

⟶

Figure 4. All photographs ×400 unless otherwise mentioned.
1. *Sigmopollis* sp.; slide Tob-1a; 127.2 × 6.1; size 36.3 × 29.6 µm; wall thickness 2.5 µm. **2.** *Proxapertites verrucatus* G.A. Sarmiento 1992; slide Tob-1a; 126.5 × 7; size 33 × 30 µm. **3.** Acritarch type. (opening by cryptosuture); slide Tob-1a; 127.5 × 8; size 84 × 80 µm. **4.** *Proxapertites verrucatus* G.A. Sarmiento 1992; slide Tob-1a; 133.5 × 16.3; size 32.2 × 29.4 µm. **5.** *Leiosphaeridia* sp.; slide Tob-1a; 132.3 × 15.3; size 63 × 61 µm. **6.** *Sigmopollis* sp.; slide Tob-1b; 138.2 × 5.3; size 28.4 × 27.3 µm. **7.** *Sigmopollis* sp.; slide Tob-1b; 140 × 4.4; size 59 × 46 µm. **8.** *Proxapertites verrucatus* G.A. Sarmiento 1992; slide Tob-1b; 137 × 18; size 48 × 42 µm. **9.** *Micrhystridium* sp.; slide Tob-2a; 128.7 × 6.8; size 14.8 µm (diameter); 1.5-1.0 µm (length of processes). **10.** *Leiosphaeridia* sp.; slide Tob-2a; 133.5 × 7.3; size 26.5 × 19.7 µm. **11.** Algal cyst; slide Tob-3a; 138.5 × 8; size 21 × 18 µm; wall thickness 3.0 µm. **12.** Algal cyst; slide Tob-3a; 135 × 11.5; size 16.4 µm (diameter). **13.** cf. Dinoflagellate cyst; slide Tob-3a; 141.5 × 11.5; size 47 × 33 µm, apical horn 9 × 2.7 µm. **14.** *Dacrydium* type (*Podocarpaceae*); slide Tob-4a; 129 × 9.2; size 31.2 µm (diameter). **15.** *Ceratium* cyst (Cyst of *Ceratium monoceras* K.N. Mert. et al. 2012, supplementary matrials Figure S 19): slide Tob-4a; 137 × 12.8; size 24.7 × 17 µm. **16.** *Ceratium* cyst (Cyst of *Ceratium monoceras* K.N. Mert. et al. 2012, supplementary matrials Figure S 19); slide Tob-4a; 137.5 × 14.6; size 24.6 × 19 µm. **17.** *Palaeomycites* sp. A; slide Tob-4a; 132.6 × 16.2; size 47 × 40 µm (diameter of central body). **18.** *Dicellaesporites fusiformis* Sheffy & Dilcher 1971; slide Tob-4b; 138.5 × 13; size 34.4 × 15.2 µm. **19.** *Dacrydium* type (*Podocarpaceae*); slide Tob-4b; 138 × 17; size 35 µm (diameter); wall thickness 3.5-2.5 µm. **20.** *Inapertisporites* sp. A; slide Tob-4b; 137 × 18; size 81 × 74.5 µm (×100). **21.** Algal cyst; slide Tob-3a; 141 × 7; size 21 µm, archaeopyle diameter 7 µm. **22.** *Diporisporites* sp.; slide Tob-aa; 135 × 18; size 17.6 × 11 µm.

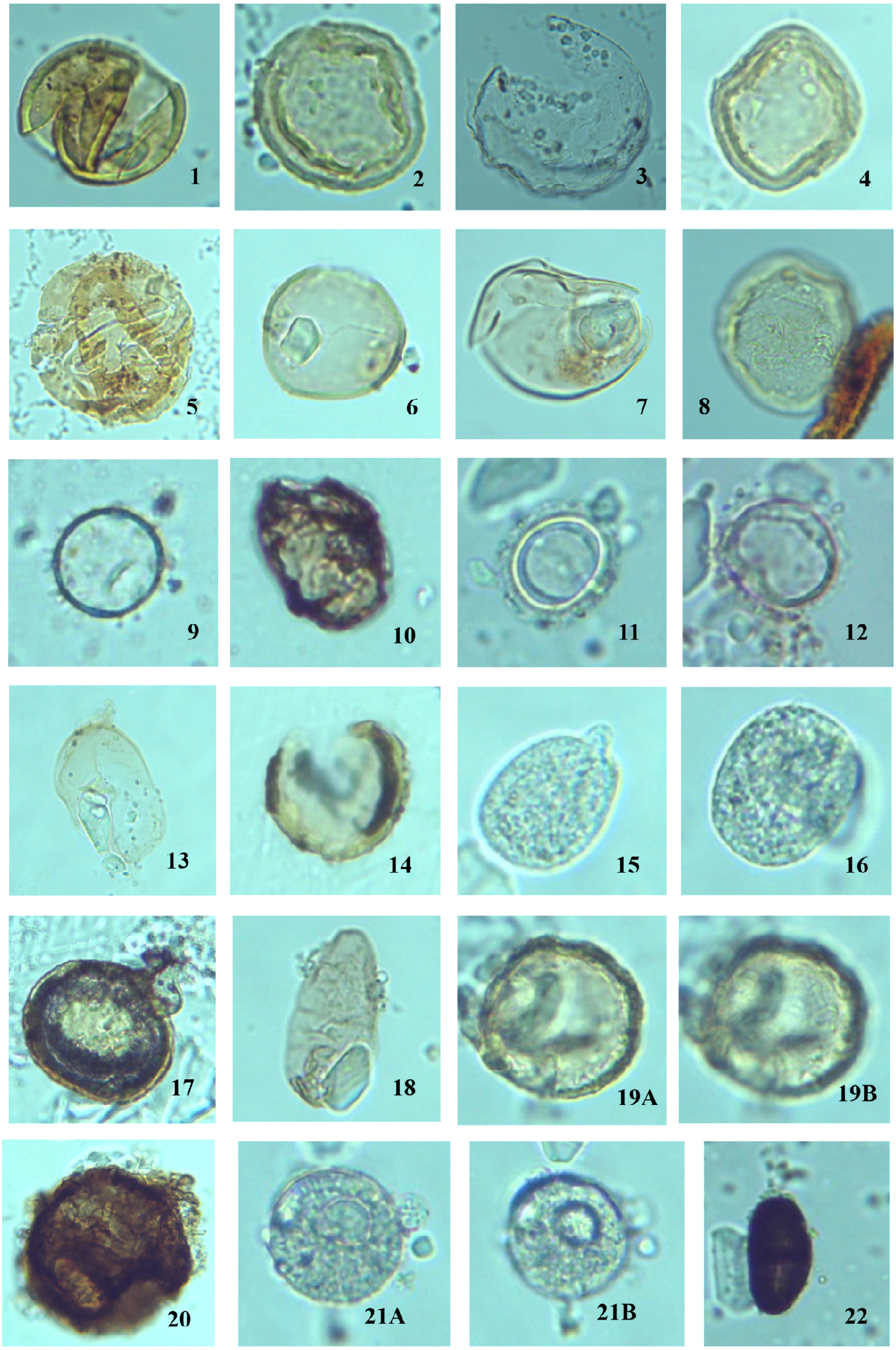

Figure 4

Genus: *Multicellites* Kalgutkar & Janson. 2000

Multicellites granulatus (P. Ke & Z.Y. Shi) Kalgutkar & Janson. 2000
Figure 5.5

Size: 46 × 22.6 µm.

Comments: An inaperturate fungal spore with elliptical-lanceolate outline; one end rounded and the other gradually becoming acute. Four celled, divided by three thin septa, largest cell at the rounded end and the smallest at the other end. Wall is thin and scabrate, size 71 × 23 µm (Ke & Shi 1978).

