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Palynological investigation of the Sindhudurg Formation (Miocene) exposed at Kalviwadi, Sindhudurg District, Maharashtra, India

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ABSTRACT

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A diversified palynofloral assemblage has been recovered from the Sindhudurg Formation exposed at Kalviwadi, Sindhudurg District, Maharashtra. The palynoflora consists of fungal remains (18 genera and 26 species), pteridophyte spores (5 genera and 5 species) and angiosperm pollen (12 genera and 13 species). Two new species of fossil angiosperm pollen are proposed: *Lakiapollis ratnagiriensis* and *Tricolporopollis sindhudurgensis*. A quantitative analysis of the spores and pollen recovered shows a dominance of fungal remains is a conspicuous feature of the assemblage. The palynomorphs in the assemblage has been compared with pollen and spores of modern taxa. The distribution of the families represented by the fossil assemblage suggests a tropical-subtropical (warm and humid) climate with high rainfall. The depositional environment is interpreted as near shore, coastal with brackish swampy lagoon.

Key-words—Palaeopalynology, Palaeoecology, Sindhudurg Formation, Miocene, Maharashtra (India).

भारत में महाराष्ट्र प्रान्त के सिन्धुदुर्ग जिले के कलवीवाड़ी में अनावरित सिन्धुदुर्ग शैलसमूह (मायोसीन) का परागाणविक अन्वेषण

मुलागलापल्ली रामचन्द्र राव

सारांश

महाराष्ट्र प्रान्त के सिन्धुदुर्ग जिले के कलवीवाड़ी में अनावरित सिन्धुदुर्ग शैलसमूह से विविध परागाणु वनस्पतिजात समुच्चय प्राप्त किए गए हैं। परागाणु वनस्पतिजात में कवकी अवशेष (18 वंश एवं 26 प्रजातियाँ), टेरिडोफाइट बीजाणु (5 वंश एवं 5 प्रजातियाँ) तथा आवृतबीजी पराग (12 वंश एवं 13 प्रजातियाँ) सम्मिलित हैं। अश्मित आवृतबीजी परागकणों की दो नयी प्रजातियाँ *लाकियापॉलिस रत्नागिरिएन्सीस* एवं *ट्राइकॉलपोरोपॉलिस सिन्धुदुर्गेन्सिस* प्रस्तावित हैं। प्राप्त बीजाणुओं एवं परागकणों का मात्रात्मक विश्लेषण कवकी अवशेषों की प्रचुरता दर्शाता है और समुच्चय का सुस्पष्ट लक्षण है। समुच्चय के परागाणु रूपों की विद्यमान वर्गक के परागकणों एवं बीजाणुओं के साथ तुलना की गई है। अश्मित समुच्चय द्वारा निरूपित कुलों का वितरण उच्च वर्षा के साथ उष्णकटिबंधीय-उपोष्ण (उष्ण एवं आर्द्र) जलवायु का संकेत करता है। निक्षेपणीय - वातावरण खारे अनूपीय लैगून तट के निकट निर्वचन करता है।

संकेत-शब्द—पुरापरागाणुविज्ञान, पुरापारिस्थितिकी, सिन्धुदुर्ग शैलसमूह मायोसीन, महाराष्ट्र (भारत)।

INTRODUCTION

THE Ratnagiri beds were first reported by Wilkinson (1871) from a number of well sections along the Ratnagiri Coast, Maharashtra. Subsequently, the Sindhudurg Formation was formally described a lithostratigraphic unit by Saxena (1995) for a distinct sequence of grey to bluish clays with carbonaceous and lignite seams, which are well developed in the Konkan Coast of the Ratnagiri and Sindhudurg districts of Maharashtra. Earlier this sequence was informally referred to as the Ratnagiri beds (Wilkinson, 1871; Saxena *et al.*, 1992).

Previously palynological studies on the Ratnagiri Lignite and associated sediments have been carried out by Phadtare and Kulkarni (1980, 1984a, b), Kulkarni and Phadtare (1983), Kulkarni *et al.* (1985), Saxena (2000), Saxena and Misra (1990) and Saxena *et al.* (1992).

Saxena *et al.* (1992) and Saxena (1995) made a detailed lithostratigraphic study of number of outcrops and well and mine sections of the Ratnagiri and Sindhudurg districts of Maharashtra. The sedimentary sequence studied which forms part of the Sindhudurg Formation, is exposed at Kalviwadi (Lat. 16° 24'30" N : Long. 73° 26'10" E) about 0.6 km east of Mondtor bus stop near Tembhavi Village, Devgarh Taluk, Sindhudurg District (Fig. 1). The Sindhudurg Formation rests unconformably over Precambrian rocks or Deccan Traps, it is overlain by Laterite. The sequence of the stratigraphic unit which is exposed in the area is shown in Fig. 2.

