Palynological investigation of the Ratnagiri beds of Sindhu Durg District, Maharashtra

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A palynological assemblage consisting of 60 genera and 95 species has been recovered from the Ratnagiri beds of Sindhu Durg District, Maharashtra. Quantitatively, pteridophytic spores and fungal remains are dominant, sharing 44 and 40 per cent of the total assemblage respectively. These are followed by angiospermous pollen (16%). On the basis of comparative morphology, the palynofossils have been assigned affinities to extant genera or families. The present day distribution of such taxa suggests a tropical-subtropical climate (warm-humid) with plenty of rainfall. The environment of deposition has been interpreted as near-shore with sufficient fresh water supply.

Key-words—Palynology, Palaeoecology, Ratnagiri beds, Neogene (India).

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सारॉश

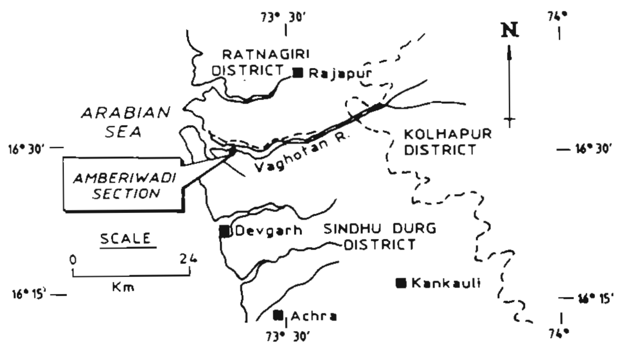
महाराष्ट्र में सिन्धु दुर्ग जनपद के रत्नागिरी संस्तरों का परागाणविक अन्वेषण

रमेश कुमार सक्सेना एवं नरेन्द्र कुमार मिश्रा

महाराष्ट्र में सिन्धु दुर्ग जनपद के रत्नागिरी संस्तरों से उपलब्ध परागाणविक समुच्चय में 60 प्रजातियाँ एवं 95 जातियाँ मिली हैं। संख्यात्मक दृष्टि से टेरीडोफ़ाइटी बीजाणुओं एवं कवकीय अवशेषों की बाहुल्यता है जो कुल समुच्चय के क्रमशः 44 एवं 40 प्रतिशत हैं। इनके पश्चात् आवृतबीजी परागकणों का क्रम आता है। तुलनात्मक आकारिकी के आधार पर उपलब्ध अश्मित परागाणुओं की वर्तमान प्रजातियों एवं कुलों से सजातीयता प्रदर्शित की गई है। इन वर्गकों के वर्तमान वितरण से अत्याधिक वर्षा से युक्त उष्णकटिबन्धीय से उपोष्णकटिबन्धीय जलवायु का होना इंगित होता है। निक्षेपण-वातावरण पर्याप्त स्वच्छ जल आपूर्ति से युक्त तटीय प्रस्तावित किया गया है।

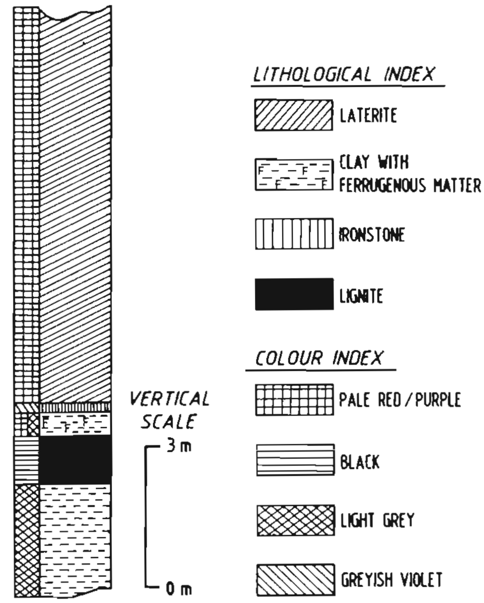
THE Ratnagiri beds were first reported by Wilkinson (1871) from a number of quarries and well sections along Ratnagiri coast, Maharashtra. The geological literature on these beds is rather meagre, mainly because of their poor exposure and less thickness. So far, the palynological studies on Ratnagiri beds are confined to the subsurface lignite samples collected from a well located 10 km south of Ratnagiri, near Third Dharamshala bus-stop on Ratnagiri-Pawas road (Phadtare & Kulkarni, 1980a, b, 1984a, b; Kulkarni & Phadtare, 1983; Kulkarni *et al.*, 1985). The cuticular studies on these beds have been published by Kulkarni and Phadtare (1980) and Dalvi and Kulkarni (1982). Phadtare and Kulkarni (1984c) described fossil woods of Anacardiaceae from these beds.

Saxena *et al.* (in press) made a lithostratigraphic study of these beds in a number of well, outcrop, cliff, road, mine and other sections in Ratnagiri and Sindhu Durg districts of Maharashtra. Of these, Amberiwadi section near Tirlot Village and Kalviwadi section near Tembhavli Village are outcrop sections. The present palynofloral investigation has been carried out on the Amberiwadi section located in Devgarh Taluk of Sindhu Durg District, Maharashtra (Lat. 16°30′20″N : Long. 73°23′20″E, Text-fig. 1). The base of the section is composed of grey clay followed by lignite (1 m), grey clay mixed with



Text-figure 1—Showing the location of Amberiwadi section in Sindhu Durg District, Maharashtra.

ferruginous matter (0.5 m) and ironstone (0.2 m). This is covered by about 9 m thick laterite (Text-fig. 2). Carbonized remains of wood and fragmentary leaves are also found in the lignite bed of this section.



Text-figure 2—Litholog of Amberiwadi section showing sequence of various strata of Ratnagiri beds.

MATERIAL AND METHOD

A total of 24 samples were collected from clay and lignite beds of Amberiwadi section at a regular stratigraphic interval of 0.20 m. In order to obtain a rich and complete assemblage, samples were also collected laterally. Precautions were taken to collect samples only from fresh and unweathered surfaces, to avoid any kind of contamination.

Samples were treated with HNO_3 and HF followed by 5 per cent solution of KOH. The slides were prepared in polyvenyl alcohol and mounted in canada balsam Lietz Laborlux microscope has been used for the study and photomicrography. The material, slides and negatives of figured specimens have been deposited in the museum of the Birbal Sahni Institute of Palaeobotany, Lucknow.