Genus: *Palaeomycites* Mesch. 1902 emend. Kalgutkar & Janson. 2000

Comments: This genus covers fungal remains such as mycelium of branched, usually interwoven hyphae, generally lacking septa and terminating in large round to ovoid vesicles. The fossil genus *Glomites* Taylor et al. 1995 is related to the extant fungal genus *Glomus* (Kalgutkar & Jansonius 2000). Geological record of *Glomites* goes back to Early Devonian (Karatygin et al. 2006). Now *Glomites* is transferred to the genus *Palaeomycites* (Kalgutkar & Jansonius 2000).

Palaeomycites bharwainensis (H.P. Singh & R.K. Saxena) Kalgutkar & Janson. 2000
Figures 5.1, 7

Size: 51 × 28 µm; hypha length 43 µm (Figure 5.1) and 30.5 × 27 µm, hypha length 29.5 µm (Figure 5.7).

Comments: These are long, non-septate hyphae (29.5–43 µm) attached to an almost rounded or a distorted (may be due to poor preservation) thin-walled vesicle. This species is relatively more common in the palynomorph assemblages of the Rockly Bay Formation. Sometimes hyphae and vesicles are separated from each other.

***Palaeomycites* sp. A**
Figures 4.17, 5.2, 9

Size: 47–81 × 40–69 µm (vesicle diameter); wall thickness 2.5–3.0 µm.

Comments: These are large, rounded, thick-walled vesicles attached with noticeably short hyphae. Wall surface is generally psilate or at places scabrate. This form is like *Palaeomycites butleri* (F. Rosend.) Kalgutkar & Janson. 2000 except that the present specimen does not show any features of hyphae. The diameter of vesicles ranges from 75 × 79 to 103 × 124 µm (Kalgutkar & Jansonius 2000) thus the present specimens of *Palaeomycites* sp. A are smaller in size.

Genus: *Papulosporonites* Schmied. & G. Schwab 1964

Papulosporonites enormis (V.S. Ediger) Kalgutkar & Janson. 2000
Figure 5.14

Size: 25.0 µm.

Comments: Polyad globular fungal spore

⟶

Figure 5. All photographs ×400 unless otherwise mentioned.
1. *Palaeomycites bharwainensis* (H.P. Singh & R.K. Saxena) Kalgutkar & Janson. 2000; slide Tob-1a; 129 × 6; size 51 × 28 µm; hypha length 43 µm. **2.** *Palaeomycites* sp. A; slide Tob-1a; 130 × 13; size 81 × 69 µm, wall thickness 4.2 µm. **3.** *Inapertisporites* sp. B; slide Tob-1a; 129.6 × 8.5; size 33.3 × 11.5 µm. **4.** *Inapertisporites* sp. C; slide Tob-1a; 133 × 11.8; size 28 × 24 µm. **5.** *Multicellites granulatus* (P. Ke & Z.Y. Shi) Kalgutkar & Janson. 2000; slide Tob-1a; 137.8 × 16.8; size 46 × 22.6 µm. **6.** cf. *Dicellaesporites reniformis* Zhong Y. Zhang) 1980; slide Tob-1b; 135.5 × 4; size 35.5 × 15.3 µm. **7.** *Palaeomycites bharwainensis* (H.P. Singh & R.K. Saxena) Kalgutkar & Janson. 2000; slide Tob-1b; 139.2 × 4.6; size 30.5 × 27 µm, length 29.5 µm. **8.** *Brachysporisporites ovoidus* Z.C. Song & Liu Cao 1994; slide Tob-1b; 141 × 6.2; size 41.5 × 23.7 µm. **9.** *Palaeomycites* sp. A; slide Tob-1b; 133.6 × 6; size 57 × 47.6 µm; wall thickness 2,8 µm. **10.** *Brachysporisporites ovoidus* Z.C. Song & Liu Cao 1994; slide Tob-1b; 178.4 × 10; size 41 × 19 µm. **11.** *Brachysporisporites catinus* (Elsik & Janson.) Kalgutkar & Janson. 2000; slide Tob-1b; 131 × 11.2; size 36 × 20.3 µm. **12.** Fungal fruit body; slide Tob-1b; 132 × 14.6; size 47 × 40 µm. **13.** cf. *Dictyosporites fibrassi* (Hammen) Kalgutkar & Janson. 2000; slide Tob-1b; 137 × 18.3; size 11.6 × 10.6 µm (largest) 8.4 × 8.0 µm (smallest). **14.** *Papulosporonites enormis* (V.S. Ediger) Kalgutkar & Janson. 2000; slide Tob-1b; 140.2 × 20; size 25.0 µm. **15.** *Brachysporisporites catinus* (Elsik & Janson.) Kalgutkar & Janson. 2000; slide Tob-1b; 134 × 6.5; size 39.7 × 20.6 µm; size 39.7 × 20.6 µm. **16.** *Inapertisporites* sp. C; slide Tob-1b; 133.7 × 7.8; size 38.3 × 34 µm. **17.** Fungal thallus (damaged); slide Tob-2a; 141.5 × 11; size 122 × 61 µm. **18.** *Dyadosporites* sp. A; slide Tob-2a; 134.4 × 17; size 61 × 27 µm. **19.** Fungal thallus (damaged); slide Tob-3a; 130 × 10.4; size 48 × 37.7 µm. **20.** cf. *Milesites* sp.; slide Tob-3a; 134 × 12; size 46.5 × 26.8 µm. **21.** *Pluricellaesporites malayensis* (Trivedi & C.L. Verma) Kalgutkar & Janson. 2000 slide Tob-3b; 144 × 4.7; size 33 × 10.3 µm. **22.** cf. *Chaetosphaerites obscurus* (P. Ke & Z.Y. Shi) Kalgutkar & Janson. 2000; slide Tob-4a; 137 × 8.5; size 43 × 19 µm. **23.** *Inapertisporites circularis* (Sheffy & Dilcher) Kalgutkar & Janson. 2000; slide Tob-4a; 139 × 9.3; size 13.2 µm (diameter).

