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Dispersed organic matter from Neogene and Pleistocene sediments of Site 218 of Deep Sea Drilling Project Leg 22, Bengal Fan, Indian Ocean

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ABSTRACT

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Dispersed organic matter has been recorded from the Neogene-Pleistocene sediments of site 218 of the Deep Sea Drilling Project Leg 22, Bengal Fan and depositional environment of the studied sequences has been deduced. An attempt has been made to calibrate frequency abundance of organic matter in order to identify variation at various depth levels. Based on the occurrence and frequency of various types of organic matter the borehole section has been divided into lower, middle and upper zones. The lower zone is rich in biodegraded terrestrial organic matter, whereas the upper zone exhibits abundance of structured terrestrial and black debris. Spores and pollen are poorly represented. Recycled Cretaceous palynofossils have been recorded throughout the sequence. The analysis of lithologic and organic matter data indicates that these sediments were deposited in deltaic environment. The behaviour pattern of biodegraded, structured and black debris indicates reducing condition in the lower zone and oxidizing condition in the upper zone.

Key-words—Dispersed organic matter, Deep Sea Drilling Project, Environment of deposition, Neogene and Pleistocene, Bengal Fan, Indian Ocean.

हिन्द महासागर में बंगाल फैन के गभीर सागर वेध परियोजना चरण 22 के स्थल 218 के निओजीन तथा प्लीस्टोसीन युगीन अवसादों से प्राप्त परिक्षिप्त जैव पदार्थ

माधव कुमार, रमेश कुमार सक्सेना एवं अनिल चन्द्रा

सारांश

परिक्षिप्त जैव पदार्थ को बंगाल फैन के गभीर सागर वेध परियोजना चरण 2 के स्थल 218 के निओजीन-प्लीस्टोसीन, युगीन अवसादों से अभिलिखित किया गया है तथा नियोजित अनुक्रम के निक्षेपणीय पर्यावरण का निगमन किया गया है।

जैव पदार्थ की विभिन्न प्रकारों की उपस्थिति तथा आवृत्ति के आधार पर वेध छिद्र अनुभाग को निम्न, मध्य तथा उपरि क्षेत्रों में विभाजित किया गया है। निम्न क्षेत्र जैवनिम्नीकृत स्थलीय जैव पदार्थ में प्रचुर है जबकि उपरि क्षेत्र संरचनात्मक स्थलीय तथा काले मलवे की प्रचुरता प्रदर्शित करता है। बीजाणु तथा परागकण अल्प निरूपित हैं। पुन : चक्रित क्रिटेशस परागणु पादपाश्मों पूरे अनुक्रम में अभिलिखित किया गया है। अश्मिक तथा जैव पदार्थ आंकड़ों का विश्लेषण यह संकेत

करता है कि ये अवसाद डेल्टीय वातावरण में निक्षेपित थे। जैवनिम्नीकृत, संरचनात्मक तथा काले मलवे की व्यवहार पद्धति निम्न क्षेत्र में अवकारक परिस्थितियों तथा उपरि क्षेत्र में ऑक्सीकारक परिस्थितियों का संकेत करती है।

संकेत शब्द—परिक्षिप्त जैव पदार्थ, गभीर सागर वेध परियोजना, निक्षेपणीय पर्यावरण, निओजीन तथा प्लीस्टोसीन युगीन, बंगाल फैन, हिन्द महासागर।

INTRODUCTION

PALYNOLOGICAL studies on the Tertiary sediments of the Deep Sea Drilling Project sites in the Indian Ocean have been published by Kemp (1974, 1978), Kemp and Harris (1975, 1977), Chandra and Kumar (1997) and Saxena *et al.* (1999). Kemp (1978) discussed Tertiary climatic evolution and vegetational history in the southeastern Indian Ocean. Van der Borch *et al.* (1974) published site data, description of cores and lithological summary of Site 218 of DSDP Leg 22. Curry *et al.* (1982) described sedimentary succession of the Bengal Fan and dated borehole sequences of the DSDP sites 217 and 218 as uppermost Miocene and basal Eocene.

