Palynology of the Late Tertiary sediments (DSDP Site 218) in the Bengal Fan, Indian Ocean

Anil Chandra & Madhav Kumar

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Palynological assemblage from DSDP Site 218 in the Bengal Fan comprises spores, pollen, fungal fruiting bodies and dinoflagellate cysts. The palynofloral composition has minor variation in core no. 27 to 12. The microthyriaceous fungal remains show comparatively higher frequency than other fungal entities. The gymnosperms are represented mostly by the pollen grains of Podocarpaceae and Araucariaceae. Angiosperm pollen are sparsely observed in the assemblage. The pteridophytic spores occur mostly in the bottom and middle cores (core nos. 27-26 and 23-20). Recycled Cretaceous spores have also been found in most of the core samples. This palynoassemblage from Site 218 is comparable to that of the Miocene sediments of north-east India. The environmental relationship of the taxa shows similarity with the modern plants inhabited in the subtropical climate.

Key-words—Palynology, DSDP Site 218, Late Tertiary, Indian Ocean.

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सारांश

हिन्द महासागर में बंगाल फैन के अनंतिम टर्शियरी कालीन अवसादों (डी.एस.डी.पी. 218) का परागाणविक अध्ययन

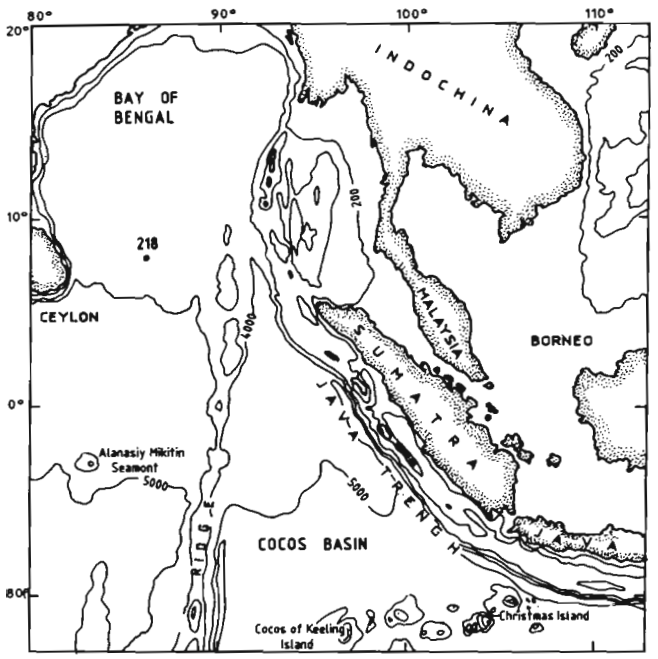
अनिल चन्द्रा एवं माधव कुमार

बंगाल फैन के डी.एस.डी.पी. 218 नामक स्थान से प्राप्त परागाणविक समुच्चय में बीजाणु, परागकण, कवकीय फलन काय एवं घूर्णीकशाभ पुटी विद्यमान है। क्रोड़ संख्या 27 से 12 तक से प्राप्त परागाणविक रूपकों में थोड़ी सी विभिन्नता है। अनावृतबीजीयों में पोडोकार्पेसी एवं अॅराकेरिएसी कुल के परागकण अधिकांशतः मिलते हैं। टेरीडोफाइटी बीजाणु प्रायः तली एवं बीच के क्रोड़ों में ही मिलते हैं। वैसे पुनर्वासित क्रीटेश्यस बीजाणु लगभग सभी क्रोड़ों में प्रेक्षित किये गये हैं। यह समुच्चय उत्तर-पूर्व भारत की मायोसीन कालीन समुच्चयों से तुलनीय है तथा इसमें प्राप्त वर्गक उपोष्ण कटिबन्धीय जलवायु में उगने वाले पौधों से सदृशता वयक्त करते हैं।

PALYNOLOGICAL investigation of Ninetyeast ridge Site 214 and 254 was carried out by Kemp (1978) and Kemp and Harris (1975, 1977). The palynological records from other land masses, bordering the Indian Ocean are from Tertiary of India and Australia. The palynoflora recovered here from the DSDP Site 218, Leg 22 of the Bengal Fan is similar with the Miocene microflora of north-east India and south India (Kar, 1992; Ramanujam, 1982; Rao & Ramanujam, 1982; Ramanujam & Rao, 1993; Jain & Kar, 1979; Jain & Gupta, 1970).

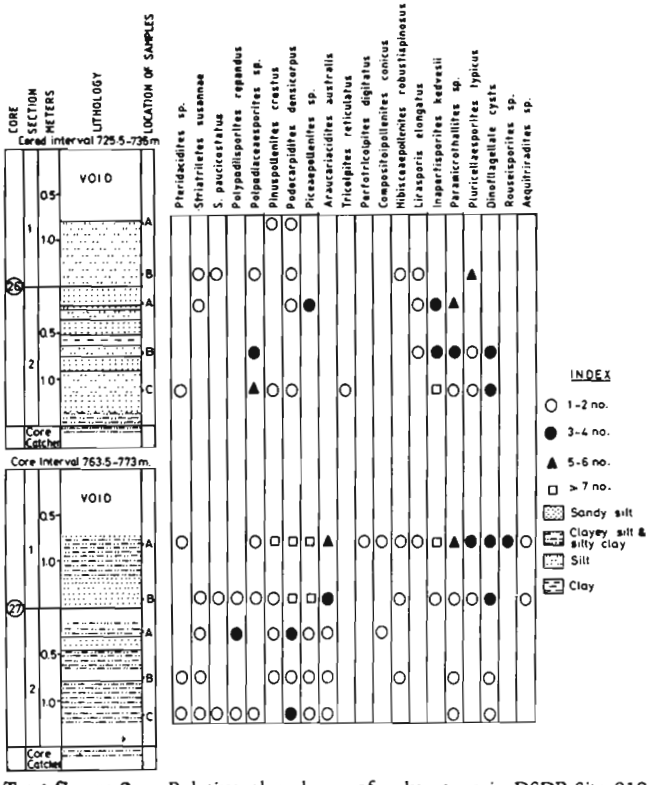
Qualitatively, the palynoassemblage of DSDP Site 218 (Core no. 27-12)is evenly distributed in the vertical sequence with some minor changes, apart from the introduction of marine forms in some sequences. The samples from core no. 11-1 (Pliocene) show poor representation of palynotaxa.

Most of the fossil palynotaxa of the assemblage are attributed with extant botanical affinities. In their brief description we have not used morphologic and superageneric classification; only some important taxa with their limited morphologic descriptions, occurrence and depths have been considered. The palaeoenvironment is drawn on the basis of habitat of modern taxa. The prolific fungal fruiting bodies referred to the family Microthyraceae show limited usefulness in stratigraphic and palaeoclimatic demarcation. The samples of Site 218 contain common

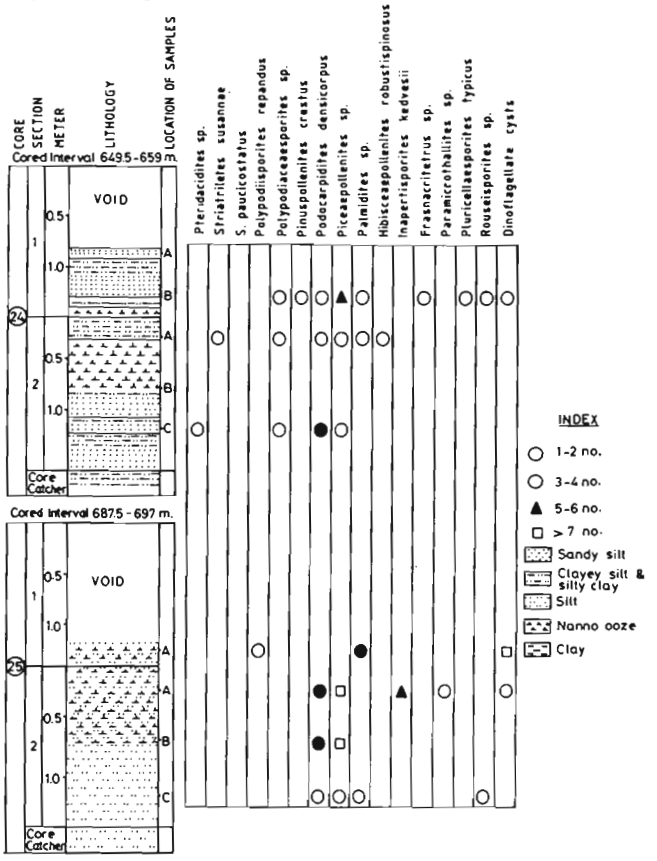


Text-figure 1—Location of DSDP-Site 218, Bengal Fan, Indian Ocean.

Neogene microflora and some recycled Cretaceous spores of *Rousetsporites* and *Aequitriradites* indicate Late Tertiary influence of Cretaceous sediments from



Text-figure 2 — Relative abundance of palynotaxa in DSDP Site 218, core nos. 27-26.