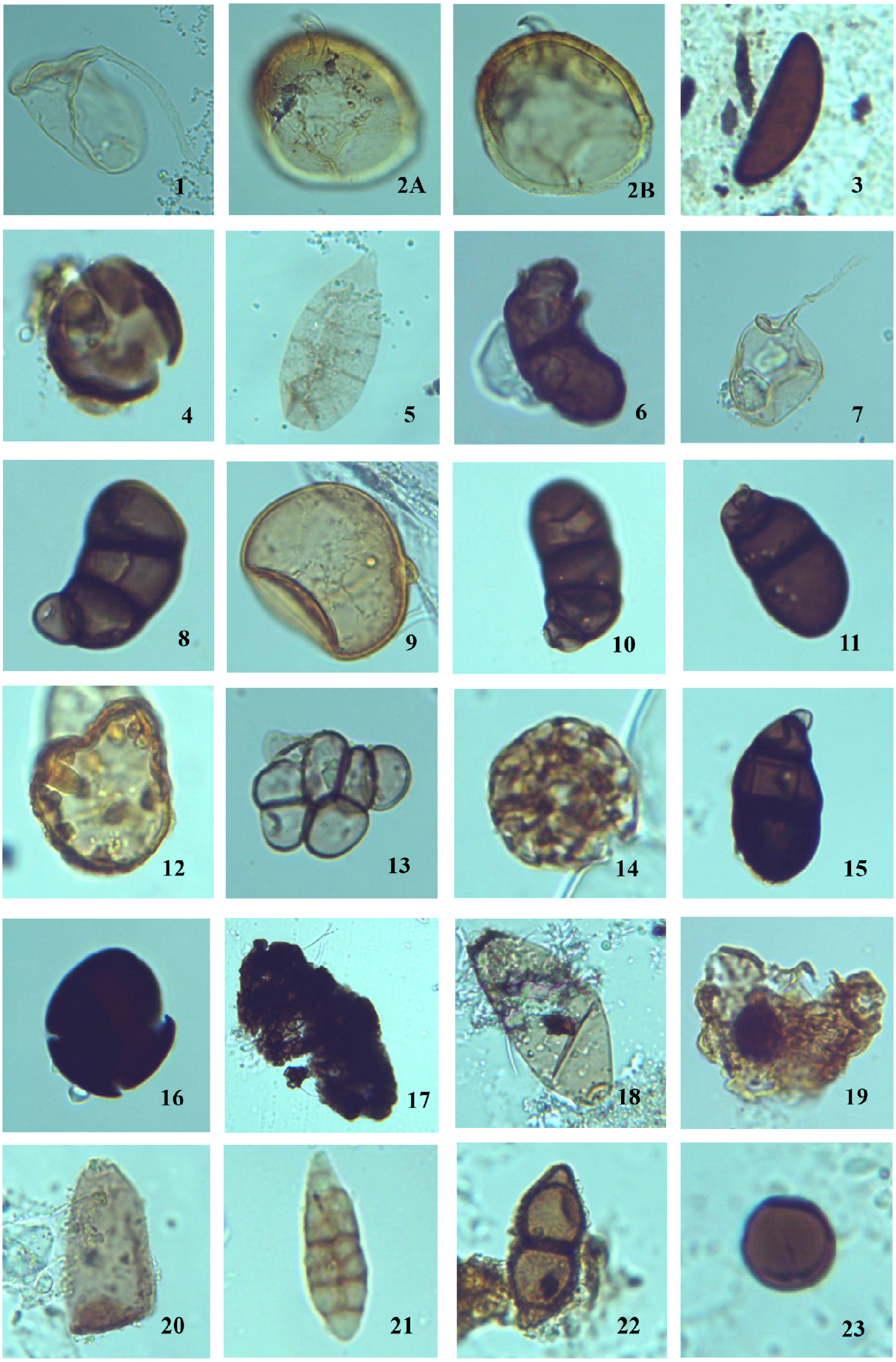

Figure 5

consisting of many subrounded or polygonal cells fused to form a cluster of cells. Size 25–35 µm. Ediger (1981) described this species as *Polyadosporites enormis* from Late Eocene-Pliocene sediments of Turkey. Kalgutkar and Jansonius (2000) transferred it to the genus *Papulosporonites*.

Genus: *Pluricellaesporites* Hammen 1954 emend. Elsik & Janson. 1974

Pluricellaesporites malayensis (Trivedi & C.L. Verma) Kalgutkar & Janson. 2000
Figure 5.21

Size: 33 × 10.3 µm.

Comments: These are monoporate fungal spores, fusiform-elongate, tapering toward both ends. It has five septa; septa are thick, while spore wall is psilate and thin. This species was originally described as *Alternaria malayensis* (Trivedi & C.L. Verma) from Eocene of Malaysia.

2.3. Crustacean palynomorphs

Crustacean exoskeleton
Figure 6.3, 6, 8

Size: 232 × 182 µm (Figure 6.3); 89 × 66.3 µm (Figure 6.6); 35.6 × 28.4 µm; opening 12.8 µm (Figure 6.8).

Comments: Broken pieces of a copepod appendage or of some other crustaceans (Figure 6.3) and broken pieces of exoskeleton of a copepod (probably setae) or may be some other crustaceans occur frequently in these assemblages.

Crustacean wing
Figure 6.4

Size: 121 × 67.7 µm

Comments: It is a broken piece of a crustacean wing.

Crustacean antennae
Figure 6.10–11, 15

Size: 78.5–586 × 20.6–57; 238 × 20.6 µm

Comments: These are parts of copepod antennae or may be some other crustacean.

Crustacean egg sac
Figure 6.9

Size: 174 × 15.4 µm

Forma A
Figures 6.1–2, 17

Size: 69 × 67 µm (Figure 6.1); 77 × 74 µm (Figure 6.2) and 94 µm (Figure 6.17)

Comments: These are spherical bodies, of yellowish brown to light brown color, without any aperture. Wall single layered, 1.0–1.5 µm thick, uniformly alveo-reticulate, muri 0.5–1.0 µm thick. Forma A appears morphologically similar to the alveo-reticulate morphotype (no. 11) eggs of planktonic crustaceans described from Holocene sediments of the Banda Sea, Indonesia and considered to be copepod eggs (van Waveren 1992). The size of the Banda Sea specimens range between 80–129 µm with a mean of 102 µm, based on 40 specimens. Thus, the Banda Sea specimens are larger than Forma A.

⟶

Figure 6. All photographs ×400 unless otherwise mentioned.
1. Forma A; slide Tob-1a; 129 × 7.8; size 69 × 67 µm. **2.** Forma A; slide Tob-1a; 132 × 13.2; size 77 × 74 µm. **3.** Crustacean exoskeleton; slide Tob-1b; 134.5 × 4; size 232 × 182 µm (×100). **4.** Crustacean wing; slide Tob-1b; 137.5 × 4.8; size 121 × 67.7 µm. **5.** Scolecodont type 1; slide Tob-1b; 138.5 × 13.8; size 77.3 × 53.2 µm. **6.** Crustacean exoskeleton; slide Tob-1b; 143.5 × 18.5; size 89 × 66.3 µm (×100). **7.** Ostracod jaw; slide Tob-1b; 140.5 × 8.5; size 49 × 34 µm. **8.** Crustacean exoskeleton; slide Tob-1b; 136.7 × 7; size 35.6 × 28.4 µm; opening 12.8 µm. **9.** Crustacean egg sac; slide Tob-2a; 141 × 19; size 174 × 15.4 µm (×100). **10.** Crustacean antennae; slide Tob-4a; 134.5 × 7; size 586 × 27 µm (×100). **11.** Crustacean antennae; slide Tob-3a; 140 × 9.8; size 78.5 × 57 µm. **12.** ?*Cyclopyxis* sp.; slide Tob-3a; 145.5 × 9.5; size 78.5 × 57 µm. **13.** *Centropyxis* sp.; slide Tob-3a; 133.5 × 12; size 48 µm (daiameter); 12,8 µm (aperture). **14.** *Centropyxis* sp.; slide Tob-3a; 139.5 × 14.5; size 43.3 µm (daiameter); 14 µm (aperture). **15.** Crustacean antennae; slide Tob-3a; 135 × 17; size 238 × 20.6 µm (×100). **16.** Scolecodont type 2; slide Tob-3b; 132.5 × 9.5; size 43.7 × 28.8 µm. **17.** Forma A (damaged specimen); slide Tob-4a; 134.5 × 13.3; size 94 µm (diameter). **18.** *Centropyxis aculeata* (Ehrenb.) Stein 1859; slide Tob-3b; 145.5 × 10; size 268 × 210 µm; aperture diameter 132 × 114 µm (**18a** is the complete specimen (×100); **18b** shows unusually thick spines covered with xenosomes of mineral grains, and **18c** shows xenosomes of mineral grains mainly sand attached around the aperture (×400). **19.** ?*Palaeomycites* sp.; slide Tob-1b; 135.3 × 7; size 62.6 × 55.6 µm.