The objective of the present study is to analyse the dispersed organic matter in the borehole sequence of Site 218 of the DSDP Leg 22 and interpret the data for deducing depositional environment during Middle to Late Miocene and Pliocene to Pleistocene. The presentation of data may help in evaluation of palaeofloral diversity and regional correlation of the sedimentary deposits.

MATERIAL AND METHODS

The present study was done on the samples collected from Site 218 of the Deep Sea Drilling Project Leg 22 (core nos. 27 to 1; depth up to 773 m below sea floor; Figs 1, 2). These samples were chemically processed in dilute Hydrochloric and Hydrofluoric acids, following the method of Batten and Morrison (1983). Various types of organic matter and spores-pollen were observed under light microscope. The data obtained from the qualitative and quantitative analyses of the dispersed organic matter are shown in Fig. 3. For quantitative analysis, about 200 specimens of palynodebris and palynofossils were counted in each sample. These organic matters are categorized according to the classification proposed by Masron and Pocock (1981), Venkatachala (1981) and Tyson (1993). The details of sampling locations and core-catchers (CC) are provided in Chandra and Kumar (1997). Slides and negatives of the figured specimens are stored in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

DISPERSED ORGANIC MATTER ANALYSIS

The sedimentary sequence of the DSDP Site 218 has a number of organic matter horizons, which have yielded palynofossils. The assemblage includes distinct palynotaxa, probably of local origin and also those recycled from the older deposits. The Middle to Late Miocene sedimentary sequence (core nos. 27 to 12; depth 773 to 336 m) contains polypodiaceous and schizaeaceous spores and gymnospermous and angiospermous pollen with recycled Late Mesozoic palynofossils (Chandra & Kumar 1997; Saxena *et al.* 1999). The overlying Pliocene-Pleistocene sedimentary sequence (core nos. 11 to 1; depth 336 to 0 m) contains pteridophytic spores, a few gymnospermous pollen and recycled Permian and Late Mesozoic palynofossils. The sedimentary matrix is mainly formed of terrestrial elements, which includes structured terrestrial, biodegraded terrestrial, amorphous, grey amorphous and black debris. Quantitatively, resins and spores-pollen are next to biodegraded terrestrial and structured matters. A brief account of various types of organic matter is given below:

The sedimentary sequence of the borehole is divided into: (i) Lower Zone - core nos. 27 to 12 at 763.5 to 336 m depth (Middle to Late Miocene); (ii) Middle Zone - core nos. 11 to 9 at 307.5 to 231.5 m depth (Pliocene); and (iii) Upper Zone - core nos 8 to 1 at 184 to 0 m depth (Pleistocene).

Structured terrestrial—The structured terrestrial type consists of fragments of terrestrial plants, e.g. woody remains

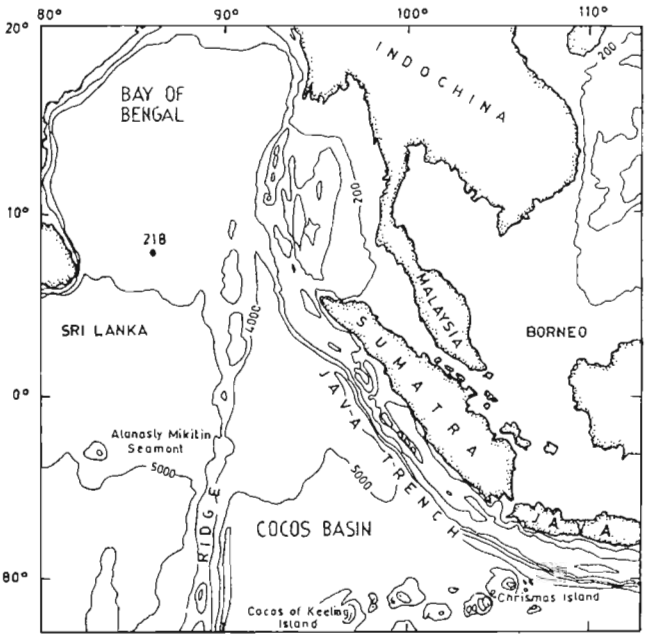

Fig. 1—Showing location of DSDP site 218 in Bengal Fan, Indian Ocean.