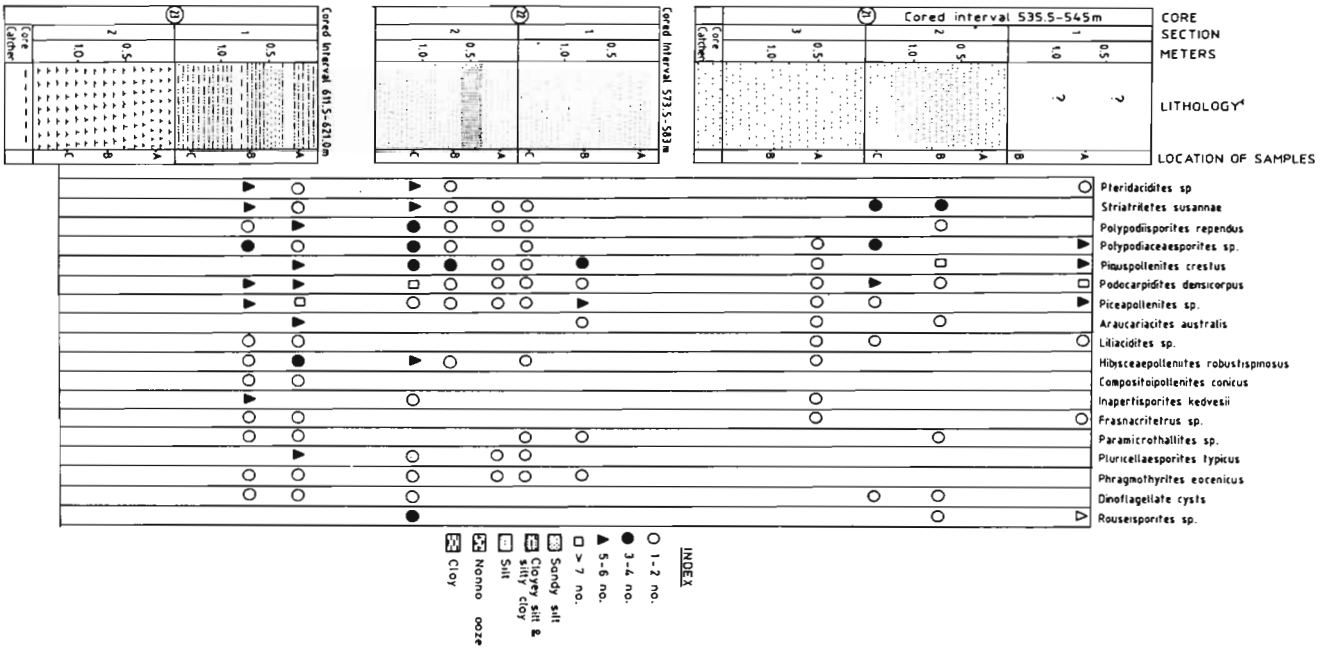


Text-figure 3—Relative abundance of palynotaxa in DSDP Site 218, core nos. 25-24.

other land masses during deposition which may be closer to this island.

MATERIAL AND METHOD

About 5-10 gms of rock samples from various cores (27-12) of the DSDP Site 218 were chemically processed for recovery of palynofossils by using conventional method. The slides were prepared in polyvinyl alcohol and mounted in Canada Balsam. The palynoflora was counted in each sample for quantitative analysis and has been shown in histograms (Text-figures 1-6). The samples from core nos. 11-1 could not be studied due to poor representation of palynofossils. The slides of these palynological preparations have been deposited at the repository of Birbal Sahni Institute of Palaeobotany, Lucknow. Site data, coring summary and lithological summary of Leg 22, Site 218 are from von der Borch *et al* (1974).



Text-figure 4—Relative abundance of palynotaxa in DSDP Site 218, core nos. 23-21.

SITE DATA

Date occupied	-	1 March 1972 (1030)
Date departed	-	4 March 1972 (1030)
Time on site	-	72 hours
Position	-	lat. 08°00: 42'N long. 86°16.97'E
Water depth (to rig floor)	-	3737 m (Echo sounding) 3759 m (Drill pipe)
Penetration	-	773 m
Number of cores	-	27
Total length of the cored section	-	251 m
Total core recovered	-	59.4 m
Acoustic Basement Depth	-	? m
Nature	-	Unknown
Age of the oldest sediments	-	Middle Miocene
Basement	-	Not reached

LIST OF PALYNOTAXA

Bryophytes

Operculosculptites sp.

Pteridophytes

Cyathidites australis Couper 1953

Dictyophillidites sp.

Polypoditisporites repandus Takahashi 1964

Polypodiaceaesporites sp.

Pteridacidites sp.

Schizaeoisporites sp.

Striatriletes susannae van der Hammen 1956

S. paucicostatus Kar 1985

Reworked spores

Aequitriradites sp.

Bicingulispora sp.

Hammulatisporites sp.

Rouseisporites sp.

Gymnosperms

Araucariacites australis Couper 1953

Piceapollenites sp.

Pinuspollenites crestus Kar 1985

Podocarpidites densicorpus Kar 1985

Angiosperms

Liliacidites sp.

Palmidites sp.

Coring Summary (Hole 218)

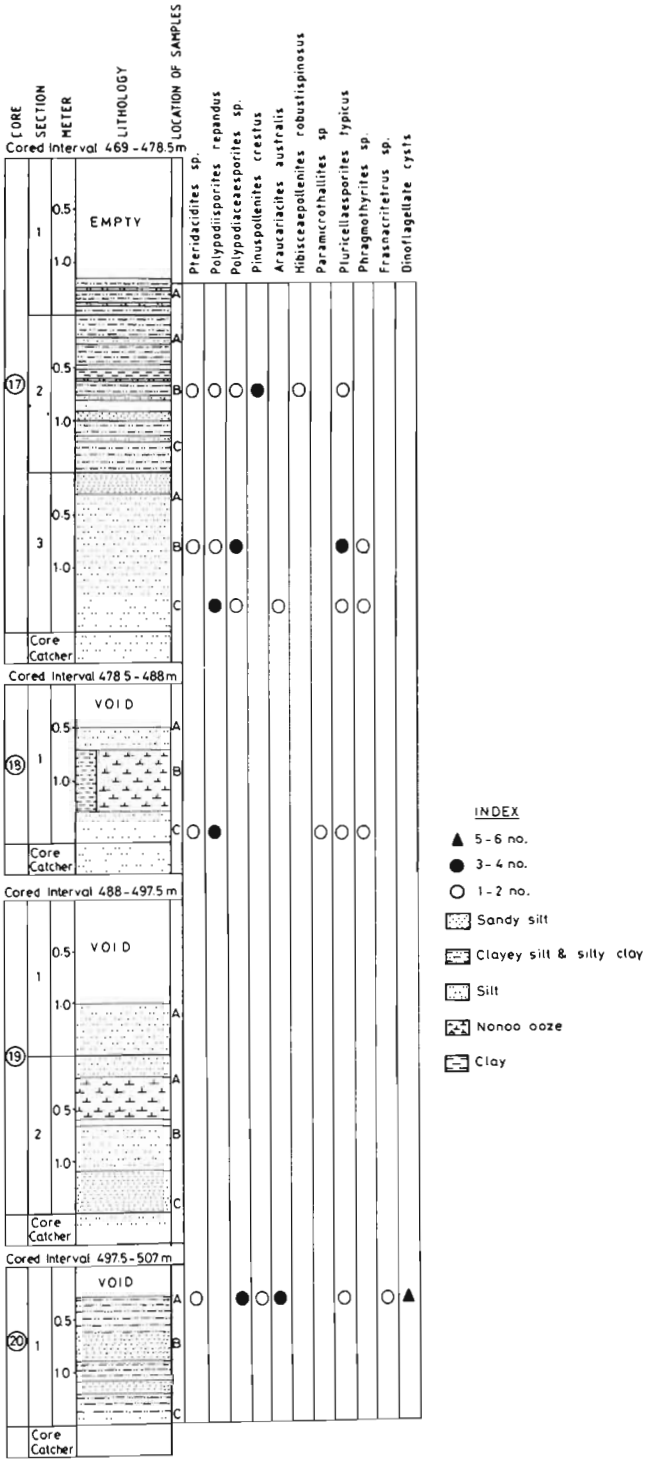
Core	No. of sections (each sec. 1.5 m.)	Date March	Time	Depth from Drill floor (meters)	Depth below Sea floor (meters)	Cored (meter)	Recovered (meters)	Recovery (%)
1.	3	1	1930	3759.0-3763.0	0.0-4.0	4.0	1.5	37
2.	6	1	2040	3763.0-3772.5	4.0-13.5	9.5	8.1	85
3.	2	1	2200	3772.5-3782.0	13.5-23.0	9.5	2.4	25
4.	2	1	2345	3800.5-3810.0	41.5-51.0	9.5	2.3	24
5.	3	2	0140	3829.0-3838.5	70.0-79.5	9.5	4.2	44
6.	2	2	0325	3867.0-3876.5	108.0-117.5	9.5	2.0	21
7.	core catcher	2	0519	3905.0-3914.5	146.0-155.5	9.5	0.1	1
8.	3	2	0726	3943.0-3952.5	184.0-193.5	9.5	4.2	44
9.	1	2	0915	3981.0-3990.5	222.0-231.5	9.5	0.6	6
10.	1	2	1115	4019.0-4028.5	260.0-269.5	9.5	0.9	10
11.	2	2	1314	4057.0-4066.5	298.0-307.5	9.5	1.8	19
12.	1	2	1525	4095.0-4104.5	336.0-345.5	9.5	0.3	3
13.	2	2	1735	4133.0-4142.5	374.0-383.5	9.5	2.4	25
14.	1	2	2005	4171.0-4180.5	412.0-421.5	9.5	0.8	8
15.	1	2	2215	4209.0-4218.5	450.0-459.5	9.5	1.3	14
16.	2	2	2334	4218.5-4228.0	459.5-469.0	9.5	1.8	19
17.	3	3	0106	4228.0-4237.5	469.0-478.5	9.5	3.3	35
18.	1	3	0221	4237.5-4247.0	478.5-488.0	9.5	1.1	12
19.	2	3	0336	4247.0-4256.5	488.0-497.5	9.5	2.0	21
20.	1	3	0446	4256.5-4266.0	497.5-507.0	9.5	1.2	13
21.	2	3	0730	4294.5-4304.0	535.5-545.0	9.5	2.9	30
22.	2	3	1005	4332.5-4342.0	573.5-583.0	9.5	2.9	30
23.	2	3	1235	4370.5-4380.0	611.5-621.0	9.5	3.0	31
24.	2	3	1513	4408.5-4418.0	649.5-659.0	9.5	2.1	22
25.	2	3	1730	4446.5-4456.0	687.5-697.0	9.5	1.7	18
26.	2	3	2230	4484.5-4994.0	725.5-735.0	9.5	2.2	23
27.	2	4	0120	4522.5-4532.0	763.5-773.0	9.5	2.3	24
Totals	53					251.0	59.4	24