PALYNOFLORA

The palynotaxa recovered from the Ratnagiri beds are as follows:

Pteridophytic spores

Assamiasporites tertiarus Mehrotra & Sah 1980 (Pl. 3, fig. 4)
Cyathidites congoensis Sah 1967
Cyathidites minor Couper 1953 (Pl. 1, fig. 1)
**Cyathidites giganticus* sp. nov. (Pl. 1, fig. 17)
Dictyophyllidites kyrtomatus Kar & Kumar 1986
Laevigatosporites lakiensis Sah & Kar 1969
Laevigatosporites ovatus Wilson & Webster 1946
Leptolepidites sp. (Pl. 1, fig. 3)
Lygodiumsporites lakiensis Sah & Kar 1969 (Pl. 3, fig. 1)
Lygodiumsporites pachyexinus Saxena 1978
Monolites mawkmaensis Dutta & Sah 1970
Monolites ovatus Sah 1967
**Monolites amberiwadiensis* sp. nov. (Pl. 1, fig. 6)
Osmundacidites cephalus Saxena 1978 (Pl. 3, fig. 7)
Osmundacidites microgranifer Sah & Jain 1965 (Pl. 1, fig. 2)
Polypodiaceaesporites levis Sah 1967
Polypodiaceaesporites tertiarus Dutta & Sah 1970
Polypodiisporites ornatus Sah 1967
Polypodiisporites repandus Takahashi 1964
**Polypodiisporites minutiverrucus* sp. nov. (Pl. 1, fig. 5)
Polypodiisporites sp. (Pl. 1, fig. 4)
Pteridacidites fistulosus Sah 1967 (Pl. 3, fig. 6)
Striatriletes susannae Van der Hammen 1956 emend. Kar 1979 (Pl. 3, fig. 15)
Todisporites minor Couper 1958 (Pl. 3, fig. 3)

Angiospermous pollen grains

Arecipites punctatus Wodehouse 1933
Assamiapollenites sp. (Pl. 3, fig. 5)
Clavaperiporites jacobi Ramanujam 1966
Clavaperiporites sp. (Pl. 2, fig. 6)
Dermatobrevicolporites sp. (Pl. 1, fig. 19)
Dicolpopollis sp. (Pl. 2, fig. 2)
Favitricolporites retiformis Sah 1967 (Pl. 3, fig. 10)
Foveotricolpites prolatus Rao & Ramanujam 1982

Inaperturopollenites punctatus (Saxena) Saxena & Bhattacharyya 1987
Inaperturotetradites sp. 1 (Pl. 2, fig. 7)
Inaperturotetradites sp. 2 (Pl. 2, fig. 3)
Lakiapollis ovatus Venkatachala & Kar 1969
Lakiapollis sp. (Pl. 1, fig. 13)
Malvacearumpollis sp. (Pl. 2, fig. 5)
Paleosantalaceaepites dinoflagellatus Biswas 1962 emend. Dutta & Sah 1970
Palmidites maximus Couper 1958
Palmidites sp. (Pl. 1, fig. 8)
Pandaniidites sp. (Pl. 1, fig. 14)
Polyadopollenites sp. (Pl. 1, fig. 16)
Proxapertites microreticulatus Jain *et al.* 1973 (reworked)
Proxapertites sp. (Pl. 1, fig. 12, reworked)
Quilonipollenites ornatus Rao & Ramanujam 1978
Quilonipollenites sp. (Pl. 1, fig. 9)
Retipilonapites delicatissimus Ramanujam 1966
Retipilonapites sp. (Pl. 3, fig. 9)
Retitrescolpites splendens Sah 1967
Retitricolpites dipterocarpoides Rao & Ramanujam 1982 (Pl. 3, fig. 2)
Retitricolporites crassioratus Rao & Ramanujam 1982
**Retitricolporites subcircularis* sp. nov (Pl. 1, fig. 11)
Thomsonipollis sp. (Pl. 1, fig. 10)
Tricolpites reticulatus Cookson 1947
Tricolpites sp. 1 (Pl. 2, fig.1)
Tricolpites sp. 2 (Pl. 1, fig. 15)
Tricolporopollis matanamadhensis (Venkatachala & Kar) Tripathi & Singh 1985
Triporotetradites sp. (Pl. 2, fig. 8)
Verrualetes assamicus Singh & Saxena 1984 (Pl. 1, fig. 20)
Verrumonocolpites sp. (Pl. 1, fig. 7)
**Verrutriporites grandioratus* sp. nov. (Pl. 1, fig. 18)

Salt glands of Mangrove plants

**Heliospermopsis ankleshvarensis* (Srivastava 1967) comb. nov.
Heliospermopsis hungaricus Nagy 1965
Heliospermopsis sp. (Pl. 2, fig. 10)

Fungal remains

Basidiosporites fournierii Elsik 1968
Basidiosporites sp. 1 (Pl. 3, fig. 12)
Basidiosporites sp. 2 (Pl. 3, fig. 8)
Dendromyceliates splendens Jain & Kar 1979
Dicellaesporites fusiformis Sheffy & Dilcher 1971
Dicellaesporites popovii Elsik 1968
**Diporicellaesporites wilkinsonii* sp. nov. (Pl. 3, fig. 13)
Diporicellaesporites sp. (Pl. 3, fig. 19)
Dyadosporonites sp. 1 (Pl. 2, fig. 11)
Dyadosporonites sp. 2 (Pl. 2, fig. 4)
Fusiformisporites sp. (Pl. 2, fig. 12)
**Inapertisporites kedresii* Elsik 1968
I. suboroideus Sheffy & Dilcher 1971
Involutisporonites wilcoxii Elsik 1968
Kutchiathyrites eccentricus Kar 1979
Lirasporis intergranifer Potonié & Sah 1960 emend. Jain & Kar 1979
Lirasporis sp. (Pl. 3, fig. 18)
**Microthyriacites ramanujamii* sp. nov (Pl 2, fig. 13)
Multicellaesporites elsikii Kar & Saxena 1976
**Paramicrothallites konkanensis* sp. nov (Pl 2, fig. 9)
Parmathyrites ramanujamii Singh *et al.* 1986
Parmathyrites sp. (Pl. 3, fig. 17)
Phragmothyrites assamicus (Kar *et al.*) Saxena *et al.* 1984
Phragmothyrites edwardsii (Rao) Kar *et al.* 1972
Phragmothyrites eocaenica Edwards 1922 emend Kar & Saxena 1976
**Ratnagiriathyrites hexagonalis* gen. et sp. nov (Pl. 2, fig. 14, Pl. 3, fig. 11)
Staphlosporonites sp. 1 (Pl. 3, fig. 14)
Staphlosporonites sp. 2 (Pl 3, fig. 16)
**Trichothyrites amorphus* (Kar & saxena) comb. nov
**Trichothyrites setiferus* (Cookson) comb. nov

Taxa with asterisk (*) mark have either been described or commented upon herein. Plate and figure numbers given in the above list in parentheses refer to the illustration of the present paper. The spore/pollen types which could not be assigned to any known species and are represented by very few specimens have also been listed in the check-list (eg. *Leptolepidites* sp., *Lakiapollis* sp., etc.) and illustrated in the plates. However, their descriptions have not been given.