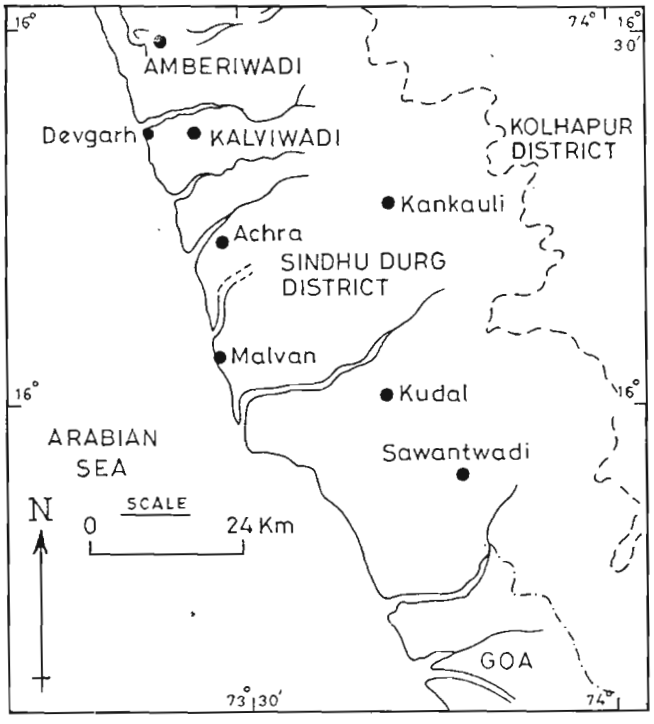

Fig. 1—Showing the location of Kalviwadi section in Sindhudurg District, Maharashtra.

MATERIAL AND METHODS

A total of 12 samples were collected from the clay and lignite sediments of the Kalviwadi section. The samples were treated with HCL, HF and HNO_3 followed by 5% solution of KOH. The slides were prepared in polyvinyl alcohol and mounted in Canada Balsam. An Olympus BH2 microscope has been used for the study and photomicrography. The material, slides and negatives have been deposited in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

PALYNOFLORAL ASSEMBLAGE

The palynoflora recovered from the Kalviwadi section are listed below. Taxa with an asterisk (*) mark are described in the text.

Fungal remains

Phragmothyrites eocaenica Edwards emend. Kar & Saxena, 1976
Phragmothyrites sp.
Microthyriacites ramanujamii Saxena & Misra, 1990
Microthyriacites sp.
Trichothyrites setiferus (Cookson, 1947) Saxena & Misra, 1990
Parmathyrites indicus Jain & Gupta, 1970
P. ramanujamii Singh *et al.*, 1986
Kutchiathyrites eccentricus Kar, 1979
Ratnagiriathyrites hexagonalis Saxena & Misra, 1990
**Siwalikiathyrites* sp. (Pl. 1.19)
Kalviwadithyrites saxenae Rao, 2003 (Pl. 2. 11-12)
Lirasporis intergranifer Potonié & Sah, 1960 emend. Jain & Kar, 1979
*Fungal Fruiting body Type (Pl. 2.9)
Inapertisporites kedvesii Sheffy & Dilcher, 1971
**Inapertisporites* sp. (Pl. 1.11)
**Dyadosporonites* sp. (Pl. 2.1)

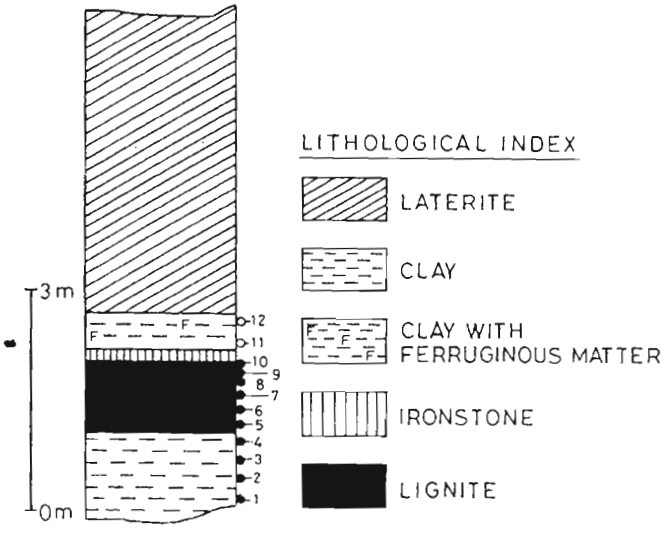

Fig. 2—Litholog of Kalviwadi section, Sindhudurg Formation.

**Diporicellaesporites* sp. (Pl. 3.10)
**Multicellaesporites* sp. A (Pl. 3.4)
**Multicellaesporites* sp. B (Pl. 2.5)
**Pluricellaesporites* sp. (Pl. 2. 3-4)
Meliola sp.
**Palaeocirrenalia* sp. (Pl. 1.13)
**Involutisporonites* sp. (Pl. 1. 14)
**Frasnacritetrus* sp. (Pl. 3.11)
*Fungal spore Type I (Pl. 3.13)
*Fungal spore Type II (Pl. 1. 17-18)
Fungal hyphae I
Fungal hyphae II

Pteridophyte spores

Lygodiumsporites lakiensis Sah & Kar, 1969
Dandotiaspora telonata Sah *et al.*, 1971
**Dictyophyllidites* sp. (Pl. 1.1)
Striatriletes susannae van der Hammen emend. Kar, 1979
Cheilanthoidspora monoleta Sah & Kar, 1974

Angiosperm pollen

Verrualetes sp.
**Verruinaperturites* sp. (Pl. 1.12)
Quilonipollenites ornatus Rao & Ramanujam, 1978
**Perfotricolpites neyvelii* (Navale & Misra, 1979) Mandal & Kumar, 2000 (Pl. 1 6-8)
Dipterocarpuspollenites retipilatus Kar, 1992
Lakiapollis ovatus Venkatachala & Kar, 1969
**Lakiapollis ratnagiriensis* sp. nov. (Pl. 1.2-4)
**Dermatobrevicolporites* sp. (Pl. 3.7)
**Tricolporopollis sindhudurgensis* sp. nov. (Pl . 3.1-3)
**Tricolporopilites* sp. (Pl. 1.5)
Polygonaceaepites frequens Sah & Dutta, 1966
Malvacearumpollis bakonyensis Nagy, 1962
**Triporotetradites* sp. (Pl. 1.20)
*Pollen Type 1 (Pl. 1.16)

Incertae sedis

Heliospermopsis anklesvarensis (Srivastava) Saxena & Misra, 1990
Heliospermopsis sp.

