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Occurrence of Australian element in the Deccan Intertrappean flora of India

*M. B. Bande, R. C. Mehrotra & Uttam Prakash

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Three new fossil woods, viz., *Eucalyptus dharmendrae* sp. nov., *Tristania confertoides* sp. nov. and *Callistemonoxylon deccanensis* gen. et sp. nov. resembling the modern Myrtaceous taxa *Eucalyptus*, *Tristania conferta* and *Callistemon-Melaleuca* respectively and an infructescence *Callistemonites indicus*, also resembling *Callistemon-Melaleuca*, have been described from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. As all these genera are Australian, their presence in the Deccan Intertrappean flora is phytogeographically important.

Key-words—Xylotomy, *Eucalyptus*, *Tristania*, *Callistemon*, *Melaleuca*, Myrtaceae, Infructescence, Deccan Intertrappean beds (India).

M. B. Bande, R. C. Mehrotra & Uttam Prakash, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226007, India.

साराँश

भारत के दक्खिन अन्तर्ट्रैपी वनस्पतिजात में ऑस्ट्रेलिया के अवयवों की उपस्थिति

मोहन बलवंत बाँडे, राकेश चन्द्र मेहरोत्रा एवं उत्तम प्रकाश

मध्य प्रदेश में मँडला जनपद के दक्खिन अन्तर्ट्रैपी संस्तरों से वर्तमान मिर्टेसी कुल के क्रमशः यूकेलिप्टस, त्रिस्तानिआ कनफ़र्टा एवं केलिस्टीमोन-मिलाल्यूका नामक वर्गकों से मिलते-जुलते तीन काष्ठाश्मों अर्थात् यूकेलिप्टस धरमेंन्द्री नव जाति, त्रिस्तानिआ कनफ़र्टायडिस नव जाति एवं केलिस्टीमोनॉक्सीलॉन दक्खिनेन्सिस नव प्रजाति व जाति तथा केलिस्टीमोनॉयटिस इन्डिकस नामक फलीय अक्ष जो कि केलिस्टीमोन-मिलाल्यूका से मिलता-जुलता है, वर्णित किये गये हैं। चूँकि ये सभी प्रजातियाँ ऑस्ट्रेलिया की हैं अतएव दक्खिन अन्तर्ट्रैपी वनस्पतिजात में इनकी उपस्थिति पादप-भौगोलिक दृष्टि से महत्वपूर्ण है।

INTRODUCTION

THE fossil plants described from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh have added considerably to our knowledge about the early Tertiary flora of India. Their study during the last nearly 15 years has developed a better understanding of the vegetation, climate and phytogeography of Central India during the early Tertiary.

The fossil taxa described from Mandla District were listed by Bande and Prakash (1983) and Mehrotra, Prakash and Bande (1984). Since then three more records have been added. These are: (i) a palm peduncle *Palmostroboxylon arengoidum* Ambwani (1984a), (ii) a palm wood *Palmoxylon dilacunosum* Ambwani (1984b), and (iii) a dicot wood *Canarioxylon shahpuraensis* Trivedi & Srivastava (1985).

Recent investigations on plant fossils on these beds have revealed the occurrence of four characteristic Myrtaceous taxa representing Australian element. As the Australian element has so far not been reported from the early Tertiary beds of India, the present discovery is significant and is reported here. Out of these four new taxa, three are based on silicified woods and one on a petrified infructescence. They represent the taxa *Eucalyptus*, *Tristania*, *Melaleuca* and *Callistemon*.

Regarding the nomenclature of fossil woods the recommendations given by Lakhanpal and Prakash (1980) and further enumerated by Bande (1986) have been followed. Accordingly, two of the fossil woods,

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*The authorship is in alphabetical order.

because of their close anatomical similarities with the modern genera, have been assigned modern generic names. The third wood shows affinities with two genera which can not be distinguished anatomically and hence has been assigned to an organ genus with the suffix *oxylon* added to one of them. As regards the fruiting axis, it has also been placed under an organ genus because more precise identification is not possible on the basis of available data.

SYSTEMATIC DESCRIPTION

Family—Myrtaceae

Genus—*Eucalyptus L'Herit*

Eucalyptus dharmendrae sp. nov.

Pl. 1, figs 1, 3, 4, 6, 7

Material—A single piece of well-preserved secondary wood measuring about 7 cm in length and 5 cm in width.

Description—*Wood* diffuse-porous (Pl. 1, fig. 1). *Growth rings* distinct, demarcated by crowding of vessels and thick-walled fibres. *Vessels* usually small to medium-sized, rarely very small, t.d. 47-137 μm, r.d. 51-185 μm, usually in definite echelon arrangement of 2-10 vessels, sometimes solitary and in clusters, evenly distributed, 13-21 per sq mm, usually circular to oval (Pl. 1, figs 1,3); vessel members 450-690 μm long with oblique to horizontal ends; perforations simple; vessel-tracheid pits usually 1-2 seriate, bordered, in vertical rows, small, about 4-6 μm in diameter, oval to circular in shape (Pl. 1, fig. 7); tyloses present. *Tracheids* vasicentric, associated with parenchyma forming a sheath of 2-5 cells around most of the vessels or vessel groups and joining the vessels radially and tangentially (Pl. 1, fig. 3). *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma occurring as few cells around the vessels; apotracheal parenchyma diffuse and sparse (Pl. 1, figs 1,3); parenchyma cells thin-walled, 13-17 μm in diameter and 20-26 μm in length. *Xylem rays* almost exclusively uniseriate, rarely biseriate, usually made up of procumbent cells only, 13-25 μm in width and 4-36 cells or 90-600 μm in height, 13-18 per mm (Pl. 1, fig. 4); ray tissue mostly homogeneous to rarely weakly heterogeneous due to occasional presence of upright cells (Pl. 1, fig. 6); ray cells thin-walled, usually filled with dark-coloured deposits, 13-26 μm in tangential height and 34-52 μm in radial length. *Fibres* semi-libriform to libriform, circular to angular in cross section, septate, 12-20 μm in diameter and 390-900 μm in length (Pl. 1, figs 3,4).

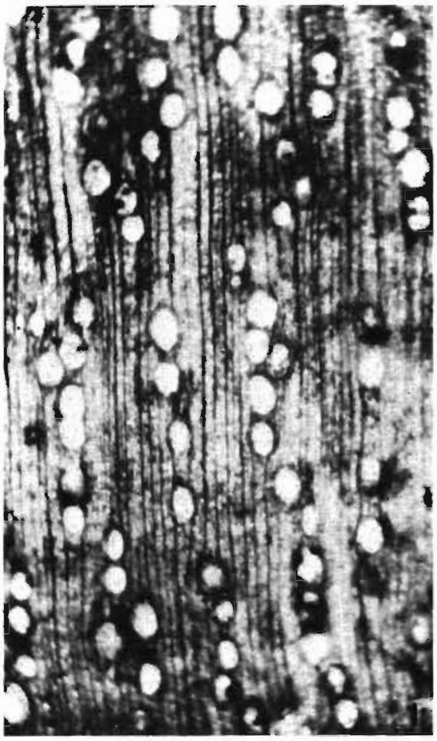
Affinities—The important anatomical characters of the fossil wood, namely small to medium-sized vessels arranged in echelon pattern, both paratracheal and apotracheal type of parenchyma, narrow, homogeneous to weakly heterogeneous xylem rays and vasicentric tracheids, strongly indicate its affinities with the genus *Eucalyptus* L' Hérit of Myrtaceae (Metcalfe & Chalk, 1950; Miles, 1978). For further comparison wood slides of 22 modern species of *Eucalyptus* were examined at the xylaria of the Forest Research Institute, Dehradun and the Birbal Sahni Institute of Palaeobotany, Lucknow. Besides, the photographs and published descriptions of a number of its species were also consulted (Greguss, 1945, p. 128, fig. 156; Kribs, 1959, pp. 122-126, figs 263-272, 439; Miles, 1978, pp. 153-158). It was found that although *Eucalyptus* has some characteristic anatomical features there is a lot of variation within its numerous species. Hence, it is very difficult to differentiate the species on the basis of wood anatomy. However, the fossil was found to have maximum similarity with *E. resinifera* Sm. (F.R.I. Slide no. F. 1236) in the shape, size and distribution of the vessels, structure of the xylem rays and fibres, parenchyma pattern and the presence of vasicentric tracheids and tyloses.

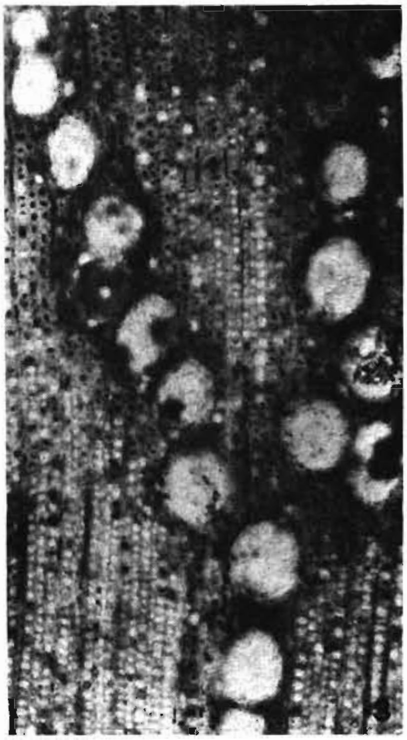
As far as we are aware this is the first record of a fossil wood of *Eucalyptus*. Therefore it has been described as a new species, *E. dharmendrae*. The specific name is after Dr Dharmendra Prasad, who was of great help to us in the collection of this material.

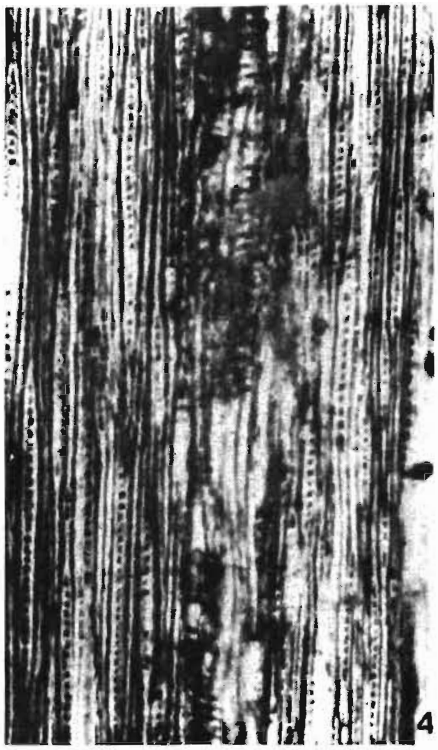
There are not many references to the occurrence of *Eucalyptus* in fossil state. Berry (1915) had mentioned about 50 fossil records of *Eucalyptus* from the

PLATE 1 →

1. *Eucalyptus dharmendrae* sp. nov.—Cross section of the fossil wood in low power showing shape, size and distribution of the vessels. × 30; slide no. 35882-I.
2. *Eucalyptus paniculata*—Cross section of the modern wood showing similar shape, size and distribution of the vessels. × 30.
3. *Eucalyptus dharmendrae* sp. nov.—Magnified cross section of the fossil wood showing oblique pattern of the vessels and the parenchyma distribution. × 80; slide no. 35882—I.
4. *Eucalyptus dharmendrae* sp. nov.—Tangential longitudinal section of the fossil wood showing structure of xylem rays. × 80; slide no. 35882-II.
5. *Eucalyptus paniculata*—Tangential longitudinal section of the modern wood showing similar structure of xylem rays. × 80.
6. *Eucalyptus dharmendrae* sp. nov.—Radial longitudinal section of the fossil wood showing homocellular xylem rays. × 160; slide no. 35882-III.
7. *Eucalyptus dharmendrae* sp. nov.—Magnified vasicentric tracheids of the fossil wood. × 325; slide no. 35882-IV.
8. *Tristania confertoides* sp. nov.—Magnified vasicentric tracheids of the fossil wood. × 660; slide no. 35883-II.







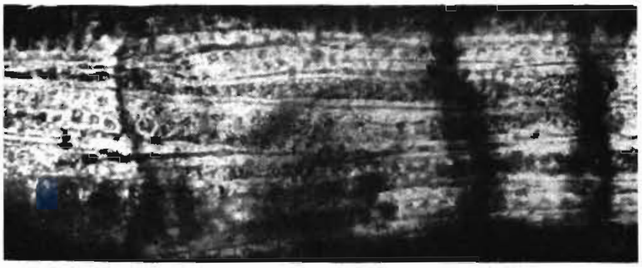


PLATE 1

Cretaceous and Tertiary deposits of North America, Europe and Asia. A leaf fragment showing affinities with *Eucalyptus* was described as *Eucalyptophyllum oblongifolium* from the Cretaceous of Virginia, U.S.A. (Fontaine, 1889). From India the only record is by Varma (1968) who described a leaf impression, *Eucalyptophyllum raoi*, from the Middle Siwalik beds of Hardwar. Awasthi (1982) considered this finding in the Tertiary of India as highly improbable. However, in the light of the present discovery, the occurrence of *Eucalyptus* in the Neogene flora of India should not be ruled out and deserves a verification.

Holotype—B.S.I.P. Museum specimen no. 35882.

Locality—Ghughua (23°7′ N 80°37′E) near Shahpura, Madhya Pradesh.

Horizon—Deccan Intertrappean beds.

Age—Early Tertiary.

Genus—*Tristania* R. Br.

Tristania confertoides sp. nov.

Pl. 1, fig. 8; Pl. 2, figs 9, 11, 13

Material—A single piece of secondary wood measuring 12 cm in length and 8 cm in width.

Description—*Wood* diffuse-porous (Pl. 2, fig. 9). *Growth rings* absent. *Vessels* mostly medium-sized, occasionally small to large, t.d. 65-258 µm, r.d. 75-280 µm, almost exclusively solitary, rarely in radial pairs, evenly distributed, 8-16 per sq mm, usually circular to oval when solitary, with flat contact walls when in pairs (Pl. 2, fig. 9); vessel members 250-900 µm long with transverse to oblique ends; perforations simple; vessel-tracheid pits 1-2 seriate, bordered, opposite to alternate, small, about 4 µm in diameter, circular to oval in shape with linear apertures (Pl. 1, fig. 8); tyloses occasionally present. *Tracheids* vasicentric, forming a thin sheath around most of the vessels. *Parenchyma* apotracheal appearing scanty diffuse (Pl. 2, fig. 9); parenchyma cells thin-walled, 16-20 µm in diameter and 48-64 µm in length. *Xylem rays* closely spaced, 8-11 per mm, usually uniseriate, sometimes biseriate, made up of procumbent cells only, 24-52 µm in width and 6-26 cells or 82-430 µm in height (Pl. 2, fig. 11); ray tissue homogeneous (Pl. 2, fig. 13); ray cells thin-walled, 34-56 µm in radial length and 12-20 µm in tangential height. *Fibres* semi-libriform with big lumen, polygonal in cross section, non-septate, 8-12 µm in diameter and 300-775 µm in length (Pl. 2, figs 9, 11).

Affinities—Presence of almost exclusively solitary vessels, diffuse parenchyma, usually uniseriate xylem rays, non-septate fibres and vasicentric tracheids are the important anatomical characters of the fossil wood, which indicate its affinities with the family Myrtaceae (Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Kribs, 1959; Normand, 1960; Miles, 1978). Amongst the various genera of Myrtaceae the fossil wood shows maximum resemblance with *Xanthostemon* F. Muell. and *Tristania* R. Br. in distribution of vessels, parenchyma pattern, structure of the fibres and presence of usually uniseriate xylem rays (Kribs, 1959; Miles, 1978). However, in *Xanthostemon* and some species of *Tristania*, the xylem rays are heterogeneous as against the homogeneous xylem rays of the present fossil wood (Metcalfe & Chalk, 1950, p. 627; Kribs, 1959, p. 127; Miles, 1978, p. 159). Consequently, the affinities of the fossil wood should be traced among those species of *Tristania* which possess homogeneous xylem rays. Three such species of *Tristania*, viz., *T. conferta* R. Br., *T. laurina* R. Br. and *T. suaveolens* Sm. were available for study. After a detailed comparison it was found that the fossil wood is very close to *T. conferta* (B. S. I. P. slide nos. 919, 1214, 762; Pl. 2, figs 10, 12) in almost all the anatomical characters.

This is the first record of a fossil wood of *Tristania* and hence has been placed under a new species, *T. confertoides*, indicating its close resemblance with modern *T. conferta*.

Fossil records of the genus *Tristania* are very few. *Tristania*-like fruits have been described as *Tristanites* by Saporta (1865) who described its infructescence as *T. cloeziaeformis* from the Tertiary of Armissan, France (Andrews, 1970). Fruits resembling *Tristania* are also

PLATE 2

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9. *Tristania confertoides* sp. nov.—Cross section of the fossil wood showing shape, size and distribution of the vessels. × 30; slide no. 35883-I.
10. *Tristania conferta*—Cross section of the modern wood in low power showing similar shape, size and distribution of the vessels. × 30.
11. *Tristania confertoides* sp. nov.—Tangential longitudinal section of the fossil wood showing structure of the xylem rays and fibres. × 80; slide no. 35883-II.
12. *Tristania conferta*—Tangential longitudinal section of the modern wood showing similar structure of the xylem rays and fibres. × 80.
13. *Tristania confertoides* sp. nov.—Radial longitudinal section of the fossil wood showing homocellular xylem rays. × 125; slide no. 35883-III.
14. *Callistemonoxylon deccanensis* gen. et sp. nov.—Cross section of the fossil wood showing shape, size and distribution of the vessels. × 40; slide no. 35884-I.
15. *Melaleuca quinquenervia*—Cross section of the modern wood showing similar shape and distribution of the vessels. × 40.
16. *Callistemonoxylon deccanensis* gen. et sp. nov.—Radial longitudinal section of the fossil wood showing heterocellular rays. × 80; slide no. 35884-III.
17. *Callistemonoxylon deccanensis* gen. et sp. nov.—Magnified vasicentric tracheids of the fossil wood. × 325; slide no. 35884-III.

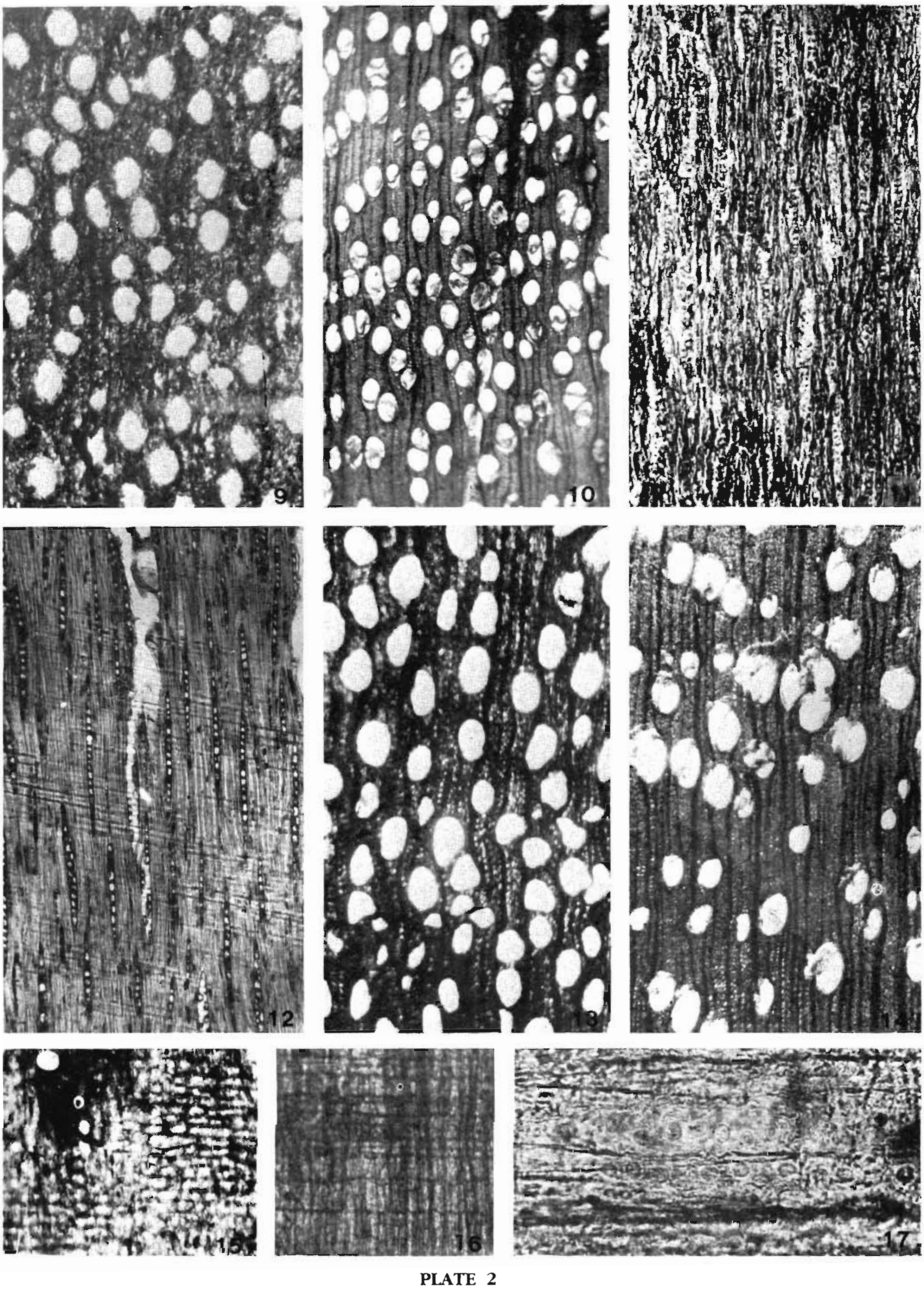

PLATE 2

known from the Miocene of Australia (Berry, 1915, p. 490). Deane (1902, 1923) has also described *Tristanites angustifolia* as well as leaves resembling *Tristania* from the Tertiary of Australia (Andrews, 1970).

Holotype—B. S. I. P. Museum specimen no. 35883.

Locality—Umaria (23° 6′ N 80°38′ E) near Shahpura, Madhya Pradesh.

Horizon—Deccan Intertrappean beds.

Age—Early Tertiary.

Genus—*Callistemonoxylon* gen. nov.

Callistemonoxylon deccanensis sp. nov.

Pl. 2, figs 14, 16, 17; Pl. 3, fig. 18

Material—A piece of secondary wood measuring about 10 cm in length and 6 cm in width.

Description—*Wood* diffuse-porous (Pl. 2, fig. 14). *Growth rings* absent. *Vessels* small to large-sized, t.d. 60-250 μm, r.d. 80-215 μm, almost always solitary, very rarely in radial and tangential pairs, evenly distributed, 15-25 per sq mm, circular to oval, sometimes variously shaped (Pl. 2, fig. 14); vessel members 190-525 μm long with oblique to transverse ends; perforations simple; vessel tracheid pits 1-2 seriate, bordered, alternate, about 6-8 μm in diameter, circular to oval in shape (Pl. 2, fig. 17); tyloses rarely present. *Tracheids* vasicentric forming a thin sheath around the vessels. *Parenchyma* scanty paratracheal (Pl. 2, fig. 14); parenchyma cells thin walled, 50-84 μm in length and 16-25 μm in diameter. *Xylem rays* 1-3 (rarely 4) seriate, 7-10 per mm; ray tissue heterogeneous (Pl. 2, fig. 16); rays of two types, (a) uniseriate rays made up of upright cells only, 8-12 μm in width and 1-8 cells or 45-290 μm in height, (b) multiseriate rays made up of procumbent cells in the central portion and 1-4 rows of upright cells at one or both the ends, 16-34 μm in width and 8-24 cells or 240-856 μm in height (Pl. 3, fig. 18); sheath cells occasionally present; ray to ray fusion observed; ray cells thin-walled, procumbent cells 28-64 μm in radial length and 12-21 μm in tengential height; upright cells 16-30 μm in radial length and 54-85 μm in tangential height (Pl. 2, fig. 16). *Fibres* semi-libriform, oval to angular in cross section, usually non-septate, occasionally septate, 12-20 μm in diameter and 425-935 μm in length (Pl. 2, fig. 14; Pl. 3, fig. 18).

Affinities—The important anatomical characters of the fossil wood, viz., almost exclusively solitary vessels, vasicentric tracheids, scanty paratracheal parenchyma and narrow to moderately broad, heterogeneous xylem rays, indicate its affinities with the family Myrtaceae (Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Kribs, 1959; Miles, 1978; Purkayastha, Shahi & Taneja, 1982). A detailed comparison of the present fossil with various genera of Myrtaceae from their wood slides, published descriptions and figures (Metcalfe & Chalk, 1950, pp. 624-628, figs 140-141; Kribs, 1959, pp. 122-127, figs 263-275, 439; Miles, 1978, pp. 153-159; Purkayastha, Shahi & Taneja, 1982, pp. 1-17, figs 559-584) indicates that its affinities should be traced amongst various species of *Callistemon* R. Brown and *Melaleuca* L.

Thin sections of eight species of *Callistemon* and 16 species of *Melaleuca* were studied and it was found that it is not possible to distinguish these two genera anatomically. A detailed comparison of the fossil wood with all the available species of both these genera indicates that its closest affinities are with two species of *Melaleuca*, *M. quinquenervia* (Cav.) S. T. Blakeand *M. linariifolia* Sm. However, our fossil differs from *M. quinquenervia* in the structure of xylem rays which are comparatively narrower in the modern species. On the other hand *Melaleuca linariifolia* shows closer proximity in having similar rays but it differs from the fossil in having apotracheal parenchyma and comparatively smaller vessels.

As it is not possible to differentiate the genera *Callistemon* and *Melaleuca* on the basis of wood anatomy, a new organ genus *Callistemonoxylon* has been constituted to include fossil woods of both these genera and the fossil has been assigned to it. Its specific name *C. deccanensis* indicates its occurrence in the Deccan Intertrappean flora.

PLATE 3

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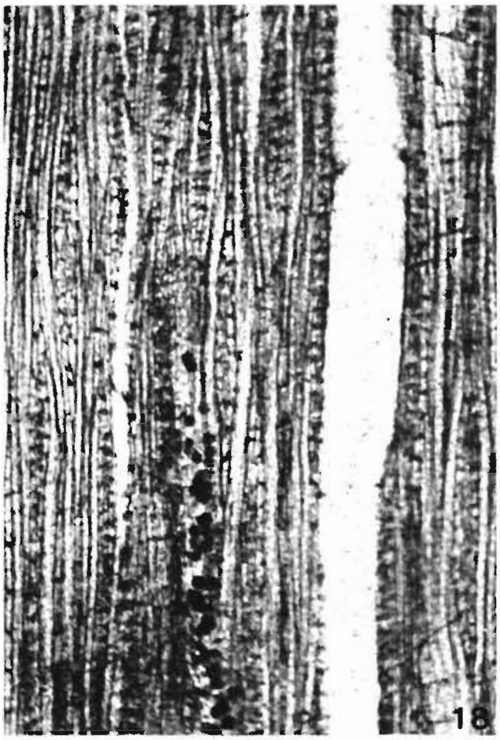
18. *Callistemonoxylon deccanensis* gen. et sp. nov.—Tangential longitudinal section of the fossil wood showing structure of the xylem rays and fibres. × 90; slide no. 35884-II.
19. *Melaleuca quinquenervia*—Tangential longitudinal section of the modern wood showing similar structure of the xylem rays and fibres. × 90.
20. *Callistemonites indicus* gen. et sp. nov.—Fossil infructescence-1 under reflected light showing shape, size and arrangement of the fruits. × 1; speciment no. 35885.
21. *Callistemonites indicus* gen. et sp. nov.—Fossil infructescence-2 under reflected light showing shape, size and arrangement of the fruits. × 1; specimen no. 35885.
22. *Callistemonites indicus* gen. et sp. nov—Fossil infructescence-3 under reflected light showing shape, size and arrangement of the fruits. × 1; specimen no., 35885.
23. *Melaleuca leucadendron*—Infructescence of the modern plant showing similar shape, size and arrangement of the fruits. × 1.
24. *Callistemon lanceolatus*—Infructescence of the modern plant showing similar shape, size and distribution of the fruits. × 1.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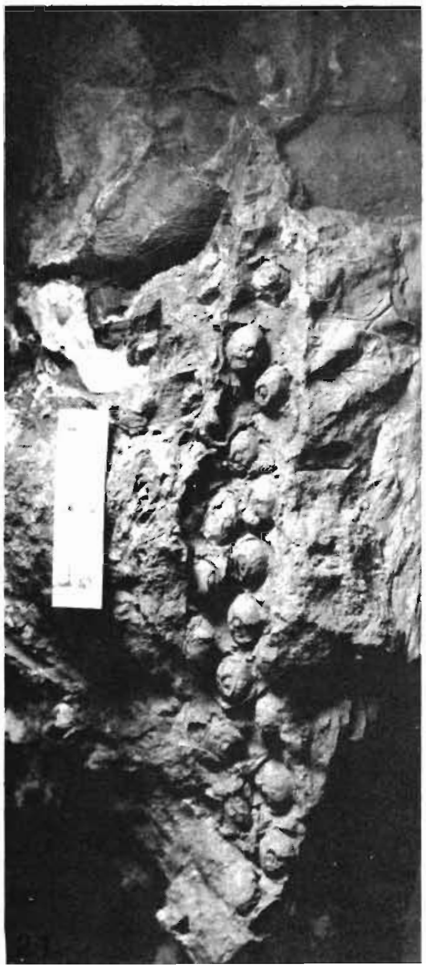
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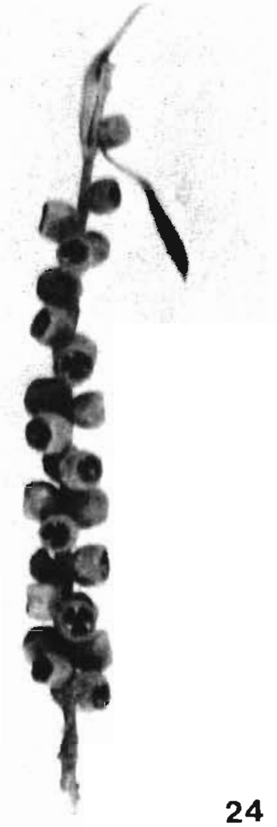
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PLATE 3

GENERIC DIAGNOSIS

***Callistemonoxylon* gen. nov.**

Wood diffuse-porous. *Growth rings* usually absent or indistinct, demarcated by denser zone of fibres. *Vessels* small to large-sized, usually exclusively solitary, very rarely in radial or tangential pairs; perforations simple. *Tracheids* vasicentric. *Parenchyma* scanty paratracheal. *Xylem rays* 1-4 seriate; ray tissue heterogeneous. *Fibres* libriform to non-libriform, septate or non-septate.

Genotype—*Callistemonoxylon deccanensis* sp. nov.

SPECIFIC DIAGNOSIS

Callistemonoxylon deccanensis sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* small to large-sized, t.d. 60-250 μm, r.d. 80-215 μm, usually exclusively solitary, rarely in radial or tangential pairs, 15-25 per sq mm; tyloses rarely present; vessel members 190-525 μm long with oblique to transverse ends; perforations simple; vessel-tracheid pits 1-2 seriate, bordered, alternate, about 6-8 μm in diameter, circular to oval in shape. *Parenchyma* scanty paratracheal. *Xylem rays* 1-3 (rarely 4) seriate, 7-10 per mm; ray tissue heterogeneous, uniseriate rays made up of upright cells, multiseriate rays made up of procumbent cells in the central portion and 1-4 rows of upright cells at one or both the ends. *Fibres* semi-libriform, oval to angular in cross section, mostly non-septate, occasionally septate, 12-20 μm in diameter and 425-935 μm in length; interfibre pits could not be seen.

Holotype—B. S. I. P. Museum specimen no. 35884.

Locality—Ghughua (23°7′N 80°37′E) near Shahpura, Madhya Pradesh.

Horizon—Deccan Intertrappean beds.

Age—Early Tertiary.

Genus—*Callistemonites* gen. nov.

Callistemonites indicus gen. et sp. nov.

Pl. 3, figs 20-22

Material—The material consists of two chert pieces, one of them bearing two and the other with three incomplete infructescences. Transverse and longitudinal sections of some of the fruits were prepared to study their internal structure but due to poor preservation no anatomical details were available. This study is, therefore, based only on the external morphological characters.

Description—The infructescences are 4-12 cm in length and 1-2 cm in diameter, made up of 6-34 small fruits (Pl. 3, figs 20-22). The fruits are sessile and usually spirally arranged giving the appearance of a spike. They are mostly ovoid, measuring 8/4 mm in size. A cup-shaped perianth encloses each fruit to most of its length with a circular to truncate opening about 2-3 mm in diameter near the apex.

Affinities—The important morphological characters of the fossil are spike-like infructescence consisting of a number of fruits enclosed by persistent, cup-shaped perianth. These features are found in both the monocotyledons and dicotyledons and show affinities of the fossil with the families Bromeliaceae and Burmanniaceae of monocotyledons and Phytolaccaceae, Basellaceae, Lauraceae, Lythraceae, Myrtaceae, Plumbaginaceae, Symplocaceae and Plantaginaceae amongst the dicotyledons (Hooker, 1872-1897; Lawrence, 1964; Hutchinson, 1979). After going through the various genera belonging to these families at the Herbaria of the Forest Research Institute, Dehradun and National Botanical Research Institute, Lucknow, it was found that the fossil infructescence shows close resemblance with that of *Callistemon* R. Br. and *Melaleuca* L. of Myrtaceae. Ten species of *Callistemon* and 17 species of *Melaleuca* were examined in detail and it was found that fruits of both *Callistemon* and *Melaleuca* are almost identical and it is not possible to separate them from each other (N. B. R. I. Herbarium Sheet nos. 41318, 20258, 72405, 72452) on the basis of external morphology. However, the present fossil shows maximum similarities with the infructescences of *Callistemon brachyandrus* Lindl., *C. lanceolatus* DC., *C. paludosa* R. Br., *C. salignus* DC., *Melaleuca gibbosa* Labill., *M. glomerata* F. Muell., *M. leucadendron* Linn., *M. styphelioides* Sm. and *M. uncinata* R. Br. especially in shape, size and arrangement of the fruits (Pl. 3, figs 23, 24).

As the present fossil shows close affinities with *Callistemon* and *Melaleuca* whose infructescences can not be differentiated, it has been placed under a new organ genus *Callistemonites* which stands for the fossil infructescences of both *Callistemon* and *Melaleuca*. The species has been named as *Callistemonites indicus* indicating its occurrence in the Indian strata.

As far as the authors are aware, *Melaleuca* is not known in the fossil state, whereas *Callistemon* has been identified in both the Upper Cretaceous and the Tertiary of Europe. According to Berry (1915) not less than 25 fossil species have been referred to the genus *Callistemophyllum* Ettingshausen. These include Upper Cretaceous forms in both America and Europe, Eocene or Oligocene forms from Greenland, and numerous Oligocene and Miocene species in Europe and Australia.

GENERIC DIAGNOSIS

***Callistemonites* gen. nov.**

Spike-like infructescence made up of a number of ovoid, small fruits enclosed by persistent, cup-shaped perianth.

Genotype—*Callistemonites indicus* sp. nov.

SPECIFIC DIAGNOSIS

Callistemonites indicus sp. nov.

Incomplete spike-like infructescence, 4-12 cm in length and 1-2 cm in diameter, made up of 6-34, small fruits. *Fruits* spirally arranged, ovoid in shape measuring 8/4 mm in size and enclosed by persistent, cup-shaped perianth. Each fruit has a circular to truncate opening at the apex measuring 2-3 mm in diameter.

Holotype—B. S. I. P. Museum specimen no. 35885.

Paratype—B. S. I. P. Museum specimen no. 35886.

Locality—Ghughua (23°7′N 80°37′E) near Shahpura, Madhya Pradesh.

Horizon—Deccan Intertrappean beds.

Age—Early Tertiary.

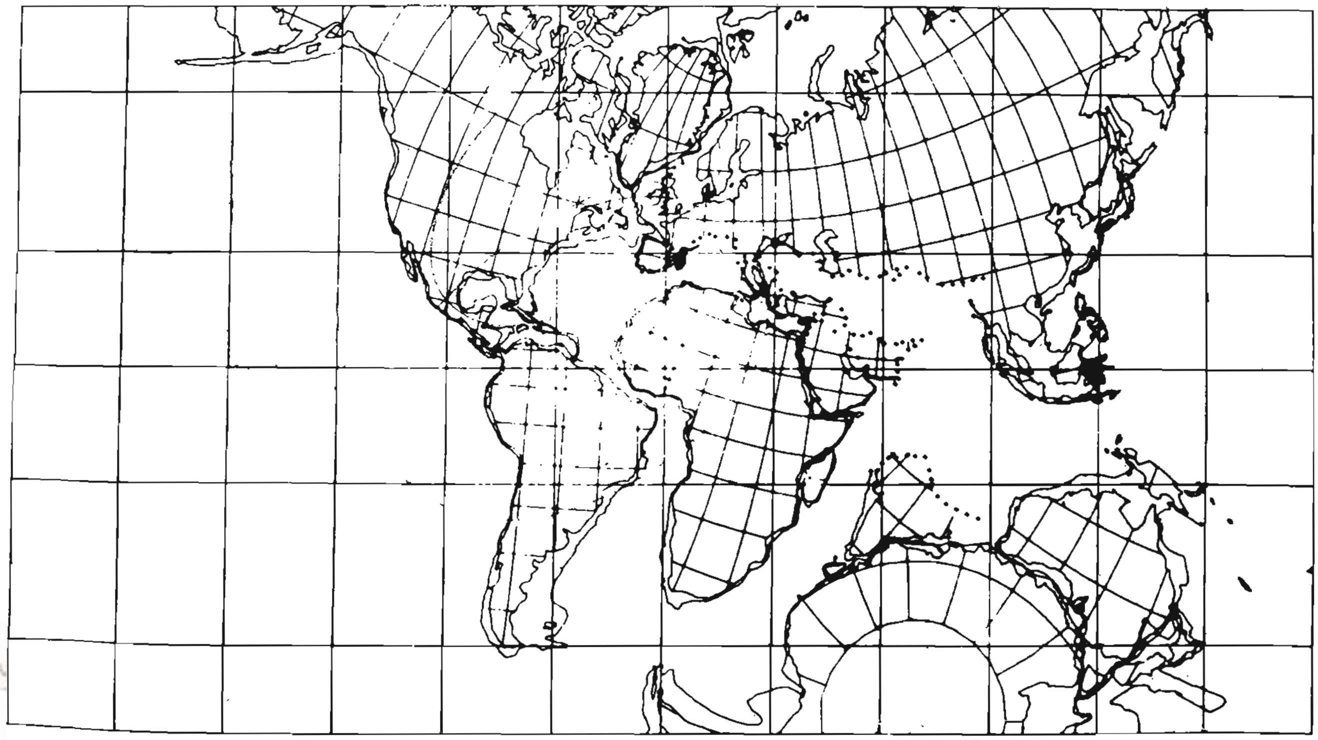
DISCUSSION

Ever since the discovery of *Rodeites dakshini* Sahni (1943) and *Cyclanthodendron sahnii* (Rode) Sahni & Surange (1944, 1953) the possible occurrence of plant taxa belonging to the Gondwanaland continents other than India, has been suspected in the Deccan Intertrappean flora. While *Rodeites* shows affinities with *Regnellidium*, a water fern of Brazil, *Cyclanthodendron* has been said to possess affinities with the tropical American family Cyclanthaceae. Like the Central and South American forms, the presence of tropical African element in the Deccan Intertrappean flora is evidenced by a fossil fruit comparable with the branched palm *Hyphaene* from Ghughua (Bande, Prakash & Ambwani, 1982). Although one species of this palm *Hyphaene indica*, does grow along the western coast in India, all the other 40 species of this genus are distributed in tropical and subtropical Africa and Arabia. Similarly, the occurrence of a palm wood (from the same locality—Ghughua) resembling *Chrysalidocarpus*, a genus presently growing in Madagaskar is a further evidence in the same direction (Ambwani & Prakash, 1983).

Araucariaceae is supposed to be a southern hemisphere family (Sporne, 1971). It is represented in the Deccan Intertrappean flora as a cone as well as a petrified wood (Prakash, 1957, 1962; Lakhanpal, Prakash & Bande, 1977). This is yet another evidence of the occurrence of some common plant taxa in India and other Gondwanaland continents during the Early Tertiary.

With this background it should not be surprising to find in the Deccan Intertrappean flora also an element from Australia, an another continent belonging to the Gondwanaland. However, its occurrence in these beds deserves a critical analysis.

Although plantations of *Eucalyptus* are a common sight at present in various parts of the country, phytogeographically the genus is not indigenous to India. It was introduced in this country in the late 18th Century (Gamble, 1972). The genus consisting of about 500 species is mainly distributed in Australia.



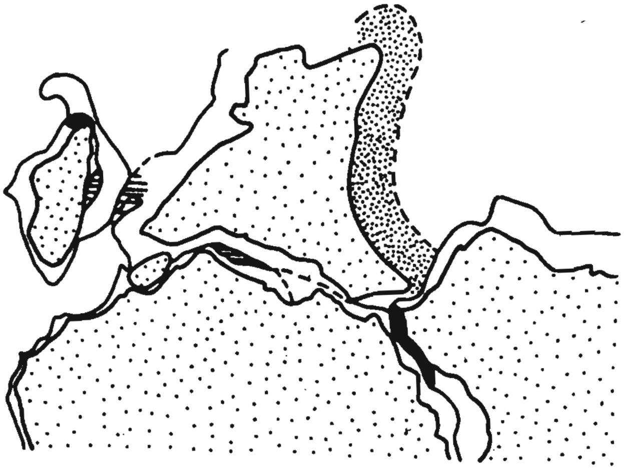
Map 1—Position of the Indian Plate 100 million years ago (after Smith & Briden, 1979).

The other genus *Tristania* comprises trees or tall shrubs, of which about 50 species are distributed in Malaysia, Queensland, New Caledonia, Australia, Fiji, Burma and India. However, *Tristania conferta* with which the fossil wood described in this paper shows affinity is found in North Australia, Queensland and New South Wales (Bentham, 1866; Santapau & Henry, 1973; Willis, 1973).

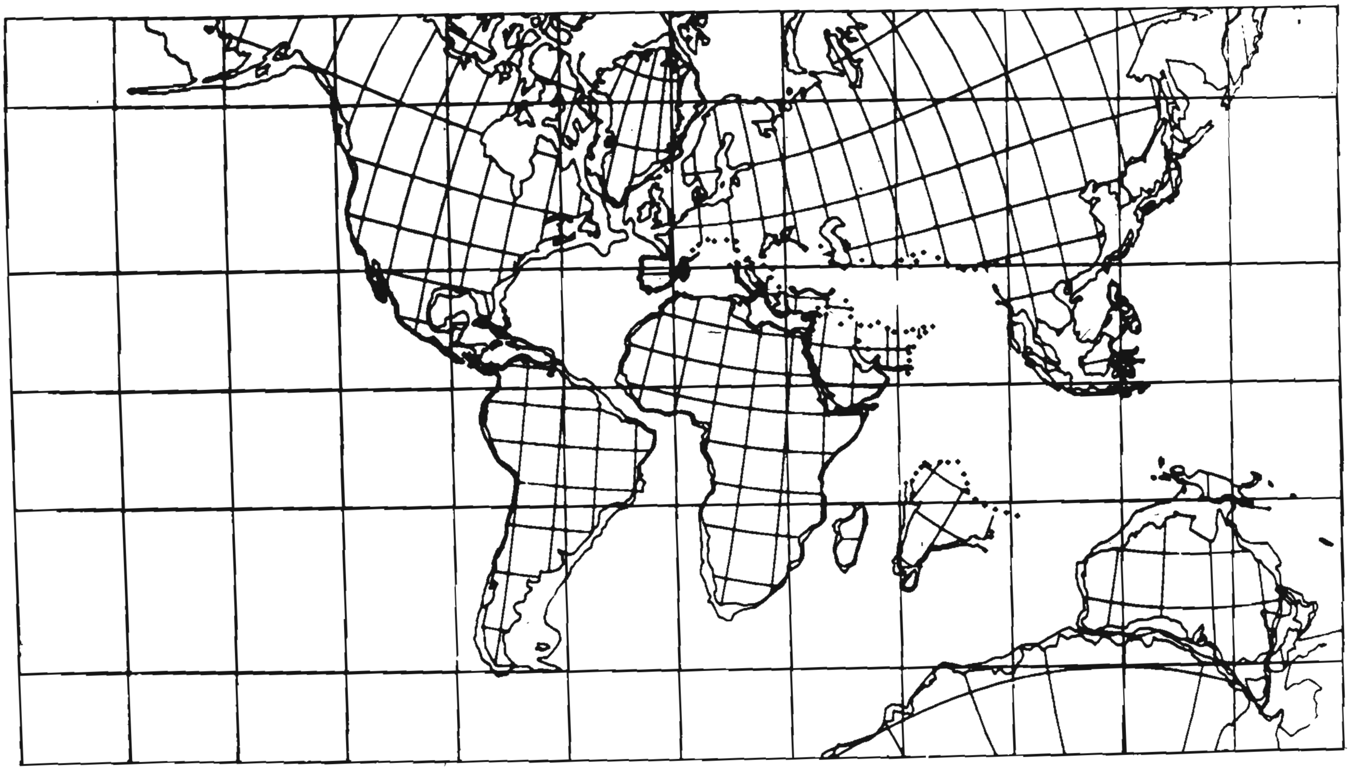
The third genus, *Melaleuca* is also a tropical form consisting of about 100 species of trees and shrubs which occur in Australia and the Pacific (Bentham, 1866; Willis, 1973). Only one species *M. leucadendron* is found in the Indian subcontinent. However, *M. linariifolia* and *M. quinquenervia*, with which the fossil wood described here shows close resemblance, are confined to Australia.

Lastly, the genus *Callistemon* with which the fruiting axis described in the previous pages shows resemblance is also a tropical genus of about 25 species of tall shrubs or small trees distributed in Australia and New Caledonia (Bentham, 1866; Willis, 1973). Thus the finding of all these Australian taxa in the Deccan Intertrappean beds of Mandla District furnishes a definite evidence for the occurrence of some common plants in India and Australia during the early Tertiary times when these beds were deposited.

The study of the Mesozoic and Cenozoic palaeocontinental maps given by Smith and Briden (1979) indicates that as late as mid-Cretaceous (100 million years back) India and Australia were situated roughly at the same latitudes and interconnected through Antarctica (Map 1). In their revised reconstruction of the southern continents Barron, Harrison and Hay (1978) have even suggested that the north eastern tip of India lay in direct contact with Australia (Map 2).



Map 2—Position of India, Antarctica and Australia showing direct connections of the Indian Plate with the Australian Plate (after Barron, Harrison & Hay, 1978).



Map 3—Position of the Indian Plate 80 million years ago (after Smith & Briden, 1979).

Whether we accept the position of India, Australia and Antarctica as suggested by Smith and Briden or by Barron, Harrison and Hay, it is apparent that during the Late Cretaceous or even a little later India and Australia must have enjoyed a similar type of climate permitting the existence of some common plant taxa. A study of the palaeocontinental maps of successive ages shows that Late Cretaceous onwards India started its northward journey towards Asia. Subsequently, this resulted in an entirely different latitudinal position for India in comparison to Australia, and a consequent change of climatic conditions ultimately leading to the extinction of Australian taxa from India.

The occurrence of Myrtaceous genera in the Deccan Intertrappean flora raises another point which needs consideration. Myrtaceae is considered to be one of the most primitive families of the dicotyledons with an advancement index of 27 (Sporne, 1977). Long ago, Berry (1915) suggested that America was the original home of the family. However, in the light of present finding Berry's statement needs critical analysis. Obviously, further studies are needed to throw more light on the origin and diversification of this family.

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The Palaeobotanist **35**(1) : 13-21, 1986.

Thinnfeldia indica Feistmantel and associated plant fossils from Tiruchirapalli District, Tamil Nadu

Hari K. Maheshwari

ABSTRACT

Maheshwari, Hari K. (1986). *Thinnfeldia indica* Feistmantel and associated plant fossils from Tiruchirapalli District, Tamil Nadu. *Palaeobotanist* **35**(1) : 13-21.

Plant mega-and microfossils recovered from the Teraini clay pits and a tube well near Naicolam, both in Tiruchirapalli District, have been listed. Cuticular features of *Thinnfeldia indica* Feistmantel have been described in detail and its affinities traced to the cycads. On the basis of totality of characters, an independent taxonomic status of the genus *Thinnfeldia* vis-a-vis the genera *Dicroidium* and *Pachypteris* is confirmed. Data pertaining to the age of Utatur plant beds are briefly reviewed.

Key-words—*Thinnfeldia*, Cuticle, Cycadales, Sivaganga Formation, Palynofossils, Lower Cretaceous (India).

Hari K. Maheshwari, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226007, India

साराँश

तमिलनाडु में तिरुचिरापल्ली जनपद से थिन्फ़ेल्डिआ इन्डिका फ़ाइस्टमॅन्टॅल एवं सहयुक्त पादपाश्म

हरिकृष्ण माहेश्वरी

तेरानी मृत्तिका गर्त्तों एवं नैकोलम् के समीप एक नलकूप से उपलब्ध गुरु-एवं सूक्ष्मपादपाश्मों की तालिका दी गई है। ये दोनों स्थान तिरुचिरापल्ली जनपद में हैं। थिन्फ़ेल्डिआ इन्डिका फ़ाइस्टमॅन्टॅल के उपचर्मीय लक्षणों का विस्तृत वर्णन किया गया है तथा साइकेडेल्स से इसकी सजातीयतायें अन्वेषित की गई हैं। सम्पूर्ण लक्षणों के आधार पर डाइक्रोयडियम और पेकिप्टेरिस की तुलना में थिन्फ़ेल्डिआ प्रजाति का एक स्वतन्त्र वर्गीकरणिक स्थान सुनिश्चित किया गया है। उत्तातुर पादप संस्तरों की आयु सम्बन्धी आँकड़ों की संक्षिप्त रूप से समीक्षा भी की गई है।

INTRODUCTION

ON the East Coast of India, in the districts of Cuttack, Krishna Godavari, Nellore, Guntur, Chingleput, Tiruchirapalli and Ramanathapuram, occurs a series of small exposures of 'Upper Gondwana' rocks. Some of these contain plant fossils associated with marine animals. The plant remains usually occur as impressions though carbonaceous matter is not entirely unknown, having been found in Siddheswar Hill near Cuttack, and in the subsurface near Naicolam. A majority of the plant fossils recovered from these sediments resembles the ones from the Rajmahal Intertrappean Beds, though a few species are allied to the Jabalpur forms.

In the Tiruchirapalli District, the Upper Gondwanas are represented by the 'Uttatur Plant Beds' which directly rest upon the Archaean gneiss. These beds, which occur in five small isolated patches along a 20 kilometer long north-south strip, are unconformably overlain by the marine beds (Utatur Formation) of Upper Cretaceous age. These beds, later named as "Terani Beds" by Shah and Singh (1972) after the village Teraini (Terani, Terany, 11°6' : 18°52'30") have a white and ash-grey clay as the predominant lithology.

Acharyya, Singh and Ghosh (1977, p. 85) include the Uttatur Plant Beds and Teraini Beds in the Sivaganga Formation whose outcrop thickness is not known but in subsurface is estimated to be more than 1090 meters. That the Uttatur Plant Beds occur within the Sivaganga Formation is yet to be convincingly demonstrated. The type section of the Sivaganga Formation is exposed near Paiyur (9°51' : 78°31') which is more than 75 kilometers south of Uttatur (11°04' : 78°55'). In the type area the formation comprises a basal conglomerate overlain by alternating shales and grits. The "Uttatur Pland Beds" on the other hand comprise predominantly white and ash-grey clays with subordinate ferruginous and argillaceous sandstones.

The plant fossils from the Utatur Plant Beds of the Tiruchirapalli District were first reported by Foote (1878). Plant fossils recorded from different locations were listed by Feistmantel (1879, p. 9-11). Somehow, all these records were missed by Lakhanpal *et al.* (1976) in their *Catalogue of Indian Fossil Plants.* Feistmantel's list, with names updated, is as follows : (numerals in parentheses represent the localities, 1. Naicolam, 2. Utatur, 3. Teraini, 4. Between Teraini and Kari, 5. North of Kalpadi, and 6. Marvatur).

Todites indicus (Oldham & Morris) Bose & Sah (2, 3)
Ptilophyllum acutifolium Morris (1, 2, 3, 6)
P. cutchense Morris (?2, 5)
P. cutchense var. *minimum* Feistmantel (4)
Otozamites angustatus Feistmantel (1, 3)
Dictyozamites indicus Feistmantel (3, 6)
Taeniopteris spathulata McClelland (2, 3, 5, 6)
Macrotaeniopteris ovata Schimper (6)
Araucarites ?indicus (6)
Elatocladus conferta (Morris) Seward & Sahni (3)
E. jabalpurensis (Feistmantel) Sahni (3)
Echinostrobus (3)
Pachyphyllum? (2)
Pterophyllum? *Macrotaeniopteris*? (5)

Gopal, Jacob and Jacob (1957, p. 494, table 3) listed following additional forms from the "Uttatur" of Tiruchirapalli :

Otozamites rarinervis
Dictyozamites falcatus
Taeniopteris ovata
Elatocladus plana
Araucarites cutchensis
Actinopteris sp.

Some more taxa were added to the flora of the Teraini bed by Mamgain, Sastry and Subbaraman (1973). They also found three taxa of ammonites associated with *Ptilophyllum cutchense* in a 2 meter thick ash-grey clay and sandy clay. The fossils recorded include :

Ptilophyllum cutchense
Pseudoctenis footeanum
Nilssonia fissa
Rhizomopteris sp.
Desmiophyllum sp.
Araucarites sp. cf. *A. cutchense*
?*Ginkgoites* sp., and the ammonites
Pascoeites sp. cf. *P. crassus*
Gymnoplites sp. cf. *G. simplex*, and
?*Inoceramus* sp.

In the present communication plant fossils are recorded from two of Foote's localities, and the cuticular structure of one of the species is also illustrated.

MATERIAL

The plant fossils, both mega- and micro-, reported here were collected from (1) Teraini clay pits, and (ii) shale dumps of a tube well near Naicolam, Tiruchirapalli District, Tamil Nadu. The fossils from the Teraini clay pits are impressions on a grey-buff, micaceous sandy shale. The Naicolam fossils occur in a grey, micaceous-carbonaceous, carbonaceous, coarse- to fine-grained shale. Sometimes, the carbonified crust of the fossil is also present, though very rarely it yielded the cuticle. All hand specimens and cuticular preparations are in the repository of Birbal Sahni Institute of Palaeobotany, Lucknow.

CHECKLIST OF FOSSIL PLANTS

Leaves (*with well-preserved cuticle)

Ptilophyllum acutifolium Morris
P. cutchense Morris
Dictyozamites indicus Feistmantel
Otozamites sp.
**Thinnfeldia indica* Feistmantel
Taeniopteris spathulata McClelland
**Elatocladus heterophylla* Halle
E. conferta (Morris) Seward & Sahni
**Pagiophyllum marwarensis* Sukh Dev & Bose
Araucarites cutchensis Feistmantel

Pollen and spores—(figure in parentheses indicates the per cent occurrence of the genus as calculated from a count of 600 identifiable specimens) :

Cyathidites minor Couper
Deltoidospora hallei Miner (1.66%)
Biretisporites sp.
Gleicheniidites sp.
Osmundacidites wellmanii Couper (0.33%)
Neoraistrickia sp.
Klukisporites sp.
Contignisporites fornicatus Dettmann (2.83%)
C. glebulentus Dettmann
Cooksonites sp. (0.8%)
Trilites tuberculaeformis Dettmann
Monolites grandis Dev (0.33%)
Thymospora sp. (1.5%)
Callialasporites dampieri (Balme) Dev (24.5%)
C. trilobatus (Balme) Srivastava
Araucariacites + *Inaperturopollenites* (47.0%)
Podocarpidites ellipticus Cookson (7.0%)
Alisporites spp. (9.5%)
Vitreisporites pallidus Reissinger (1.83%)
Cedripites nudis Kar & Sah (0.66%)
Microcachryidites antarcticus Cookson

DESCRIPTION

Thinnfeldia indica Feistmantel

Pl. 1, figs 1, 4; Pl. 2, figs 1-6

1876 *Thinnfeldia indica* Feistmantel, *Rec. geol. Surv. India* **9**(2) : 35.

1877 *Thinnfeldia indica* Fstm. : Feistmantel, *Mem. geol. Surv. India Palaeont. indica* **2** : 35, pl. 39, fig. 1, 1a; pl. 47, figs 1, 2, 2a.
1914 *Thinnfeldia indica* Feistm. : Antevs, *K. svenska VetenskAkad. Handl.* **51**(6) : 36, pl. 5, fig. 3.
1979 *Thinnfeldia indica* Feistmantel, 1876 : Zeba-Bano, Maheshwari & Bose, *Palaeobotanist* **26** : 145, pl. 1, figs 1-6; pl. 2, figs 8, 9; text-fig. 2 A-D.

Morris (in Oldham & Morris, 1863) reported an incomplete specimen possibly representing the apical part of a fern frond, from Teladuni near Ghutiari, Rajmahal Hills, Bihar, under the name *Pecopteris* (?) *salicifolia* n. sp., though he found it rather nearer to *Kirchneria trichomanoides* Braun. Feistmantel (1876, 1877) described and illustrated a number of similar specimens from Burio and Buskoghat in the Rajmahal Hills, with which is also identified Morris' *P. salicifolia*. However, for reasons unknown, he gave a new species epithet, *indica*, to his specimens and described these under the genus *Thinnfeldia*.

Zeba-Bano, Maheshwari and Bose (1979) reported similar well-preserved specimens from Pathargama, Rajmahal Hills, but again included these under *Thinnfeldia indica* Feistmantel. Their work does not refer to Morris' species.

A specimen from Amarjola, Rajmahal Hills, referred to *Thinnfeldia lancifolia* (Morris) Walkom, 1925 by Sharma *et al.* (1971) possibly represents the apical part of a *T. indica* frond. A definite statement can not be made without examining the hand specimen as there is a discrepancy in the magnifications of illustrations [cf. Sharma, Surana & Singh, 1971, pl. 1, fig. 3 (x 2) and text-fig. 6 (x 6)] and as the venation pattern has not been described by these authors.

Morphologically, all the specimens referred to above from Burio, Buskoghat and Pathargama conform to the delimitation of the genus *Thinnfeldia*. The Tiruchirapalli specimens conform to the circumscription of *Thinnfeldia indica* in overall morphography. Diagnosis of the taxon as given by Zeba-Bano *et al.* (1979) is accepted here.

Cuticular features—Cuticle stiff, well-preserved, though infected with many species of fungi, equally thick on both surfaces, characteristically amphistomatic, i.e. on lower surface stomata present all over except over midrib and secondary veins (Pl. 2, figs 2-3), whereas on upper surface stomata distributed only in midrib region (Pl. 2, fig. 1). Abnormally, however, a stoma or two present over midrib region of lower surface or very sparse over midrib region of upper surface.

Vein and intervein areas clearly decipherable over both surfaces. Basically, epidermal cells on both surfaces polygons, but those of upper surface of relatively shorter dimensions. Veins, however, distinguished by elongate polygonal or rectangular cells, mostly arranged end-to-end in 4-19 rows (Pl. 2, fig 3). Cell walls 2.5-3.75 μm thick, both lateral and end walls straight, surface walls unspecialised, with a granulate texture. Angles between adjacent cells sharp or rounded. Cells over midrib region of upper surface not much different than other cells, but on lower surface 4-6 times longer than broad, arranged end-to-end in 16-51 rows.

Stomata similarly constructed on both surfaces, irregularly distributed but oriented more or less parallel to course of midrib on upper surface. On lower surface stomata irregularly distributed but oriented mostly along course of veins (Pl. 2, fig. 3).

Stomata haplocheilic, varying considerably in size and shape. Guard cells bean-shaped, cutinised, deeply sunken, 26-58 μm long, encircled by 5-6 (rarely more) subsidiary cells which overarch stomatal pit forming a "crater"-like structure (epistomal chamber) (Pl. 2, figs 5, 6). On compression overarching part of subsidiary cells usually forms a thick rim around stomatal pit encompassing an isodiametric to ellipsoid opening (Pl. 2, fig. 6), 15-25 μm wide and 25-55 μm long, usually eccentrically placed over stomata. Possibly encircling cells also play a part in formation of epistomatal chamber.