SYSTEMATIC PALYNOLOGY

Genus—*Cyathidites* Couper 1953

Cyathidites giganticus sp. nov.
Pl. 1, fig. 17

Holotype—Pl. 1, fig. 17, size 96 μm, Slide no. BSIP 10135, coordinates: 51.8 × 104.2.

Type horizon & locality—Ratnagiri beds, Amberiwadi section, Sindhu Durg District, Maharashtra.

Diagnosis—Spores triangular with concave interapical margin, size range 94-100 μm; trilete, rays extending up to the equator; exine 4.5-5.5 μm thick, slightly thicker at apices than at interapical region, laevigate.

Comparison—*Cyathidites australis* Couper 1953 (54-77 μm), *C. minor* Couper 1953 (31-45 μm, exine 1.5 μm thick) and *C. congoensis* Sah 1967 (32-46 μm, exine 1.5-2.5 μm thick) differ from the present species in having smaller size and thinner exine.

Number of specimens studied—13.

Genus—*Monolites* Erdtman 1947 ex Potonié 1956

Monolites amberiwadiensis sp. nov.
Pl. 1, fig. 6

Holotype—Pl. 1, fig. 6, size 61 × 50 μm, Slide no. BSIP 10127; coordinates: 59.8 × 97.1.

Type horizon & locality—Ratnagiri beds, Amberiwadi section, Sindhu Durg District, Maharashtra.

Diagnosis—Spores circular to oval; size range 51-63 × 44-51 μm; monolete, ray extending more than half the longer axis; exine 2 to 2.5 μm thick, psilate, perine present, more or less punctate.

Comparison—The present species is distinguished from *M. ovatus* Sah 1967 and *M. mawkmaensis* Dutta & Sah 1970 by the presence of punctate perine, bigger size and thicker exine.

Number of specimens studied—17.

Genus—*Polypodiisporites* Potonié 1934

Polypodiisporites minutiverrucus sp. nov.
Pl. 1, fig. 5

Holotype—Pl. 1, fig. 5, size 49 × 31 μm, Slide no. BSIP 10126; coordinates: 53.5 × 99.2.

Type horizon & locality—Ratnagiri beds, Amberiwadi section, Sindhu Durg District, Maharashtra.

Diagnosis—Spores bean-shaped, size range 49-59 × 29-50 μm; monolete, ray distinct, extending up to half the longer axis; exine 2.5 μm thick, verrucose, verrucae small, 3-4 μm in size, flat, closely placed.

Comparison—*Polypodiisporites* sp. (Saxena, 1978, pl. 2, figs 37, 38, p. 452) resembles present species in having small verrucae but differs in being bigger in size (68-92 × 58-68 μm).

Number of specimens studied—18.

Genus—*Retitricolporites* Van der Hammen 1956 ex Van der Hammen & Wijmstra 1964

Retitricolporites subcircularis sp. nov.
Pl. 1, fig. 11

Holotype—Pl. 1, fig. 11, size 52 × 46 μm, Slide no. BSIP 10130; coordinates: 48.1 × 96.5.

Type horizon & locality— Ratnagiri beds, Amberiwadi section, Sindhu Durg District, Maharashtra.

Diagnosis—Pollen isopolar, circular to

PLATE 1 →

(All photomicrographs are *ca* ×750, unless otherwise stated. Coordinates refer to Leitz Laborlux microscope no. 512794/067304).

1. *Cyathidites minor* Couper, Slide no. BSIP 10122; coordinates: 35.2 × 96.4.
2. *Osmundacidites microgranifer* Sah & Jain, Slide no. BSIP 10123: coordinates 58.4 × 98.7.
3. *Leptolepidites* sp., Slide no. BSIP 10124; coordinates: 51.1 × 100.1.
4. *Polypodiisporites* sp., Slide no. BSIP 10125; coordinates: 60.3 × 96.8.
5. *Polypodiisporites minutiverrucus* sp. nov., Slide no. BSIP 10126; coordinates: 53.5 × 99.2 (Holotype).
6. *Monolites amberiwadiensis* sp. nov., Slide no. BSIP 10127; coordinates: 59.8 × 97.1 (Holotype).
7. *Verrumonocolpites* sp., Slide no. BSIP 10128; coordinates: 52.3 × 98.5.
8. *Palmidites* sp., Slide no. BSIP 10129; coordinates: 52.6 × 103.4.
9. *Quilonipollenites* sp., Slide no. BSIP 10130; coordinates: 52.2 × 94.1.
10. *Thomsonipollis* sp., Slide no. BSIP 10131; coordinates: 69.6 × 99.9.
11. *Retitricolporites subcircularis* sp. nov., Slide no. BSIP 10130; coordinates: 48.1 × 96.5 (Holotype).
12. *Proxapertites* sp., Slide no. BSIP 10132; coordinates: 48.2 × 100.2.
13. *Lakiapollis* sp., Slide no. BSIP 10133; coordinates: 42.0 × 106.9.
14. *Pandaniidites* sp., × 850, Slide no. BSIP 10134; coordinates: 51.4 × 99.8.
15. *Tricolpites* sp. 2, Slide no. BSIP 10122; coordinates: 31.5 × 99.1
16. *Polyadopollenites* sp., Slide no. BSIP 10126; coordinates: 51.8 × 103.7.
17. *Cyathidites giganticus* sp. nov., × 500, Slide no. BSIP 10135; coordinates: 51.8 × 104.2 (Holotype).
18. *Verrutriporites grandioratus* sp. nov., Slide no. BSIP 10136; coordinates: 51.2 × 94.2 (Holotype).
19. *Dermatobrevicolporites* sp., Slide no. BSIP 10137; coordinates: 39.8 × 103.1.
20. *Verrualetes assamicus* Singh & Saxena, Slide no. BSIP 10134; coordinates: 43.7 × 106.8.