Note : Echo sounding depth (to drill floor) = 3737 meters, drill pipe length to bottom = 3759 meters

Lithological Summary

Leg 22, Hole 218

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 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

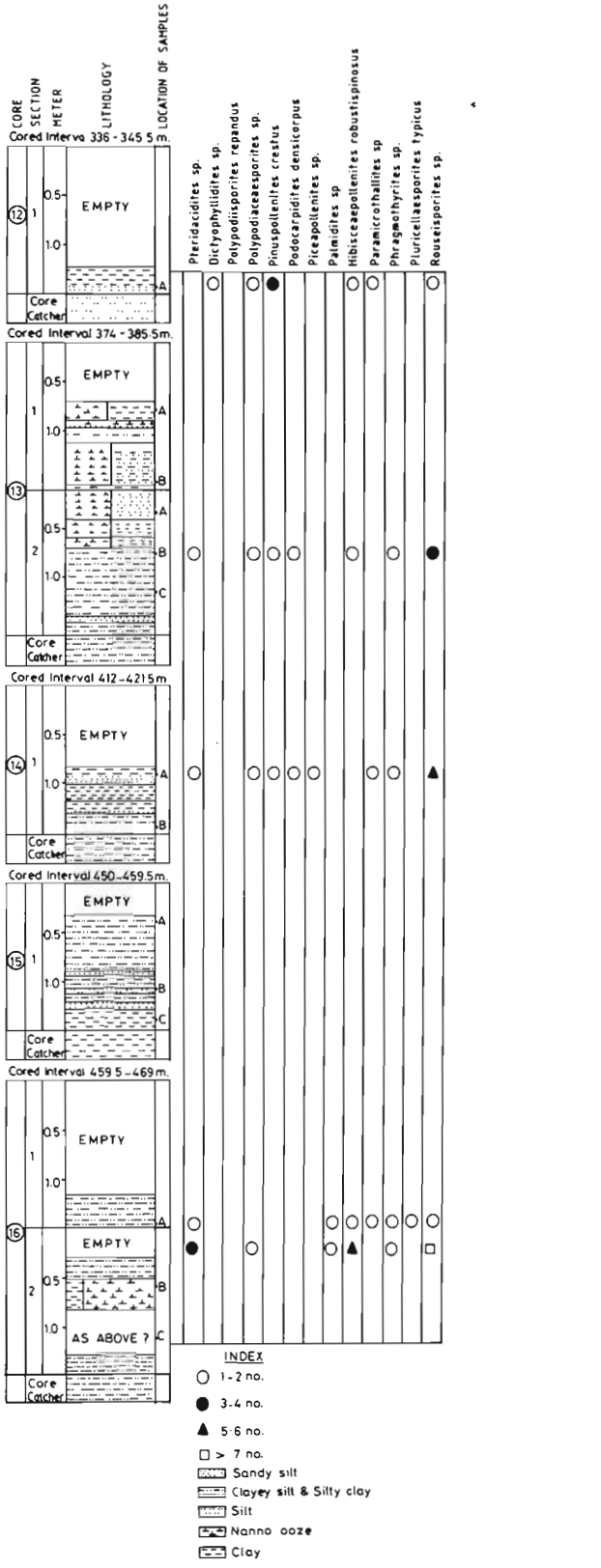


Text-figure 5 — Relative abundance of palynotaxa in DSDP Site 218, core nos. 20-17.

Compositoipollenites conicus Sah 1967

Hibisceaepollenites robustispinosus Kar 1990

Perfotricolpites digitatus Guzman 1967



Text-figure 6 — Relative abundance of palynotaxa in DSDP Site 218, core nos. 19-12.

Polyadopollenites miocenicus Ramanujam 1966

Retipollenites arcotense Ramanujam 1966

Retistephanocolporites sp.

Pollen tetrad Type A

Pollen Type A

Fungi

Diporicellaesporites sp.

Dyadosporonites schwabii Elsik 1968

Dyadosporonites sp.

Inapertisporites variabilis van der Hammen 1954

Frasnacritetrus sp.

Lirasporis elongatus Kar 1990

Meliolinites spinksii Selkirk 1975

Meliolinites sp.

Paramicrothallites sp.

Parmathyrites indicus Jain & Gupta 1970

Phragmothyrites eocenicus (Edwards) Kar & Saxena 1976

Pluricellaesporites typicus van der Hammen 1954

Trichopeltinites kiandrensis Selkirk 1975

Trichothyrites sp.

SYSTEMATIC DESCRIPTION OF SOME SELECTED TAXA

Fungal fruiting bodies

All samples from DSDP Site 218 included in the present paper contain abundant fungal remains, including *Paramicrothallites, Phragmothyrites, Pluricellaesporites, Frasnacritetrus, Trichopeltinites,* etc. These dispersed fungal remains generally can not be identified with living forms. Their diversity and quantity provide little palaeoclimatic information. Most of the fungal fructifications of this assemblage can be referred to the family Microthyraceae. The extant taxa of this family are epiphyllous and host of these fungi are gymnospermic and angiospermic leaves.

Genus—*Paramicrothallites* Jain & Gupta 1970

Type species—*Paramicrothallites spinulatus* (Dilcher) Jain & Gupta 1970.

Paramicrothallites sp.
Pl. 1, fig. 16; Pl. 3, fig. 7

Remarks—These semi-circular microthyraceous flattened ascomata show pseudoparenchymatous cells and have abundant occurrence in the assemblage.

Occurrence—Core length 773.0-687.5 m, 621.0-535.5 m and 488.0-478 m.

Genus—*Phragmothyrites* Edwards 1922

Type species—*Phragmothyrites eocaenica* Edwards 1922.

Phragmothyrites eocenicus Edwards, emend. Kar & Saxena 1976
Pl. 3, fig. 5

Remarks—This scutate fruiting body lacks an ostiole. The cells are perforated. The extant epiphyllous fruiting fungi generally occur on the leaves of gymnosperms.