Remarks—The case with which fairly large pieces of cuticle could be recovered from the fossil shows that the epidermis was highly cutinised giving a characteristic leathery texture to the leaf compression. The stomatal apparatus with its characteristic overarching cutinized subsidiary cells is reminiscent of cycadalean stomatal apparatus, particularly those of *Zamia muricata* (Arnold, 1953, figs 1-3), *Dioon edule* (Greguss, 1957, pl. 3, figs 11, 12) and *Cycas revoluta* (Greguss, 1957, pl. 3, figs 7, 8). In the last two species, however, the stomatal pit is formed by overarching of encircling cells. In *Dioon edule* the encircling cells have lignitized walls. There is some

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PLATE 1

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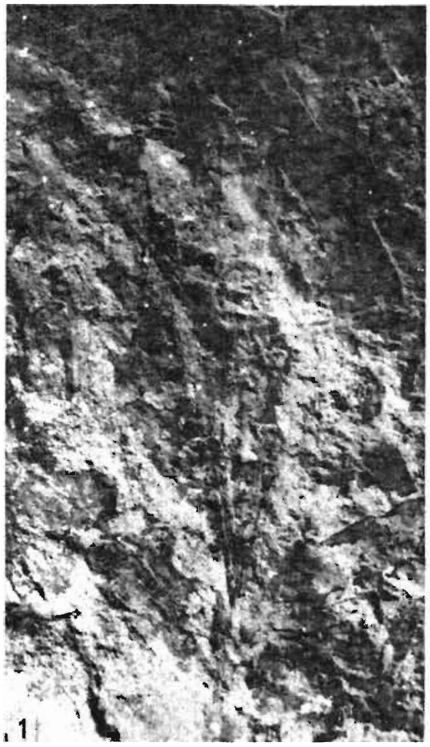
Thinnfeldia indica Feistmantel, 1877

1. Near apical part of a frond. Locality—near Naicolam. Specimen no. 54/2117B. × 1.
2. An impression showing a pinnate leaf, longitudinally striated rachis, longish petiole, subopposite, lanceolate pinnules with decurrent basiscopic margins, a faint midrib and distinct lateral veins. Locality—near Naicolam. Specimen no. 26/2117 × 1.
3. Near apical part of a frond with well-preserved carbonified crust. Locality—near Naicolam. Specimen no. 57/2117. × 2. (counterpart no. 58/2117, not figured here).
4. A single pinnule showing a feeble midrib and bifurcating lateral veins. Locality—Teraini Clay Pits. Specimen no. 44/2118. × 2.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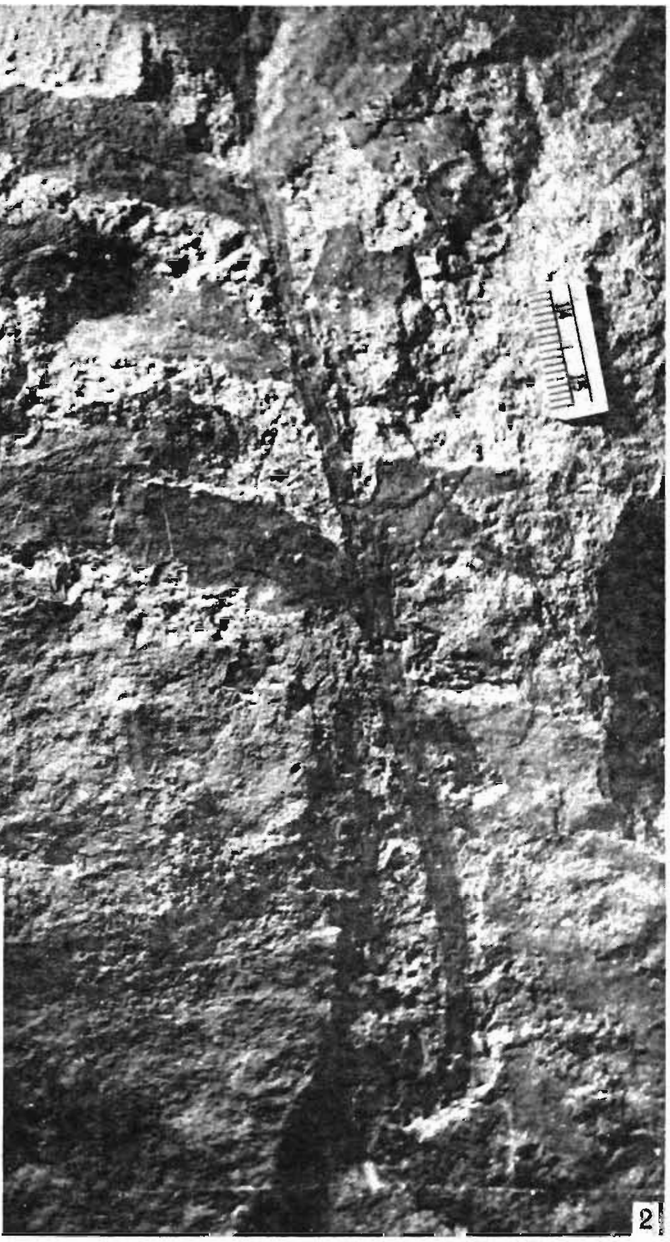
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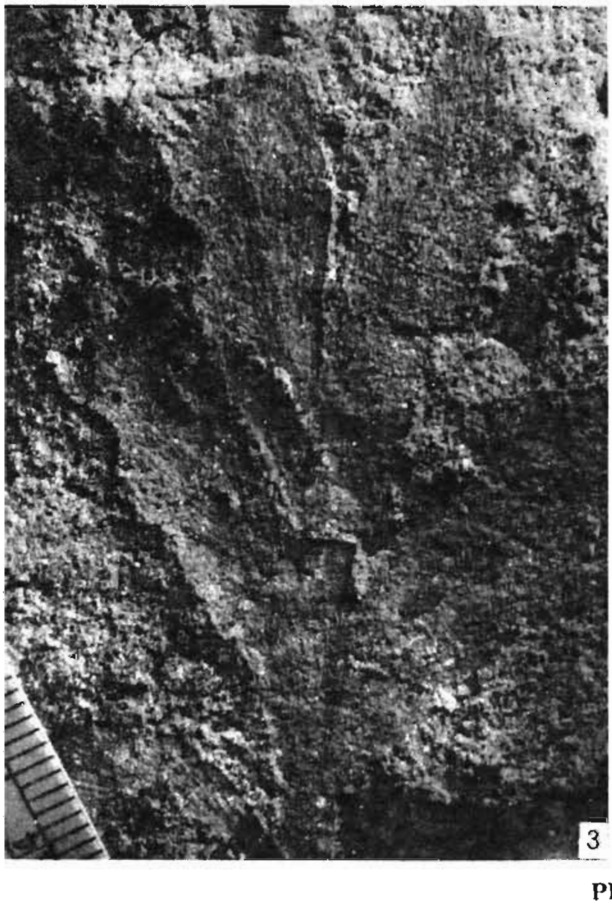
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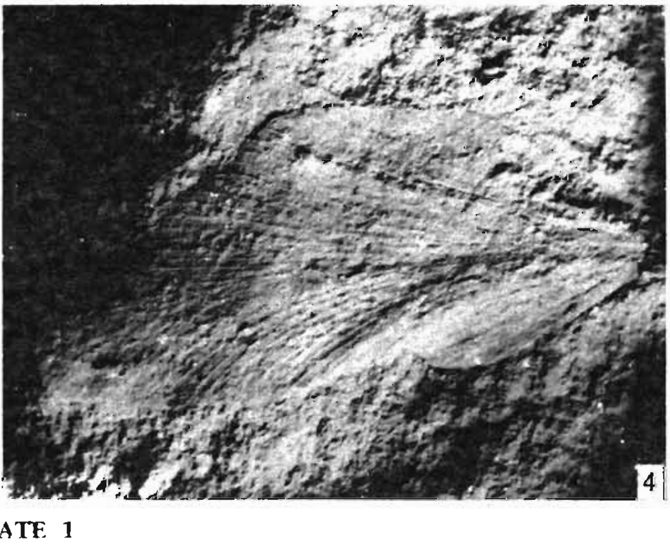
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PLATE 1

evidence of lignitization of subsidiary cells in *Thinnfeldia indica* as evidenced by the different texture of their inner halves. However, it can not be proved without a microchemical analysis. The stomatal apparatus is remarkably similar to that of *Ticoa lamellata* Archangelsky (1966, pl. 2, fig. 11; pl. 3, figs 15, 16).

Epidermal features of *Thinnfeldia indica* are indicative of xerophytic environment. The heavy cutinization of epidermis was probably in response to an arid or semiarid climate (Arnold, 1953, p. 54). The low frequency of stomata, 15-44 per sq mm and the protection of the stomatal aperture by overarching cells also point towards conditions of water loss (Eames & MacDaniels, 1947, pp. 167, 333).

TAXONOMIC POSITION OF THE GENUS *THINNFELDIA*

The genus *Thinnfeldia* was established by Ettingshausen (1852, p. 2) for a plant fossil from the Liassic of Steierdorf, which he presumed was related to the conifer *Phyllocladus*. Ettingshausan identified four species, viz., *T. rhomboidalis* and *T. speciosa* from the Liassic of Banat (Rumania) and *T. muensteriana* and *T. parvifolia* from the Liassic of Germany. Andrae (1855, p. 43) opined that the genus *Thinnfeldia* was indistinguishable from the genus *Pachypteris* Brongniart. A thorough investigation of *Thinnfeldia* was undertaken by Schenk (1867, p. 105) whose circumscription of the genus was based on uniformity of characters, i.e. alethopteroid venation. However, soon thereafter forms with odontopteroid venation were also included in this genus, e.g. *T. crassinervis* Geinitz (1876, p. 4) and *Pecopteris odontopteroides* Morris. Seward (1904, p. 31) significantly emended and amplified the genus so much so that *Cycadopteris brauniana* Zigno, *C. heterophylla* Zigno, *Lomatopteris jurensis* (Kurr) Schimper and *Stenopteris desmomera* Saporta were also included.

Gothan (1912) recommended that the genera should be based on homogeneous characters and accordingly he separated forms with forked rachides under a new genus *Dicroidium*. Antevs (1914), however, did not agree with this approach as he felt that forking of rachis is a universal character and has been found in entirely different forms. He also did not support Gothan's surmise that the two genera differed in the characters of the epidermis, too. In a specimen of *Dicroidium feistmantelli* which he investigated (Antevs; 1913, p. 4) the cells have thick and straight walls as in *Thinnfeldia*. Townrow (1957) placed Antevs' specimen in his new genus *Hoegia* as *H. papillosa*. Dicroidia with straight-walled cells of the epidermis have also been reported from the Nidhpuri beds of South Rewa Gondwana Basin and Ischigualasto Formation of Argentina (Bose & Srivastava, 1971; Archangelsky, 1968). However, few of these specimens show the forking rachides, presumed to be characteristic of the genus *Dicroidium*. According to Archangelsky (1968, p. 501) it is not easy to find the forked main rachis as the fronds were large and commonly got broken. Interestingly, one of several typical *Dicroidium* specimens illustrated by Flint and Gould (1975, pl. 3, fig. 10) shows an unusual double dichotomy of the rachis.

All the same, Antevs found some remarkable differences between the genera *Thinnfeldia* and *Dicroidium*. For example, the pinnules of *Thinnfeldia* in general are more or less elongate-rhomboid with alethopteroid venation, whereas the smaller and broader pinnules of *Dicroidium* have typically odontopteroid venation. However, *D. lancifolium* (Morris) Gothan (=*Thinnfeldia lancifolia* Morris) shows both types of venation and consequently represents a connecting link between the two genera.

Antevs believed that the stomatal apparatus has a complete analogy with the recent xerophytes as the stomata occur in a pit.

Thinnfeldia indica Feistmantel, as defined morphologically by Zeba-Bano, Maheshwari and Bose (1979) and with its cuticular features described in the present paper, matches in all major characters the genus *Thinnfeldia* as defined above by Antevs (1914). Of course, there is a noticeable difference in the distribution of the stomata. In *T. indica* these are characteristically found on the entire lower epidermis except for the midrib and lateral vein areas, while confining themselves to midrib region only of the upper surface. Thus the occurrence of the genus *Thinnfeldia* in the southern hemisphere is confirmed. *Thinnfeldia* was possibly widely distributed in Gondwanaland at one time (Jack & Etheridge, 1882; Shirley, 1898; Seward, 1904; Halle, 1913; Jain & Delevoryas, 1967).

PLATE 2

Thinnfeldia indica Feistmantel, 1877

1. Cultícle of the midrib region of upper surface showing very sparsely distributed stomata. Slide no. 58/2117-1. × 120.
2. Lower cuticle showing region near midrib. Slide no. 58/2117-2. × 120
3. Lower cuticle showing stomatiferous and nonstomatiferous regions corresponding to intervein and vein areas respectively. Slide no. 54/2117A-1, × 120.
4. Lower cuticle of a leaf showing a near nonstomatiferous midrib flanked by stomatiferous intervein regions. Slide no. 58/2117-2. × 50.

5, 6. Stomata on the lower surface. 5, slide no. 58/2117.2; 6, slide no. 54/2117B-2. All × 470.

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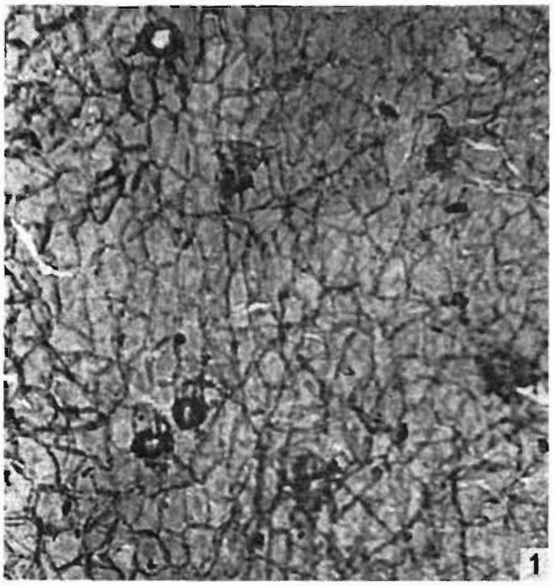
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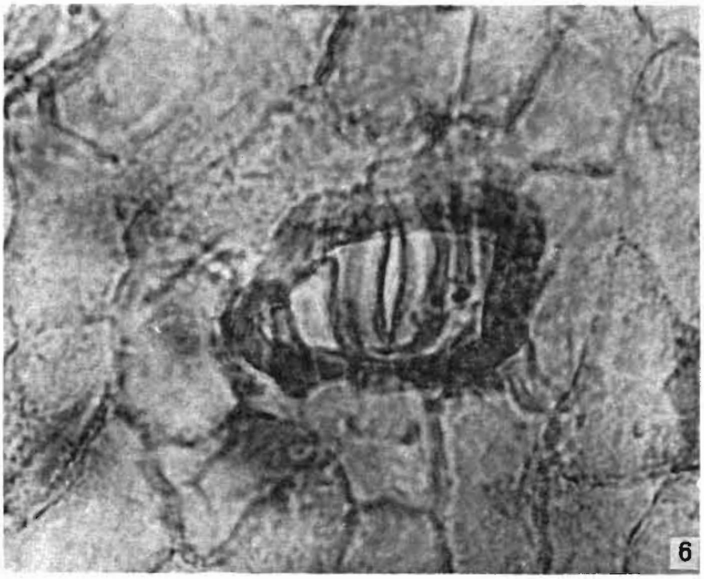
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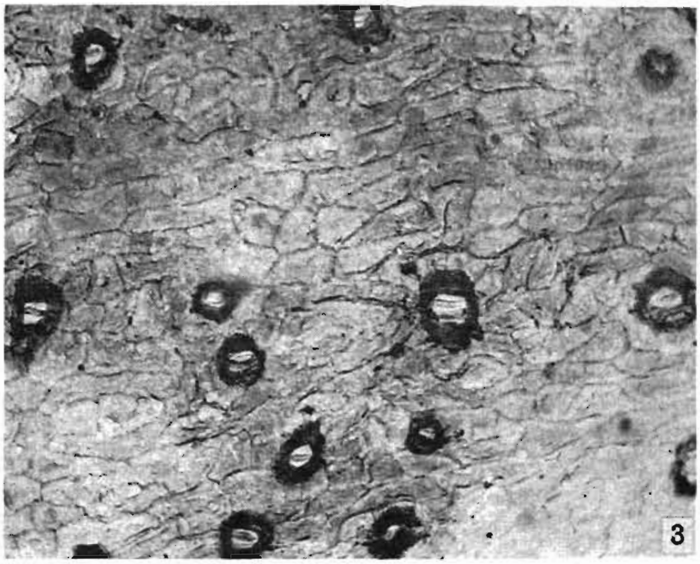
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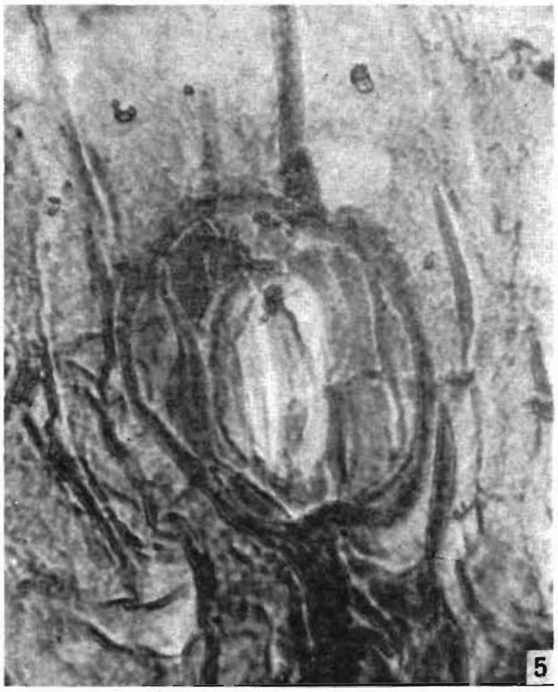
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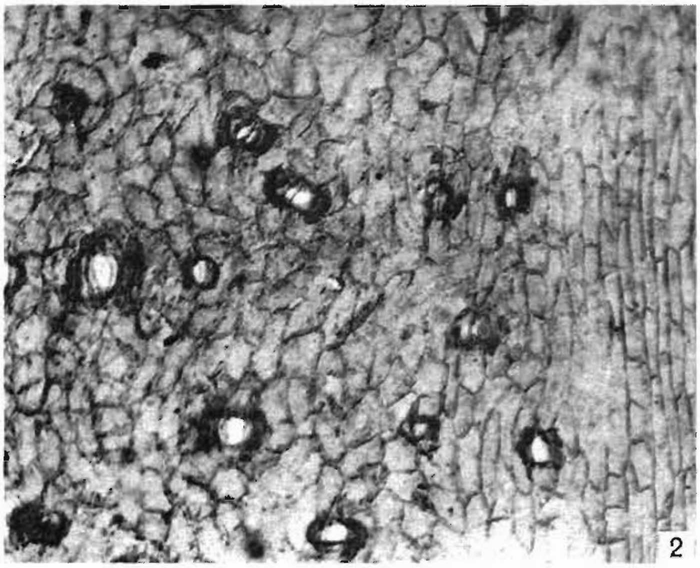
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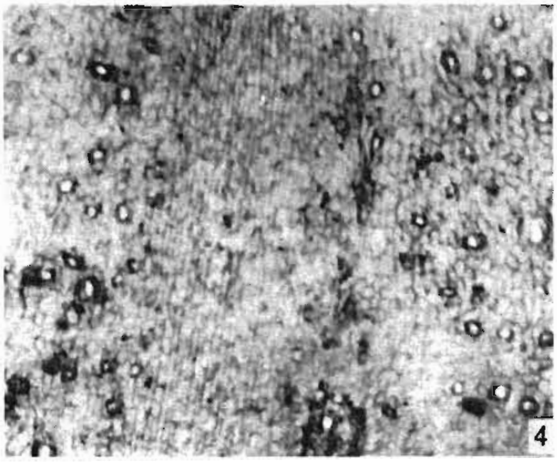
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PLATE 2

Doludenko (1967, 1969, 1974) believes that the leaves of the genus *Thinnfeldia* do not differ from those of *Pachypteris*, either in external morphology or in epidermal features. She bases this conclusion on a comparison of the epidermal features of a specimen of *Thinnfeldia* from the collection of Faculty of Geology and Geophysics, Bucharest University and that of *Pachypteris lanceolata* from the type locality. However, according to Harris (1964) the subsidiary cells of *Thinnfeldia* are arranged in a neat collar while in *Pachypteris* their arrangement is not so regular and the number is also comparatively less. Epidermal features of several other species of *Thinnfeldia* are also known (Bose, 1959; Vladimirovich, 1965, etc.). Their epidermal features do seem to be similar to species of the genus *Pachypteris* (Delle, 1967; Doludenko, 1969; Doludenko & Svanidze, 1969). The epidermis of *Thinnfeldia indica* has characteristic stomata which are rather like those of *Pachypteris holdenii* Bose & Roy, 1968 and to a lesser extent like those of *Pachypteris indica* (Oldham & Morris, 1863) Bose & Roy, 1968. Similar stomata had also been reported for *Thinnfeldia rhomboidalis* from Yorkshire (Thomas, 1915). The common feature in stomata of all these species is the heavy cutinization of the inner half of subsidiary cells which form the stomatal pit. It would thus seem that the cuticular features are a result of ecological niches in which the plants grew and can not be taken as characters of taxonomic value on an inter-regional basis.

Morphologically it is not difficult to separate *Thinnfeldia* from *Pachypteris*, the latter being bipinnate (excepting *Pachydermophyllum papillosum* cf. Harris, 1964) with extremely feeble midrib and obscure lateral veins (Barnard, 1965; Zeba-Bano, Maheshwari & Bose, 1979, p. 148). While *Thinnfeldia* possesses leathery, comparatively thin pinnules, *Pachypteris* shows mostly small and very thick, sometimes almost round and succulent pinnules. The genera *Cycadopteris* Zigno and *Lomatopteris* Schimper also differ from the genus *Thinnfeldia* in having either linear, long and narrow or very small and broad pinnules with the characteristic margin and imperceptible venation.

AFFINITIES OF THE GENUS *THINNFELDIA*

The affinities of this genus have been traced to almost all groups of vascular plants, e.g. Pteridophyta, Pteridosperms, Cycadophyta, Coniferophyta, etc. Ettingshausen (1852, p. 2) and Andrae (1855, p. 43) placed *Thinnfeldia* with the conifers. Schenk (1867, p. 107) considered it to be a cycadean plant, particularly so on the basis of the stomatal structure but later (Schenk, 1888, p. 44) he seemingly changed his opinion and regarded *Thinnfeldia* as a fern. This view was also held by Schimper (1869, p. 495), Saporta (1873, p. 341), Nathorst (1878, p. 491), Raciborski (1894), Zeiller (1900, p. 97; 1907, p. 191). Seward (1910, p. 537) observed that *Thinnfeldia* answers to the Pteridosperms. Gothan (1912, p. 79) opined that the structure of stomata, thick texture and characteristic habit, all show that *Thinnfeldia* could not have been a fern. According to Antevs (1914) the resemblance between some species of the genus (*Thinnfeldia* and twigs of *Phyllocladus* in habit, venation and epidermal structure is so impressive that such *Phyllocladus* twig, when found as a fossil, will certainly be described as a *Thinnfeldia*. There is, however, one very important and major difference that in *Thinnfeldia* one never finds twigs in spiral attachment or in whorled simulations, which shows that these are leaves and not twigs.

If we leave aside the typical amphistomatic distribution of stomata, other characters, particularly those of the epidermis, as observed in *Thinnfeldia indica* point towards a cycadean affinity.

AGE OF THE UTATUR PLANT BEDS OF TIRUCHIRAPALLI

As mentioned earlier, the fossil flora of the Utatur Plant Beds of Tiruchirapalli District has a fairly large percentage of elements of the Mesozoic flora of the Rajmahal Hills, Bihar. Latest addition to the list of common plants is *Thinnfeldia indica* Feistmantel. Feistmantel (1877) regarded the Rajmahal flora to be of Liassic age while Sah and Jain (1965) palynologically dated it as Upper Jurassic. The palynological age has now been revised to Lower Cretaceous by Maheshwari and Jana (1984). Occurrence of the genus *Thinnfeldia* also supports a Lower Jurassic age. However, in recent years a radiometric Lower Cretaceous age has been advocated for the Rajmahal Traps (McDougall & McElhinny, 1970). Therefore, the Utatur Plant Beds could also be of the same age if the radiometric age of the Rajmahal Traps also encompasses the fossiliferous intertrappean layers. A Lower Cretaceous age is further indicated by the associated ammonites (Pascoe, 1959, p. 998; Mamgain, Sastry & Subbaraman, 1973, p. 199). The association, on the East Coast, of plants indicating a Jurassic age and ammonites indicating a Lower Cretaceous age was attributed by Bhalla (1972) to reworking. I find it difficult to visualise reworking of plant megafossils on such an extensive scale and that too resulting in their alignment parallel to overall bedding plane, as in the Teraini clay pits. Overall evidence from ammonites, plant megafossils and palynofossils suggests a Lower Cretaceous (Neocomian) age to these sediments.

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Stratigraphy, age and palaeoecology of Upper Gondwana equivalents of the Krishna-Godavari Basin, India

B. S. Venkatachala & R. N. Sinha

ABSTRACT

Venkatachala, B. S. & Sinha, R. N. (1986). Stratigraphy, age and palaeoecology of Upper Gondwana equivalents of the Krishna-Godavari Basin, India. *Palaeobotanist* **35**(2) : 22-31.

Age equivalents of the Upper Gondwana sediments are exposed in the Krishna-Godavari Basin which comprises three depressions separated from one another by basement ridges. The sequence exposed in the West Godavari Depression is classified into the Golapalli Sandstone (oldest), Raghavapuram Shale and Tirupati Sandstone (youngest) on the basis of lithologic characteristics. Likewise, in the Krishna Depression, towards the south, this sequence is classified into the Budavada Sandstone (oldest), Vemavaram Shale and Pavalur Sandstone. A number of shallow wells have been drilled on the outcrops. The dominantly arenaceous units, the Golapalli, Tirupati, Budavada and Pavalur sandstones, of the outcrop are represented by shales in the subsurface. The Raghavapuram and Vemavaram shales, however, continue to have the same lithology in the subsurface. It is concluded that the tripartite classification in the outcrops is not tenable in the subsurface and the respective units are probably lithofacial variants of a major argillaceous sequence.

The exposed sequence is devoid of palynofossils. Plant megafossils, though scarce, are considered referable to the Late Jurassic. The sequence met in the shallow wells contains abundant palynofossils of non-marine and transitional environments. The assemblages recorded from the dominantly argillaceous beds contain numerous taxa characteristic of an Early Cretaceous age. Hence, the sequences in the two depressions are homotaxial and of Early Cretaceous age as is also inferred from microfaunal assemblages. An inter-relationship between the gymnosperm and phytoplankton populations has enabled to delineate some of the major environmental regimes which vary from non-marine in the west to shallow marine in the east through transitional swampy environments. The upland floral elements are predominant at the basin margin. The bulk of the terrigenous matter was derived from areas located westwards. It is significant to note that the phytoplankton progressively increase due east and southeast. It could be as high as 20 per cent near about the western margin of the basin. If the sequences remain to be dominantly shaly in the subsurface of the present day coastal areas they are likely to possess good characters of source rocks of hydrocarbons especially in view of the progressive increase in phytoplankton percentages and favourable depths of burial and palaeotemperatures which are evidenced by geophysical data and occurrence of extrusives in the outcrop area respectively.

Key-words—Palynostratigraphy, Palaeoecology, Megafossils, Upper Gondwana, Krishna-Godavari Basin (India).

B. S. Venkatachala, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226007, India.
R. N. Sinha, "Laxmi Nivas", Jagatnarain Road, Kadam Kuan, Patna 800003, India.

साराँश

कृष्णा-गोदावरी द्रोणी (भारत) के समतुल्य उपरि गोंडवाना का स्तरविन्यास, इसकी आयु एवं पुरापास्थितिकी

बेंगलूर श्रीनिवासा वेंकटाचाला एवं रवीन्द्रनाथ सिन्हा

कृष्णा-गोदावरी द्रोणी में उपरि गोंडवाना अवसादों के समकालीन समतुल्य विगोपित हैं जिनमें एक दूसरे से आधार-कटकों द्वारा पृथक्कृत तीन अवनमन विद्यमान हैं। पश्चिम गोदावरी अवनमन में विगोपित अनुक्रम शैलिकीय लक्षणों के आधार पर गोलापल्ली बालुकाश्म (पुरातनतम्), राघवपुरम शैल एवं तिरुपति बालुकाश्म (अल्पतम् आयु का) में विभक्त किया गया है। इसी भाँति कृष्णा अवनमन में दक्षिण की ओर यह अनुक्रम बुडवाड़ा बालुकाश्म (पुरातनतम्), वेमावरम् शैल एवं पावालूर बालुकाश्म में विभक्त किया गया है। दृश्याँशों पर कई उथले कुएँ वेधित किये गये हैं। इन दृश्याँशों की प्रभावी बालुकामय इकाईयाँ—गोलापल्ली, तिरुपति, बुडवाड़ा एवं पावलूर बालुकाश्म—उपसतह में शैलों से निरूपित हैं। तथापि राघवपुरम् एवं वेमावरम् शैलों का स्तर-विन्यास उपसतह में वैसा ही है। यह निष्कर्ष निकाला गया है कि दृश्याँशों में किया गया त्रिपक्षीय वर्गीकरण उपसतह में मान्य नहीं है तथा सम्बद्ध इकाईयाँ एक मुख्य मृण्मय अनुक्रम के सम्भवतया शैल-संलक्षणीय रूपान्तर हैं।

विगोपित अनुक्रम परागकणविहीन है। गुरुपादपाश्म, यद्यपि कम हैं, अन्तिम जूराई युग के माने गये हैं। उथले कुओं में विद्यमान अनुक्रम में असमुद्री एवं परिवर्तनशील वातावरणों के परागकण आदि प्रचुर मात्रा में मिलते हैं। प्रभावी मृण्मय संस्तरों से अभिलिखित समुच्चयों में प्रारम्भिक क्रीटेश्यस युग के अनेक

लाक्षणिक वर्गक मिलते हैं, अतएव इन दोनों अवनमनों के अनुक्रम समवर्गकी हैं तथा प्रारम्भिक क्रीटेश्यस आयु के हैं जैसा कि सूक्ष्मजन्तु-जातीय समुच्चयों से भी इंगित होता है। अनावृतबीजीयों एवं पादप-प्ल्वकों के मध्य अन्तरबन्धुता से कुछ वातावरणीय प्रवृत्तियों को चित्रित करने में सहायता मिली है। ये प्रवृत्तियाँ परिवर्तनशील दलदली वातावरणों के फलस्वरूप पश्चिम में असमुद्री से पूर्व में उथली समुद्री तक विस्तृत हैं। द्रोणी तट पर भूमीय वनस्पतिजातीय अवयवों की पूर्व बाहुल्यता है। स्थलजात पदार्थ का पुंज पश्चिम की ओर के क्षेत्रों से व्युत्पादित था। यह उल्लेखनीय है कि पादपप्लवकों की प्रतिशततायें पूर्व एवं दक्षिण-पूर्व में क्रमिक रूप से बढ़ती हैं। द्रोणी के पश्चिम किनारे के आस-पास यह 20 प्रतिशत तक भी प्रेक्षित की गई है। वर्तमान तटीय क्षेत्रों की उपसतह में यदि अनुक्रम प्रधान रूप से शैलवत् हों तो उनमें हाइड्रोकार्बनों की स्रोत चट्टानों, विशेषतया पादपप्लवकों की प्रतिशतता में क्रमिक वृद्धि तथा पुरातापक्रमों एवं शवाधान की अनुकूल गहराईयों जो कि क्रमशः भूभौतिक आँकड़ों एवं दृश्यांश क्षेत्र में अन्तर्वेधीयों की उपस्थिति से प्रमाणित हैं, के विशिष्ट लक्षण विद्यमान हो सकते हैं।

INTRODUCTION

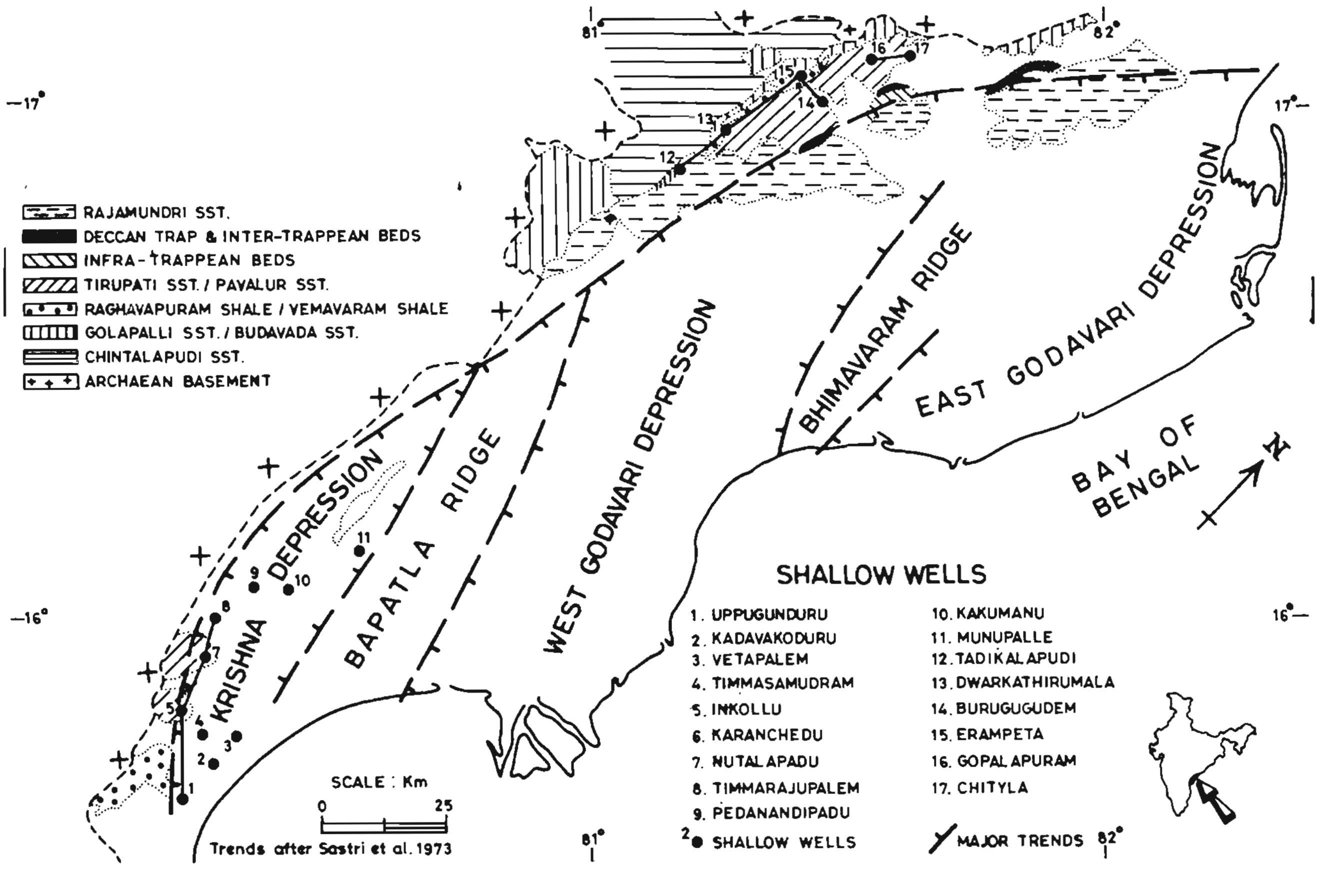
THE Krishna-Godavari Basin, situated on the eastern coast of India (Text-fig. 1, inset), is divided into several depressions separated from one another by subsurface ridges (Text-fig. 1) on the basis of geophysical data (Sastri *et al.*, 1973). The ridges are aligned similar to the north-east-southwest striking Eastern Ghats and so is also true of the axis of depressions.

Sediments correlatable to those of Upper Gondwana are exposed near the western fringes of the Krishna and West Godavari depressions (Text-fig. 1). These do not contain adequate fossil fauna and megaflora as well as palynological assemblages and those that are present, do not assist in precise dating, stratigraphical correlation or palaeoecological reconstructions.

A number of shallow wells (200 m depth) have been drilled by the Oil and Natural Gas Commission, for near-surface stratigraphic information (Text-fig. 1). A few of these wells, penetrated sediments equivalent to Upper Gondwana which, though almost devoid of microfauna and megaflora, contain rich palynological assemblages.

This paper discusses the available data with a view to date and correlate the surface and subsurface sediments which are Upper Gondwana equivalents. An attempt has been made to trace marine influences during their deposition and discuss their status. A few remarks on the development of source rocks of hydrocarbons are also offered.

The samples studied are from shallow wells located at Inkollu, Uppugunduru, Timmasamudram, Nutalapadu, Kadavakoduru, Timmarajapalem, Vetapalem, Karanchedu,



Text-fig. 1—Geological map of Godavari-Krishna Basin, India.

Peddanadipadu, Kakumanu, Munupalle, Tadikalapudi, Errampeta, Buruguguḍem, Gopalapuram and Chityala (Text-fig. 1, after Sharma *et al*, 1977).

LITHOLOGY AND STRATIGRAPHY

The term 'Gondwana' first published by Feistmantel (1876) was originally introduced by Medlicott in 1872 in an unpublished report. It includes Permo-Carboniferous-Jurassic sediments deposited under non-marine environments in the Peninsular India (Fox, 1931). These sediments contain abundant plant megafossils and palynofossils. Thin beds included into the Upper Gondwana sediments (Vemavaram Shale, Raghavapuram Shale, Sriperumbudur Beds & Budavada Sandstone) and containing paralic-marine fossils were regarded as marine intercalations. The sequence, however, continued to be designated as Gondwana although, this term included strictly non-marine sediments. It may therefore be suggested that these sediments containing paralic-marine fossils should be identified separately as has been the Jurassic of Kutch (Pascoe, 1968) and earlier opined by Rao and Venkatachala (1971).

The Upper Gondwana sediments are exposed towards the western and northwestern fringes of the basin (Text-fig. 1). The Gondwana sediments exposed around Ellore (16°43′N : 81°07′E) in the West Godavari Depression are classified into three lithologic units. The Golapalli Sandstone, the oldest, named after the type area around the village Golapalli (16°43′30″N : 80°55′E; King, 1880), comprises nearly 50 m thick highly micaceous and dark purplish coarse grits and ferruginous and partly lateritized sandstones interbedded with light grey medium to coarse grained sandstones. Buff-coloured nodular limestones at places underlain by light grey soft clay are also present. The Raghavapuram Shale (King, 1880) named after the village Raghavapuram (17°00′02″N : 81°15′30″E) is poorly exposed and overlies the Golapalli Sandstone unconformably (Pascoe, 1968). It is nearly 75 m thick (Subrahmaniyam, 1960) and consists of brittle shales and soft clays both of which are at times sandy and also contain thin lenses of light buff to greyish white medium grained sandstones. The Tirupati Sandstone, the youngest and named after the type area around Dwarkatirumalai (10°57′15″N : 81°35′45″E) is 350 m thick and comprises light grey to pale buff, friable, current-bedded, partly lateritized, medium to coarse grained, occasionally gritty, micaceous and clayey sandstone containing a few bands of grey coloured clays.

The Upper Gondwana sediments exposed around Ongole (15°30′N : 80°03′E) in the Krishna Depression are also divided into three lithologic units, the Budavada Sandstone (oldest), Vemavaram Shale and the Pavalur Sandstone (youngest). Desikachary and Ramachandra (1962), however, do not favour such a tripartite division. According to them the Budavada Sandstone exposes a nearly 500 m thick succession of shales (80%) and sandstones (20%). These sandstones are locally designated as Budavada Sandstone and are similar to those included in the Golapalli Sandstone. The Budavada Sandstone is overlain by the Vemavaram Shale which lithologically resembles the Raghavapuram Shale. Likewise, the Pavalur Sandstone appears similar to the Tirupati Sandstone in lithologic characters.

The Golapalli sandstone is considered older to the Budavada Sandstone (Pascoe, 1959). The Raghavapuram Shale is correlated to the Vamavaram Shale and Tirupati Sandstone to Pavalur Sandstone.

Subsurface Lithology—A number of shallow wells (200 m deep) are drilled on the outcrops of Budavada Sandstone, Raghavapuram Shale and Tirupati Sandstone for near-surface stratigraphic information. The lithologic data (Text-figs 2, 3) from these wells are significant and are outlined below:

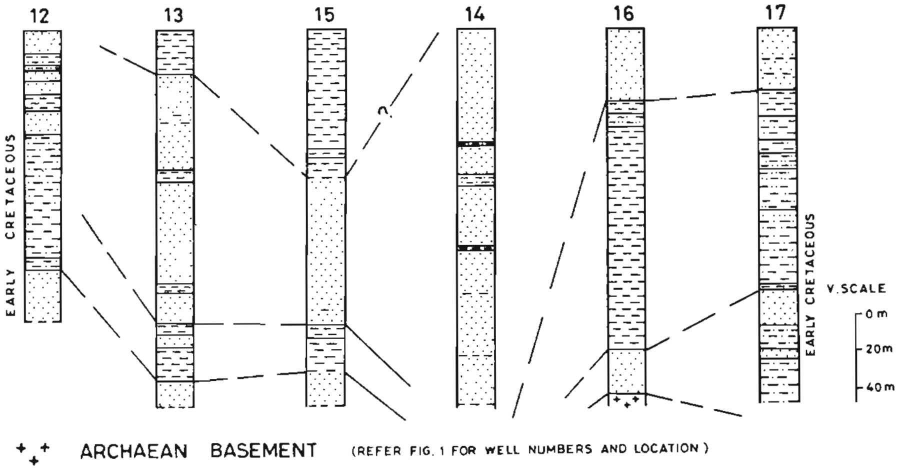
1. The section in Errampeta well (No. 15, Text-fig. 2) drilled on the outcrops of Raghavapuram Shale (Text-fig. 1) comprises only a small thickness (80 cm) of shales that overlie thick sandstones which resemble the sandstones included into the Golapalli Sandstone.

2. Five shallow wells drilled on the outcrops of Tirupati Sandstone offer interesting data. More than 50 per cent of the drilled section at Tadikalapudi (No. 12, Text-fig. 2) comprises shales which diminish to only 25 per cent at Dwarkathirumala (No. 13, Text-fig. 2) nearly 12 km due northeast. Further 20 km to the northeast at Buruguguḍem (No. 14, Text-fig. 2), the sequence comprises sandstones and these also change to mainly shales at Gopalapuram (No. 16, Text-fig. 2) located 12 km northeast of Buruguguḍem.

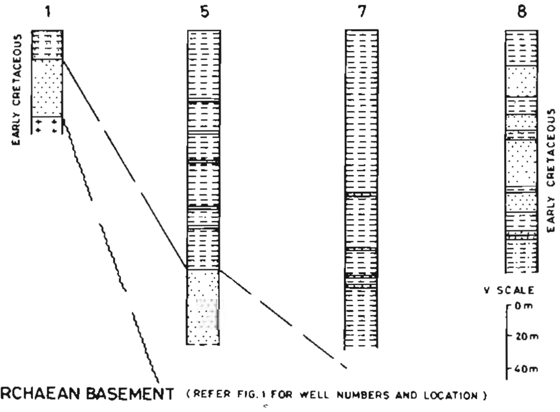
3. The Nutalapadu (No. 7, Text-fig. 3) well, though drilled on the outcrops of Budavada Sandstone penetrates an almost monotonous shale section. Likewise, the Inkollu well (No. 5, Text-fig. 3) drilled very close to the outcrops of Budavada Sandstones penetrates a thick shale section.

4. The Uppugunduru well (No. 1, Text-fig. 3) drilled up to the Archaean basement (top at 115 m) penetrated 55 m of Upper Gondwana sequence comprising 34 m thick sandstones overlain by 21 m thick silty shales even though the well is located very close to the type locality of the Vemavaram Shale.

The lithologic data enumerated above establish that a sequence mapped in the outcrop area as dominantly sandstone or shale and therefore identified as a sandstone or shale unit, viz., Golapalli Sandstone/Raghavapuram Shale, ceases to be so in the subsurface. It is significant that this change occurs within very short distance as is evident from wells drilled on the respective outcrops. Hence, the subsurface data from shallow wells suggests that the lithologic units mapped in the outcrops are represented in the subsurface by a



Text-fig. 2—Stratigraphic section through shallow wells.



Text-fig. 3—Stratigraphic section through shallow wells.

dominantly shale sequence. The tripartite classification of the exposed Upper Gondwana sediments, therefore, does not seem tenable.

REMARKS ON THE AGE

Palaeobotanical evidences—Feistmantel (1879), Seward and Sahni (1920) and Sahni (1928, 1931) have described a number of plant megafossils from the Vemavaram area. These include—*Pseudoctenis footeana*, *Otozamites bunbaryanus zigno* var. *indica*, *Ptilophyllum acutifolium*, *Araucarites cutchensis*, *Retinosporites indica*, *Torreyites constricta*, *Elatocladus jabalpurensis*, *Elatocladus* sp., *Brachyphyllum feistmantelii*, *B. expansum*, *Conites sessilis*, and *C. rajmahalensis*. *Ginkgoites lobata*, *Brachyphyllum expansum*, *Desmiophyllum indicum* and *Elatocladus plana* are recorded from the Raghavapuram area. Equisetalean stem compressions were reported by Sarma (1958) from the Golapalli Sandstone. Suryanarayana (1954) described fragmentary plant remains (*Sphenopteris* sp., *Pterophyllum bifurcatum*—an unidentified cycadophytic stem) from Vemavaram. Rao (1959) recorded *Dicroidium feistmantelii* from the Vemavaram shales. On the basis of flora, a Jurassic age was assigned by Bose (1966). Baksi (1967) described a rich plant megafossil assemblage comprising *Cladophlebis* sp., *Dicroidium* sp., *Taeniopteris spathulata*, *Ptilophyllum acutifolium*, *P. cutchense*, *P. tennerrimum*, *Otozamites rarinervis*, *O. abbreviatus*, *Dictyozamites falcatus*, *Williamsonia blanfordi*, *Cycadolepis indica*, *Ginkgoites feistmantelii*, *Ginkgoites* sp., *Elatocladus plana*, *Brachyphyllum rhombicum*, *B. feistmantelii*, *Pagiophyllum* sp. cf. *P. peregrinum*, *Araucarites cutchensis* and *Conites* sp. from Raghavapuram Shale which according to him is of Early Cretaceous age. However, Shah *et al.* (1971) assign a doubtful Jurassic age to the entire Upper Gondwana Sequence exposed on the east coast of India on the basis of plant megafossils.

The assemblage of plant megafossils from the Golapalli Sandstone is fairly similar to that from the Raghavapuram Shale except that it lacks *Elatocladus plana*, *Araucarites cutchensis*, *Ginkgo* sp., *Conites* sp., *Mesembrioxylon* and *Dadoxylon* besides *Pachypteris* (*Dichopteris*) *ellorensis*. Fossils that distinguish Golapalli Sandstone and are not recorded from the Raghavapuram shales include *Nilssonia* sp., *Retinosporites* sp., *Marattiopsis* sp., *Taeniopteris ensis*, *Williamsonia indica*, *Elatocladus conferta*, *Brachyphyllum expansum* and *Araucarites macropterus*. The Tirupati Sandstone is poorly fossiliferous and contains only *Ptilophyllum acutifolium*, *P. cutchense* and *Williamsonia blanfordii* besides unidentified fossil woods (Baksi, 1967). The difference in the megafloral composition in Golapalli Sandstone, Raghavapuram Shale and Tirupati Sandstone is ascribed to preservational variations and limited palaeobotanical findings and not vegetational differentiation.

The plant megafossil assemblage lacks the characteristic early Cretaceous fronds, *Weichselia* and

Onychiopsis. These fronds are reported from Umia, Jabalpur and Himmatnagar sandstones which are conclusively dated as Early Cretaceous. The absence of these two Early Cretaceous forms, therefore, could be ascribed to lack of preservation in the Upper Gondwanas of the Krishna-Godavari Basin.

The Golapalli and Budavada sandstones are correlated with the Rajmahal Sandstone in Bihar and Athgarh sandstones in Mahanadi Basin. The Raghavapuram and Sivaganga beds and also the Kota Stage which is dated as middle-late Jurassic in age are correlated with Golapalli and Budavada sandstones (Bose, 1966). The Rajmahals are considered as Jurassic in age. The Tirupati and Pavalur sandstones and the Satyavedu Bed are correlated with the Jabalpur Series which is regarded as Early Cretaceous in age. Thus, it may be seen from the foregoing discussion that the Upper Gondwana equivalent of the Krishna-Godavari Basin are considered as Upper Jurassic-? Lower Cretaceous in age on the basis of plant megafossil evidences.

Faunal evidences—Faunal assemblages, especially those diagnostic of marine habitat, are restricted to the upper part (Vemavaram & Raghavapuram shales and Tirupati Sandstone) of the exposed Gondwana Sequence. The lower part of the shale sequence included into the Raghavapuram Shale contains ammonites, foraminifera and fish scales (Bhalla, 1972).

Sastri *et al.* (1961, 1963) record arenaceous forms consisting of *Ammobaculites fisheri* var. *tirupathiensis*, *Haplophragmoides concava* and *H. chapmani* from the Raghavapuram shales and assign an Early Cretaceous age. Bhalla (1965) described *Haplophragmoides hagni*, *Ammobaculites crespinae*, *A. hofkeri*, *A. indicus*, *A. raghavapuramensis* and *A. sahnii*, from the type section of Raghavapuram shales and assigns an Early Cretaceous age. Bhalla (1968, 1969) compares the arenaceous foraminiferal assemblage with those recovered from the Early Cretaceous of the Great Artesian Basin, Australia. Baksi (1966) in a study of the Raghavapuram Shale records *Ammobaculites funicularis*, *A. phlegeri*, *A. globosa*, *A. crespinae*, *A. hifkeri*, *A. indicus*, *A. sahnii*, *Trochammina hagni*, *T. stellifera*, *T.* sp. cf. *T. whittingtoni*, *Nonion presublaeva* and *N. barakondai* which are referable to a Post-Jurassic but pre-Late Cretaceous age.

Mitra *et al.* (1971) consider the entire east coast Gondwana sediments as younger to the Rajmahals (Jurassic) and assign them an Early Cretaceous age. This is in agreement with the age deduced from foraminiferal assemblages (Sastri *et al.*, 1963; Baksi, 1966; Bhalla, 1969).

Sastri and Mamgain (1971, table 2) assign a Neocomian-Aptian age to the East Coast Gondwana sediments, i.e. Golapalli Sandstone, Raghavapuram Shale, Tirupati Sandstone and Budavada Sandstone and Vemavaram Shale and correlated them with the Sriperumbudur and Satyavedu beds.

Palynological evidences—The palynological assemblages in the subsurface sequences met in shallow well are well diversified. A total of 57 genera and 78 species of spores and pollen and 9 types of phytoplankton (hystrichosphaerids & dinoflagellates) are recorded (Sharma *et al.*, 1977). The preservation of fossils is usually good and affords a detailed morphological study and precise taxonomic evaluation. In general, the assemblages are relatively richer in dominantly argillaceous sequences. The diagnostic palynofossils are also present in the arenaceous sequences.

Species spectrum curves as recommended by Wilson (1959) are used to determine the number of fossils counted in each sample. Quantitative assessments are based on 200 fossil counts per sample. The distribution pattern of the various taxa is fairly uniform in the Krishna and West Godavari depressions and also in Bapatla-Vellupucherla Ridge.

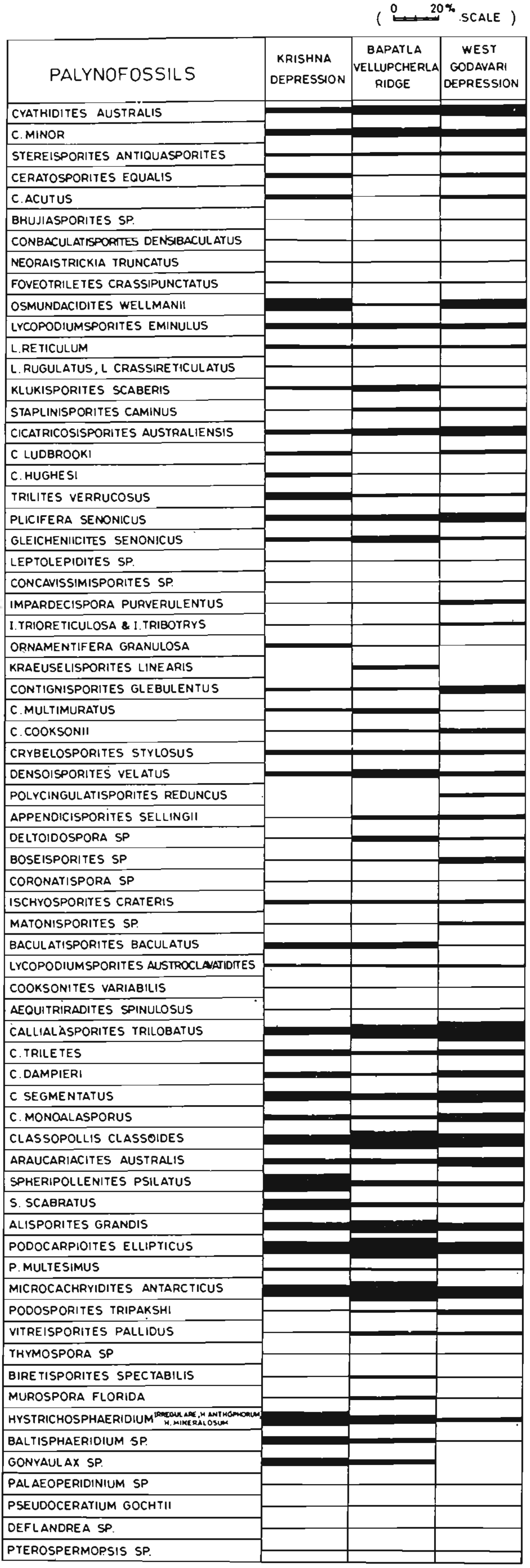
The palynoflora from the continental Upper Gondwana and equivalent sediments are reviewed by Bharadwaj (1969) and Venkatachala (1970). The earliest Jurassic assemblage from the subsurface in the Jaisalmer Basin is distinguished by *Cosmosporites*, *Gliscopollis* and *Exesipollenites*. A comparable assemblage is recorded in the Early Jurassic sediments from Nommal Gorge, Salt range. The assemblage in the Krishna-Godavari Basin, however, is distinct and not comparable as the distinguishing genera enumerated above are conspicuously absent.

The Neocomian-Aptian assemblages from the subsurface of Cauvery Basin are closely comparable (Venkatachala, 1974; Venkatachala *et al.*, 1972). *Microcachryidites antarcticus*, *Trilites verrucosus*, *Sphaeripollenites* spp., *Leptolepidites major*, *Podosporites tripakshi*, *Klukisporites scaberis*, *Aequitriradites verrucosus*, *Kraeuselisporites majus*, *Impardecispora perverulentus*, and *Crybelosporites stylosus*, dominant in the Neocomian-Aptian assemblage of the Cauvery Basin, are significant fossils of the Krishna-Godavari Basin. The Aptian-Early Albian assemblage in the Cauvery basin is distinguished by the occurrence of *Coptospora cauveriana*, *Polypodiaceoisporites* spp. and *Appendicisporites tricornitatus*. The absence of these characteristic taxa in the assemblages under discussion precludes any comparison with those of Late Aptian-Early Albian recorded from the Cauvery Basin.

The assemblages in the Upper Gondwana sediments of Krishna-Godavari Basin are closely comparable to those of the *Crybelosporites stylosus* and the *Dictyotosporites speciosus* zones (Dettmann & Playford, 1969) in Australia. These zones, dated as Neocomian and Neocomian-Aptian, are characterised by *Aequitriradites hispidus*, *Crybelosporites stylosus*, *Murospora floriada*, *Contignisporites cooksonii, Cyclosporites hughesi, Kraeuselisporites linearis, Biretisporites spectabilis, Cicatricosisporites australiensis, C. ludbrookii, Dictyotosporites speciosus, Cooksonites variabilis* and *Foraminisporis asymmetricus*, all of which are present in the Upper Gondwana sediments of Krishna-Godavari Basin.

The assemblage described by Ramanujam (1957) from presumably the Vemavaram shales is dated as Late Jurassic and the assemblage as deduced from illustrations and descriptions includes *Cyathidites* sp., *Gleicheniidites* sp. cf. *Osmundacidites, Neoraistrichia* sp., *Lycopodiumsporites* spp., *Ischyosporites* sp., *Cicatricosisporites* sp., *Callialasporites* sp., *Cycadopites* sp. cf. *Vitreisporites* sp., *Podocarpidites* sp. and *Dacrycarpites* sp. All these genera, except *Dacrycarpites*, are present in the subsurface assemblage described from the Krishna-Godavari Basin (Text-fig. 4). However, the presence of characteristic genera, e.g. *Aequitriradites, Feotriletes, Cooksonites, Murospora, Appendicisporites*, etc. in the subsurface of the Krishna-Godavari Basin renders the two assemblages incomparable. It is considered that the assemblage described by Ramanujam (1957) from Vemavaram shales is incomplete and obviously a reassessment of this material is necessary; the same is also applicable to the Vemavaram assemblage described by Kar and Sah (1970).

The rich palynological assemblages recorded from the subsurface sequences met in wells drilled on the outcrops of the Upper Gondwana sediments conclusively prove that these sediments are Neocomian-Aptian in age. There is an apparent difference of opinion on the age as deduced from the plant megafossil evidences and foraminiferal evidences, the latter substantiated by palynological evidences. As Baksi (1967, p. 213) has rightly commented "…..the presence or absence of any element in the Upper Gondwana flora is more related to chance finding than the absence of it". Thus, the plant megafossil assemblage though distinct, might not be the representative or complete. The age can not be assigned only on the negative evidences such as the absence of *Weichselia* and *Onychiopsis*. Palynological evidences discussed in detail in this paper emphasize the close comparison with Early Cretaceous assemblages of Kutch and the subsurface sediments of Cauvery Basin. Foraminiferal evidences also favour the Early Cretaceous age assignment. Thus on the available evidences it is concluded that the Upper Gondwana sequence represented by Golapalli Sandstone, Raghavapuram Shale and Tirupati Sandstone in the West Godavari Depression and their equivalents (Budavada Sandstone, Vemavaram Shale & Pavalur Sandstone) in the Krishna Depression are Early Cretaceous.



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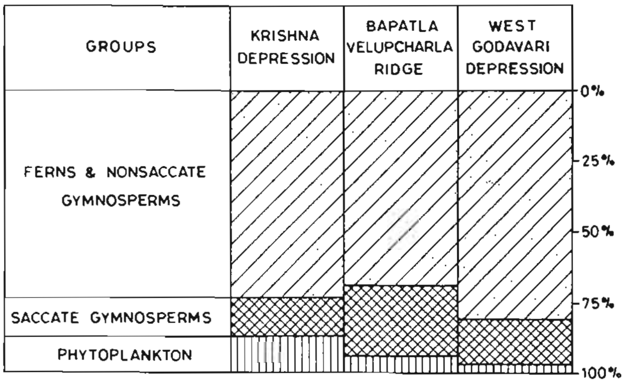
Text-fig. 4—Distribution of palynofossils.

The frequently mentioned discrepancy in age inferred from faunal and floral assemblages appears a falacy as far as the sediments on the east coast of India are concerned. From the foregoing discussion, it is clear that the incompleteness of the evidence, either faunal or floral, is a reality and should be ascribed to nonfinding of forms rather than their actual absence.

PALAEOECOLOGY

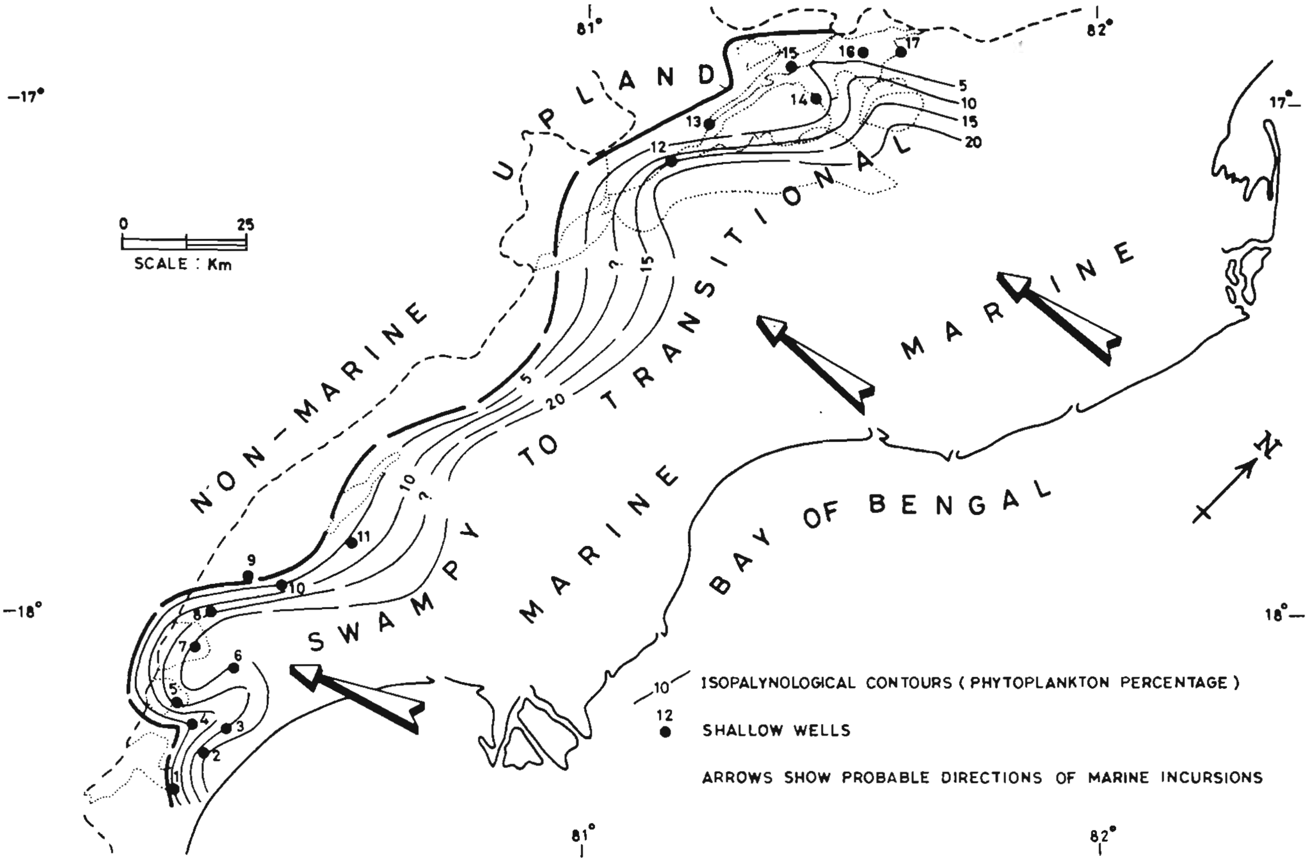
The relative abundance of saccate gymnospermous pollen, ferns as well as non-saccate gymnospermous pollen and phytoplankton (Text-fig. 5) are used for inferring the palaeoecology. The saccate gymnospermous pollen being wind pollinated are considered allochthonous and thus represent "Upland vegetation." The fern and non-saccate assemblage designate swampy environments. While the phytoplanktons designate shallow marine (mainly neritic) environments.

There is a general abundance of pteridophytic spores, phytoplankton and gymnospermous pollen are fairly well represented. The palynofloral assemblage (Text-fig. 4) is indicative of a marine swamp mainly dominated by ferns of Schizaeaceae, Osmundaceae, Cyatheaceae, Lycopodiaceae, Matoniaceae and Gleicheniaceae.



Text-fig. 5—Abundance of major floral groups.

Gymnospermous plants mainly of Araucariaceae and Cheirolepidaceae also occupied an important position in the vegetation of the neighbouring region. Cheirolepidaceae, a near shore representative represented by pollen of *Classopollis* (Venkatachala, 1966), is known to represent brackish marine sediments throughout the Mesozoic sequence. Saccate Podocarpaceous and other gymnospermous pollen including *Callialasporites* could have flown into the basin of deposition from various sources. A sizeable representation, such as 20 per cent and more of the total



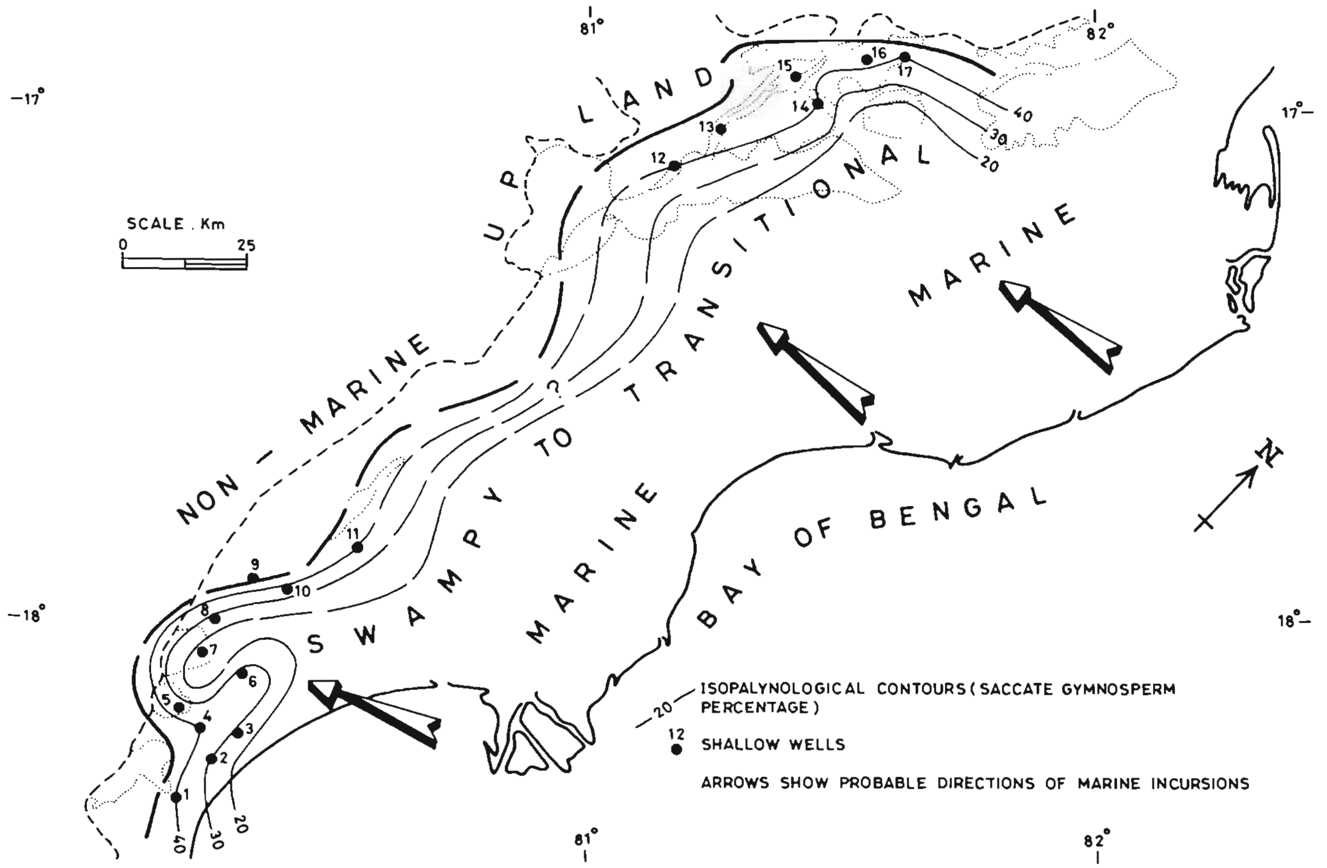
Text-fig. 6—Major environmental regimes reconstructed on the basis of phytoplankton percentage -Neocomian-?Aptian.

population of phytoplankton at a few horizons in Nutalapadu shallow well (Text-fig. 6) confirms marine influence/transgression. The saccate gymnosperms represented by *Microcachrydites, Podosporites, Podocarpidites, Alisporites, Araucariacites, Vitreisporites* and *Callialasporites* are allochthonous elements. These forms are of upland habitat and are concluded to have flown into the depositional area from areas close to the basin margins as is also suggested by their distribution (Text-fig. 7). Their relatively greater abundance in the Upper Gondwana sequence met at Tadikalapudi, in the northern part of the Bapatla-Velupcharla ridge may indicate that the southern parts of the Pranhita-Godavari graben had already been uplifted supporting an upland vegetation during the sedimentation of the coastal Gondwana sediments under study.