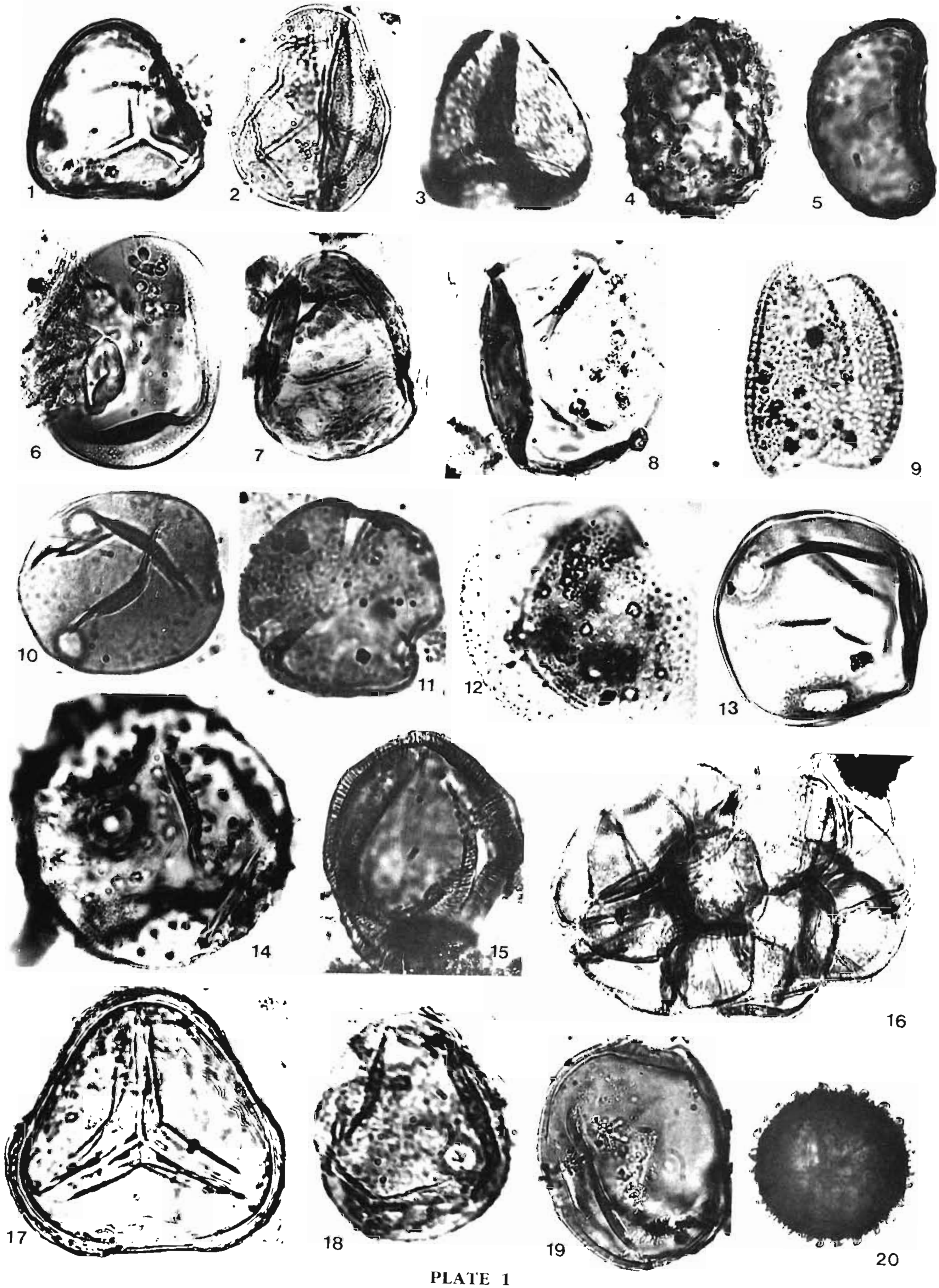


PLATE 1

subtriangular, 43-56 μm in size, tricolporate, zonicolporate, colpi deep, colpi margin thickened with ± blunt ends, pores distinct, oval, 8-10 × 4-6 μm in size, pore margin thickened; exine 2.5-3 μm thick, tectate, columella distinct, reticulate to foveoreticulate, lumina circular, *ca* 1 μm, sexine thicker than nexine.

Comparison—The present species is distinguished from *R. guianensis* Van der Hammen & Wijmstra 1964, *R. annulatus* Salard-Cheboldaeff 1978 and *R. crassioratus* Rao & Ramanujam 1982 by its bigger size, thickened ora and colpi margins and reticulate to foveoreticulate ornamentation.

Number of specimens studied—12.

Genus—*Verrutriporites* Muller 1968

Verrutriporites grandioratus sp. nov.
Pl. 1, fig. 18

Holotype—Pl. 1, fig. 18, size 57 × 47 μm, Slide no. BSIP 10136; coordinates: 51.2 × 94.2.

Type horizon & locality—Ratnagiri beds, Amberiwadi section, Sindhu Durg District, Maharashtra.

Diagnosis—Pollen oval, size range 50-58 × 39-47 μm; triporate, pores oval, 7-9 × 3.5-6 μm, pore margin thickened, pores subequatorial in position; exine 1-1.5 μm thick, verrucate, verrucae small to large, closely placed and evenly distributed, folds present.

Comparison—*V. lundensis* Muller 1968 differs from present species in having smaller size (18-34 μm) and smaller pore diameter (2-3 μm).

Number of specimens studied—5.

Genus—*Heliospermopsis* Nagy 1965

Heliospermopsis ankleshvarensis (Srivastava 1967) comb. nov.

Basionym—*Oudhkusumites ankleshvarensis* Srivastava 1967, *Rev. Micropaleontol.* **10**(1), pl. 1, figs 1-16, p. 38.

Holotype—Srivastava, 1967, pl. 1, fig. 1

Fungal remains

Genus—*Microthyriacites* Cookson 1947

Microthyriacites ramanujamii sp. nov.
Pl. 2, fig. 13

Holotype—Pl. 2, fig. 13, size 116 × 94 μm, Slide no. BSIP 10143; coordinates: 50.7 × 100.5.

Type horizon & locality—Ratnagiri beds, Amberiwadi section, Sindhu Durg District, Maharashtra.

Diagnosis—Ascostromata circular to subcircular, nonostiolate, size range 110-126 × 90-95 μm, hyphae radiating, forming pseudoparenchymatous, small, thickened central cells and larger, rectangular to squarish outer cells, cells nonporate, margin thin and wavy.

Comparison—The present species is distinguished from *Microthyriacites sahnii* Rao 1959, *M. cooksonii* Rao 1959 and *M. edwardsii* Rao 1959 by its thickened central cells and smaller size.

Number of specimens studied—5.

Genus—*Ratnagiriathyrites* gen. nov.

Type species—*Ratnagiriathyrites hexagonalis* gen. et sp. nov.

Diagnosis—Ascostromata subcircular or irregular in shape, dark brown in colour, nonostiolate, cells not arranged radially, porate, pores generally distributed throughout stromata, cells hexagonal, bigger towards periphery than in the central region; margin thick, wavy.