SYSTEMATICS

Fungal Remains

Genus—SIWALIKIATHYRITES Saxena & Singh, 1984

Type species—SIWALIKIATHYRITES RAMANUJAMII Saxena & Singh, 1984

SIWALIKIATHYRITES sp.

(Pl. 1.19)

Description—Fungal fruiting body sub-circular in shape. Size: 105 x 85 µm, no free hyphae, dimidiate, non-ostiolate. Body made up of different types of parenchymatous cells, non-porate.

Comparison—The present species is closely comparable with the type species *Siwalikiathyrites ramanujamii* Saxena & Singh 1984 with the shape and other general characters but the latter is differentiated in having central polygonal and outer elongated pseudoparenchymatous cells

FUNGAL FRUITING BODY—TYPE I

(Pl. 2.9)

Description—Fungal fruiting body sub circular in shape. Size: 135 x 105 µm, dimidiate, non-ostiolate, no free hyphae, divided into two cells. Marginal cells quadrangular to rectangular, distinct, central cells irregular, indistinct. Pores absent.

Genus—INAPERTISPORITES (van der Hammen, 1954) emend. Elsik, 1968

Type species — INAPERTISPORITES PSEUDORETICULATUS Rouse, 1959

INAPERTISPORITES sp.

(Pl. 1.11)

Description—Fungal spore more or less circular in shape. Size: 80 µm. A slit like structure present in the centre. Body wall 6 µm thick, smooth.

Genus—DYDOSPORONITES Elsik, 1968

Type species—DYDOSPORONITES SCHWABII Elsik, 1968

DYDOSPORONITES sp.

(Pl. 2.1)

Description—Fungal spore di-cellular. Size: 122 x 62 µm. Diporate, pore present on both the sides. Septa not complete. Body wall 1.5 µm thick, striations present on the body wall.

Comparison—The present species is closely comparable with the type species by its diporate and di-cellular condition but the former is distinguished in having bigger size and striations present on the body wall.

Genus—DIPORICELLAESPORITES Elsik, 1968

Type species—DIPORICELLAESPORITES STACYI Elsik, 1968

DIPORICELLAESPORITES sp.

(Pl. 3.10)

Description—Fungal spore dark brown in colour. Size: 135 x 75 µm. Multicellular, septa not complete, diporate, pore present on both ends. Wall thin.

Comparison—The present species is comparable with the type species by its diporate condition but latter can be distinguished by its smaller size and granular to punctate surface.

Genus—MULTICELLAESPORITES (Elsik, 1968) emend. Sheffy & Dilcher, 1971

Type species—MULTICELLAESPORITES NORTONII Elsik, 1968

MULTICELLAESPORITES sp. A

(Pl. 3.4)

Description—-Fungal spore 4 cellular, light brown in colour. Size: 62 x 19 µm. Multicellate, anterior and posterior cells narrow and pointed and middle cells are broad. Body wall 1.5 µm thick, faintly structured.

Comparison—The type species is distinguished from the present species by its smaller size (15 x 39 µm) and the outer wall showing finely scabrate to punctate structure.

MULTICELLAESPORITES sp. B

(Pl. 2.5)

Description—Fungal spore dark brown in colour. Size: 125 x 60 µm. Multicellate, septa complete, Tetracellular, unequal in size, cells of anterior and posterior triangular in shape. Body wall 2.5 µm thick, ornamented with sparsely placed verrucae.

Comparison—The present species is distinguished from the type species by its bigger size and verrucate ornamentation.

Genus—PLURICELLAESPORITES (van der Hammen, 1954) Elsik, 1968

Type species—PLURICELLAESPORITES TYPICUS van der Hammen, 1954

PLURICELLAESPORITES sp.

(Pl. 2.3-4)

Description—Fungal spores dark brown in colour. Size range: 128-135 x 47-50 µm. Multicellular, 6 celled, septa complete, posterior and anterior cells small. Monoporate, pore present at the anterior. Wall 4 µm thick, smooth.

Genus—PALAEOCIRRENALIA Ramanujam & Srisailam, 1980

Type species—PALAEOCIRRENALIA ELEGANS Ramanujam & Srisailam, 1980

PALAEOCIRRENALIA sp.

(Pl. 1.13)

Description—Fungal spore coiled in shape and dark brown in colour. Size: 80 x 72 µm, non-aperturate, helicoid, 6 septate, septa distinct, central cells larger than the others, depression present. Body wall thin and smooth.

Comparison—The type species is distinct from *Palaeocirrenalia* sp. by its smaller size and different shapes of cells in the posterior and anterior sides.

Genus—INVOLUTISPORONITES (Clarke, 1965) Elsik, 1968

Type species—INVOLUTISPORONITES FORAMINUS Clarke, 1965

INVOLUTISPORONITES sp.

(Pl. 1.14)

Description—Fungal spore coiled and dark brown in colour. Size: 73 x 63 µm. Multicellate, 14 cells, thick septa present. Central cells darkened. Body wall 1.5 µm thick, smooth.

Genus—FRASNACRITETRUS Taugourdeau, 1968 emend. Saxena & Sarkar, 1986

Type species—FRASNACRITETRUS JOSETTAE Taugourdeau, 1968

PLATE 1 →

(All photomicrographs are enlarged *ca.* x 500. Coordinates of the specimens refer to the stage of the BH2 Olympus Microscope No. 217267)

1 *Dictyophyllidites* sp., Slide No. BSIP 12697, Coordinates 12.3 x 132.0.