The fern spores are abundant and fairly uniform in their distribution (Text-fig. 5). They mostly include *Leptolepidites, Neoraistrickia, Ceratosporites, Foveotriletes, Concavissimisporites, Impardecispora, Cicatricosisporites, Klukisporites, Appendicisporites, Contignisporites, Murospora* and others which are concluded to be autochthonous; they are suggestive of warm and humid climates and swampy environments.

The phytoplankton distribution is not uniform. Their abundance at several levels indicates marine incursions in an otherwise dominantly swampy environment. The relative percentages of the major floral groups have been contoured (Text-fig. 6, 7) for inferring the special distribution of the various ecological regimes. The saccate gymnosperm pollen are most abundant in the basin margins and progressively decrease basin wards (Text-fig. 7). The phytoplankton are low nearer the basin margins and increase basin wards (Text-fig. 6). The contours for the saccate gymnospermous pollen and phytoplankton are complimentary to one another and display similar trends. These trends are suggestive of bay-like extensions in both the Krishna and West Godavari depressions. In the former, however, they were relatively in a more inland position. The progressive increase of phytoplankton was from the southwest to the northeast.

The sampling depths are limited to only 200 m and therefore do not permit a study of the entire Upper Gondwana sequence. Due to the presence of plant megafossils in the oldest exposed coastal Upper Gondwana sequence it may be surmised that the initial sedimentation took place under dominantly non-marine environments which gave place to swampy environments as is suggested by ferns, through interruptions by marine incursions which are evidenced by the occurrence of phytoplankton.



Text-fig. 7—Major environmental regimes—Neocomian-?Aptian (Reconstructed on the basis of saccate gymnosperm percentage.

Occurrence of hydrocarbons is related to source rocks which generally include argillaceous rock types. Hydrocarbons are formed in source beds from organic matter of the right kind and state when they are subjected to certain physiochemical-geologic processes over some period of time. Autochthonous living organic matter are the chief sources of the organic matter and among these, the most notable are the phytoplankton (Bordovsky, 1965). As already mentioned, the phytoplankton percentages are as high as 25 per cent and they increase towards the southwest in which direction the lithologies would be dominantly shaly. The increased percentage of phytoplankton as well as the dominance of argillaceous facies towards the southeast together with higher subsurface palaeotemperatures, as may be inferred from occurrence of Deccan trap lava flows (Text-fig. 1) in the exposed area, indicate that the coastal areas are likely to contain Early Cretaceous potential source rocks of hydrocarbons.

CONCLUSIONS

1. The tripartite classification of the exposed Upper Gondwana equivalents in the Krishna-Godavari Basin is not tenable in the subsurface. The three lithologic units identified in the outcrops give place to a major argillaceous sequence in the near subsurface.
2. The lower age limit of the exposed sequence does not see to extend into the Jurassic.
3. The discovery in age inferred from faunal and floral components is more apparent than real. Foraminiferal and palynological assemblages indicate an Early Cretaceous age.
4. The major palaeoecologic regimes vary from non-marine to paralic through swampy environments.
5. Phytoplankton percentages increase in the coastal area in which direction relatively better Early Cretaceous source rocks of hydrocarbons might develop in the subsurface.

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Ancient crop economy of Harappans from Rohira, Punjab (C. 2,000—1,700 B. C.)

K. S. Saraswat

ABSTRACT

Saraswat, K. S. (1986). Ancient crop economy of Harappans from Rohira, Punjab (C. 2,000—1,700 B.C.). *Palaeobotanist*, **35**(1) : 32-38.

This paper records the discovery of seven kinds of carbonised grains belonging to the Indian dwarf-wheat, emmer wheat, hulled barley, naked barley, lentil, horse-gram and fenugreek from the habitational deposits of mature-Harappan culture dating back from C. 2,000 to 1,700 B.C. at an ancient mound in Rohira Village, district Sangrur, Punjab. The remains of emmer wheat (*Triticum dicoccum*) and fenugreek (*Trigonella foenum-graecum*), both of Mediterranean region and Central Asia, have been reported for the first time in the Harappan economy. The present finds further throw light on the crops cultivated by Harappans about 4,000 years ago in the plains of Punjab in India.

Key-words—Palaeoethnobotany, Carbonised-grains, *Triticum*, *Trigonella*, Harappan Culture (India).

K. S. Saraswat, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

पंजाब में रोहिड़ा से हड़प्पा कालीन प्राचीन फसल अर्थ-व्यवस्था (लगभग 2,000 से 1,700 वर्ष ई० पूर्व)

कृपा शंकर सारस्वत

पंजाब में संगरूर जनपद के रोहिड़ा नामक गाँव में विद्यमान एक प्राचीन टीले से लगभग 2,000 से 1,700 वर्ष ईसा पूर्व की हड़प्पा-सभ्यता के आवासीय निक्षेपों से भारतीय बौना-गेहूँ, ऐंमर गेहूँ, शल्क युक्त जौ, शल्कविहीन जौ, मसूर, कुल्थी एवं मेथी के कार्बनमय दानों का अभिलेख किया गया है। हड़प्पा कालीन अर्थ व्यवस्था में ऐंमर गेहूँ (ट्रिटिकम् डाइकोक्कम्) एवं मेथी (ट्राइगोनेल्ला फ़ीनम-ग्रीकम्), जो कि मूलतः केन्द्रीय एशिया व भूमध्यसागरीय क्षेत्र के हैं, का यह सर्वप्रथम अभिलेख है। इन अन्वेषणों से भारत में पंजाब के मैदानों में लगभग 4,000 वर्ष पूर्व हड़प्पा कालीन मानव द्वारा उगाई गई फसलों पर प्रकाश पड़ता है।

INTRODUCTION

THE ancient mound in the village Rohira (lat. 30°35'N & long. 75°50'E), district Sangrur of Punjab, is situated about 13 km from Malerkotla township on the Malerkotla-Ludhiana Road, about 2 km south of the road. The mound, as now exists above the surrounding agricultural land, measures about 6 m in height and covers an area of about 15 acres. The rest of the portion has been levelled off for cultivation. The Department of cultural Affairs, Archaeology and Museums, Punjab has recently carried out archaeological excavations in an area of about 900 sq m on the main mound.

The excavations have revealed the sequence of cultures from C. 2300 B.C. up to Early Historic and Medieval times. The earliest is the pre-Harappan phase (C. 2,300-2,000 B.C.) succeeded by the mature-Harappan (C. 2,000-1,700 B.C.) and thereafter, the late-Harappan phase dating back from C. 1,700 to 1,100 B.C. The carbonised grains were collected from the trench C-8, stratum 4 at one meter depth (Period IB), which collectively reveal a rich and varied crop economy of the Harappans at this site.

MATERIAL AND METHODS

Two lots of the carbonised grains mixed with mud were handed over to the author by the excavator, Shri G. B. Sharma. Some of the grains are complete while the rest are broken ones. To remove the dust particles the grains were repeatedly washed with water and then treated with 5 per cent acetic acid for about 10 minutes to remove the remaining dirt. The duly washed grains have been examined under a stereobinocular microscope and the identification is based on the external morphological grounds.

For comparative study authentically identified material of extant plants was made available by the herbarium of the Birbal Sahni Institute of Palaeobotany and the Indian Agricultural Research Institute, New Delhi.

DESCRIPTION

In all, the following seven kinds of grains have been described.

1. Dwarf Wheat : *Triticum sphaerococcum* Percival

Pl. 1, fig. 1

The kernels of shot wheat, inspite of some puffing during carbonization, have retained much of their broad and somewhat rounded or oval-round shape with broad and circular hump on the dorsal side. They measure 4.00-3.00 mm in length, 3.50-2.50 mm in breadth and 3.00-2.25 mm in thickness. The pericarp of some of the grains has got partly rubbed off. On the basis of these characters the carbonised grains differ from those of *T. aestivum* and *T. compactum*, but resemble that of *T. sphaerococcum*. The ratios of various indices based on the dimensions of carbonised grains, as given in Table 1, also compare with those of *T. sphaerococcum*. The L/B and L/T indices under 2 and B/L index above 0.50 as suggested by Vishnu-Mittre and Savithri (1982) for shot wheat, further support the identification of ancient Rohira wheat to *T. sphaerococcum*, though the number of the kernels was limited for such statistical considerations.

Table 1—Dimensions of *T. sphaerococcum* grains (in mm)

	Length (L)	*Breadth (B)*	*Thickness (T)*	*L/B*	*L/T*	*B/L*	*B/T*	*T/L*	*T/B*
	3.00	3.00	2.70						
	3.00	3.40	3.00						
	4.00	3.50	3.00						
	3.70	3.00	3.00						
	3.70	2.80	2.50						
	3.60	3.00	2.50						
	4.00	3.00	2.50						
	3.50	2.30	2.25						
Average:	3.56	3.00	2.68	1.19	1.33	0.84	1.12	0.75	0.89

2. Wheat : *Triticum* sp.

Pl. 1, fig. 5

The lot is represented by a dozen elongated grains tapering towards both the ends with distinctly curved dorsal side and flattish ventral side. The distortion during the course of preservation in some of the kernels seems to have blurred the distinct morphological appearance. On a close examination under a stereobinocular microscope, a few kernels have been found to be partially enclosed within a hull or glume showing very faint longitudinal striations. One of the kernels (Pl. 1, fig. 5) has a small part of rachis attached. The grains measure 5.60-4.00 mm in length, 2.50-2.00 mm in breadth and 2.00-1.75 mm in thickness. The cheeks along the sharp and deep ventral furrow are slightly puffed. Embryo is rather large. The dimensions of well-preserved nine kernels are given in Table 2.

Table 2—Dimensions (in mm) of wheat (*Triticum* sp.) grains

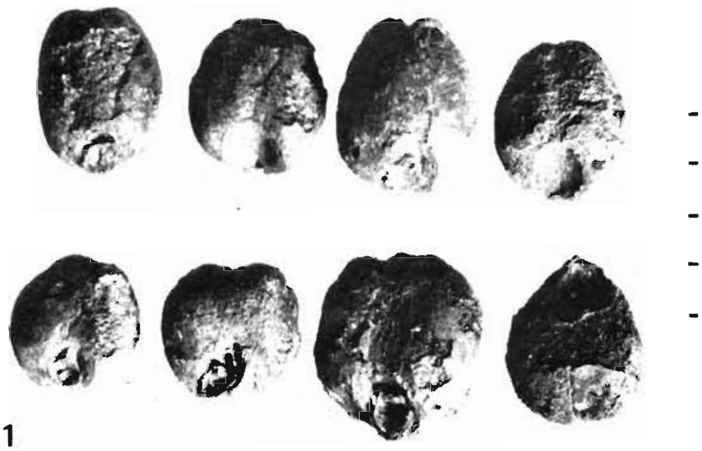
	Length (L)	*Breadth (B)*	*Thickness (T)*
	4.00	2.00	1.80
	4.00	2.50	2.00
	5.50	2.00	2.00
	5.00	2.00	1.75
	5.00	2.50	2.00
	5.50	2.50	2.00
	5.20	2.30	2.00
	5.50	2.30	2.00
	5.60	2.40	2.00
Average:	5.03	2.27	1.95

→

PLATE 1

(Magnification of grains in mm)

1. Shot wheat (*Triticum sphaerococcum*) grains.
2. Lentil (*Lens culinaris*) seeds.
3. Fenugreek (*Trigonella foenum-graecum*) seeds.
4. Naked barley (*Hordeum vulgare* L.-var. *nudum*) grains.
5. Emmer wheat (*Triticum dicoccum*) grains.
6. Horse-gram (*Dolichos biflorus*) seeds.
7. Grains of hulled barley (*Hordeum vulgare* L. emend. Bowden).



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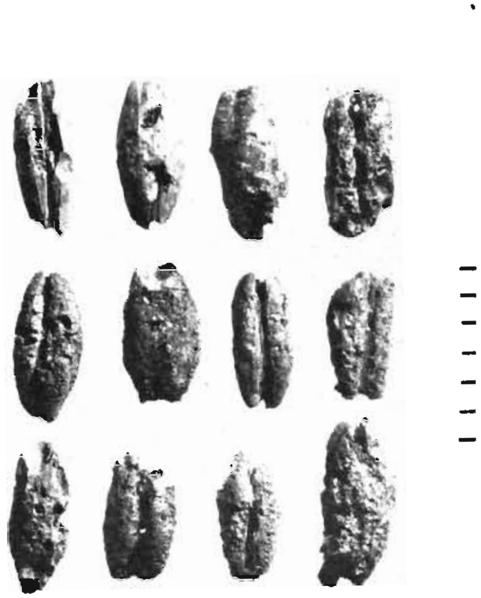

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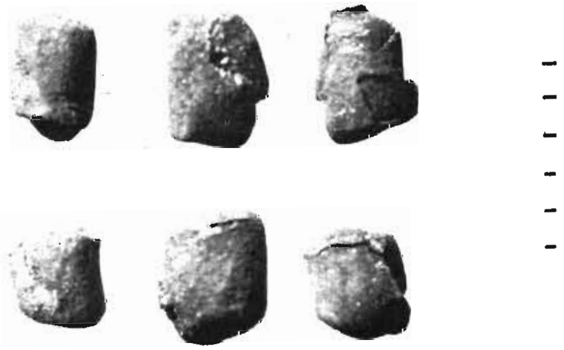

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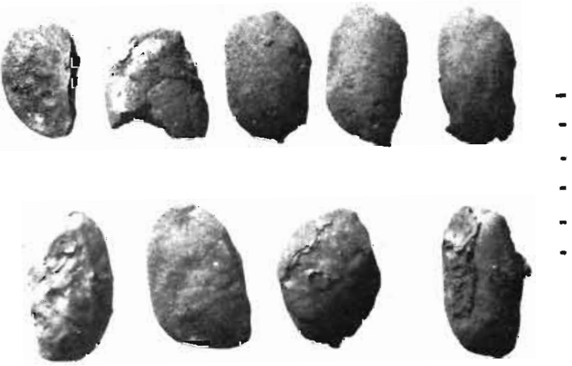

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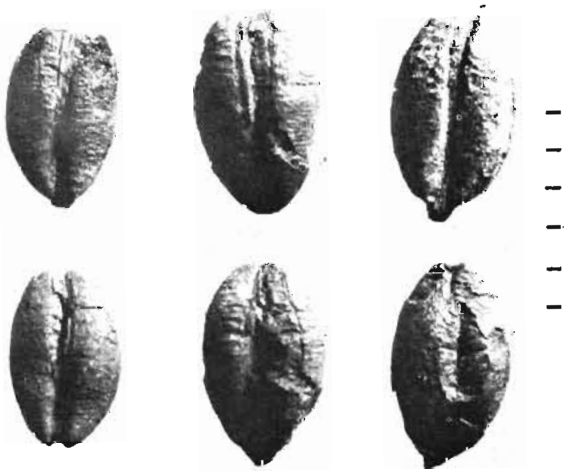

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7

PLATE 1

The kernels enclosed in a hull, elliptical in shape with tapering ends and deep ventral furrow differ from those of cultivated barley having pointed embryonal end and shallow and wide ventral furrow, and also differ from the caryopses of oat (*Avena* sp.) which are more slender and sharply pointed at one end. Taking into consideration the feature of rechis found attached to one of the carbonized kernels, a comparison has been attempted with the kernels of wild grasses of tribe Festuceae (such as *Bromus*, *Festuca*, *Glyceria*, *Poa*, *Eragrostis*, etc.) growing in north-western India, which are characterised with short, erect stalk or rachis at the base of grain-enclosing floret. There is nothing common in these, particularly in the shape of kernels and the features of embryo, which could be regarded as comparable with the unknown grains. Further, the carbonized grains are much unlike those of the free-threshing wheats, viz., the bread wheat (*T. aestivum*) which have grains broader in middle and narrower towards both the ends and with raised dorsal side; club wheat (*T. compactum*) of which grains have rounded or broader apex and the shot wheat (*T. sphaerococcum*) which have short, more or less rounded grains. However, on morphological grounds, the carbonised, elongated and elliptical grains with distinctly curved dorsal side, seem to compare with those of Emmer wheat (*T. dicoccum*). It is important to note that in Emmer, the rachis does not break readily but yields to pressure. The part of rachis attached with one of the carbonized kernels (Pl. 1, fig. 5) further suggests close resemblance with those of Emmer-like form. The ancient grains having thickness less than, or at the most equal to, the width (Table 2) further compare in breadth-thickness ratio with those of cultivated *T. dicoccum* as suggested by Helbaek (1958).

The emmer is the crop of West Asia and Egypt and it might have entered through the west coast of India by the traders (Howard, 1916; Rao, 1974). The modern cultivation of emmer in the parts of peninsular India (especially in Gujarat) and its total absence in the main wheat producing zones of north-western, north-eastern and central India is suggestive of its introduction through western coastal regions. If the identification of these grains to *T. dicoccum* is correct, it may suggest its cultivation in the plains of Punjab about 4,000 years ago. This inference is likely to be questioned on botanical and archaeobotanical grounds. Emmer wheat is not cultivated in north-western India today. If emmer is presumed to have existed in ancient agriculture in the region of Punjab, this type would have been represented elsewhere also in the contemporaneous or earlier or later archaeobotanical finds. Moreover, it has not been represented in the highly advanced agriculture of Harappans who have, evidently, been regarded on archaeological grounds to have established their intimate contacts and trade with western Asia. In addition, the north-western India is not the ancestral home of *T. dicoccum* as its evolution is regarded to involve the occurrence of its wild progenitors, i.e. wild emmer grass (*T. dicoccoides*) and goat-face grass (*Aegilops tauschii*). *Ae. tauschii* is, however, reported to occur in Kashmir (Bor, 1960) but not in the plains of Punjab. Wild emmer grass does not occur in the Indian subcontinent.

The possibility of ancient wheat kernels, belonging to some aberrated forms of cultivated wheat, may also not be completely ruled out. In modern wheat crops, aberrant grains do occur which differ in their appearance from the normal ones and their classification up to specific level can hardly be justified on the morphological grounds. A critical observation on the occurrence of aberrant grains is explained as a result of the presence of a few wheat plants in the barley fields and vice versa. These aberrant kernels reveal the characteristics intermediate between wheat and barley. Such wheat grains have shallow ventral furrow which does not run end to end as in barley. The aberrant barley grains share the characters of wheat grains in having smooth surface and dorsal hump (Vishnu-Mittre & Savithri, 1982). The carbonised grains enclosed in the husk compare with the hulled barley; the deep, narrow, ventral furrow running end to end is manneristic of wheat caryopses. Further, the Rohira grains are characteristically elliptical having dorsal side curved which does not compare with flattish dorsal side of barley. Features of embryo are similar to wheat and the pointed embryonal beak, as in barley, is also wanting in the present carbonised grains. Thus the Rohira grains do not compare morphologically with the aberrant grains of both wheat and barley. The elliptical hulled grains tapering at both the ends, with curved dorsal side, deep and narrow ventral furrow running end to end and large, broad embryo, are comparable in all respects with cultivated emmer wheat (*T. dicoccum*). The part of tough rachis attached to one of the kernels further supports the same contention. These characters have been regarded useful not only for the modern wheats but also for the classification of ancient wheats (Helbaek, 1960). Therefore, the ancient glumed wheat from Rohira is placed under a tetraploid species of *Triticum dicoccum* Schübl.

3. Barley : *Hordeum vulgare* L. emend. Bowden

Pl. 1, fig. 7

Description—All the 15 complete carbonised kernels of barley are partially or completely enclosed in a thick husk. They are angular in cross view because of the closely appressed palea veins running longitudinally. The longitudinal striations of husk are more distinctly observed on the ventral cheeks along the shallow furrow which arises from the base and gradually widens towards the upper end of the grains. The kernels vary from 7.40

to 4.40 mm in length and 4.00 to 2.70 mm in breadth (Table 3). The lot of the carbonised grains reveals a mixture of comparatively larger and straight grains having a distinct bulge in the middle, and smaller, somewhat assymmetrical grains with ventro-lateral twists. In this regard, the carbonised barley grains belong to the six-rowed form of hulled barley in which all the three florets present at each node of spike are fertile. The middle caryopses have developed a distinct bulge and the lateral ones are pushed outwardly developing the characteristic twists.

Table 3—Showing length and breadth (in mm) of carbonised barley grains

	Length (L)	Breadth (B)
	7.40	4.00
	6.00	3.00
	5.20	3.30
	6.90	3.00
	6.00	3.50
	5.00	3.00
	6.50	3.80
	4.40	3.00
	6.20	3.00
	5.90	3.80
	5.30	3.20
	5.50	3.20
	6.00	3.00
	6.00	2.70
	6.00	2.90
Average:	5.89	3.23

4. Naked barley : *Hordeum vulgare* L. var. *nudum*

Pl. 1, fig. 4

Description—Six kernels measuring 6.50-5.00 mm in length and 3.50-3.00 mm in breadth (Table 3) appear to be much broader in relation to their length than the kernels of hulled barley. The grains are almost circular in cross view and some of them exhibit slight lateral twists. In the absence of husk (lemma & palea fused with pericarp), the grains appear hull-less or naked. The peculiar transverse rippling on the grain surface, more prominently on the cheeks along the shallow furrow on ventral side, developed as a result of pericarp contraction during drying of the kernels. They compare in all respects with those of the six-rowed form of naked barley.

Table 4—Showing length and breadth (in mm) of naked-barley grains

	Length (L)	Breadth (B)
	6.00	3.20
	6.50	3.50
	5.00	3.00
	5.70	3.30
	5.50	3.40
	5.00	3.20
Average:	5.61	3.26

5. Lentil : *Lens culinaris* Maedik

Pl. 1, fig. 2

Description—Four seeds of lentil measuring about 3.30-2.50 × 3.00-2.20 mm (L × B) are circular and flattened with keeled-margins. They are more or less lenticular in appearance. The hilum is small and acutely lanceolate in shape. In one of the seeds, the seed coat has partly been rubbed off. Morphologically, the seeds compare with some small-seeded variety of *Lens culinaris*.

Table 5—Dimensions (in mm) of Horsegram seeds

	Length	*Breadth*	*Thickness*
	4.50	2.70	2.00
	4.70	2.50	2.20
	4.00	2.50	2.20
	4.80	2.80	2.25
	4.40	3.50	2.30
	5.00	3.00	2.30
	5.00	2.40	2.00
Average:	4.63	2.78	2.18

6. Horse-gram : *Dolichos biflorus* Linn.

Pl. 1, fig. 6

Description—There are, in all, seven ellipsoid and somewhat kidney-shaped, laterally flattened complete seeds and the rest are broken. Seed surface is smooth. The small elliptical hilum measures 1.30-1.00 × 0.50 mm. The seeds measure 5.00-4.40 mm in length, 3.50-2.40 mm in breadth and 2.30-2.00 mm in thickness. The cotyledon (the left most in upper row) measures 3.70 mm in length, 2.40 mm in breadth and 1.25 mm in thickness. The seeds resemble those of *Dolichos biflorus*, vernacularly known as Horse-gram or Kulthi.

Table 6—Showing length and breadth (in mm) of fenugreek seeds

	Length	*Breadth*
	3.30	2.70
	4.00	3.00
	3.00	2.70
	3.70	2.50
	3.70	2.30
	3.70	2.50
Average:	3.56	2.61

7. Fenugreek : *Trigonella foenum-graecum* L.

Pl. 1, fig. 3

Six seeds of fenugreek measuring 4.00-3.30 mm in length and 3.00-2.30 mm in breadth have been encountered. They are somewhat oblong, having deep grooves across one corner. The seeds in the upper row (Pl. 1, fig. 3) show the radicle appressed to cotyledons up to approximately more than half the length of seeds. The dimensions of the seeds are given below in Table 6. They are very much alike, both in shape and size, to those of modern fenugreek or Methi seeds used in spices and condiments.

DISCUSSION AND CONCLUSIONS

The grains recovered from Period IB (Harappan occupation) at Rohira and dating back to about C.2,000-1,700 B.C., amply reveal the rich and varied crop economy of the Harappans in the plains of Punjab. The grains comprise two forms of barley—Hulled (*Hordeum vulgare* L. emend. Bowden) and naked (*H. vulgare* L. var. *Nudum*); two forms of wheat—shot wheat (*Triticum sphaerococcum* Percival) and some grains comparing with those of Emmer (*T. dicoccum*); lentil (*Lens culinaris* Maedik); horse-gram (*Dolichos biflorus* L.); and fenugreek (*Trigonella foenum-graecum* L.).

The grains of hulled and naked barley and shot wheat (*T. sphaerococcum*) have already been reported from Harappa, Mohenjodaro and Chanudaro in Pakistan and Pre-Harappan levels at Kalibangan in Rajasthan, India (Percival, 1921; Stapf, 1931; Vats, 1941; Shaw, 1943; Vishnu-Mittre, 1974; Vishnu-Mitre & Savithri, 1982). These crops were widely cultivated throughout the Harappan empire in the north-western part of the Indian subcontinent.

The cultivation of barley by the Harappans is clearly understood and explained because of its adaptability to extremely dry climate and saline or alkaline conditions of soil. Further, barley, being tolerant of alkalinity, frost and drought, needs less nutritive requirements than wheat. Obviously, it was the most profitable crop of Harappans in the north-western regions of India.

Shot wheat (*T. sphaerococcum*), selected by Harappans at Rohira, is a highly drought resistant species. It can adapt under adverse climatic conditions and to the soil having low fertility with high percentage of salts. This species can thrive in the areas with low precipitation. The dry climate is an added advantage to the pest control of this wheat crop which is highly susceptible to the pestiferous infections in humid conditions. The Harappans at Mohenjodaro and Chanudaro were growing and consuming the grains of both *T. sphaerococcum* and *T. aestivum/T. compactum*; at Rohira the grains could be referred only to *T. sphaerococcum*. *T. sphaerococcum*, formerly grown in Sind and Punjab, has now gone out of cultivation in these areas and at present it is grown as an important crop in Baluchistan.

Further discussion on the wheat grains comparable with those of emmer is unwarranted until their identity has been established from some other sites. It may, however, be of interest to mention that the emmer wheat along with einkorn wheat (*T. monococcum*), hard wheat (*T. durum*) and bread wheat, i.e. *T. aestivum* has been reported from the Neolithic level at Mehrgarh in the Kachi plains of Baluchistan (Jarrige & Meadow, 1980). At Mehrgarh and its surrounding area on the Bolan, a continuous sequence of occupations has been noticed from Neolithic to Harappan times. But strangely, emmer wheat has not been encountered in the Harappan deposits at this site.

Lentil is the pulse crop of much ancient cultivation. In northern India, the lentil seeds have been encountered from Neolithic sites at Gufkral in Kashmir Valley dating back about C. 2,500 B.C. (Sharma, 1982) and at Chirand in Bihar (Vishnu-Mittre, 1972) dating back between C. 1,900-1,400 B.C. (1,755 ± 155 to 1,270 ± 105: Agrawal, Kusumgar & Pant, 1975). Besides, its seeds have been recovered from the late Harappan site at Hulas (District Saharanpur) in western Uttar Pradesh (Saraswat, unpublished).

Horse-gram (*Dolichos biflorus*) is an indigenous species which is cultivated as a dry crop in most of the States. It can easily sustain on poor soils and is hardy and drought-resistant. The seeds are extensively used as a feed for cattle and horses in the same way as of gram (*Cicer arietinum*) and consumed by man also.

Wild fenugreek (*Trigonella foenum-graecum*) now grows in Kashmir, Punjab and Upper Gangetic plains. It is widely cultivated in many parts of India. In Punjab, it is cultivated as a fodder crop. The fenugreek is indigenous to the countries bordering the eastern shores of the Mediterranean, extending to Central Asia. Its independent centre of origin is believed to be in Ehiopia (Anonymous, 1976). The occurrence of seeds of *Trigonella foenum-graecum* identified at ancient Rohira is a new contribution to the ancient plant economy of India.

As a result of intensive explorations, the area of Harappan Culture complex has expanded enormously, but the plant remains have not frequently been encountered for botanical study at many of the excavation sites. Thus, our knowledge on the Harappan food economy has not progressed very far. The presence of barley at Kalibangan; wheat and barley at Harappa, Mohenjodaro and Chanudaro; and the predominance of wheat and barley at Rohira too suggests that wheat and barley were the main cereal crops of Harappans in the north-western region of the Indian subcontinent. At Rohira, it is of interest to mention that Emmer wheat and fenugreek seeds have also been encountered with other food grains. Both these crops do not have their ancestry in India. Moreover, the remains of Emmer wheat and fenugreek have not been found so far at any of the Harappan and pre-Harappan sites. Emmer wheat is originally of West-Asia and Egypt and fenugreek is indigenous to the countries bordering the eastern shores of Mediterranean, extending to Central Asia. Although, their occurrence in the Harappan food economy at Rohira, by and large, is fragmentary, but it is certain that these remains are suggestive of Indo-West Asian connections during the Harappan times. Since the excavations of Harappa and Mohenjodaro, the workers have tried to ascertain every bit of material evidence which may throw light on the Indian contacts with West-Asia. Except for a very few specific items of seals, beads, etc. there is nothing very tangible to establish the fact. Thus, under such circumstances the finds of Emmer wheat and fenugreek bear ample testimony to their importance in context of Harappan contacts with West Asia. The factual informations on plant remains are scanty and widely scattered. Under the present limitations of our knowledge, it is difficult to work out the exact mechanism and source through which these crops of West-Asian ancestry diffused into Punjab. There might have been, probably other plants as well, but certain evidence is lacking. Further investigations on plant remains may, indubitably, provide the valuable informations in this regard.

ACKNOWLEDGEMENTS

Grateful thanks are due to Shri G.B. Sharma, the excavator of the site and to the Director, Department of Cultural affairs, Archaeology and Museums, Panjab, for kindly entrusting this material to me for investigation. I feel grateful to Dr Vishnu-Mittre for his valuable suggestions during this investigation. Thanks are also due to the herbarium staff of B.S.I.P. for the extant material for comparative study and to Mr P. C. Roy for his assistance in photography.

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On two new fossil woods from the Raniganj Formation : with remarks on *Zalesskioxylon zambesiensis* from Mozambique

Usha Bajpai & Hari K. Maheshwari

ABSTRACT

Bajpai, Usha & Maheshwari, Hari K. (1986). On two new fossil woods from the Raniganj Formation: with remarks on *Zalesskioxylon zambesiensis* from Mozambique. *Palaeobotanist* **35** (1) : 39-47.

Fossil woods are rather scarce in Lower Gondwana. A large percentage of woods so far reported belong to Raniganj or equivalent formations. The two new species of wood reported here also originate in the Raniganj Formation. Lepekhina's circumscription of the genus *Araucarioxylon* is not accepted as it overlaps the diagnosis of the genus *Dadoxylon*. Her assignment of *D. brandlingii* (Lindley & Hutton) Endlicher as lectogenotype of *Dadoxylon* is not acceptable because the correct type species is *D. withamii* (Lindley & Hutton) Endlicher. *Zalesskioxylon zambesiensis* Maithy has been re-investigated and found to be conspecific with *Australoxylon teixeirae* Marguerier. The genera *Parapalaeoxylon* Prasad and *Kamthioxylon* Mahabale & Vagyani are probably superfluous.

Key-words—*Araucarioxylon, Australoxylon, Damudoxylon, Zalesskioxylon,* Raniganj Formation (India).

Usha Bajpai & Hari K. Maheshwari, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226007, India.

सारांश

रानीगंज शैल-समूह से दो नवीन काष्ठाश्म एवं मोज़ाम्बिक की ज़लेस्किऑक्सीलॉन ज़ेम्बेज़ियेन्सिस पर टिप्पणी

ऊषा बाजपेई एवं हरिकृष्ण माहेश्वरी

अधरि गोंडवाना में अश्मित काष्ठ वस्तुतः बहुत कम मिलती हैं। अभी तक अभिलिखित काष्ठाश्मों में अधिकाँश रानीगंज अथवा समतुल्य शैल-समूहों से सम्बद्ध हैं। इस शोध-पत्र में वर्णित काष्ठाश्मों की दो नवीन जातियाँ भी रानीगंज शैल-समूह से ही हैं। लेपेखिना का अँरोकेरिऑक्सीलॉन प्रजाति का परिसीमन मान्य नहीं है क्योंकि यह डेडॉक्सीलॉन प्रजाति के निदान से काफी समानता प्रदर्शित करता है। इन्हीं का डे. ब्रॉडलिंगाई (लिन्डले व हट्टन) एँण्डलिशर का डेडॉक्सीलॉन के चयनवंशप्ररूप के रूप में नामाँकन स्वीकार्य नहीं है क्योंकि डे. विदॅमाई (लिन्डले व हट्टन) एँण्डलिशर ही उपयुक्त जाति है। ज़लेस्किऑक्सीलॉन ज़ेम्बेज़ियेन्सिस माइती का पुनः अध्ययन किया गया तथा इसे ऑस्ट्रेलॉक्सीलॉन तीक्सीयॅरी मारग्वेरियर से समजातिक पाया गया। पैरापेलिऑक्सीलॉन प्रसाद एवं कामथीऑक्सीलॉन महाबले व वाग्यानी नामक प्रजातियाँ सम्भवतया निरर्थक हैं।

INTRODUCTION

WHILE the Lower Gondwana formations of India abound in impressions and compressions of leaves, fossils of woods, like those of the fertile organs, are rather rare. Most of the woody axes, e.g. *Vertebraria*, are again known in the form of impressions or compressions, there being only occasional records of petrifactions.

Of the five sedimentary formations recognised in the Lower Gondwana of India, viz., Talchir, Karharbari, Barakar, Barren Measures and Raniganj in ascending order, only two, viz., Barakar and Raniganj formations have yielded identifiable woods. The major part of the Lower Gondwana woods reported so far has come from Raniganj Formation in the Raniganj Coalfield and Kamthi Formation in the Chandrapur District. Comprehensive reviews have been published by Kräusel, Maithy and Maheshwari (1963), Maheshwari (1972), Maithy (1974) and Prasad (1982).

In the present paper some new fossil woods associated with a coal seam of Raniganj Formation in the Lodna Colliery, East Raniganj Coalfield have been described and assigned to two new species. Taxonomic notes on *Zalesskioxylon zambesiensis* have also been given.

Though one of the first fossil woods recorded from the Raniganj Coalfield was *Araucarioxylon robertianum* Schenk, 1882, first detailed description was provided by Sahni (1933) who described *Dadoxylon zalesskyi* from the Kumarpur Sandstone Member of the Raniganj

Formation. Bradshaw and Sahni (1925) had earlier recorded large tree trunks from the area. Some more fossil woods have been reported by Fox (1934), Rao (1935), Maheshwari (1965, 1967), Prasad and Chandra (1980) and others.

A large number of fossil wood pieces ranging in size from 4.6-6.4 cm in length and 5.6-7.8 cm in width were cut. Both ground thin sections and acetate paper peels were prepared. Some of the pieces were also processed for scanning electron microscopy (cf. Bajpai & Maheshwari, 1983). The present account is based on observations made on four better preserved woods. Of these four, three are only pieces of secondary wood and exhibit more or less similar features. These have been assigned to the genus *Araucarioxylon* Kraus, 1870. The fourth piece has pith and primary xylem preserved and on the basis of totality of characters is referable to the genus *Damudoxylon* Maheshwari, 1967.

Genus—*Araucarioxylon* Kraus, 1870 emend. Maheshwari, 1972

Type species—*Araucarioxylon carbonaceum* (Witham) Kraus (in Schimper, 1870)

1966 *Zalesskioxylon* Lepekhina & Yatsenko-Khmelevsky, *Taxon* **15** (2) : 78.
1972 *Araucarioxylon* Kraus, 1870 : Lepekhina, *Palaeontographica* **B138** : 55 (pars).
1982 *Parapalaeoxylon* Prasad, *Rev. Palaeobot. Palynol.* **38** : 147.

Remarks—Lepekhina's (1972) circumscription of the genus *Araucarioxylon* Kraus, 1870, which includes 1-5 seriate xylem rays, is against Kraus' (1870) original concept of the genus. Woods with araucarioid pits and multiseriate rays should be placed under the genus *Dadoxylon* Endlicher, 1847 because the type species of this genus, *D. withamii* (Lindley & Hutton) Endlicher has 1-4 seriate xylem rays (Lindley & Hutton, 1831, figs 2,3). The genus *Araucarioxylon* as recircumscribed by Maheshwari (1972) includes only those araucarioid fossil woods which have uniseriate or occasional biseriate rays.

The genus *Zalesskioxylon* Lepekhina & Yatsenko-Khmelevsky, 1966 differs from the genus *Araucarioxylon* only in the nature of cross-field pits, which are said to be simple, minute and numerous in the former and cupressoid in the latter. It should, however, be recollected that quite often, due to differential degradation during preservation, the border of the pits of radial walls of the tracheids is so affected that only pit pore is clearly distinguishable making it appear as if the pits are minute and simple. Further, one has to be very careful in interpreting, particularly so in ground thin sections, that the pits seen in the cross-field are in actuality cross-field pits and not the regular radial pits of the tracheid lying below the ray. There also seems to some confusion about the typification of the genus *Zelesskioxylon*. According to the authors of the genus, the type species is *Zalesskioxylon angustum* (Felix) Lepekhina, but according to Lepekhina (1972, p. 66), the type species is *Zalesskioxylon hallei* Lepekhina. She thought that about 6 species described under the genus *Dadoxylon* should find place under *Zalesskioxylon* but proposed no formal transfer. As such Prasad (1982, p. 140) was in error in ascribing *Z. chandaensis* (Chitaley, 1949) and *Z. jamudhiense* (Maheshwari, 1964) to Lepekhina.

We may add that there is no unanimity so far as to whether cross-field pits are more important or radial pitting is more important for generic separation in secondary wood. For example, Lepekhina (1972, p. 66) places *Dadoxylon barakarense* Surange & Saxena, 1959 under *Zalesskioxylon* on the basis of number of pits in the cross-field, while Marguerier (1973b, p. 101) includes the same species under her new genus *Australoxylon* erected for woods apparently similar to *Araucarioxylon* but differing in having "mixed" type of pitting on the radial walls of the tracheids, i.e. (i) 1-3 seriate, alternate, araucarioid pits, (ii) 1-3 seriate, opposite, abietinioid pits, and (iii) groups of 2 to 5 circular pits. We would concur with her that this type of variation in radial pitting was important for generic separation only if we were certain that the abietinioid or grouped pitting was not a result of

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PLATE 1

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Araucarioxylon bradshawianum sp. nov.

1. Transverse section showing late and early wood. BSIP slide no. 35542/1. x 40.
2. Radial longitudinal section through the secondary xylem showing 2-3 seriate bordered pits. BSIP slide no. 35542/3. x 400.
3. Tangential longitudinal section showing uniseriate to partly biseriate xylem rays. BSIP slide no. 35542/2. x 100.
4. Radial longitudinal section through the secondary xylem showing uniseriate bordered pits. Note two opposite pits in lower half. BSIP slide no. 35542/3. x 400.
5. Radial longitudinal section through the secondary xylem showing alternate to sub-opposite araucarioid pits. BSIP slide no. 35542/3. x 400.
6. Radial longitudinal section through the secondary xylem showing triseriate araucarioid pits, each with a circular pit pore. BSIP slide no. 35542/3. x 400.
7. SEM micrograph of wood along a radial longitudinal fracture. Note the disintegration of pit border at corners. One of the pits shows a torus. x 750.
8. SEM micrograph of pits in the cross-field. The borders of the pits are clearly visible. x 750.

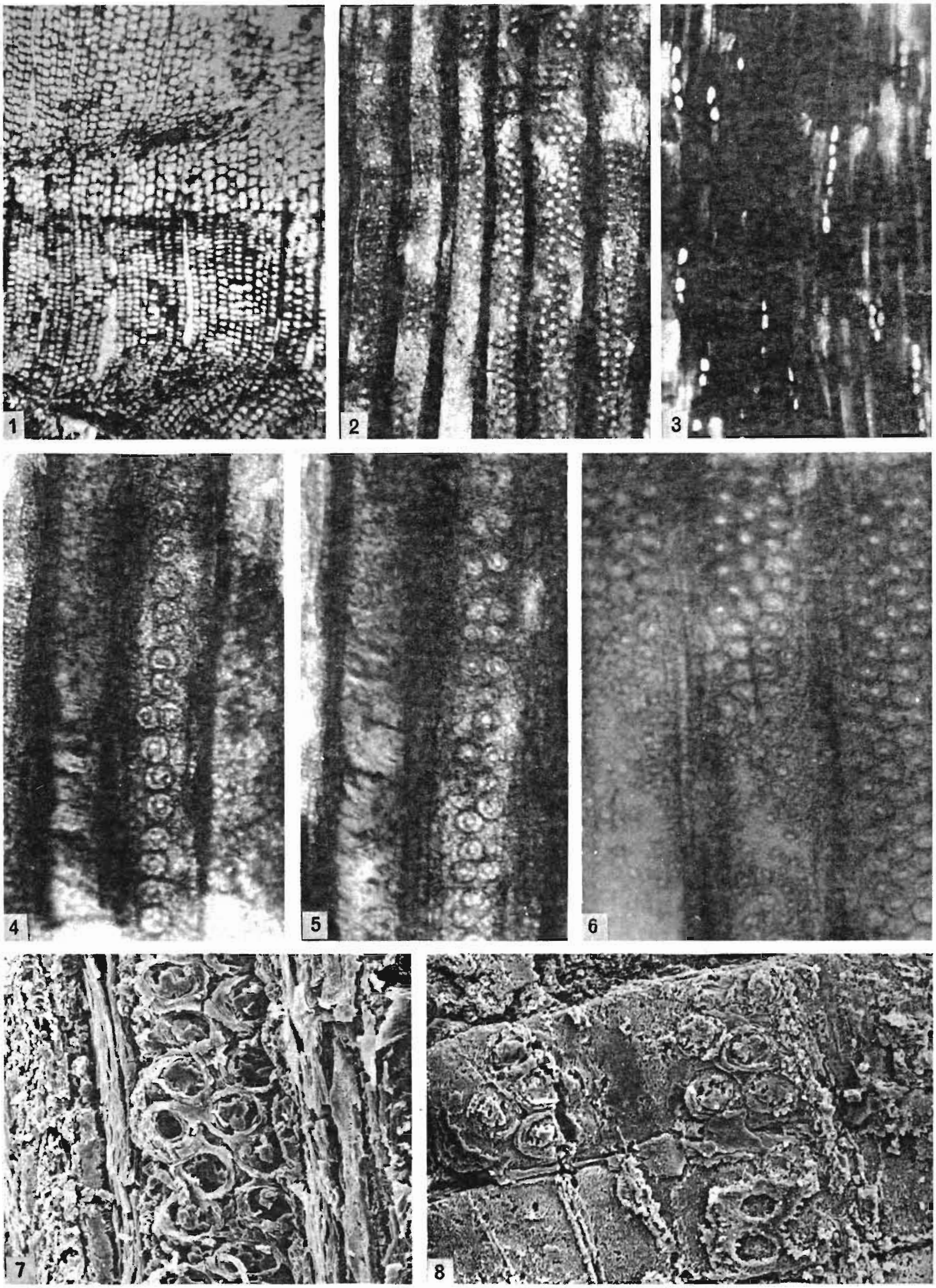

PLATE 1

disintegration or distortion of pit borders or even complete pits during preservation. Once it is conclusively proved, we have little doubt that most of Gondwana Palaeozoic secondary woods would have to be referred to the genus *Australoxylon*. However, we would certainly not agree to transfer woods with pith and primary xylem under this genus (Marguerier, 1973b, p. 101). The genus *Parapalaeoxylon* proposed by Prasad (1982, p. 147) is based on characters of dubious importance. Majority of new species proposed by him in the same work also seem to be based on too little information compounded with wrong interpretations. The genus *Kamthioxylon* Mahabale & Vagyani, 1980 is probably superfluous because it is based on interpretations not warranted by observable details in the wood.

Araucarioxylon bradshawianum sp. nov.

Pl. 1, figs 1-8; Pl. 2, figs 2, 6

Diagnosis—Secondary wood, annual growth increments distinct, autumn wood 4-5 tracheids wide, spring wood 60-75 tracheids wide; tracheids in transverse section squarish to rectanguloid in shape with a polygonal to more or less rounded lumina, arranged end to end in regular rows, xylem rays separating 2-9 tracheids wide radial bands; autumn wood tracheids measure 13-19.5 μm radially and 26-52 μm tangentially, lumina oval to rectanguloid, 13-45 μm; spring wood tracheids measure 26-52 μm radially and 32.5-52 μm tangentially with a 26-45.5 μm wide lumina; thickness of tacheidal walls 13-19.5 μm.

Tangential walls of tracheids smooth. Xylem rays in tangential section homogeneous, mostly uniseriate, at some places partly biseriate due to a middle or terminal ray cell pair, 1-21 cells high, majority of rays having 2-7 cells, cells 26-39 μm deep and 19.5-26 μm wide. Radial walls of tracheids showing uni- to penta-seriate bordered pits, pits about ·13 μm in diameter, pit-pore 7 μm in diameter. Uniseriate pits more or less circular in shape and usually contiguous, pit pore small, conforming to overall shape of pit. Multiseriate pits araucarioid, alternate and hexagonal. Due to natural degeneration of tracheidal walls during fossilization many a time pits appearing somewhat circular and more or less separate. Pits in cross-field 2-4, usually 4, apparently bordered, 9-10 μm in diameter.

Description—There is nothing remarkable about the transverse and tangential sections of these fossil woods which could help separating them from other known species of secondary woods (Pl. 1, figs 1, 3). The pitting of the radial walls of the tracheids is, however, quite interesting. Most of the autumn wood tracheids have uniseriate, circular and almost separate, radial pits (Pl. 1, fig. 4). In some of the autumn tracheids and the late spring tracheids the radial pits may be partly biseriate, most of the time being opposite, contiguous and slightly flattened (Pl. 1, fig. 5). They are yet not araucarioid in appearance.

The spring tracheid pits are typically araucarioid, whether biseriate or penta-seriate (Pl. 1, figs 2, 6; Pl. 2, fig. 2). The apparent circular/separate, though alternate, pits, are a result of natural degeneration of the tracheidal walls during preservation. This fact is clearly seen in scanning electron micrographs (Pl. 1, fig. 7). A torus has usually not been reported in pre-Mesozoic wood. In one of the scanning electron micrographs there is definite evidence of the presence of torus (Pl. 1, fig. 7). The pit border is composed of small granules arranged in concentric rings (Pl. 2, fig. 6). The tracheidal walls show minute pits, real nature and significance of which is not yet clear to us.

Holotype—BSIP specimen No. 35542; Upper Permian, Raniganj Formation, Lodna Colliery (Sripur Group of Collieries), East Raniganj Coalfield, West Bengal.

Comparison—About 10 species of the genus *Araucarioxylon* are known so far from the Lower Gondwana. A comparison of *A. bradshawianum* with these species is shown in Table 1. Out of these ten species, only *A. parbeliense* and *A. gondwanense* compare closely with the new species in radial pitting. However, *A. gondwanense* is distinguished by its deeper xylem rays and up to 8 cross-field pits. *A. parbeliense*, too, has larger number of cross-field pits.

Genus—*Damudoxylon* Maheshwari, 1966 emend. 1972

Type species—*Damudoxylon waltonii* Maheshwari, 1967

PLATE 2

Araucarioxylon bradshawianum sp. nov.

2. Scanning electron micrograph showing 2-3 seriate araucarioid pits on the radial walls of the tracheids. x 750.
6. SEM micrograph showing an advance stage in disintegration of material composing the pit border resulting in almost circular and separate alternate pits. x 1500.

Damudoxylon lepekhinae sp. nov.

1. Transverse section through the secondary wood showing parts of two growth rings. BSIP slide no. 35544/1. x 40.
3. Transverse section through the pith showing bunches of cells with dark contents. BSIP slide no. 35544/2. x 40.
5. Radial longitudinal section through primary xylem showing annular, scalariform and bordered pitted tracheids. BSIP slide no. 35544/3. x 40.

Australoxylon teixeirae Marguerier 1973

4. Radial longitudinal section showing bordered pits in the cross-field. Slide no. RG 17039 RLS.

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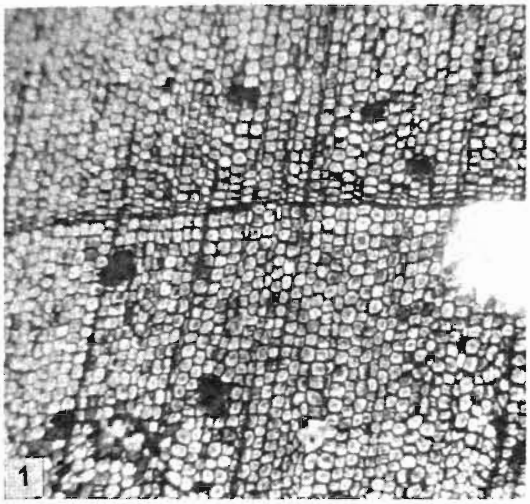

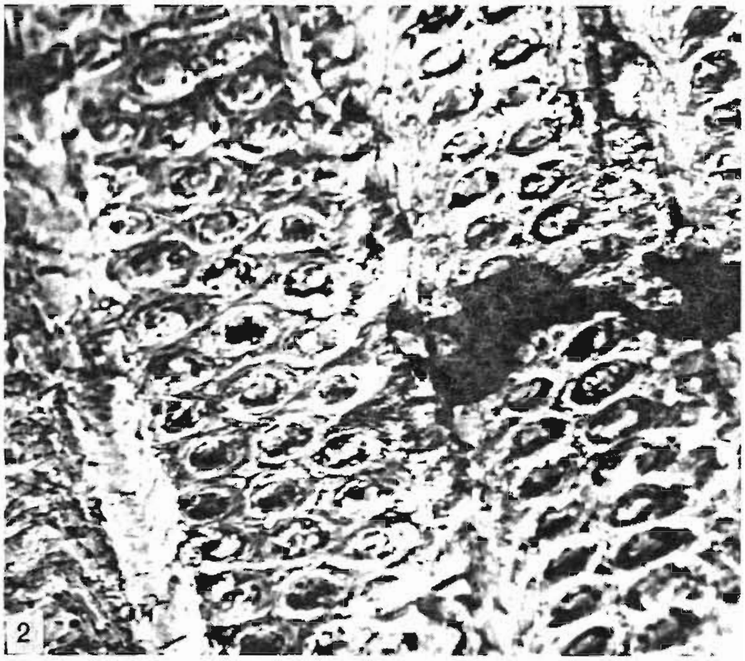

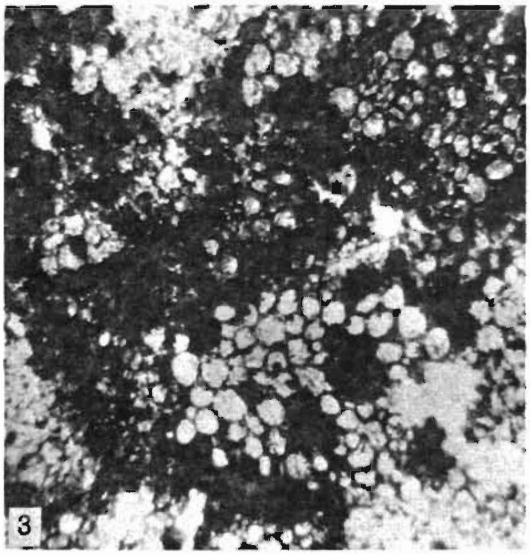

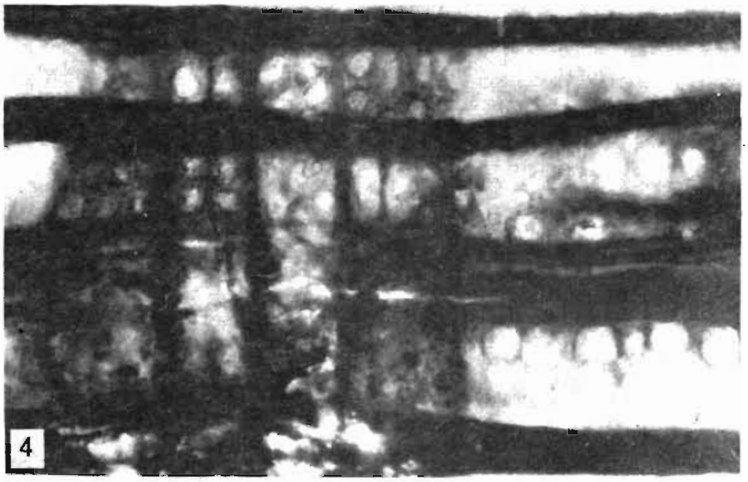

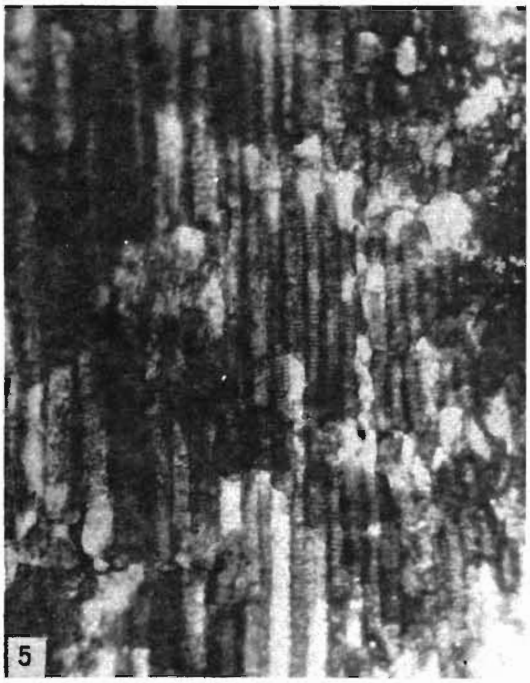

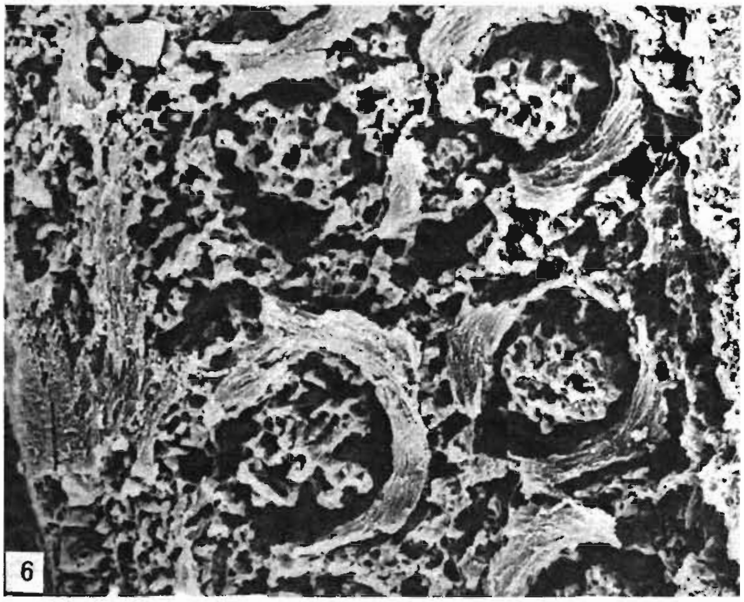

PLATE 2

Table 1

Species	*Height of Xylem rays in cells*	*Pitting on tangential walls*	*Pitting on the radial walls*	*Cross-field pits*
Araucarioxylon parbeliense (Rao, 1935) Maheshwari, 1972	1-24 (average 2-3), uniseriate	Absent	1-5 seriate, araucarioid, pore circular to oval	8-9, bordered, pore oblique, slit like
A. gondwanense (Maithy, 1964) Maheshwari, 1972	1-43 (average 8-9), 13% bi-seriate	Absent	1-5 seriate, alternate or sub-opposite, contiguous	2-8, contiguous or separate, circular oval
A. ningahense Maheshwari, 1964	1-11 (average 2-3 cells), uniseriate	Present	1-4 seriate, alternate or opposite, contiguous, hexagonal	1-6, bordered, pore oval
A. kharkhariense (Maithy, 1964), Maheshwari, 1972	1-29 (average 6-7), uni-to biseriate	Absent	1-3 seriate, contiguous; biseriate pits alternate or opposite, triseriate pits alternate	2-7, contiguous, pore elliptical
A. lobarense Agashe, *et al.*, 1978	1-27 (average 11), biseriate common	Present	1-4 seriate, separate or contiguous, hexagonal or circular or slightly elongated appearing araucarioid	2-9, most common 2,4,6
A. nandori Vagyani *et al.*, 1981	2-30 (average 8)	Absent	1-3 seriate, araucarioid	2-6, cupressoid, circular to oval
A. surangei Agashe *et al.*, 1981	1-35 (average 4), uni-to biseriate	Absent	1-4 seriate, separate or contiguous, opposite or alternate, pit pore circular or oblique in shape	1-11, Cupressoid, round to oval in shape
A. lathiense Agashe *et al.*, 1981	1-27 (average 5), uniseriate	Absent	1-4 seriate, separate or contiguous, round, oval to hexagonal.	1-10, cupressoid, circular to oval with thin border
A. bengalense (Holden, 1917) Maheshwari, 1972	1-20	Absent	1-3 seriate, araucarioid	2-7, cupressoid
Dadoxylon ghorawariense Pareek, 1969	1-10, uniseriate	Absent	1-3 seriate, mostly biseriate, araucarioid	2-6, border pits circular oval
Araucarioxylon bradshawianum sp. nov.	1-21 (average 2-7) uni- to biseriate	Absent	1-5 seriate, araucarioid	2-4, bordered pits

Remarks—The genus *Damudoxylon* was established by Maheshwari (1967) for gymnospermous fossil axes having araucarioid secondary wood, endarch primary xylem and a parenchymatous pith with secretory cells. Later, he (Maheshwari, 1972) enlarged the circumscription of the genus to include woods with homogeneous pith, too. Lepekhina and Yatsenko-Khmelevsky (1966) and Lepekhina (1972) diagnosed the genus *Dadoxylon* Endlicher, 1847 in such a way that its circumscription overlapped that of the genus *Damudoxylon*. They, however, erred in assigning *Dadoxylon brandlingii* (Lindley & Hutton) Endlicher, 1847 as the lectogenotype (type species) of *Dadoxylon*. The correct assignment is *D. withamii* (Lindley & Hutton) Endlicher, 1847 (see Andrews, 1970, p. 68), being the first species included under *Dadoxylon* by Endlicher (1847, p. 298). They further erred in believing that remains with nonseptate pith and endarch primary xylem belong to the genus *Dadoxylon* according to its original diagnosis. Prasad (1982, p. 127) also made the similar mistake in believing that original descriptions of Lindley and Hutton (1831) and Endlicher (1847) had made references to the nature of pith and primary xylem. Keeping in view that the publications of Lindley and Hutton (1831) and Endlicher (1847) are not easily accessible to all the workers, we reproduce below description of the genus *Dadoxylon* given by Endlicher (1847, pp. 298-299).

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PLATE 3

Damudoxylon lepekhinae sp. nov.

1. Tangential longitudinal section showing uniseriate sparse xylem rays. BSIP slide no. 35544/4. x 100.
2. Radial longitudinal section of the wood showing triseriate araucarioid pits. BSIP slide no. 35544/5. x 500.
3. SEM micrograph of pit borders showing onset of disintegration of material composing the pit borders, particularly at corners. x 3000.

Australoxylon teixeirae Marguerier, 1973

4. 2-3 seriate radial wall pitting showing alternate to sub-opposite arrangement. Grouping of pits is more evident here. Slide no. RG 17039 R.L.S.
5. Radial longitudinal section showing pits in groups of 2, 3 or 4. Note the large space between groups of pits. Slide no. RG 17039 R.L.S.
6. Radial longitudinal section showing pairs of opposite pits. Note the large space between pairs of pits. Slide no. RG 17039 R.L.S.

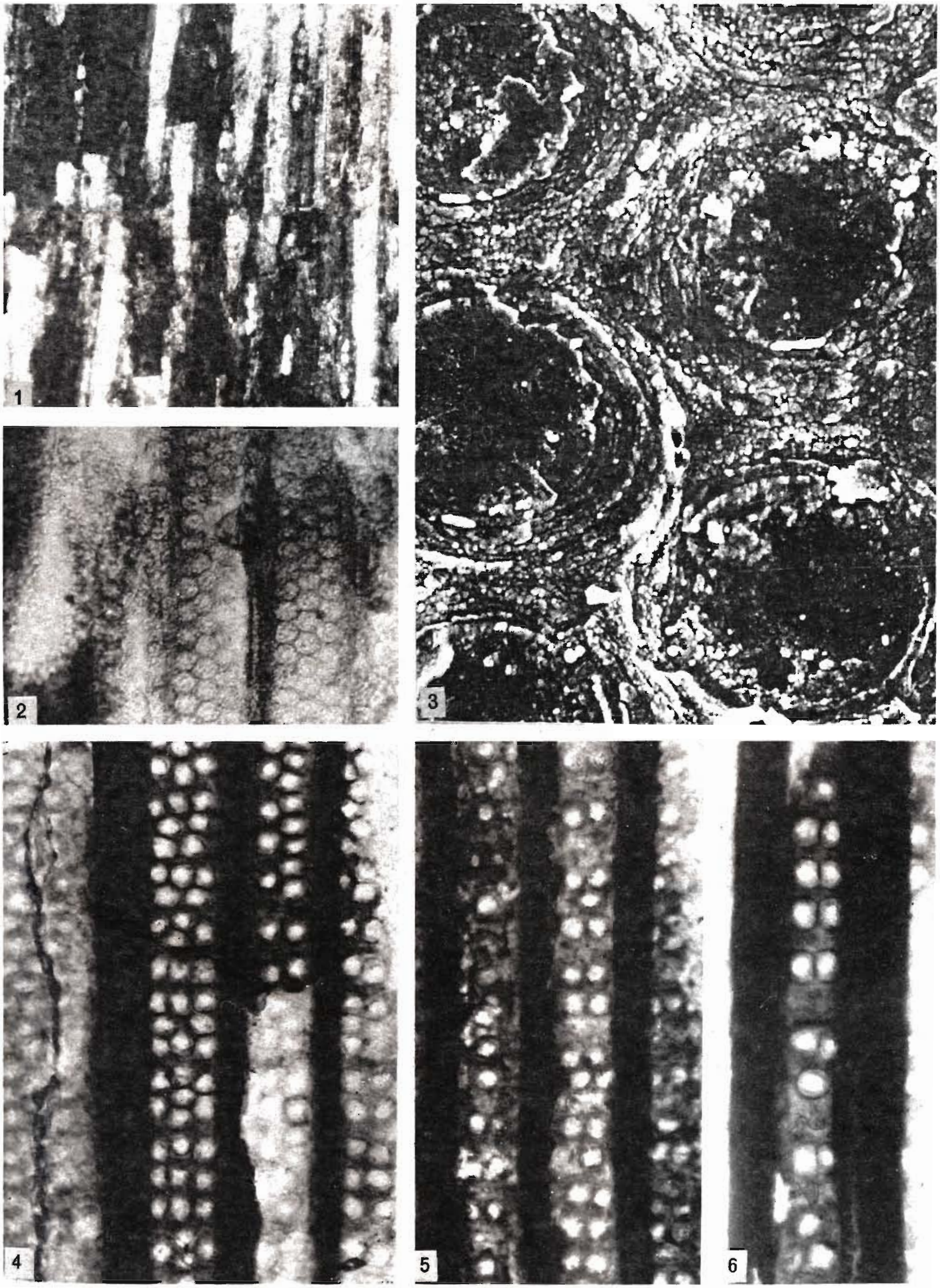

PLATE 3

"Truncus cylindricus, e medulla centrali. et ligni stratis concentricis obsoletis aut rarius distinctes et e cortice compositus. *Vasa* ligni cellulae prosenchymatosae poroso, poris in series 1-4 spiraliter dispositis, quam maxime approximatis, demum ob mutuam pressionem sexangularibus, plerumque nonnisi in parietibus radiis medullaribus parallelis et invicem oppositis obviis. *Radii medullares* e cellularum parenchymatosarum series unice v. pluribus formati, simplices v. compositi".