Comparison—The present genus is

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PLATE 2

1. *Tricolpites* sp. 1 × 650, Slide no. BSIP 10122; coordinates: 37 × 105.4.
2. *Dicolpopollis* sp., Slide no. BSIP 10138; coordinates: 61.3 × 94.0.
3. *Inaperturotetradites* sp. 2, × 550, Slide no. BSIP 10139, coordinates: 43.7 × 99.4.
4. *Dyadosporonites* sp. 2, Slide no. BSIP 10140; coordinates: 39.4 × 98.2.
5. *Malvacearumpollis* sp., Slide no. BSIP 10130; coordinates: 62.7 × 98.9.
6. *Clavaperiporites* sp., Slide no. BSIP 10130; coordinates: 41.1 × 97.7.
7. *Inaperturotetradites* sp. 1, × 850, Slide no. BSIP 10141; coordinates: 51.8 × 108.2.
8. *Triporotetradites* sp., × 500; Slide no. BSIP 10142; coordinates: 69.0 × 93.8.
9. *Paramicrothallites konkanensis* sp. nov., × 500; Slide no. BSIP 10137; coordinates: 44.6 × 102.5 (Holotype).
10. *Heliospermopsis* sp., Slide no. BSIP 10140; coordinates 65.3 × 110.8.
11. *Dyadosporonites* sp. 1, Slide no. BSIP 10140; coordinates: 59.0 × 93.1.
12. *Fusiformisporites* sp., Slide no. BSIP 10142; coordinates: 50.5 × 105.2.
13. *Microthyriacites ramanujamii* sp. nov., Slide no. BSIP 10143; coordinates: 50.7 × 100.5 (Holotype).
14. *Ratnagiriathyrites hexagonalis* sp. nov., Slide no. BSIP 10126; coordinates: 38.3 × 104.7 (Holotype).

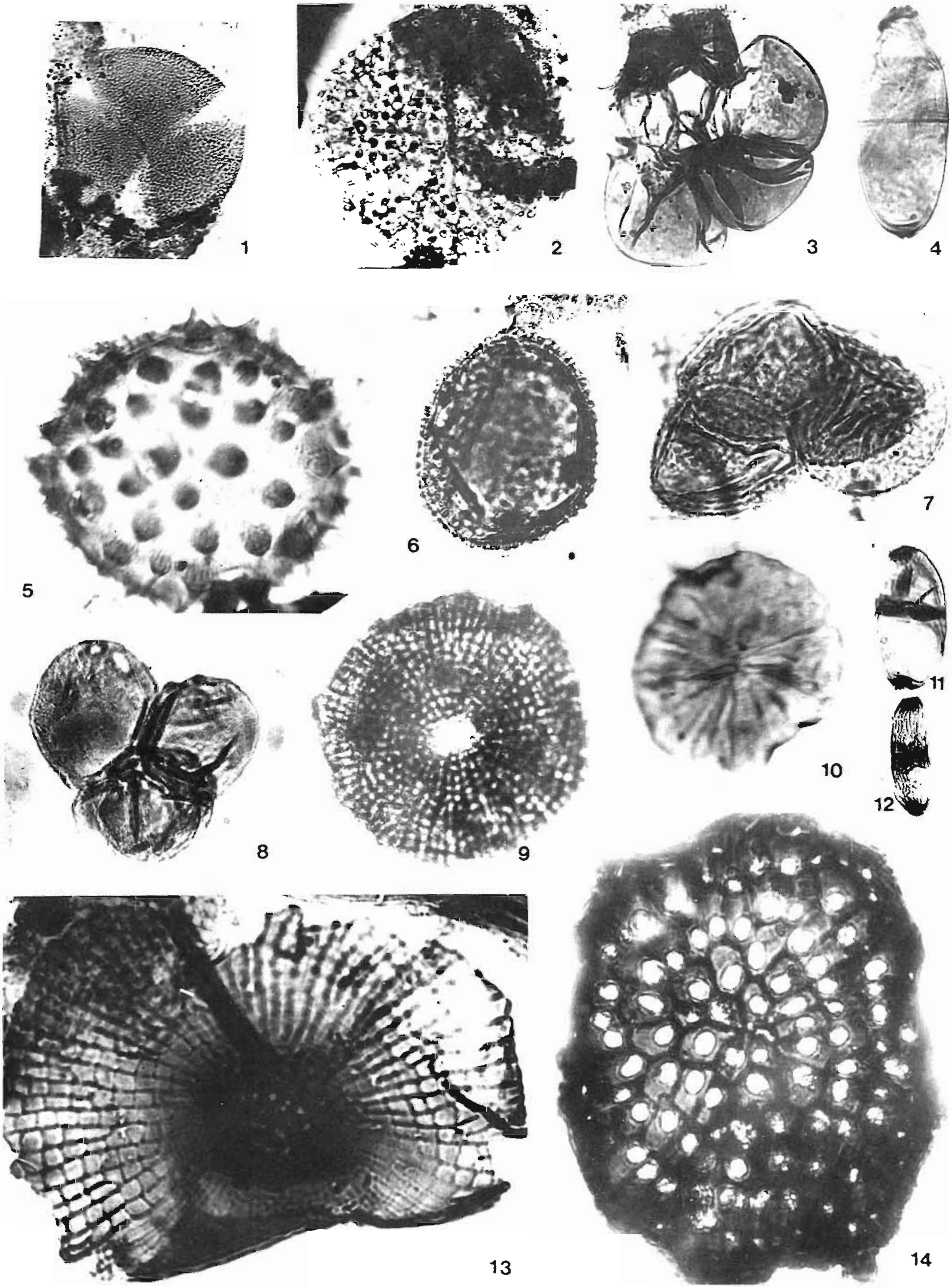


PLATE 2

distinguished from *Phragmothyrites* Edwards 1922 emend. Kar & Saxena 1976 and *Microthyriacites* Cookson 1947 by its non-radiating and hexagonal, porate cells. *Siwalikiathyrites* Saxena & Singh 1982 resembles the present genus in having non-radial cells but differs in being nonporate.

Ratnagiriathyrites hexagonalis sp. nov.
Pl 2, fig. 14; Pl. 3, fig. 11

Holotype—Pl. 2, fig. 14, size 114 × 95 μm, Slide no. BSIP 10126; coordinates: 38.3 × 104.7.

Type horizon & locality—Ratnagiri beds, Amberiwadi section, Sindhu Durg District, Maharashtra.

Diagnosis—Ascostromata subcircular to irregular in shape, dark brown in colour, nonostiolate, size range 66-114 × 55.5-95 μm, cells not arranged radially, porate, pores mostly distributed throughout ascostromata, marginal cells nonporate, cells hexagonal, sometimes pentagonal, cells increasing in size towards periphery, margin thick, wavy.

Number of specimens studied –19.

Genus—*Paramicrothallites* Jain & Gupta 1970

Paramicrothallites konkanensis sp. nov.
Pl. 2, fig. 9

1986 *Paramicrothallites menonii* Jain & Gupta *in* Singh *et al.*, Pl. 1, fig. 4, p. 96

Holotype—Pl. 2, fig. 9, size. 103 × 98 μm, Slide no. BSIP 10137; coordinates: 44.6 × 102.5.

Type horizon & locality—Ratnagiri beds; Amberiwadi section, Sindhu Durg District, Maharashtra.