2-4. *Lakiapollis ratnagiriensis*, Slide Nos. BSIP 12698, coordinates 9.5 x 157.4; 12699, coordinates 11.6 x 140.0; 12700, coordinates 19.0 x 169.0.

5 *Tricolporopilites* sp., Slide No. BSIP 12700, coordinates 3.5 x 134.5.

6-8. *Perfotricolpites neyvelii*. Slide Nos. BSIP 12701, coordinates 20.0 x 141.0; 12701, coordinates 13.0 x 145.0; 12702, coordinates 11.4 x 139.0.

9. *Striatriletes susannae*, Slide No. BSIP 12703, coordinates 10.5 x 145.0.

10. *Cheilanthoidspora monoleta*, Slide No. BSIP 12704, coordinates 6.0 x 157.0.

11 *Inapertisporites* sp., Slide No. BSIP 12705, coordinates 20.0 x 149.0.

12. *Verruinaperturites* sp., Slide No. BSIP 12690, coordinates 21.7 x 143.0.

13. *Palaeocirrenalia* sp., Slide No. BSIP 12690, coordinates 15.0 x 135.0.

14. *Involutisporonites* sp., Slide No. BSIP 126706, coordinates 14.6 x 147.0.

15. *Polygonacidites frequens* Sah & Dutta, Slide No. BSIP 12702 coordintes 10.0 x 133.3.

16. Pollen type I, Slide No. BSIP 12707, coordinates 15.0 x 150.0.

17-18. Fungal spore type II. Slide Nos. BSIP 121708, coordinates 7.9 x 142.0; 12709, 11.6 x 145.4.

19. *Siwalikiathyrites* sp., Slide No. BSIP 12710, coordinates 16.4 x 138.5.

20. *Triporotetradites* sp., Slide No. BSIP 12711, coordinates 9.0 x 142.0.


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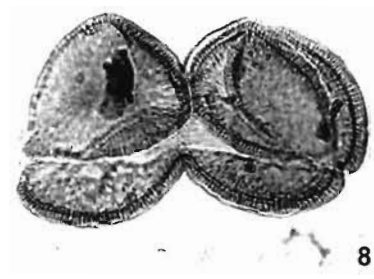
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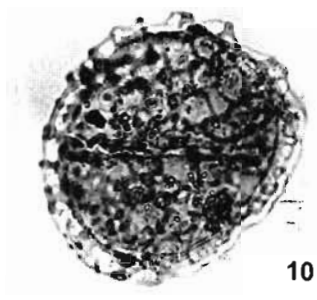
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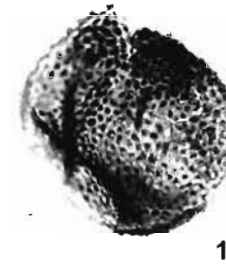
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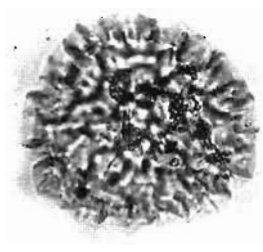
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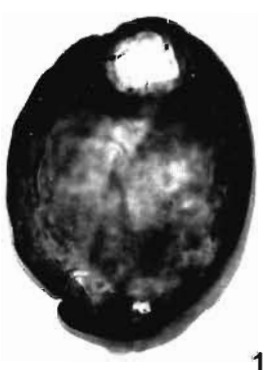
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PLATE 1

Botanical Group/Family	Palynotaxa	Present day distribution
FUNGI		
Fungal fruiting bodies (Microthyriaceae)	*Phragmothyrites eocaenica, Parmathyrites indicus, P. ramanujamii, Microthyriacites ramanujamii, Kutchiathyrites eccentricus, Ratnagiriathyrites hexagonalis, Lirasporis intergranifer, Trichothyrites setiferus, Kalviwadithyrites saxenae, Siwalikiathyrites* sp.	Warm and humid tropical climate
Fungal spores and mycelium (Ascomycetes, Basidiomycetes and Deuteromycetes)	*Inapertisporites kedvesii, Inapertisporites* sp. *Dicellaesporites, Dyadosporonites, Diporicellaesporites, Multicellaesporites, Pluricellaesporites, Meliola, Involutisporonites* and *Fungal hyphae*	
PTERIDOPHYTES		
Schizaeaceae (*Lygodium*)	*Lygodiumsporites lakiensis*	Tropical-subtropical
Dicksoniaceae	*Dictyophyllidites* sp.	Tropical-subtropical
Parkeriaceae (*Ceratopteris*)	*Striatriletes susannae*	Tropical-subtropical
ANGIOSPERMS		
Bombacaceae	*Lakiapollis ovatus, L. ratnagiriensis*	Tropical-subtropical
Dipterocarpaceae	*Dipterocarpuspollenites retipilatus*	Tropical-subtropical
Malvaceae	*Malvacearumpollis bakonyensis*	Tropical-subtropical
Plumbaginaceae	*Perfotricolpites neyvelii*	Tropical-temperate
Arecaceae (*Eugeissonia*)	*Quilonipollenites ornatus*	Pan tropical-subtropical
Potamogetonaceae	*Verruinaperturites* sp.	Cosmopolitan
Polygonaceae (*Polygonum*)	*Polygonacidites frequens*	Tropical-subtropical
INCERTAE SEDIS	*Heliospermopsis ankalesvarensis*	Tropical

Fig. 3—Possible affinities of palynotaxa recognized in the assemblage and present day distribution.

FRASNACRITETRUS sp.