Knowing fully well that a number of woods with comparative secondary xylem have different types of pith and primary xylem, there is no justification for placing woods with pith and primary xylem under the genus *Dadoxylon* because, so far no detailed information is available about these features in the holotype of *D. withamii*.

Damudoxylon lepekhinae sp. nov.

Pl. 2, figs 1, 3, 5; Pl. 3, figs 1-3

Diagnosis—Pith solid, parenchymatous, homogeneous, 1.5 mm in cross section. Pith cells oval to isodiametric in cross-section, thick-walled, 19.5-105 μm in diameter, intercellular spaces present, but probably result of cell wall decay during preservation, longitudinally pith cells squarish to rectanguloid in shape, arranged end to end in vertical tiers, 19.5-104 μm in width, 30-97.5 μm in height, radial walls pitted.

Primary xylem not clearly decipherable in transverse section but distinctly seen in radial longitudinal sections, 10-13 cells deep, endarch, showing spiral and scalariform secondary thickenings, annular thickening not seen.

Secondary wood with distinct annual growth zones, autumn wood 1-4 tracheids wide, spring wood 35-69 tracheids wide, a xylem ray separates 2-18 tracheids wide radial bands; autumn wood tracheids rectanguloid in shape in cross section, measuring 13-15 μm radially and 32.5-39 μm tangentially, lumina oval to rectanguloid; spring wood tracheids polygonal in cross section, 19.5-45.4 μm radially and 26-52 μm tangentially, lumina subcircular to polygonal, tracheidal walls 6.5 μm thick.

Tangential walls of the tracheids smooth. Xylem rays in tangential section homogeneous, mostly uniseriate, 1-7 cells high, individual ray cells 9-13 μm wide, 13-26 μm deep.

Radial walls of the tracheids showing 1-3 seriate bordered pits. Uniseriate pits mostly circular, usually contiguous, rarely separate, mostly occurring in autumn wood tracheids. Multiseriate pits araucarioid, alternate, hexagonal and contiguous, pits borders often showing signs of preservational decay resulting in an apparently circular shape. Average diameter of pits 13 μm, that of pit pore 6.5 μm. Pits in the cross-field 2-4 in number, bordered, 13 μm in diameter.

Description—The pith is only partially preserved. In living plant it was probably circular in cross-section; the present distortion in shape possibly took place during fossilization. Some of the pith cells have dark contents, but it is not clear if these have any thing to do with the secretion activity (Pl. 2, fig. 3). The primary xylem, though endarch, is surprisingly lacking annular elements (Pl. 2, fig 5). Metaxylem elements comprise scalariform and pitted tracheids. The pitted metaxylem elements gradually pass into secondary wood tracheids.

The xylem rays are usually uniseriate and relatively sparse (Pl. 3, fig. 1). Average spring wood tracheid has araucarioid pits on its radial walls (Pl. 3, fig. 2).

Holotype—BSIP specimen no. 35543; Upper Permian, Raniganj Formation, Lodna Colliery (Sripur Group of Collieries), East Raniganj Coalfield, West Bengal.

Comparison—A comparison of *Damudoxylon lepekhinae* with the four known species of the genus is shown in Table 2. *D. parenchymosum* and *D. jamuriense* are distinct in having a homogeneous pith. *D. indicum* has a transfusion sheath around the pith. *Dadoxylon adhariense* and *D. maharashtraensis* lack growth rings. *Damudoxylon waltonii* has larger number (1-9) of pits in the cross-field.

Genus—*Australoxylon* Marguerier, 1973

Type species—*Australoxylon teixeirae* Marguerier, 1973

Australoxylon teixeirae Marguerier, 1973

Pl. 2, fig 4; Pl. 3, figs 4-6

1977 *Zalesskioxylon zambesiensis* Maithy, *Geophytology* **7** (1) 24, pl. 1, figs 1-7.

Remarks—As discussed elsewhere, the genus *Australoxylon* was established for those Palaeozoic secondary woods in which the radial walls of the tracheids had 'mixed' pitting. Two species, viz., *A. teixeirae* and *A. natalense*, were referred to this genus by Marguerier (1973a). The woods, which originated from Mozambique and Natal respectively, differed mainly in the presence of "bars of Sanio" in the latter wood. Maithy (1977) reported another wood from Mozambique under the name *Zalesskioxylon zambesiensis*. As this wood has mostly abietinioid or grouped pits on the radial walls of the tracheids, it rather belongs to the genus *Australoxylon*. Maithy reports that the pits in the cross-field in his wood are simple and up to 14 in number. That is not so. This wood not only has all the characters of *Australoxylon teixeirae* but was also collected from the same general locality, i.e. Tete Basin near Carinde, Mozambique. A re-examination of the Maithy specimen (no. 17039, Museé Royal du Africa Centrale, Tervuren, Belgium) shows following salient features.

Wood pycnoxylic. Annual growth increments clearly demarcated, autumn wood 1-2 tracheids wide in transverse section.

Xylem rays homogeneous, 1-30 cells high, uniseriate, up to 12 per cent partly biseriate. Tangential walls of the tracheids with doubtful pits.

Pits on radial walls of tracheids bordered, 1-3 seriate, mostly separate, subcircular-circular in out-line and

Table 2

Species	*Pith*	*Growth rings*	*Xylem rays*	*Radial pitting*	*Cross-field pits*
Damudoxylon waltonii Maheshwari, 1972	With secretory Cells	Distinct	1-14 cells high mostly 2-3 cells	1-3 seriate, rarely 4 seriate, araucarioid	1-9, bordered
D. indicum (Holden, 1917) Maheshwari, 1972	Heterogeneous with transfusion sheath	Distinct	2-7 cells	1-2 seriate, araucarioid	1-4, bordered
D. parenchymosum (Surange & Maithy, 1962) Maheshwari, 1972	Homogeneous	Distinct	1-18 cells, average 3 cells	1-4, mostly 2-3 seriate	2-8, bordered
D. jamuriense Maheshwari (1964) 1972	Homogeneous	Distinct	1-45 cells, mostly 6-8 cells	1-2 seriate, rarely 3 seriate	1-5, bordered
Dadoxylon chandrapurensis Prasad, 1982	Heterogeneous	Distinct	1-30 cells, average 10-11 cells	1-2 seriate	1-6, bordered
D. maharashtraensis Prasad, 1982	Heterogeneous with with secretory cells	—	1-16 cells, average 5-6 cells	1-3 seriate	5-6, bordered
D. adhariense Prasad, 1982	Heterogeneous	Absent	1-17 cells, transverse walls are pitted	1-4 seriate	3-5, araucarioid
Damudoxylon lepekhinae sp. nov.	With secretory cells	Distinct	1-7 cells	1-3 seriate, araucarioid	2-4, bordered

opposite, occasionally hexagonal in outline and alternately disposed in adjacent rows (Pl. 3, figs 4-6). Very often pits separate, circular and in groups of 2-6 (Pl. 3, fig 5). Pit pore always circular and central. Pits in cross-field bordered, 2-6 in number, more or less cupressoid.

The larger number of pits reported in the cross-field, both by Marguerier (1973a) and Maithy (1977) is due to the fact that they observed not real cross-field pits but those pits on the radial walls of the tracheids which fell under the area of cross-field observed (see Marguerier, 1973a, fig. 7).

Two of the Palaeozoic woods from India referred to the genus *Australoxylon*, viz., *A. kanhargaoense* Prasad & Chandra, 1978 and *A. longicellularis* Prasad & Chandra, 1981, require better photographic documentation to prove that these have real "mixed" pitting.

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Observations on some Tertiary zonisulcate pollen grains

H. P. Singh & S. K. M. Tripathi

ABSTRACT

Singh, H. P. & Tripathi, S. K. M. (1986). Observations on some zonisulcate pollen grains. *Palaeobotanist* **35** (1) : 48-52.

A morphological study of the genus *Assamialetes* has been carried out and its generic diagnosis has been emended. Various taxonomic changes, through which *Proxapertites* and *Assamialetes* have undergone, have also been discussed. Further, in order to understand these genera, a comparative study of the allied taxa has also been done.

Key-words—Palynology, Zonisulcate pollen, *Assamialetes*, *Proxapertites*, Tertiary (India).

H. P. Singh & S. K. M. Tripathi, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226007, India

सारॉश

कुछ तृतीयक युगीन पट्टपरिखीय परागकणों पर प्रेक्षण

हरीपाल सिंह एवं सूर्यकान्त मणि त्रिपाठी

असमिआलिटीज़ प्रजाति का विस्तृत आकारिकीय अध्ययन किया गया है तथा इसके प्रजातीय निदान में भी संशोधन किया गया है। इसके अतिरिक्त इस शोध-पत्र में प्रोक्सापर्टाइटिस एवं असमिआलिटीज़ में अभी तक किये गये विभिन्न वर्गीकरणिक परिवर्तन भी विवेचित किये गए हैं। इन दोनों प्रजातियों को स्पष्टतया समझने के लिए घनिष्ठ रूप से सम्बद्ध वर्गकों का तुलनात्मक अध्ययन भी प्रस्तुत किया गया है।

INTRODUCTION

A PERUSAL of the published literature shows that the Tertiary sediments of the Indian subcontinent contain a variety of zonisulcate pollen grains. Various authors described these pollen grains under different genera, viz., *Potamogetonaceaepites* Biswas (1962), *Microreticulatipites* Baksi (1962), *Weylandipollis* Takahashi (1964), *Nymphaeoipollis* Venkatachala & Kar (1969), *Assamialetes* Singh (1975) and *Proxapertites* van der Hammen (1956). Subsequently, Singh (1975) while attempting to streamline the taxonomy of zonisulcate pollen grains emended the diagnosis of *Proxapertites* and grouped *Potamogetonaceaepites, Microreticulatipites, Weylandipollis* and *Nymphaeoipollis* under it.

The genus *Proxapertites* was proposed by van der Hammen (1956 pl. 1, fig. 5) with the following diagnosis: "Pollen grains with big and wide aperture at the proximal side of the grain (remnants of an extremely thin exine layer can be found sometimes in the aperture). Grains of this type are sometimes found still in dyads (or sometimes in tetrads, etc.)". In the description van der Hammen (1956) mentioned that the exine is microfoveolate.

Muller (1968) regarded the dyads of the genus *Proxapertites* as zonisulcate pollen grains having a tendency to split into two slightly unequal parts. Potonié (1970) stated that these pollen grains consist of two discs, jointed by a rim in such a manner that a fine groove runs around the periphery.,

Singh (1975, p. 101) regarded these pollen grains as zonisulcate and emended the diagnosis of the genus *Proxapertites* as follows: "Pollen grains circular to subcircular in shape, zonisulcate, sulcus ± parallel to the margin, resulting into breaking of the pollen into two ± equal halves. Size range 20-70 × 25-50 μ. Exine tectate, variable in ornamentation and sculpture generally ranging from punctate, psilate, granulose or microfoveolate and reticulate."

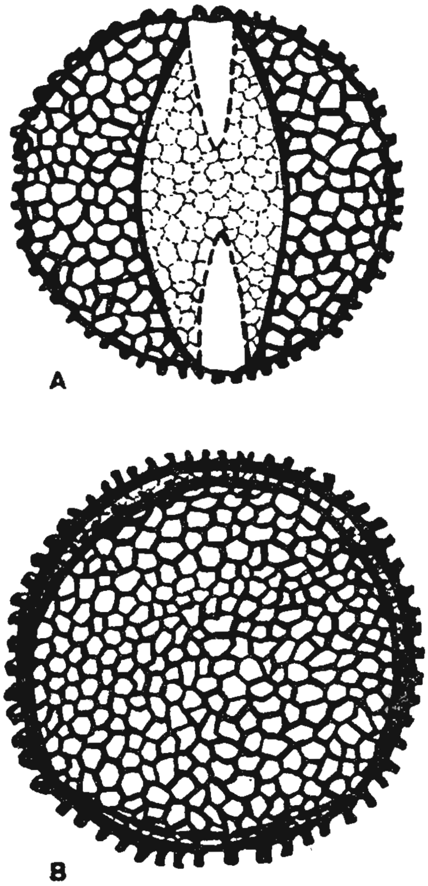
Singh (1975) also transferred *Schizosporis assamicus* Sah & Dutta (1966) and *Schizosporis crassimurus* Sah & Dutta (1966) to *Proxapertites*. The genus *Schizosporis* was instituted by Cookson and Dettmann (1959) with the following characters: "Miospores medium to large, with an equatorial line or furrow along which a separation into two approximately equal parts takes place."

Cookson and Dettmann (1959) recognized four species in this genus, viz., *Schizosporis reticulatus*, *S. rugulatus*, *S. spriggi* and *S. parvus*. All these forms are nontectate and vary in size from 78-135 μm and thus do not fall in the circumscription of the genus *Proxapertites*. However, the transfer of *Schizosporis assamicus* into the genus *Proxapertites* by Singh (1975) is justified as in this case the exine is tectate. The taxonomic status of *Schizosporis crassimurus* has been discussed in the later part of the text.

Sah and Dutta (1966, pl. 1, figs 16, 17) instituted a genus *Retialetes* for nonaperturate and coarsely reticulate pollen grains. Later, it was found that Staplin (1960, pl. 6, figs 2, 3) had already published a genus having the same name for the spores which are alete, reticulate, ellipsoidal in outline and have fine grooves arranged parallel to the longer axis. To overcome this difficulty Singh (1975, p. 103) instituted another genus *Assamialetes* to accommodate the forms previously described under *Retialetes*.

Singh (1975, p. 103) diagnosed the genus *Assamialetes* as a nonaperturate form but while describing *Assamialetes* sp. (Singh, 1977) he regarded it as zonisulcate, thus contradicting the diagnosis of the genus of which he himself is the author. The present authors recently examined a large number of reticulate pollen grains from the Palaeocene-Eocene sediments of Jowai-Sonapur Road Section, Jaintia Hills, Meghalaya. Examination of specimens of *Assamialetes emendatus* reveals that these specimens are separated halves of a single zonisulcate pollen grain. This fact is clear as the type specimen of *Assamialetes emendatus* exhibits reticulations only on a single surface. So the present authors believe that the type species of the genus *Assamialetes*, viz., *A. emendatus* (Sah & Dutta) Singh (1975) is based on the split half part of a single zonisulcate pollen grain. This fact has been confirmed by the examination of specimens illustrated here (Pl. 1, figs 2, 9) showing two partially separated discs of *Assamialetes*.

From the present study it appears that the sulcus is very long and covers the pollen grain at equator, almost all along its perimeter. With such an organization two discs of a single pollen grain will get separated off very easily. A split half part can be confused as a nonaperturate pollen. Therefore, the diagnosis of the genus *Assamialetes* has been emended and dealt with in the latter part of the text.



Text-figure 1—*Assamialetes emendatus*, A. equatorial view, and B. lateral view.

The morphological resemblance between *Longapertites* Hoeken Klinkenberg (1964) and *Assamialetes* Singh (1975) appears to be superficial although both are tectate, reticulate and possess single, long aperture. The sulcus in *Assamialetes* is longer than that in *Longapertites* providing a weak union between the two halves in the former. This may be one of the reasons that in *Assamialetes* it is extremely rare to get the two halves attached to each other. In addition to this, *Assamialetes* is more or less circular in shape, whereas *Longapertites* is ovoidal with lateral ends unequally broad. In *Assamialetes* the reticulate pattern is not made up of baculae as in the case of *Longapertites*. These basic differences preclude a close resemblance between *Assamialetes* and *Longapertites*.

Van Hoeken Klinkenberg (1964) did not give diagnosis of the genus *Longapertites*. The variation of shape was also not mentioned and only two photographs of a single specimen were given. On this scanty available information it is difficult to clearly understand the morphography of *Longapertites*.

SYSTEMATIC DESCRIPTION

Recently, detailed palynostratigraphic studies have been carried out on the Palaeocene-Eocene sediments exposed along the Jowai-Sonapur Road, Jaintia Hills, Meghalaya. The sediments yielded a rich and diversified palynoflora. The Palaeocene sediments are rich in having zonisulcate pollen grains. In this palynoflora the zonisulcate pollen grains are represented by

Proxapertites and *Assamialetes*. The geological map and lithological information about the area has already been published by Saxena and Tripathi (1982). The morphological observations on these pollen grains are given below.

Genus—*Proxapertites* van der Hammen emend. Singh, 1975

Type species—*Proxapertites operculatus* van der Hammen, 1956

Proxapertites assamicus (Sah & Dutta) Singh, 1975
Pl. 1, figs 9, 11, 12, 13, 14

Description—Subcircular to oval, 45-60 × 39-54 μm in size, zonisulcate. Zonisulcus distinct, running almost parallel to the equator. Exine 1.5-2 μm thick, tectate, sexine as thick as nexine, faintly structured to microfoveolate.

Previous records—Palaeocene of Cherra Formation, Meghalaya (Dutta & Sah, 1970); Lower Eocene of Tura Formation, Meghalaya (Sah & Singh, 1974); and Palaeocene of Mikir Formation, Assam (Mehrotra & Sah, 1982).

Occurrence—Lower-Middle part of Therria Formation (Palaeocene), Meghalaya.

Affinity—Zonisulcate pollen grains are found in some members of the family Liliaceae and Nymphaeaceae.

Genus—*Assamialetes* Singh, 1975 emend.

Type species—*Assamialetes emendatus* Singh, 1975 emend.

Emended Generic Diagnosis—Pollen grains mostly subcircular; zonisulcate, zonisulcus distinct, long along the equator; exine finely to coarsely reticulate, muri raised or flat.

Assamialetes emendatus Singh, 1975 emend.
Pl. 1, figs 1, 2, 5, 10, 15

Holotype—Pl. 1, fig. 16; Sah and Dutta, 1966.

Type Locality—India, Maukma; South Shillong Plateau, Assam; Lower Eocene.

Emended Diagnosis—Pollen grains subcircular to slightly ovoidal in shape, 57-95 μm in size; zonisulcate, zonisulcus distinct; exine 2-4 μm thick, distinctly reticulate.

Description—Pollen grains mostly subcircular, rarely slightly ovoidal in shape, 57-95 μm is size, zonisulcate. Zonisulcus distinct, covering almost full perimeter of the pollen grain at the equator. Pollen grains having a tendency of splitting into two disc-like halves, suggesting a weak union between them. Exine 2-4 μm thick, reticulate, lumen 3-13 μm wide, muri 2-2.5 μm thick and 2.5 μm high.

Previous records—Palaeocene-Lower Eocene of Cherra Formation, Meghalaya (Sah & Dutta, 1966); Palaeocene of Tura Formation, Meghalaya (Sah & Singh, 1974) and Palaeocene of Mikir Formation, Assam (Mehrotra & Sah, 1982).

Occurrence—Lower and upper part of Therria Formation (Palaeocene), Meghalaya.

Affinity—Morphologically *Assamialetes emendatus* is comparable to the pollen grains found in some members of the family Nelumbonaceae like *Nelumbo nucifera*. In the pollen grains of *Nelumbo nucifera* the exine is not very coarsely reticulate.

Assamialetes crassimurus comb. nov.
Pl. 1, figs 3, 4, 6, 7, 8

1966 *Schizosporis crassimurus* Sah & Dutta, pl. 1, figs 18, 19. *Palaeobotanist 15* (1-2) : 72-86.

Holotype—Sah & Dutta, 1966, pl. 1, fig. 19.

Diagnosis—As published by Sah and Dutta, 1966.

Remarks—Singh (1975) transferred *Schizosporis crassimurus* Sah & Dutta (1966) to the genus *Proxapertites* and emended the generic diagnosis of the latter. Singh (1975) in fact emended the diagnosis of *Proxapertites* to accommodate zonisulcate pollen grains having variable morphological characters such as pollen grains ranging from 20-70 μm in size and possessing psilate, punctate, granulose, microfoveolate and reticulate type of exine ornamentations. The present authors do not agree with this treatment for the reason that the morphological limits of *Proxapertites* have been

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PLATE 1

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(All photomicrographs are enlarged ca × 750)

1,2,5,10 & 15. *Assamialetes emendatus* Singh, 1975 emend.; B.S.I.P. slide nos. 7038, 7028, 7038, 7035 and 7032; coordinates 90.10 × 20.9, 79.2 × 11.0, 90.10 × 20.9, 112.2 × 11.7 and 104.8 × 20.9 respectively.

3,4,6,7 & 8. *Assamialetes crassimurus* Sah & Dutta, 1966 comb. nov.; B.S.I.P. slide nos. 7036, 7036, 7028, 7028 and 7028; coordinates : 100.8 × 7.7, 100.8 × 7.7, 77.5 × 5.3, 115.10 × 19.5 and 115.10 × 19.5 respectively.

9,11,12,13 & 14. *Proxapertites assamicus* van der Hammen emend. Singh, 1975; B.S.I.P. slide nos. 7028, 7031, 7031, 7030 and 7030; coordinates : 109.9 × 14.6, 109.10 × 24.8, 109.10 × 24.8, 97.7 × 3.2 and 97.7 × 3.2 respectively.

B.S.I.P.

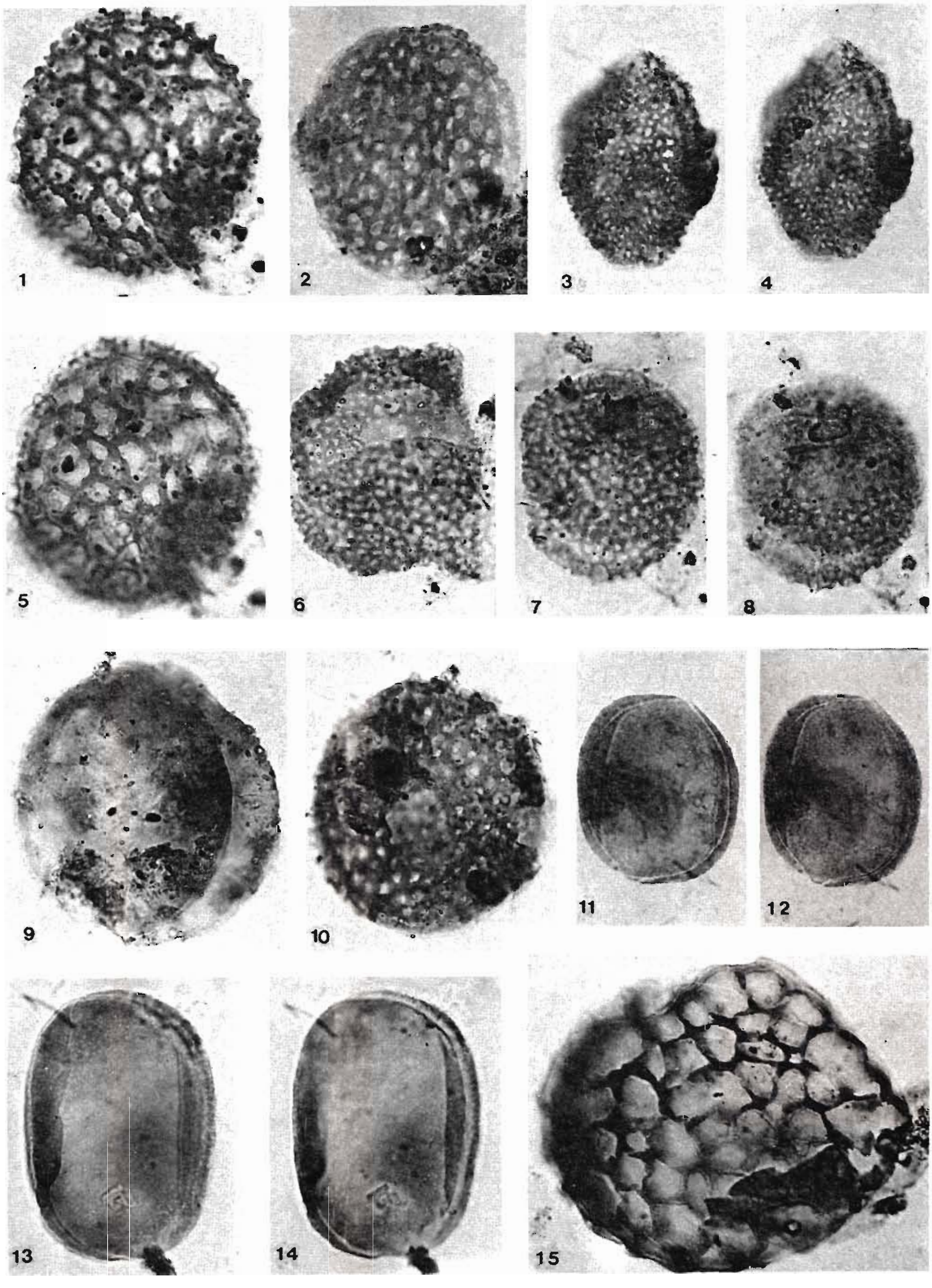

PLATE 1

enlarged more than necessary. It is proposed here that zonisulcate pollen with psilate to microfoveolate ornamentation should be grouped under the genus *Proxapertites*, whereas those with distinctly reticulate to coarsely reticulate ornamentation should be kept under the genus *Assamialetes*, the diagnosis of which has been emended earlier in the text.

Since the forms described as *Schizosporis crassimurus* are zonisulcate and the exine ornamentation in it is reticulate, they have been transferred to the genus *Assamialetes*.

Discussion—The stratigraphical importance of zonisulcate pollen grains in the Palaeocene and Lower Eocene sediments is established by the works of Sah and Dutta (1966), Dutta and Sah (1970), Sah and Singh (1974) and Mehrotra and Sah (1982). The genus *Assamialetes* identifies a palynological zone in the Lower Palaeocene sequence of Tura Formation, Meghalaya (Sah & Singh, 1974), Cherra Formation, Meghalaya (Sah & Dutta, 1974), and Mikir Formation, Assam (Mehrotra & Sah, 1982). It is based on the percentage frequency of this particular genus. The frequency counts made by various authors have obviously been established by counting only half part of a single specimen. Therefore, it is essential to reduce the frequency of this genus to half for all practical purposes. In all the above mentioned palynozones the prominence of *Assamialetes* is because of its dominance over other genera in this particular palynozone. But with the result of the present study, it may lose its validity.

CONCLUSION

The fossil pollen grains of *Assamialetes*, diagnosed as nonaperturate, have been found to be zonisulcate. They possess a long zonisulcus covering almost full perimeter of the pollen grain providing a weak union between the two halves of the exine. This results in breakage of the grain into two more or less equal parts. Each separated half of the pollen grain was confused to be representing a nonaperturate pollen by the previous workers, a mistaken notion which has been convincingly removed in the present paper.

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Araucarioxylon kumarpurensis, a new gymnospermous wood from the Upper Permian of West Bengal

Usha Bajpai & V. K. Singh

Bajpai, Usha & Singh, V. K. (1986). *Araucarioxylon kumarpurensis*, a new gymnospermous wood from the Upper Permian of West Bengal. *Palaeobotanist* **35**(1) : 53-56.

The new species is identified after a study of ground thin sections and cellulose acetate paper peels prepared from a number of petrified wood pieces collected from Coal Seam IX, Raniganj Formation, West Raniganj Coalfield. The woods are mostly limonitic and usually very much crushed; however, at places they show good preservation. The secondary xylem shows distinct annual rings, mostly uniseriate xylem rays and 1-2 seriate araucaroid pits on the radial walls of tracheids and 2-8 cupressoid pits in its cross-fields. The new species closely compares with *Dadoxylon bengalense* Holden which however, is easily distinguished by "mixed" type of radial pitting.

Key-words—Fossil woods, Gymnosperms, Raniganj Formation, Upper Permian (India).

Usha Bajpai & V. K. Singh, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

सारॉश

अॅरोकेरिऑक्सीलॉन कुमारपुरेन्सिस, पश्चिम बंगाल के उपरि परमी से एक नव अनावृतबीजी काष्ठ

ऊषा बाजपेई एवं विनय कुमार सिंह

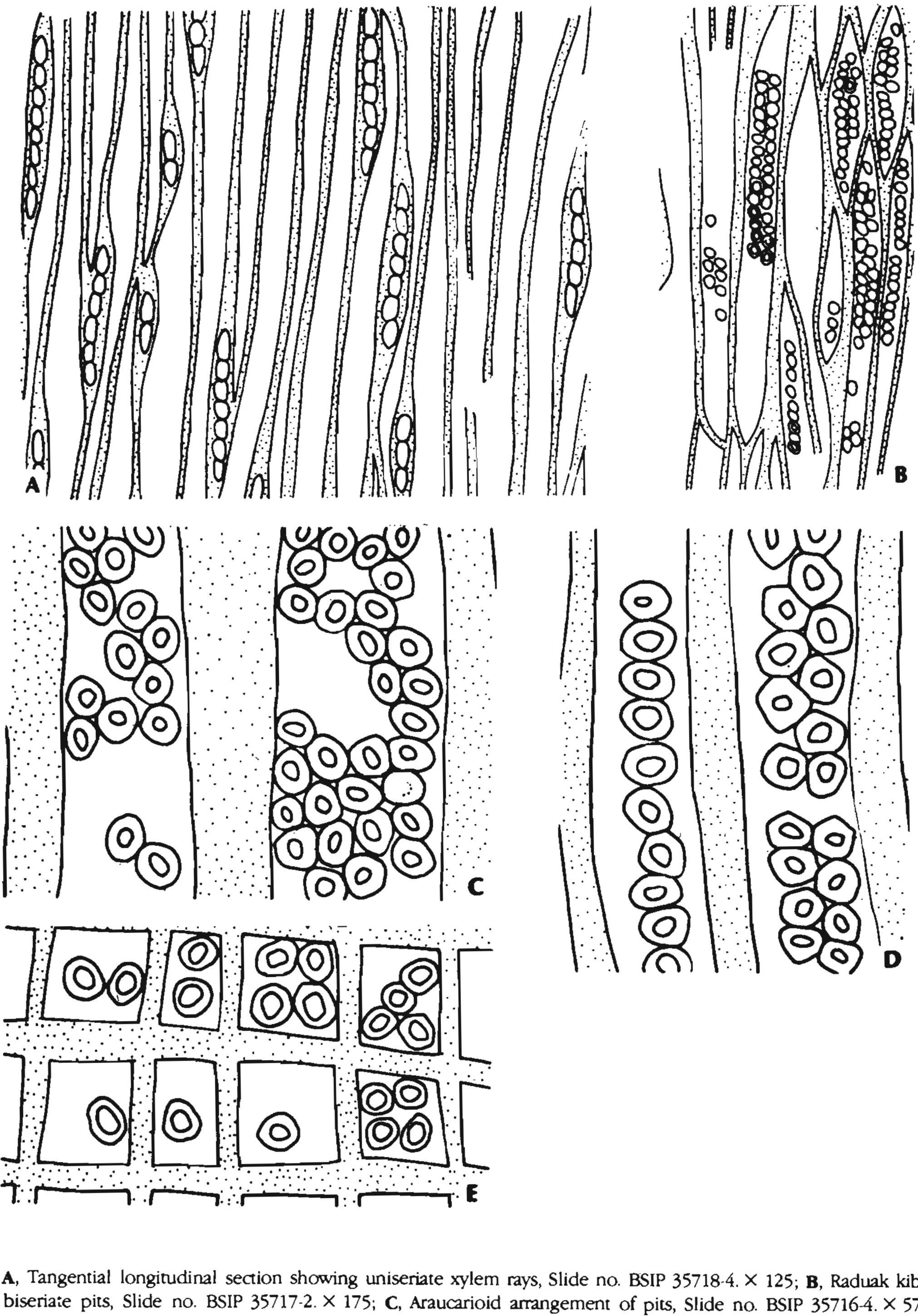
पश्चिमी रानीगंज कोयला-क्षेत्र में रानीगंज शैल-समूह की नवीं कोयला-सीम से एकत्रित अनेक अश्मीभूत काष्ठ के टुकड़ों की सेल्यूलोज़ एसीटेट पील तथा पतली काटों के गहन अध्ययन के उपरान्त यह नव जाति अभिनिर्धारित की गई है। यद्यपि ये काष्ठ प्रायः लिमोनीटी तथा कुचली हुई हैं तथापि, इनमें कहीं कहीं पर अभिलक्षण सुपरिरक्षित हैं। द्वितीयक दारु स्पष्ट वार्षिक वलय, प्रायः एकपंक्तिक किरणें एवं वाहिनीकीयों की अरीय भित्तियों पर 1-2 पंक्तिक अॅरोकेरॉयड गर्त्त तथा इसके क्रास क्षेत्रों में क्यूप्रेसाभ गर्त्त प्रदर्शित करती है। यह नव जाति डेडॉक्सीलॉन बंगालेन्सिस होल्डन से तुलनीय है जो "मिश्रित" प्रकार के अरीय गर्त्तों द्वारा सरलता से पहचानी जा सकती है।

INTRODUCTION

THE Raniganj Formation comprises four members, viz, Kumarpur Sandstone Member, Nituria Coal Member, Hijuli Sandstone Member and Sitarampur Coal member in descending order (Gee, 1932). The Raniganj Formation is very rich in plant megafossils, the upper part containing a number of fossil woods. Bradshaw and Sahni (1925) reported a fossil tree of about 22 meters length from the railway cutting about 3.2 kilometers west of Asansol, which however, did not have well-preserved structural details. Bradshaw (1925) considered the fossil tree trunk as belonging to the Panchet Series (Triassic) but according to Fox (1928) and Pascoe (1959) the fossil wood sandstone bed of Kumarpur, west of Asansol should be considered as the uppermost horizon of the Raniganj Formation (Upper Permian) rather than the lowermost horizon of the Panchet Formation.

Sahni (1932) reported *Dadoxylon zalesskyi* from the same locality which showed a heterogeneous pith, endarch primary xylem and araucaroid secondary wood. This wood was later transferred to *Kaokoxylon* Kräusel (1956), as *K. zalesskyi* (Sahni, 1932) by Maheshwari (1967) due to the presence of sclerotic cells in the solid, heterogeneous pith.

Fox (1934) gave a list of fossil plants from the Raniganj Formation, Raniganj Coalfield in which he mentioned *Dadoxylon kumarpurensis* from the Kumarpur Sandstone Member but the wood was neither described and figured by Fox nor by others.



Text-fig. 1—A, Tangential longitudinal section showing uniseriate xylem rays, Slide no. BSIP 35718-4. × 125; **B**, Raduak kibgutydubak sectuib sgiwubg biseriate pits, Slide no. BSIP 35717-2. × 175; **C**, Araucarioid arrangement of pits, Slide no. BSIP 35716-4. × 575; **D**, Unibiseriate arrangement of pits, Slide no. BSIP 35716-12. × 575; and **E**, Cross-field areas showing bordered pits in the cross-fields, Slide no. BSIP 35716-13. × 575.

PLATE 1 →

1. Transverse section through the secondary wood, slide no. BSIP 35716-1. × 90.
2. Tangential longitudinal section showing uniseriate xylem rays, slide no. BSIP 35718-4. × 90.

3, 4. Radial longitudinal section showing 1-2 seriate bordered pits, slide no. BSIP 35717-2. × 250.

5. Radial longitudinal section showing araucaroid arrangement of pits, slide no. 35717-2. × 550.

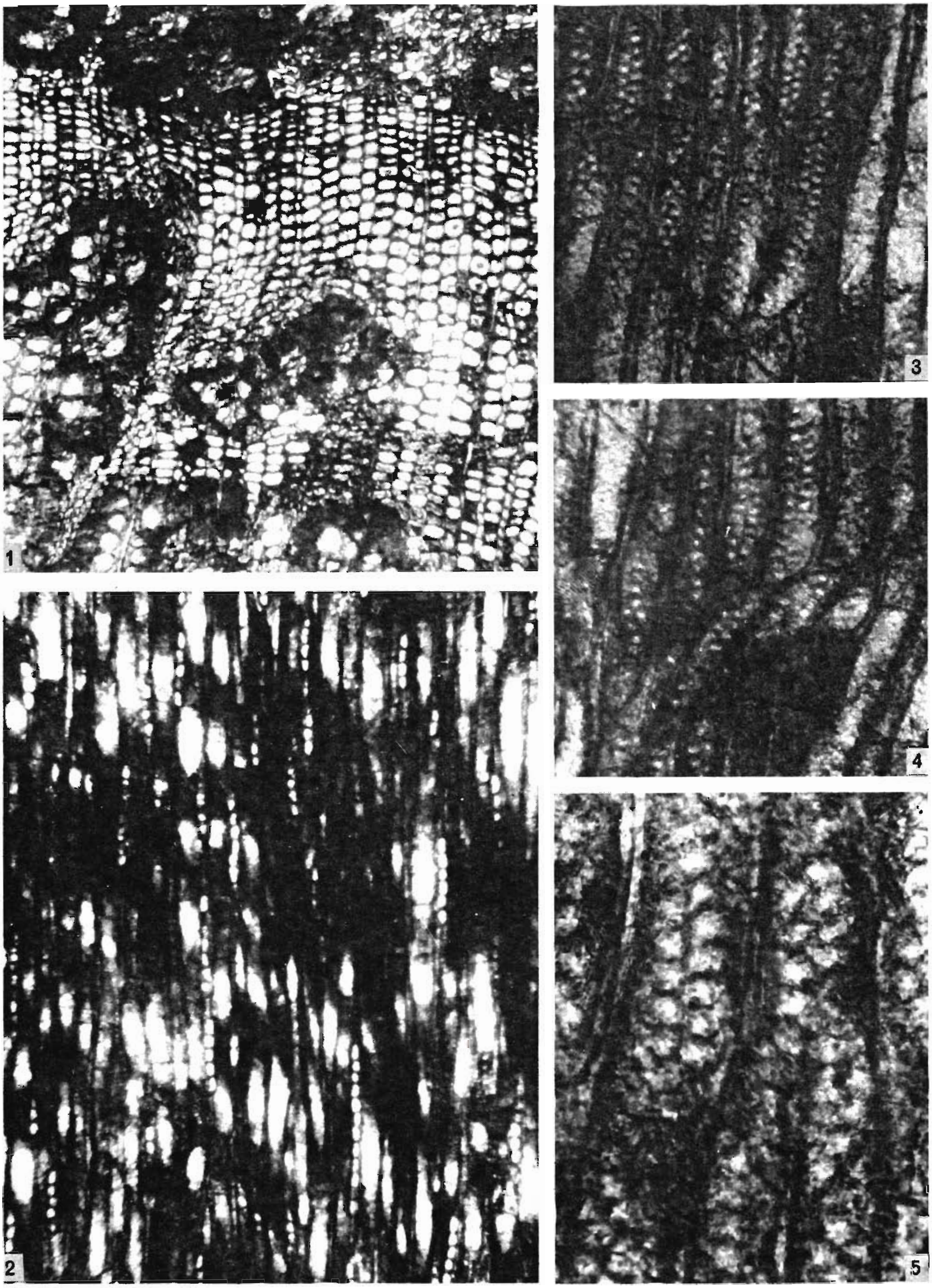


PLATE 1

MATERIAL AND METHOD

The material for the present study was collected from the Kumarpur Sandstone exposed in Nonia Khal, Raniganj Coalfield. The fossil woods are limonitic. Both, ground thin sections and acetate paper peels were prepared. Out of the 30 woods, only 3 specimens gave useful information. The present observations are based on the three better preserved woods all of which exhibit similar characters and therefore have been assigned to the same species.

DESCRIPTION

Genus—*Araucarioxylon* Kraus, 1870

Araucarioxylon kumarpurensis sp. nov.

Pl. 1, figs 1-5; Text-fig. 1A-E

Diagnosis—Secondary wood with distinct growth rings. Xylem rays homogeneous, uniseriate or sometimes partly biseriate, 1-19 cells high. Radial tracheidal walls usually with 1-2 seriate (rarely up to tetraseriate), contiguous, usually alternate, rarely sub-opposite and flattened or polygonal (araucarioid), bordered pits. Cross-field pits bordered, 2-8 (usually 4-6) in number and more or less cupressoid.

Holotype—Specimen no. BSIP 35717; Nonia Nala near Kumarpur, West Raniganj Coalfield, West Bengal; Raniganj Formation, Upper Permian.

Description—Most of the specimens being ill-preserved the information is derived from specimen nos. 35716, 35717 and 35718 which are identical anatomically. Pith, primary xylem and extraxylary elements are not preserved in any of the woods. Even the secondary xylem is satisfactorily preserved only in patches. Because of this reason, it has not been possible to decipher the width of a single growth ring. In cross-sections, the spring wood tracheids are polygonal or rectanguloid, about 44-79 μm wide radially and 31-63 μm wide tangentially. The width of spring wood zone is unknown due to partial disorganization of the growth rings. Autumn wood zones are narrow and the tracheids are about 11-32 μm wide radially and about 31-48 μm wide tangentially. The double walls between the spring wood tracheids are about 9-24 μm thick and those between autumn wood tracheids about 7-17 μm thick. Xylem parenchyma is absent.

The height of rays is 1-19 cells, averaging at 3-11 cells. The ray-cells are ovoid or rectanguloid in shape, about 23-40 μm high and about 8-20 μm wide at widest. Tangential and horizontal walls of ray cells and tangential walls of tracheids are unpitted.

Tracheidal pits are about 9-13 μm × 7-13 μm in size, pit pores oval or circular, about 4-6 μm × 3-6 μm in size. Cross-field pits are about 3-8 μm × 3-6 μm in size.

Comparison—In showing 1-3 seriate radial tracheidal pits, 2-8 cupressoid cross-field pits and 1-19 cells high rays, the Kumarpur woods are comparable with *Dadoxylon bengalense* Holden, 1917; but at the same time the latter species differs in showing grouped or mixed pits on the radial tracheidal walls (*A. kumarpurensis* invariably shows araucarioid pits).

The investigated woods are also comparable to *A. ningahense* Maheshwari (1965) 1972 and *A. lobarense* Agashe & Gowda, 1978 in having 1-4 seriate radial pits and 2-8 cupressoid cross-field pits but differ in smooth tangential tracheidal walls. Further, *A. kumarpurensis* shows predominantly 1-2 seriate pits on tracheids; 3 or 4 seriate pits are extremely rare (*A. ningahense* and *A. lobarense* show pits on their tangential tracheidal walls besides having frequently up to 4 seriate radial tracheidal pits).

Likewise, the woods are also comparable in one or other characters with all the known species of *Araucarioxylon* but differ in most other characters.

For these woods a new species *Araucarioxylon kumarpurensis* has been erected, the species epithet signifies the occurrence of the species in the Kumarpur Sandstone Member of the Raniganj Formation.

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The Palaeobotanist **35**(1) : 57-60, 1986.

A carbonised wood resembling *Parinari* from the Neyveli Lignite deposits, India

Nilamber Awasthi & Anil Agarwal

ABSTRACT

Awasthi, Nilamber & Agarwal, Anil (1986). A carbonised wood resembling *Parinari* from the Neyveli Lignite deposits, India. *Palaeobotanist* **35**(1) : 57-60.

A carbonised wood showing close resemblance with that of *Parinari* (*Parinarium*) belonging to the sub-family Chrysobalanoideae of Rosaceae has been described from the Neyveli Lignite deposits. It is named as *Parinarioxylon neyveliensis* sp. nov. The occurrence of *Parinari* is also indicative of tropical humid conditions in this area at the time of its deposition.

Key-words—Xylotomy, Carbonised wood, Rosaceae, *Parinarioxylon*, Neyveli Lignite, Miocene (India).

Nilamber Awasthi & Anil Agarwal, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226007, India.

सारॉंश

भारत के निवेली लगुडांगार निक्षेपों से पैरीनारी सदृश एक कार्बनी काष्ठ

नीलाम्बर अवस्थी एवं अनिल अग्रवाल

भारत के निवेली लगुडांगार निक्षेपों से एकत्रित रोज़ेसी कुल के क्राइसोबैलेनॉयडी नामक उपकुल की पैरीनारी (पैरीनारियम्) से घनिष्ठ समानता प्रदर्शित करने वाली एक कार्बनी काष्ठ का वर्णन किया गया है तथा इसे पैरीनारिऑक्सीलॉन निवेलीयेन्सिस नव जाति से नामांकित किया गया है। पैरीनारी की उपस्थिति से इस क्षेत्र में इसके निक्षेपण के समय उष्णकटिबन्धीय आर्द्र परिस्थितियाँ व्यक्त होती हैं।

INTRODUCTION

SYSTEMATIC studies on the carbonised woods from the Neyveli lignite deposits have been initiated recently by one of us (Awasthi, 1984) who described the dicotyledonous woods resembling those of *Hopea, Carallia, Gluta, Diospyros* and *Cordia*. Further investigations of more carbonised woods carried out by the present authors from the same mine also revealed the presence of several new forms; one of them being described here shows close similarity with that of *Parinari* of the family Rosaceae.

The carbonised wood measures about 5.00 × 2.00 cm in length and width having central core which obviously represents a twig small branch of the tree. The material was embedded in paraffin wax and sectioned on a sliding microtome.

DESCRIPTION

Family—Rosaceae
Sub-family—Chrysobalanoideae

Genus—*Parinarioxylon* Pfeiffer & Van Heurn, 1928

Parinarioxylon neyveliensis sp. nov.

Pl. 1, figs 1-5

Wood diffuse-porous (Pl. 1, fig. 1). *Growth rings* not seen. *Vessels* small to medium, round to oval, t.d. about 30-140 μm, r.d. 30-160 μm, exclusively solitary, unevenly distributed, tending to arrange in oblique radial lines or echelon (Pl. 1, figs 1, 2), about 10-25 per sq mm; perforations simple, vessel-members truncate or with slightly inclined ends; pits leading to contiguous fibres or fibre-tracheids small to medium (Pl. 1, fig. 5), about 6-8 μm, in diameter, alternate, with seemingly linear apertures; tyloses occasionally present. *Parenchyma* apotracheal, in numerous fine lines, 1-2(mostly 1) seriate, almost continuous to sometimes broken, wavy (Pl. 1, figs 1,2), about 12-18 per mm, sometimes more towards centre; cells about 12-24 μm in diameter. *Rays* fine, uniseriate (Pl. 1, fig. 3), rarely with paired cells, about 25-30 per mm in cross-section, about 4-30 cells in height, heterocellular, consisting of procumbent cells and 1-2 marginal rows of upright cells (Pl. 1, fig. 4). *Fibres* about 12-16 μm in diameter, thick-walled (Pl. 1, fig. 2), walls 4-6 μm, in thickness, with narrow lumen, nonseptate; pits on tangential walls occasionally seen, uniseriate, small, about 3-4 μm, in diameter with small slit-like apertures.

COMPARISON WITH MODERN SPECIES

In important and characteristic features, such as: exclusively solitary vessels, apotracheal parenchyma in fine, 1-2 (mostly 1) seriate lines with long strands; uniseriate, heterocellular rays and the thick-walled fibres with bordered pits the carbonised wood resembles those of *Acioa, Angelesia, Chrysobalanus, Couepia, Grangeria, Hirtella, Licania, Parastemon* and *Parinari* (Metcalfe & Chalk, 1950) of sub-family Chrysobalanoideae (Rosaceae). After examining thin sections as well as available literature on a number of species of these genera (Desch, 1954, p. 474, pl. 95, fig. 2; pl. 96, fig. 2; pl. 97, fig. 1; Henderson, 1953, p. 62, fig. 322; Kribs, 1959, p. 135, figs 450, 451; Metcalfe & Chalk, 1950, p. 552, fig. 121; Miles, 1978, p. 160; Normand, 1950, p. 92, pls. 21-23; Purkayastha & Sahi in Ramesh Rao & Purkayastha, 1972, p. 151, pl. 86, fig. 514) a close agreement in all anatomical features is observed between the Neyveli carbonised wood and those of *Acioa, Angelesia, Chrysobalanus, Licania, Parastemon* and *Parinari*. These genera are so similar in their xylotomy that they cannot be easily differentiated from one another though Metcalfe and Chalk (1950) have pointed out a few minor differences between them. Since *Parinari* (*P. indicum* and *P. travancoricum*) is the only genus that also occurs on the Indian mainland, it is assumed that the carbonised wood belongs to the genus *Parinari*. The fossil being a piece of small branch/twig, possesses relatively smaller vessels.

COMPARISON WITH FOSSIL SPECIES

So far three species of fossil woods resembling *Parinari* Aubl. (*Parinarium* Juss.) are known. These are *Parinarioxylon itersonii* from the Tertiary of Java (Pfeiffer & Van Heurn, 1928) and Omo Basin, Ethiopia (Lemoigne, 1978), *P. cuddalorense* from the Cuddalore Sandstones near Pondicherry (Awasthi, 1969) from and *P. splendidum* from the Lower Siwalik beds of Kalagarh (Trivedi & Ahuja, 1979). The affinities of *P. splendidum* with that of *Parinari* are doubtful as bordered pits are absent on the tangential wall of the fibres. Even the gross xylotomical characters as revealed by the photographs do not tally with those of *Parinari*. It instead, appears somewhat similar to *Ebenoxylon miocenicum* from the same locality (Prakash, 1978).

The Neyveli wood differs from both the other species in one or two characters which may justifiably be considered as specific differences. In *P. itersonii* the vessels are comparatively very large and less frequent while in *P. cuddalorense* the vessels are relatively smaller and more frequent and the parenchyma bands are 1-3 seriate and less closely placed, i.e. 6-10 per mm as against 12-18 in the present fossil wood.

Of the two species of *Parinari* occurring in India, *P. indicum* is distributed in the evergreen forest of Western Ghats, while *P. travancoricum* is confined to the evergreen forest of Travancore Hills (Gamble, 1972). Thus the occurrence of *Parinari* in the Neyveli lignites also suggests the prevalence of tropical humid condition in this region of South India during its deposition.

Holotype—B.S.I.P. Museum Specimen no. 35734; Neyveli Lignite Mine I; Cuddalore Series; Miocene.

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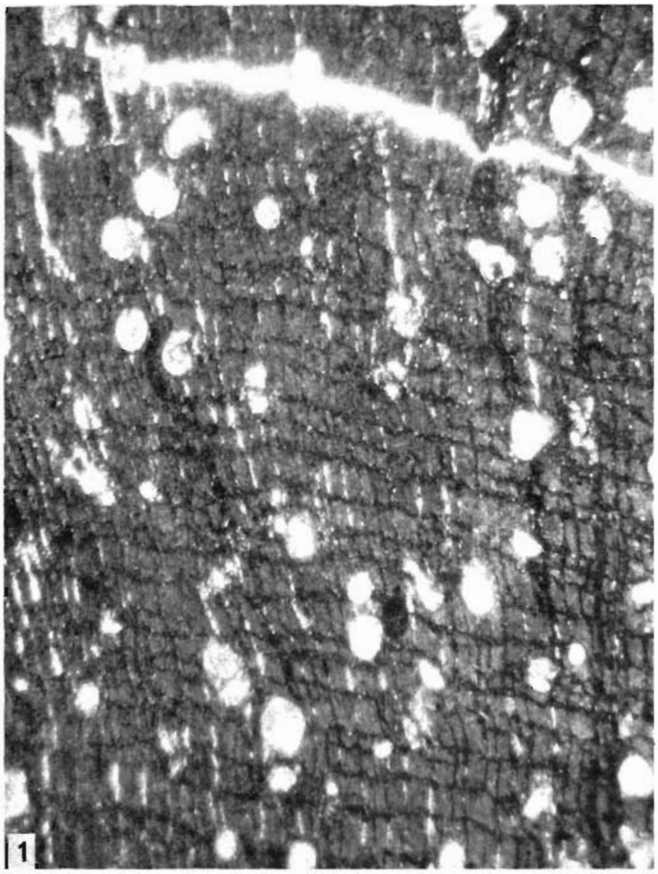
PLATE 1

Parinarioxylon neyveliensis sp. nov.

1. Cross section showing nature and distribution of vessels, parenchyma and rays. × 45 (BSIP slide no. 35734-1).
2. Cross section magnified showing details of vessels and parenchyma. × 105 (BSIP slide no. 35734-1).
3. Tangential longitudinal section showing heterocellular rays. × 155 (BSIP slide no. 35734—2).
4. Radial longitudinal section showing heterocellular rays. × 155 (BSIP slide no. 35734-3).
5. Tangential longitudinal section showing vascular pittings. × 750 (BSIP slide no. 35734-2).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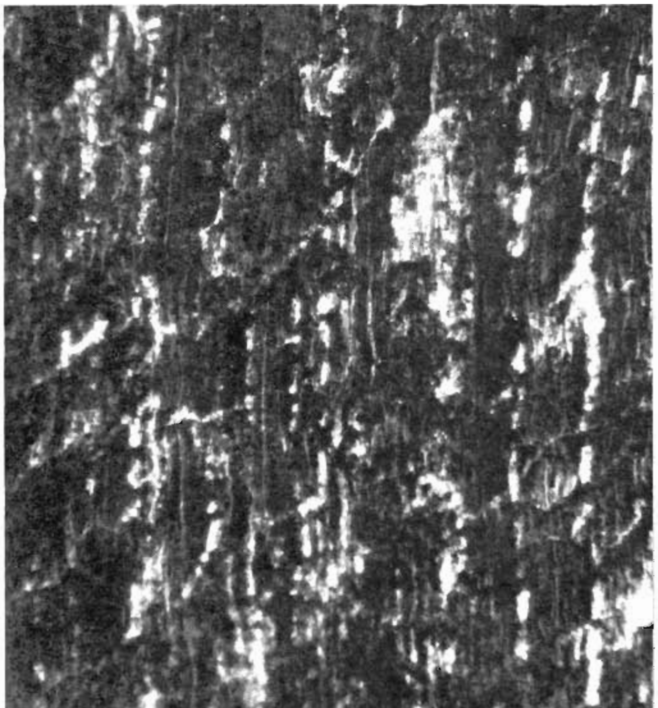
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5

PLATE 1

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Revision and reassessment of a dinoflagellate cyst assemblage from Sangchamalla Formation (Upper Flysch), Malla Johar area, Kumaon Himalaya, India

K. P. Jain & Rahul Garg

ABSTRACT

Jain, K. P. & Garg, R. (1986). Revision and reassessment of a dinoflagellate cyst assemblage from Sangchamalla Formation (Upper Flysch) Malla Johar area, Kumaon Himalaya, India. *Palaeobotanist*, **35** (1) : 61-68.

A dinoflagellate cyst assemblage described by Mehrotra and Sinha (1981) from the Sangchamalla Formation (Upper Flysch) of Malla Johar area in the Tethyan zone of higher Kumaon Himalaya is critically re-evaluated.

The taxonomic revision of the assemblage on its face value indicates total absence of *Areosphaeridium diktyoplokus* (Klumpp) Eaton, *A. arcuatum* Eaton, *Homotryblium tenuispinosum* Davey & Williams, *Hystrichokolpoma unispinum* Williams & Downie, *Diphyes colligerum* (Deflandre & Cookson) Davey & Williams and *Deflandrea speciosa* Alberti based on which a Lower Tertiary age was assigned by Mehrotra and Sinha (1981). Instead it is characterised by the predominance of *Oligosphaeridium* with common occurrence of *Coronifera, Gonyaulacysta, Hystrichosphaerina, Tityrosphaeridium* and *Cordosphaeridium*. A new species, viz., *Hystrichosphaeridium himalayaensis* proposed by Mehrotra and Sinha (1981) is treated as a junior synonym of *Oligosphaeridium complex* (White) Davey & Williams.

The revised dinocyst assemblage is devoid of exclusive Tertiary taxa and indicates an Upper Cretaceous age. Possibility of Lower Cretaceous reworking in the 'Upper Flysch' assemblage is suggested. The occurrence of dinocysts in the deep oceanic environment of the 'Upper Flysch' sediments is considered to be most probably due to transportation from shallower regions through sedimentary processes.

Key-words—Palynology, Dinoflagellates, Sangchamalla Formation, Upper Cretaceous (India).

K. P. Jain & Rahul Garg, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

कुमायूँ हिमालय (भारत) में मल्ला-जोहर क्षेत्र के संगचामल्ला शैल-समूह से उपलब्ध घूर्णीकशाभ पुटी समुच्चय का संशोधन एवं पुनर्मूल्यॉंकन

कृष्ण प्रसाद जैन एवं राहुल गर्ग

उच्चतर कुमाऊँ हिमालय के टॅथीय मंडल में मल्ला-जोहर क्षेत्र के संगचामल्ला शैल-समूह (उपरि फ़्लिश) से महरोत्रा एवं सिन्हा (1981) द्वारा वर्णित एक घूर्णीकशाभ पुटी समुच्चय का समीक्षात्मक मूल्यॉंकन किया गया है।

इस समुच्चय के वर्गीकरणिक संशोधन से ऍरिओस्फ़ेयरीडियम् डिक्टियोप्लोकस (क्लम्प) ईटन, ऍ. आर्कुएटम् ईटन, होमोट्राइब्लियम् टेनुइस्पाइनोसम् डावे व विलियम्स, हिस्ट्रीकोकॉल्पोमा यूनीस्पाइनम् विलियम्स व डाऊनी, डाइफ़िस कॉलिजेरम् (डिफ्लान्ड्रे व कुक्सन) डावे व विलियम्स एवं डिफ्लान्ड्रीआ स्पेसिओसा अॅल्बर्टाई की पूर्ण अनुपस्थिति व्यक्त होती है जिनके आधार पर महरोत्रा एवं सिन्हा ने इसकी अधरि तृतीयक आयु निश्चित की थी। अतः इसके बजाय यह समुच्चय ओलिगोस्फ़ेयरीडियम् की पूर्वबाहुल्यता के साथ-साथ कोरोनिफ़ेरा, गोनीओलासिस्टा, हिस्ट्रीकोस्फ़ेयरीना, ?टिटॉयरोस्फ़ेयरीडियम् एवं कोर्डोस्फ़ेयरीडियम् की सामान्य उपस्थिति से अभिलक्षणित है। महरोत्रा एवं सिन्हा द्वारा प्रस्तावित हिस्ट्रीकोस्फ़ेयरीडियम् हिमालयेन्सिस नामक एक नवजाति को ओलिगोस्फ़ेयरीडियम् कॉम्प्लेक्स (व्हाइट) डावे व विलियम्स के कनिष्ठ पर्यायनाम के रूप में प्रयुक्त किया गया है।

यह संशोधित घूर्णीकशाभ पुटी समुच्चय वर्जनकारी तृतीयक युगीन वर्गकों से विहीन है तथा उपरि क्रीटेशी आयु इंगित करती है। उपरि फ्लिश समुच्चय में अधरि क्रीटेशी की संभावना प्रस्तावित की गई है। उपरि फ्लिश अवसादों के गहरे समुद्री वातावरण में घूर्णीकशाभ पुटीयों की उपस्थिति सम्भवतया अवसादीय प्रक्रियाओं द्वारा छिछले क्षेत्रों से वहन के कारण मानी गई है।

INTRODUCTION

RECENTLY Mehrotra and Sinha (1978, 1981) described dinoflagellate cysts from the Sangchamalla Formation (Upper Flysch of Heim and Gansser, 1939) which forms the uppermost part of the Tethyan sequence exposed in the Malla Johar area, Kumaon Himalaya, Uttar Pradesh. They assigned an Upper Cretaceous to Middle Eocene or ?Upper Eocene age to this succession on dinocyst evidence. However, based on the other microplankton evidences, an Upper Cretaceous age has been assigned to the 'Upper Flysch' sediments by most of the workers (Kalia, in Shah & Sinha, 1974; Mamgain & Sastry, 1975; Sastry & Mamgain, 1977; Jain *et al.*, 1978; Garg *et al.*, 1981). Only the uppermost part of the 'Upper Flysch' (the Balcha Dhura Formation of Kumar *et al.*, 1977) has been considered to be Lower-Middle Palaeocene in age based on planktonic foraminifera (Singh *et al.*, 1981).

The occurrence of dinocysts in the 'Upper Flysch' sediments further led Mehrotra and Sinha (1978, 1981) to visualise a shallow marine depositional environment within the flysch sedimentation cycle. This also does not conform with the known deep water depositional framework of this part of the Tethyan sequence (Heim & Gansser, 1939; Mamgain & Sastry, 1975; Kumar *et al.*, 1977). In the present note, a critical reassessment of the dinoflagellate cyst assemblage described by Mehrotra and Sinha (1981) is made to resolve these discrepancies of age and palaeoenvironment of the 'Upper Flysch' succession.

STRATIGRAPHIC STATUS AND AGE OF 'UPPER FLYSCH'

The term 'Upper Flysch' was introduced by von Kraft (1902) for a thick sedimentary sequence of shales, sandstones, limestones and 'tuffs', overlying the Giumal Sandstone and overlain by the Exotic Blocks'. The term was retained by Heim and Gansser (1939) who mentioned that the uppermost unit of this succession forming the crest of Balcha Dhura, are not 'tuffs' but are red and green alternations of chert, with thiner cherty or shaly layers, rich in radiolarians. Kumar *et al.* (1972) named the 'Upper Flysch' succession as Flysch Series. They pointed out that the topmost units are actually basic volcanic rocks (spilite and associated serpentinite) and are neither 'tuffs' nor alternations of sandstones, shales and radiolarian cherts. These basic rocks were termed 'Balcha Dhura Volcanics' by Kumar *et al.* (1972). Shah and Sinha (1974) subsequently proposed a new name Sangchamalla Formation for the 'Upper Flysch' succession lying between Giumal Sandstone and the 'Exotic Blocks', with a remark that "the name 'Upper Flysch' used by Gansser has no significance".

Kumar *et al.* (1977) carried out a comprehensive study of the Malla Johar succession, providing a revised lithostratigraphic scheme alongwith measured litholgs and details of sedimentary structures, trace fossils, palaeocurrents and depositional environment of the entire sequence. They preferred to subdivide the 'Upper Flysch' succession into two formations, eg. Jhangu and Balcha Dhura formations. The Jhangu Formation is represented by a thick sequence of dark coloured shales and graywacke, typical flysch sediments, with associated calcareous sandstone, foraminiferal limestone, radiolarian chert and red and green clays. The younger Balcha Dhura Formation (renamed after 'Balcha Dhura Volcanics' of Kumar *et al.*, 1972) is represented by the topmost ophiolite succession consisting of basic and ultrabasic volcanic rocks and associated with red and green shales and radiolarian cherts.