PLATE 1

(All photographs are magnified ca x 500, unless otherwise mentioned)

1. *Dictyophyllidites* sp., Slide no. BSIP 11114 M31
2. *Hammulatisporites* sp., Slide no. BSIP 11084 P25/4
3, 6. *Rouseisporites* sp., Slide nos. BSIP 11103 K14/4, 11097 V30/2
4. *Striatriletes susannae,* Slide no. BSIP 11082 K40/4
5. *Bicingulispora* sp., Slide no. BSIP 11076 X41/2
7. *Meliolinites spinksii,* Slide no. BSIP 11099 Q10
8. *Pluricellaesporites typicus,* Slide no. BSIP 11080 V14/4
9. *Dyadosporonites* sp., Slide no. BSIP 11113 V21/4
10. *Dyadosporonites schwabii* Elsik, Slide no. BSIP 11112 D30
11, 15. *Lirasporis elongatus* Kar, Slide nos. BSIP 11079 L25/2,11069 M45/3
12. Dinoflagellate cyst, Slide no. BSIP 11101 V43
13. *Frasnacritetrus* sp., Slide no. BSIP 11098 R17/4
14. *Dictyosporites* sp., Slide no. BSIP 11102 O40
16. *Paramicrothallites* sp., Slide no. BSIP 11077 J38/2
17. *Parmathyrites indicus* Jain & Gupta, Slide no. BSIP 11105 N35/3
18. *Trichopeltinites* sp. (250x), Slide no. BSIP 11109 D7
19. *Diporicellaesporites* sp., Slide no. BSIP 11090 P36

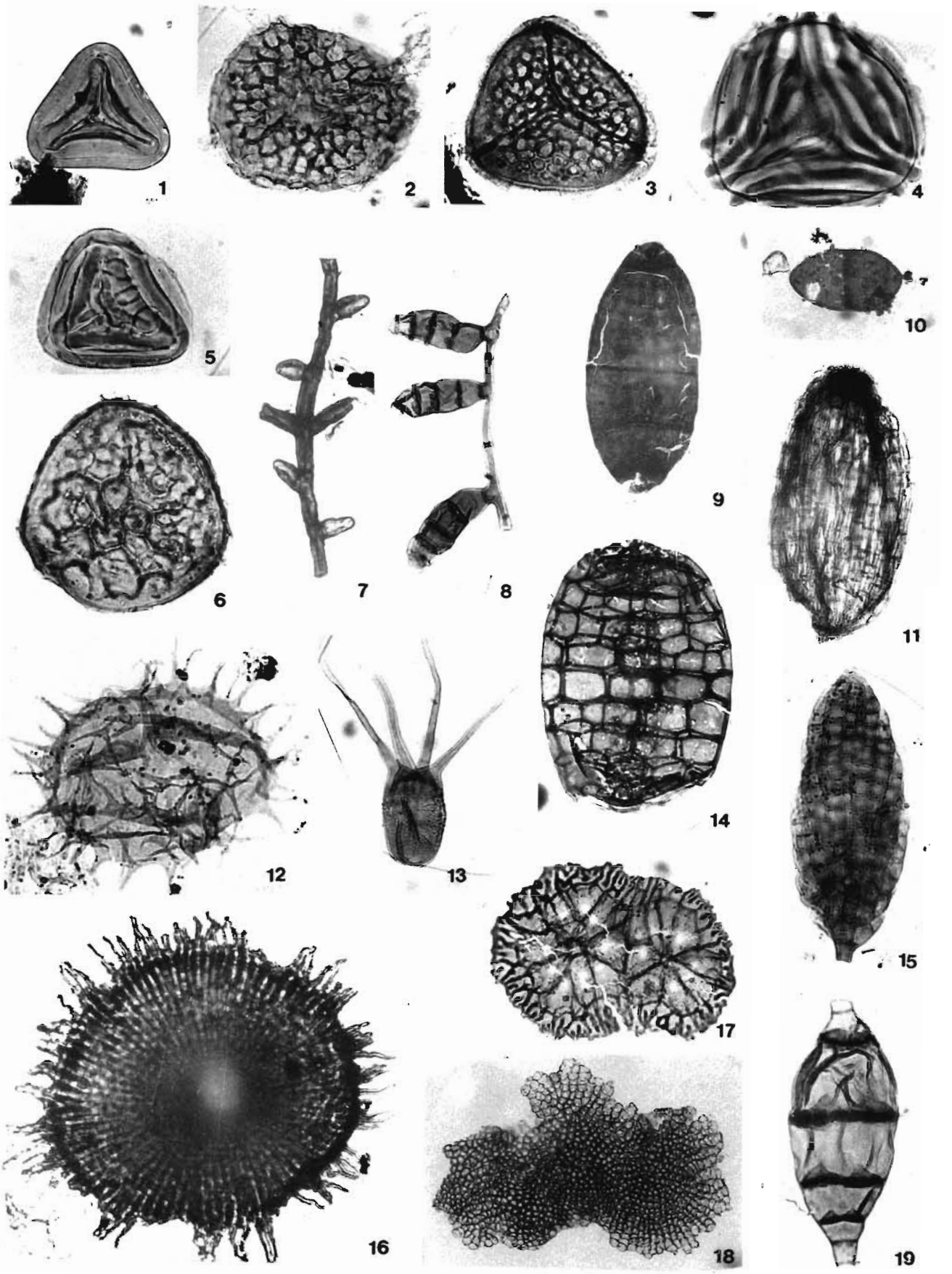
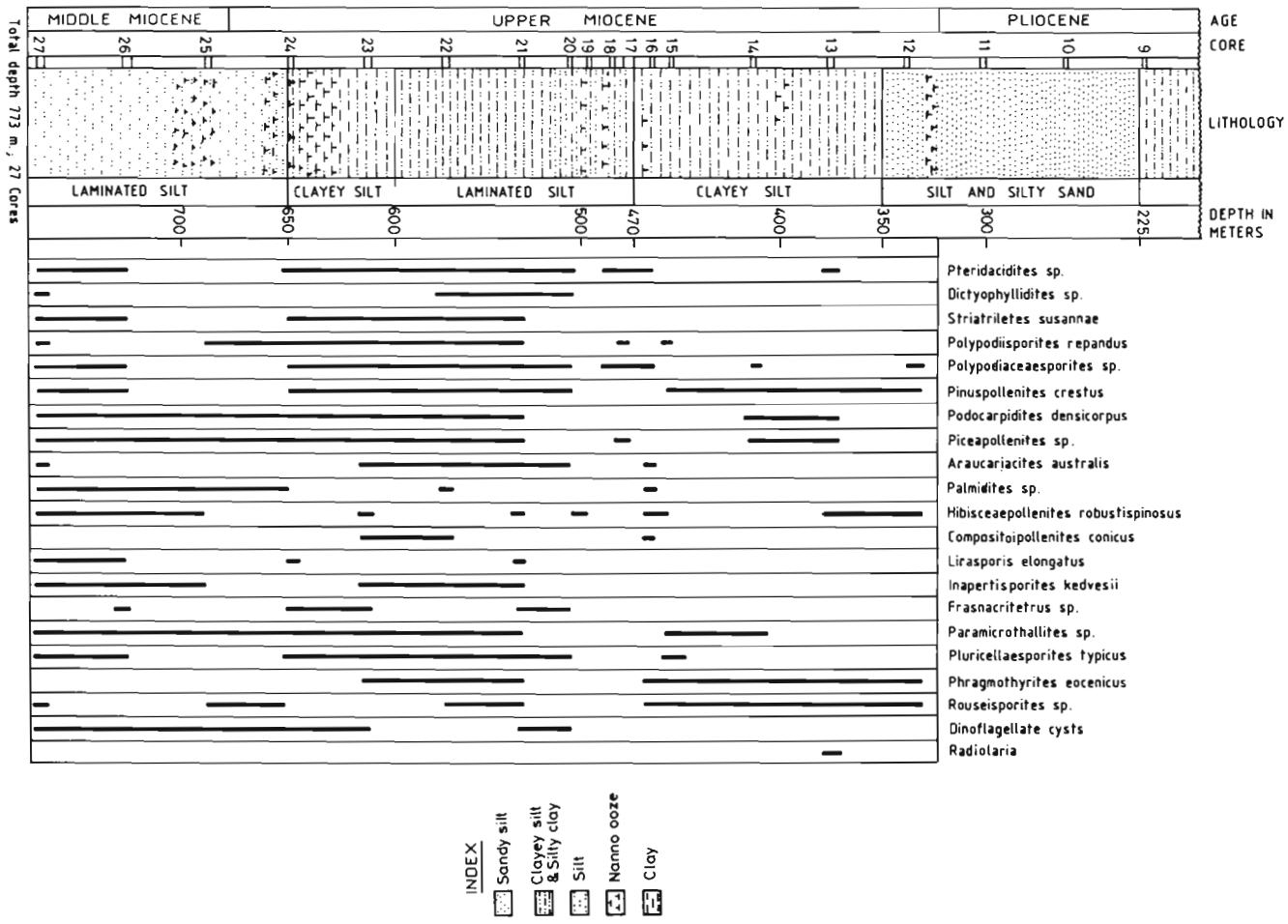


PLATE 1



Text-figure 7— Composite histogram showing representation of palynotaxa from core nos. 27-12 in DSDP Site-218, Bengal Fan, Indian Ocean.

Occurrence—Core length 621.0-611.5m, 583.0-573.5m, 488.0-459.5m, 421.5-412.0 and 383.5-374.0 m.