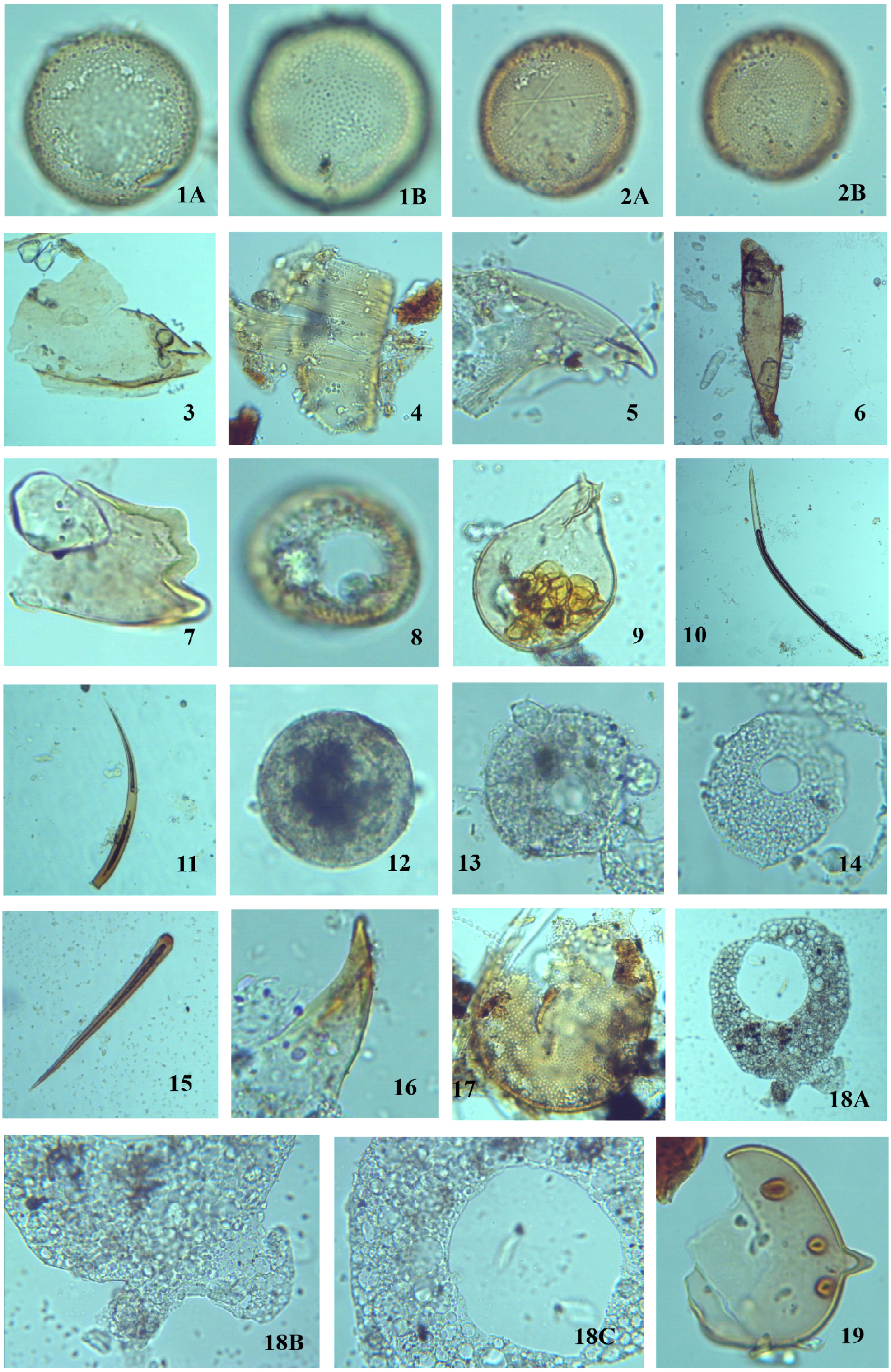

Figure 6

Ostracod jaw
Figure 6.7

Size: 49 × 34 µm

2.4. Annelid palynomorphs

Scolecodont type 1
Figure 6.5

Size: 77.3 × 53.2 µm.

Comments: The jaw has more than one tooth.

Scolecodont type 2
Figure 6.16

Size: 43.7 × 28.8 µm.

Comments: The jaw has only one tooth.

2.5. Arcellinidan palynomorphs

Genus: *Centropyxis* W.E. Stein 1859

Centropyxis aculeata (Ehrenb.) W.E. Stein 1859
Figures 6.18a–c

Size: 268 × 210 µm; aperture diameter 132 × 114 µm.

Comments: Test bilaterally symmetrical, outline ovoid, shell composed of proteinaceous matrix agglutinated with abundant mineral grains, mainly sand (Figure 6.18a–b), aperture sub-terminal with only two thick spines. This specimen differs from all other specimens of *Centropyxis aculeata* (Ehrenb.) Stein 1859 in having significantly thicker spines (50 × 40 µm and 35 × 30 µm). This thickness is suggested to be due to the abundant agglutination of mineral grains over the spines. The length of the spines varies significantly, thus the length of the spines in this specimen is within the normal range.

***Centropyxis* sp.**
Figure 6.13–14

Size: 48 µm (test diameter); 12.8 µm (aperture diameter) (Figure 6.13); 43.3 µm (test diameter); 14 µm (aperture diameter) (Figure 6.14).

Comments: These specimens of *Centropyxis* are without spines. Their shells are agglutinated with mineral grains, mainly sand.

Genus: *Cyclopyxis* Deflandre 1929

?*Cyclopyxis* sp. Deflandre 1929
Figure 6.12

Size: 78.5 × 57 µm.

Comments: A circular test with a central aperture. The aperture is not clearly visible because it is covered under the debris.

3. Ascidian Spicules

Ascidians belong to Phylum Chordata, Class Ascidiacea, also known as sea squirts; they are sac-like marine invertebrate filter feeders characterized by a tough outer "tunic" made of the polysaccharide cellulose. They are sessile animals that remain attached to their substratum, such as rocks and shells. They are found in all marine habitats from shallow water to the deep sea. Ascidians generate calcareous spicules (15– 100 µm) of characteristic shapes that accumulate in their tunic or internal tissues. Spicule morphology is quite diverse; thus, they are significant in ascidian taxonomy (Varol 1996; Shenkar & Swalla 2011).

An overview of the fossil record of ascidian spicules is provided by Lukowiak (2012) and Ferreira et al. (2019). The more recent fossils are from Pliocene-Quaternary marine sediments from Antalya Basin (Sagular 2009); Late Eocene of Australia (Lukowiak 2012); Miocene of Moldova (Lukowiak et al. 2016); and Quaternary marine sediments of Argentina (Ferreira et al. 2019) and recent coastal sediments of the southern Red Sea coast of Saudi Arabia (Kumar 2020, 2021). Ascidian spicules in the present assemblage are few and not identifiable with published forms.

Ascidian spicules
Figure 3.18–19, 21

Size: 22.7 µm (Figure 3.18), 21 µm (Figure 3.19a) and 16 µm (Figure 3.19b), 25 × 20 µm (Figure 3.21a) and 10 × 9 µm (Figures 3.21b).

Comments: These are stellate spicules having several rays of different shapes. Ascidian spicules are calcareous mineral microfossils, thus cannot be considered as palynomorphs. However, they are reported in this study because they occur in the same palynological slides along with palynomorphs.

DISCUSSION

The palynomorph assemblages recovered from the four surface samples of the Rockly Bay Formation are impoverished and preservation generally is fair to good. Palynomorphs represent diverse affinities and origins such as angiosperm and gymnosperm pollen, bryophytic and pteridophytic spores, and non-pollen palynomorphs (NPP) such as dinoflagellate cysts, acritarchs, algal cysts, fungal palynomorphs, and only a few with animal affinity such as crustacean palynomorphs, annelid palynomorphs, and arcellinidan palynomorphs. Although ascidian spicules are not palynomorphs, they are recorded in this study since they occur in the same palynological slides along with other palynomorphs.