Heim and Gansser (1939) assigned an Upper Cretaceous (post-Albian) age to the 'Upper Flysch' succession. Later Kalia (1972, in Shah & Sinha, 1974), Mamgain and Sastry (1975) and Sastry and Mamgain (1977) supported Upper Cretaceous (Upper Cenomanian-Turonian to Maestrichtian) dating of these sediments based on the planktonic foraminiferal evidences. Subsequent study on planktonic foraminifera from the upper part of the Balcha Dhura Formation, representing the topmost part of the 'Upper Flysch', however, led Singh *et al.* (1981) to suggest Lower-Middle Palaeocene age for the studied horizon.

Since 1978, the authors have also been engaged to work out the Upper Jurassic-Cretaceous biostratigraphy of the sedimentary sequence exposed in Malla Johar area, Kumaon Himalaya. The studied microplankton include Jurassic dinocysts from Spiti Shale and Cretaceous radiolarians from Giumal Sandstone, Jhangu Formation and Balcha Dhura Formation (Jain *et al.*, 1978, 1984; Garg *et al.*, 1981). Based on thin section study of radiolarian assemblages from Jhangu Formation and Balcha Dhura Formation, Jain *et al.* (1978) and Garg *et al.* (1981) favoured an Upper Cretaceous age for these sediments. Incidentally, the planktonic foraminiferal fauna from Balcha Dhura Formation studied by Singh *et al.* (1981) was recovered from a slightly younger horizon than the samples which yielded the radiolarian assemblage (see Singh *et al.*, 1981, p. 384). Singh *et al.* (1981, p. 385) remarked that the discrepancy in age as suggested by radiolarians (Upper Cretaceous) and planktonic foraminifers (Palaeocene) could be deceptive as the succession consists of alternate cherts and calcareous shales in association with volcanic rocks. They further suggested that the Cretaceous-Palaeocene boundary may be sharp in the area, which can only be deciphered accurately by closer sampling of the deep sea deposits of the Balcha Dhura Formation.

Mention must be made of the views expressed by Kumar *et al.* (1977) and Singh *et al.* (1981) who, on stratigraphic grounds, expressed that the possibility of the 'Upper Flysch' succession extending into Upper

Palaeocene or even Eocene could not be totally ruled out. It was considered surprising by them that a thick sequence of more than 500 m could have been deposited under constantly deep water environment beyond continental slope within a relatively short span of time during Upper Cretaceous, mainly Maestrichtian, as the lowermost units of Jhangu Formation yielded nannoplankton indicative of Campanian-Maestrichtian boundary (Jafar in Kumar *et al.*, 1977, p. 419). However, definite microfossil evidences from the top of Balcha Dhura Formation, just underlying the 'Exotic Blocks' to date do not suggest an age younger than Lower-Middle Palaeocene.

All these evidences, thus, support Upper Cretaceous age for the major part of Heim and Gansser's 'Upper Flysch' succession and Early-Middle Palaeocene age for the topmost part of the ophiolite succession. However, Mehrotra and Sinha (1981, p. 159), on the basis of certain dinoflagellate cysts, proposed Palaeocene to Middle Eocene or Upper Eocene (?) age for the major part of the 'Upper Flysch' and suggested Upper Cretaceous age only for the lowermost part of the succession.

In order to resolve this age controversy as well as to check the accountability of the reported dinocyst assemblages vis-a-vis other microplankton assemblages (planktonic foraminifers and rediolarians) recorded from the same succession, we thought it best to reassess the identifications of the dinocyst taxa documented by Mehrotra and Sinha (1981, pls. 1-3) as some striking discrepancies were noticed in their identifications. This is also desirable in view of the fact that if age determination of the studied succession based on one evidence is believed to be true, the other evidences suggesting some different age have to be reviewed and logically explained within the known sedimentation and tectonic framework.

DINOFLAGELLATE CYSTS FROM THE 'UPPER FLYSCH'

Out of the four major units of the Sangchamalla Formation recognised by Shah and Sinha (1974), dinocysts have been reported by Mehrotra and Sinha (1981) from nearly all the stratigraphic levels except the basal 50 m dark greenish shale containing a few graywacke bands. The overlying 70 m thick purple marly shale with bands of foraminiferal ooze yielded abundant dinocysts, viz., *Odontochitina cribropoda* and *Systematophora schindewolfi* and has been assigned an Upper Cretaceous age. The succeeding 650 m thick unit represented by greenish graywacke and dark shales with bands of radiolarian cherts towards the top, is also found to be quite rich in dinoflagellate cysts. The dinocysts were recovered by Mehrotra and Sinha (1981) from ten samples representing different levels of this unit. Based on the predominance of *Oligosphaeridium complex*, *O pulcherrimum*, *Cordosphaeridium exilimurum*, *Diphyes colligerum*, and the first appearance of *Areosphaeridium diktyoplokus*, *A. arcuatum* and *Homotryblium tenuispinosum*, a Palaeocene to Lower Eocene age is assigned to this unit by Mehrotra and Sinha (1981, p. 159). The topmost 300 m thick sequence consisting of greenish shales with bands of chocolate sandstone and dark grey radiolarian cherts is also found to be palynologically productive. Predominance of *Areosphaeridium diktyoplokus*, *A. arcuatum*, *Homotryblium tenuispinosum* and absence of *Hystrichokolpoma unispinum* together with rarity of *Oligosphaeridium complex* and *O. pulcherrimum*, further led them to suggest Middle Eocene to Upper Eocene (?) age for this uppermost part of the Sangchamalla Formation. Thus, Sangchamalla Formation was considered by Mehrotra and Sinha (1978, 1981) to range in age from the Upper Cretaceous to Middle or ?Upper Eocene. Mehrotra and Sinha (1981) identified the following dinocysts:

* *Hystrichosphaeridium himalayaensis* Mehrotra & Sinha, 1981; pl. 152, p. 1, figs 7-9.
* *Areosphaeridium diktyoplokus* (Klumpp) Eaton, in Mehrotra & Sinha, 1981; p. 152, pl. 2, fig. 1.
* *A. arcuatum* Eaton, 1971; in Mehrotra & Sinha, 1981; p. 152, pl. 2, fig. 2.
* *Hystrichokolpoma unispinum* Williams & Downie, 1966, in Mehrotra & Sinha, 1981; p. 152, pl. 2, fig. 9.
Oligosphaeridium complex (White) Davey & Williams, 1966, in Mehrotra & Sinha, 1981; p. 152, pl. 1, figs 1, 2.
O. pulcherrimum (Deflandre & Cookson) Davey & Williams, 1966, in Mehrotra & Sinha, 1981; p. 152, pl. 1, figs 3-5.
* *Oligosphaeridium* sp., in Mehrotra & Sinha, 1981; p. 153, p. 1, fig. 6.
Gonyaulacysta sp., in Mehrotra & Sinha, 1981; p. 153, pl. 3, figs 5, 6.
* *Deflandrea speciosa* Alberti, 1959, in Mehrotra & Sinha, 1981; p. 153, pl. 3, fig. 9.
* *Homotryblium tenuispinosum* Davey & Williams, 1966, in Mehrotra & Sinha, 1981; p. 153, pl. 2, figs 3-5.
* *Cordosphaeridium exilimurum* Davey & Williams, 1966, in Mehrotra & Sinha, 1981; p. 153, pl. 2, fig. 6.
* *C. sangchamallai* sp. nov. Mehrotra & Sinha, 1981; p. 153, pl. 2, figs 7, 8.
* *Systematophora schindewolfi* (Alberti) Neale & Sarjeant, 1962; in Mehrotra & Sinha, 1981; p. 153, pl. 3, fig. 4.
* *Diphyes colligerum* (Deflandre & Cookson) Davey & Williams, 1966 in Mehrotra & Sinha, 1981; p. 153, pl. 3, fig. 2.
* *Cleistosphaeridium disjunctum* Davey *et al.*, 1966, in Mehrotra & Sinha, 1981; p. 154, pl. 3, fig. 1.
* *Adnatosphaeridium* sp., in Mehrotra & Sinha, 1981; p. 154, pl. 3, fig. 3.
* *Odontochitina cribropoda* Deflandre & Cookson, 1955, in Mehrotra & Sinha, 1981; p. 154, pl. 3, figs 7, 8.

The dinocyst taxa marked by an asterisk in the above list need a proper reallocation and are discussed.

TAXONOMIC REMARKS

Our interpretations presented here are solely based upon the face value of illustrations and descriptions provided by Mehrotra and Sinha (1981). Repository of the type material is not given by the authors and the slides were not available for restudy. The plate and figure numbers cited in this present paper refer to Mehrotra and Sinha (1981).

1. *Hystrichosphaeridium himalayensis* Mehrotra & Sinha (1981) is considered to be a junior synonym of *Oligosphaeridium complex* (white) Davey *et al.* (1966). The holotype of this species illustrated by Mehrotra & Sinha (1981, pl. 1, fig. 7) is a poorly preserved specimen showing presence of a process-free paracingular area, an apical archaeopyle and intratabular tubiform processes which are distally expanded with aculeate terminations. These characters suggest its placement under *Oligosphaeridium complex* rather than *Hystrichosphaeridium* which differs from *Oligosphaeridium* in having paracingular processes. The paratype illustrated in Pl. 1, fig. 8 differs from the holotype in having greater number of processes which are relatively shorter and broader, and a few processes with trifurcate distal ends; the archaeopyle is not clearly marked. Hence, this specimen is tentatively referred here to *Achomosphaera*.

2. *Areosphaeridium diktyoplokus* (Klumpp) Eaton (1971) is distinguished by its solid, fibrous intratabular processes with stems of variable length and breadth terminating in a broad, net-like distal platform which is circular to polygonal in outline with irregular to entire margin. The development of distal platform is not a uniform all round expansion of stem but a broad, blunt bifurcation (Eaton, 1971, p. 359). Based on restudy of the type material, Sarjeant (1981, p. 114) noted that the distinctive clypeate distal terminations of the processes of both holotype and paratype have irregular, not entire, margins.

The Sangchamalla specimen referred to *A. diktyoplokus* by Mehrotra and Sinha (1981, pl. 2, fig. 1) does not show the characteristic process termination of this species. Instead, it shows gradual funnel-like distal expansion of the processes giving an indication that lumen is extending into the stem which apparently seems to be hollow. The distal terminations of processes have distinctly spinose margins. Illustrations of *A. diktyoplokus* provided by Eaton (1971) and Sarjeant (1981) do not show spinose margins of the distal platform. The Sangchamalla form shows closer affinity with *Oligosphaeridium* which differs from *Areosphaeridium* in having non-fibrous, hollow, tubiform processes and lacks the characteristic distal terminations. Although the non-fibrous and hollow nature of the process stem are not clearly discernible in the poorly preserved Sangchamalla specimen, the fenestrated funnel-like distal terminations of the long, slender processes with spinose margins, alongwith process-free paracingular zone and apical archaeopyle suggest its placement under *Oligosphaeridium pulcherrimum* (Deflandre & Cookson) Davey & Williams, 1966.

3. *Areosphaeridium arcuatum* Eaton was considered by Sarjeant (1981, p. 115) as a junior synonym of *Areosphaeridium dictyostilum* (Menendez) Sarjeant. However, this was rejected by Lentin and Williams (1981) maintaining *A. arcuatum* as proposed by Eaton (1971).

A. arcuatum is characterised by intratabular processes having solid, fibrous stems which are distally expanded and bifurcate (licrate). The bifurcations are of variable length and have denticulate or irregular distal margin, sometimes with a net-like structure.

The poorly preserved Sangchamalla specimen referred to *A. arcuatum* by Mehrotra and Sinha (1981, pl. 2, fig. 2) shows a process free paracingular area, apical archaeopyle and apparently hollow processes with gradual funnel-like distal expansions showing development of lumen, and aculeate distal margins. These features clearly suggest *Oligosphaeridium complex* affinity.

4. The specimens referred to *Homotryblium tenuispinosum* Davey & Williams (1966) by Mehrotra and Sinha (1981, pl. 2, figs 3-5) include two different morphotypes. Two specimens (figs 3, 4) belong to *Oligosphaeridium complex* due to smaller number of slender and hollow tubular processes with distinctly aculeate distal ends, an apparently process free paracingular area and an apical archaeopyle. The third specimen (fig. 5) shows broader and apparently fibrous processes and does not show any resemblance to the figs 3 and 4 of the same Plate. It, however, appears to be similar to the other three specimens illustrated in pl. 2, figs 7-9 as discussed below.

5. The dinocyst specimens referred to *Homotryblium tenuispinosum* (pl. 2, fig. 5), *Cordosphaeridium sangchamallai* (pl. 2, figs 7, 8) and *Hystrichokolpoma unispinum* (pl. 2, fig. 9) are poorly preserved and distorted.

Cordosphaeridium sangchamallai Mehrotra & Sinha (1981) is stated to differ from *C. inodes* only in the slightly smaller size range of the cyst and the processes. This is, however, not a significant character for the creation of a new species. The holotype of *C. sangchamallai* (Mehrotra & Sinha, 1981, pl. 2, fig. 7) shows a process free paracingular area and fibrous, tubular processes. These characters suggest its placement under *Cordosphaeridium* sensu Sarjeant (1981). Though Mehrotra and Sinha (1981) mention the archaeopyle to be apical and haplotabular, it is not clearly marked in the illustrated specimens. Should the archaeopyle prove to be precingular, these specimens may be assigned to *Cordosphaeridium inodes*.

The forms illustrated in pl. 2, figs 5 and 9, referred to as *Homotryblium tenuispinosum* and *Hystrichokolpoma unispinum* respectively, show close resemblance to figs 7 and 8 of the same plate in having tubular, apparently fibrous and hollow, intratabular processes with slightly expanded distal ends. These forms are also referred to *Cordosphaeridium* for the present.

6. The dinocyst specimen referred to *Cordosphaeridium exilimurum* by Mehrotra and Sinha (1981, pl. 2, fig. 6) is poorly preserved and distorted. In a recent study, Sarjeant (1981) observed that the holotype of *C. exilimurum* displays the presence of paracingular processes and is, therefore, not assignable to *Cordosphaeridium* as emended therein. He suggested its alternative placement under *Hystrichosphaerina* or *Plethysyrinx* depending upon the apical or precingular archaeopyle type respectively. Jain and Garg (1985) preferred to place this species questionably under *Tityrosphaeridium* due to the apparent absence of trabecular interconnection between processes. The 'Upper Flysch' forms having greater number of broad and fibrous processes are tentatively placed under ?*Tityrosphaeridium exilimurum*.

7. *Diphyes colligerum* (Deflandre & Cookson) Davey & Williams (1966) is differentiated from *Coronifera* Cookson & Eisenack emend. Davey (1974) in having apical archaeopyle rather than precingular, found in the latter. The Sangchamalla specimen (Pl. 3, fig. 2) shows the presence of precingular archaeopyle and compares very closely to *Coronifera oceanica* described from the Lower Albian of Dalmiapuram Formation (Jain, 1977a, pl. 2, figs 18-22).

8. *Deflandrea speciosa* Alberti (1959), in Mehrotra and Sinha (1981, pl. 3, fig. 9), is characterised by a distinct apical archaeopyle with three horns—one apical, one postcingular and one antapical—suggesting affinity with *Endoceratium ludbrookiae* (Cookson & Eisenack), Loeblich & Loeblich (1968) rather than *Deflandrea* which has intercalary archaeopyle and one apical and two antapical horns.

9. Davey *et al.* (1966, pp. 169-170) instituted the species, *Cleistosphaeridium disjunctum* with a remark that the regular arrangement of processes seen in the specimen is not a typical feature of the genus and therefore made a provisional allocation to *Cleistosphaeridium*. Later Reid (1974, p. 591) considered that species to be a junior synonym of *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall (1967).

The illustration of Mehrotra and Sinha (1981, p. 158, pl. 3, fig. 1) shows a badly preserved specimen which indicates the presence of an apical archaeopyle. It can be referred to ?*Cleistosphaeridium* but not to *Lingulodinium machaerophorum*.

10. Alberti (1961, p. 60; pl. 10, figs 1-3, 6, 7) described *Hystrichosphaerina schindewolfi*, the type species of the genus, from the Turonian sediments of Germany. Later, Neale and Sarjeant (1962, p. 455) by implication transferred this species to *Systematophora*. Stover and Evitt (1978, pp. 57-58) and Davey (1982, p. 20) maintained the original status of this species. The Malla Johar specimens assigned to *Systematophora schindewolfi* by Mehrotra and Sinha (1981, pl. 3, fig. 4) should, therefore, be attributed to *Hystrichosphaerina schindewolfi*.

11. The specimen described as *Adnatosphaeridium* sp. and considered to represent a new species of the genus by Mehrotra and Sinha (1981, p. 154, pl. 3, fig. 3) does not show the process form of *Adnatosphaeridium*. It shows two different types of few intratabular processes and lacks interconnecting trabecular development. Position of archaeopyle, though mentioned to be 'apical' haplotabular by Mehrotra and Sinha (1981, p. 154), is not clearly marked in the illustrated specimen. It is referred here to as Dinocyst type A.

Checklist of revised dinocyst assemblages:

1. *O. complex* (Pl. 1, figs 1, 2, 4, 7 & 9; Pl. II, figs 2-4)
2. *O. pulcherrimum* (Pl. I, figs 3, 5, 6; Pl. II, fig. 1)
3. ?*Achomosphaera* sp. (Pl. I, fig. 8)
4. ?*Tityrosphaeridium exilimurum* (Pl. II, fig. 6)
5. *Cordosphaeridium inodes* (Pl. II, figs 7-8)
6. *Cordosphaeridium* sp. (Pl. II, figs 5, 9)
7. *Coronifera oceanica* (Pl. III, fig. 2)
8. *Hystrichosphaerina schindewolfi* (Pl. III, fig. 4)
9. *Odontochitina cribropoda* (Pl. III, figs 7, 8).
10. *Endoceratium ludbrookiae* (Pl. III, fig. 9)
11. ?*Cleistosphaeridium* sp. (Pl. III, fig. 1)
12. *Gonyaulacysta* sp. (Pl. III, figs 5, 6)
13. Dinocyst type A (Pl. III, fig. 3)

AGE OF THE DINOCYST ASSEMBLAGE

The revised Upper Flysch dinocyst assemblage discussed above suggests total absence of Tertiary dinocyst taxa, identified and recorded by Mehrotra and Sinha (1981), viz., *Areosphaeridium diktyoplokus*, *A. arcuatum*, *Homotryblium tenuispinosum*, *Hystrichokolpoma unispinum*, *Deflandrea speciosa* and *Cleistosphaeridium disjunctum*. It further shows the absence of *Diphyes colligerum*, an Upper Cretaceous-Tertiary form. On the contrary, it has been noted that *Odontochitina cribropoda* and *Hystrichosphaerina schindewolfi* are restricted to the lowermost part of the Sangchamalla Formation, whereas the younger assemblages are characterised by the abundance of *Oligosphaeridium complex* and *O. pulcherrimum*, which occur in association with ?*Tityrosphaeridium exilimurum*, *Cordosphaeridium* sp. and *Coronifera oceanica*. The stratigraphic position of the remaining species, viz., *Endoceratium ludbrookiae* (identified as *Deflandrea speciosa* by Mehrotra & Sinha, 1981), *Gonyaulacysta* sp., *Cleistosphaeridium* sp. and Dinocyst type A in the studied sequence, has not been provided by Mehrotra and Sinha (1978, 1981). However, from their explanations of plates it appears that *E. ludbrookiae* (recorded as *Deflandrea speciosa*) comes from the same sample (No. 6828/76/6) from which species like '*Hystrichokolpoma unispinum*', (*Cordosphaeridium* sp.), '*Areosphaeridium diktyoplokus*' (*Oligosphaeridium pulcherrimum*), occurring in the topmost levels of the Sangchamalla Formation, are recorded. In our opinion, *Endoceratium* is most likely reworked from the older sediments in this area. The occurrence of *Endoceratium ludbrookiae* is quite intriguing as it has a restricted geologic range from Albian to Early Cenomanian (Millioud, 1975). The planktonic foraminifera indicate Turonian-Maestrichtian age for the 'Upper Flysch' succession.

The typical Upper Cretaceous marker dinocyst genus, *Dinogymnium*, is absent in the described dinocyst assemblages of 'Upper Flysch' sediments, though this is well represented in the Campanian-Maestrichtian sediments of Assam, southern India and other parts of the world (Jain *et al.*, 1975; Jain, 1977, 1977a).

In our opinion the dinocyst assemblage recorded from the 'Upper Flysch' succession primarily consists of Cretaceous taxa with *Cordosphaeridium* and ?*Tityrosphaeridium* as the only Upper Cretaceous elements extending into Lower Tertiary. The known stratigraphic ranges of the above mentioned taxa clearly reflect as Upper Cretaceous aspect.

For reasons discussed above, the proposal of Mehrotra and Sinha (1981) that the age of the Sangchamalla Formation does not restrict to Upper Cretaceous but extends from Upper Cretaceous to ?Upper Eocene, is not acceptable.

DEPOSITIONAL ENVIRONMENT OF 'UPPER FLYSCH' AND DINOCYSTS

Heim and Gansser (1939) and Mamgain and Sastry (1975) considered the 'Upper Flysch' to be deep water open sea deposits. However, Mehrotra and Sinha (1981, p. 160) visualised the predominance of dinocysts in the Upper Flysch sequence as an indication of shallow marine depositional environment within the flysch sedimentational cycle. They further inferred that the flysch graben with loaded sediments experienced pulsational vertical movements with shallowing and deepening of the basin.

Based on the lithology, sedimentary structures, trace fossils and microplankton evidences, it has now been well established by Kumar *et al.* (1977) that the Giumal Sandstone is a deposit of continental margin, mainly the continental slope, and the overlying 'Upper Flysch' succession (Jhangu Formation) was laid down in still deeper environment in a rapidly sinking basin. Further, according to Kumar *et al.* (1977, pp. 420, 431), the uppermost part of the 'Upper Flysh' represents an ophiolite succession, developed during the last phase of sedimentation when submarine fissures appeared leading to outpouring of the basic and ultrabasic lavas. These volcanic rocks occur interbedded with deep sea clays, radiolarian cherts and foraminiferal oozes in the Balcha Dhura Formation.

It is thus quite obvious that in such a sedimentation and tectonic framework, mere occurrence of dinocysts cannot be taken to indicate occurrence of a shallow marine environment within a 'pulsationally sinking and rising flysch basin' as surmised by Mehrotra and Sinha (1981). Any explanation put forward to account for the occurrence of dinocysts in the 'Upper Flysch' succession should logically conform with the palaeoenvironmental model visualised by Kumar *et al.* (1977). According to Mehrotra and Sinha (1981, p. 151), dinocysts are mostly recovered from purple, green and black shales while arenaceous and calcareous lithologies are barren. The recorded assemblage represents an open sea assemblage due to the abundance of chorate cysts. Occurrence of dinocysts in these deep sea 'Upper Flysch' sediments can be attributed to two processes. These dinocysts might have accumulated through direct settling from the euphotic zone to the deep sea basin where these were ultimately deposited alongwith clay/silt size sediments. Equally significant may be the role of turbidity currents which might have periodically transported dinocysts with fine terrigenous clastics that were being laid down contemporaneously at the shallower regimes of the basin. Before drawing any inferences, it is, however, desirable to have a look at the known distribution of dinoflagellate cysts in the surface sediments of the present day oceans.

In modern sediments, fairly rich assemblages of dinoflagellate cysts are recorded from abyssal plain in western Carribean by Wall (1967) and continental slope of South Africa by Davey (1971). Dinocysts have been recorded throughout the Atlantic from ocean trench to intertidal sediments (Williams, 1971; Reid & Harland, 1977, p. 155). Occurrence of dinocysts in deep sea 'red clays' is also known (Williams, 1971, p. 239). Wall (1967) considered direct settling of cysts from the euphotic zone as the main cause for accumulation of dinocysts in Yacatan Basin lutites from two sediment cores at depths of over 4,000 m in the Carribean. Redeposition of neritic sediments, which contain a far greater number of dinocysts, is thought to be a less likely cause in view of the small amount of reworking of microplankton noted in these lutites. Wall (1967) has, nevertheless, suggested further investigation of 'possibly disturbing influence' of turbidity currents on composition of deep sea microplankton assemblages. Davey (1971)noted the richness of dinocysts in continental slope and shelf sediments of South Africa in areas within the zone of current mixing in surface waters and with very little turbulence. This, according to Davey (1971), would have allowed rapid settling and concentration of dinocysts acting as fine grained sedimentary particles. Though dinocysts are recorded from a variety of lithologies in modern sediments, it has generally been found that cysts are selectively concentrated in fine grained sediments and appear to act as fine silt particles (Wall, 1971; Dale, 1976).

It is true that palaeoenvironmental interpretations of older dinocyst assemblages shall remain only tentative till more information is gathered about the biocoenosis and thanotocoenosis of Recent dinoflagellates and their cysts in the modern sediments. In spite of this, it would not be preposterous to attribute the occurrence of dinocysts in deep sea 'Upper Flysch' sediments of Malla Johar to direct settling from surface waters as well as to the periodic influence of turbidity currents. It is to be noted that low density and low energy turbidity currents were periodically operative during the deposition of Giumal Sandstone and Jhangu Formation (Kumar *et al.*, 1977). Association of turbidite sequences, dark coloured shales and oozes which occur interstratified in the Jhangu Formation, is attributed by Kumar *et al.* (1977, p. 431) to quick changes in the supply of material from land and minor fluctuations in the basin depth. The latter remained almost throughout near the continental margin on or beyond the continental slope. The dinocysts might have been brought down periodically to the deeper regimes of the basin through turbidity currents alongwith fine terrigenous clastics from the shelf areas. This also lends some credence to our contention that reworking of Lower Cretaceous dinocysts might have taken place.

It is also interesting to note that Mamgain and Sastry (1975) and Sastry and Mamgain (1977) reported the occurrence of pteridophytic spores and angiospermous and gymnospermous pollen grains in the 'Upper Flysch' sediments. They considered the occurrence of these land derived microfloral elements in deep water open sea deposits as only indicating proximity of the coast and presence of near shore vegetation.

It is, therefore, considered that the dinoflagellate cysts recovered from the 'Upper Flysch' were most probably brought down in a deeper environment near the continental margin through transportation from shallower regions by some sedimentary processes and were subsequently deposited there.

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The Palaeobotanist **35**(1) : 69-72, 1986.

Maheshwariella spinicornuta, a new gymnospermous seed from the Karharbari Formation

Hari K. Maheshwari & Rajni Tewari

ABSTRACT

Maheshwari, Hari K. & Tewari, Rajni (1986). *Maheshwariella spinicornuta*, a new gymnospermous seed from the Karharbari Formation. *Palaeobotanist* **35**(1) : 69-72.

Maheshwariella spinicornuta sp. nov. is established for an orthotropus, platyspermic, bilaterally symmetrical seed having two long tubular expansions ('horns') at the micropylar end. The 'horns' have characteristic spinate appendages. In this character this species differs from the type species, viz., *M. bicornuta* Pant & Nautiyal. On the basis of overall morphography, *Cornucarpus (Cordaicarpus) furcata* (Surange & Lele) Maithy is transferred to the genus *Maheshwariella*. Certain dispersed seeds ascribed by Pant and Nautiyal to *Buriadia* '*heterophylla*' are found to be indistinguishable from *M. bicornuta*.

Key-words—*Maheshwariella, Buriadia*, Seed, Karharbari Formation, Lower Permian (India).

Hari K. Maheshwari & Rajni Tewari, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

सारॉँश

माहेश्वरीयॅल्ला स्पाइनीकॉर्नूटा, करहरबारी शैल-समूह से एक नया अनावृतबीजी बीज

हरिकृष्ण माहेश्वरी एवं रजनी तिवारी

माहेश्वरीयॅल्ला स्पाइनीकॉर्नूटा नव जाति एक ऋजु, बहुबीजी, द्विपार्श्वीय सममित बीज है जिसके अंडद्वार पर दो लम्बे नालाकार प्रवर्ध (श्रंगी) विद्यमान हैं। ये श्रंगी लाक्षणिक कंटकी उपांगों से युक्त हैं जिसके आधार पर यह जाति माहेश्वरीयॅल्ला बाइकॉर्नूटा पन्त व नौटियाल से भिन्न है। समग्र आकृति-वर्णना के आधार पर कॉर्नूकार्पस (कोर्डायकार्पस) फ़र्केटा (सुरंगे व लेले) माइती को माहेश्वरीयॅल्ला प्रजाति में स्थानान्तरित कर दिया गया है। पन्त एवं नौटियाल द्वारा बुरियाडिआ हैट्रोफ़िल्ला के नाम से वर्णित किये गये कुछ विकरणित बीज माहेश्वरीयॅल्ला बाइकॉर्नूटा से अविभेद्य पाये गये हैं।

INTRODUCTION

A NUMBER of compressed seed genera of gymnospermous affinities have been described from the Lower Gondwana of India notably by Feistmantel (1880), Seward and Sahni (1920), Saksena (1955), Lele (1953, 1963, 1966, 1969) Surange and Lele (1957), Maithy (1965), Surange (1957), Pant and Nautiyal (1960, 1963, 1965), Pant and Srivastava (1963), Surange and Singh (1952), Srivastava and Chandra (1982), and others. The epidermal features of almost all the genera are now known, though some are relatively better known.

During the course of bulk acid processing of samples for the recovery of megaspores from the Karharbari Formation of a number of coalfields, a few seeds were also recovered. One of the types is interesting and forms the content of this paper. The seed is referable to the genus *Maheshwariella* Pant & Nautiyal, 1963.

REMARKS

Seeds of the genus *Maheshwariella* resemble those of the genus *Cornucarpus*, which was proposed by Arber (1914) for the platyspermic compressed seeds earlier described by Lindley and Hutton (1831-37) as *Cardiocarpon acutum*. However, there is a major difference between the diagnosis of *Cornucarpus* and the description of *Cardiocarpon acutum*. Former has a broad apex, bifurcated into long horns, and a broad base, while the latter has an acute apex, which is not bifurcated into horns and has an obtuse base. Seward (1919) also opined that the two were different. The seeds (belonging to the specimens of Kidston collection) described by Seward (1919) are broadly oval, have an obtuse base and two divergent acute processes at the apex suggesting that they are of *Cornucarpus* type.

Separation of bicornute seeds from other genera was also supported by Halle (1927). According to him, "It is undoubtedly desirable to divide the large number of seeds, which do not show the internal structure, into form-genera on the basis of characters which in the majority of cases can be recognised in specimens preserved as impressions or casts. Such characters as symmetry, and the differentiation of the integument, while of greater systematic importance, very often cannot be recognised in material of this kind, and it would seem to be a practical advantage to be able to sort out the bicornute forms, which are as a rule, easily recognisable."

Halle (1927) mentioned that in "*Cornucarpus* the horns are prolongations of a narrow wing which continues round almost the whole seed." Here, however, he did not include *Samaropsis* seeds with the wings merely notched at the apex, e.g. *S. emarginata*.

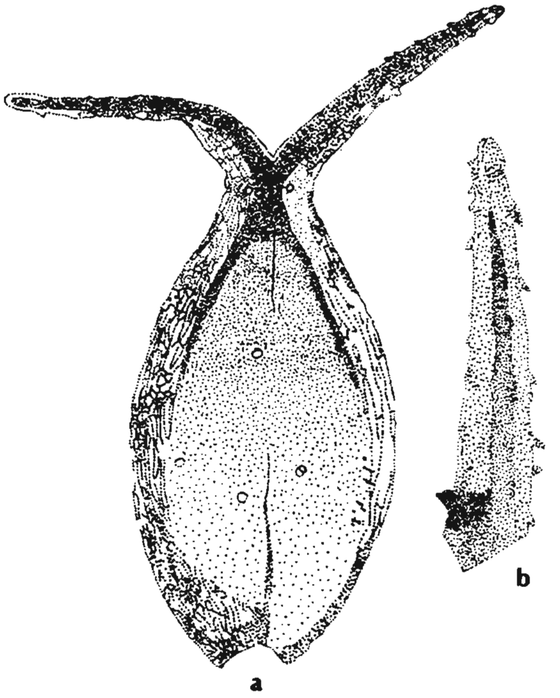
In view of the above description of the genus *Cornucarpus*, it is now possible to differentiate it from the seed genus *Maheshwariella*. Both the genera, though at a glance, look similar in their morphography in having bifurcated horns at their apices, they are essentially different in the respect that in the former the horns are prolongations of wings, while in the latter the wing is absent and horns are two distinct, elongated tubular processes of the integument. Moreover, the micropylar neck is very narrow in the latter so that a deep curve is formed in between the horns and rest of the body of seed.

On the basis of the above differentiation between the two genera, it is hereby proposed that *Cornucarpus furcata* (Maithy, 1965, text-fig. 4, pl. 1, fig. 5) and *Cornucarpus* sp. (Du Toit, 1927, pl. XLI, fig. 11) should be transferred to the genus *Maheshwariella*.

Pant and Nautiyal (1967) described some attached and detached seeds of *Buriadia heterophylla*. The detached seeds are similar to *Maheshwariella bicornuta* in having bifurcated horns and hairs on narrow marginal borders. Therefore, it is assumed that the detached seeds of *B. heterophylla* are referable to *Maheshwariella*. Pant and Nautiyal (1967) have also mentioned that out of the two bifurcations at micropylar end, one is stalk and the other is horn. Micropyle lies in between the stalk and the horn. Since, the structure of both is similar, they should be regarded as horns.

Maheshwariella spinicornuta sp. nov.

Pl. 1, figs 1-4; Text-fig. 1a-b



Text-fig. 1—*Maheshwariella spinicornuta* sp. nov. : (**a**) Complete seed showing narrow micropylar end bifurcated into two long tubular horns, broad chalazal end and narrow marginal border. Outer surface of seed showing monosaccate and disaccate pollen grains; and (**b**) a horn enlarged to show spines.

Diagnosis—Seeds platyspermic, almond-shaped, bilaterally symmetrical, orthotropus. Seed coat 2-layered, having outer integumental cuticle and inner nucellar cuticle, micropylar neck narrow, chalazal end broad, former bifurcated into two, long, distinct tubular processes—broad at base, narrow at apex—formed by prolongation of bifid nucellar beak and integumental cuticle, narrow border present on the margins on either side of seed, discontinuous ridge present on flattened surface of seed, margins of outer sides of horns show spines directed backwards.

Description—There are only two specimens, of which only one is complete. The complete seed (Pl. 1, fig. 1) is 6 mm long, 2.5 mm broad, micropylar neck is 1 mm wide, bifurcated into two horns, each *ca* 750 μm long, 480 μm wide at base, acute at apex; the spines (Pl. 1, fig. 3) present on the horns vary in length from 38 to 58 μm and in width from 38 to 48 μm at base and are

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PLATE 1

Maheshwariella spinicornuta sp. nov.

1. Complete seed showing micropylar horns, Slide no. BSIP 8338. × 20.
2. Apical portion of seed in fig. 1 enlarged to show marginal border on sides. × *ca* 40.
3. Single horn showing presence of backward directed spines on the outer sides. × *ca* 100.
4. Macerated seed showing outer integumental and inner nucellar cuticle, Slide no. BSIP 8339. × 15.

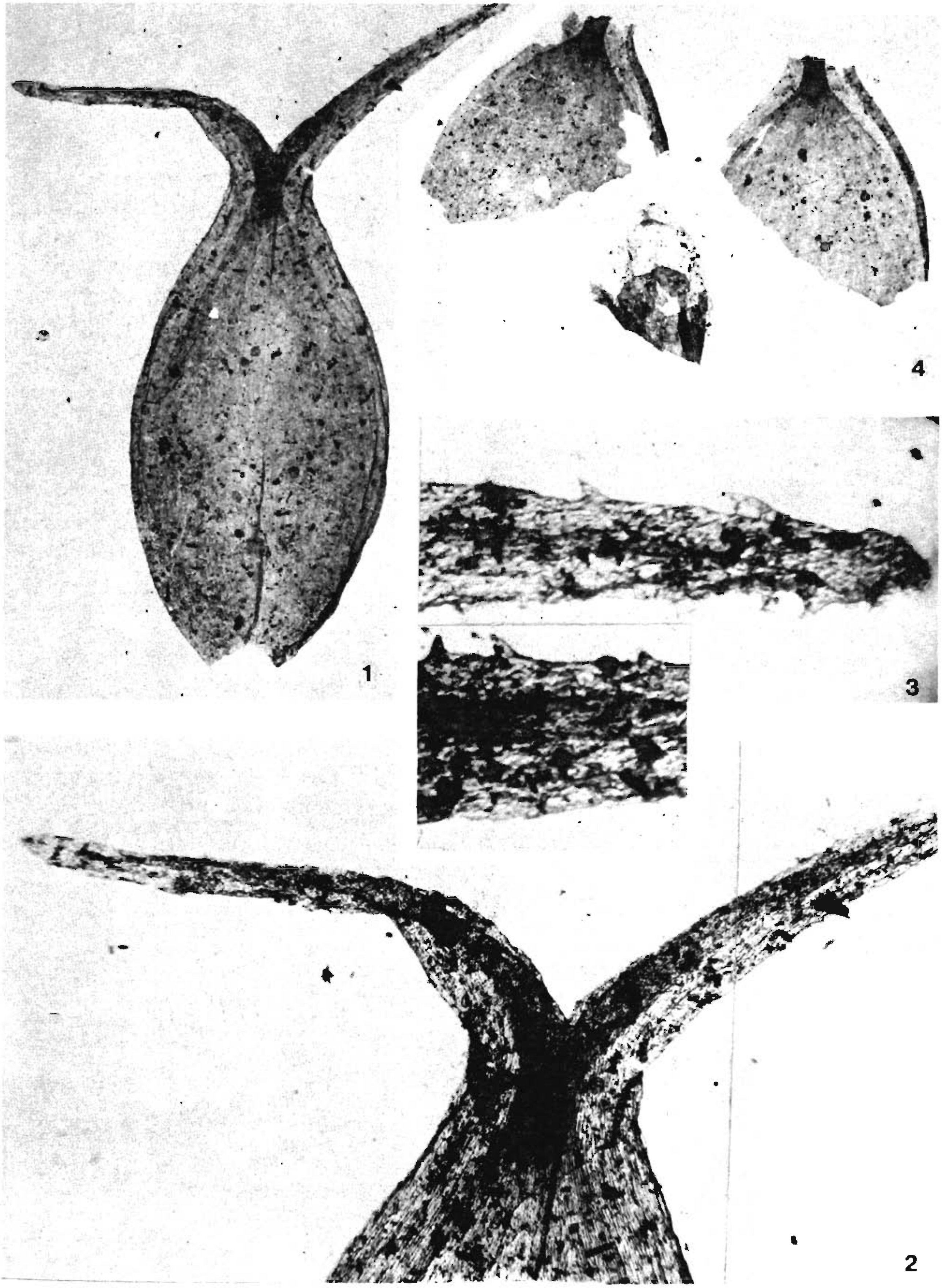

PLATE 1

directed backwards. A narrow border (Pl. 1, fig. 2), about 124 μm wide, is present on margins of the seed. Monosaccate and disaccate pollen grains are present on outer surface of the seeds, former ranging in size from 105-115 × 106-125 μm while the latter are 105 × 112—122 × 80 μm in size.

Seed cuticle shows rectangular thin-walled cells, longitudinally arranged, ranging in length from 44-69 μm, average width being 25 μm. Only one integument of seed is present of which the outer cuticle is visible and the inner cuticle could not be recovered. Cells of marginal border are narrow-elongate, trapezoidal, average size being 124 × 12 μm. Cells of micropylar horns are polygonal, 38-76 μm long, 19-32 μm broad. Cells of nucellar cuticle are polygonal, 44-82 μm long and 32-50 μm broad.

Comparison—The seeds described above are comparable to *Maheshwariella bicornuta* Pant & Nautiyal, 1963 and attached seeds of *Buriadia heterophylla* (Pant & Nautiyal, 1967) from both of which these differ in the absence of an inner cuticle of the integument and hair-like processes on narrow marginal borders.

Holotype—Slide no. BSIP 8338; Ganjra Nalla beds near its confluence with Johilla River, Birsinghpur-Pali, Shahdol District, Madhya Pradesh; Karharbari Formation, Lower Permian.

Maheshwariella furcata (Surange & Lele) comb. nov.

1957 *Cordaicarpus furcata* Surange & Lele, *Palaeobotanist* **5**(2), p. 84, pl. 1, figs 9, 10; text-fig. 2.

1965 *Cornucarpus furcata* (Surange & Lele) Maithy, *Palaeobotanist* **13**(1), p. 47, pl. 1, fig. 5; text-fig. 4.

Diagnosis—Seeds platyspermic, oval, orthotropus, unwinged, somewhat flattened at base with bifid apex, single integument present which prolongs into two small horns at micropylar end.

Holotype—Specimen no. BSIP 5225; Goraia, Shahdol District, Madhya Pradesh; Talchir Formation, Lower Permian.

Distribution—Central pit, Jubillee pit and Srirampur open quarry, Giridih Coalfield, Bihar, Karharbari Formation, Lower Permian.

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Fossil floras of Kutch-Part VI. Jurassic dinoflagellates

K. P. Jain, B. N. Jana & Hari K. Maheshwari

ABSTRACT

Jain, K. P., Jana, B. N. & Maheshwari, Hari K. (1986). Fossil floras of Kutch-Part VI. Jurassic dinoflagellates. *Palaeobotanist* **35**(1) : 73-84.

Fossil dinoflagellate cysts and acritarchs have been reported and described from the various members of the Jhuran Formation exposed at a number of localities in the Kutch Basin. The assemblage comprises 31 species referable to 24 genera. On the basis of qualitative and quantitative analyses the age of the dinoflagellate assemblage has been concluded to be Upper Oxfordian to Kimmeridgian, probably extending up to *Pectinatites pectinatus* zone.

Key-words—Palynology, Dinoflagellates, Acritarchs, Jhuran Formation, Jurassic (India).

K.P. Jain, B. N. Jana & Hari K. Maheshwari, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

कच्छ के अश्मित वनस्पतिजात. भाग 6–जूराई युगीन घूर्णीकशाभ पुटीयाँ

कृष्ण प्रसाद जैन, बृजेन्द्र नाथ जाना एवं हरिकृष्ण माहेश्वरी

कच्छ द्रोणी में कई स्थानों पर विगोपित झुरान शैल-समूह के विभिन्न सदस्यों से अश्मित घूर्णीकशाभ पुटीयाँ एवं एँक्रीटार्क अभिलिखित किये गये हैं। इस समुच्चय में 24 प्रजातियों की 31 जातियाँ विद्यमान हैं। गुणात्मक एवं परिमाणात्मक विश्लेषणों के आधार पर घूर्णीकशाभ समुच्चय की आयु उपरि ऑक्सफ़ोर्डियन से किम्मॅरिडजियन, सम्भवतया पैक्टीनेटाइटिस पैक्टीनेटस मंडल तक विस्तृत, आँकी गई है।

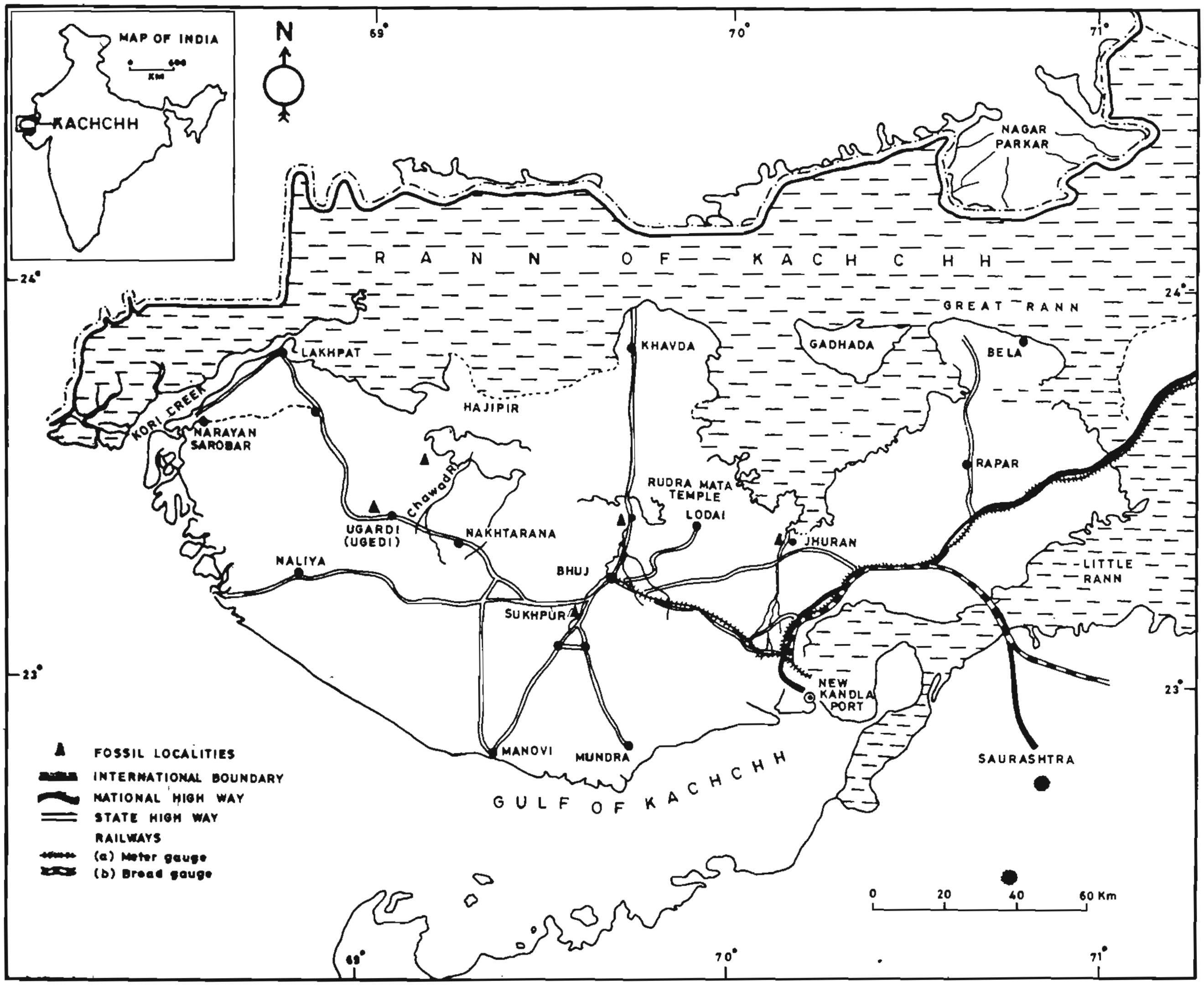
INTRODUCTION

THE massive deposits of Mesozoic sediments of Kutch Basin attracted many palynologists to work on various aspects since 1964. Most of the workers, however, concentrated on the spores and pollen grains and in palynological assemblage from the traverse Orara-Bhoyad (correct name : Orira-Bhurud) noted a few dinoflagellate cysts. Venkatachala (1967) also illustrated some microplankton along with spores and pollen grains from Walkamata (Correct name : Walkamota) belonging to the Bhuj Formation. Venkatachala and Kar (1968) described a few dinoflagellate cysts from Jhuran Formation exposures around Rudra Mata Temple. The present paper deals with a rich microplankton assemblage comprising 24 genera and 31 species recovered from the surface and sub-surface exposures of Jhuran Formation from the following localities (Map 1).

1. Jhuran River Section—About 50 km east-south-east of Bhuj Town and about 3 km west of the Village Jawahar Nagar.
2. Exposure near Rudra Mata Temple—About 100 m north of Rudra Mata Dam.
3. Sukhpur Nala Section—10 km from Bhuj Town on the left side of Bhuj-Mandvi road.
4. Hajipir Road Section—About 21 km from Bhuj-Lakhpat road on way to Hajipir.
5. Ugedi well cutting—The well is about 5.5 km north of Ugedi and on the eastern side of the Bhuj-Lakhpat road.

The dinoflagellate cysts and acritarchs were isolated from rock samples following conventional method of maceration. The slides were prepared by using polyvenyl alcohol and were mounted in Canada balsam.

The photomicrographs were taken on Agfa ortho 25 or Ilford 35 mm negative films with a Carl Zeiss Amplival



Map 1

microscope and automatic camera attachment. The negatives were printed by using different grades of Agfa Brovira glossy paper.

The slides bearing figured specimens have been deposited in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

SYSTEMATICS

Division—*Pyrrhophyta* Pascher, 1914
Class—*Dinophyceae* Fritsch, 1929
Order—*Peridiniales* Schutt, 1896
Family—*Gonyaulacystaceae* Sarjeant & Downie emend. Sarjeant & Downie, 1974

Genus—*Gonyaulacysta* Deflandre ex. Norris & Sarjeant emend. Sarjeant, 1982

Gonyaulacysta jurassica subsp. *jurassica* Deflandre emend. Sarjeant, 1982

Pl. 2, figs 15, 22; Pl. 3, fig. 44.

1968 *Gonyaulax jurassica* Deflandre, in Venkatachala & Kar, *Curr. Sci.*, **37** : 409, figs 1, 2; Kutch Basin, Jhuran Formation (Upper Jurassic).

1978 *Gonyaulacysta* (al. *Gonyaulax*) *jurassica* (Deflandre) Norris & Sarjeant, in Jain, *Aspects & Appraisal of Indian Palaeobotany*, p. 587, table 1.

Dimensions :

Overall size of the cyst	— 114 × 72 μm
Overall size of endoblast	— 90 × 60 μm
Size of apical horn	— 22 × 10 μm

Gonyaulacysta sp. cf. *G. perforans* (Cookson & Eisenack) Sarjeant, 1969

Pl. 1, fig 2; Pl. 2, figs 26, 27

Description—Cyst mostly elongate to ovoidal in shape, epi-and hypo-cyst almost equal in size, apical horn short; paracingulum present; paratabulation incomplete, postcingular paraplates when present elongate; paraplate boundaries marked by membranous porate crests, extending beyond body margin (4 to 6 μm), best seen around antapex. Archaeopyle precingular (3″).

Dimensions :

Overall cyst size — 74 × 60 μm
Length of apical horn — up to 10 μm

Remarks—The Kutch forms are comparable with *G. perforans* (Cookson & Eisenack) Sarjeant (1969) and show closest resemblance to the specimens described and illustrated by Ioannides *et al.* (1976, p. 454; pl. 3, figs 3,4) as *Gonyaulacysta* cf. *perforans* and Gitmez and Sarjeant (1972, pp. 202-203; pl. 4, fig. 6), both from Kimmeridgian of England.

Gonyaulacysta ehrenbergii Gitmez, 1969

Pl. 2, figs 25, 30

Dimensions :

Overall size of cyst — 90 × 70 μm
Length of apical horn — up to 10 μm

Remarks—The taxonomic status of the genus *Millioudodinium* Stover & Evitt (1978) is doubtful *sensu* Duxbury (1980, p. 122). *G. ehrenbergii* is, therefore, retained here for the time being. This species has been described from the basal Kimmeridgian of France.

Genus—*Spiniferites* Mantell emend. Sarjeant, 1970

Spiniferites sp.

Pl. 3, fig. 39

Description—Cyst skolochorate, central body ovoidal, 44 × 52 μm in size, with clearly defined reflected paratabulation of the genus, periphragm and endophragm appressed, paraplate boundaries indicated by variably developed sutural crests or low membranes, processes typically short, distally closed with briefly bifid or trifid distal ends.

Genus—*Leptodinium* Klement emend. Sarjeant, 1982

Leptodinium eumorphum (Cookson & Eisenack) Sarjeant, 1969

Pl. 1, figs 6, 13

Dimensions :

Overall size of cyst — 88 × 72 μm

Remarks—Cookson and Eisenack (1960, p. 246) reported this species from Oxfordian-Kimmeridgian of western Australia.

Genus—*Tubotuberella* Vozzhennikova emend. Sarjeant, 1982

Tubotuberella apatela (Cookson & Eisenack) Ioannides, Stavrinos & Downie emend. Sarjeant, 1982

Pl. 1, fig. 7

Dimensions :

Overall size of cyst —80-95 × 45-60 μm

Remarks—Presence of an opisthopyle in the present forms of *T. apatela* is common to *G. jurassica* but possesses no paratabulation. This species is quite common in Oxfordian-Lower Kimmeridgian sediments of western Australia.

Genus—*Egmontodinium* Gitmez & Sarjeant, 1972

Egmontodinium polyplacophorum Gitmez & Sarjeant, 1972

Pl. 2, fig. 16; Pl. 3, fig. 42

Dimensions :

Overall size of cyst —70-85 × 42-54 μm
Maximum height of crest —4 μm

Remarks—This species has been reported from the Kimmeridge Clay (*Pectinatus* Zone). In Kutch Basin, this species is common in samples of Lower Member of the Jhuran Formation.

The Kutch specimens show some resemblance to *Meiourogonyaulax* sp. described and illustrated by Gitmez (1969, p. 278; pl. 13, fig. 10) from the basal Kimmeridgian of Scotland, in its shape, size and to some extent in the distribution of paraplates but differs mainly in having anterior and posterior circle paraplates.

Genus—*Occisucysta* Gitmez, 1970

Occisucysta sp.

Pl. 2, fig. 21

Description—Cyst proximate, subspherical, apical horn short and stout; paracingulum present, dividing cyst into smaller epicyst and large hypocyst; paratabulation indistinct due to unsatisfactory preservation; periphragm granular, paraplate boundaries ornamented with short spines. Archaeopyle broad, made up of two precingular paraplates (2″ & 3″).

Dimensions :

Overall size of cyst —78 × 78 μm
Length of apical horn —up to 10 μm

Remarks—The present forms have been attributed to *Occisucysta* Gitmez (1970) in view of broad precingular archaeopyle made of two paraplates (2″ & 3″). It differs from *Occisucysta* sp. described by Gitmez (1969, p. 269, pl. 7, fig. 8) from the Lower Kimmeridgian of England in having shorter apical horn, otherwise it is quite comparable.

Family—Apteodiniaceae Eisenack emend. Sarjeant & Downie, 1972

Genus—*Apteodinium* Eisenack, 1958

Apteodinium granulatum Eisenack, 1958

Pl. 2, fig. 31

Dimensions :

Overall cyst size	—86 × 76 μm
Length of horn	— up to 8 μm

Remarks—Gitmez (1969) reported *A. granulatum* from the basal Kimmeridgian of England and France.

Apteodinium sp. A

Pl. 1, fig. 9

Description—Cyst ovoidal, small, double-walled, periphragm smooth, apical horn short having knob at distal end; paracingular region marked by the presence of a thick band. Archaeopyle precingular (3″).

Dimensions :

Overall size	— 62 × 42 μm
Length of apical horn	— up to 10 μm

Remarks—The present form differs from the known species of the genus in its small cyst size, thick paracingular band and typically short apical horn with distal knob.

Genus—*Ellipsoidictyum* Klement, 1960

Ellipsoidictyum cinctum Klement, 1960

Pl. 2, figs 17, 24

Dimensions :

Overall cyst size	—50-65 × 38-50 μm

Remarks—The Kutch forms though are within the size range of *Ellipsoidictyum cinctum* described from the Upper Jurassic of north-west Germany (Gocht, 1970, p. 152), yet occupy intermediate position when compared with West German and Australian forms (Klement, 1960; Cookson & Eisenack, 1960).

Family—*Canningiaceae* Sarjeant & Downie, 1966 emend. Sarjeant & Downie, 1974

Genus—*Escharisphaeridia* Erkmen & Sarjeant, 1980

Escharisphaeridia pocockii (Sarjeant) Erkmen & Sarjeant, 1980

Pl. 2, figs 19, 23

Dimensions :

Overall cyst size	—70-80 × 50-80 μm

Genus—*Sentusidinium* Sarjeant & Stover, 1978

Sentusidinium echinatum (Gitmez & Sarjeant) Sarjeant & Stover, 1978

Pl. 3, fig. 50

Dimensions :

Overall size of cyst	—64 × 70 μm
Length of spines	— up to 4 μm

Family—*Adnatosphaeridiaceae* Sarjeant & Downie, 1966

Genus—*Adnatosphaeridium* Williams & Downie, 1966

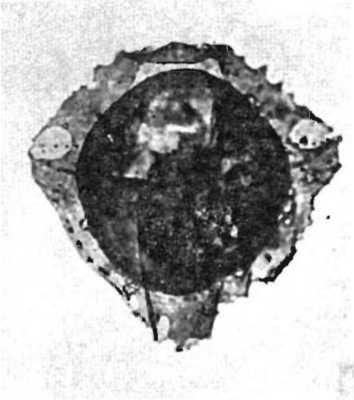
Adnatosphaeridium aemulum (Deflandre) Williams & Downie, 1969

→

PLATE 1

(All photomicrographs × 500)

1. *Scriniodinium luridum* (Deflandre) Klement, 1960; slide no. BSIP 8559; co-ordinates : 107.5 × 17.5.
2. *Gonyaulacysta* sp. cf. *G. perforans* (Cookson & Eisenack) Sarjeant, 1969; slide no. BSIP 8565; co-ordinates : 93.8 × 5.0.
3. *Oligosphaeridium* sp.; slide no. BSIP 8566; co-ordinates : 104.6 × 15.0.
4. *Nannoceratopsis pellucida* Deflandre emend. Evitt, 1961; slide no. BSIP 8562; co-ordinates : 96.6 × 10.0.
5. *Adnatosphaeridium paucispinum* (Klement) Gitmez & Sarjeant, 1972; slide no. BSIP 8557; co-ordinates : 102.4 × 22.4.
6. *Leptodinium eumorphum* (Cookson & Eisenack) Sarjeant, 1969; slide no. BSIP 8561; co-ordinates : 104.6 × 15.0.
7. *Tubotuberella apatela* (Cookson & Eisenack) Ioannides *et al.* emend. Sarjeant, 1982; slide no. BSIP 8566; co-ordinates: 18.5.
8. *Nummus similis* (Cookson & Eisenack) comb. nov.; slide no. BSIP 8566; co-ordinates: 114.4 × 10.4.
9. *Apteodinium* sp. A; slide no. BSIP 8565; co-ordinates: 108.8 × 21.4.
10. *Prolixosphaeridium anasillum* Erkmen & Sarjeant, 1980; slide no. BSIP 8565; co-ordinates: 108 × 10.0.
11. *Verybachium valensii* (Valensi) Downie & Sarjeant, 1963; slide no. BSIP 8561; co-ordinates: 98.7 × 8.2.
12. *Adnatosphaeridium filamentosum* (Cookson & Eisenack) Williams & Downie, 1969; slide no. BSIP 8556; co-ordinates: 92 × 14.9.
13. *Leptodinium eumorphum* (Cookson & Eisenack) Sarjeant, 1969; slide no. BSIP 8561; co-ordinates: 110.5 × 12.2.
14. *Systematophora penicillata* (Ehrenberg) Sarjeant, 1980; slide no. BSIP 8557; co-ordinates: 92.0 × 14.9.



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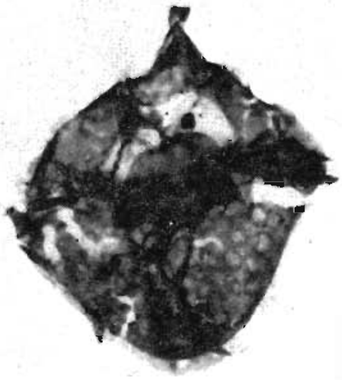

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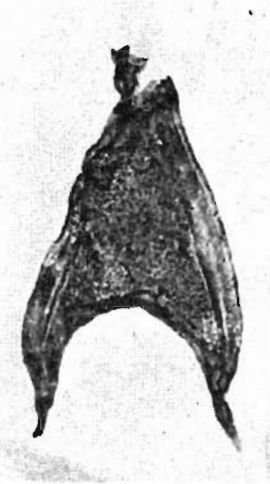

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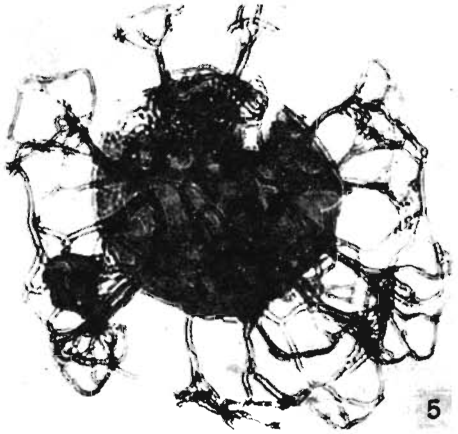

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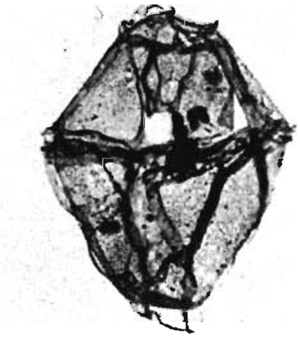

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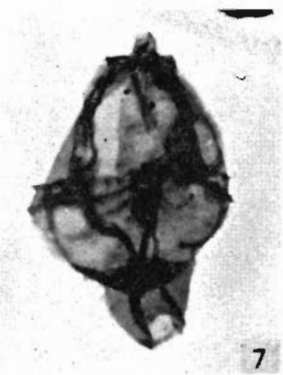

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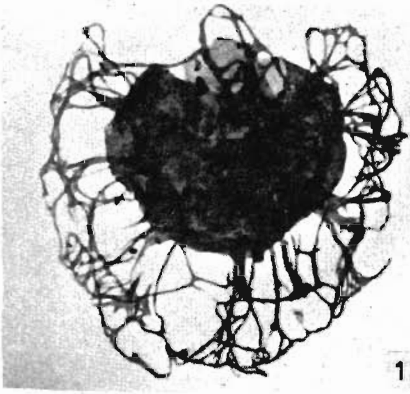

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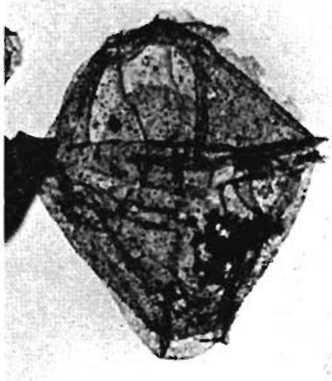

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PLATE 1


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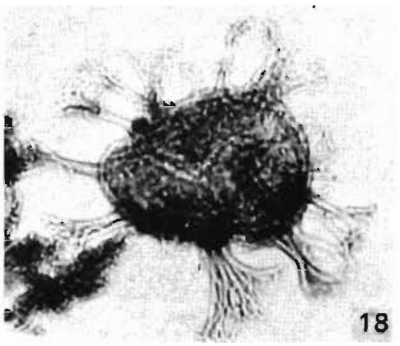
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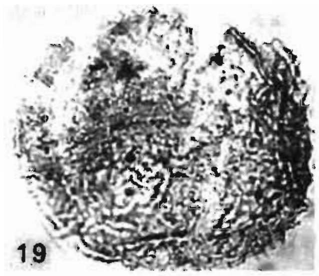
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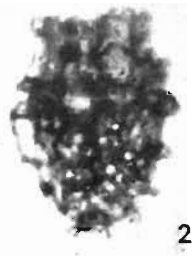
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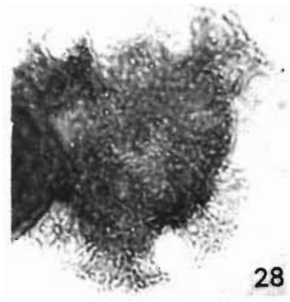
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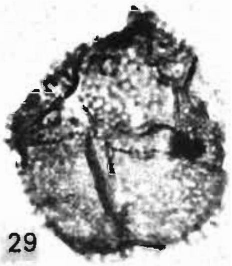
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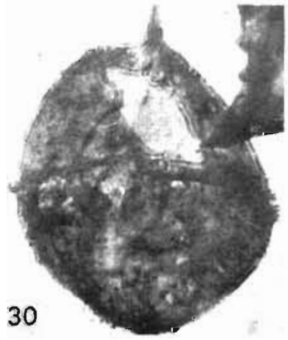
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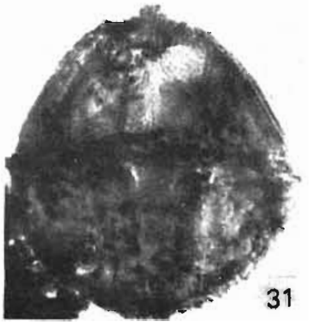
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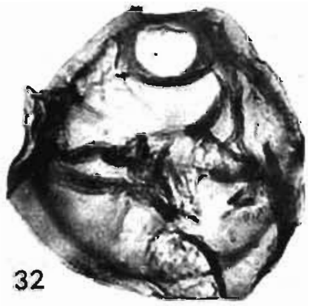
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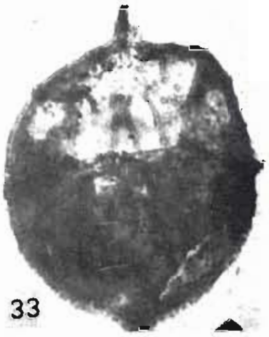
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PLATE 2

Pl. 3, fig. 34

1968 *Hystrichosphaeridium aemulum* Deflandre: Venkatachala & Kar; *Curr. Sci.* **37** : p. 409, fig. 3; Kutch Basin, Jhuran Formation (Upper Jurassic).