Genus—*Lirasporis* Potonié & Sah 1960

Type species—*Lirasporis intergranifer* Potonié & Sah 1960 emend. Jain & Kar 1979

Lirasporis elongatus Kar 1990
Pl. 1, figs 11, 15

PLATE 2

(All photographs are magnified ca x 500, unless otherwise mentioned)

1. *Pteridacidites* sp., Slide no. BSIP 11100 R35
2. Pollen tetrad Type A, Slide no. BSIP 11085 V41/4
3. *Hibisceaepollenites robustispinosus* Kar, Slide no. BSIP 11093 T17
4. *Perfotricolpites digitatus* Guzman, Slide no. BSIP 11095 G50
5. *Retistephanocolporites* sp., Slide no. BSIP 11095 M41/3
6. *Schizaeoisporites* sp., Slide no. BSIP 11094 L8/1
7. *Rouseisporites* sp., Slide no. BSIP 11092 G6
8. Pollen Type A, Slide no. BSIP 11104 S9/4
9. *Podocarpidites* sp., Slide no. BSIP 11111 V20/2
10, 11. *Compositoipollenites conicus* Sah, Slide no. BSIP 11076 H36
12. Radiolaria Type A, Slide no. BSIP 11109 J19/3
13. Radiolaria Type B, Slide no. BSIP 11109 S25
14, 17. *Retipilonapites arcotense* (1000x) Ramanujam, Slide nos. BSIP 11106 R14/2, 11108 V37/1
15. *Operculosculptites* sp. (1000x), Slide no. BSIP 11115 P44/3
16. *Piceaepollenites* sp., Slide no. BSIP 11095 L40/2
18. *Cyathidites australis* Couper, Slide no. BSIP 11107 Q21
19. *Aequitriradites* sp., Slide no. BSIP 11116 G24

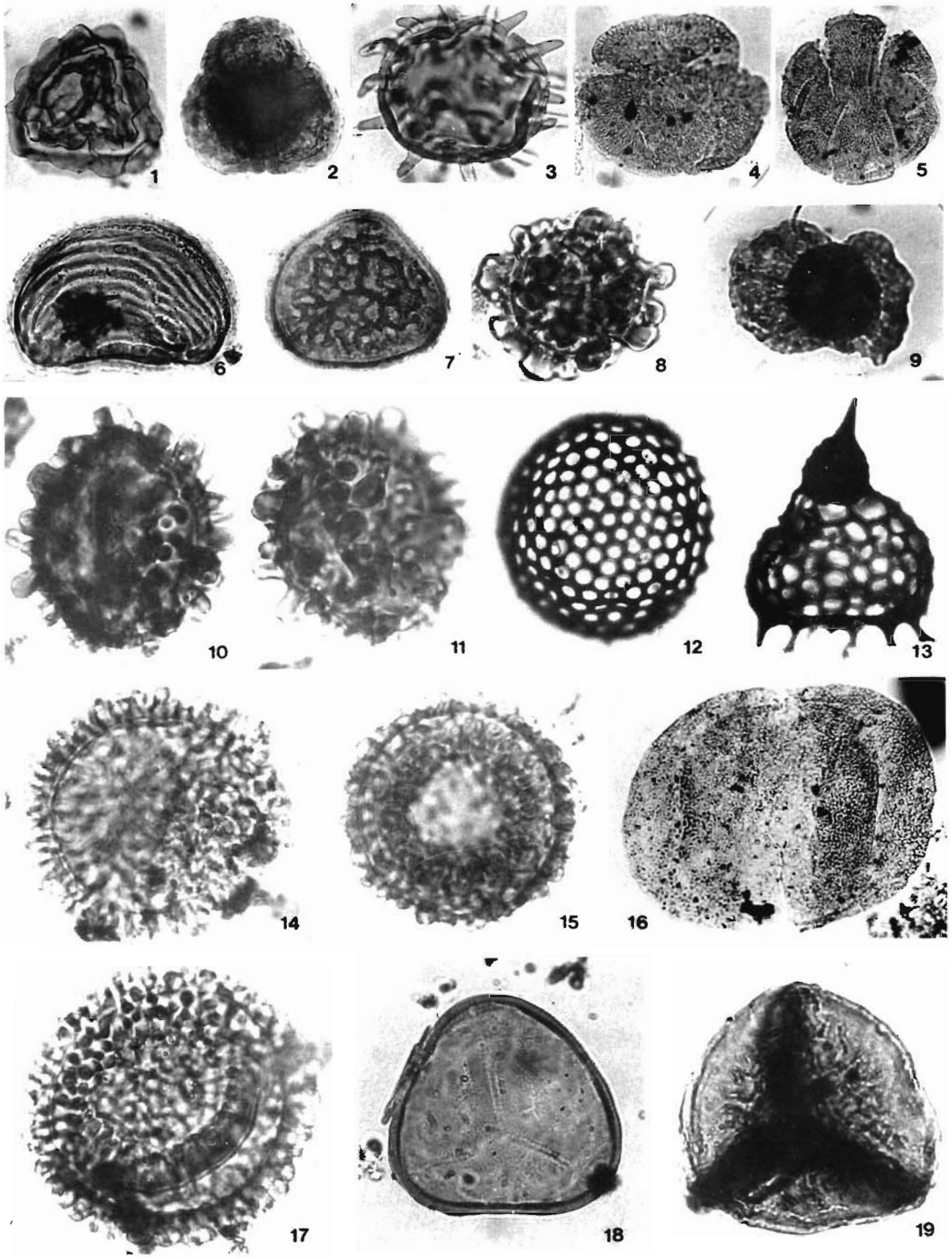


PLATE 2

Remarks—The oval spores segmented in longer axis are common in the core samples from the bottom sediments of the DSDP SITE 218. *Lirasporis elongatus* is also reported from the Miocene sediments of North-East India (Kar, 1990).

Occurrence—Core length 773.0-763.5 m and 7350.0-725.5 m.

Genus—*Meliolinites* Selkirk 1975

Type species—*Meliolinites spinksii* (Dilcher) Selkirk 1975.

Meliolinites spinksii Selkirk 1975
Pl. 1, fig. 7

Remarks—The epiphyllous colony of straight mycelium with hypopodium arranged in alternate fashion on hyphal cells is the characteristic feature of this taxon. The fossil forms resemble modern *Meliola*. The specimens of DSDP SITE 218 match with those recorded from Neyveli lignite (Miocene) of Tamil Nadu (Reddy *et al.*, 1982) and Lower Miocene sediments of Australia (Selkirk, 1975).

Occurrence—Core length 621.0-611.5 m.

Genus—*Frasnacritetrus* Taugourdeau emend. Saxena & Sarkar 1986

Type species—*Frasnacritetrus josettae* Taugourdeau 1968.

Frasnacritetrus sp.
Pl. 1, fig. 13; Pl. 3, fig. 10

Remarks—These quadriseriate fungal conidia (dark coloured) with stiff transversely septate setae show scanty appearance in the assemblage. These specimens resemble *Tetraploa* (Berkeley & Broome, 1850), a modern genus of dematiaceous Hypomycetes (fungi) occuring on dead culms and leaves of grasses.

Occurrence—Core length 773.0-763.5 m, 621.0-611.5 m, 545.0-535.5 m and 507.0-497.5 m.

Genus—*Trichopeltinites* Cookson 1947

Type species—*Trichopeltinites pulcher* Cookson 1947.

Trichopeltinites kiandrensis Selkirk 1975
Pl. 1, fig. 18

Remarks—The epiphyllous mycelium forming radiating prosenchymatous one layered membranous cells without free hyphal outgrowth is the characteristic feature of this species. The thallus is a union of mycelium hyphae. The mycelium shows much similarity with the family Trichopeltaceae which commonly occurs on the leaf cuticle of higher plants.

Occurrence—Core length 583.0-573.5 m.

Genus—*Trichothyrites* Rosendahl 1943

Type species—*Trichothyrites pleistocenica* Rosendahl 1943.

Trichothyrites sp.
Pl. 3, fig. 6

Remarks—This fruiting body with ostiole shows small and thin-walled cells near periphery and around central opening. The central cells are thick-walled, dark brown in colour, while marginal cells are asymmetrical in size and shape.

Occurrence—Core length 773.0-763.5 m.

Genus—*Parmathyrites* Jain & Gupta 1970

PLATE 3

(All photographs are magnified ca x 500, unless otherwise mentioned)

1. *Inapertisporites kedvesii* Elsik, Slide no. BSIP 11086 X24/4
2. *Polypodiisporites repandus* Takahashi, Slide no. BSIP 11081 T43/2
3. *Araucariacites australis* Cookson ex Couper, Slide no. BSIP 11074 O30/2
4. *Polyadopollenites miocenicus* Ramanujam, Slide no. BSIP 11076 T18
5. *Phragmothyrites eocenicus* Edwards, Slide no. BSIP 11078 E31/1
6. *Trichothyrites* sp., Slide no. BSIP 11078 N24/4
7. *Paramicrothallites* sp., Slide no. BSIP 11075 P25/1
8, 9. *Pinuspollenites crestus* Kar, Slide nos. BSIP 11083 M30/4, 11087 L36
10. *Frasnacritetrus* sp., Slide no. BSIP 11077 E49/1
11, 14. *Podocarpites densicarpus* Kar, Slide nos. BSIP 11091 P39, 11087, J49/4, 11089 J30, 11088 P41/1
15. *Pluricellaesporites* sp., Slide no. BSIP 11078 Y25/1