Angiosperm pollen are represented by families, *Arecaceae* (the palm family) and *Poaceae* (grasses). *Arecaceae* is widespread in the Caribbean region and forms a significant constituent of the flora of Trinidad and Tobago. The palm flora of Trinidad and Tobago has close affinity with species in South America (Kuyl et al. 1955, Kumar 1981). A variety of palm trees are commonly found along the coastal regions of these islands. Grasses (*Poaceae*) occur widespread from coastal regions to highlands in these islands. *Polytrichum* sp. is a moss, and the fern family *Schizaeaceae* occurs in these islands as they have a cosmopolitan distribution.

A morphologically diverse assemblage of fungal spores, hyphae and a few fruit bodies were observed and assigned to different taxa. Some could be identified only at the genus level and few others could not be identified due to their poor preservation or fragmented state. Comments are made about their morphology, and their distribution in time and space. Since fungi have no chlorophyll, they sustain as heterotrophs and survive as epiphytes, saprophytes, parasites or in symbiotic associations on or in living or dead plants and animals. A wide-ranging account of diverse aspects of palaeomycology is provided by Elsik (1996) and Kalgutkar and Jansonius (2000). The fungal palynomorphs observed in these samples represent the environment of the host plants and animals.

Crustaceans remains such as pieces of exoskeleton, wings and antennae are common in palynological preparations of lacustrine, marine, or marginal marine sediments; they are termed as crustacean palynomorphs (Kumar 2020). Crustaceans are large, diverse group of invertebrate animals belonging to the subphylum Crustacea (phylum Arthropoda). Common crustaceans are crabs, lobsters, shrimps, and wood lice. Generally, they are aquatic (freshwater or marine) species that inhabit the open waters of lakes and oceans, and some are sessile, for example, barnacles. Many broken and damaged specimens of crustacean exoskeleton, crustacean wing, crustacean antennae, and one specimen of crustacean egg sac were found in these assemblages. One specimen of an ostracod jaw was observed as well. Two types of Scolecodonts were noted and classed as annelid palynomorphs (Kumar 2020). Arcellinidans are protists belonging to order *Arcellinida* Kent 1880 that occur in almost every lacustrine environment and prefer warmer waters above the thermocline; they are termed as arcellinidan palynomorphs (Kumar 2020, 2021). *Centropyxis aculeata* and ?*Cyclopyxis* sp. were observed in this assemblage.

Algal palynomorphs (Kumar 2020) in this assemblage are represented by algal cysts, acritarchs, dinoflagellate cysts, ovoid zygospores of algal family *Zygnemataceae*, and freshwater Cyanophyte algae. Mostly they inhabit freshwater environments except for few taxa that may be from marine environments. Algal cyst (Figure 4.11) is compared with *Halodinium* which is known to inhabit freshwater to estuarine environments. Specimens of cf. Dinoflagellate cyst (Figure 4.13) have a morphological affinity with the genus *Peridinium*, a cosmopolitan freshwater dinoflagellate that occurs in freshwater lakes, ponds, and brackish environments. *Ceratium* cyst also is a cyst of freshwater dinoflagellate. The genus *Ovoidites* is an ovoid zygospore of the filamentous green algae of family *Zygnemataceae* and has a close association with freshwater peats, shallow, stagnant, oxygen-rich, open fresh waters, lake margins and marsh habitats. *Sigmopollis* is a freshwater Cyanophyte alga that prefers meso-to eutrophic, stagnant or slowly flowing shallow waters. All these taxa indicate that the assemblage was deposited in a freshwater environment.

The algal palynomorphs that indicate marine environments are parts of this assemblage as well. They are, algal cyst (Figure 4.21) showing a distinct archaeopyle, interpreted be a dinoflagellate cyst and acritarchs such as *Leiosphaeridia* and *Tasmanites. Leiosphaeridia* spp. have biological affinity with modern planktic green alga *Halosphaera* (Tschudy& Scott 1969) that inhabit shallow marine environments. *Tasmanites* also occurs in marine environments. According to Wall (1962) modern algal genus *Pachysphaera* is similar to *Tasmanites*. The affinity of *Tasmanites* with the modern prasinophycean algae *Pachysphaera, Halosphaera*, and *Pterosphaera* was reported by Guy-Ohlson (1988).

Rockly Bay Formation is mainly a siliciclastic succession that was deposited in intertidal to subtidal environments (Donovan 1989). This formation has two distinct lithologies; the upper part is about 2 m thick "unfossiliferous, thin bedded, grey and brown clay and sandy clay", and the lower part is about 3 m thick "Balanus Beds". The present study suggests that the 2 m thick "unfossiliferous" upper part is fossiliferous that contains a variety of nonmarine palynomorphs which dominate the assemblage. However, there are a few palynomorphs of the marine origins as well. Thus, lithology and palynomorph assemblages indicate that this part of the Rockly Bay Formation was deposited under a supratidal environment where lakes and ponds existed in which a variety of algal forms thrived. This was primarily a terrestrial environment that was periodically influenced by high tides and cyclones.

The pollen and spore flora and associated fungal palynomorphs indicate tropical climate that is also evident from the tropical location of Tobago during mid-Pliocene. The crustacean palynomorphs, annelid palynomorphs, and arcellinidan palynomorphs reported in this study have a cosmopolitan distribution. Similarly, algal palynomorphs of this assemblage are cosmopolitan as well.

A diverse assemblage of pollen and spores with few phytoplankton was reported from the Pitch Lake, Trinidad (Kumar 1979,1981). It was dominated by terrestrial palynomorphs including pteridophytic spores and a diverse assemblage of angiosperm pollen. Several angiosperm families are represented but Poaceae (Graminae), Arecaceae (Palmae) and Compositae dominate the assemblage indicating Miocene age (Germeraad et al. 1968). The pollen assemblages from the Rockly Bay Formation and Pitch Lake have few common elements such as presence of Poaceae (Graminae), Arecaceae (Palmae), and gymnosperm family Podocarpaceae. Fungal remains occur in both assemblages. The Pitch Lake assemblage is much more diverse indicating tropical to subtropical climate for the Miocene Epoch in Trinidad and tropical climate for Tobago during the mid-Pliocene times.

SUMMARY AND CONCLUSIONS

1. Four fresh surface outcrop samples from the upper section of the Rockly Bay Formation (mid-Pliocene), a siliciclastic stratigraphic unit in the southwestern end of Tobago, were studied. This part was previously described as "unfossiliferous, thin bedded, grey and brown clay and sandy clay" by Donovan (1989).
2. Present study demonstrates that the upper section of the Rockly Bay Formation is not unfossiliferous. These samples yielded low numbers but a high diversity of palynomorphs, dominated by fungal remains (Table1).
3. Palynomorphs are generally well preserved and exhibit diverse affinities. Few forms are poorly preserved and damaged that were identified only at the generic level or not identified at all. Identified palynomorphs are illustrated in figures 3 through 6.
4. These palynomorphs exhibit diverse affinities. They are angiosperm and gymnosperm pollen, pteridophytic spores, and non-pollen palynomorphs (NPP) such as dinoflagellate cysts, acritarchs, algal cysts, fungal palynomorphs, crustacean palynomorphs, annelid palynomorphs, and arcellinidan palynomorphs.
5. Ascidian spicules are calcareous mineral microfossils and are reported here because they occur in the same palynological slides. Their presence indicates marine environment.
6. Palynomorphs present in these assemblages are predominantly of terrestrial origin. However, a few are of marine origin as well for example, few

acritarchs and cf. dinoflagellate cysts and ascidian spicules.