Unit	Depth below Sea floor (m)	Lithology	Age	Cores
1.	0-9	Clay silt-rich nanno ooze with interbeds of silty clay	Quaternary	1, 2
2.	9-70	Silt with interbeds of sand, sandy silt and clayey silt	Quaternary	2, 4
3.	70-225	Nanno-rich clayey silt and silty clay with interbeds of nanno ooze	Quaternary-Pliocene	5-9
4.	225-350	Silts with interbeds of silty sand and clayey silt	Pliocene- Upper Miocene	9-12
5.	350-470	Clayey silt and silty clay with occasional interbeds of nanno-ooze and sandy silt	Upper Miocene	13-16
6.	470-600	Interlaminated clean silt, clayey silt and sandy silt with occasional interbeds of mottled nanno ooze	Upper Miocene	17-22
7.	600-650(?)	Interlaminated clayey silt, silty clay and sandy silt with interbeds of nanno ooze	Upper Miocene	23, 24
8.	650-773	Interlaminated clean silt, sandy silt and clayey silt	Middle Miocene	24-27

Fig. 2—Lithological summary of the bore hole at DSDP site 218 of Leg 22.

of stem, twigs and root tissues, stem barks, vessels and fragments of leaves, cuticles and other unidentified cellular tissues (Pl. 1.16). They represent 3-6% in the Lower Zone (depth 621 to 385.5 m) but gradually increase to 15-35% in the Upper Zone (depth 155.5 to 115 m, Fig. 3).

Biodegraded terrestrial—The biodegraded terrestrial organic matter includes plant fragments affected by microbial activities. They are the most dominant (up to 65%) at the lower and middle parts and gradually decrease (40-5%) in the upper part of the sequence.

Amorphous—The amorphous organic matters are non-structured in appearance and may have been derived from highly biodegraded plant remains. Its frequency is about 25% at base. In the Lower Zone, the amorphous constitutes 6 to 14 %, whereas in the Upper Zone it is represented by only 3-6 %.

Grey amorphous—The grey amorphous organic matter is poorly represented (up to 2 % at depths 478 m, 79.5 m and 4.0 m). They may have been derived from highly biodegraded tissues of algal origin.

Resins—The resins are translucent, lipid-rich, globular structures and occur in both lower and upper zones. Resins are derived mainly from arboreal gymnosperms and angiosperms. Secretion of resin is mainly by gymnosperms and some arboreal angiosperms during biological and physical injury to the stem tissues. Resins contain complex biopolymers, which are most resistant to microbial decay. The occurrence of resin and woody matters in good frequency at various levels of the borehole indicates deltaic plain environment (Masron & Pocock, 1981).

Black debris—Black debris is dominant (up to 65 %) in the Upper Zone (Pleistocene). However, their frequency varies from 6 to 45 % in the lower zone. Black debris are the oxidized fragments of terrestrial plants (Fig. 3).

Pyrite—The pyrite crystals are embedded in. They biodegraded terrestrial and amorphous organic matters are result of the bacterial activity where a greater amount of sulphate minerals are transformed to sulphia. They are available within the pore water under anoxic condition with marine influence. Pyrites are represented in most of the samples.

Spore-pollen—The representation of spores-pollen in total dispersed organic matter is poor (1-2 %). They occur only in the Upper Zone.

Fungi—Fungal hyphae, conidia and fruiting bodies are recorded throughout the sequence. *Meliola* sp. and microthyriaceous ascomata are common.