Diagnosis—Ascostromata subcircular in shape, dark brown in colour, size range 94-103 × 90-98 μm, ostiolate, ostiole subcircular, *ca* 7-9 μm in diameter, unthickened, hyphae radiating, forming nonporate pseudoparenchymatous cells, central cells squarish, marginal cells rectangular, margin uneven.

Comparison—*Paramicrothallites menonii* Jain & Gupta 1970 reported by Singh *et al.* (1986, pl. 1, fig. 4) resembles the present species.

Number of specimens studied—16.

Genus—*Trichothyrites* Rosendahl 1943

Trichothyrites setiferus (Cookson) comb. nov.

Basionym—*Notothyrites setiferus* Cookson 1947, *Proc. Linn. Soc. N.S.W.* **72**, pl. 11, figs 1-6, p. 209.

Holotype—Cookson, 1947, pl. 11, fig. 1.

Trichothyrites amorphus (Kar & Saxena) comb. nov.

Basionym—*Notothyrites amorphus* Kar & Saxena 1976, *Palaeobotanist* **23**(1), pl. 4, figs 44-45, p. 9.

Holotype—Kar & Saxena, 1976; pl. 4, figs 44-45.

Genus—*Inapertisporites* Van der Hammen 1954 ex Rouse 1959 emend. Saxena & Bhattacharyya 1987

Inapertisporites kedvesii Elsik 1968

Remarks—The present specimens are bigger (44-54.5 × 39.2-53.2 μm) than those described by Elsik (1968, 28-38 μm) from the rockdale lignite (Palaeocene) of Texas. Kar and Saxena (1976, pl. 3, fig. 23; pl. 4, fig. 47) described similar but larger (27-72 μm) spores from the Matanomadh Formation (Palaeocene) of Kutch. The spores described by Chandra *et al.* (1984) from the sediment cores from

PLATE 3 →

1. *Lygodiumsporites lakiensis* Sah & Kar, Slide no. BSIP 10126; coordinates: 53.4 × 93.6.
2. *Retitricolpites dipterocarpoides* Rao & Ramanujam, Slide no. BSIP 10144; coordinates: 61.7 × 98.4.
3. *Todisporites minor* Couper, Slide no. BSIP 10126; coordinates: 49 × 93.5.
4. *Assamiasporites tertiarus* Mehrotra & Sah, Slide no. BSIP 10144; coordinates: 31.6 × 109.8.
5. *Assamiapollenites* sp., Slide no. BSIP 10148A; coordinates: 43.8 × 106.8.
6. *Pteridacidites fistulosus* Sah, Slide no. BSIP 10132; coordinates: 38 × 95.4.
7. *Osmundacidites cephalus* Saxena, Slide no. BSIP 10145; coordinates: 49.3 × 107.3.
8. *Basidiosporites* sp. 2, Slide no. BSIP 10146; coordinates: 35.3 × 91.9.
9. *Retipilonapites* sp., Slide no. BSIP 10130; coordinates: 64.5 × 95.7.
10. *Favitricolporites retiformis* Sah, Slide no. BSIP 10134; coordinates: 62.8 × 92.3.
11. *Ratnagiriathyrites hexagonalis* sp. nov., Slide no. BSIP 10138; coordinates: 67.2 × 108.2.
12. *Basidiosporites* sp. 1, Slide no. BSIP 10147; coordinates: 45.6 × 107.4.
13. *Diporicellaesporites wilkinsonii* sp. nov., Slide no. BSIP 10122; coordinates: 70.5 × 104.6 (Holotype).
14. *Staphlosporonites* sp. 1, Slide no. BSIP 10132; coordinates: 43.2 × 97.5.
15. *Striatriletes susannae* van der Hammen emend. Kar, Slide no. BSIP 10134; coordinates: 41.2 × 91.7
16. *Staphlosporonites* sp. 2, Slide no. BSIP 10122; coordinates: 44.2 × 106.8.
17. *Parmathyrites* sp., Slide no. BSIP 10130; coordinates: 55.4 × 106.2.
18. *Lirasporis* sp., Slide no. BSIP 10130; coordinates: 49.9 × 103.5.
19. *Diporicellaesporites* sp., Slide no. BSIP 10148; coordinates: 39.8 × 101.5.