7. Lithology and palynomorph assemblages suggest that the upper section of the Rockly Bay Formation was deposited under supratidal environment, where lakes and ponds existed in which a variety of algal forms thrived. This was primarily a terrestrial environment that was periodically influenced by high tides and cyclones.
8. The pollen and spore flora and associated fungal palynomorphs indicate tropical climate as also evident from the tropical location of Tobago during mid-Pliocene. The crustacean palynomorphs, annelid palynomorphs, and arcellinidan palynomorphs reported in this study have a cosmopolitan distribution. Similarly, algal palynomorphs of this assemblage are cosmopolitan as well.

ACKNOWLEDGMENTS

I express my sincere gratitude to my friend Ramesh Ramcharan and his wife Dolly Ramcharan of Tacarigua, Trinidad for taking me to Tobago in February 2013. Ramesh helped me in collecting the samples that were studied for this research. I thank my son, Anshuman Kumar, for linguistic improvements to this paper. I dedicate this paper to the memory of my wife, late Mrs. Sushma Kumar, who passed away in Ottawa, Canada on January 3, 2019, when this work was in progress.

REFERENCES

Boonstra M., Ramos M.I.F., Lammertsma E.I., Antoine P.-O. & Hoorn C. 2015. Marine connections of Amazonia: Evidence from foraminifera and dinoflagellate cysts (early to middle Miocene, Colombia/ Peru). Palaeogeography, Palaeoclimatology, Palaeoecology 417: 176–194.

Brenner M. & Binford M.W. 1988. A sedimentary record of human disturbance from Lake Miragoâne, Haiti. Journal of Paleolimnology 1: 85–97.

Bringué M., Thunell R.C., Pospelova V., Pinckney J.L., Romero O.E. & Tappa, E.J. 2018. Physico-chemical and biological factors influencing dinoflagellate cyst production in the Cariaco Basin. Biogeosciences 15: 2325–2348. https://doi.org/10.5194/bg-15-2325-2018.

Bringué M., Pospelova V., Tappa E.J. & Thunell R.C. 2019. Dinoflagellate cyst production in the Cariaco Basin: a 12.5 year-long sediment trap study. Prog. Oceanogr. 171: 175–211. https://doi.org/10.1016/j.pocean.2018.12.007

Bujak J.P. 1984. Cenozoic dinoflagellate cysts and acritarchs from the Bering Sea and northern North Pacific, D.S.D.P. Leg 19. Micropaleontology 30(2): 180–212.

Burney D.A., Burney L.P. & Macphee R. 1994. Holocene charcoal stratigraphy from Laguna Tortuguero, Puerto Rico, and the timing of human arrival on the island. Journal of Archaeological Science 21: 273–281.

Cárdenas D., Jaramillo C. & Oboh-Ikuenobea F. 2020. Early Miocene marine palynology of the Colombian Caribbean Margin: biostratigraphic and paleoceanographic implications. Palaeogeography, Palaeoclimatology, Palaeoecology 558. https://doi.org/10.1016/j.palaeo.2020.109955

Clarke R.T. 1965. Fungal spores from Vermejo Formation coal beds (Upper Cretaceous) of Central Colorado. Mountain Geologist 2: 85–93.

Deflandre G. 1929. Le genre *Centropyxis* Stein. Archiv für Protistenkunde. 67: 322–375.

Donovan S.K. 1989. Palaeoecology and significance of barnacles in the mid-Pliocene Balanus Bed of Tobago, West Indies. Geological Journal 24: 239–250.

Donovan S.K., Nagassar V. & Sankar K. 2001. A fossil shark from the Plio-Pleistocene of Tobago. Caribbean Journal of Science 37(1–2): 119–122.

Ediger V.S. 1981. Fossil fungal and algal bodies from Thrace Basin, Turkey. Palaeontographica Abt. B 179: 87–102.

Ehrenberg C.G. 1830. Beiträge zur Kenntnis der Organisation der Infusorien und ihrer geographischen Verbreitung, besonders in Sibirien. Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin. 1830: 1–88.

Ehrenberg C.G. 1832. Über die Entwicklung und Lebensdauer der Infusionsthiere, nebst ferneren Beiträgen zu einer Vergleichung ihrer organischen Systeme. Abhandlungen der Königliche Akademie der Wissenschaften zu Berlin, Physikalische Klasse 1831: 1–154.

Eisenack A. 1958. Mikroplankton aus dem norddeutschen Apt nebst einigen Bemerkungen iiber fossile Dinofiagellaten. Neues Jb. Geol. Palaont. Abh. 106: 383–422.

Elsik W.C. 1968. Palynology of a Palaeocene Rockdale lignite, Milam County, Texas. 1. Morphology and taxonomy. Pollen et Spores 10(2): 263–314.

Elsik W.C. 1990. *Hypoxylonites* and *Spirotremesporites*, form genera for Eocene to Pleistocene fungal spores bearing a single furrow. Palaeontographica Abt. B 216: 137–169.

Elsik W.C. 1996. Fungi. In Palynology: principles and applications. Jansonius J. & McGregor D.C. (Editors). American Association of Stratigraphic Palynologists Foundation 1: 293–306.

Elsik W.C. & Jansonius J. 1974. New genera of Paleogene fungal spores. Canadian Journal of Botany 52: 953–958.

Felix J. 1894. Studien über fossile Pilze; Zeitschrift der Deutschen Geologischen Gesellschaft 46: 269–280.

Ferreira E.P., Alves C.F., Sanjinés A.E.S. & Alves M.C. 2019. Ascidian spicules of Quaternary sediments from the lower slope of the Campos Basin (Brazil). Quaternary International 508(1): 116–124.

Frost C.D. & Snoke A.W. 1989. Tobago, West Indies, a fragment of Mesozoic oceanic island crust: petrochemical evidence. Journal of the Geological Society, London 146: 953–964.

Germeraad J.H., Hopping C.A. & Muller J. 1968. Palynology of Tertiary sediments of from tropical areas. Review of Palaeobotany and Palynology 6: 189–348.

González C., Urrego L.E., Martínez J.I., Polanía J. & Yokoyama Y. 2010. Mangrove dynamics in the southwestern Caribbean since the 'Little Ice Age': a history of human and natural disturbances. The Holocene 20(6): 849–861.

González Guzmán A.E. 1967. A palynological study on the Upper Los Cuervos and Mirador formations (Lower and Middle Eocene; Tibu area, Colombia). Thesis, Univ. of Leiden, Leiden, pp.1–68.

Guy-Ohlson D. 1988. Developmental stages in the life cycle of Mesozoic *Tasmanites*. Botanica Marina 31: 447–456.

Hedlund R.W. 1965. *Sigmopollis hispidus* gen. et sp. nov. from Miocene sediments, Elko County, Nevada. Pollen et Spores 7(1): 89–92.

Islebe G.A., Hooghiemstra H. & van't Veer R. 1996. Holocene vegetation and water level history in two bogs of the Cordillera de Talamanca, Costa Rica. Vegetatio 124:155–171. https://doi.org/10.1007/BF00045491

Jackson T.A. & Donovan S.K. 1994. Tobago, In: Donovan S.K. & Jackson T.A. (Editors) Caribbean Geology: An Introduction, pp. 193–207. University of the West Indies Publishers' Association, Kingston, Jamaica.

Jackson T.A., Scott P.W. & Smith T.E. 1998. The petrology of ultramafic and maficigenous rocks from the Blue Mountain Inlier, Jamaica. In: Ali W., Paul A. & Young, O.V. (Editors), Transactions of the 14th Caribbean Geological Conference, Trinidad. July 16–21, 1995: 188–197.