(Pl. 3.11)

Description—Fungal spore tetra-cellular. Overall size: 137 µm. Body more or less rectangular in shape, 3 ridges present. Size: 27 x 20 µm, finely structured. Processes 4, septate, 93 x 10 µm long, ends funnel shaped.

FUNGAL SPORE TYPE I

(Pl. 3.13)

Description—Fungal hyphae with spores, spores attached alternate intervals. Each spore oval-sub circular in shape. Size range: 18-21 x 15-18 µm. Pore present surrounded by thickening. Body wall 2.5 µm thick. Surface showing warty lines.

PLATE 2 →

(All photomicrographs are enlarged *ca.* x 500. Coordinates of the specimens refer to the stage of the BH2 Olympus Microscope No 217267)

1 *Dyadosporonites* sp., Slide No. BSIP 12701, coordinates 11.0 x 165.0.
2. *Meliola* sp., Slide No BSIP 12712, coordinates 7.6 x 140.5.
3-4. *Pluricellaesporites* sp. Slide Nos. BSIP 12689 coordinates 11.0 x 156.0; 12713, coordinates 23.0 x 134.5.
5 *Multicellaesporites* sp. B, Slide No. BSIP 12706, coordinates 12.6 x 162.5.
6. *Phragmothyrites* sp., Slide No. BSIP 12706, coordinates 17.3 x 160.0.
7 *Microthyriacites* sp., Slide No. BSIP 12714, coordinates 3.0 x 139.0.
8. *Parmathyrites ramanujamii*, Slide No. BSIP 12689, coordinates 11.0 x 142.0.
9. Fungal fruiting body I, Slide No. BSIP 12715, coordinates 6.6 x 140.0.
10. *Heliospermopsis* sp., Slide No. BSIP 12616, coordinates 12.4 x 163.4.
11-12. *Kalviwadithyrites saxenae* sp. nov., Slide Nos. BSIP 12689, coordinates 14.0 x 151.0; 12690, coordinates 7.7 x 156.0.
13. Fungal hyphae I, Slide No. BSIP 12717, coordinates 20.1 x 149.0.
14. Fungal hyphae II,. Slide No. BSIP 12716, coordinates 12.4 x 163.4.


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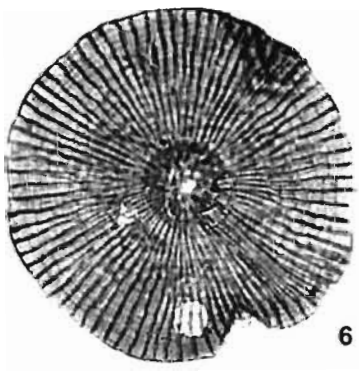
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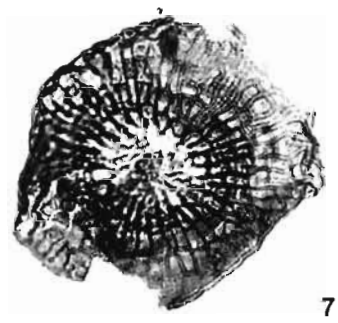
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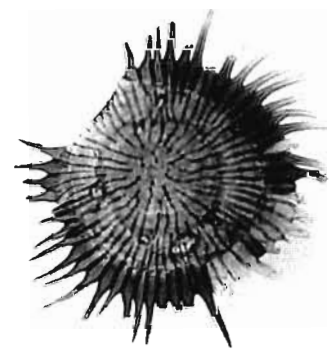
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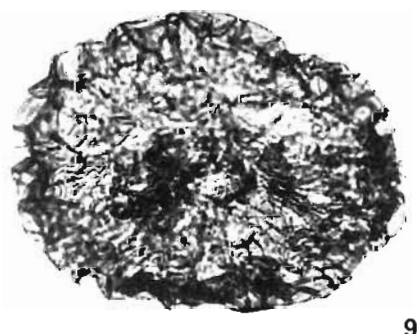
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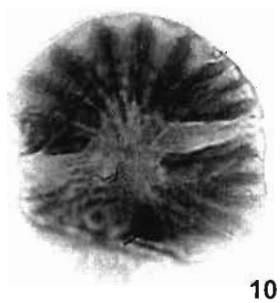
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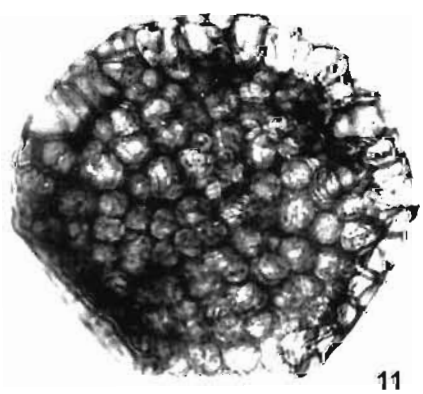
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PLATE 2

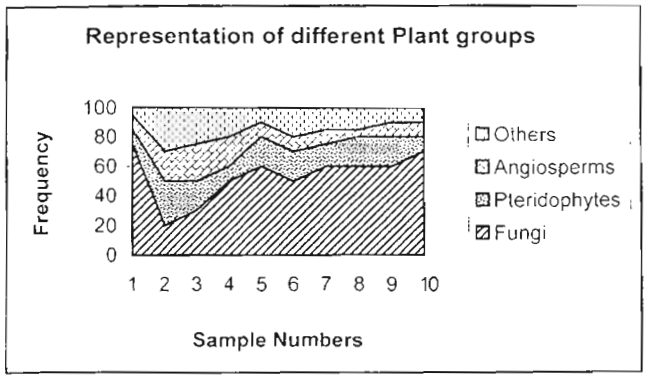

Fig. 4—Representation of different plant groups in Kalviwadi section.