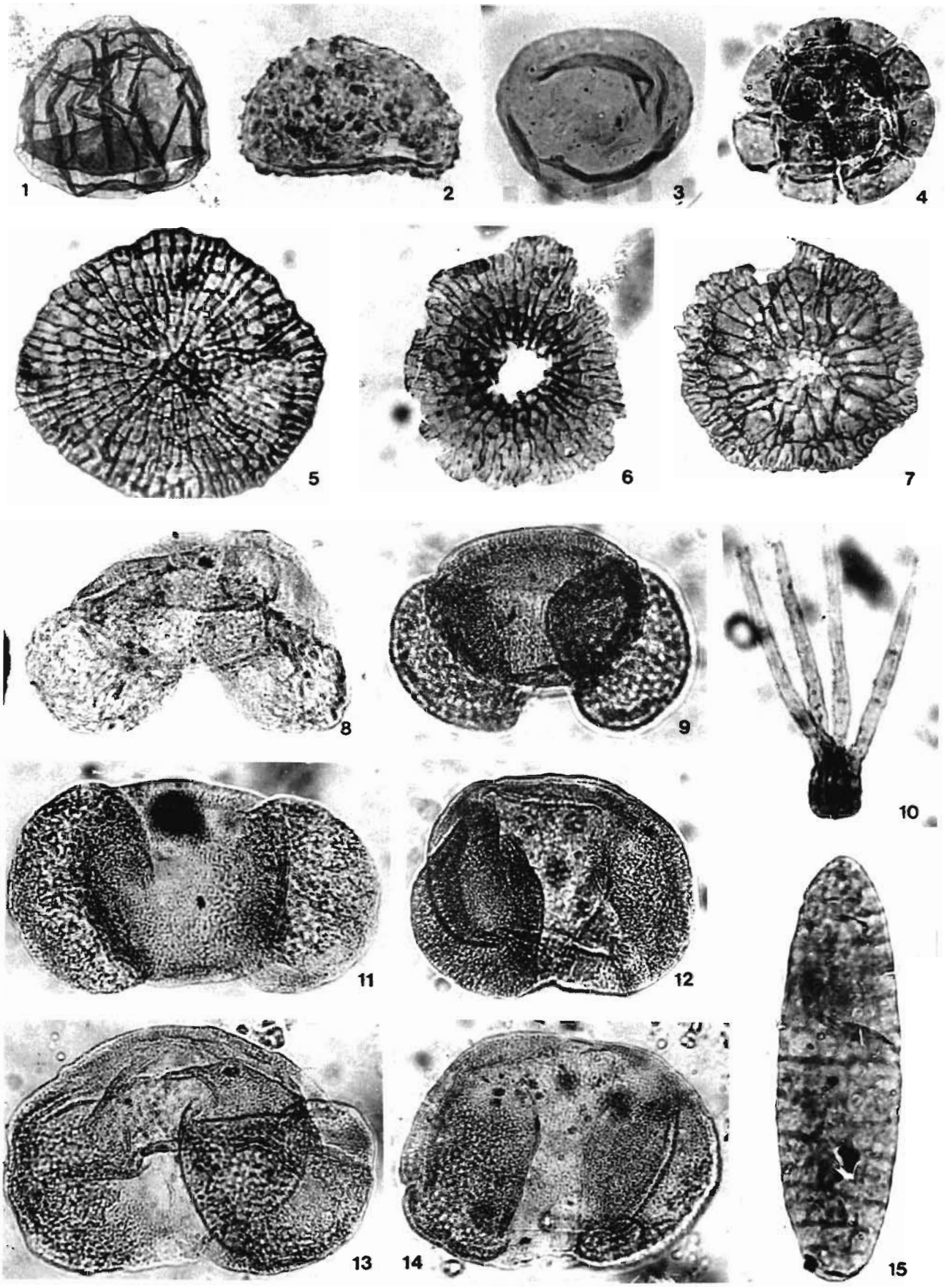


PLATE 3

Type species—*Parmathyrites indicus* Jain & Gupta 1970.

Parmathyrites indicus Jain & Gupta 1970
Pl. 1, fig. 17

Remarks—Dark brown flattened ascomata show distinct cells with robustly built spines on marginal cells. These specimens show much resemblance with those recorded from Warkali sediments of Kerala (Jain & Kar, 1979; Jain & Gupta, 1970).

Occurrence—Core length 469.0-459.5 m.

Genus—*Pluricellaesporites* van der Hammen emend. Elsik 1968

Type species—*Pluricellaesporites* typicus van der Hammen 1954.

Pluricellaesporites typicus van der Hammen 1954
Pl. 1, fig. 8

Remarks—Spores show thin-walled psilate sculpture with 3-4 transverse septa. These are abundantly found in the DSDP Site 218 assemblage.

Occurrence—Core length 735.0-725.5 m, 659.0-649.5 m, 621.0-611.5 m, 583.0-573.5 m, 507.0-497.5 m.

Genus—*Dyadosporonites* Elsik 1968

Type species—*Dyadosporonites schwabii* Elsik 1968.

Dyadosporonites schwabii Elsik 1968
Pl. 1, fig. 1

Remarks—Uniseptate psilate spores are rare in the assemblage.

Occurrence—Core length 345.5-336.0 m.

Dyadosporonites sp.
Pl. 1, fig. 9

Remarks—Psilate uniseptate fruiting body shows numerous pseudo-septae in both the cells. The spores are comparatively larger than *D. schwabii* (Elsik, 1968).

Occurrence—Core length 269.5-260.0 m.

Genus—*Diporicellaesporites* Elsik 1968

Type species—*Diporicellaesporites stacyi* Elsik 1968.

Diporicellaesporites sp.
Pl. 1, fig. 9

Remarks—Psilate diporate, tetracellate fungal spores with simple pores and unique septal flaps are the characteristic features of this taxon. They are poorly represented in the assemblage.

Occurrence—Core length 697.0-687.5 m.

Genus—*Inapertisporites* van der Hammen emend. Elsik 1968

Type species—*Inapertisporites variabilis* van der Hammen 1954.

Inapertisporites kedvesii Elsik 1968
Pl. 3, fig. 1

Remarks—Dark brown inaperturate fruiting bodies with folded smooth wall are common in the assemblage.

Occurrence—Core length 773.0-763.5 m, 735.0-725.5 m, 697.0-687.5 m, 621.0-611.0 m, 583.0-573.5 m, 545.0-535.5 m.

Bryophytic spores

Genus—*Rouseisporites* Pocock 1962

Type species—*Rouseisporites reticulatus* Pocock 1962.

Rouseisporites sp.
Pl. 1, figs 3, 6; Pl. 2, fig. 7

Remarks—These spores show various types of sculpturing on their proximal surface. The trilete mark sometimes extends up to membranous equatorial zona. Dettmann (1963) proposed resemblance of this genus with those of Ricciaceae and reported several species of *Rouseisporites* from the Mesozoic sediments of South-eastern Australia. The illustrated spores show affinity with *Riccia cavernosa* (Hoffm.) Gupta & Udar 1986. The extant representative of *Rouseisporites* are found in the open habitat.

Occurrence—Core length 773.0-763.5 m, (core no. 27), 697.5-649.5 m (core no. 25-24), 583-535.5 m (core no. 22-21) and 469-336 m (core no. 16-12).

Table—Ecological and geographical distribution of some extant taxa and their affinity with fossil palynotaxa

TAXA	AFFINITY	HABITAT	CLIMATE	GEOGRAPHIC DISTRIBUTION
Pteridophytes				
Cyathidites	Cyatheaceae	Stream side in wet montane forest	Tropical to Temperate	Widely distributed in oceanic islands, forests of tropical mountains
Dictyophyllidites	Gleicheniaceae	Terrestrial,widely creeping in forest open habitat	Tropical to subtropical	Pantropics and sometimes in extratropics
Polypodiisporites repandus	Polypodiaceae	Rain forests	Tropical to boreal	Cosmopolitan
Pteridacidites	Pteridaceae	Forests along rocky stream banks	Tropical	Pantropic but also occur in South Africa, Korea, Japan, New Zealand
Schizaeoisporites	Schizaeaceae	Terrestrial, diverse habitat	Tropical to warm temperate	Mostly Southern Hemisphere
Striatriletes susannae	Parkeriaceae	Terrestrial, usually aquatic, wet habitat	Tropical and subtropical	Tropical America, Africa, Southern and SE Asia, Fiji, etc.
Gymnosperms				
Araucariacites	Araucariaceae	Evergreen Forest	Tropical	South America, Australia, New Guinea, New Caledonia
Piceaepollenites sp.	Pinaceae	Evergreen Forest	Temperate	Widely distributed in the temperate region of Northern Hemisphere, Himalaya and North America, Europe, Siberia, North Asia, etc.
Pinuspollenites crestus	Pinaceae	Evergreen Forest	Subtropical to warm temperate	Europe, North America, Central America, Myanmar, SE Asia, etc.
Podocarpidites densicarpus	Podocarpaceae	Montane Evergreen	Tropical to warm temperate	Europe, North America, Central and Southern Hemisphere
Angiosperms				
Compositoipollenites conicus	Compositae	Widely distributed in lowlands	Tropical to subtropical	Pantropical, America, Madagascar, Asia, Australia, etc.
Hibisceaepollenites robustispinosus	Compositae	Widely distributed in lowlands	Tropical to subtropical	Pantropical, America, Madagascar, Asia, Australia, etc.
Polyadopollenites miocenicus	Mimosoideae	Terrestrial dry land forests	Tropical	Cosmopolitan
Retipilonapites arcotense	Potamogetonaceae	Aquatic (fresh water) or subaquatic	Cosmopolitan	Mostly in Mediterranean and Indo-Pacific region

Genus—*Aequitriradites* Delcourt & Sprumont emend. Cookson & Dettman 1961

Type species—*Aequitriradites dubius* Delcourt & Sprumont emend. Delcourt, Dettmann & Hughes 1963.