Jaramillo C., Cárdenas D., Correa-Metrio A., Moreno J.E., Trejos R., Vallejos D., Hoyos N., Martínez C., Carvalho D., Escobar J., Oboh-Ikuenobe F., Prámparo M.B. & Pinzón D. 2020. Drastic vegetation change in the la Guajira Peninsula (Colombia) during the Neogene. *Paleoceanography and Paleoclimatology 35*. https://doi.org/10.1029/2020PA003933

Jaramillo C.A. & Dilcher D.L. 2001. Middle Paleogene palynology of Central Colombia, South America: A study of pollen and spores from tropical latitudes. Palaeontographica Abt. B 258(4): 87–213.

Jaramillo C., Moreno E., Ramírez V., da Silva S., de la Barrera A., de la Barrera A., Sánchez C., Morón S., Herrera F., Escobar J., Koll R., Manchester S.R. & Hoyos N. 2014. Chapter: 8. Palynological record of the last 20 million years in Panama. Paleobotany and Biogeography: A Festschrift for Alan Graham in his 80th year. Missouri Botanical Garden Publication pp.134-251.

Kalgutkar R.M. & Jansonius J. 2000. Synopsis of fossil fungal spores, mycelia and fructifications. A.A.S.P. Contribution Series 39: 1–428.

Karatygin I.V., Snigirevskaya N.S. & Demchenko K.N. 2006. Species of the genus *Glomites* as plant mycobionts in Early Devonian ecosystems. Paleontological Journal 40 (5): 572–579.

Ke P. & Shi Z.Y. 1978. (Pseudonym of Sung, Z. C., Tsao, L., Chou, H. I., Kwang, H. I., and Wang, K. T.) Early Tertiary spores and pollen grains from coastal region of the Bohai (in Chinese). Academy of Petroleum Exploration, Department and Planning Research of the Ministry of Petroleum and Chemical Industries and the Nanjing Institute of Geology and Paleontology, Chinese Academic of Sciences, Kexue Chubanshe, Peking, 177 pp.

Kedves M. & Simoncsics P.1964. Spores nouvelle sextraites de minerai manganese Jurassique de la régiond Urkut (Hongrie). Pollen et Spores 6: 605–610.

Kent W.S. 1880. A Manual of the Infusoria: Including a description of all known Flagellate, Ciliate, and Tentaculiferous Protozoa, British and Foreign, and an Account of the Organization and Affinities of the Sponges. D. Bogue, London, 412 p.

Krutzsch W. 1959. Mikropalaontologische (Sporenpaliontologische) Untersuchungen in der Braunkohle des Geiseltales. Geologie8(21-22): 1–425.

Krutzsch W. & Pacltová B. 1985. Palynology of the Cheb Basin Pliocene (a revision). In: MlíkovskýJ. and Novák V.J.A. (Editors), Evolution and Morphogenesis, Academia, Praha, 811–816.

Kumar A. 1979. A note on the palynological investigation of the Pitch Lake, Trinidad, West Indies. Geophytology 9(2): 189–190.

Kumar A. 1981. Palynology of the Pitch Lake, Trinidad, West Indies. Pollen et Spores 23(2): 259–272.

Kumar A.1994. Palynology of the Tertiary sediments of southern Assam (Silchar-Haflong Road Section). Keshav Dev Malaviya Institute of Petroleum Exploration (KDMIPE), Oil & Natural Gas Corporation (ONGC) Publication, Dehradun, India, Paleontographica Indica 2: 1–315.

Kumar A. 2020. Palynology of the recent intertidal sediments of the southern Red Sea Coast of Saudi Arabia. Palynology. https://doi.org/10.1080/01916122.2020.1 767708

Kumar A. 2021. Palynomorph assemblages and mineral microfossils from various southern Red Sea coastal environments of Saudi Arabia. Earth Science India 14(2): 41–97. https://doi.org/10.31870/ESI.14.2.2021.4.

Kumar A. & Takahashi K. 1991. Palynology of the Tertiary sediments of southern Assam. Bulletin of Faculty of Liberal Arts, Nagasaki University Science Publication, Nagasaki, Japan 31(2): 514–659.

Kuyl O.S., Muller J. & Waterbolk H.T. 1955. The application of palynology to oil geology with reference to western Venezuela. Geologieen Mijnbouw 17: 49–76.

Lamy A. 1985. Plio-Pleistocene palynology and visual kerogen studies, Trinidad, W.I., with emphasis on the Columbus Basin. Transactions of the First Geological Conference of the Geological Society of Trinidad and Tobago: 115–125.

Lange R.T. & Smith P.H. 1971. The Maslin Bay flora, South Australia. 3. Dispersed fungal spores. Neues Jahrb. Geol. Palaontol. Monatsh. 11: 663–681.

Leidelmeyer P. 1966. The Palaeocene and Lower Eocene pollen flora of Guyana. Leidse Geol. Meded. 38: 49–70.

Lukowiak M. 2012. First record of late Eocene Ascidians (Ascidiacea, Tunicata) from southwestern Australia. Journal of Paleontology 86(3): 521–526.

Lukowiak M., Dumitriu S.D. & Ionesi V. 2016. First fossil record of early Sarmatian didemnid ascidian spicules (Tunicata) from Moldova. Geobios, 49(3): 201–209.

Lewis D.N. & Donovan S.K. 1991. The Pliocene Echinoidea of Tobago, West Indies. Tertiary Research 12: 139–146.

Mathur Y.K. & Jain A.K. 1980. Palynology and age of the Dras Volcanics near Shergol, Ladakh, Jammu and Kashmir, India. Geoscience Journal 1(1): 55–74.

Maxwell J.C. 1948. Geology of Tobago, British West Indies. Geological Society of America Bulletin 59: 801–854.

Medeanic S., Zamora N. & Correa I.C.S. 2008. Non-pollen palynomorphs as environmental indicators in the surface samples from mangrove in Costa Rica. Revista geológica de América Central 39: 27–51. https://doi.10.15517/rgac.v0i39.12246

Mertens K.N., Rengefors, K., Moestrup Ø & Ellegaard M. 2012. A review of recent freshwater dinoflagellate cysts: taxonomy, phylogeny, ecology and palaeoecology. Phycologia, 51(6): 612–619.