FUNGAL SPORE TYPE II

(Pl. 1.17-18)

Description—Fungal spores dark brown in colour, oval in shape. Size range: 110-115 x 78-83 µm. Diporate. One pore at the top, pore diameter 28 µm, surrounded by thickening, 3 µm thick; another pore present below, 6 µm in diameter. Body wall thin, wavy margins present on the wall.

Pteridophyte spores

Genus—DICTYOPHYLLIDITES Couper, 1958

Type species—DICTYOPHYLLIDITES HARRISII Couper, 1958

DICTYOPHYLLIDITES sp.

(Pl. 1.1)

Description—Miospore sub triangular in proximal view. Size: 70 x 67 µm. Trilete, distinct, surrounded by thick wavy kyrtome, 12 µm thick. Exine 5.5 µm thick, laevigate.

Comparison—Dictyophyllidites harrisii Couper 1958 is distinguished from the present species by its longer rays reaching almost to the equator.

Angiosperm pollen

Genus—VERRUINAPERTURITES Pierce, 1961

Type species—VERRUINAPERTURITES DEPRESSUS Pierce, 1961

VERRUINAPERTURITES sp.

(Pl. 1.12)

Description—Pollen grain sub circular in polar view. Size: 76 x 67 µm. Inaperturate. Exine verrucate, verrucae sparsely placed. Surface showing reticulate ornamentation.

Genus—PERFOTRICOLPITES (Navale & Misra, 1979) Mandal & Kumar, 2000

Type species—PERFOTRICOLPITES DIGITATUS Garcia Guzman, 1967

PERFOTRICOLPITES NEYVELII (Navale & Misra, 1979)

Mandal & Kumar, 2000

(Pl. 1.6-8)

Description—Pollen grains oval-elongate in equatorial view. Size range: 77- 85 x 55-62 µm. Tricolpate, colpi distinct. Exine 5 µm thick. Sexine and nexine not differentiated, foveo-reticulate ornamentation.

Remarks—Perfotricolpites neyvelii (Navale & Misra) Mandal & Kumar (2000) (1979) recorded from the present study are smaller in size and thinner exine.

PLATE 3

(All photomicrographs are enlarged *ca.* x 500. Coordinates of the specimens refer to the stage of the BH2 Olympus Microscope No. 217267)

1-3. *Tricolporopollis sindhudurgensis* sp. nov., Slide Nos. BSIP 12716, coordinates 9.0 x 154.0; 12711, coordinates 4.5 x 149.0; 12718, coordinates 13.3 x 167.0.
4. *Multicellaesporites* sp. A, Slide No. BSIP 12718, coordinates 20.0 x 142.3.
5 *Quilonipollenites ornatus* Ramanujam, Slide No. BSIP 12719, coordinates 15.0 x 137.6.
6. *Inapertisporites kedvesii*, Slide No. BSIP 12720, coordinates 8.2 x 157.0.
7 *Dermatobrevicolporites* sp., Slide No. BSIP 12707, coordinates 17.0 x 135.0.
8 Spore moss, Slide No. BSIP 12697, coordinates 16.0 x 141.6.
9. *Verrualetes* sp., Slide No. BSIP 12721, coordinates 13.0 x 137.4.
10. *Diporicellaesporites* sp., Slide No. BSIP 12690, coordinates 19.0 x 132.0.
11 *Frasnacritetrus* sp., Slide No. BSIP 12704, coordinates 22.0 x 136.3.
12. *Lirasporis intergranifer*, Slide No. BSIP 12709, coordinates 17.0 x 147.0.
13. Fungal spore type I, Slide No. BSIP 12709, coordinates 20.5 x 141.0.
14. *Phragmothyrites eocaenica*, Slide No. BSIP 12722, coordinates 15.8 x 161.0.
15. *Kutchiathyrites eccentricus*, Slide No. BSIP 12723, coordinates 11.0 x 148.0.
16. *Trichothyrites setiferus* Slide No. BSIP 12697, coordinates 5.4 x 149.0.

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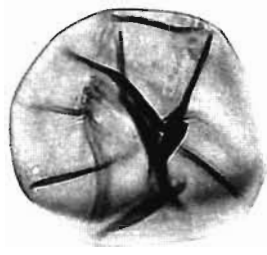

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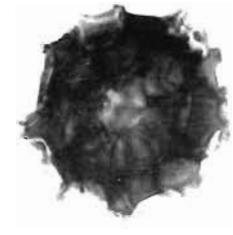

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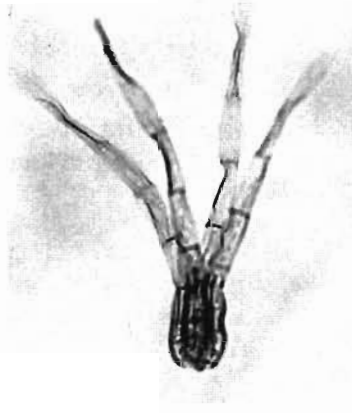

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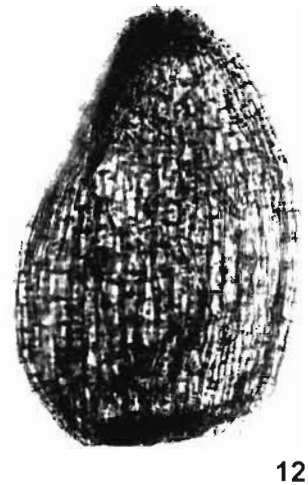