Aequitriradites sp.
Pl. 2, fig. 19

Remarks—These Mesozoic recycled forms are triradiate, zonate spores with prominent triradiate scar. The spores have rare occurrence and show affinity with the modern hepatic spores of Sphaerocarpaceae.

Occurrence—*Aequitriradites* sp. occurs only in the samples of core no. 27 (depth 773.0-763.5 m).

Genus—*Operculosculptites* Kar 1990

Type species—*Operculosculptites globatus* Kar 1990.

Operculosculptites sp.
Pl. 2, fig. 15

Remarks—Circular spores with an operculum and dense sculptural elements are rare in the sediments. They resemble the spores of extant mosses. Kar (1990) reported *O. globatus, O. rokhiensis* and *O. baculatus* from the Miocene sediments of north-east India.

Occurrence—Core length 193.5-184.0 m.

Pteridophytic spores

Genus—*Striatriletes* van der Hammen 1956

Type species—*Striatriletes susannae* van der Hammen 1956.

Striatriletes susannae van der Hammen 1956

Pl. 1, fig. 4

Remarks—The trilete spores show equatorial costae which sometimes coalesce at apices. The spores of S. *susannae* and *S. pauscostatus* are present ,in most of the samples. These interesting Neogene spores closely resemble the spores of extant genus *Ceratopteris* of Parkeriaceae, which grows in terrestrial shallow water conditions.

Occurrence—Core length 773.0-763.5m, 735-725.5m, 659.0-649.5m, 621.0- 611.5m, 583.0-573.5m, 545.0-535 m.

Genus—*Dictyophyllidites* Couper 1958

Type species—*Dictyophyllidites harrisii* Couper 1958.

Dictyophyllidites sp.
Pl. 1, fig. 1

Remarks—The laevigate spores with prominent laesurae are common in the Tertiary sediments. These specimens resemble the spores of the family Gleicheniaceae. The members of the family grow in variable habitats of tropical to subtropical region.

Occurrence—Core length 773.0-763.5 m, 583.0-573.5 m, 545.0-535.5 m.

Genus—*Bicingulispora* Frederiksen *et al.* 1983

Type species—*Bicingulispora concentrica* Frederiksen *et al.*, 1983.

Bicingulispora sp.
Pl. 1, fig. 5

Remarks—Spores of *Bicingulispora* show trilete mark with two subequatorial bicingulate structures. Our specimens resemble spores of *Pityrogramma* (Tryon & Tryon, 1982) and *Onychium* (Nayer & Devi, 1967) of family Pteridaceae.

Occurrence—Core length 773.0-763.5 m.

Genus—*Pteridacidites* Sah 1967

Type species—*Pteridacidites africanus* Sah 1967.

Pteridacidites sp.
Pl. 2, fig. 1

Remarks—The spores show single cingulum with verrucose sculptures. Most of the specimens resemble the extant spores of *Pteris* (Pteridaceae) which is widely distributed in subtropical to tropical wet forests.

Occurrence—Core length 773.0-763.5 m, 735.0-725 m, 659.0-649.5 m, 621.0-611.5 m, 583.0-573.5 m, 545.0-535.5 m, 507.0-497.5 m, 488.0-469.0 m.

Genus—*Schizaeoisporites* (Potonié 1951) Potonié 1960

Type species—*Schizaeoisporites eocenicus* Potonié 1956.

Schizaeotsporites sp.
Pl. 2, fig. 6

Remarks—The monolete spores have prominent costae on proximal side and show affinity with those of modern Schizaeaceae. Plants of this family are widely distributed in tropical moist forest of southern hemisphere.

Occurrence—Core length 345.5-336.0 m.

Genus—*Hammulatisporites* Krutzsch 1959

Type species—*Hammulatisporites hamulatus* Krutzsch 1959.

Hammulatisporites sp.
Pl. 1, fig. 2

Remarks—The spores show humulate sculpture with weakly developed flanges on the margin. The laesura is distinct. These specimens resemble extant spores of *Lycopodium*.

Occurrence—Core length 735.0-725.5 m.

Genus—*Polypoditisporites* (Potonié 1931) ex Potonié 1956

Type species—*Polypoditisporites favus* (Potonié 1931) ex Potonié 1956.

Polypoditisporites repandus Takahashi 1964
Pl. 3, fig. 2

Remarks—Monolete spores with verrucate sculptures are abundant in the assemblage. Kar (1990) also recorded this species from Mio-Pliocene sediments of north-east India.

Occurrence—Core length 773.0-763.5 m, 697.0-687.5 m, 621.0-611.5 m, 583.0-573.5 m, 545.0-535.5 m and 488.0-459.5 m.

Genus—*Cyathidites* Couper 1953

Type species—*Cyathidites australis* Couper 1953.

Cyathidites australis Couper 1953
Pl. 2, fig. 18

Remarks—These laevigate trilete spores are rare in the assemblage, which closely resemble the spores of extant Cyatheaceae. This tree fern grows in wet montane forests in subtropical to tropical climate.

Occurrence—Core length 421.5-412 m.

Gymnosperm pollen

Genus—*Araucariacites* Cookson ex Couper 1953

Type species—*Araucariacites australis* Cookson 1947 ex Couper 1953.

Araucariacites australis Couper 1953
Pl. 3, fig. 3

Remarks—Folded thin-walled inaperturate pollen show affinity with modern pollen grains of Araucariaceae, probably with *Araucaria*. The fossil pollen show long and extensive stratigraphic records in the Tertiary sediments.

Occurrence—Core length 773.0-763.5 m, 583.0-573.5 m, 545.0-535.5 m, 507.0- 497.5 m and 478.5-469.0 m.

Genus—*Podocarpidites* Cookson ex Couper 1953

Type species—*Podocarpidites ellipticus* Cookson ex Couper 1953.

Podocarpidites densicarpus Kar 1985
Pl. 3, figs 11-14

Remarks—The bisaccate pollen grains show more or less circular body and intrareticulate bladders with distinct and wide furrow. The specimens are very similar to the extant pollen of *Podocarpus* (Podocarpaceae) which is restricted to the higher elevation, generally in montane forest of high rainfall. Kar (1990) recorded this species from the Mio-Pliocene sediments of northeast India.

Occurrence—Core length 773.0-763.5 m, 735.0-725.5 m, 697.0-687.5 m, 659.0- 649.5 m, 621.0-611.5 m, 583.0-573.5 m, 545.0-535.5 m, 421.5-412.0 m,383.5-374.0 m.

Genus—*Pinuspollenites* Raatz 1938 ex Potonié 1958

Type species—*Pinuspollenites labdacus* Raatz ex Potonie' 1958.

Pinuspollenites crestus Kar 1985
Pl. 3, figs 8, 9

Remarks—These bisaccate pollen grains have circular to oval body with moderately reticulate exine. The bladders are more or less circular to semicircular

in shape. *Pinuspollenites crestus* is common in DSDP Site 218 palynoassemblage. Our specimens show affinity with pollen of extant *Pinus* (Pinaceae).

Occurrence—Core length 773.0-763.5 m, 735.0-725.5 m, 659.0-649.5 m, 621.0-611.5 m, 583.0-573.5 m, 545.0-535.5 m, 307.0-497.5 m, 478.5-469.0 m, 421.5-412.5 m, 383.5-374.0 m, 345.5-336.0 m.

Genus—*Piceaepollenites* Potonié 1931

Type species—*Piceaepollenites alatus* Potonié 1931.

Piceaepollenites sp.
Pl. 2, fig. 16

Remarks—The bisaccate pollen grains with laterally elongated body show punctate exine with infrareticulate bladders. These specimens are similar to the pollen of modern *Picea* (Pinaceae). *Picea* is usually found in cooler regions of the northern hemisphere.

Occurrence—Core length 773.0-763.5 m, 735.0-725.5 m, 697.0-687.5 m, 659.0- 649.5 m, 621.5-611.0 m, 583.0-573.5 m, 545.0-535.5 m and 421.5-412.0 m.

Angiosperm pollen

Genus—*Hibisceaepollenites* Kar 1985

Type species—*Hibisceaepollenites splendus* Kar 1985.

Hibisceaepollenites robustispinosus Kar 1990
Pl. 2, fig. 3

Remarks—Subcircular, panporate pollen grains with robustly built spines are common in the assemblage of DSDP Site 218. These pollen grains resemble extant pollen grains of the family Malvaceae.

Occurrence—Core length 773.0-763.5 m, 735.0-725.5 m, 659.0-649.5 m, 621.0- 611.5 m, 583.0-573.5 m, 545.0-535.5 m, 507 478.5-459.5 m, 383.5-374.0 m, 345.5- 336.0 m.

Genus—*Compositoipollenites* Potonié ex Potonié 1960

Type species—*Compositoipollenites rizophorus* (Potonié) Potonié 1960.