Meschinelli A. 1902. Fungorum fossilium omnium Iconographia. In Aedibus J. Galla, Vicetiae, 144 p.
Meyer B.L. 1956. Mikrofloristische Untersuchungen an jungtertiaren Braunkohle nimostlichen Bayern Geologica Bavarica, 25: 100–128.
Muller J. 1959. Palynology of the Recent Orinoco Delta and shelf sediments: reports of the Orinoco Shelf expedition. Micropaleontology 5: 1–32.
Newton E.T. 1875. On "Tasmanite" and Australian "white coal". Geologial Magazine 12: 337–342.
Payne N. 1991. An evaluation of post Middle Miocene geological sequences, offshore Trinidad. In: Gillezeau K.A. (Editor) Transactions of the Second Geological Conference of the Geological Society of Trinidad and Tobago, Port of Spain, Trinidad and Tobago: 70–87.
Peros M.C., Gregory B., Matos F. Reinhardt E. & Desloges J. 2015. Late-Holocene record of lagoon evolution, climate change, and hurricane activity from southeastern Cuba. The Holocene 25: 1483–1497.
Pohl M.D., Pope K.O., Jones J.G., Jacob J.S., Piperno D.R., deFrance S.D., Lentz D.L., Gifford J.A., Danforth M.E. & Josserand J.K. 2017. Early agriculture in the Maya Lowlands. Latin American Antiquity 7(4): 255–372. https://doi.org/10.2307/972264
Potonié R. 1951. Revision stratigraphisch wichtiger Sporomorphen des mittel europaischen Tertiars. Palaeontographica Abt. B 91: 131–151.
Potonié R. 1958. Synopsis del' Gattungen del' sporae dispersae. II. Teil: Sporites (Nachtrage), Saccites, Aletes, Praecolpates, Polyplicates, Monocolpates. Beiheftezum Geologisches Jahrbuch 31: 1–114.
Potonié R. 1960. Synopsis der Gattungen der sporae dispersae III. Teil: Nachtrage sporites, Fortsetzung Pollenites mit general register zu Teil 1–III. Beiheftezum Geologisches Jahrbuch 39: 1–189.
Ramanujam C.G.K. & Ramachar P. 1980. Recognizable spores of rust fungi (Uredinales) from Neyveli lignite, Tamil Nadu. Records of the Geological Survey of India 113(5): 80–85.
Ramanujam C.G.K. & Rao K.P. 1978. Fungal spores from the Neogene strata of Kerala in South India. Proceedings of the IV International Palynological Conference, Lucknow, 1976–1977, Volume 1: 291–304.
Ramcharan E.K. 2004. Mid to Late Holocene Sea level influence on coastal wetland development in Trinidad. Quaternary Research 120: 145–151.
Ramcharan E.K. 2005. Late Holocene development of the Graeme Hall swamp, Barbados, West Indies. Caribbean Journal of Science 41: 147–150.
Ramcharan E.K. & McAndrews J.H. 2006. Holocene development of coastal wetland at Maracas Bay, Trinidad, West Indies. Journal of Coastal Research 22(3): 581–586.
Rao K.P. & Ramanujam C.G.K. 1978. Palynology of the Neogene Quilon Beds of Kerala state in South India. I. Spores of pteridophytes and pollen of monocotyledons. Palaeobotanist 25: 397–427.
Rich F.J., Kuehn D. & Davies T.D. 1982. The paleoecological significance of *Ovoidites*. Palynology 6(1): 19–28.
Rull V. 2002. High impact palynology in petroleum geology: Application from Venezuela (northern South America). American Association of Petroleum Geologists Bulletin 86(2): 279–300.
Sagular E.K. 2009. Fossil didemnid ascidian spicule records in the Pliocene-Quaternary marine clastics of the Antalya Basin (Eastern Mediterranean) and their stratigraphic calibration to new nannofossil data. Geoscience Journal 13: 121–131.
Sah S.C.D. & Dutta S.K. 1966. Palynostratigraphy of Tertiary sedimentary formations of Assam–I. Stratigraphical position of the Cherra Formation. Palaeobotanist 15: 75–86.
Salard-Cheboldaeff M. & Locquin M.V. 1980. Champignons présents au Tertiaire le long du littoral de l'Afrique équatoriale. 105e Congrès National des Sociétéesavantes, Caen, 1980, Sciences, fascicule 1: 183–195.
Sarmiento G.A. 1992. Palinología de la Formación Guaduas: Estratigrafía y sistemática. Boletín Geológico Ingeominas 32: 45–126.
Saunders J.B. & Muller-Merz E. 1985. The age of the Rockly Bay Formation, Tobago. Transactions of the Latin American Geological Congress, Trinidad and Tobago 1: 339–344.
Schmiedeknecht M. & Schwab G. 1964. Bulbillen fossiler Pilzeauseiner tertiär en Weichbraun kohle. Deutsche Akademie der Wissenschaftenzu Berlin 6: 683–692.
Scott P.W., Jackson T.A. & Dunham A.C. 2000. Ore mineral associations and industrial minerals in the ultramafic rocks of Jamaica and Tobago. Caribbean Journal of Earth Science 34: 5–16.
Sheffy M.V. & Dilcher D. L. 1971. Morphology and taxonomy of fungal spores. Palaeontographica Abt. B 133: 34–51.
Shenkar N. & Swalla B.J. 2011. Global Diversity of Ascidiacea. PLoS ONE 6(6): e20657. https://doi.org/10.1371/journal.pone.0020657.
Singh R.Y. 1975. Morphological study of the Retialetes complex from Indian Tertiaries. Geophytology 5(1): 98–104.
Snoke A.W., Rowe D.W., Yule J.D. &. Wadge G. 1988. Geologic Map of Tobago, West Indies. Ministry of Energy and Energy Industries of Trinidad and Tobago 1998.
Song Z.-C. & Cao L. 1994. Late Cretaceous fungal spores from King George Island, Antarctica. Stratigraphy and Palaeontology of Fides Peninsula, King George Island, Antarctica, Monograph 3: 47–49.
Stein S.F.N. von. 1859. Über die ihm aus eigener Untersuchung bekannt gewordenen Süsswasser Rhizopoden. Abhandlungen der Koniglische Bohmischen Gesellschaft der Wissenschaften 5. Folge 10: 41–43.
Sum L.S., Wilson B. & Moonan X. 2015. Micropalaeontological reconnaissance of the Rockly Bay Formation, Tobago. 20th Caribbean Geological Conference 2015, AAPG Latin America and Caribbean Region, Port of Spain, Trinidad & Tobago, West Indies, May 17–22.
Taylor T.N., Remy W., Hass H. & Kerp H. 1995. Fossil arbuscular mycorrhizae from the Early Devonian. Mycologia 87(4): 560–573.
Thomson P.W. & Pflug H. 1953. Pollen und sporen des mittel europaischen Tertiars. Palaeontographica Abt. B 94: 1–138.
Traverse A. & Ginsburg R.N. 1966. Palynology of the surface sediments of Great Bahama Bank, as related to water movement and sedimentation. Marine Geology 4(6): 417–459. https://doi.org/10.1016/0025-3227(66)90010-7
Tschudy R.H. & Scott R.A. 1969. Aspects of Palynology. Wiley Interscience, NY. 1–510.
Urquhart G.R. 2009. Paleoecological record of hurricane disturbance and forest regeneration in Nicaragua. Quaternary International 195(1): 88–97. https://doi. 10.1016/j.quaint.2008.05.012
van der Hammen T. 1954. El desarrollo de la flora Colombiana en los periodosgeologicos–1. Maestrichtiano hasta Terciaro mas inferior

(Una investigacion Palinologica de la formacion de Guaduas y equivalentes). Boletin Geologico (Bogota) 2(1): 49–106.

van der Hammen T. 1956. A palynological systematic nomenclature. Boletin Geologico (Bogota) 4: 63–101.

van Geel B. & van der Hammen T. 1978. Zygnemataceae in Quaternary Colombian sediments. Review of Palaeobotany and Palynology 25: 377–392.

van Waveren I.M. 1992. Morphology of probable planktonic crustacean eggs from the Holocene of the Banda Sea (Indonesia). In: Head M.J. & Wrenn J.H. (Editors) Neogene and Quaternary dinoflagellate cysts and acritarchs. American Association of Stratigraphic Palynologists Foundation, Dallas, Texas, USA.: 89–120.

Varol O. 1996. A review and classification of fossil didemnid ascidian spicules. Journal of Micropalaeontology 15: 135–149.

Wall D. 1962. Evidence from recent plankton regarding the biological affinities of *Tasmanites* Newton 1875 and *Leiosphaeridia* Eisenack 1958. Geological Magazine, Cambridge 99(4): 353–362.

Zhang Z.Y. 1980. Lower Tertiary fungal spores from Lunpola Basin of Xizang, China (English summary). Acta Palaeontologica Sinica 19: 296–301.