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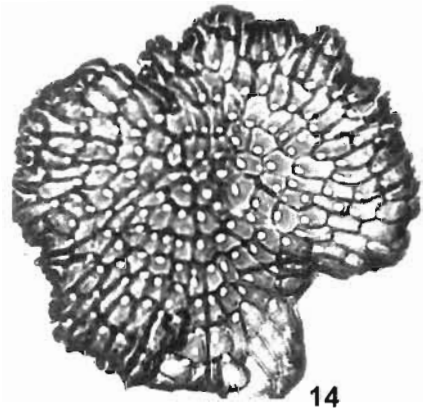

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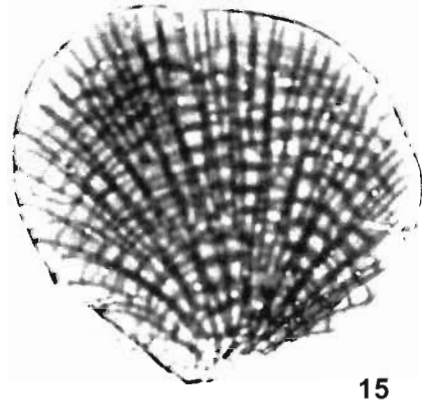

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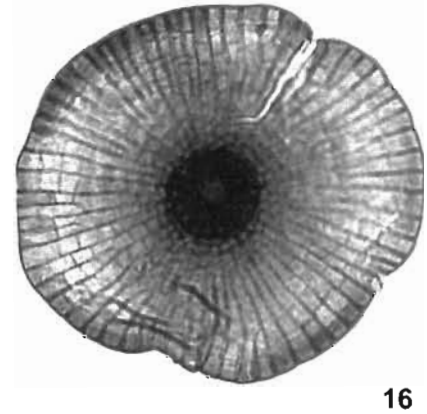

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PLATE 3

Genus—LAKIAPOLLIS Venkatachala & Kar, 1969

Type species—LAKIAPOLIS OVATUS Venkatachala & Kar, 1969

LAKIAPOLLIS RATNAGIRIENSIS sp. nov.

(Pl. 1.2-4)

Holotype—Pl. 1.2, size 75 x 65 µm, Slide No. BSIP 12698.

Type Locality, Horizon and Age—Kalviwadi, Sindhudurg District, Maharashtra, Sindhudurg Formation, Miocene.

Diagnosis—Pollen grains elliptic to sub circular in polar view, size range: 70-80 x 53-65 µm. Tricolporate, brevicolpate, colpi narrow, Pores well developed, 7-12 µm wide, surrounded by thickening, 3 µm thick. Exine 3. 5 to 5 µm thick, sexine and nexine not differentiated. Surface showing finely scrobiculate ornamentation associated with folds.

Comparison—Lakiapollis ovatus Venkatachala & Kar 1969 is smaller (up to 50 µm) and possesses subequatorial apertures. *L. assamicus* Tripathi & Singh 1985 is larger (up to 95 µm), irregularly placed aperture and thinner exine (1 µm) .

Affinity—Bombacaceae.

Genus—DERMATOBREVICOLPORITES Kar, 1985

Type species—DERMATOBREVICOLPORITES DERMATUS Kar, 1985

DERMATOBREVICOLPORITES sp.

(Pl. 3.7)

Description—Pollen grain sub circular in polar view. Size: 68 x 65 µm. Tricolporate, brevicolpate, pore distinct, about 3 µm in diameter. Exine 4 µm thick, sexine and nexine not differentiated. Surface showing finely scrobiculate ornamentation.

Genus—TRICOLPOROPOLLIS Dutta & Sah, 1970

Type species—TRICOLPOROPOLLIS DECORIS Dutta & Sah, 1970

TRICOLPOROPOLLIS SINDHUDURGENSIS sp. nov

(Pl. 3.1-3)

Holotype—Pl. 3. 3, size 80 x 68 µm, Slide No. BSIP 12718.

Type Locality and Horizon—Kalviwadi, Sindhudurg District, Maharashtra, Sindhudurg Formation, Miocene.

Diagnosis—Pollen grains elliptic in equatorial view, size range: 75-80 x 50-68 µm. Tricolporate, brevicolpate, pore oval-circular in shape, 8-11 µm wide surrounded by thickening. Exine 3-5 µm thick. Surface showing distinct foveo-reticulate ornamentation.

Comparison—The present species is comparable with the type species *Tricolporopollis decoris* Dutta & Sah 1970 by its brevicolporate condition but the former is distinguished by its distinct reticulate ornamentation. *T. globosa* is differentiated by its smaller size (up to 38 µm) and coarsely reticulate sculpture. *T. matanomadhensis* (Venkatachala & Kar) Tripathi & Singh 1985 is distinct by its reticulate ornamentation formed by pila and bacula.

Genus—TRICOLPOROPILITES Kar emend. Singh & Misra, 1991

Type species—TRICOLPOROPILITES ROBUSTUS Kar, 1985

TRICOLPOROPILITES sp.

(Pl. 1.5)

Description—Pollen grain sub circular in polar view. Size: 77 x 72 µm. Tricolporate, brevicolpate, pores distinct. Exine 5 µm thick, pilate.

Comparison—Tricolporopilites sp. is closely comparable with the type species *T. robustus* Kar (1985) in its general characters but the latter is distinguished in having granulose exine.

Genus—TRIPOROTETRADITES van Hoeken-Klinkenberg, 1964

Type species—TRIPOROTETRADITES SCABRATUS van Hoeken-Klinkenberg, 1964

TRIPOROTETRADITES sp.