Compositoipollenites conicus Sah 1967
Pl. 2, figs 10, 11

Remarks—The panporate pollen grains are ornamented with spines which are bulbous at the base. These specimens having affinity with Compositae pollen have been observed only in the bottom sediments.

Occurrence—Core length 773.0-763.5 m.

Genus—*Retipilonapites* Ramanujam 1966

Type species—*Retipilonapites arcotense* Ramanujam 1966.

Retipilonapites arcotense Ramanujam 1966
Pl. 2, figs 14, 17

Remarks—The retipilate and non-aperturate spheroidal pollen grains are rare in the assemblage. These specimens show similarity with the pollen grains of extant *Potamogeton*.

Occurrence—Core length 469.5-450.0m, 421.5-412.0 m.

Genus—*Polyadopollenites* Pflug & Thomson in Thomson & Pflug 1953

Type species—*Polyadopollenites multipartitus* Thomson & Pflug 1953.

Polyadopollenites miocenicus Ramanujam 1966
Pl. 3, fig. 4

Remarks—The occurrence of the species is rare in the assemblage. These grains are commonly found in Miocene sediments of Neyveli lignite of south India. The polyads are similar to the pollen grains of extant species of *Albizia lucida* (Mimosoideae) .

Occurrence—Core length 773.0-763.5 m.

Genus—*Perfotricolpites* Guzman 1967

Type species—*Perfotricolpites digitatus* Guzman 1967.

Perfotricolpites digitatus Guzman 1967
Pl. 2, fig. 4

Remarks—This subspheroidal tricolpate pollen shows perforate tectum with scabrate sculpture and is rare in DSDP Site 218 palynoassemblage.

Occurrence—Core length 773.0-763.0 m.

Genus—*Retistephanocolporites* van der Hammen & Wijmstra 1964

Typespecies—*Retistephanocolporites quadriporus* van der Hammen & Wijmstra 1964.

Retistephanocolporites sp.
Pl. 2, fig. 5

Remarks—The stephanocolporate pollen with reticulate sculpture has been reported from the Lower Tertiary sediments of India (Kar & Kumar, 1986). However, it is rare in DSDP Site 218 assemblage.

Occurrence—Core length 583.0-573.5 m.

Pollen tetrad Type A
Pl. 2, fig. 2

Remarks—The tetrahedral pollen tetrad is rare in the assemblage. The present specimen resembles the pollen tetrad of Ericaceae.

Occurrence—Core length 735.0-725.5 m.

Pollen Type A
Pl. 2, fig. 8

Remarks—The circular pollen grain ornamented with robustly built gemmae and pila on the exine shows distinct morphological feature. It is rare in the assemblage.

Occurrence—Core length 469.0-459.5 m.

COMPOSITION OF THE ASSEMBLAGE

The palynoassemblage of DSDP Site 218 from Bengal Fan consists of 35 genera and 38 species, in which 7 genera and 8 species belong to pteridophytic spores, 4 genera and 4 species of gymnosperms and 8 genera and 8 species belong to angiospermic pollen. Fungal fruiting bodies are represented by 11 genera and 13 species. Distribution of these taxa in different core samples is shown in Text-figures 1-6. Except for a minor difference in the quantity of pteridophytic spores and angiosperm pollen, the other taxa show uniform distribution in this section. The overall assemblage is dominated by fungal fruiting bodies followed by gymnosperm pollen specially in the bottom cores (no. 27-21: 773 -583 m core length) where *Lirasporis elongatus, Inapertisporites kedvesii, Paramicrothallites* sp., *Pluricellaesporites* sp., *Pinuspollenites crestus, Podocarpidites densicorpus,* and *Piceaepollenites* sp. are quite common. In upper cores (nos. 20-12, core length 497.5-345.5 m) the frequency of these woody gymnosperm pollen decreases.

The pteridophytic spores show good representation in core nos. 27, 23 and 22, where *Striatriletes susannae, Polypoditisporites repandus* and *Polypodiaceaesporites* sp. are dominant taxa, while *Cyathidites* spp., *Dictyophyllidites* sp., *Schizeotsporites* sp. and *Lycopodiumsporites* sp. show comparatively less representation. The spores of *Bicingulispora* sp. was observed only in core no. 27. Some characteristic Cretaceous forms like *Rouseisporites* sp. are represented in several cores like 27, 25, 22, 21 and 14-12, while *Aequitriradites* sp. is observed in core no. 27 only. Perhaps these two spores were recycled from nearby Cretaceous sediments. The *Operculosculptites* sp., probably a bryophytic spore commonly known from subsurface Miocene sediments of north-east India (Kar, 1990), is observed in core no. 8.

The angiosperm pollen, viz., *Palmidites* sp., *Liliacidites* sp., *Hibisceaepollenites robustispinosus, Compositoipollenites conicus* are commonly found in core nos. 27, 26, 23 and 21. They are poorly represented in core nos. 20-12. *Tricolpites reticulatus, Retistephanocolporites* sp., *Perfotricolpites digitatus,* etc. are poorly represented in the assemblage. The dinoflagellate cysts occur in almost all cores except 22 and 19-12. Radiolarians are abundant in core no. 13 (core length 374- 345.5 m) only.

COMPARISON WITH MIOCENE PALYNOASSEMBLAGES OF INDIA

North-east India

The present palynoassemblage is closely comparable with the palynoassemblage recovered from

Surma-Tipam Sandstones (Kar, 1990-91). The taxa, viz., *Polypoditsporites repandus, Polypodiaceaesporites* sp., *Striatriletes susannae, Operculosculptites* sp., *Compositotpollenites* sp., *Hibisceaepollenites robustispinosus, Podocarpidites densicorpus, Pinuspollenites crestus, Phragmothyrites eocenicus, Ltrasporis elongatus,* etc. have been found common in DSDP Site 218 palynoassemblage and north-east Indian assemblages.

South India

There are some similarities in the palynoassemblages from DSDP Site 218 and Cuddalore Formation (Miocene) of Neyveli Lignite (Tamil Nadu) and Warkali sediments of Kerala (Ramanujam, 1966; Ramanujam, 1982; Reddy *et al.*, 1982). Several taxa like *Polypoditsporites repandus, Pteridacidites* sp., *Schizaeotsporites* sp., *Polypodiaceaesporites* sp., *Tricolpites reticulatus* also occur in the present palynoassemblage. Some fungal remains, e.g., *Meltolinites, Parmathyrites, Trichopeltinites,* etc. reported by Jain and Gupta (1970) and Reddy *et al.* (1982) from the Neogene of south India also occur in DSDP Site 218 palynoassemblage. Jacob and Jacob (1953) mentioned that fruiting bodies of family Tricopeltaceae occur on the cuticle of leaves of higher plants, which have also been observed in the sample of core no. 22 (depth 583-573.5 m) in DSDP Site 218.

PALAEOECOLOGY

The palynoassemblage of DSDP Site 218 shows a considerable uniformity from samples of core no. 27-13. Most of the taxa which are attributed to extant plants show subtropical distribution and presence of moist evergreen rain forests. The dominance and diversity of fungal fruiting bodies indicate warm and humid climate during the emergence of this site. Presently these microthyriaceous fruiting bodies occur in tropical to subtropical climate.

Rouseisporites, Aequitriradites and *Operculosculptites* occur in core from 773.0 to 345.5 m depth. The pteridophytic spores, viz., *Cyathidites* spp. (Cyatheaceae), *Dictyophyllidites* sp. (Gleicheniaceae), *Pteridacidites* sp. (Pteridaceae), *Bicingulispora* sp., *Lycopodiumsporites* sp., *Schizaeotsporites* sp. (Schizaeaceae) and *Striatriletes* spp. (Parkeriaceae) are common in different cores. The cyatheaceous and parkeriaceous plants show the presence of terrestrial land water transport during sedimentation and are streamside colonisers. The *Pteris* (Pteridaceae) and *Gleichenia* grow mostly in variable habitat in tropical to subtropical regions. These plants are found in terrestrial habitat in stream side forests. In core nos. 27-20, the gymnosperm pollen are represented by *Podocarpidites* (Podocarpaceae) and *Araucariacites* (Araucariaceae). At present woody conifers abundantly occur in montane rainforest of north-east India, Andaman and Nicobar Islands and temperate regions. These plants generally flourish in humid climate with very rich annual precipitation. The occurrence of angiosperm pollen in DSDP Site 218, viz., *Hibisceaepollenites, Compositotpollenites, Tricolpites reticulatus,* etc. represents the flora of low land vegetation. Some dinoflagellate cysts (in depth 773.0-449.0 m) and radiolarians are also recorded at the depth from 383.5-374.0 m, which indicate marine influence in addition to the deposition of local vegetation.

CONCLUSION

The palyno fossil from DSDP Site 218 represent terrestrial deposits during the time of emergence except a few impact of marine infiltrations especially in bottom sediments. The occurrence of low land angiospermous and pteridophytic palynofossils indicates a flat depositional site with scattered hill slopes while montane elements of Podocarpaceae and Araucariaceae of wide range habitat flourished due to seasonal precipitation. The present assemblage is comparable with the Miocene palynoassemblages from north east and south India.

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