DISCUSSION

Various types of dispersed organic matter (DOM) and their frequency at different levels of the borehole indicate that the lower part of the sequence was deposited under reducing condition whereas, the upper part, containing well preserved woody and leaf structures and black debris, exhibit moderate oxidizing condition.

The organic matter contents of core numbers 27 to 12 (Middle-Late Miocene) indicate dominance of biodegraded terrestrial and black debris followed by amorphous and resins. The structurred terrestrial matter is next in abundance to the biodegraded and black debris in upper zone.

The basal part of the borehole (depth 621 to 385.5 m) experienced higher input of terrestrial plant matter that was transformed into the biodegraded forms through microbial actions. Microbial activities and sedimentation rate in the lower zone indicate prevalence of reducing conditions. High fungal activity and abundant black debris with unaltered structured terrestrial indicate aerobic condition in the upper zone. This phenomenon is common in the basins experiencing low sedimentation rate and oxidation of organic particles (Demaison & Moore, 1980).

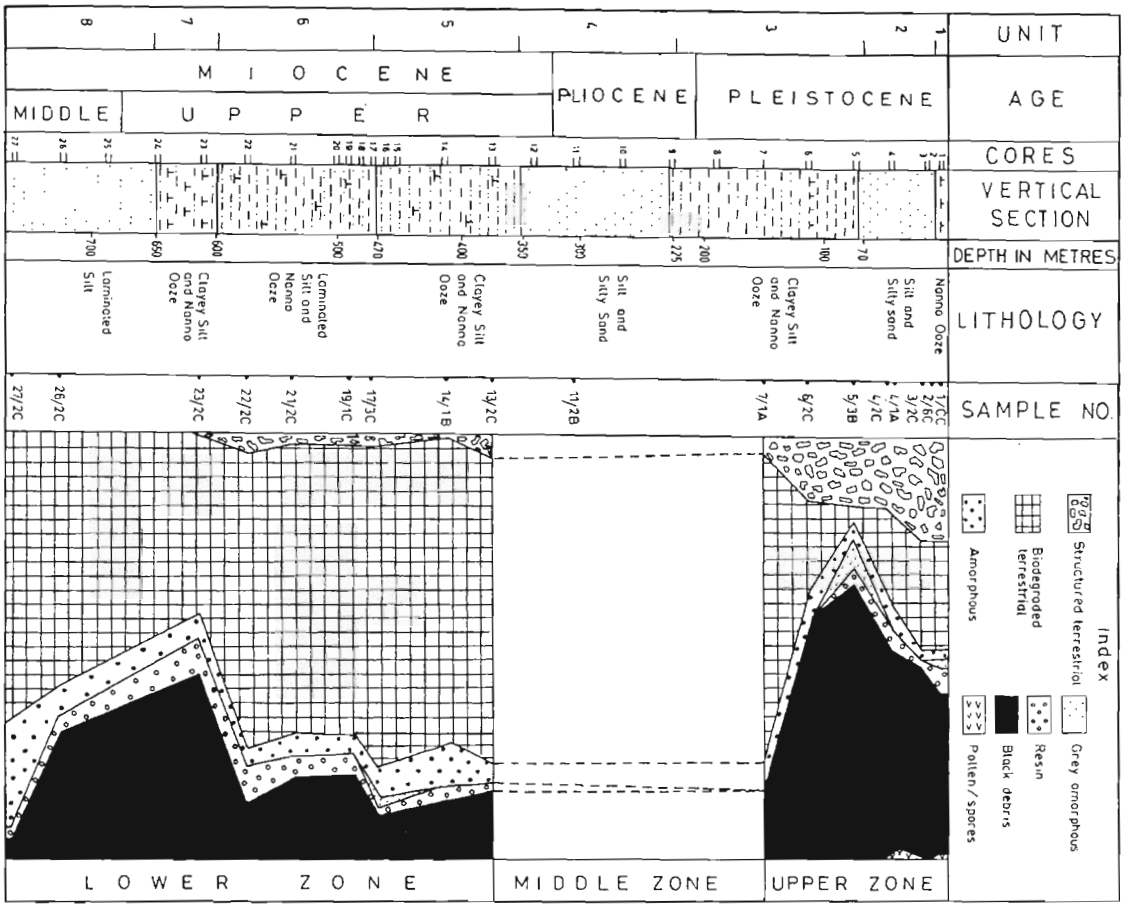

Fig. 3—Showing quantitative representation of various types of organic matter in borehole sequence at DSDP Site 218, Leg 22.

The dominance of biodegraded terrestrial organic matter in the Lower Zone indicates moderate level of degradation under reducing environment. This part has lower frequency of structured terrestrial. Contrary to this, the structured terrestrial organic matter increases from 15 to 37 % in the Upper Zone whereas, biodegraded terrestrial matter