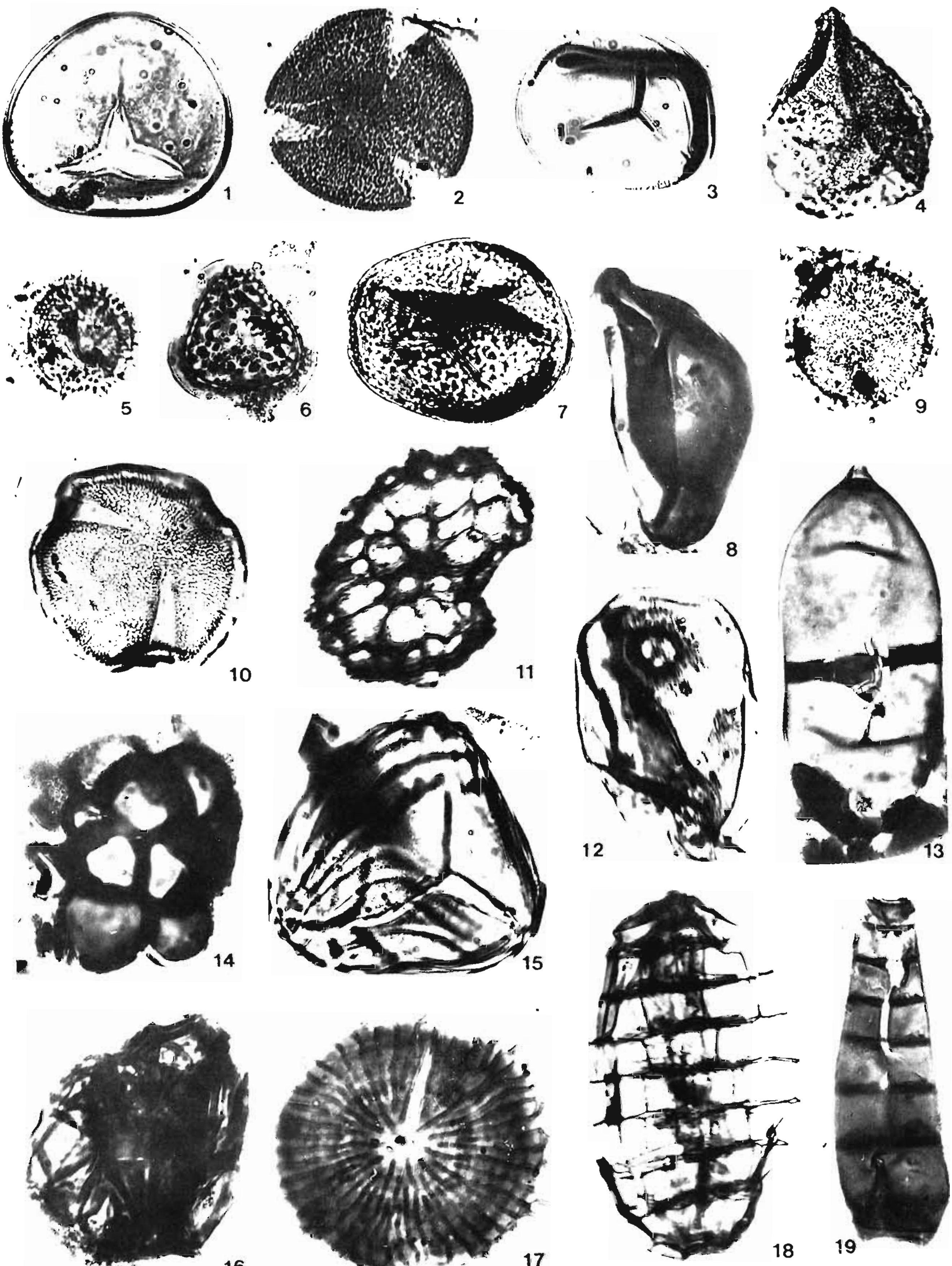


PLATE 3

Arabian Sea range from 14 to 88 μm in size

Number of specimens studied—47

Genus—*Diporicellaesporites* Elsik 1968

Diporicellaesporites wilkinsonii sp. nov
Pl 3, fig. 13

Holotype—Pl. 3, fig. 13, size 100 × 40 μm, Slide no. BSIP 10122; coordinates: 70.5 × 104.6.

Type horizon & locality—Ratnagiri beds, Amberiwadi section, Sindhu Durg District, Maharashtra.

Diagnosis—Fungal spores capsular in shape, size range 98-126 × 36-40 μm; tetracellate, middle septum complete, 2.5-3 μm thick, whereas other two septa incomplete, not covering full width of spore; diporate, pores apical, situated on protuberances, sometimes slightly offset; wall up to 1.0 μm thick, psilate.

Comparison—The present species is distinguished from *D. stacyii* Elsik 1968 and *D. acuminatus*, *D. puryearensis* and *D. tetralocularis* all instituted by Sheffy and Dilcher 1971 by its bigger size and two ill-developed and incomplete septa.

Number of specimens studied—17.

DISCUSSION

The qualitative and quantitative analyses of the present palynofloral assemblage indicate that the fungal remains and pteridophytic spores are the dominant constituents, whereas the angiospermous pollen are poorly represented. The assemblage is devoid of algal, bryophytic and gymnospermous elements.

Qualitative Analysis

The known botanical affinities of palynotaxa and present day distribution of the various families are given in table 1

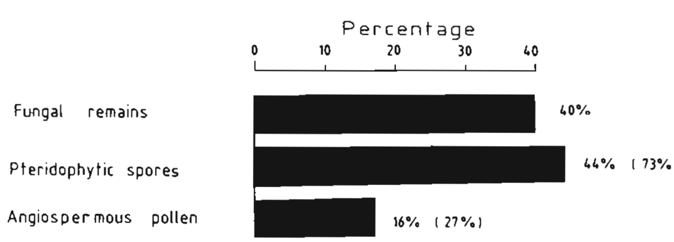
Table 1

Botanical group/Family	Palynotaxa	Present day distribution of the family	Remarks
DIVISION-THALLOPHYTA			
Fungal fruiting bodies (Microthyriaceae)	*Parmathyrites ramanujamii*, *Parmathyrites* sp., *Phragmothyrites eocaenica*, *P. edwardsii*, *P. assamicus*, *Microthyriacites ramanujamii*, *Kutchiathyrites eccentricus*, *Ratnagiriathyrites hexagonalis*, *Lirasporis intergranifer*, *Lirasporis* sp., *Paramicrothallites konkanensis*, *Trichothyrites setiferus*, *T amorphus*	Warm and humid Tropical climate	
Fungal spores and mycelia (Ascomycetes, Basidiomycetes and Deuteromycetes)	*Inapertisporites kedvesii*, *I. subovoideus*, *Fusiformisporites* sp., *Dicellaesporites popovii*, *Dicellaesporites fusiformis*, *Multicellaesporites elsikii*, *Staphlosporonites* spp. 1 and 2, *Dendromyceliates splendens*, *Basidiosporites fournierii*, *Basidiosporites* spp. 1 and 2, *Involutisporonites wilcoxii*, *Dyadosporonites* spp. 1 and 2, *Diporicellaesporites wilkinsonii*, *Diporicellaesporites* sp.		
DIVISION-PTERIDOPHYTA			
Cyatheaceae	*Cyathidites congoensis*, *Cyathidites minor*, *Cyathidites giganticus*	Tropical-subtropical	
Osmundaceae	*Osmundacidites micrograniſer*, *O. cephalus*, *Todisporites minor*	Cosmopolitan	Shady places or swamps
Dicksoniaceae	*Dictyophyllidites kyrtomatus*	Tropical-subtropical	
Schizaeaceae (*Lygodium*)	*Lygodiumsporites lakiensis*, *L pachyexinus*, *Leptolepidites* sp.	Tropical-subtropical	
Lycopodiaceae	*Assamiasporites tertiarus*	Cosmopolitan	Humid shady habitat
Parkeriaceae (*Ceratopteris thalictroides*)	*Striatriletes susannae*	Tropical-subtropical	