1974 *Cannosphaeropsis aemulum* (Deflandre) Deflandre, 1947: Jain, *Aspects & Appraisal of Indian Palaeobotany*, p. 591, table 1.

Dimensions :

Overall size of cyst including processes	—90-130 × 86-120 µm
Diameter of cyst without processes	—40-66 µm
Process length	— up to 35 µm

Adnatosphaeridium paucispinum (Klement) Gitmez & Sarjeant, 1972

Pl. 1, fig. 5

Dimensions :

Spherical body diameter	— up to 60 µm
Overall body size	— 38-50 × 50-62 µm
Process length	— 20-40 µm

Adnatosphaeridium filamentosum (Cookson & Eisenack) Williams & Downie, 1969

Pl. 1, fig. 12

Dimensions :

Spherical body diameter	— 55-65 µm
Process height	— up to 45 µm

Family—Systematophoraceae Sarjeant & Downie, 1974

Genus—*Systematophora* Klement, 1960

Systematophora penicillata (Ehrenberg) Sarjeant, 1980

Pl. 1, fig. 14; Pl. 2, fig. 18

Dimensions :

Overall cyst size including process	— 80 × 80 µm
Cyst size without processes	— 44 × 44 µm
Process complex	— up to 20 µm long

Systematophora orbifera Klement, 1960

Pl. 2, fig. 28; Pl. 3, fig. 53

Dimensions :

Overall cyst size including process	— 120 × 90 µm
Cyst size without processes	— 80 × 60 µm

Genus—*Prolixosphaeridium* Davey *et al.*, 1966

Prolixosphaeridium anasillum Erkmen & Sarjeant, 1980

Pl. 1, fig. 10; Pl. 3, fig. 45

Dimensions :

Cyst size	— 32-48 × 22-28 µm
Process length	— 10-14 µm

Remarks—The Kutch specimens resemble best the Lamberti Zone specimens in shape, size and process distribution (Sarjeant, 1961, 1976). The known stratigraphical range of *Prolixosphaeridium anasillum* is from Upper Callovian to Upper Kimmeridgian (Erkmen & Sarjeant, 1980, p. 65).

Family—Endoscriniaceae Vozzhennikova, 1965 emend. Sarjeant & Downie, 1974

Genus—*Scriniodinium* Klement, 1957

Scriniodinium luridum (Deflandre) Klement, 1960

Pl. 1, fig. 1; Pl. 3, fig. 37

←

PLATE 2

(All photomicrographs × 500)

15, 22. *Gonyaulacysta jurassica* subsp. *jurassica* Deflandre emend. Sarjeant, 1982; slide no. 8557; co-ordinates: 104.7 × 10.0 and 108.6 × 15.0 respectively.

16. *Egmontodinium polyplacophorum* Gitmez & Sarjeant, 1972; slide no. BSIP 8562; co-ordinates: 99.0 × 20.4

17. *Ellipsoidictyum cinctum* Klement, 1960; slide no. BSIP 8559; co-ordinates: 116.6 × 13.7.

18. *Systematophora penicillata* (Ehrenberg) Sarjeant, 1980; slide no. BSIP 8556; co-ordinates: 92.0 × 22.0.

19, 23. *Escharisphaeridia pocockii* (Sarjeant) Erkmen & Sarjeant, 1980; slide no. BSIP 8559; co-ordinates: 96.4 × 8.0.

20. *Form A*; slide no. BSIP 8559; co-ordinates: 108.5 × 4.0.

21. *Occisucysta* sp.; slide no. BSIP 8559; co-ordinates: 178.5 × 13.7.

24. *Ellipsoidictyum cinctum* Klement, 1960; slide no. BSIP 8569; co-ordinates: 125.0 × 8.0

25, 30. *Gonyaulacysta ehrenbergii* Gitmez, 1969; slide no. 8560; co-ordinates: 122.0 × 17.0 and 128.0 × 15.0.

26, 27. *Gonyaulacysta* sp. cf. *G. perforans* (Cookson & Eisenack) Sarjeant, 1969; slide no. BSIP 8565; co-ordinates: 126.3 × 12.7 and 95.0 × 15.2 respectively.

28. *Systematophora orbifera* Klement, 1960; slide no. BSIP 8558; co-ordinates: 106.6 × 14.9.

29. *Scriniodinium dictyotum* subsp. *papillatum* Gitmez, 1970; slide no. BSIP 8563; coordinates: 118.4 × 14.6.

31. *Apteodinium granulatum* Eisenack, 1958; slide no. BSIP 8559; co-ordinates: 108.1 × 4.3.

32. *Nummus similis* (Cookson & Eisenack) comb. nov.; slide no. BSIP 8557; co-ordinates: 103.4 × 15.7.

33. *Apteodinium* sp. B; slide no. BSIP 8565; co-ordinates: 108.8 × 21.4.

1970 *Endoscrinium luridum* (Deflandre) Vozzhennikova, 1967; Gitmez, *Bull. Br. Mus. nat. Hist. (Geol)* **18**(7) : 302-303, pl. 2; text-fig. 28.

Dimensions :

Overall size — 80-90 × 80-100 μm
Endoblast size — 58-70 × 56-74 μm

Remarks—The Kutch forms show marked resemblance to the figured specimens of *Scriniodinium luridum* from France (Deflandre, 1938, pl. 5, figs 4, 6), Germany (Klement, 1960, pl. 1, figs 2, 3) and Australia (Cookson & Eisenack, 1960, pl. 37, fig. 10). Status of the genus *Endoscrinium* as enumerated by Stover and Evitt (1975, p. 187) is maintained here, rejecting the view of Lentin and Williams (1981, p. 97).

Scriniodinium dictyotum subsp. *papillatum* Gitmez, 1970
Pl. 2, fig. 29; Pl. 3, figs 40, 47

Dimensions :

Overall cyst size — 65-70 × 50-60 μm

Family—Broomeaceae Eisenack, 1969 emend. Sarjeant & Downie, 1974

Genus—*Broomea* Cookson & Eisenack, 1958 emend. Lentin & Williams, 1976

Broomea ramosa Cookson & Eisenack, 1958
Pl. 3, figs 41, 49

Dimensions :

Overall cyst length — 124 μm
Overall cyst breadth — 32 μm
Body size of cyst — 90 × 32 μm
Length of apical horn — 24 μm
Length of antapical appendages — up to 10 μm

Family—Membranilanaciaceae Eisenack, 1963 emend. Sarjeant & Downie, 1966

Genus—*Chlamydophorella* Cookson & Eisenack, 1958

Chlamydophorella wallala Cookson & Eisenack, 1960
Pl. 3, fig. 48

Dimensions :

Overall cyst size (without operculum) — 76 × 66 μm
Process length — 6-10 μm

Family—Pareodiniaceae Gocht, 1957 emend. Sarjeant & Downie, 1974

Genus—*Pareodinia* Deflandre emend. Wiggins emend. Stover & Evitt, 1978

Pareodinia ceratophora Deflandre emend. Gocht, 1970
Pl. 3, fig. 35

Dimensions :

Overall cyst size — 70 × 40 μm
Length of apical horn — 8-12 μm

Family—Hystrichosphaeridiaceae Evitt, 1963 emend. Sarjeant & Downie, 1974

Genus—*Tanyosphaeridium* Davey & Williams, 1966

Tanyosphaeridium torynum (Cookson & Eisenack) Stover & Evitt, 1978
Pl. 3, fig. 36

PLATE 3

(All photomicrographs × 500)

34. *Adnatosphaeridium aemulum* (Deflandre) Williams & Downie, 1969; slide no. BSIP 8572; co-ordinates: 129.2 × 18.2.
35. *Pareodinia ceratophora* Deflandre emend. Gocht, 1970; slide no. BSIP 8570; co-ordinates: 103.3 × 16.0.
36. *Tanyosphaeridium torynum* (Cookson & Eisenack) Stover & Evitt, 1978; slide no. BSIP 8565; co-ordinates: 93.8 × 5.0.
37. *Scriniodinium luridum* (Deflandre) Klement, 1960; slide no. BSIP 8570; co-ordinates: 104.4 × 9.0.
38. *Ctenidodinium culmulum* (Norris) Lentin & Williams, 1973; slide no. BSIP 8569; co-ordinates: 125.4 × 16.0.
39. *Spiniferites* sp.; slide no. BSIP 8569; co-ordinates: 106.7 × 7.4.

40, 47. *Scriniodinium dictyotum* subsp. *papillatum* Gitmez, 1970; slide no. BSIP 8563; co-ordinates; 107.8 × 19.0 and 134.4 × 15.8 respectively.

41, 49. *Broomea ramosa* Cookson & Eisenack, 1958; slide no. BSIP 8566 & 8562; co-ordinates: 135.0 × 17.6 and 96.6 × 10.0 respectively.

42. *Egmontodinium polyplacophorum* Gitmez & Sarjeant, 1972; slide no. BSIP 8562; co-ordinates: 99.4 × 11.9.
43. *Oligosphaeridium* sp., slide no. BSIP 8566; co-ordinates: 93.7 × 8.2.
44. *Gonyaulacysta jurassica* subsp. *jurassica* Deflandre emend. Sarjeant, 1982; slide no. BSIP 8556; co-ordinates: 105.0 × 15.8.
45. *Prolixosphaeridium anasillum* Erkmen & Sarjeant, 1980; slide no. 8565; co-ordinates: 107.5 × 14.8.
46. cf. *Gonyaulacysta* sp.; slide no. BSIP 8569; co-ordinates: 103.6 × 11.5.
48. *Chlamydophorella wallala* Cookson & Eisenack, 1960; slide no. BSIP 8568; co-ordinates: 131.7 × 6.9.
50. *Sentusidinium echinatum* (Gitmez & Sarjeant) Sarjeant & Stover, 1978; slide no. BSIP 8571; co-ordinates: 116.3 × 18.8.

51, 52. *Surculosphaeridium vestitum* (Deflandre) Davey *et al*, 1966; slide no. BSIP 8557; co-ordinates: 105.6 × 8.4 & 103.6 × 8.0 respectively.

53. *Systematophora orbifera* Klement, 1960; slide no. BSIP 8558; co-ordinates: 136.7 × 15.8.

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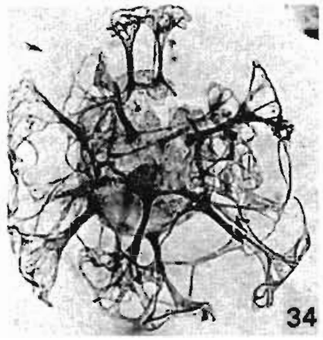
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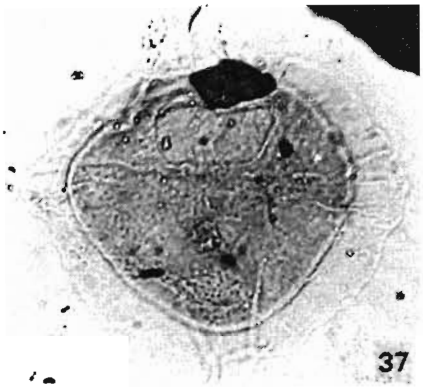
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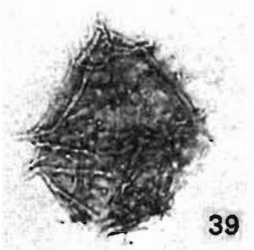
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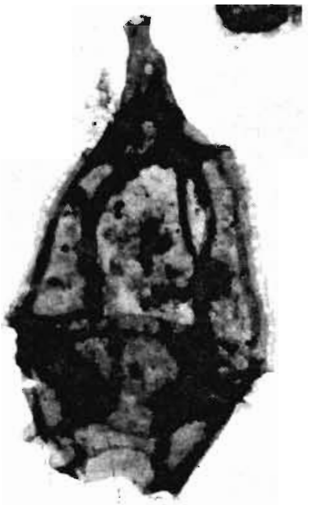
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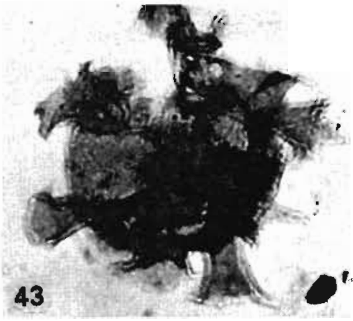
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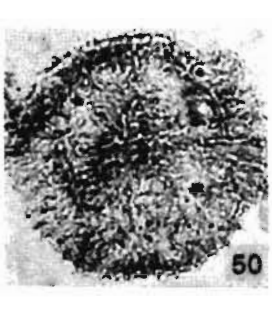
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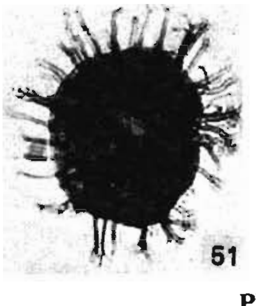
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PLATE 3

Remarks—The transfer of *T. torynum* to *Eomontodinium* by Davey (1979, p. 60) is not acceptable due to lack of reticulation on the cyst surface of the holotype.

Genus—*Surculosphaeridium* Davey *et al.*, 1966

Surculosphaeridium vestitum (Deflandre) Davey *et al.*, 1966
Pl. 3, figs. 51, 52

Dimensions :

Size of cyst — 70 × 65 µm
Length of process —up to 16 µm

Remarks—*Surculosphaeridium vestitum* is common in the Oxfordian beds of Calvados, France (Deflandre, 1978). In Kutch Basin this species is frequent in the shale samples of Rudra Mata Temple (Jhuran Formation).

Genus—*Oligosphaeridium* Davey & Williams, 1966

Oligosphaeridium sp.
Pl. 1, fig. 3; pl. 3, fig. 43

Description—Body spherical, endophragm and periphragm thin, appressed; periphragm punctate; processes formed by periphragm alone, 14 in number with detached operculum. Process formula 4′, 6″, 6‴, 1p, 1″″. Processes broad at base but distally variable in size, bearing aculeate spines which vary in length and breadth, sometimes short and broad.

Dimensions :

Diameter of cyst — 45 to 60 µm
Size of processes — 10 × 14 to 16 × 24 µm

Remarks—Present forms differ from the known species in process size variation and punctate periphragm.

Family—Ctenidodiniaceae Sarjeant & Downie emend. Sarjeant & Downie, 1974

Genus—*Ctenidodinium* Deflandre emend. Gocht, 1970

Ctenidodinium culmulum (Norris) Lentin & Williams, 1973
Pl. 3, fig. 38

Dimensions :

Overall cyst diameter — 20-30 µm

Order—Nannoceratopsiales Piel & Evitt, 1980

Family—Nannoceratopsitaceae Deflandre emend. Piel & Evitt, 1980

Nannoceratopsis pellucida Deflandre emend. Evitt, 1961
Pl. 1, fig. 4

Dimensions :

Overall cyst size — 100 × 42 µm

ACRITARCHS

Genus—*Verybachium* Deunff emend. Downie & Sarjeant, 1963

Verybachium valensii (Valensi) Downie & Sarjeant, 1963
Pl. 1, fig. 11

Dimensions :

Cyst size — 25 × 25 µm
Length of spine — up to 25 µm

Genus—*Nummus* Morhan, 1968

Nummus similis (Cookson & Eisenack) comb. nov.
Pl. 1, fig. 8; Pl. 2, fig. 32

1960 *Leiosphaeridia similis* Cookson & Eisenack, *Palaeontology*, **2** : 254, pl. 38, fig. 14.

Dimensions :

Diameter of shell — 80 × 80 µm
Diameter of pylome — 14 µm

DISCUSSION AND COMPARISON

The three dinocyst assemblages, which have been identified, represent Lower, Middle and Upper members respectively of the Jhuran Formation. The distribution of different species of dinocysts in various samples and their geological ranges have been plotted in Table 1.

In overall aspect the Kutch dinocyst assemblages show a distinct similarity with Upper Jurassic dinoflagellate cyst assemblage described from southern Germany by Klement (1969), specially in the common occurrence of the genera *Adnatosphaeridium*, *Scriniodinium*, *Systematophora*, *Gonyaulacysta* and *Ellipsoidictyum*.

A comparison with Upper Oxfordian-Lower Kimmeridgian dinocyst assemblage described by Cookson and Eisenack (1958, 1960) from western Australia also shows a close resemblance. The common elements of the two assemblages are, viz., *Leptodinium eumorphum*, *Scriniodinium dictyotum*, *Scriniodinium luridum*, *Tubotuberella apatela*, *Tanyosphaeridium torynum*, *Nummus similis*, *Chlamydophorella wallala*, *Gonyaulacysta jurassica*, *Broomea ramosa*, *Adnatosphaeridium aemulum* and *Nannoceratopsis pellucida*.

Wiseman (1980) distinguished seven palynological assemblage zones in the Upper Jurassic and Early Cretaceous in the Carnarvon Basin, western Australia. The

TABLE 1—DISTRIBUTION OF DINOFLAGELLATE CYST AND ACRITARCH TAXA IN THE JHURAN FORMATION, KUTCH

LITHOSTRATIGRAPHIC UNITS		JHURAN FORMATION					Geologic ranges of Dinocyst and Acritarch taxa (Sarjeant, 1979; Sarjeant & Gitmez, 1972)
		Lower	Middle Member			Upper	
Sl. No.	Dinocyst and Acritarch Taxa / Locality Name & Number	Jhuran River (2401)	Jhuran River Section (2401)	Sukhpur Nala Section (2405)	Rudra-Mata Temple Section (2205)	Ugedi well (2086)	
1.	*Pareodinia ceratophora*	C		C			Pre-Bajocian-Cretaceous
2.	*Ellipsoidictyum cinctum*	R		R			Callovian-Kimmeridgian
3.	*Occisucysta* sp.	R		R			
4.	*Apteodinium granulatum*	R			C		Probably Upper Oxfordian to Portandian
5.	*Escharisphaeridia pocockii*	R					Bathonian onwards
6.	*Sentusidinium echinatum*	R	C				Kimmeridgian
7.	*Gonyaulacysta ehrenbergii*	R	R	C			Kimmeridgian (*P. baylei* to *P. rotunda* Zone)
8.	*Scriniodinium luridum*	C	R	C	C		Oxfordian-Kimmeridgian
9.	*Leptodinium eumorphum*	C	R	C	C		Oxfordian-Kimmeridgian
10.	*Egmontodinium polyplacophorum*	C	R	R			Kimmeridgian (Basal)
11.	*Veryhachium valensii*	R		A			Oxfordian-Kimmeridgian
12.	*Nannoceratopsis pellucida*	A	R	R			Bathonian-Kimmeridgian (*P. baylei* Zone)
13.	*Adnatosphaeridium aemulum*	R		A	A		Callovian-Kimmeridgian (*P. baylei* Zone)
14.	*Gonyaulacysta jurassica jurassica*	R		A	A	C	Callovian-Kimmeridgian (*P. pectinatus*
15.	*Scriniodinium dictyotum papillatum*	R				R	Oxfordian-Kimmeridgian
16.	*Nummus similis*			C			Upper Jurassic (Cookson & Eisenack, 1960)
17.	*Surculosphaeridium vestitum*			C	C		Callovian-Oxfordian
18.	*Adnatosphaeridium filamentosum*			C			Callovian-Oxfordian
19.	*Adnatosphaeridium paucispinum*			C			Callovian-Oxfordian
20.	*Gonyaulacysta* sp. cf. *G. perforans*			R		R	?Kimmeridgian-Portlandian
21.	*Systematophora orbifera*			C	C	C	Kimmeridgian (*P. wheatleyensis* Zone to Portlandian)
22.	*Systematophora penicillata*					C	Oxfordian-Early Kimmeridgian
23.	*Oligosphaeridium* sp.					C	
							Kimmeridgian (*P. wheatleyensis* Zone to *T. giganteus* Zone)
24.	*Tanyosphaeridium torynum*					C	
25.	*Prolixosphaeridium anasillum*					C	Basal Kimmeridgian
26.	*Chlamydophorella wallala*					C	Kimmeridgian
27.	*Ctenidodinium culmulum*					C	Kimmeridgian-Portlandian
28.	*Spiniferites* sp.					R	
29.	*Tubotuberella apatela*					C	Oxfordian-Middle Kimmeridgian
30.	*Apteodinium* sp.					R	
31.	*Broomea ramosa*					C	Kimmeridgian (*P. wheatleyensis* Zone to Upper Portlandian & later)

R = Rare; C = Common; A = Abundant

Assemblage Zones I and II of Wiseman (1980) need special reference here. Assemblage Zone I is characterised by the occurrence of the following dinocyst elements : *Nannoceratopsis pellucida, Scriniodinium (Endoscrinium) luridum, Ellipsoidictyum cinctum, Psaligonyaulax apatela, Adnatosphaeridium filamentosum, Gonyaulacysta ambigua, Pyxidiella pandora, Pareodinia ramosa, Adnatosphaeridium aemulum, Gonyaulacysta jurassica.* All of these species are long ranging, occurring in sediments older than Assemblage Zone I and extending into Assemblage Zone II. Apart from these, the Assemblage Zone II consists of some other taxa, e.g. *Omatia butticula* in its upper part. It also includes *Systematophora penicillata (S. fasciculigera), Tanyosphaeridium (Prolixosphaeridium) torynum, Peridictyocysta mirabilis, Bourkidinium* sp. cf. *B. granulosum, Heslertonia teichophora* and *Tenua atlantica.*

The age derivation for Assemblage Zone I as Early Oxfordian or older is tentative (Wiseman, 1980, p. 342). The Assemblage Zone II has been dated to range from Late Oxfordian to Tithonian.

The occurrence of *Omatia montgomeryii* and *O. (Herendeenia) pisciformis* in the upper part of Assemblage Zone II compares well with the recent finds from Upper Jurassic of Tethys Himalayas (Jain *et al*, 1984), where the microplankton Assemblage Zone containing *Omatia* spp. is placed in lower part of Upper

Tithonian. *Omatia* is totally absent in all the three assemblages recovered from the Jhuran Formation.

The Ugedi dinocyst assemblage representing the Upper Member of Jhuran Formation is devoid of *Omatia* but includes *Tanyosphaeridium torynum, Oligosphaeridium* sp. and *Broomea ramosa* which indicate a Kimmeridgian aspect whereas two older dinocyst assemblages representing the Lower and Middle members of the Jhuran Formation on the basis of overall aspect of dinocyst element (Table 1) suggest an Upper Oxfordian-Lower Kimmeridgian age.

With this dinocyst data in hand from Jhuran Formation, it is concluded that the age of the Jhuran Formation ranges from Upper Oxfordian to Kimmeridgian probably extending up to *Pectinatites pectinatus* zone.

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Palynological studies of Coal Measures in South Rewa Gondwana Basin and their biostratigraphical significance

Anil Chandra & A. K. Srivastava

ABSTRACT

Chandra, A. & Srivastava, A. K. (1986). Miofloral studies of Coal Measures in South Rewa Gondwana Basin and their biostratigraphical significance. *Palaeobotanist*, **35**(1) : 85-92.

Palynological assemblages from Coal Measures (Lower Permian) of four areas, namely Umaria, Birsinghpur Pali, Anuppur and Chirimiri of South Rewa Gondwana Basin, Madhya Pradesh are described. A brief description of the stratigraphy and geology of the relevant sections is given. Available information on some other significant Coal Measures (Barakars) has been taken into consideration for bringing out their palynological characteristics with reference to stratigraphy. Qualitative and quantitative distribution of palynotaxa in various areas reveal that the miofloral assemblages reported here are closer to the Karharbari mioflora. A rich palynofloral assemblage is reported for the first time from Coal Measures of Anuppur.

Key-words—Palynology, Mioflora, Coal Measures, South Rewa Gondwana Basin, Lower Permian (India).

Anil Chandra & A. K. Srivastava, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

सारॉंश

दक्षिण रीवा गोंडवाना द्रोणी के कोयला-मेज़र्स से उपलब्ध सूक्ष्मवनस्पतिजात का अध्ययन तथा इसका जैवस्तरिकीय महत्व

अनिल चन्द्रा एवं अश्विनी कुमार श्रीवास्तव

मध्य प्रदेश में दक्षिण रीवा गोंडवाना द्रोणी के उमरिया, बीरसिंहपुरपाली, अनूपपुर एवं चिरीमिरी नामक चार क्षेत्रों के कोयला-मेज़र्स से उपलब्ध परागाणविक समुच्चय का वर्णन किया गया है। सम्बद्ध अनुखंडों का स्तरिकीय एवं भूवैज्ञानिक अध्ययन संक्षिप्त रूप में दिया गया है। कुछ अन्य विशिष्ट कोयला-मेज़र्स (बराकार) के सूक्ष्मवनस्पतिजातों से सम्बन्धित उपलब्ध जानकारी का उपयोग स्तरविन्यास के सन्दर्भ सहित उनकी परागाणविक विशेषताओं को प्रकाश में लाने के लिए किया गया है। विभिन्न क्षेत्रों में परागाणविक वर्गकों के परिमाणात्मक एवं गुणात्मक वितरण से यह व्यक्त होता है कि सूक्ष्मवनस्पतिजातीय समुच्चय करहरबारी वनस्पतिजात के काफी अनुरूप है। अनूपपुर के कोयला-मेज़र्स से पहली बार एक प्रभावी सूक्ष्मवनस्पतिजातीय समुच्चय का भी उल्लेख किया गया है।

INTRODUCTION

ANY stratigraphical, palaeobotanical or palynological study of the Lower Gondwana Formations of India appears to be incomplete without the consideration of rock formations exposed in South Rewa Gondwana Basin in Madhya Pradesh. The huge outcrops of Talchir and Barakar Formation (Lower Permian) are exposed from one end to the other in this basin. The eurydesmids at the base of the Talchir in Manendragarh and the productids at the top of Talchir Formation in Umaria add further geological importance to this basin.

Feistmantel (1879, 1882) considered the coal beds of South Rewa Gondwana Basin (now described as Son Valley Basin) as equivalent to Karharbari 'Stage' on the basis of the floral comparison. Fermor (1914) reported *Glossopteris*, *Vertebraria* and *Schizoneura* from Barakar of Kurasia Coalfield. Biswas (1955) suggested Karharbari correlation of at least a part of Chirimiri Coal Measures on the basis of Fermor's collection. Datta (1957) observed that the Barakar flora in Jhagrakhund area is comparable to the lower section of the Lower Gondwana flora. Plant fossils from Coal Measures of Chirimiri were described by Ganguly (1959). Lele and Maithy (1964) described two new species of *Noeggerathiopsis* from the Karharbari beds of Ganjra Nala, Birsinghpur Pali. Pant and Varma (1964) recognised three species of *Noeggerathiopsis* from the Lower Gondwana sequence of Manendragarh. Maithy (1966) considered the coal bearing beds at Umaria as equivalent to the Karharbari beds of Giridih. Maithy (1968) reported two new fossil plants from the Karharbari beds of Ganjra nala, Birsinghpur Pali Coalfield. Recently, Chandra and Srivastava (1982) have suggested that Coal Measures (so-called Barakar) of Umaria, Birsinghpur Pali, Anuppur and Chirimiri are equivalent to Karharbari Formation of the Peninsular India on the basis of plant fossils

Because of the controversy about stratigraphical position of the karharbari Formation, South Rewa Gondwana Basin was selected for palaeobotanical and stratigraphical studies. The well-developed nature of Talchir sediments was an equally important factor favouring the selection of this basin. Consequently, detailed field excursions to study the Lower Gondwana formations were undertaken in Umaria, Birsinghpur Pali, Anuppur, Manendragarh and Chirimiri areas of this basin. The results of the microfossil studies including acritarchs and megaspores from the Talchir Formation (Lele & Chandra, 1967, 1969, 1972, 1973, 1974; Chandra & Lele, 1979), megafossil studies from Talchir and Coal Measures (Chandra & Srivastava, 1982; Srivastava & Chandra, 1982) and a new species of *Arberia* from the Coal Measures (Chandra & Srivastava, 1981) have been already published.

The remaining portion, i.e. the microfossil study of the Coal Measures of selected areas of this basin is presented in this paper. Some well preserved and fairly rich palynofloras from Coal Measures of the four areas, viz., Umaria, Birsinghpur Pali, Anuppur and Chirimiri (Text-figs 1-4) have been described here. These assemblages have been compared with the equivalent palynofloral assemblages. Palynological work in some of the areas of this basin has also been carried out by Saksena (1969), Bharadwaj & Srivastava (1969), Srivastava (1980) and Srivastava and Anand Prakash (1984).

GEOLOGY

South Rewa Gondwana Basin (included in Son Basin) forms a small part of the great central basin of the Gondwana rocks, occupying a large part of the Central India. According to Hughes (1884) the general geological succession of this basin is as follows :

Surface deposits
Deccan Traps and Lametas
Gondwana System:
    Supra Barakar
    Barakars with Karharbaris
    Talchirs

The geology of Umaria, Birsinghpur Pali, Anuppur and Chirimiri alongwith various traverses undertaken in the field has earlier been described by Chandra and Lele (1979) and Chandra and Srivastava (1982). We are, therefore, giving only those sections (Coal Measures) from where miospores have been recovered.

UMARIA

Under the Umaria Railway Station—Kirintal-Umaria traverse rock samples belonging to Coal Measures were collected from the following two sections (about 2.4 km south east of the Umaria Railway Station) :

1. Section below and north of the railway bridge

Lithology	*Thickness in m*	*Field nos.*
Coal	1.22	KU 5
Greyish sandstone	5.49	KU 6
Carbonaceous shale (rich in miospores)	3.05	KU 7

2. Section beneath and slightly south of the railway bridge

Lithology	*Thickness in m*	*Field nos.*
Whitish greyish sandstone	9.15	RB 1
Coal	1.24	RB 2
Carbonaceous shale	2.48	RB 3
Shaly sandstone	2.17	RB 4
Coarse whitish sandstone	1.55	RB 5

BIRSINGHPUR PALI

1. Along the Patpara-Marjada Nala traverse, in a section about 3.2 km east of the village Khodargaon (after crossing the road bridge) the succession is as follows :

Lithology	*Thickness in m*	*Field nos.*
Massive yellowish sandstone	3.05	K 7
Carbonaceous shaly sandstone	1.22	K 6
Yellowish sandstone	0.61	K 5
Carbonaceous shaly sandstone (rich in miospores)	0.31	K 4
Carbonaceous shale	0.31	K 3
Coal	1.22	K 2

These beds dip gently (4-8°) due north.

2. Under the Ganjra Nala-Johilla River traverse, miospores have been recovered in the following sections :

(i) Section about 0.27 km east of the Ganjra Nala-Johilla River confluence along the Ganjra nala.

Lithology	*Thickness in m*	*Field nos.*
Sandstone	—	GN 3
Carbonaceous shale (rich in miospores)	1.83	GN 2
Grey micaceous sandstone	1.53	GN 1F
Carbonaceous shale	2.14	GN 1
Coal	—	

(ii) Section exposed near the Ganjra Nala-Johilla River confluence

Lithology	*Thickness in m*	*Field nos.*
Carbonaceous shale and sandstone intercalations (rich in miospores)	—	GN 10
Carbonaceous shale (containing miospores)	2.76	GN 9

ANUPPUR

Under the Bakan Nala railway bridge-Son River traverse, the succession of different beds exposed about 0.8 km south west of the Bakan nala-Son River confluence is as follows :

Lithology	*Thickness in m*	*Field nos.*
Coarse sandstone	6.10	BN 27
Carbonaceous shale	0.31	BN 26
Coal	0.31	BN 25
Carbonaceous shale (rich in miospores)	0.31	BN 24
Coal	0.93	
Carbonaceous shale	0.31	BN 23
Whitish-bluish sandstone	4.22	BN 21

CHIRIMIRI

Under Chirimiri-Paradol railway cutting traverse samples from following two sections have yielded miospores.

1. Section exposed about 0.8 km north-west of the Chirimiri Railway Station along Chirimiri-Paradol railway line :

Lithology	*Thickness in m*	*Field nos.*
Yellowish-white coarse sandstone (current bedded)	9.15	CP_7
Coal	0.15	CP_6
Carbonaceous shale and sandstone intercalations	3.65	CP_5
Carbonaceous shale	0.92	CP_4
Sandstone	3.05	CP_3
Carbonaceous shale (rich in miospores)	0.25	CP_2
Fine grained sandstone	9.15	CP_1

The beds dip 10° due north.

2. Section exposed about 8 km north-west of Chirimiri Railway Station along the northern side of railway line.

Lithology	*Thickness in m*	*Field nos.*
Massive greyish white sandstone	15.25	CP_{24}
Coal, sandstone and shale	0.31	CP_{23}
Sandstone (poor in miospores)	0.15	CP_{22}
Sandstone shale intercalation (poor in miospores)	0.31	CP_{21}
Bluish sandstone (poor in miospore)	0.31	CP_{20}
Carbonaceous shale (poor in miospores)	0.15	CP_{19}
Bluish sandstone (rich in miospores)	0.15	CP_{18}

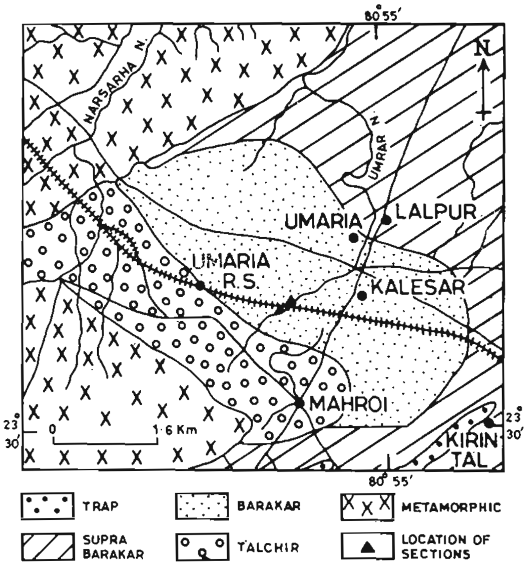
PALYNOFLORAL CHARACTERISTICS OF INDIVIDUAL AREA

UMARIA

Following two palynological assemblages have been recovered from Coal Measures of Umaria.

Assemblage A—It has been recovered from the carbonaceous shales (Field no. KU 7) under the Umaria Railway Station—Kirintal-Umaria traverse in which *Plicatipollenites* Lele (22.5%), *Parasaccites* Bharadwaj & Tiwari (18.5%), *Callumispora* Bharadwaj & Srivastava (14.5%) and *Caheniasaccites* Bose & Kar (12.5%) are the dominant genera. Next in frequency order are *Stellapollenites* Lele (7.5%), *Crucisaccites* Lele & Maithy (7.5%), *Potonieisporites* Bharadwaj emend. Bharadwaj (5%), *Faunipollenites* Bharadwaj (5%), *Strotersporites* Wilson emend. Klaus (5%) and *Tiwariasporis* Maheshwari & Kar (2%). Monosaccates form the dominant group constituting 73.5 per cent of the total assemblage.

Assemblage B—This has been recovered from the carbonaceous shale bed (Field no. RB 3) of section no. 3



Text-figure 1—Geological map of Umaria, Madhya Pradesh (after Hughes, 1884).

under Umaria R. S.—Kirintal-Umaria traverse. It is dominated by the genera *Parasaccites* Bharadwaj &. Tiwari (28%), *Jayantisporites* Lele & Makada (22.5%) and *Plicatipollenites* Lele (12.5%). The other quantitatively important genera are *Callumispora* Bharadwaj & Srivastava (7.0%), *Potonieisporites* Bharadwaj emend. Bharadwaj (5%) and *Indotriradites* Tiwari (5%). And next in frequency are *Latosporites* Potonié & Kremp (2.5%), *Pachysaccus* Lele & Maithy (2.5%), *Caheniasaccites* Bose & Kar (2.5%), *Limitisporites* Leschik emend. Potonie (2.5%), *Scheuringipollenites* Tiwari (2.5%) and *Faunipollenites* Bharadwaj (4.5%).

Obviously, in this assemblage the monosaccate genera form the dominant elements (50.5%). The trilete forms are significantly high contributing to 34.5 per cent of the assemblage.

Both the palynological assemblages A and B from Umaria show the dominance of the radial monosaccate and trilete forms.

BIRSINGHPUR PALI

Three palynological assemblages have been obtained from the Coal Measures of Birsinghpur Pali.

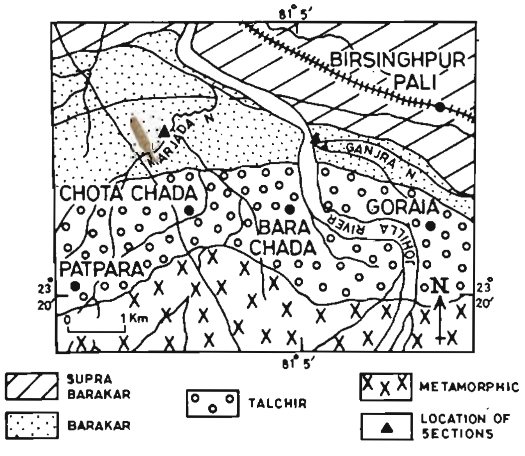
Assemblage A—It has been recovered from the carbonaceous shaly sandstone (Field no. K4) of a section exposed about 3.2 km east of the village Khodargaon under Patpara-Marjada Nala traverse. *Parasaccites* Bharadwaj & Tiwari (38.5%), *Caheniasaccites* Bose & Kar (12.5%) and *Pachysaccus* Lele & Maithy (10%) are the dominant forms. These are followed by *Callumispora* Bharadwaj & Srivastava (16.5%), *Plicatipollenites* Lele (7.5%), *Crucisaccites* Lele & Maithy (5%), *Stellapollenites* Lele (7.5%), *Scheuringipollenites* Tiwari (2.5%) and *Faunipollenites* Bharadwaj (2.5%) and *Strotersporites* Wilson emend. Klaus (2.5%). This assemblage is also characterized by the dominance of monosaccate group constituting 76 per cent of the total assemblage.

Assemblage B—This has been recovered from the carbonaceous shale bed (Field no. GN 2) of a section exposed about 0.27 km east of the Ganjra Nala-Johilla confluence along Ganjra Nala. The significant elements are *Plicatipollenites*, Lele (29%), *Parasaccites* Bharadwaj & Tiwari (28%) and *Potonieisporites* Bharadwaj emend. Bharadwaj (11.0%) which are followed by *Striatites* Pant emend. Bharadwaj (8%), *Caheniasaccites* Bose & Kar (6%), *Limitisporites* Leschik emend. Potonié (5%), *Pachysaccus* Lele & Maithy (5%), *Lahirites* Bharadwaj (2%), *Scheuringipollenites* Tiwari (2%), *Converrucosisporites* Potonié & Kremp (1%), *Jayantisporites* Lele & Makada (1%), *Vesicaspora* Schemel emend. Venkatachala & Wilson (1%), *Gondwanopollis* Lele & Maithy (0.5%) and *Crucisaccites* Lele & Maithy (0.5%). The monosaccate group forms the characteristic element of the assemblage.

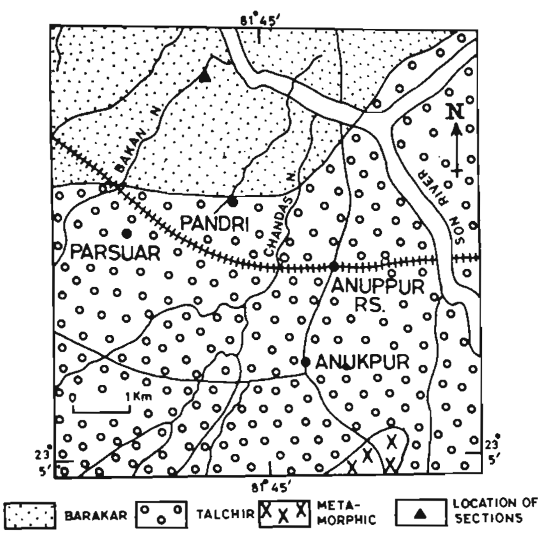
Assemblage C—This assemblage has been found in a bed of carbonaceous shale and sandstone intercalation (Field no. GN 10) exposed near the Ganjra nala-Johilla River confluence. *Parasaccites* Bharadwaj & Tiwari (28%), *Pachysaccus* Lele & Maithy (22.5%) and *Caheniasaccites* Bose & Kar (8.5%) are the significant elements followed by *Callumispora* Bharadwaj & Srivastava (13.5%), *Crucisaccites* Lele & Maithy (5%), *Striatites* Pant emend. Bharadwaj (5%), *Plicatipollenites* Lele (5%), *Stellapollenites* Lele (5%), *Faunipollenites* Bharadwaj (2.5%), *Scheuringipollenites* Tiwari (2%), *Latosporites* Potonié & Kremp (1.5%) and *Jayantisporites* Lele & Makada (1.5%). The assemblage is dominated by the monosaccate grains which contribute 74 per cent of the total assemblage.

ANUPPUR

Assemblage A—It has been recovered from the carbonaceous shale bed (Field no. BN24) exposed about



Text-figure 2—Geological map of Birsinghpur Pali, Madhya Pradesh (after Hughes, 1884).

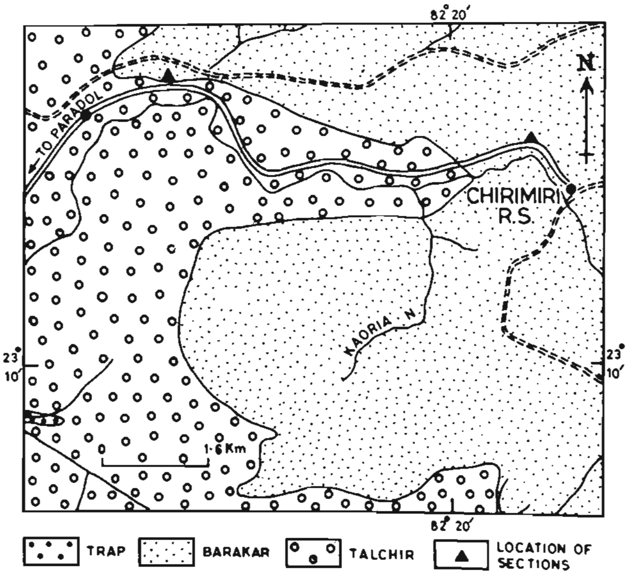


Text-figure 3—Geological map of Anuppur, Madhya Pradesh (after Hughes, 1884).

0.8 km south-west of the Bakan Nala-Son River confluence along Bakan Nala. *Parasaccites* Bharadwaj & Tiwari (36.5%), *Caheniasaccites* Bose & Kar (12.5%), *Callumispora* Bharadwaj & Srivastava (14.5%) and *Pachysaccus* Lele & Maithy (11.5%) are significant genera in the assemblage. These are followed by *Plicatipollenites* Lele (9%), *Strotersporites* Wilson emend. Klaus (6%), *Stellapollenites* Lele (3.5%), *Scheuringipollenites* Tiwari (2.5%), *Divarisaccus* Venkatachala & Kar (2%), *Latosporites* Potonié & Kremp (1%), *Leiotriletes* Naumova ex. Potonié & Kremp (0.5%) and *Striatites* Pant emend. Bharadwaj (0.5%). Thus this assemblage is dominated by the monosaccate forms contributing to 75 per cent of the total assemblage.

CHIRIMIRI

Two palynological assemblages were obtained from this area.



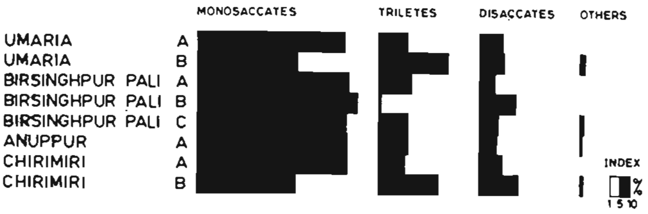
Text-figure 4—Geological map of Chirimiri, Madhya Pradesh (after Hughes, 1884 with certain modifications).

Assemblage A—It was recovered from carbonaceous shale bed (Field no. CP2) of a section exposed about 0.8 km north-west of the Chirimiri Railway Station along the Chirimiri-Paradol railway line. *Parasaccites* Bharadwaj & Tiwari (45.5%) and *Caheniasaccites* Bose & Kar (14%) are the significant genera in this assemblage. Other genera in order of their frequency are *Callumispora* Bharadwaj & Srivastava (14%), *Crucisaccites* Lele & Maithy (3.5%), *Stellapollenites* Lele (3%), *Strotersporites* Wilson emend. Klaus (3%), *Leiotriletes* Naumova ex. Potonié & Kremp (2.5%), *Tiwariasporis* Maheshwari & Kar (3%), *Gondwanopollis* Lele & Maithy (1%) and *Limitisporites* Leschik emend. Potonié (0.5%). The monosaccate group forms 66 per cent of the total assemblage.

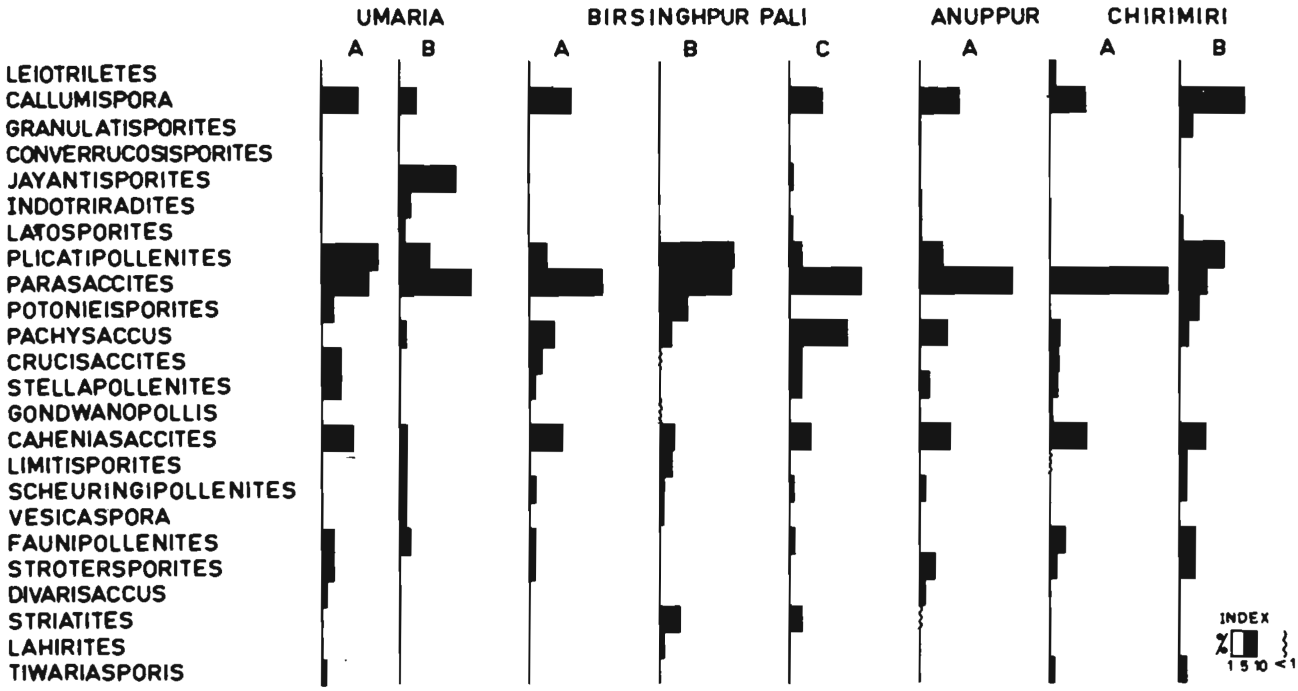
Assemblage B—It has been obtained from the bluish sandstone bed (Field no. CP 15) of a section exposed about 0.8 km north-west of Chirimiri Railway Station along the northern side of the railway line. In this assemblage *Callumispora* Bharadwaj & Srivastava (25%), *Plicatipollenites* Lele (17.5%), *Parasaccites* Bharadwaj & Tiwari (10.5%) and *Caheniasaccites* Bose & Kar (10%) are the important genera. Next in order are *Potonieisporites* Bharadwaj emend. Bharadwaj (7.5%), *Strotersporites* Wilson emend. Klaus (6%), *Faunipollenites* Bharadwaj (6%), *Granulatisporites* Ibrahim emend. Potonié & Kremp (5%), *Pachysaccus* Lele & Maithy (3.5%), *Tiwariasporis* Maheshwari & Kar (2.5%), *Scheuringipollenites* Tiwari (2.5%), *Limitisporites* Leschik emend. Potonié (2.5%) and *Latosporites* Potonié & Kremp (1.5%). Thus the assemblage is dominated by the monosaccate (49 per cent) and trilete forms (30 per cent).

PALYNOFLORISTIC COMPARISON AND BIOSTRATIGRAPHICAL SIGNIFICANCE

Well-represented Karharbari palynological assemblage has been described by Maithy (1966) from the carbonaceous shale of Umaria. Maithy (1969) has given the distribution and frequency of the characteristic Karharbari taxa in different localities of the Lower Gondwana formations of India, which has provided a reliable basis for the recognition of the Karharbari Formation. Srivastava (1973) studied the Karharbari palynological assemblage from the type area—the Giridih Coalfield—and has recognized two zones. The Lower Karharbari mioflora (younger part in Zone 1) of the Giridih Coalfield is dominated by *Callumispora* and *Parasaccites*. Similar assemblage has been described from the North Karanpura Basin (Zone II of Kar, 1973), bore-core from Korba Coalfield (Upper subzone in Zone 1 of Bharadwaj & Srivastava, 1973), Umrer Quarry, Nagpur (Zone 1 of Bharadwaj & Anand Prakash, 1974), Jayanti Coalfield (Flora of the sample nos. D_{18} & D_{19}, Lele & Makada, 1974), Auranga Coalfield (Lele & Srivastava, 1977), West Bokaro Coalfield (Anand Prakash, Srivastava & Tiwari, 1979) and Zone 1 of the Hutar Coalfield (Shukla, 1983).



Histogram 1—Showing the percentage distribution of different groups of palynotaxa.



Histogram 2—Showing the percentage distribution of the different genera.

TABLE 1—SHOWING PERCENTAGE DISTRIBUTION OF DIFFERENT GROUPS OF THE PALYNOTAXA

Groups	*Umaria*		*Birsinghpur Pali*			*Anuppur*	*Chirimiri*	
	A	B	A	B	C	A	A	B
Monosaccates	73.5	50.5	76.0	80.0	74.0	75.0	75.0	49.0
Triletes	14.5	34.5	16.5	2.0	15.0	15.0	13.5	30.0
Disaccates	12.0	12.5	7.5	18.0	9.5	9.0	11.5	19.5
Others	—	2.5	—	—	1.5	1.0	—	1.5

The palynofloral assemblages from the Coal Measures of Umaria, Birsinghpur Pali, Anuppur and Chirimiri, in general, are dominated by the monosaccate and trilete forms. The disaccate and others have comparatively low representation (Tables 1 & 2 and Histograms 1 & 2). These eight palynological assemblages are not comparable with the known Barakar assemblages (Tiwari, 1973, 1974). On the other hand, these assemblages (A & B from Umaria, A & C from Birsinghpur Pali, A from Anuppur, and A & B from Chirimiri) are comparable to the known Karharbari assemblages. Significant proportion of the disaccate forms in B assemblage of Birsinghpur Pali may be because of some local variation in the flora (Tiwari, 1974). Some of the genera, such as *Granulatisporites, Plicatipollenites, Crucisaccites, Parasaccites, Potonieisporites, Caheniasaccites, Pachyasaccus, Gondwanopollis* and *Stellapollenites* of the Karharbari assemblage have also been found in our assemblage (Table 3).

Parasaccites/Plicatipollenites/Caheniasaccites and *Callumispora/Jayantisporites* complex forms the most significant constituent of the eight palynological assemblages (Table 2 & Histogram 2). The general dominance of radial monosaccate and trilete grains in the Coal Measures of Umaria, Birsinghpur Pali, Anuppur and Chirimiri brings these assemblages more closer to the Lower Karharbari assemblages.

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Table 3—Showing the miospore genera from Umaria, Birsinghpur Pali, Anuppur and Chirimiri and their comparison with the known Karharbari assemblages.

TABLE 2—SHOWING PERCENTAGE DISTRIBUTION OF VARIOUS GENERA

Genera	*Umaria*		*Birsinghpur Pali*			*Anuppur*	*Chirimiri*	
	A	B	A	B	C	A	A	B
Leiotriletes						0.5	2.5	
Callumispora	14.5	7.0	16.5		13.5	14.5	9.0	25.0
Granulatisporites								5.0
Converrucosisporites			1.0					
Jayantisporites		22.5		1.0	1.5			
Indotriradites		5.0				1.0		
Latosporites		2.5			1.5	1.0		1.5
Plicatipollenites	22.5	12.5	7.5	29.0	5.0	9.0		17.5
Parasaccites	18.5	28.0	38.5	28.0	28.0	36.5	45.5	10.5
Potonieisporites	5.0	5.0		10.0				7.5
Pachysaccus		2.5	10.0	5.0	22.5	11.5	4.0	3.5
Crucisaccites	7.5		5.0	8.5	5.0		3.5	
Stellapollenites	7.5		2.5		5.0	3.5	3.0	
Gondwanopollis				0.5			1.0	
Caheniasaccites	12.5	2.5	13.5	6.0	8.5	12.5	14.0	10.0
Limitisporites		2.5		5.0			0.5	2.5
Scheuringipollenites		2.5	2.5	2.0	2.0	2.5		2.5
Vesicaspora		2.5		1.0				
Faunipollenites	5.0	4.5	2.5		2.5		6.0	6.0
Strotersporites	5.0		2.5			6.0	3.0	6.0
Striatites				8.0	5.0	0.5		
Lahirites				2.0				
Tiwariasporis	2.0						2.0	2.5
Divarisaccus						2.0		

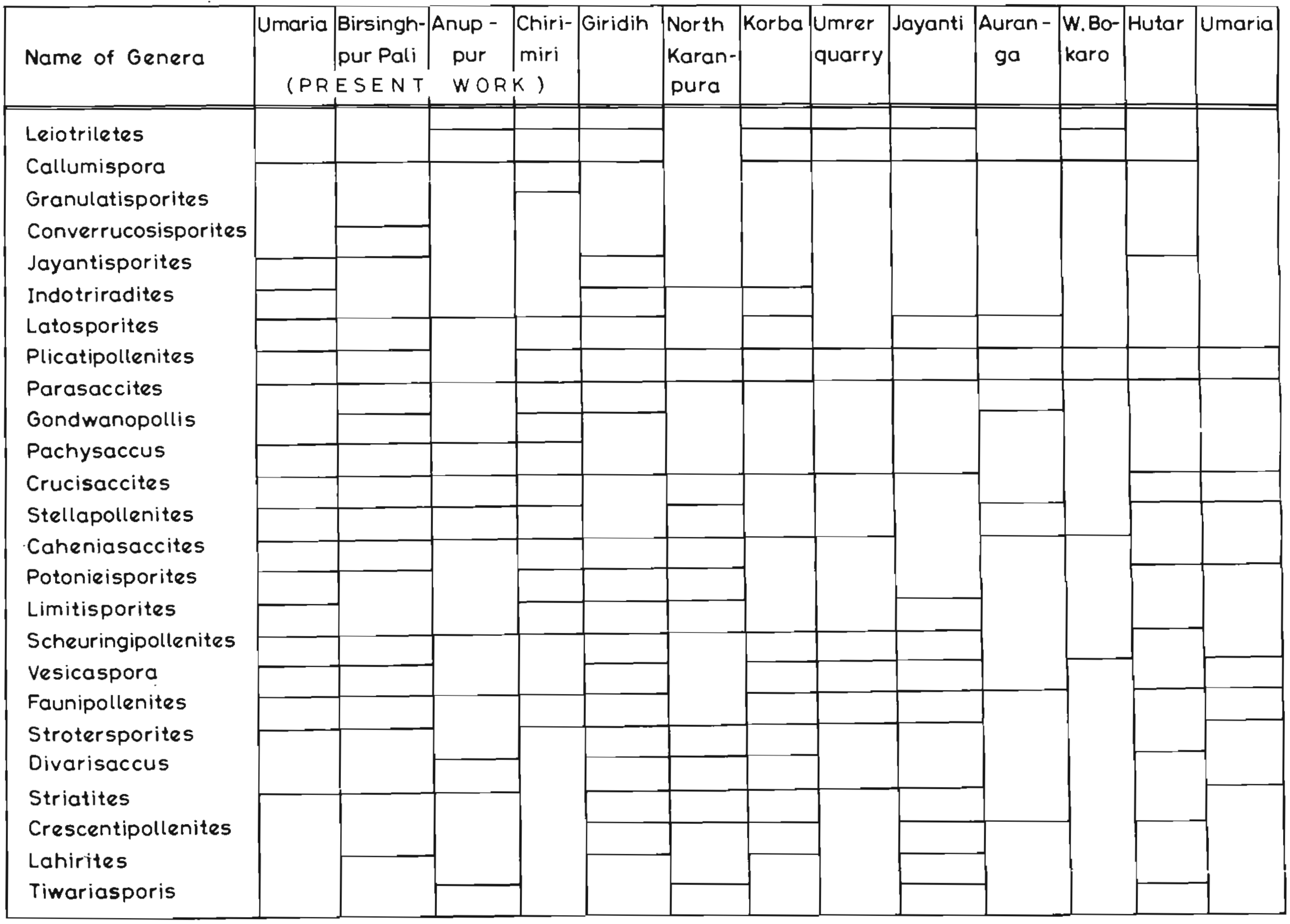

TABLE 3

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The Palaeobotanist **35**(1) : 93-105, 1986.

Palynology of the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road Section, Jaintia Hills (Meghalaya) and Cachar (Assam). Part II. Fungal remains

H. P. Singh, R. K. Saxena & M. R. Rao

ABSTRACT

Singh, H. P., Saxena, R. K. & Rao, M. R. (1986). Palynology of the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road Section, Jaintia Hills (Meghalaya) and Cachar (Assam). Part II. Fungal remains. *Palaeobotanist* **35**(1) : 93-105.

Fungal remains recovered from the Barail and Surma groups (Oligocene-Lower Miocene) exposed along the Sonapur Badarpur Road Section in Jaintia Hills, Meghalaya and Cachar, Assam have been described. The assemblage consists of 17 genera and 33 species. Of these, 6 genera and 9 species are of fungal bodies and 11 genera and 24 species of fungal spores. Five new species have been established. The important genera are : *Phragmothyrites, Notothyrites, Parmathyrites, Kutchiathyrites, Inapertisporites, Dicellaesporites, Multicellaesporites, Pluricellaesporites, Diporicellaesporites* and *Dyadosporonites*. Quantitative analysis of the assemblage reveals that both fungal bodies and spores are richly represented in the Surma Group (Lower Miocene) while their frequency decreases in the Barail Group. The assemblage has been compared with the known fungal assemblages from the Tertiary rocks in India.

Key-words—Palaeopalynology, Fungi, Jaintia Hills, Oligocene-Miocene (India)

H. P. Singh, R. K. Saxena & M. R. Rao, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

जयन्तिया पहाड़ियों (मेघालय) एवं कछार (असम) में सोनपुर-बदरपुर मार्ग खंड के संग-संग विगोपित सूरमा (अधरि मध्यनूतन) एवं बैरेल (पश्चनूतन) अवसादों क्र परागाणविक अध्ययन. भाग 2–कवकीय अवशेष

हरीपाल सिंह, रमेश कुमार सक्सेना एवं मलागलापल्ली रामचंद्र राव

इस शोध-पत्र में मेघालय एवं असम में क्रमशः जयन्तिया पहाड़ियों एवं कछार में सोनपुर-बदरपुर मार्ग खंड के संग-संग विगोपित बैरेल एवं सूरमा समूहों (पश्चनूतन-अधरि मध्यनूतन) से उपलब्ध कवकीय अवशेषों का वर्णन किया गया है। इस समुच्चय में कुल मिलाकर 17 प्रजातियाँ एवं 33 जातियाँ विद्यमान हैं। इनमें से छः प्रजातियाँ एवं नौ जातियाँ कवकीय कायों की तथा 11 प्रजातियाँ व 24 जातियाँ कवकीय बीजाणुओं की हैं। पाँच नवीन जातियाँ भी स्थापित की गई हैं। फ्रेग्मोथाइराइटिस, नोटोथाइराइटिस, परमाथाइराइटिस, कच्छिआथाइराइटिस, इनएँपर्टिस्पोराइटिस, डाइसेल्लिस्पोराइटिस, मल्टीसेल्लिस्पोराइटिस, प्लूरीसेल्लिस्पोराइटिस, डाइपोरिसेल्लिस्पोराइटिस एवं डाइएँडोस्पोरोनाइटिस नामक मुख्य प्रजातियाँ हैं। समुच्चय के परिमाणात्मक विश्लेषण से व्यक्त होता है कि सूरमा समूह में कवकीय कायों और बीजाणुओं की बाहुल्यता है जबकि बैरेल समूह में इनकी प्रतिशतता कम हो जाती है। इस समुच्चय की तुलना भारत की तृतीयक युगीन चट्टानों से ज्ञात कवकीय समुच्चयों से की गई है।

INTRODUCTION

DURING the post-fifties, considerable palynological work has been done on the Tertiary sediments of Meghalaya and Assam by various workers namely, Biswas (1962), Baksi (1962;65) Ghosh and Banerjee (1963), Banerjee (1964a,b) Bose and Sah (1964), Sah and Dutta (1966, 1968, 1974), Dutta and Sah (1970, 1974), Salujha, Kindra and Rehman (1972, 1974), Salujha, Rehman and Kindra (1973), Sah and Singh (1974), Singh, Singh and Sah (1975), Singh (1977a,b) and Mehrotra (1981,1983). However, these workers have dealt chiefly with the spore-pollen assemblages of higher plants whereas the fungal spores or their fruiting bodies seem to have been either ignored or have received relatively much less attention for their proper investigation. The present paper is an attempt to present an account of fungal remains (fungal spores and ascomata) from the Barail and Surma groups (Oligocene-Lower Miocene) exposed along Sonapur-Badarpur Road Section, Meghalaya and

Assam. This road section constitutes a part of the Shillong-Badarpur Highway (National Highway 44) and is located in the south-east of Shillong exhibiting excellent exposures of the Barail and Surma sediments. The Barail Group is represented by Laisong, Jenam and Renji formations. The Laisong Formation represents mainly the arenaceous facies consisting of grey, hard, thinly beded, fine to medium grained sandstones alternating with subordinate, hard, sandy shales. The Jenam Formation is mainly argillaceous and consists of shales and sandy shales with fine to medium grained sandstone. The shale is generally carbonaceous. The Renji Formation is also arenaceous in nature and made up of thickly bedded or massive, fine to medium grained, hard, ferruginous sandstone alternated by thin shales. This formation is unconformably overlain by the Surma Group which is divided into Bhuban and Bokabil formations. The Bhuban Formation is divided into Lubha, Umkiang and Dona members; the lower and upper members being mainly arenaceous and the middle member argillaceous. The Bokabil Formation is made up of thick sandy shales with alternations of very fine grained laminated sandstone. The detailed lithostratigraphy of the section has been described by Saxena and Tripathi (1982).