decreases from 80 % to 45% and to about 20 % in the uppermost part. According to Fisher (1980) the decrease in frequency of biodegraded forms indicates slow settling of organic matters with sediments under low energy condition where oxidation of organic particles is more. In such condition, most of the organic debris gets oxidized to form black debris.

The spores-pollen are poorly *Verrualetes* sp., *Assamiapollenites* sp., *Polypodisporites, multiverrucosus, Retiinaperturites* sp. represented by *Pteris wallichiana, Selaginella sortorii, Operculosculptites* sp., cf. *Meliola* sp., *Pluricellaesporites* sp. and a few gymnospermous pollen. The recycled palynotaxa are: *Striatites* sp., *Lycopodiacidites*

PLATE 1

1 *Lycopodiacidites asperatus*, Slide no. BSIP12560, S5.
2. *Retiinaperturites* sp., Slide no. BSIP12559, Z7.
3. Unidentified, Slide no. BSIP12561, Z43.
4. *Polypodiisporites multiverrucosus*, Rao & Ramanujam, Slide no. BSIP12563, V33.
5. *Assamiapollenites* sp. Slide no. BSIP 12565, V27
6. *Verrualetes* sp., Slide no. BSIP12571, H38.
7 Unidentified, Slide no. BSIP12564, R43/1
8. *Striatopodocarpites* sp., Slide no. BSIP12565, C22.
9. *Pteris wallichiana*, Slide no. BSIP12562, G 41
10. Unidentified, Slide no. BSIP12574.
11 *Illinites* sp., Slide no. BSIP12568, Y22/3.
12. Structured terrestrial, Slide no. BSIP12579, H52.
13. *Meliola* sp. Slide no. BSIP12567, C16.
14. *Rouseisporites reticulatus* Pocock, Slide no. BSIP12571, O31
15. Leaf fragment, Slide no. BSIP12568, G8/3.
16. Structured terrestrial, Slide no. BSIP12579, H52.
17-18. Amorphous organic matter, Slide no. BSIP12577, R40; BSIP12578, M49.
19. Unidentified, Slide no. BSIP12578, M49.