Adiantaceae	*Pteridacidites fistulosus*	Cosmopolitan	Chiefly in damp and shady places
Polypodiaceae (*Polypodium*)	*Monolites ovatus, M. mawkmaensis, Monolites amberiwadiensis, Polypodiaceaesporites levis, P. tertiarus, Laevigatosporites ovatus, L. lakiensis, Polypodiisporites ornatus, P. repandus Polypodiisporites* sp., Polypodüsporites *minutiverrucus*	Cosmopolitan	
DIVISION-SPERMATOPHYTA			
SUBDIVISION-ANGIOSPERMAE CLASS-MONOCOTYLEDONAE			
Arecaceae	*Palmidites maximus, Palmidites* sp., *Dicolpopollis* sp., *Proxapertites microretienlatus, Proxapertites* sp.	Tropical-subtropical	
Arecaceae (*Syagrus*)	*Arecipites punctatus*		
Arecaceae (*Eugeissona*)	*Quilonipollenites ornatus, Quilonipollenites* sp.		
Potamogetonaceae (*Potamogeton*)	*Retipilonapites* sp., *R. delicatissimus*	Cosmopolitan	Aquatic
Pandanaceae (*Pandanus*)	*Pandaniidites* sp.	Cosmopolitan	
CLASS-DICOTYLEDONAE			
Dipterocarpaceae (*Dipterocarpus*)	*Retitricolpites dipterocarpoides*	Tropical-Subtropical	
Gunneraceae	*Tricolpites reticulatus*	Cosmopolitan	
Rubiaceae	*Retitricolporites crassioratus*	Tropical-subtropical	
Oleaceae	*Retitrescolpites splendens*	Cosmopolitan	Chiefly tropical subtropical
Bombacaceae (*Durio*)	*Lakiapollis ovatus, Lakiapollis* sp.	Tropical-subtropical	
Gentianaceae	*Favitricolporites retiformis*	Cosmopolitan	
Thymeliaceae (*Wilkstroemia*)	*Clavaperiporites jacobi, Clavaperiporites* sp.,	Cosmopolitan	
Malvaceae	*Malvacearumpollis* sp.	Tropical-subtropical	
Rhizophoraceae	*Paleosantalaceaepites dinoflagellatus*	Tropical-subtropical	
Mimosaceae	*Polyadopollenites* sp.	Tropical-subtropical	
Lamiaceae	*Tricolpites* spp. 1 and 2	Cosmopolitan	
Sonnertiaceae	*Verrutriporites grandioratus*	Tropical-subtropical	
Sapotaceae	*Thomsonipollis* sp.	Tropical-subtropical	
Avicenniaceae (*Avicennia*)	*Retitricolporites subcircularis*	Tropical-subtropical	

Quantitative analysis

The Amberiwadi palynoflora comprises 60 genera and 95 species including fungal remains, pteridophytic spores, angiospermous pollen and salt glands of mangrove plants. The quantitative analysis has been done on the basis of frequency of various palynotaxa in a count of 100 specimens per sample. This revealed that fungal remains, being represented by 18 genera and 30 species constitute 40 per cent of the assemblage. The significant fungal taxa have been referred to *Phragmothyrites, Ratnagiriathyrites, Lirasporis, Trichothyrites* and *Inapertisporites.* The pteridophytic spores, represented by 13 genera and



Text-figure 3—Percentage of various botanical groups in the palynoassemblage of Amberiwadi section.

24 species, constitute 44 per cent of the assemblage. The dominant genera of pteridophytic spores are: *Cyathidites, Todisporites, Lygodiumsporites, Assamiasporites, Laevigatosporites, Monolites, Polypodiaceaesporites* and *Polypodiisporites.* The angiospermous pollen being represented by 28 genera and 38 species are poorly represented (16%). The significant angiospermous pollen taxa are: *Lakiapollis, Dermatobrevicolporites* and *Verrutriporites.* Not considering the fungal remains, the pteridophytic spores and angiospermous pollen come to 73 and 27 per cent, respectively (Text-fig. 3). The rich representation of local elements, viz., fungal remains and pteridophytic spores, appears to have masked the frequency of the angiospermous elements. The genera which are represented by more than 5 per cent are: *Phragmothyrites, Trichothyrites, Todisporites, Lygodiumsporites, Laevigatosporites, Polypodiisporites* and *Lakiapollis. Lakiapollis* is a dominant taxon constituting more than half of the angiospermous pollen assemblage.

Palaeoclimate

The Amberiwadi assemblage consists of palynofossils having affinities with 25 extant families. Of these, 14 families are restricted to the tropical-subtropical climate, whereas others are cosmopolitan in distribution (Table 1). The prevalence of tropical-subtropical climate with heavy rainfall during the sedimentation of the Ratnagiri beds is evident from the composition of the assemblage and the present day distribution of their nearest extant families. The rich representation of fungal remains is also indicative of warm and humid climate.

Environment of deposition

The present palynoflora contains elements belonging to various ecological groups, viz., montane, fresh water swamps and water edge, mangrove, back-mangrove and sandy beach.

Montane elements—*Clavaperiporites.*

Fresh-water swamps and water-edge elements—*Lygodiumsporites, Striatriletes, Pteridacidites, Laevigatosporites, Monolites, Polypodiisporites, Retipilonapites, Proxapertites.*

Back mangrove and mangrove elements—*Retitricolporites, Favitricolporites, Paleosantalaceaepites, Verrutriporites.*

Sandy beach elements—*Arecipites, Quilonipollenites, Dicolpopollis.*

The qualitative analysis of the Amberiwadi assemblage reveals that the presence of *Lygodiumsporites* and *Striatriletes* is indicative of fresh-water swampy environment. Pollen taxa referable to Potamogetonaceae show aquatic environment. The presence of family Rhizophoraceae (*Paleosantalaceaepites*), Avicenniaceae (*Retitricolporites*) and Gentianaceae (*Favitricolporites*) suggests mangrove vegetation. Back-mangrove elements belonging to family Sonneratiaceae (*Verrutriporites*) are also present in this assemblage. Coastal and shore line elements are represented by *Quilonipollenites, Arecipites, Palmidites* and *Dicolpopollis* related to family Arecaceae. The montane elements belonging to family Thymeliaceae (*Clavaperiporites*) appear to be derived from some distance. From the overall vegetational pattern the environment of deposition appears to be near-shore with sufficient fresh water supply or fresh water swamps nearby, or both.

CONCLUSIONS

On the basis of foregoing account, the following conclusions have been derived:

1. Amberiwadi palynofloral assemblage consists of fungal remains (including spores and fruiting bodies), pteridophytic spores and angiospermous pollen. The bryophytic and gymnospermous elements are totally unrepresented.
2. The fungal remains (40%) are represented by 18 genera and 30 species. Of these, 9 genera and 16 species are of fungal spores.
3. The pteridophytic spores (44%) are represented by 13 genera and 24 species and have been assigned to Cyatheaceae, Osmundaceae, Dicksoniaceae, Schizaeaceae, Lycopodiaceae, Parkeriaceae, Adiantaceae and Polypodiaceae. The spores assigned to Cyatheaceae, Osmundaceae, Schizaeaceae and Polypodiaceae are dominantly present in the Amberiwadi assemblage.
4. The angiospermous pollen (16%) are represented by 28 genera and 38 species and are referable to Arecaceae, Potamogetonaceae, Pandanaceae, Dipterocarpaceae, Gunneraceae, Rubiaceae, Oleaceae, Bombacaceae, Gentianaceae, Thymeliaceae, Malvaceae, Rhizophoraceae, Mimosaceae, Lamiaceae, Sonneratiaceae, Sapotaceae, Avicenniaceae. The members of

Bombacaceae, being represented by *Lakiapollis* are dominant in the assemblage.

5. The palynoflora suggests a warm, humid (tropical-subtropical) climate with heavy rainfall during the deposition of Ratnagiri beds.

6. The environment of deposition has been interpreted as near-shore with sufficient fresh water supply or fresh water swamps nearby or both. The occurrence of a mixture of elements from various ecological groups could be possible only in such condition.

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