(Pl. 1.20)

Description—Pollen grain in tetrad stage. Individual grain size: 60 x 47 µm. Triporate. Exine 1.5 µm thick, surface showing foveo-reticulate ornamentation.

POLLEN TYPE I

(Pl. 1.16)

Description—Pollen grain sub circular in polar view. Size: 90 x 75 µm. Polyporate, pores about 6 µm wide. Exine thin. Surface showing distinct reticulate ornamentation.

The palynoflora recorded from the Sindhudurg Formation consists of 35 genera and 44 species comprising to fungal remains, pteridophyte spores and angiosperm pollen. The fungal remains are the major component than pteridophyte spores, followed by angiosperm pollen. The best represented genera are: *Phragmothyrites, Trichothyrites, Parmathyrites, Inapertisporites, Dicellaesporites, Diporicellaesporites, Multicellaesporites, Palaeocirrenalia, Pluricellaesporites,*

Involutisporonites, Striatriletes, Quilonipollenites, Lakiapollis, Perfotricolpites, Dipterocarpuspollenites, Polygonacidites and *Malvacearumpollis*. Of these, *Lakiapollis ratnagiriensis* and *Tricolporopollis sindhudurgensis* have been proposed as new species.

QUALITATIVE AND QUANTITATIVE ANALYSES

Possible botanical affinities for the palynotaxa with modern families, taking in account the current distribution of the extant taxa are given in Fig. 3.

The quantitative analysis is based on the frequency of the various palynotaxa in a count of 100 specimens per sample. The quantitative study shows a dominance of fungal remains, represented by 18 genera and 26 species and constituting 53.5 per cent of the assemblage. The significant fungal taxa have been referred to *Phragmothyrites, Trichothyrites, Parmathyrites, Inapertisporites, Multicellaesporites, Palaeocirrenalia, Pluricellaesporites* and *Involutisporonites*. The pteridophyte spores, represented by 5 genera and 5 species, constitute 17.5 per cent of the assemblage, and the dominant genera are *Cheilanthoidspora* and *Striatriletes*. Angiosperm pollen are represented by 12 genera and 13 species are less represented (13%). The significant angiosperm pollen taxa are: *Quilonipollenites, Lakiapollis, Tricolporopollis, Perfotricolpites* and *Polygonacidites*. The cuticles, tracheids, salt glands of mangrove plants and unidentified plant groups are placed under others. The representation of different plant groups are presented in Fig. 4.

DISCUSSION

PALAEOCLIMATE

The palynoflora recovered from the Sindhudurg Formation contains fungal remains (fruiting bodies, spores and hyphae), pteridophyte spores, angiosperm pollen and salt glands of mangrove plants and other organic debris. The assemblage has been critically studied, and compared with modern plant families. Although not all fossil taxa could be compared with modern genera, some comparisons have made representing 11 families. Of these, 7 families are restricted to the tropics -subtropics, 2 families are cosmopolitan, one Arecaceae is tropical and the other Potamogetonaceae is tropical-temperate (Fig. 3). A tropical-subtropical climate, with heavy rainfall prevailing during the sedimentation of the Sindhudurg Formation is inferred from the composition of the assemblage when compared to the present day distribution of the associated modern families. The rich representation of fungal fruiting bodies and spores are typical of microthyriaceous epiphyllous fungi. Their occurrence in the present assemblage indicates the existence of a terrestrial plant ecosystem and supported by a warm and humid conditions with heavy rainfall. Furthermore, the overall vegetation pattern is also indicative of a tropical-subtropical humid climate with high precipitation.

ENVIRONMENT OF DEPOSITION

The palynoflora contains elements belonging to various ecological groups such as fresh water swamp and water edge: (*Lygodiumsporites, Striatriletes, Polygonacidites, Verruinaperturites*); low-land: (*Lakiapollis, Perfotricolpites, Dipterocarpuspollenites, Tricolporopollis*); sandy beach: (*Quilonipollenites*) and back-mangrove elements (*Malvacearumpollis, Heliospermopsis*). The pteridophyte taxa generally favour a moist and shady habitat. The presence of *Lygodiumsporites* and *Striatriletes*, is indicative of freshwater swamps and lakes condition near the deposition site. Freshwater and marshy conditions are also indicated by the presence of *Polygonacidites* (Polygonaceae) and *Verruinaperturites* (Potamogetonaceae). Pollen grains belonging to Arecaceae and Bomabacaceae suggest plants with luxuriant growth and contributed to the development of rich vegetation in the area. Back-mangrove is represented by *Malvacearumpollis* (Malvaceae). Salt glands of mangrove-type plants are represented by *Heliospermopsis* have also been recorded from the assemblage corroborating the back-mangrove brackish water indicated by the presence of *Malvacearumpollis*. In summary, the vegetational pattern supports the supposition that the deposition of Sindhudurg Formation took place in a near shore, coastal environment with lagoon or swampy conditions nearby.

CONCLUSIONS

1. The Kalviwadi palynofloral assemblage consists of fungal remains, pteridophyte spores and angiosperm pollen. Fungal remains represent the highest proportion of taxa, then pteridophyte spores, followed by angiopserm pollen.

2. *Lakiapollis ratnagiriensis* and *Tricolporopollis sindhudurgensis* are proposed as new species.

3. On the basis of affinity with modern families, a tropical-subtropical humid climate with high precipitation appears to have prevailed during the sedimentation of the Sindhudurg Formation.

4. The assemblage represents a mixture of lowland ecological groups, including freshwater, coastal, back-mangrove and sandy beach.

5. The Sindhudurg Formation was deposited in a near shore, coastal environment with lagoon or swampy conditions nearby, the coastline was bordered by back-mangrove and other coastal elements.

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