The material was collected from the Barail and Surma groups (Oligocene-Lower Miocene) exposed along the above sections by one of us (R.K.S.). Altogether, 288 rock samples were collected, of which 201 samples proved to be palynologically productive. The palynofossils recovered from these samples include dinoflagellate cysts, fungal remains, spores, pollen grains and some other micro-remains of obscure origin. The first part of this study dealing with the dinoflagellate cysts has already been published (Saxena & Rao, 1984). All slides, negative and unused material have been deposited in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

DESCRIPTION

Genus—*Phragmothyrites* Edwards, 1922 emend. Kar & Saxena, 1976

Type species—*Phragmothyrites eocaenica* Edwards, 1922 emend. Kar & Saxena, 1976

Phragmothyrites eocaenica Edwards, 1922 emend. Kar & Saxena, 1976

Pl. 1, figs 1, 2; Pl 2, fig. 15

Description—Ascomata circular to subcircular in shape with crenate to almost entire margin. Nonostiolate. Size range 65-130 × 60-115 μm in diameter. Hyphae not free, radially arranged and interconnected with each other to form mostly one-celled thick pseudoparenchymatous cells. Generally cells in the middle region less elongated than the marginal ones, marginal cells being darker and setose. In some specimens, cells of the central region bear a single pore in each cell, pore 1 to 2.5 μm in diameter.

Occurrence—Barail and Surma groups.

Distribution—Palaeocene, Lower Eocene and Oligocene of Kachchh, Gujarat (Kar & Saxena, 1976; Venkatachala & Kar, 1969; Kar, 1979). Neogene sediments around Quilon and Warkalli, Kerala (Jain & Kar, 1979).

Phragmothyrites sp.

Pl. 1, fig. 3

Description—Ascomata subcircular in shape. Nonostiolate. Size 90 × 110 μm in diameter. Hyphae radially arranged, interconnected with each other by means of transverse septa to form pseudoparenchymatous cells. The middle cells less elongated than the marginal cells. Outer margin thickened. Cells ornamented with finely foveolate-reticulate ornamentation.

→

PLATE 1

(All photomicrographs are enlarged. ca × 500)

1, 2. *Phragmothyrites eocaenica* Edwards emend. Kar & Saxena; B.S.I.P. slide no. 8100, coordinates 47.10 × 102.10; B.S.I.P. slide no. 8101, coordinates 70.0 × 93.8.

3. *Phragmothyrites* sp.; B.S.I.P. slide no. 8102, coordinates 50.5 × 110.4.

4. *Paramicrothallites menonii* Jain & Gupta; B.S.I.P. slide no. 8103, coordinates 48.8 × 103.8.

5, 6. *Notothyrites setiferus* Cookson; B.S.I.P. slide no. 0000, coordinates 48.8 × 103.8, coordinates 51.0 × 108.7; B.S.I.P. slide no. 8105, coordinates 57.1 × 107.3.

7. *Notothyrites padappakarensis* Jain & Gupta; B.S.I.P. slide no. 8107, coordinates 70.2 × 114.6.

8, 9. *Parmathyrites ramanujamii* sp. nov.; B.S.I.P. slide no. 8108, coordinates 45.3 × 105.2; B.S.I.P. slide no. 8109, coordinates 48.4 × 93.5 (Holotype).

10. *Notothyrites amorphus* Kar & Saxena; B.S.I.P. slide no. 8106, coordinates 75.7 × 113.6.

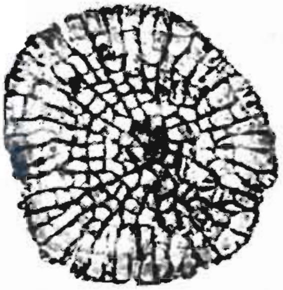
11, 12. *Kutchiathyrites* sp.; B.S.I.P. slide no. 8110, coordinates 55.1 × 96.10.

13. *Lirasporis intergranifer* Potonié & Sah emend. Jain & Kar; B.S.I.P. slide no. 8110, coordinates 40.0 × 103.5.

14. *Dyadosporonites* sp.; B.S.I.P. slide no. 8129, coordinates 65.0 × 104.4.

15. *Lacrimasporonites* sp.; B.S.I.P. slide no. 8120, coordinates 52.5 × 107.8.

16. *Diporisporites* sp.; B.S.I.P. slide no. 8130, coordinates 71.6 × 104.6.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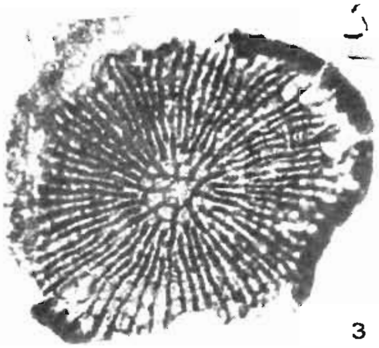
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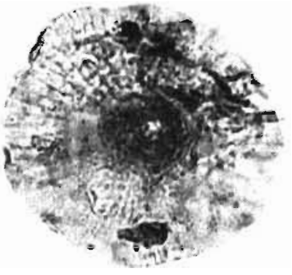
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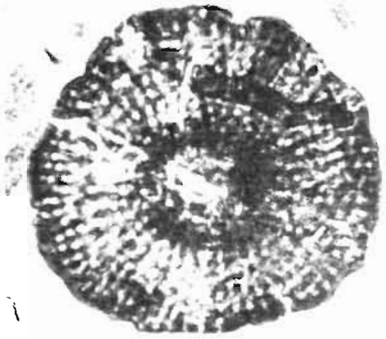
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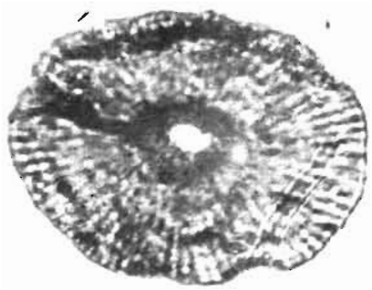
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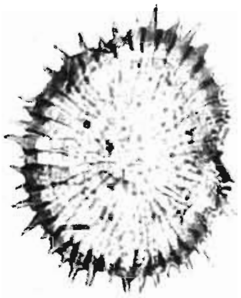
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PLATE 1

Comparison—*Phragmothyrites* sp. closely compares with *P. eocaenica* Edwards (1922) emend. Kar & Saxena (1976), but the former can be distinguished by having foveolate to finely reticulate ornamentation.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Genus—*Paramicrothallites* Jain & Gupta, 1970

Type species—*Paramicrothallites spinulatus* (Dilcher, 1965) Jain & Gupta, 1970.

Paramicrothallites menonii Jain & Gupta, 1970

Pl. 1, fig. 4

Description—Ascomata circular in shape. Ostiolate. Size range 75-87 × 73-83 μm. Hyphae radially arranged, interconnected with each other forming pseudoparenchymatous cells. Central cells squarish, marginal cells rectangular, walls thin. Ostiole well defined, about 9 μm in diameter, centrally placed, not surrounded by any specialised cells. Margin lobed. Hyphae absent. Ascospores unknown.

Occurrence—Barail and Surma groups.

Distribution—Miocene sediments around Padappakara and Quilon, Kerala (Jain & Gupta, 1970).

Genus—*Notothyrites* Cookson, 1947

Type species—*Notothyrites setiferus* Cookson, 1947

Notothyrites setiferus Cookson, 1947

Pl. 1, figs 5, 6

Description—Ascomata circular to subcircular in shape. Ostiolate. Size range 80-125 × 70-115 μm in diameter. Cells of radiating hyphae interconnected, forming pseudoparenchymatous cells, cells towards ostiole squarish, peripheral cells rectangular. Ostiole 17-37 μm in diameter, bordered by 2-4 layers of thick-walled, dark brown cells. Hyphae absent. Ascospores unknown.

Occurrence—Barail and Surma groups.

Distribution—Palaeocene of Kachchh (Kar & Saxena, 1976). Upper Miocene (Warkalli Lignite) of Kerala (Ramanujam & Rao, 1973). Neogene sediments around Quilon and Warkalli, Kerala (Jain & Kar, 1979).

Notothyrites amorphus Kar & Saxena, 1976

Pl. 1, fig. 10

Description—Ascomata asymmetrical with uneven margin. Size 200 × 95 μm. Hyphae radially arranged, not anastomosing and hence do not form distinct pseudoparenchymatous cells. Ostiolate, ostiole ovoidal in shape surrounded by a few cells thick wall. No free hyphae observed. Ascospores unknown.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Distribution—Palaeocene of Kachchh, Gujarat (Kar & Saxena, 1976).

Notothyrites padappakarensis Jain & Gupta, 1970

Pl. 1, fig. 7

Description—Ascomata circular to subcircular in shape, flattened, outline sinuous. Size range 60-100 ×50-95 μm in diameter. Ostiolate. Radiating hyphae interconnected, cells smaller in central region and bigger towards periphery, tangential walls of peripheral cells strongly thickened and entire. Ostiole 7-10 μm in diameter, distinctly elevated, centric to slightly eccentric, bordered by two to four layers of dark brown, thick-walled papillate cells. Hyphae absent. Ascospores unknown.

Occurrence—Bhuban Formation, Surma Group.

Distribution—Miocene sediments around Padappakara and Quilon, Kerala (Jain & Gupta, 1970).

Genus—*Parmathyrites* Jain & Gupta, 1970

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

Parmathyrites ramanujamii sp. nov.

Pl. 1, figs 8, 9

Holotype—Pl. 1, fig. 9, size 90 μm; B.S.I.P. slide no. 8109.

Type locality—154.25 kilometre-stone, Sonapur-Badarpur Road Section, Meghalaya.

Type Horizon—Umkiang Member, Bhuban Formation, Surma Group, Lower Miocene.

Diagnosis and description—Ascomata circular to subcircular in shape. Nonostiolate. Size range 80-90 μm in diameter. Hyphae radially arranged, interconnected, forming pseudoparenchymatous nonporate cells. Central and marginal cells being squarish and rectangular in shape respectively. Outer peripheral cells prominent with thickened radial walls, each peripheral cell developing into a spine-like process, spines unequal, 5-15 μm long, pointed at the apex and broader at the base, about 40 in number, wall thick, radially fused at the base forming a continuous peripheral sheath around ascomata. Ascospores unknown.

Comparison—*Parmathyrites ramanujamii* sp. nov. closely compares with *P. indicus* Jain & Gupta (1970) in shape and the presence of spines along the margin but the former can be distinguished in having continuous arrangement of spines. Moreover, spines in the present species are smaller (5-15 μm long) than those in *P. indicus* (20-50 μm long). *P. turaensis* Kar, Singh & Sah (1972) differs in possessing ostiolate ascomata. *P. robustus* Jain & Kar (1970) possesses thickened cells in the central region and strongly built spines hence not comparable.

Derivation of name—The species is named after Dr C. G. K. Ramanujam, Botany Department, Saifabad Science College, Hyderabad.

Occurrence—Umkiang Member, Bhuban Formation, Surma Group.

Genus—*Kutchiathyrites* Kar, 1970

Type species—*Kutchiathyrites eccentricus* Kar, 1979

Kutchiathyrites sp.

Pl. 1, figs 11, 12

Description—Ascomata ± semicircular in shape some specimens look like fish scales, eccentric in development. Size range 88-110 × 67-75 μm. Nonostiolate. No free hyphae present, dimidiate. Radially arranged hyphae thick, dark, diverging from one another; transverse hyphae comparatively thinner, interconnecting radial ones forming squarish, pseudoparenchymatous cells without having any pore. Some specimens exhibit development of spines from the marginal cells.

Comparison—*Kutchiathyrites* sp. resembles *K. eccentricus* Kar (1979) in general organisation but can be distinguished by having spines which are developed as extensions of the marginal cells. Moreover, the present specimens are longer than broad as compared to *K. eccentricus* Kar (1979).

Occurrence—Bhuban Formation, Surma Group.

Genus—*Lirasporis* Potonié & Sah, 1960 emend. Jain & Kar, 1979

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

Lirasporis intergranifer Potonié & Sah, 1960 emend. Jain & Kar, 1979

Pl. 1, fig. 13

Description—Fungal body oval-elliptical in shape with equal or unequal, broad, notched ends. Size 100 × 35 μm. Mycelia long, distinct, run from end to end, parallel to one another. Wall laevigate.

Remarks—The present specimens are comparatively smaller in size than those described by Jain and Kar (p. 196)

Occurrence—Lubha Member, Bhuban Formation, Surma Group.

Distribution—Miocene sediments (Cannanore Lignite) of Kerala (Potonié & Sah, 1960).

Genus—*Inapertisporites* van der Hammen, 1954 emend. Sheffy & Dilcher, 1971

Type species—*Inapertisporites pseudoreticulatus* Rouse, 1959.

Inapertisporites ovalis Sheffy & Dilcher, 1971

Pl. 2, fig. 14

Description—Fungal spore oval. Size range 15-17 × 10-11 μm. Unicellular, nonseptate. Inaperturate. Spore wall 15 μm thick, laevigate. Medium pigment.

Occurrence—Lubha Member, Bhuban Formation, Surma Group.

Distribution—Puryear Clay, south of Puryear, Henry County, Tennessee (Sheffy & Dilcher, 1971).

Inapertisporites miocenicus sp. nov.

Pl. 2, figs. 12, 13

Holotype—Pl. 2, fig. 13, size 218 × 24 μm; B.S.I.P. slide no. 8121.

Type locality—173 Kilometrestone, Sonapur-Badarpur Road Section, Meghalaya.

Type Horizon—Dona Member, Bhuban Formation, Surma Group, Lower Miocene.

Diagnosis and Description—Fungal spores elongated in shape. Size range 112-218 × 21-24 μm. Unicellate, nonseptate, inaperturate. Spores pointed at one end, blunt at the other. Spore wall hyaline, laevigate and irregularly folded.

Comparison—The present species can be differentiated from all the known species of *Inapertisporites* by being exceptionally long size (up to 218 μm).

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Inapertisporites sp. cf. *I. kedvesii* Elsik, 1968

Pl. 1, fig. 1

Description—Fungal spores sub-spherical in shape. Size 67-73 × 55-64 μm. Unicellate. Inaperturate. Spore wall up to 1 μm thick, laevigate. Several irregular folds present.

Comparison—*Inapertisporites kedvesii* Elsik (1968) compares in all the characters with the present species but the latter can be differentiated by being bigger in size.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Inapertisporites sp.

Pl. 1, fig. 3

Description—Fungal spore lanceolate in shape. Size 175 × 88 μm. Unicellate. Inaperturate. Spore wall 1 μm thick, laevigate. Few folds present.

Comparison—*Inapertisporites* sp. compares with *I. Pseudoreticulatus* Rouse (1959) in having laevigate spore wall but differs by being bigger in size (175 × 88 μm).

Occurrence—Lubha Member, Bhuban Formation, Surma Group.

Genus—*Dicellaesporites* Elsik, 1968 emend. Sheffy & Dilcher, 1971

Type species—*Dicellaesporites popovii* Elsik, 1968

Dicellaesporites fusiformis Sheffy & Dilcher, 1971

Pl. 2, fig. 7

Description—Fungal spore elliptical. Size 25 × 10 μm. Dicellate, both cells equal in size and shape. Uniseptate. Spore wall 1 μm thick, laevigate.

Occurrence—Dona Member, Bhuban Formation. Surma Group.

Distribution—Puryear Clay, south of Puryear, Henry County, Tennessee (Sheffy & Dilcher, 1971).

Dicellaesporites sp. A

Pl. 2, fig. 18

Description—Fungal spore elliptical in shape. Size 85 × 33 μm. Dicellate. Inaperturate. Uniseptate, septa 1 μm thick. Spore wall laevigate.

Comparison—The spore wall in *D. ellipticus* Jain & Kar (1979) is granulose-microverrucose whereas it is laevigate in the present species.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Dicellaesporites sp. B

Pl. 2, fig. 23

Description—Fungal spore elongated, biconvex. Size 126 × 46 μm. Dicellate. Inaperturate. Uniseptate, septa faint but clearly discernible, thicker than the spore wall. Spore wall less than 1 μm thick, foveolate, foveola sparsely placed but evenly distributed. Few irregular folds present.

Comparison—The present species can be differentiated from all the known species of *Dicellaesporites* in having foveolate spore wall.

Genus—*Multicellaesporites* Elsik, 1968 emend. Sheffy & Dilcher, 1971

Type species—*Multicellaesporites nortonii* Elsik, 1968.

Multicellaesporites sp. A

Pl. 2, fig. 5

Description—Fungal spore filamentous in shape. Size 140 × 12 μm, 13-celled, cells broader towards one end and narrower towards the other. Inaperturate. Septa 1.5-4 μm thick. Spore wall laevigate.

Comparison—*Multicellaesporites nortonii* Elsik (1968) is distinguished from the present species by possessing 5-celled spores with smaller size (37 × 15 μm).

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Multicellaesporites sp. B

Pl. 2, fig. 17

Description—Fungal spore spindle-shaped. Size 58 × 18 μm. Tetracellate, middle cells much bigger than the terminal ones. Inaperturate, triseptate, each septum 1 μm thick. Spore wall 0.5 μm thick, laevigate.

Comparison—The present specimen can be differentiated from *M. nortonii* Elsik (1968) in having dissimilar cells and bigger size (58 × 18 μm).

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Multicellaesporites sp. C

Pl. 2, fig. 21

Description—Fungal spore rod-shaped. Size 92 × 20 μm, 9-celled, all cells equal in size and shape except the terminal ones. Inaperturate. Septa prominent, complete, biconvex, about 4 μm thick. Spore wall 1 μm thick, laevigate.

Comparison—*Multicellaesporites* sp. C. can be distinguished from *M. nortonii* by its prominent septa (4 μm thick) and laevigate spore wall.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Multicellaesporites sp. D

Pl. 2, fig. 19

PLATE 2

(All photomicrographs are enlarged, ca × 500)

1. *Inapertisporites* sp. cf. *I. kedvesii* Elsik; B.S.I.P. slide no. 8115, coordinates 49.9 × 114.2.

2. *Monoporisporites* sp.; B.S.I.P. slide no. 8128, coordinates 52.5 × 99.5.

3. *Inapertisporites* sp.; B.S.I.P. slide no. 8116, coordinates 46.8 × 109.5.

4. *Pluricellaesporites* sp. cf. *P alleppeyensis* Ramanujam & Rao; B.S.I.P. Slide no. 8133, coordinates 55.6 × 115.2.

6, 22. *Dyadosporonites grandiporus* sp. nov.; B.S.I.P. slide no. 8100, coordinates 70.5 × 98.5 (Holotype); B.S.I.P. slide no. 8123, coordinates 41.1 × 98.4.

7. *Dicellaesporites fusiformis* Sheffy & Dilcher; B.S.I.P. slide no. 8119, coordinates 45.0 × 109.8.

8. *Fusiformisporites* sp.; B.S.I.P. slide no. 8137, coordinates 69.0 × 104.10.

9. *Frasnacritetrus* sp.; B.S.I.P. slide no. 8138, coordinates 41.5 × 109.3.

10. *Diporicellaesporites verrucatus* sp. nov.; B.S.I.P. slide no. 8134, coordinates 58.7 × 104.10 (Holotype).

11. *Pluricellaesporites* sp. A.; B.S.I.P. slide no. 8132, coordinates 52.2 × 111.5.

12, 13. *Inapertisporites miocenicus* sp. nov.; B.S.I.P. slide no. 8117, coordinates 54.1 × 98.10; B.S.I.P. slide no. 8121, coordinates 55.3 × 106.2 (Holotype).

→

14. *Inapertisporites ovalis* Sheffy & Dilcher; B.S.I.P. slide no. 8113, coordinates 39.6 × 117.4.

15. *Phragmothyrites eocaenica* Edwards emend. Kar & Saxena

16. *Heliospermopsis* sp.; B.S.I.P. slide no. 8112, coordinates 53.5 × 114.3.

17. *Multicellaesporites* sp. B; B.S.I.P. slide no. 8127, coordinates 51.0 × 98.5.

18. *Dicellaesporites* sp. A; B.S.I.P. slide no. 8123, coordinates 62.4 × 106.5.

19. *Multicellaesporites* sp. D; B.S.I.P. slide no. 8125. coordinates 62.3 × 97.10.

20. *Pluricellaesporites verrucatus* sp. nov.; B.S.I.P. slide no. 8131, coordinates 67.2 × 109.2 (Holotype).

21. *Multicellaesporites* sp. C; B.S.I.P. slide no. 8126, coordinates 67.2 × 103.6.

23. *Dicellaesporites* sp. B; B.S.I.P. slide no. 8122, coordinates 52.5 × 107.8.

24. *Pluricellaesporites* sp. B; B.S.I.P. slide no. 8135, coordinates 69.5 × 104.6.

25. *Diporicellaesporites* sp. B; B.S.I.P. slide no. 8136; coordinates 57.1 × 98.5.

26. *Diporicellaesporites* sp. A; B.S.I.P. slide no. 8112, coordinates 63.0 × 99.5.


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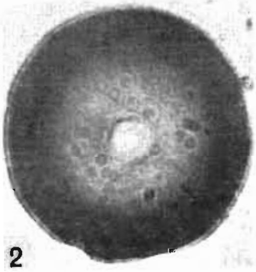
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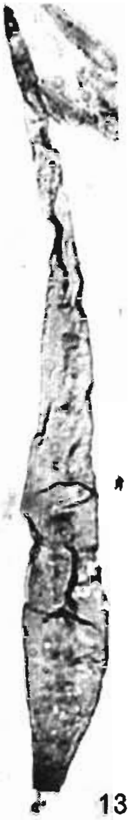
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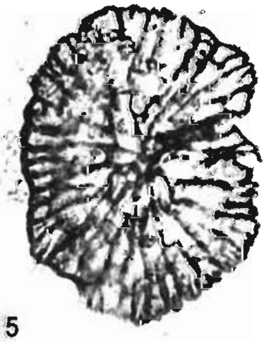
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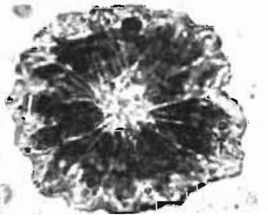
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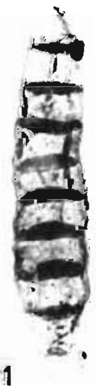
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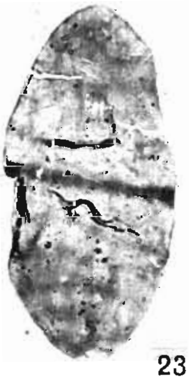
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PLATE 2

Description—Fungal spore elongated. Size 126 × 30 μm, 15-celled, broader in the middle and pointed towards the ends. Inaperturate. Septa clearly discernible, thicker than the spore wall, complete. Spore wall 1 μm thick, laevigate.

Comparison—*Multicellaesporites* sp. D differs from *M. nortonii* Elsik (1968) in having 15-celled spore with laevigate spore wall.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Genus—*Lacrimasporonites* Clarke, 1965 emend. Elsik, 1968

Type species—*Lacrimasporonites levis* Clarke, 1965

Lacrimasporonites sp.

Pl. 1, fig. 15

Description—Fungal spore capsular in shape. Size 37 × 18 μm. Unicellate, nonseptate. Monoporate, pore apical, about 1 μm in diameter, pore margin not thickened, apertural end of the spore rounded while the other one completely flat. Spore wall less than 0.5 μm thick, laevigate.

Comparison—*Lacrimasporonites levis* Clarke (1965) is distinguished from *Lacrimasporonites* sp. in having bigger pore diameter (1-2 μm) and smaller size.

Occurrence—Laisong Formation, Barail Group.

Genus—*Monoporisporites* van der Hammen, 1954 emend. Sheffy & Dilcher, 1971

Type species—*Monoporisporites minutus* van der Hammen, 1954.

Monoporisporites sp.

Pl. 2, fig. 2

Description—Fungal spore spherical in shape. Size μm. Monoporate, pore circular, 8 μm in diameter, centrally located. Spore wall 1.5 μm thick, laevigate.

Comparison—The present specimen can be differentiated from *Monoporisporites smithii* Elsik (1968) by having a bigger pore (8 μm) and comparatively thinner and lighter pore margin.

Genus—*Dyadosporonites* Elsik, 1968

Type species—*Dyadosporonites schwabii* Elsik, 1968.

Dyadosporonites grandiporus sp. nov

Pl. 2, figs 6, 22

Holotype—Pl. 2, fig. 6, size 112 × 47 μm; B.S.I.P. slide no. 8100.

Type locality—165.75 kilometrestone, Sonapur-Badarpur Road Section Meghalaya.

Type Horizon—Dona Member, Bhuban Formation, Surma Group, Lower Miocene.

Diagnosis and description—Fungal spores cylindrical in shape. Size range 95 × 34 μm. Dicellate, both cells equal in size and shape. Diporate, pore 14-16 μm in diameter, pore margin very much thickened. Uniseptate, septa 2 μm thick, complete. Spore wall less than 1 μm thick, laevigate, slightly folded.

Comparison—The present species can be distinguished from *D. schwabii* Elsik (1968) by being bigger in size (112 × 47 μm), having bigger pore diameter (14-16 μm), thicker pore margin and also thicker septa. *D. reticulatus*, *D. cannanorensis* and *D. denticulatus* described by Ramanujam and Rao (1978) from the Neogene sediments of Kerala, South India, can be distinguished by their smaller pores (up to 4 μm) and smaller size range.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Dyadosporonites sp.

Pl. 1, fig. 14

Description—Fungal spore oval in shape. Size 38 × 29 μm. Dicellate, both cells almost equal in size and shape. Uniseptate, septum with a slit-like opening, connecting the two cells. Diporate, one pore present at each end of the spore, measuring about 2 μm in diameter. Spore wall 0.5 μm thick, laevigate having some irregular wrinkles.

Comparison—*Dyadosporonites schwabii* Elsik (1968) is distinct from the present species in having two-layered spore wall and smaller size 9 × 20 μm.

Occurrence—Jenam Formation, Barail ,Group.

Genus—*Diporisporites* van der Hammen, 1954 emend. Elsik, 1968

Type species—*Diporisporites elongatus* van der Hammen, 1954.

Diporisporites sp.

Pl. 1 fig. 16

Description—Fungal spore oval in shape. Size 60 × 38 μm. Diporate, one pore at each end, 6 μm wide, annulus thick, present around both the pores. Spore wall serrate on one side and smooth on the other.

Comparison—*Diporisporites elongatus* var der Hammen (1954) resembles the present species but the latter can be distinguished by having bigger pores (6 μm in diameter) with distinct annulus.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Genus—*Pluricellaesporites* van der Hammen, 1954 emend. Sheffy & Dilcher, 1971

Type species—*Pluricellaesporites typicus* van der Hammen, 1964.

Pluricellaesporites verrucatus sp. nov.

Pl. 2, fig. 20

Holotype—Pl. 2, fig. 20, size 111 × 33 μm; B.S.I.P. slide no. 8131.

Type locality—150 Kilometrestone, Sonapur-Badarpur Road Section, Meghalaya.

Type Horizon—Lubha Member, Bhuban Formation, Surma Group, Lower Miocene.

Diagnosis & Description—Fungal spore elongated with one end wider and the other end tubular. Size 111 × 33 μm. 18-celled, cells wider in the middle than those towards the apertural end. Monoporate, pore apically placed at the narrower end. Septa 1-1.5 μm thick. Spore wall 1 μm thick, granulose-verrucose. Surface view giving a verrucose appearance.

Comparison—This species can be differentiated from all the other species of *Pluricellaesporites* by having a verrucose spore wall.

Occurrence—Lubha Member, Bhuban Formation, Surma Group.

Pluricellaesporites sp. cf. *P. allepoeyenesis* Ramanujam & Rao, 1978

Pl. 2, fig. 4

Description—Fungal spore straight to slightly curved. Size range 70 × 13 μm. Multicellate. Uniseriate. Septa about 3 μm thick, middle part of the spore broad with narrower and blunt ends. Spore wall 1 μm thick.

Comparison—The present specimen closely compares with *P. allepoeyensis* Ramanujam & Rao (1978) in its shape and general organisation but the latter can be distinguished in having larger size range (80-165 μm) and thicker septa (8-16 μm).

Occurrence—Lubha Member, Bhuban Formation, Surma Group.

Pluricellaesporites sp. A

Pl. 2, fig. 11

Description—Fungal spore fusiform in shape. Size 83 × 28 μm. Spore multicellate, cells unequal in size. Monoporate, pore apical, pore margin not thickened. Septa faint but visible, sometimes incomplete, thicker than the spore wall. Spore wall less than 0.5 μm thick, laevigate. Some folds present.

Comparison—The present species can be differentiated from the other species of *Pluricellaesporites* by having thinner and faintly visible septa and as such it is difficult to count the exact number of cells.

Occurrence—Umkiang Member, Bhuban Formation, Surma Group.

Pluricellaesporites sp. B

Pl. 2, fig. 24

Description—Fungal spore with blunt ends. Size 106 × 39 μm. Spore multicellate, 11 celled, middle cells wider than the terminal ones. Monoporate, pore apical, pore margin not thickened, 10 μm in diameter. Septa distinct, about 2.5 μm thick, thicker than spore wall. Spore wall less than 0.5 μm thick, pitted, pits sparsely placed.

Comparison—*Pluricellaesporites* sp. B can be differentiated from *Pluricellaesporites* sp. A by having distinct septa and sparsely pitted spore wall.

Occurrence—Lubha Member, Bhuban Formation, Surma Group.

Genus—*Diporicellaesporites* Elsik, 1968

Type species—*Diporicellaesporites stacyi* Elsik, 1968

Diporicellaesporites verrucatus sp. nov.

Pl. 2, fig. 10

Holotype—Pl. 2, fig. 10, size 155 × 53 μm; B.S.I.P. slide no. 8134.

Type Locality—157.5 Kilometrestone, Sonapur-Badarpur Road section, Meghalaya.

Type Horizon—Dona Member, Bhuban Formation, Surma Group, Lower Miocene.

Diagnosis and description—Fungal spore lanceolate in shape, biconvex. Size 155 × 53 μm. 12-celled, cells wider in the middle and narrower at the ends. Diporate, pores apical, 11 μm in diameter. Septa 2-4 μm thick, dark, complete, thicker than the spore wall. Spore wall 1 μm thick, verrucose, verrucae flat-topped, 5 μm in size.

Comparison—The present specimen can be differentiated from *D. stacyi* Elsik (1968) in having bigger size (155 μm long), more number of cells (12 cells) and verrucose spore wall.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Diporicellaesporites sp. A

Pl. 2, fig. 26

Description—Fungal spore elongated, fusiform in shape. Size 110 × 91 μm. Multicellate, cells wider in the middle and narrower towards the apices. Diporate, pores apical. Septa prominent, complete thicker than the spore wall. Spore wall less than 0.5 μm thick, laevigate.

Comparison—*D. verrucatus* sp. nov. differs from the present species having verrucose spore wall. Also this specimen can be distinguished from *D. stacyi* Elsik (1968) by its bigger size, lanceolate shape and verrucose spore wall.

Occurrence—Umkiang Member, Bhuban Formation, Surma Group.

Diporicellaesporites sp. B

Pl. 2, fig. 25

Description—Fungal spore fusiform in shape. Size 177 × 36 μm. 15-celled, cells in the middle broader than the terminal ones. Diporate, one pore at each end, pore 6 μm in diameter, annulus not developed. Septa 1.5-3.5 μm thick, thicker in the middle and at the terminal ends. Spore wall less than 1 μm thick, laevigate.

Comparison—*Diporicellaesporites stacyi* Elsik (1968) possesses 4 cells with granular to punctate spore wall, hence different from the present specimen.

Occurrence—Lubha Member, Bhuban Formation, Surma Group.

Genus—*Fusiformisporites* Rouse, 1962 emend. Elsik, 1968

Type species—*Fusiformisporites crabbi* Rouse, 1962

Fusiformisporites sp.

Pl. 2, fig. 8

Description—Fungal spore ellipsoidal in shape, dark brown in colour. Size 100 × 45 μm. Dicellate, ends broadly arched. Transverse septa conspicuous, about 4 μm thick. Prominently striate, striae 4, longitudinal, seen on either side of the septum. Spore wall 1.5 μm thick, much thicker at each end.

Comparison—The present specimen can be distinguished from all the known species of *Fusiformisporites* by having bigger size (100 μm long) and thicker septum (4 μm thick).

Occurrence—Laisong Formation, Barail Group.

Genus—*Frasnacritetrus* Taugourdeau, 1968 emend.

Type species—*Frasnacritetrus josettee* Taugordeau, 1968 Saxena & Sarkar, 1985.

Frasnacritetrus sp.

Pl. 2, fig. 9

Description—Main body of the spore quadrangular, longer than wide. Size 37 × 21 μm. Longitudinally divided into 4 chambers. 4 multicellular hyphae arise from the main body, hyphae wider at the base and tapering towards the apcies, twisted, one hypha broken and incomplete. Spore wall about 0.5 μm thick, laevigate.

Occurrence—Barail and Surma groups.

INCERTAE—SEDIS

Genus—*Heliospermopsis* Nagy, 1965

Type species—*Heliospermopsis hungaricus* Nagy, 1965.

Heliospermopsis sp.

Pl. 2, fig. 16

Description—Body circular in outline with uniform wavy margin. Outer zone very distinct, consisting of long, linear to club shaped, radiating zones, 16 in number. Inner zone not clearly seen but darker than the outer zone, occupying more than half of the radius. Central zone well differentiated. Surface ornamentation granulose.

Dimensions—Body diameter: 57 μm; ridges in the outer zone: 11-13 × 5-7 μm; central zone: 12 μm in diameter.

Occurrence—Barail and Surma groups.

DISCUSSION

The fungal remains described here from the Barail and Surma groups (Oilgocene-Lower Miocene) are represented by 17 genera and 33 species. Of these, 6 genera and 9 species are of fungal bodies and 11 genera and 24 species of fungal spores. The fungal bodies show higher frequency (69%) than that of the fungal spores (31%). Quantitative analysis of the fungal remains reveals that their frequency is very high in Bhuban Formation (50%) whereas in Laisong, Jenam and Renji formations, they constitute 17%, 24% and 21% respectively. In Bokabil Formation they are meagrely represented (7%).

Qantitative evaluation of the various fungal taxa is summarized below (Table 1). The percentages of various

Table 1—Quantitative analysis of fungal taxa studied

Taxa	Laisong Formation %	Jenam Formation %	Renji Formation %	Bhuban Formation %	Bokabil Formation %
Phragmothyrites eocaenica	3 (18)	8 (34)	7 (34)	6 (12)	—
Paramicrothallites menonii	1 (6)	5 (21)	4 (19)	3 (6)	—
Notothyrites setiferus	4 (24)	4 (17)	5 (24)	5 (10)	—
Notothyrites padappakarensis	—	—	—	1.5 (3)	—
Notothyrites amorphus	—	—	—	1 (2)	—
Parmathyrites ramanujamii	—	—	—	2 (14)	—
Kutchiathyrites sp.	—	—	—	2 (4)	—
Lirasporis intergranifer	—	—	—	1 (2)	—
Heliospermopsis sp.	4 (24)	5 (21)	5 (24)	6 (12)	—
Inapertisporites ovalis	—	—	—	2 (4)	—
Inapertisporites miocenicus	—	—	—	3 (6)	
Inapertisporites sp. C. *I. kedvesii*	—	—	—	—	6
Dicellaesporites fusiformis	—	—	—	2.5 (5)	—
Dicellaesporites sp. A	1 (6)	—	—	—	—
Dicellaesporites sp. B	—	—	—	2 (4)	—
Lacrimasporonites. sp.	2 (12)	—	—	—	—
Multicellaesporites. sp.	—	—	—	2.5 (5)	—
Pluricellaesporites. sp.	—	—	—	2 (4)	—
Monoporisporites. sp.	—	—	—	—	1
Diporisporites. sp.	—	—	—	2 (4)	—
Fusiformisporites sp.	1 (6)	—	—	—	—
Diporicellaesporites verrucatus	—	—	—	2.5 (5)	—
Diporicellaesporites sp.	—	—	—	1.5 (3)	—
Dyadosporonites grandiporus	—	—	—	1.5 (3)	—
Dyadosporonites grandiporus	—	—	—	2.5 (5)	—
Dyadosporonites sp.	—	2 (8)	—	—	—
Frasnacritetrus sp.	1 (6)	—	—	1 (2)	—

taxa in the overall assemblage of each formation have been given outside brackets while the percentages of the same amongst the fungal remains only have been given within the brackets.

Fungal bodies like *Phragmothyrites, Paramicrothallites, Notothyrites, Parmathyrites, Kutchiathyrites* and *Lirasporis* have affinity with the fruiting bodies of Ascomycetes whereas the fungal spores may be ascribed to Deuteromycetes. *Heliospermopsis* has been kept under *Incertae-sedis.*

MIOFLORAL COMPARISON

North-eastern India—Kar, Singh and Sah (1972) described 8 genera of fungal remains, viz., *Phragmothyrites, Notothyrites, Callimothallus, Parmathyrites, Cucurbitariaceites, Pluricellaesporites, Diporicellaesporites* and *Involutisporonites* from the Tura Formation (Palaeocene-Lower Eocene) of Garo Hills, Meghalaya. Though six of these genera are common to the present assemblage, the two assemblages are different at the specific level. Moreover, many genera like: *Kutchiathyrites, Lirasporis, Inapertisporites, Dicellaesporites, Multicellaesporites, Monoporisporites, Diporisporites, Dyadosporonites, Lacrimasporonites* and *Fusiformisporites* of the present material are absent from the Tura assemblage while reverse is the case with *Cucurbitariaceites* and *Involutisporonites.* Salujha, Kindra and Rehman (1972) described *Oudhkusumites immodicus* and *Phycopeltis* sp. from the Palaeogene of Garo Hills but these forms are absent from the present material. Salujha, Rehman and Kindra (1973) reported the presence of *Oudhkusumites immodicus* and few microthyriaceous discs in the Bhuban Formation but these forms are unrepresented in the present material. From the Palaeogene of Khasi and Jaintia Hills, Salujha Kindra and Rehman (1974) reported *Fusiformisporites foedus* and *Phycopeltis iucundus,* both of which are absent from the present material. It therefore, appears from the comparative study that the present assemblage does not closely compare with any of the fungal assemblages described so far from the Tertiary sediments of Meghalaya and Assam. The scanty representation of fungal remains in these assemblages indicates that their the fungal spores were meagrely represented therein or they have been ignored by the palynologists.

Table 2—Comparative account of fungal remains from Maniyara Fort Formation and Barail Group

Genera	*Maniyara Fort Formation (Oligocene) Kar, 1979*	*Barail Group (Oligocene) present study*
Pluricellaesporites	+	–
Phragmothyrites	+	+
Notothyrites	+	+
Kutchiathyrites	+	+
Inapertisporites	+	+
Lacrimasporonites	+	+
Dyadosporonites	+	+
Paramicrothallites	–	+
Heliospermopsis	–	+
Dicellaesporites	–	+
Fusiformisporites	–	+
Frasnacritetrus	–	+

Table 3—Comparative account of fungal remains from the Neyveli lignite, Warkalli lignite and Quilon beds of South India with those of Surma Group

Genera	*Neyveli lignite (Reddy, Ramanujam and Srisailam, 1982)*	*Warkalli lignite and Quilon beds (Jain & Gupta, 1970; Ramanujam & Rao, 1973, 1978; Kar & Jain, 1979)*	*Surma Group (Present Study)*
Meliolonites	+		
Callimothallus	+		
Haplopeltis	+		
Microthallites	+		
Trichothyrites	+		
Trichopeltinites	+		
Parmathyrites	+	+	+
Plochmopeltinites	+	+	
Euthyrites	+	+	
Paramicrothallites	+		+
Asterina		+	
Asterothyrites		+	
Bireticulasporis		+	
Chomotriletes		+	
Warkallisporonites		+	
Alleppeysporonites		+	
Cannanorosporonites		+	
Colligerites		+	
Foveolatisporonites		+	
Dendromyceliates		+	
Retihelicosporonites		+	
Diploneurospora		+	
Meliola		+	
Ornasporonites		+	
Quilonia		+	
Spegazzinia		+	
Phragmothyrites		+	+
Kutchiathyrites		+	+
Lirasporis		+	+
Dicellaesporites		+	+
Inapertisporites		+	+
Lacrimasporonites		+	+
Multicellaesporites		+	+
Pluricellaesporites		+	+
Monoporisporites		+	+
Diporisporites		+	+
Dyadosporonites		+	+
Diporicellaesporites		+	+
Frasnacritetrus		+	+

Other areas—The fungal remains are known from the Oligocene (Maniyara Fort Formation) of Kachchh and Miocene (Neyveli lignite, Warkalli lignite, Quilon Beds) of South India. A comparison of these assemblages with the present one is tabulated below (Table 2 & 3).

Table 2 clearly shows that the exception of *Pluricellaesporites*, all fungal genera of the Maniyara Fort Formation (Oligocene) are common to the present assemblage too, hence two assemblages appear to be well comparable. Similarly, Table 3 reveals that all genera, but *Frasnacritetrus*, of the present Surma assemblage also occur in the Warkalli lignite and Quilon beds of Kerala. However, the latter assemblages are more diversified and consist of many other genera whichare unrepresented in the former. The Neyveli lignite assemblage is, however, not comparable to the present Surma assemblage.

SUMMARY AND CONCLUSIONS

1. The fungal remains recovered from the Barail-Surma sediments (Oligocene-Lower Miocene) exposed along Sonapur-Badarpur Road are represented by 17 genera and 33 species (5 species new). Of these, 6 genera and 9 species (1 species new) belong to fungal bodies and 11 genera and 24 species (4 species new) pertain to fungal spores.
2. The fungal bodies show higher frequency (69%) than that of the fungal spores (31%). Quantitative analysis of the fungal remains reveals that their frequency is high (50%) in the Bhuban Formation whereas in Laisong, Jenam and Renji formations, they constitute 17 per cent, 24 per cent and 21 per cent of their respective assemblages. However, in Bokabil Formation they share only 7 per cent of the assemblage.
3. Quantitatively, *Phragmothyrites, Notothyrites, Paramicrothallites* and *Heliospermopsis* are the most important genera being represented in almost every stratigraphic unit in good percentage.
4. The fungal spores mostly occur in the Bhuban Formation while in the Laisong, Jenam and Renji formations, their representation is meagre and is only at free levels.
5. The fungal bodies described here show affinity with Ascomycetes whereas the fungal spores may be related with Deuteromycetes.
6. A comparison of the present assemblage with the known fungal assemblages from Meghalaya and Assam was made and it was observed that they are not closely comparable.
7. The fungal assemblage from the Maniyara Fort Formation (Oligocene) of Kachchh closely compares with the present Barail assemblage. Similarly, the fungal assemblages reported from the Warkalli lignite and Quilon beds of South India show similarities with the present Surma assemblage. However, the former are more diversified and consist of other genera which are not represented in the latter. The Neyveli lignite assemblage has been found to be distinctly different from the present one.
8. The high frequency of fungal remains in the Barail Group and Bhuban Formation is suggestive of warm and humid climatic conditions during the sedimentation of these sediments.

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The genus *Phyllanthus* from the Tertiary of India with critical remarks on the nomenclature of fossil woods of Euphorbiaceae

U. Prakash, M. B. Bande & V. Lalitha

ABSTRACT

Prakash, Uttam, Bande, M.B. & Lalitha, V. (1986). The genus *Phyllanthus* from the Tertiary of India with critical remarks on the nomenclature of fossil woods of Euphorbiaceae. *Palaeobotanist*, **35**(1) : 106-114.

The paper deals with in detail the problem of nomenclature of fossil woods of the family Euphorbiaceae and describes two fossil woods showing a close similarity with the modern woods of *Phyllanthus emblica* from the Tertiary of India. While one of them belongs to the Tipam sandstones of Assam, the other was collected from the Deccan Intertrappean beds of Nawargaon in Wardha District of Maharashtra. The present findings thus indicate a continuous existence of the modern genus *Phyllanthus* in India from the early Tertiary till today. Speciation of fossil woods similar in structure and resembling the modern wood of *Phyllanthus emblica*, from widely separated continents belonging to different ages, has also been discussed.

Key-words—Xylotomy, Nomenclature, *Phyllanthus*, Euphorbiaceae, Tipam Sandstones, Deccan Intertrappean beds, Tertiary (India).

Uttam Prakash & M. B. Bande, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

V. Lalitha, 2-Gayatri, Chheda Nagar, Chembur, Bombay 400 089, India.

सारॉंश

भारत के तृतीयक कल्प से फ़ाइलेन्थस प्रजाति तथा यूफ़ोर्बिएसी कुल के काष्ठाश्मों की नामपद्धति पर समीक्षात्मक टिप्पणियाँ

उत्तम प्रकाश, मोहन बलवंत बाँडे एवं वी. ललिथा

इस शोध-पत्र में यूफ़ोर्बिएसी कुल के काष्ठाश्मों की नामपद्धति की समस्या तथा भारत के तृतीयक कल्प से फ़ाइलेन्थस ॲम्बलिका के वर्तमान काष्ठों से घनिष्ठ समानता प्रदर्शित करने वाले दो काष्ठाश्मों का विस्तृत विवेचन किया गया है। इनमें से एक असम के तिपम बालुपत्थरों से सम्बद्ध है तथा अन्य महाराष्ट्र के वर्धा जनपद में नवरगाँव के दक्खिन अन्तर्ट्रैपी संस्तरों से एकत्र किया गया था। अतएव प्रस्तुत अन्वेषण से भारत में प्रारम्भिक तृतीयक कल्प से आज तक वर्तमान फ़ाइलेन्थस प्रजाति की निरन्तर विद्यमानता इंगित होती है। फ़ाइलेन्थस ॲम्बलिका की वर्तमान काष्ठ से मिलते-जुलते एवं संरचना में सदृश काष्ठाश्मों का जाति-उद्‌भवन विवेचित किया गया है, विभिन्न आयु के ये काष्ठाश्म पृथक-पृथक महाद्वीपों से सम्बन्धित हैं।

INTRODUCTION

IN palaeobotany it is always interesting to build up the fossil history of a taxon in space and time. Although it is usually from the Neogene onwards that the fossils can be identified with any particular species, sometimes this becomes possible even in the earlier strata. Thus, it becomes even more remarkable when fossils showing similarities with a single modern species are discovered in the rocks of widely separated areas belonging to different ages. The authors came across one such case while working on the fossil woods from the Tipam sandstones of Assam and the Deccan Intertrappean beds of Nawargaon in Maharashtra. From both these beds fossil woods showing a close similarity with the modern woods of *Phyllanthus emblica* were discovered. As the age of Tipam sandstones is considered to be Upper Miocene and that of the Deccan Intertrappean beds as early Tertiary, the present findings establish a continuous existence of the genus *Phyllanthus* in India since the early Tertiary.

FAMILY—EUPHORBIACEAE

Genus—*Paraphyllanthoxylon* Bailey, 1924

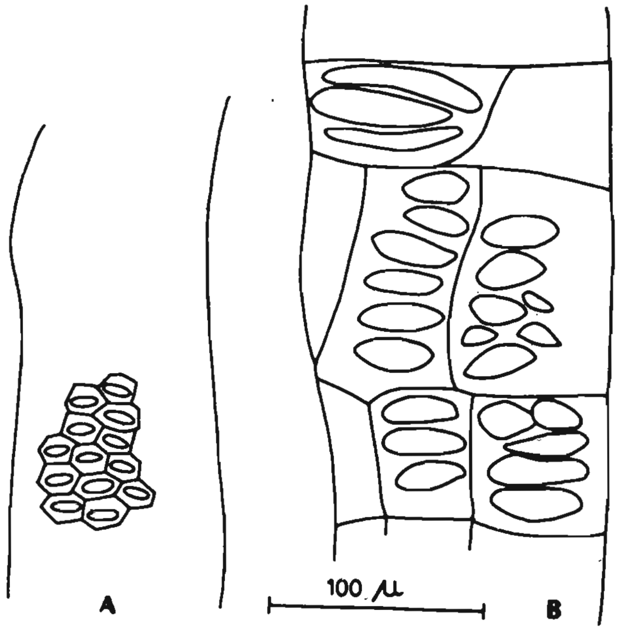
Paraphyllanthoxylon palaeoemblica sp. nov.

Pl. 1, figs 1, 2, 9, 11; Text-fig. 1a, 1b

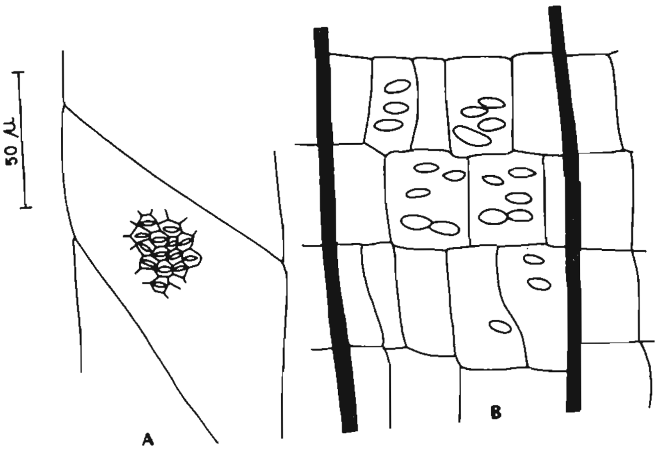
Material—A single piece of well preserved mature secondary wood measuring 6 cm in length and 4 cm in width.

Topography—*Wood* diffuse porous. *Growth rings* absent. *Vessels* small to medium-sized, solitary and mostly in radial multiples of 2-5, rarely in tangential rows and irregular clusters, 5-9 per sq mm (Pl. 1, fig. 1); tyloses absent, reddish gum deposits present in some vessels. *Parenchyma* scanty paratracheal with occasional cells touching the vessels (Pl. 1, fig. 1). *Xylem rays* 1-7 (rarely up to 9) seriate, 30-195 μm wide, 6 per mm; ray tissue heterogeneous (Pl. 1, fig. 2) rays of two types according to size and composition: (a) uniseriate rays homocellular composed of upright cells only, 3-12 cells and up to 850 μm in height (Pl. 1, fig. 2); (b) multiseriate rays heterocellular consisting of procumbent cells in the median thickened portion with distinct sheath cells on both the flanks and 1-7 rows of marginal upright cells at one or both the ends, 6-43 cells and up to 2500 μm in height (Pl. 1, fig. 2). *Fibres* aligned in radial rows.

Elements—*Vessels* anglular to circular in cross section, t.d. 75-90 μm, r.d. 120-165 μm; vessel members 164-675 μm in length with truncate or tapering ends; perforations simple; intervessel pit-pairs bordered, alternate, 8-12 μm in diameter, round to polygonal in shape with linear to lenticular apertures (Pl. 1, fig. 11; Text-fig. 1a); vessel-ray pits large, simple, usually horizontally elongated, 20-32 μm in diameter (Text-fig. 1b). *Ray cells* thin-walled, procumbent cells 28-36 μm in tangential height and 110-130 μm in radial length; upright cells 48-140 μm in tangential height 40-48 μm in radial length. *Fibres* polygonal in cross section, semilibriform to libriform, septate, about 15 μm in diameter and up to 1500 μm in length; interfibre pits could not be seen.



Text-fig. 1—*Paraphyllanthoxylon palaeoemblica* from Tipam sandstones, (**A**) intervessel pit-pairs, and (**B**) vessel-ray pits.



Text-fig. 2—*Paraphyllanthoxylon palaeoemblica* from Deccan Intertrappean beds, (**A**) intervessel pit pairs, and (**B**) vessel ray pits.

AFFINITIES AND DISCUSSION

From the above description it is clear that the fossil is characterised by important anatomical features such as small to medium-sized vessels without tyloses; simple perforations; large, alternate intervessel pit-pairs with linear to lenticular apertures; simple, large, usually horizontally elongated vessel-ray pits; scanty paratracheal parenchyma; broad heterogeneous rays with sheath cells and septate fibres. All these characters indicate the affinities of this fossil to the family Euphorbiaceae with a close resemblance with the members of the *Glochidion* group of the sub-family Phyllanthoideae.

The family Euphorbiaceae is extremely heterogeneous in wood structure. It shows a great variation of vascular tissues with no diagnostic characters which are constant in the family as a whole. This family has been divided into two sub-families, viz., Phyllanthoideae and Crotonoideae. Phyllanthoideae has been further divided into two groups; Group A—*Aporosa* Type and Group B—*Glochidion* Type (Metcalfe & Chalk, 1950, pp. 1208, 1219-1227). According to Metcalfe and Chalk (1950, p. 1221), the *Glochidion* Type includes the woods of *Antidesma* Burm. ex Linn., *Aporosella* Chodat, *Hymenocarida* Wall. (Antidesminae), *Bischofia* Bl., (Bischofinae), *Glochidion* (Glochidiinae), *Phyllanthus* L., *Securinega* Comm. ex. Juss. (Phyllanthinae), *Bridelia* Willd. and *Cleistanthus* Hook. (Brideliae) of the sub-family Phyllanthoideae and *Acalypha* Linn. (Acalypheae) of the sub-family Crotonoideae.

Since the present fossil wood belongs to the *Glochidion* type, the anatomy of the members showing this type of wood structure has been studied here in detail. The woods belonging to *Glochidion* type are distinguished mainly by the presence of septate fibres and the absence of parenchyma or its limitation to a few cells around the vessels. From a detailed comparison of the present wood with the woods of the extant genera of *Glochidion* type at the Xylaria of the Forest Research Institute, Dehra Dun and the Birbal Sahni Institute of Palaeobotany, Lucknow it has been found that the present fossil wood closely resembles the wood structure of the modern genus *Phyllanthus* Linn. and differs from all others in a number of characters.

Antidesma, *Aporosella* and *Hymenocardia* can be differentiated from the fossil under discussion in having both simple and scalariform perforation plates. Further, the intervessel pit-pairs are small in *Acalypha* and *Hymenocardia* and minute in *Aporosella*, whereas they are large in the present fossil. *Bischofia* differs from this fossil in having usually large vessels with abundant tyloses and 1-5 seriate xylem rays. *Glochidion* also differs from it in having large vessels, minute intervessel pits and 1-3 (—4) seriate xylem rays. While *Securinega* can be distinguished by its scalariform performation plates which are absent in the fossil; in *Bridelia* the growth rings are distinct, delimited by a line of parenchyma in some species and the rays are only 1-5 seriate. Moreover, intervessel pits are small in *Bridelia* and minute in *Cleistanthus* and are vestured in both (Janssonius, 1930, pp. 483-486; Bailey, 1933, p. 265, pl. 63, fig. 14) which further separate them from the wood under discussion.

When compared with all the available species of the genus *Phyllanthus*, viz., *Phyllanthus emblica* Linn., *Phyllanthus indicus* Muell., *Phyllanthus polyphyllus* Willd. and *Phyllanthus reticulatus* Poir., it was found that the fossil is almost identical to *Phyllanthus emblica* Linn. (B.S.I.P. slide no. W 493; F. R. I. slide no. A5552/C3539; Pearson & Brown, 1932, pp. 877-880, fig. 274). In both the extant wood of *Phyllanthus emblica* as well as the present fossil wood the growth rings are absent, vessels are small to medium-sized, open with simple perforations, intervessel pits are medium to large and vessel-ray pits are large and usually horizontally elongated, parenchyma is sparse, restricted to occasional cells around the vessels, xylem rays are 1-9 seriate with strongly heterogeneous ray tissue and the fibres are semilibriform or libriform and septate. However, the ray cells and vessel-ray pits of *Phyllanthus emblica* are slightly smaller than the fossil. But this is a variable feature.

So far a number of fossil woods belonging to the family Euphorbiaceae have been described under different generic names from many parts of the world. These genera are being listed below in Table 1.

It was Bailey who in 1924 instituted the fossil genus *Paraphyllanthoxylon* for the reception of dicotyledonous woods having combinations of anatomical characters which occur in mature stems of *Phyllanthus emblica* L. and other structurally similar representatives of the Phyllanthoideae. However, in 1932, Ogura, being unaware of the fossil genus *Paraphyllanthoxylon* Bailey (1924), also created a new genus *Phyllanthinium* for the fossil woods of Phyllanthoideae, although he himself was not clear about the affinities of his fossil. He has mentioned in his paper that, "it is, of course, impossible to determine the exact affinity of the fossil now in question only from the structure of the wood, but the writer considers it to be one of the Euphorbiaceae, especially of the tribe Phyllanthoideae, which is however, different from any of the living species, so that it will be a new representative of this or a related family" (Ogura, 1932, p. 189). In 1956, Ramanujam instituted another genus *Glochidioxylon* for the fossil woods which resemble the extant woods of *Glochidion* group. He says that, "Bailey (1924) while describing a fossil wood from the Cretaceous of Arizona; which according to him shows resemblance with *Phyllanthus* and other structurally similar representatives of Phyllanthoideae, instituted a new name *Paraphyllanthoxylon* for the fossil woods showing apparent similarities to the section Phyllanthoideae. Ogura (1932) created a new generic name *Phyllanthinium* for his fossil wood resembling according to him genera like *Antidesma, Glochidion, Bischofia* and *Bridelia*. Our fossil too, it is obvious, resembles these genera which by virtue of their anatomical characters fall under the wood type of the *Glochidion* group. Since the section Phyllanthoideae

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PLATE 1

1. *Paraphyllanthoxylon palaeoemblica* sp. nov.—Cross section showing radial rows of vessels, scanty paratracheal parenchyma and broad xylem rays. × 25 B.S.I.P. slide no. 8008.
2. *Paraphyllanthoxylon palaeoemblica* sp. nov.—tangential longitudinal section showing uni-to multiseriate xylem rays with sheath cells. × 30 B.S.I.P. slide no. 8009.
3. *Paraphyllanthoxylon palaeoemblica*—Cross section showing distribution of vessels and broad xylem rays. × 30 B.S.I.P. slide no. 8011.
4. *Phyllanthus emblica*—Cross section. × 30.
5. *Paraphyllanthoxylon palaeoemblica*—Cross section magnified to show vessels, broad xylem rays and scanty paratracheal parenchyma. × 80. B.S.I.P. slide no. 8011.
6. *Phyllanthus palaeoemblica*—Cross section magnified. × 80.
   Paraphyllanthoxylon emblica—Tangential longitudinal section showing broad, heterogeneous xylem rays. × 30 B.S.I.P. slide no. 8012.
8. *Phyllanthus emblica*—Tangential longitudinal section. × 30.
9. *Paraphyllanthoxylon palaeoemblica* sp. nov. Radial longitudinal section. × 150 B.S.I.P. slide no. 8010.
10. *Phyllanthus emblica*—Radial longitudinal section. × 80.
11. *Paraphyllanthoxylon palaeoemblica* sp. nov.—Intervessel pit pairs × 500. B.S.I.P. slide no. 8009.

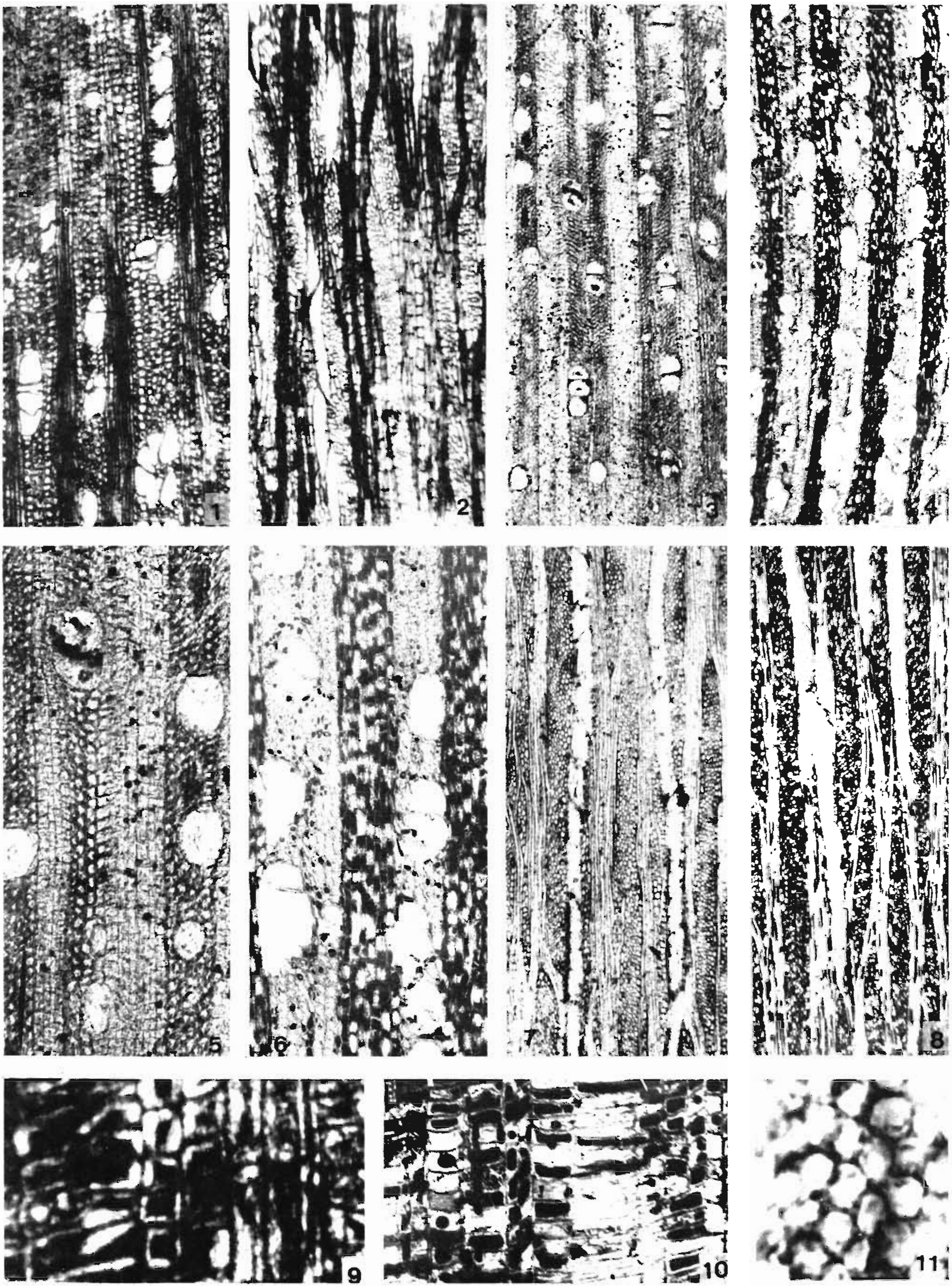

PLATE 1

Table 1

	Fossil Genus	*Author and year*	*Modern comparable taxa*
1.	*Euphorbioxylon*	Felix, 1887	Crotonoideae group (*Euphorbia, Jatropha*)
2.	*Paraphyllanthoxylon*	Bailey, 1924	*Phyllanthus emblica* and other structurally similar representatives of Phyllanthoideae
3.	*Phyllanthinium*	Ogura, 1932	Phyllanthoideae
4.	*Heveoxylon*	Kruse, 1954	*Hevea* Aubl.
5.	*Glochidioxylon*	Ramanujam, 1956	*Glochidion* type of woods
6.	*Putranjivoxylon*	Ramanujam, 1956	*Putranjiva* Wall.
7.	*Bridelioxylon* syn. Bischofioxylon	Ramanujam, 1956; Ramanujam, 1960	*Bridelia* Willd.
8.	*Aleuritoxylon*	Mädel, 1962	*Aleurites* Forst.
9.	*Securinegoxylon*	Mädel, 1962	*Securinega* Comm. ex. Juss.
10.	*Mallotoxylon*	Lakhanpal & Dayal, 1964	*Mallotus* Lour.
11.	*Bischofinium*	Bande, 1974	*Bischofia* Bl.

could be split up into two groups, *Glochidion* and *Aporosa* based on the wood anatomy, each group characterized by its own set of anatomical characters, it might be better and probably more natural, if the fossil woods showing affinities to these groups be named after these groups, unless they exhibit unmistakable resemblance with some particular genus, instead of grouping such woods under a single rather broad genus *Phyllanthinium* or *Paraphyllanthoxylon.*" However, he also added that the generic name "*Paraphyllanthoxylon* may be retained for the woods coming from the Cretaceous horizon" which seems quite unreasonable to us considering the origin and evolution in angiosperms.