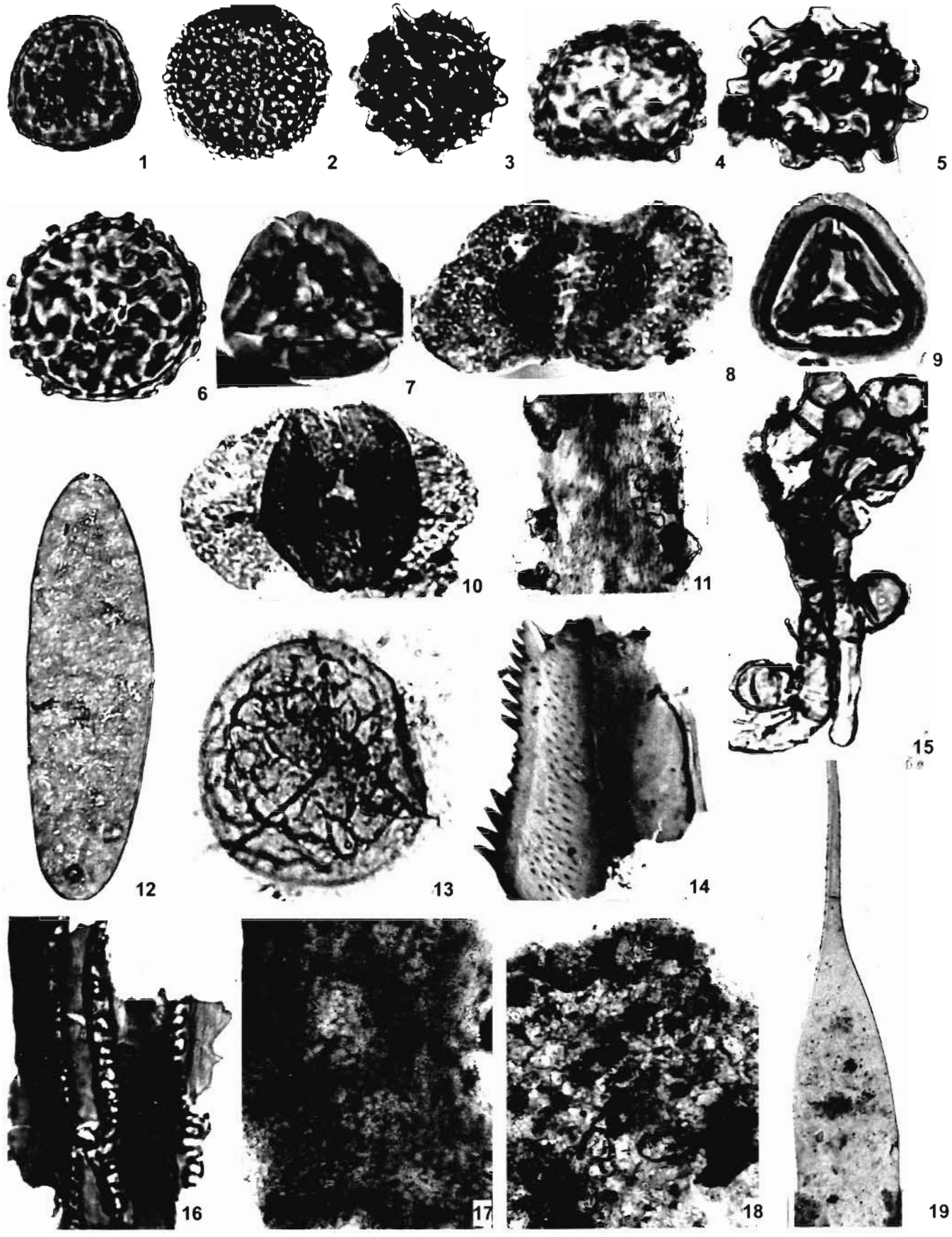

PLATE 1

asperatus and *Rouseisporites reticulatus, Illinites, Striatopodocarpites* sp. The occurrence of Cretaceous palynofossils is attributed to recycling. It is likely that the surrounding Cretaceous deposits underwent active erosion and redeposited in a delta plain.

The Bengal Fan is the largest sub-aerial delta fan in the world and received sediments from the Himalaya. The sediments were transported to this fan mainly by the Ganga and Brahmaputra rivers (Hutchinson, 1989). It is noteworthy that the Late Tertiary sediments of southern Assam and southern Tripura also contain similar reworked Permian and Cretaceous palynofossils (Kar, 1990, 1992). These palynofossils were transported to depositional site through ocean currents. It is likely that the source of reworked palynofossils of this site and the same of the Late Tertiary sediments of northeast India may be one and the same.

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