In 1962, Mädel further classified the woods of the family Euphorbiaceae in a number of groups based on their wood anatomy. These are *Aporosa* group, *Putranjiva* group, *Glochidion* group, *Bridelia* group and *Crotonoideae* group (Mädel, 1962, pp. 285, 286, Table 1). All these are being listed in Table 2 with their anatomical characters and the fossil genera included under them. Among these, the woods of *Putranjiva* group and *Aporosa* group are anatomically quite similar except that the xylem rays are broader in the woods of *Aporosa* group than in *Putranjiva* group. She (Mädal, 1962, p. 307) also transferred all the *Glochidion*-type of fossil woods, which do not show affinity with any particular genus, to *Paraphyllanthoxylon* Bailey. All those assigned to this genus by her are: *Paraphyllanthoxylon arizonense* Bailey, 1924 syn. *Laurinoxylon arizonense* (Bailey) Berger, 1950; *P. pseudohobashiraishi* (Ogura) Mädel, 1962 syn. *Phyllanthinium pseudohobashiraishi* Ogura (Ogura, 1932; Watari, 1943); *P. tertiarum* (Ramanujam) Mädel, 1962 syn. *Glochidioxylon tertiarum* Ramanujam, 1956; *P. sahnii* (Prakash) Mädel, 1962 syn. *Glochidioxylon sahnii* Prakash, 1959; *P. pfefferi* (Platen) Mädel, 1962 syn. *Carpinoxylon pfefferi* Platen, 1908; and *P. capense* Mädel, 1962.

However, while critically analysing the above three closely related fossil genera, viz., *Paraphyllanthoxylon* Bailey, *Phyllanthinium* Ogura and *Glochidioxylon* Ramanujam, it appears that they need to be redefined in the light of our recent observations.

Although, the genus *Paraphyllanthoxylon* Bailey was established for the fossil woods of *Phyllanthus emblica* and structurally similar woods of Phyllanthoideae, a critical examination of the genotype *Paraphyllanthoxylon arizonense* shows unmistakable affinities with the modern woods of *Phyllanthus.* The wood of *Phyllanthus* is characterized by large horizontally elongated vessel-ray pits and broader rays showing strikingly heterogeneous ray tissue with long sheath cells. Consequently, it is proposed here to retain the genus *Paraphyllanthoxylon* Bailey for the fossil woods of *Phyllanthus* only. As Bailey (1924) has not given any generic diagnosis for his genus *Paraphyllanthoxylon*, this is being given here in the following pages.

Considering the other two genera *Phyllanthinium* Ogura and *Glochidioxylon* Ramanujam, it appears that the first was meant theoretically for the fossil woods of Phyllanthoideae as a whole, while the other was restricted to *Glochidion*-type of woods among Phyllanthoideae and Crotonoideae. However, a critical examination of their diagnoses and a review of their discussion indicate that their genotypes were compared with the modern woods of the same set of genera such as *Glochidion, Antidesma, Bischofia* and *Bridelia.* Therefore, it would be appropriate to merge and assign them to the *Glochidion*-type of woods in general. As *Phyllanthinium* Ogura has a priority over *Glochidioxylon* Ramanujam, being published earlier, *Phyllanthinium* Ogura becomes a valid name for the fossil woods of *Glochidion* group, while *Glochidioxylon* Ramanujam becomes its synonym. Further, as some of the characteristic features of the *Glochidion* group have not been given in the original diagnosis of *Phyllanthinium* Ogura, an emended generic diagnosis is being given below, so as to include all the fossil woods showing anatomical characters similar to the modern woods of this group except *Phyllanthus.*

EMENDED GENERIC DIAGNOSIS

Phyllanthinium Ogura emend.

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* small to medium-sized; tyloses present or absent; vessel members with truncate or tailed ends; perforations simple; intervessel pits minute to large; vessel-ray pits mostly rounded. *Parenchyma* typically absent or scantly paratracheal to vasicentric. *Xylem rays* 1-4 seriate, ray tissue heterogeneous. *Fibres* non-libriform to libriform and septate.

The fossil woods which have now been transferred to this newly circumscribed genus *Phyllanthinium* Ogura emend. are: *Phyllanthinium pseudohobashiraishi* Ogura, 1932 from Tertiary, Japan; *P. idahoense* (Spackman) comb. nov. syn. *Paraphyllanthoxylon idahoense* Spackman, 1948 from Upper Cretaceous, U.S.A.; *P. tertiarum* (Ramanujam) comb. nov. syn. *Glochidioxylon tertiarum* Ramanujam, 1956 from Mio-Pliocene, Cuddalore sandstones, South India; *P. sahnii* (Prakash) comb. nov. syn. *Glochidioxylon sahnii* Prakash, 1959 from Eocene, Deccan Intertrappean beds, Central India; *P. bengalamodense* Navale, 1962 from Mio-Pliocene, Cuddalore sandstones, South India; *P. keriense* (Dayal) comb. nov. syn. *Paraphyllanthoxylon keriense* Dayal, 1967 from Eocene, Deccan Intertrappean beds, Central India; *P. yvardi* (Koeniguer) comb. nov. syn. *Paraphyllanthoxylon yvardi* Koeniguer, 1970 from

TABLE 2

	PHYLANTHOIDEAE				CROTONOIDEAE
Anatomical groups	*Aporosa* group	*Putranjiva* group	*Glochidion* group	*Bridelia* group	*Crotonoideae* group
Extant genus	*Aporosa, Baccaurea, Dicoelia, Maesobotrya, Protomegabaria, Richeria* (Antidesminae)	*Putranjiva* (Glochidienae), *Drypetes, Lingelsheimia* (Drypetinae)	*Antidesma, Aporosella, Hymenocardia* (Antidesminae), *Bischofia* (Bischoffiinae), *Glochidion* (Glochidiinae), *Phyllanthus, Securinega* (Phyllanthinae), *Acalypha* (Crotonoideae)	*Bridelia, Cleistanthus* (Brideliae)	All members of Crotonoideae except *Acalypha*
Fossil genus	Not known	*Putranjivoxylon* Ramanujam	*Paraphyllanthoxylon* Bailey, *Securinegoxylon* Mädel *Bichofinium* Bande	*Bridelioxylon* Ramanujam	*Euphorbioxylon* Felix *Heveoxylon* Kruse *Aleuritoxylon* Mädel *Mallotoxylon* Lakhanpal & Dayal
Wood	Diffuse-porous	Diffuse-porous	Diffuse-porous, seldom ring-porous	Diffuse-porous	Diffuse-porous, seldom ring-porous
Vessels	Radial groups; perforations scalariform (seldom simple and scalariform); intervessel pit-pairs small, alternate; vessel ray pits large.	Radial groups of 2-4; perforations scalariform or simple and scalariform; intervessel pit-pairs small, alternate; vessel ray pits large.	Radial groups of 2-4; tyloses may or may not be present; perforations simple or simple and scalariform; intervessel pitting alternate; vessel ray pits large or not large, seldom with spiral thickenings	Radial groups; perforations simple (seldom simple and scalariform); intervessel pits large or not large	Solitary and in radial groups of 2-4; perforations simple (seldom scalariform or simple and scalariform, intervessel pits alternate, opposite; vessel ray pits large or not large, sometimes with spiral thickenings
Fibres	Non septate, thick-walled with simple pitting	Non-septate, thick-walled with simple pitting	Septate, mostly thick-walled with simple pitting	Septate	Non-septate, mostly thick-walled with simple pitting
Parenchyma	Abundant as scattered cells and numerous short uniseriate bands; chambered crystals present	Abundant as scattered cells and numerous short uniseriate bands; chambered crystals present	Absent or as dead cells; scanty paratracheal	Spares to abundant paratracheal	Profusely diffuse, frequently one row thick or bands, sometimes paratracheal, aliform and confluent; cells crystaliferous
Xylem rays	Two types; uniseriate and broad (up to 17 cells typically 4-17 cells wide), height more than 1 mm, strongly heterogeneous	1-3 seriate, height more than 1 mm, strongly heterogeneous	Two types; uniseriates and up to 11 cells broad, height more than 1 mm, strongly heterogeneous	Moderately broad, height mostly less than 1 mm	Moderately broad, sometimes uniseriate height more than 1 mm, strongly heterogeneous

TABLE 3—FOSSIL WOODS OF *PARAPHYLLANTHOXYLON* BAILEY SHOWING IDENTITY WITH THE EXTANT GENUS *PHYLLANTHUS* LINN.

Fossil Species	Growth Rings	Vessels	Parenchyma	Xylem Rays	Fibres	Modern Equivalent	Locality and Age
Paraphyllanthoxylon arizonense Bailey, *1924*	Feebly differentiated	Solitary or grouped in radial clusters of 2-4, 8-14 per sq mm; tyloses present; perforations simple; intervessel pits bordered, alternate; vessel-ray pits transversely elongated	Scanty paratracheal	1-7 seriate; ray tissue heterogeneous	Thick walled, septate	*Phyllanthus emblica*	Arizona, U.S.A., Upper Cretaceous
Paraphyllanthoxyion capense Madel, 1962	Indistinct	Solitary and in radial rows of 2-5(-6), t.d. 35-100 μm, r.d. 60-135 μm 24-60 per sq mm; tyloses absent; perforations simple, intervessel pits large; vessel ray pits, simple, large, horizontally elongated	Absent or seldom scanty paratracheal	1-5 seriate; ray tissue heterogeneous	Libriform septate	*Phyllanthus discoideus*	South Africa; Upper Cretaceous
Paraphyllanthoxylon palaeoemblica sp. nov.	Indistinct	Solitary and in radial multiples of 2-5 and in clusters, t.d. 75-90 μm r.d. 120-165 μm, 5-9 per sq mm; tyloses absent; perforations simple; intervessel pit-pairs large; vessel ray pits simple large, horizontally elongated	Scanty paratracheal	1-9 seriate; ray tissue strongly heterogeneous; sheath cells present	Semilibriform to libriform, septate	*Phyllanthus emblica*	Nailalung Railway station, Assam. Tipam sandstones (Upper Miocene)
Paraphyllanthoxylon palaeoemblica	Absent	Solitary and in radial multiples of 2-4, t.d. 60-160 μm, r.d. 80-175 μm 10-12 per sq mm; tyloses absent; perforations simple; intervessel pits-pairs bordered, alternate, 6-8 μm in diameter; vessel ray pits simple, large, horizontally elongated	Scanty paratracheal	1-9 seriate; ray tissue heterogeneous sheath. cells present.	Semilibriform, septate	*Phyllanthus emblica*	Nawargaon near Wardha in Maharashtra; Deccan Intertrappean beds (early Tertiary)

Miocene, France; *P. alabamense* (Cahoon) comb. nov. syn. *Paraphyllanthoxylon alabamense* Cahoon, 1972 from Cretaceous, U.S.A.; and *P. utahense* (Thayn) comb. nov. syn. *Paraphyllanthoxylon utahense* Thayn in Tidwell *et al.*, 1976, Lower Cretaceous, U.S.A.

As the present fossil wood resembles the modern wood of *Phyllanthus emblica*, it is assigned to the redefined genus *Paraphyllanthoxylon* Bailey (1924). A critical examination of all the fossil woods belonging to *Glochidion* group indicates that only *Paraphyllanthoxylon arizonense* Bailey (1924) from the Cretaceous of Arizona and *Paraphyllanthoxylon capense* Mädel (1962) from the Upper Cretaceous of Africa belong to the genus *Phyllanthus*. Their anatomical characters have been summarized in Table 3. Of the two, *Paraphyllanthoxylon capense* which has been said to show similarities with *Phyllanthus discoideus* (Mädel, 1962, p. 295), differs from the present fossil in having greater frequency of vessels (24-60 vessels per sq mm) as against 5-9 vessels per sq mm in the present fossil and in possessing narrower, 1-5 seriate xylem rays which are up to 9 seriate in the wood under discussion. The other species *Paraphyllanthoxylon arizonense* Bailey, although very similar to the present fossil in its anatomical details, differs from it in having bigger vessels. While *Paraphyllanthoxylon arizonense* has been described from the upper Cretaceous of the Colorado group of Arizona, the fossil wood described here belongs to the Tipam sandstones (Upper Miocene) of Assam. Considering the occurrence of the above two fossil woods in widely separated continents of the Old and the New world, one in the United States of America and the other in north-east India, together with a vast difference in their ages, it becomes difficult to visualize that a single species of a genus could have existed in two such remote continents at different periods of time. As such the present fossil has been described under a new species *Paraphyllanthoxylon palaeoemblica*, the specific name suggesting that it might represent a form from which the modern species *Phyllanthus emblica* has evolved.

Present Distribution of Phyllanthus Linn.—The genus *Phyllanthus* consists of trees, shrubs and herbs which are mostly deciduous. These are widely distributed in the tropical and warm temperate regions of both the hemispheres except Europe and North Asia (Willis, 1973, p. 892). Over 600 species of this genus have been described of which 50 species occur in India. *Phyllanthus emblica* Linn. with which the fossil compares closely is a small to medium-sized timber tree having a wide range in India and Burma, and likewise extends to

Ceylon. In India, it is common in Uttar Pradesh, Bengal and stretches eastwards to Assam.

GENERIC DIAGNOSIS

Paraphyllanthoxylon Bailey, 1924

Wood diffuse-porous. *Growth rings* indistinct or absent. *Vessels* small to medium-sized, solitary and in radial multiples; tyloses absent or present; perforations simple; intervessel pits bordered, alternate, medium to large. *Parenchyma* absent or scanty paratracheal. *Xylem rays* 1-10 or more seriate; ray tissue heterogeneous, sheath cells present. *Fibres* non-libriform to libriform and septate.

Genotype—Paraphyllanthoxylon arizonense Bailey, 1924.

SPECIFIC DIAGNOSIS

Paraphyllanthoxylon palaeoemblica sp. nov.

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* small to medium-sized, occasionally solitary, mostly in radial rows of 2-5, sometimes in tangential rows of 2-4 and in clusters, 5-9 per sq mm, t.d. 75-90 μm, r.d. 120-165 μm; vessel members 165-675 μm long; perforations simple; intervessel pit-pairs bordered, alternate, 8-12 μm in diameter, with linear to lenticular apertures; vessel-ray pits large, mostly elliptical and horizontally elongated. *Parenchyma* scanty paratracheal with occasional cells touching the vessels. *Xylem rays* 1-7 (—9) seriate and 30-190 μm in width, 6 per mm; ray tissue heterogeneous, uniseriate rays homocellular made up of upright cells, 3-7 cells or up to 600 μm in height, the multiseriate rays heterocellular with sheath cells on the flanks, 6-43 cells or up to 2500 μm in height. *Fibres* polygonal in cross section, semi-libriform to libriform, septate, about 15 μm in diameter and up to 1500 μm in length.

Holotype—B.S.I.P. Museum no. 35538.

Locality—Near Nailalung Railway Station, about 23 km from Lumding, Assam.

Besides the fossil wood described in these pages one more fossil wood, collected from the Deccan Intertrappean beds of Nawargaon in Wardha District of Maharashtra, was found to possess a close similarity with the modern wood of *Phyllanthus emblica* (Forest Research Institute, Dehra Dun slide no. 5969). It also resembles very closely the fossil species *Paraphyllanthoxylon palaeoemblica* described earlier except that the xylem rays in this wood are longer than in *P. palaeoemblica* and the intervessel and vessel-ray pits are slightly smaller. However, these variations have also been observed in different samples of *Phyllanthus emblica*. Therefore, it is being described here under the same species indicating the variations. The occurrence of this type of wood in the Deccan Intertrappean beds further extends the antiquity of fossil woods resembling *Phyllanthus emblica* to early Tertiary.

Paraphyllanthoxylon palaeoemblica

Material—A single piece of mature secondary wood measuring 10 cm in length and 6 cm in diameter. The preservation of anatomical features is quite satisfactory.

Topography— Wood diffuse-porous. *Growth rings* absent. *Vessels* small to medium-sized, solitary and in radial multiples of 2-4 or in small clusters, 10-12 per sq mm (Pl. 1, fig. 3); tyloses absent. *Parenchyma* scanty paratracheal as few cells around the vessels to uniseriate vasicentric (Pl. 1, fig. 5). *Xylem rays* fine to broad, 1-9 seriate, visible to the naked eye as dark coloured lines running radially on the cross-surface, uniformly distributed, 5-7 per mm (Pl. 1, fig. 3); ray tissue heterogeneous, rays of two distinct types; uniseriate rays less numerous than the multiseriates, homocellular made up of upright cells only, 3-7 cells or 145 to 320 μm in height (Pl. 1, fig. 7); multiseriate rays 2-9 seriate or 35-160 μm in width and 5 to 120 cells or 180-4000 μm in height, heterocellular made up of procumbent cells in the middle part and with or without 2-10 cells high uniseriate extensions of upright cells at one or both the ends; sheath cells present (Pl. 1, fig. 7); ray to ray fusion observed. *Fibres* aligned in radial rows in between the rays.

Elements—Vessels circular to oval when solitary, with flat contact walls when in groups, t.d. 60 to 160 μm, r.d. 80-175 μm, vessel members 200-400 μm long with oblique ends; perforations simple; intervessel pit-pairs bordered, alternate, angular due to crowding, with linear to lenticular apertures, 6-8 μm in diameter (Text-fig. 2a). *Parenchyma* cells thin-walled, 20-30 μm in width and 30-70 μm in length. *Ray cells* thin-walled, upright cells 20-40 μm in radial length and 40-60 μm in tangential height, procumbent cells 12-25 μm in tangential height and 25-40 μm in radial length; vessel-ray pits simple, large, horizontally elongated, 12-16 μm in diameter (Text-fig. 2b). *Fibres* semilibriform with broad lumen, circular to angular in cross section, septate, 15-25 μm in diameter and 400 to 1000 μm in length; interfibre pits could not be seen.

Specimen—B.S.I.P. Museum no. 35539.

Locality—Nawargaon, Wardha District, Maharashtra.

Horizon—Deccan Intertrappean beds.

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THIRTY-THIRD SIR ALBERT CHARLES SEWARD MEMORIAL LECTURE

Analysis of some palaeogeographic and palaeoecologic problems of palaeobotany

Daniel I. Axelrod*

Department of Botany, University of California, Davis 95616 (U.S.A.)

FOR a lecture dedicated to the memory of Sir Albert Charles Seward, and at the Institute of Palaeobotany bearing the name of his pupil and close friend, Birbal Sahni, it seems appropriate to consider a topic that was near the center of their scientific interests—the palaeogeography and palaeoecology of past floras. This is also appropriate since in the past two decades major advances in geology-geophysics have clarified our understanding that the Earth's crust is not stable. Continents, as well as parts of them, have moved long distances during geologic time, transporting fossil floras and faunas to positions distant from areas where they earlier lived.

Some of the most interesting and elusive problems of palaeobotany, and the field is filled with them, pertain to the vertical zonation of fossil floras, the juxtaposition of dissimilar floras, as well as the occurrence of similar floras in widely separated areas. We also find in the Neogene the association of fossil species whose close modern descendants (or the same species) are now in the same general region but are widely separated in altitude and distance from the fossil site. How are these to be explained when there is no evidence of high relief in the region during deposition? Such problems naturally involve an understanding of the geologic occurrence of the fossil flora, its topographic setting, the manner in which it may be interpreted in terms of its altitude and latitude, the responses of its taxa to changes in climate, and how local climate may account for the persistence of relict taxa, as well as the origin of new ones, for plants do change in time—some slowly—others more rapidly. It is these varied aspects of palaeobotany that I have chosen to review here.

PLATE TECTONICS AND DISPLACED FLORAS

Seward and Sahni were well aware of the present disjunct positions of the Glossopteris flora. In fact, Sahni (1935, 1936) believed that the position of the Glossopteris flora "cheek by jowl" with the *Gigantopteris* (and Angaran) flora in the Himalayas was indeed proof of continental displacement (Text-fig. 1). Although Seward and Sahni supported the notion of continental displacement, in those days a physical explanation of the displaced Glossopteris flora on the widely separated lands of Antarctica, Australia, South Africa, Brazil, and India was not certainly known.

One of the overlooked, yet impressive, examples of evidence that supports continental displacement occurs in the Pennsylvanian coalfields of the Appalachians and northwestern Europe. In this case we are dealing not only with numerous similar species in now-distant areas, but with a similar sequence of floral zones [(i.e., species) *in* Moore *et al.*, 1944; Read & Mamay, 1964)] in the coal beds (Text-fig. 2). Early investigators of these sequences were concerned chiefly with evidence of their age, not with explaining the sequential identity of numerous taxa in these now widely separated areas. Under present geographic relations, and regardless of the climate that might be postulated for these areas, it would be impossible to explain the similar succession of taxa by migration around the North Atlantic. Plate tectonic reconstructions of land areas in the Pennsylvanian now indicate that the Atlantic was closed and that the coal bed floras were geographically connected, or nearly so (Text-fig. 3; see Ferm, 1974). Progressively separated by ocean-floor spreading (see Smith *et al.*, 1981), they provide an

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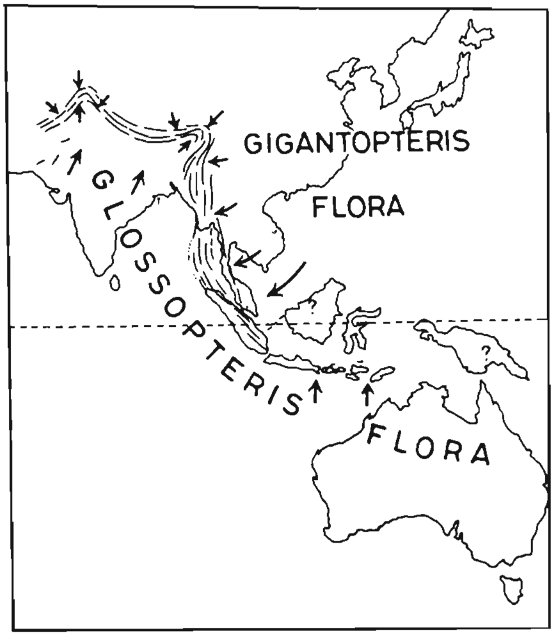


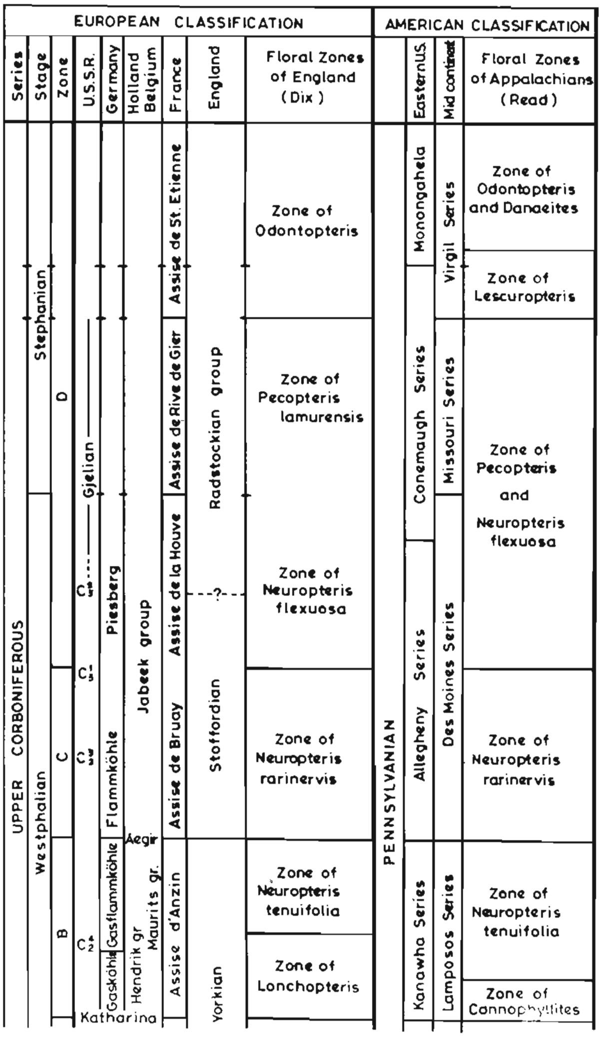
Text-fig. 1—The "cheek by jowl" occurrence of the *Glossopteris* with the *Gigantopteris* (and Angara) floras (from Sahni, 1963).

example of displacement as significant as that of the Glossopteris flora.

There are also examples of displaced Tertiary floras.

1. Two Miocene floras in southern California that are close geographically differ greatly in composition and in the climate that they suggest (Text-fig. 4). The Puente flora of the Los Angeles basin includes broadleaved evergreens (e.g. *Annona, Magnolia, Ficus, Persea, Quercus, Sabal*) and a few rare sclerophylls with small leaves. By contrast, the Mint Canyon flora, situated only 65 km north, is composed chiefly of nanophyllous taxa that reflect semidesert climate. These include species of *Acacia, Bursera, Cardiospermum, Caesalpinia, Ceanothus, Celtis, Cercocarpus, Condalia, Fouquieria, Lysilona* and many others (*in* Axelrod, 1979a). Under present conditions, geologic evidence shows that there was no major topographic barrier between these floras, for the Mint Canyon Formation is overlain with slight unconformity by marine beds of essentially the same age, and these extend west. Detailed studies by Crowell and his associates (Crowell, 1962, 1982; Ramirez, 1983; Link, 1983) show that the Mint Canyon basin was in the area of the present Salton Sea, some 240 km south and in the interior when the Mint Canyon flora was living. At that time the Puente flora was in a marine basin situated near the Mexican border, in a mesic coastal position. It was separated from the Mint Canyon basin by low hills at the site of the present Peninsular Ranges, composed chiefly of granitic rocks. It is this that largely accounts for the contrast between these contemporaneous floras, and the climates that they suggest.

2. The Miocene Carmel flora near Monterey, California, is dominated by broadleaved evergreens, distributed in species of *Ficus, Nectandra, Ocotea, Persea, Quercus* and *Sabal* and others that indicate warm temperate, frostless climate. By contrast, the Temblor flora, situated 145 km southeast is dominated by deciduous hardwoods that lived along the shores of a marine embayment. It includes species of *Glyptostrobus, Pinus, Carya, Castanea, Cornus, Diospyros, Mahonia, Platanus, Nyssa, Quercus* (deciduous) as well as several broadleaved evergreens, notably *Magnolia, Persea* and *Quercus* (Renney, 1972). The Carmel flora is very similar to the Puente of southern California, then situated near the Mexican border, not to the Temblor which is much closer. In view of the position of the Puente much farther south it is expectable that several sclerophyllous taxa are in it, but not in the Carmel or Temblor. Whereas the

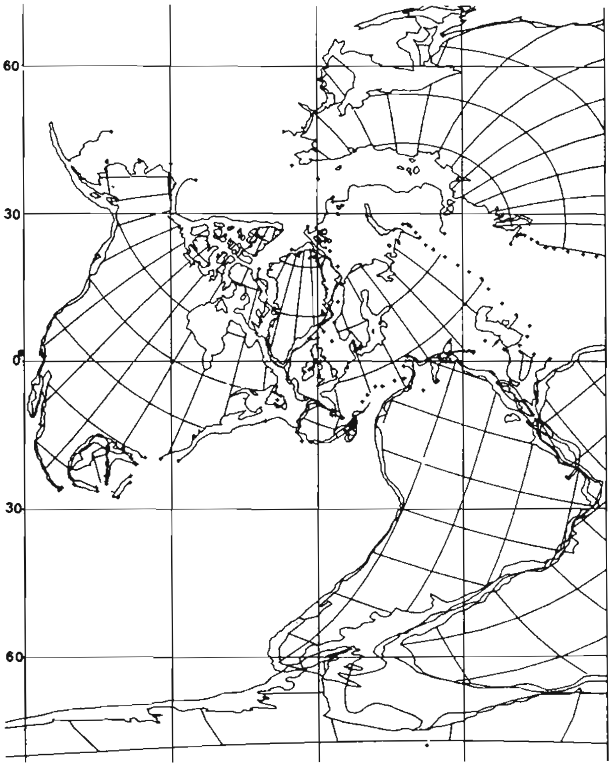


Text-fig. 2—Similar floral zones are represented in the Pennsylvanian coalfields of the Appalachians and England (from Moore *et al.*, 1944). For numerous species common to these zones, see Read and Mamay (1964).

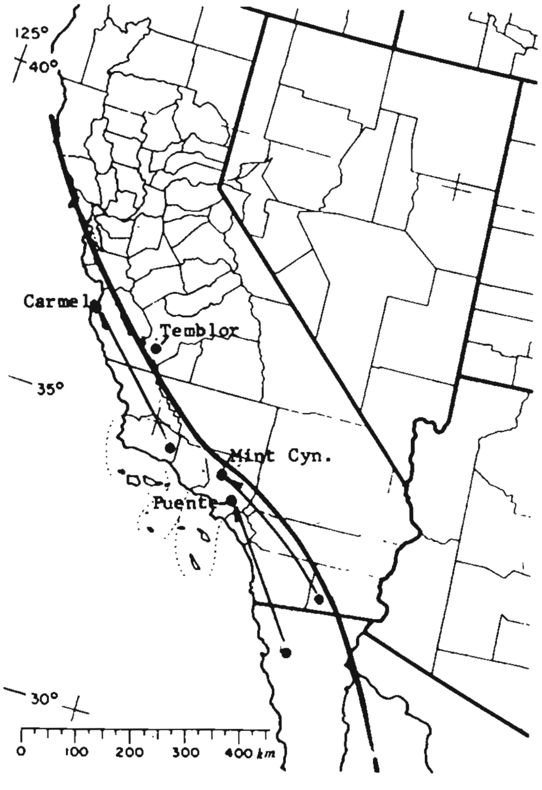
Carmel flora has been displaced northward some 300 km by movement on the San Andreas rift system, the Temblor flora, situated 20 km east of the rift, represents the Miocene vegetation of its area (Text-fig. 4).

3. One might well ask: If the California coastal strip west of the San Andreas rift system has moved northward some 300 km (or more) since the early Miocene (Text-fig. 5) is modern floristic evidence consistent with this displacement? It is noteworthy that the flora of the present outer coastal area and that of the islands off southern California and adjacent Baja California (Cedros, Guadalupe Islands) includes a number of relict trees and shrubs whose closest allies are in the moist, equable uplands of Mexico where there is ample summer rainfall Among these may be noted:

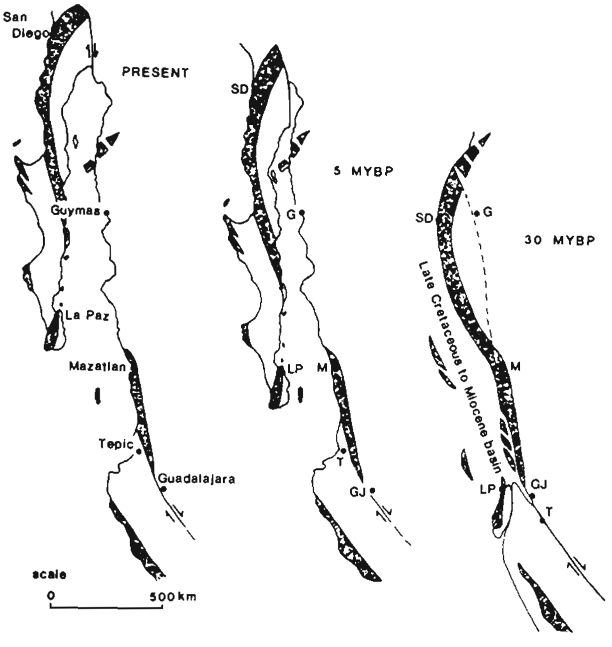
Californian Taxa	Mexican Allies
Cupressus macrocarpa	*C. guadalupensis*; spp.
Pinus muricata	*Oocarpeae* (extinct)
Pinus radiata	*P. oocarpa*
Pinus remorata	*P. oocarpa*
Pinus torreyana	*P. oaxacana*
Arbutus menziesii	*A. xalapensis*
Ceanothus arboreus	*C. coeruleus*
Comarostaphylis diversifolia	*C.* spp.
Cercocarpus traskiae	*C. mojadensis*
Garrya elliptica	*G. ovata*
Gaultheria shallon	*C.* spp.
Laurocerasus (Prunus) lyonii	*L. (P.)* prionophylla
Myrica californica	*M. mexicana*
Vaccinium ovatum	*V. confertum*



Text-fig. 3—Reconstruction of land areas around the North Atlantic region in the Pennsylvanian (from Smith *et al.*, 1981).



Text-fig. 4—Geographic relations of the Carmel, Temblor and Puente floras in the Miocene and today. Floras west of the San Andreas rift have been displaced on the order of 250-300 km.



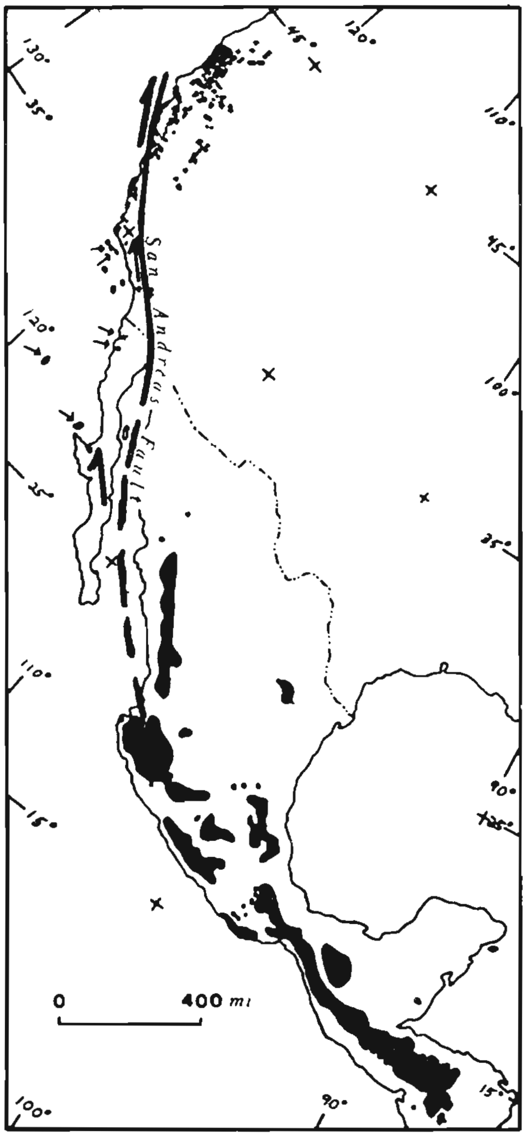
Text-fig. 5—Displacement of the Peninsula of Baja, California, opening of the Gulf of California during the Miocene and later (from Gastil & Jensky, 1973).

The list becomes more impressive when we recall that during the Miocene and Pliocene, when there was ample summer rainfall, other taxa now in the oak-laurel-pine forests of the Mexican uplands also lived in coastal California. Among these were species of *Arbutus, Ilex, Myrica, Nectandra, Populus, Persea, Quercus* and *Sabal* (see Axelrod, 1977).

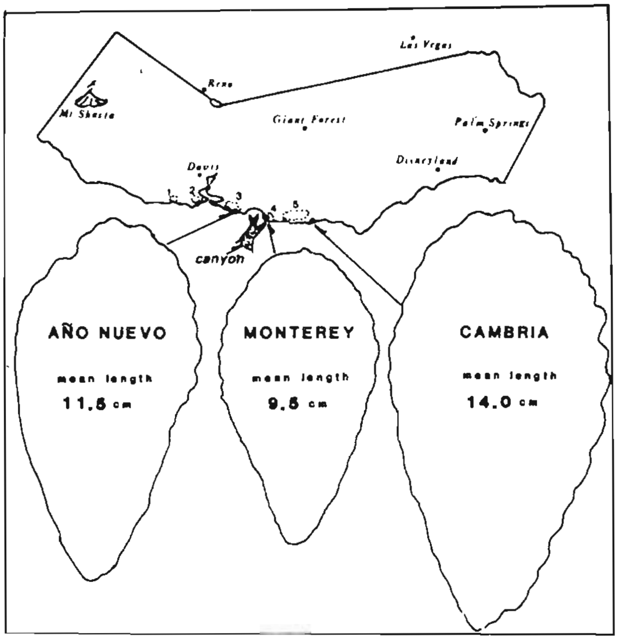
Apart from *Arbutus*, which also occurs at the lower margins of forest in the Sierra Nevada and Transverse Ranges, the listed taxa are typical members of the insular or maritime flora today. They are chiefly associated with the closed-cone pine forest dominated by *Pinus radiata* and *P. muricata.* In the past they were largely of insular or near-maritime occurrence, living under mild temperature without freezing (Axelrod, 1980a, 1983a). That they have been in the coastal area for some time is indicated by the distinctness of the coastal Puente flora as compared with the Mint Canyon and Tehachapi floras of interior southern California, a region where climate was too dry and temperatures too high for most of these coastal taxa. In brief, the taxa of the coastal region with present Mexican affinities were transported northward and have suvived in an equable climate with summer fogs that compensate for the dry summer climate (Text-fig. 6). These taxa occurred in coastal California prior to the expansion of the Sonoran Desert flora that now isolates them from their allies in Mexico (Axelrod, 1979a). This is shown by Neogene records of their occurrence in southern California, a time when the coastal area was joined to the Sonora-Sinaloa region of Mexico, prior to its northward displacement by movement on the San Andreas rift system during the Miocene and later (Text-fig. 5).

During the northward shift of the coastal strip, the fossil records of *Pinus radiata* (Monterey pine) show a trend to larger cones with larger seeds, primarily a response to the increasingly drier summer climate. The present pine groves are discontinuous, occurring at Monterey-Carmel, Año Nuevo, and Cambria in central California, and on Cedros and Guadalupe islands off northern Baja California. Proceeding northward from Cedros I., there is a gradual increase in cone size and seed size, but the trend is not clinal. In central California, the Monterey population with the smaller cones lies between the larger coned populations at Año Nuevo and Cambria (Text-fig. 7). Apparently the Monterey population is relict, for it survives in a very equable part of the coastal strip. Cold-water upwelling from Monterey submarine canyon provides the area with the coolest, foggiest climate in this part of the coastal strip (Axelrod, 1982). Fossil records of the forest show that it ranged nearly continuously along the coast into the Late Pleistocene (Text-fig. 8). It was confined to local areas as drought spread, and probably was most affected by the post-glacial warm dry Xerothermic period (8,000-4,000 B.P.) that restricted the forest to its present sites.

4. The history of the Canarian laurel forest is also clarified by plate movements (Axelrod, 1975). Many of the unique woody taxa of the present Canarian laurel forest are represented by the same (or very similar) species in the Miocene of southern Europe, from Portugal to eastward into Georgia, USSR. The notion that the laurel forest taxa (e.g. *Apollonias, Laurus, Ocotea, Persea,* and their associates) migrated from southern Europe to the islands pervades many discussions. But that does not explain the absence from the present Canarian flora of numerous taxa associated with Canarian plants in southern Europe during the Pliocene. These include: *a*) subtropicals now in the moister parts of Africa and southern Asia (e.g. *Buettneria, Cinnamomum, Myrsine,* etc.), *b*) temperate conifers and deciduous



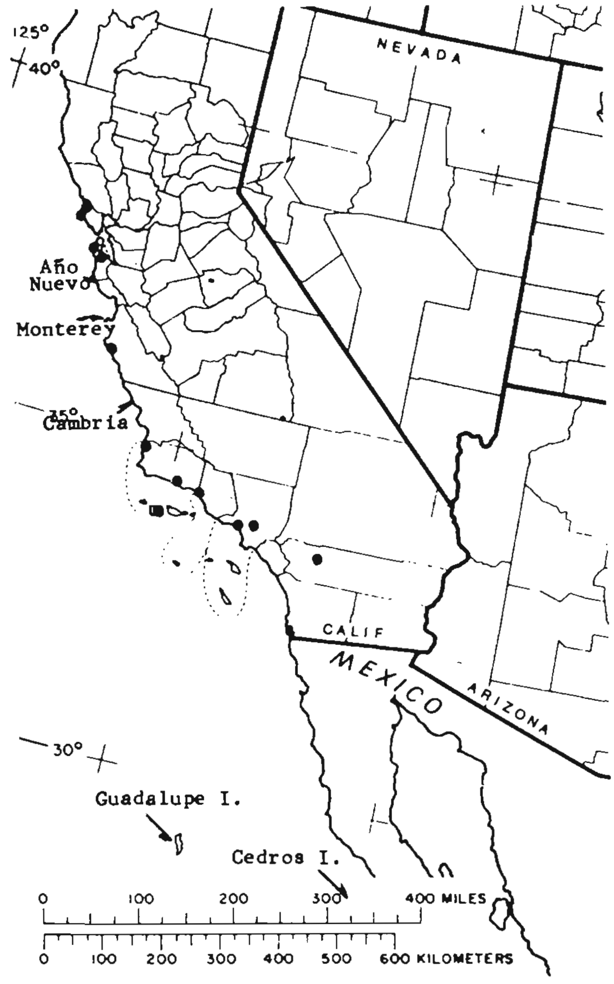
Text-fig. 6—Movement on the San Andreas rift system has displaced pines of the subsect. Oocarpeae, and their associates from Mexico to California.



Text-fig. 7—Of the 3 populations of Monterey pine, *Pinus radiata*, on the central California coast, that at Monterey has the smallest cones. This reflects the cooler, highly equable climate resulting from cold-water upwelling from Monterey submarine canyon. Numerous other relict taxa also occur in this local area (Axelrod, 1982).

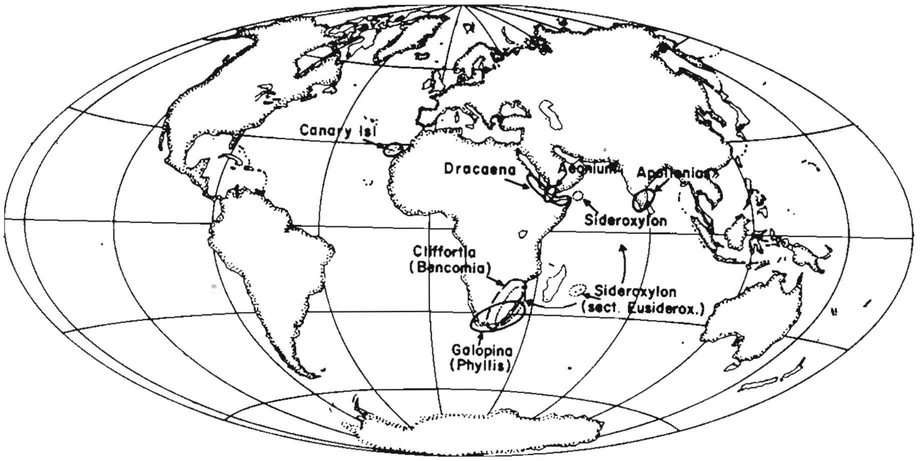
hardwoods now in the eastern North America (e.g. *Acer, Carya, Liquidambar, Liriodendron, Robinia, Taxodium*), *c*) temperate alliances that are now chiefly in eastern Asia, with some in the Colchic region (e.g. *Albizzia, Carpinus, Cercidiphyllum, Ginkgo, Clyptostrobus, Parrotia*), *d*) taxa in temperate Europe (*Acer, Aesculus, Cornus, Crataegus, Populus, Quercus*), and *e*) broadleaved sclerophylls of the present Mediterranean region (e.g. *Ceratonia, Myrtus, Nerium, Quercus*).

During the Miocene and earlier, southern Europe was covered with subtropical to tropical evergreen forests that also blanketed the area of the present Saharan Desert. Their occurrence in southern Europe and north Africa during the Miocene and earlier reflects the position of the continents 10-12° Lat. lower than at present (Smith, Hurley & Briden, 1981). Further, geologic evidence shows that the Canary islands are composed of two groups. The low eastern islands (Lanzarote, Fuerteventura) are continental and were earlier connected with the mainland as shown by the remains of ratites there. The western islands (La Palma, Tenerife) are oceanic (volcanic) and Middle Miocene in age. The laurel forest taxa probably were in the eastern islands during the Paleogene, whereas they probably invaded the present western high islands only in the Middle Miocene and later.



Text-fig. 8—*Pinus radiata* forms 5 small groves today (named), but in the Quaternary and earlier it was widely spread in coastal and near-coastal areas at sites marked (•).

This evidence, coupled with fossil records of mesic Tertiary rainforest and savanna in northern Africa into the Miocene, agrees with the distribution of a number of Canarian taxa in the eastern paleotropics. Others have their allies in southern Africa, though not all are confined to the laurel forest community today. The present disjunctions (Text-fig. 9; also see Bramwell, 1976; Sunding, 1970, 1979) are the result of range restrictions as drier climates spread following the early Miocene. Northern Africa with its Canarian taxa was therefore transported north, out of the marginal tropics to meet the temperate forests at the north. The data suggest that the Arcto-Tertiary forests of Europe did not penetrate south into the Mediterranean region during the Miocene because climate there was too warm (tropical). Only as the European and African plates shifted north were temperate taxa able to invade southern Europe in the late Miocene and Pliocene. That is, as the African plate shifted north, the laurophyllous forests were carried into an ecotone with the temperate forests, the latter having been displaced southward by cooling climate as the continent moved north. The relict nature of the Canarian flora is consistent with its high percentage of diploids that reflect its antiquity (Bramwell, 1972), as does the



Text-fig. 9—Taxa of the Canarian laurel forest are related to alliances now widely spread across the Old World tropics, including paired genera between the Canaries and south Africa, e.g. *Cliffortia—Bencomia, Galopina-Phyllis.* For other examples, including those in the New World tropics, see Bramwell, 1976; Sunding, 1979; Humphries, 1979). These data, as well as plate tectonic evidence (see text), imply an origin for the Canarian laurel forest in the outer tropics during the Tertiary, not migration from southern Europe.

woody habit of much of the flora, the numerous ferns and lianas in it, and the widely disjunct occurrences of some of its unique taxa (see Bramwell, 1972, 1976; Humphries, 1979; Sunding, 1979). The sclerophyllous shrubs in it that contribute locally to macchia also support the idea they were derived early from alliances that contributed to laurophyllous forests then widely spread across low-middle latitudes of both Eurasia and North America (Axelrod, 1975). As for the more recent endemics, and the radiation of some genera (e.g. *Aeonium, Echium, Sonchus*) (Humphries, 1974), this probably was a late Miocene-Quaternary event. Invasion of the island region by the semiarid Saharan floral element that now dominates at low altitudes where rainfall is deficient probably was chiefly in the Quaternary.

5. The Lower Ravenian Eocene flora of the Gulf of Alaska region (Hollick, 1936; Wolfe, 1977) includes a number of broadleaved evergreen dicotyledons that indicate an outer tropical climate. Distributed in diverse families that are chiefly tropical in their adaptive relations, they include species of *Cyathea, Sabalites, Tetracentron, Diploclasia, Illicium, Cananga, Myristica, Litseaphyllum, Toona, Evodia, Melanorrhoea, Phytocrene, Allophyllus, Meliosma, Parashorea, Barringtonia, Kandelia, Alangium* and *Mastixia.* To explain their occurrence at Lat. 70°N it has been concluded that the Earth's axis was not tilted (Wolfe, 1977). Under this scenario, Earth would receive more warmth in polar areas in winter so that taxa could survive there without winter darkness and cold, yet have ample warmth in summer. However, if the axis had considerably less tilt than at present, the occurrence of mild temperate climate indicated by the Eocene floras of Spitzbergen, Ellesmere Island, Greenland, Canada (mouth of Mackenzie River), and north-eastern Siberia, all of which are composed of deciduous hardwoods and conifers of temperate requirements, represent a major anomaly not considered by Wolfe. The asymmetric distribution of biota in the Gulf of Alaska region was charted earlier by Frakes and Kemp (1973, p. 547), though not explained. Geologic evidence shows that the Eocene floras of the coastal Alaska region have been displaced northward on the order of 1,000 km or more (e.g. Jones *et al.*, 1970, 1972, 1977; Packer & Stone, 1974; Coney *et. al.*, 1980; Jones & Silberling, 1982; Plumley *et al.*, 1982; Helwig & Emmett, 1983; Saleeby, 1983; Bruns, 1983). This is supported by a recent study of the Eocene marine microfossil fauna which indicates considerable latitudinal displacement of the ocean floor off Alaska (Keller *et al.*, 1985).

Since sections of the crust were transported long distances during the Tertiary, what significance does this have with respect to the proposed Tertiary Floral Stages of the Pacific coast (Wolfe, 1972, 1977, 1981). It means that their value is greatly diminished because the described Stages do not represent the sequence of taxa in their present geographic areas, but in distant sites. Furthermore, since the described Floral Stages are from the coastal strip they can not be applied outside that area because the composition of floras rapidly changed inland (Axelrod, 1965, figs 12, 13). As noted above, the dissimilar Puente and Mint Canyon floras of southern California represent coastal and interior environments; the few taxa in common (e.g. *Persea, Platanus*) are wide-ranging in time and occur in diverse environments. Furthermore, some fossil floras assigned by Wolfe (1981) to specific Stages do not have the taxa that define them. They lived well in the interior, at higher altitudes under cool to cold temperate climate and hence supported wholly different floras. For example, the Eocene Bull Run and Copper Basin floras of northeastern Nevada are dominated by taxa of montane conifer forest and mixed conifer-deciduous hardwood forest. They can not represent the Ravenian Stage of Wolfe (1981) because taxa of that Stage are characterized by broadleaved evergreen species of the outer tropical zone, none of which occur in the Eocene floras of northeastern Nevada. Similarly, Wolfe (1981) assigns the Aldrich Station flora of west central Nevada to the Homerian Stage, the type of which is in the Cook Inlet region, Alaska. But there are no species and few genera common to the Aldrich Station and the Alaskan floras of the Homerian Stage. Wolfe also assigns the Stinking Water flora of eastern Oregon to the Homerian Stage, yet it has no species in common with the Alaskan floras. It is granted that these floras are of the same Age, but they do not represent the Stages assigned to them by Wolfe. Radiometric dating or magnetic-stratigraphy provide a more reliable basis for age assignment.

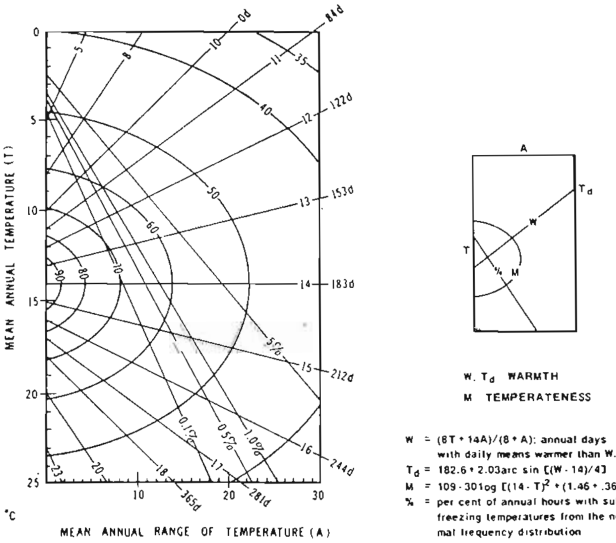
FORESTS OF POLAR REGIONS

Geologic evidence shows that land areas now in polar regions were also there in the Tertiary. In the north, fossil floras include those from Spitzbergen, Ellesmereland, Greenland, northern Canada (mouth of MacKenzie R.), Alaska, and northeast Siberia. They represent rich deciduous hardwood forest communities that reflect relatively mild temperate climate without severe winters. Regular seasonal variation in climate is attested by the marked growth rings of the fossil woods as well as the deciduous habit of the hardwood taxa.

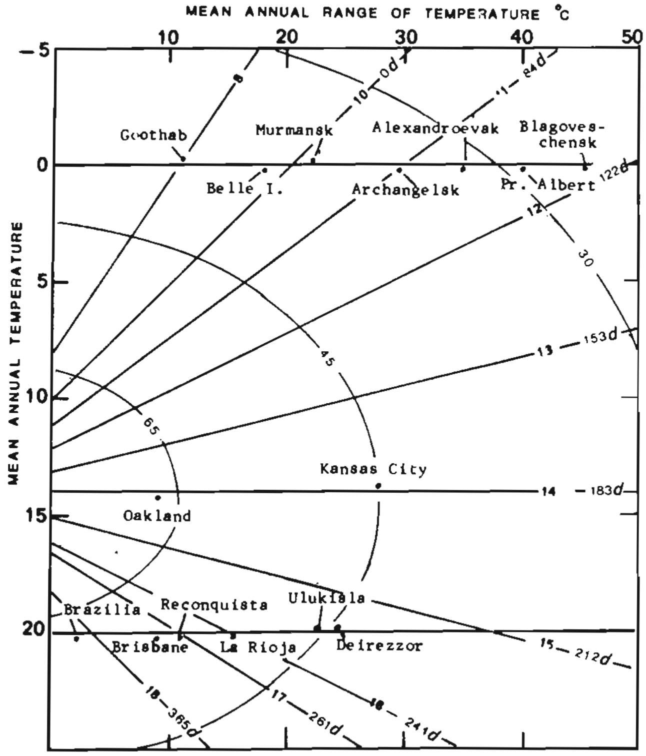
The problem of survival there is clearly one of coping with the dark season. Recall that today numerous small trees and shrubs range north of the Arctic Circle, an occurrence that owes to post-glacial warming. Also, forest trees now range to lat. 60°N on the western sides of the northern continents, areas covered by ice as recently as 9,000-10,000 years ago. In addition, at Lat. 50°-59°N inner tropical plants flower and set seed today in greenhouses that are *not* illuminated in winter, but are kept warm (see data in Axelrod, 1983). This implies that under a longer photoperiod these taxa are confined not by light, but by temperature. Furthermore, experimental physiological evidence shows that evergreen conifers and dicotyledons, as well as deciduous hardwoods, undergo metabolic shutdown in winter season in temperate latitudes. They may be expected to have done so when they occurred at higher latitudes under the more equable climates of the Eocene and earlier. In addition, it was the equable climate that enabled "tropical" taxa (i.e. *Glyptostrobus*, cycads, palms, *Cedrela*) to inhabit climatic regions where they no longer occur (Axelrod, 1981b). As for the Eocene vertebrates from high latitudes (i.e. Ellesmereland), reptiles (alligators, varanids, tortoises) probably hibernated during the low-light season when climate was mild temperate and freezing not severe. Mammals may well have been nocturnal as well as hibernating in habit, and some may have migrated into the area during the summer. The occurrence of dinosaurs in polar latitudes may also reflect seasonal migration during the poleward surge of high productivity as light and warmth increased following the polar night.

PALEOTEMPERATURE ANALYSIS

I have earlier presented a method for estimating thermal relations of a fossil flora (Axelrod, 1965) based on a method devised by Bailey (1960, 1964, 1966). It is also an effective means for estimating the altitude of a fossil flora. The method is based on estimating mean annual temperature (*T*) and the mean annual range of temperature (*A*). Together they provide a means for interpreting two very different aspects of climate, Warmth (*W*) and Equability (*M*). Warmth refers to the number of days warmer than a specified temperature. At *W* 10°C, 0 days are warmer than 10°C, at *W* 18°C, 365 days are warmer than that, and at 14°C, 183 days are equal to or warmer than 14°C (Text-fig. 10). The divisions of warmth (*W*) thus describe the duration of the *growing season*. *W*



Text-fig. 10—Monogram showing warmth and equability (temperateness) of climate (Bailey, 1960, 1964, 1966). The radii express warmth of climate (*W*) in terms of a particular temperature and the number of days (*d*) in which mean temperature rises to or above that level. The radii measure the duration of the growing season, which decreases poleward and with altitude. The arcs nearly normal to the warmth lines depict equibility (*M*). They provide an index to thermal extremes, graded from an ideal of *M* 100 to lower values farther removed from the centrum *T* 14° and *A* 0°. The percentage lines indicate the percentage of all hours of the year below freezing.

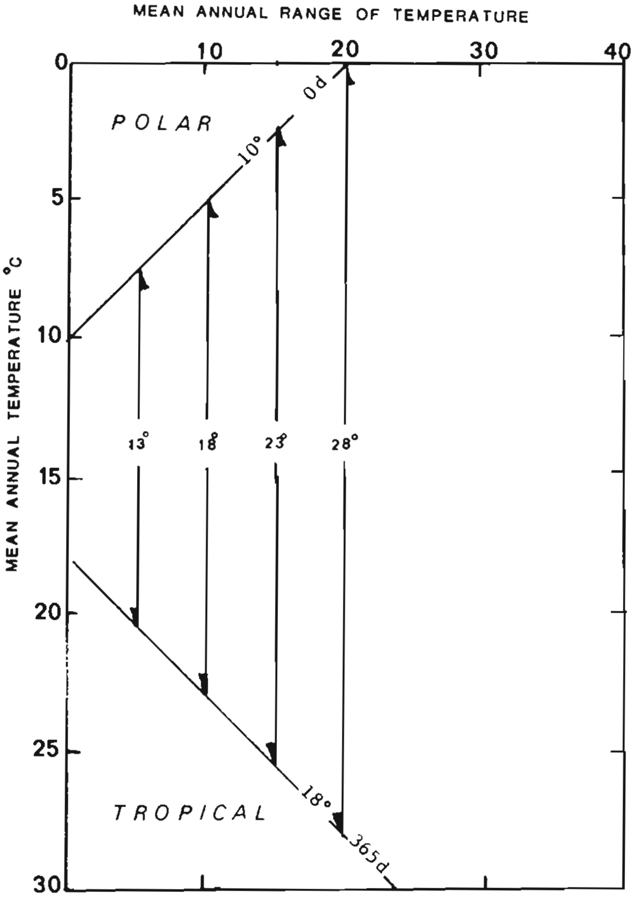


Text-fig. 11—Mean annual temperature can not provide an index to paleotemperature. Note that Oakland, California, with a low range of temperature rarely has frost whereas many days of freezing, snow and ice typify Kansas City, Missouri, which has a much greater range of temperature. Goothab, Greenland (*T* 0°) is near perpetual ice, Murmansk is close to the Tundra-boreal forest whereas Prince Albert is in a rich conifer forest. Similarly, Brasilia (*T* 20°C) is in the tropics, yet the other stations of similar mean temperature range well into warm tgemperate climates. The radiating lines of warmth show that in regions of cool climate increased range of temperature brings warmer conditions whereas in warm regions a rise in the range of temperature results in cooler conditions.

10°C represents treeline, whereas W 18°C is the margin of the tropics, and *W* 14°C lies in the middle of the temperate zone. By contrast, equability (*M*) provides a measure of thermal extremes. It is measured by a series of arcs that diverge from *T* 14° and *A* 0°C and range in value from *M* 100 (ideal, in the tropical uplands) to *M* 0 on Antarctica.

The relations shown in Text-fig. 11 reveal three major features. *First*, some stations with similar warmth (*W*) as Oakland, California, and Kansas City, Missouri, have very different equability values (*M* 67 vs. *M* 45, read the arcs). Whereas frost is rarely present in Oakland, many days at Kansas City have snow and subfreezing temperatures. *Second*, mean annual temperature (*T*) means very little in terms of paleoclimate or of vegetation. Note that stations with a mean annual temperature (*T*) of 0°C occur close to permanent ice (Goothab), are in Tundra (Belle, I.), in boreal forest (Archangelsk), and in a rich conifer forest (Prince Albert). In the case of a mean temperature of 20°C, Brasilia is in the tropical belt but as the range or temperature increases the other stations are in more temperate climates. *Third*, it is evident that an increased range of temperature in temperate regions brings warmer climates, whereas in warm regions an increase in the range of temperature results in cooler conditions.

It is also apparent that as range of temperature increases, zones of warmth are separated by a greater distance vertically (altitudinally). Text-fig. 12 shows that with a 5° range of temperature, only 13° C separates *W* 10°C and *W*18°C; the tropics and treeline are only 13°C apart. But with a range of 20°C, these same zones are separated by 28°C. Clearly, with increased equability all vegetation zones—and their species—are closer in terms of altitude. Since temperature decreases with altitude (lapse rate), it is possible to determine approximately the altitude of a fossil flora. Today the normal terrestrial lapse rate varies across continents with orientation and the location of physical barriers. But in the Tertiary, climates were more equable, terrain was generally

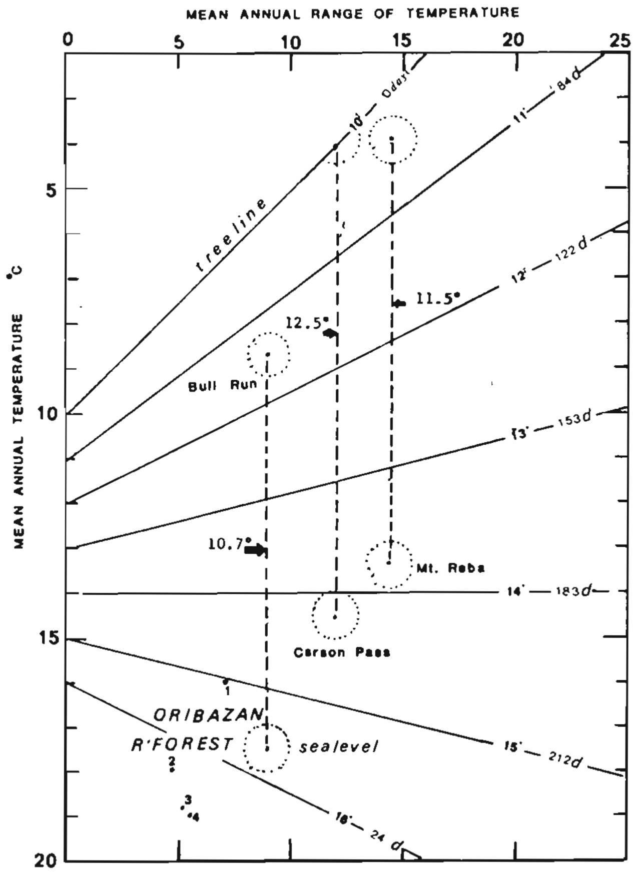


Text-fig. 12—Zones of warmth are closer in regions of more equable climate. The polar and tropical climate zones are progressively farther apart as range of temperature increases.

subdued, and oceans were warmer at middle and high latitudes. In general, the Tertiary had a normal terrestrial lapse rate of 0.55°C/100 m or 1°C/-183m (Axelrod & Bailey, 1976). An estimated warmth (*W*) and equability (*M*) of a flora in the coastal strip (sea level) or inland, thus provides a basis for inferring the probable altitude of a fossil flora in the interior.

For example, the Late Eocene Bull Run flora (40-35 m.y.), north-eastern Nevada, includes 10 florules distributed through 1,370 m (4,500 ft) of section. The lower 3 florules formed a conifer-deciduous hardwood forest, whereas the upper 7 are wholly dominated by montane conifers, notably *Abies, Larix, Picea, Pinus, Chamaecyparis* and include a few rare forest shrubs, as *Amelanchier, Berberis, Mahonia, Ribes, Sorbus* and *Vaccinium.* The coastal strip was then clothed with subtropical rainforest like that now in the cloud forest of southern Mexico. Average warmth there is *W* 16°-15°C and the range of temperature 5-7°C. Allowing for a somewhat greater range in the interior, say 9-10°C, then about 10.5°C separated the rain forest at sea level from the pure montane conifer forest in Bull run basin (Text-fig. 13). This implies an altitude near 1,958 m (10.5° × 183 m), or about 6.400 ft compared with 2,500 m (8,500 ft) for this zone today.

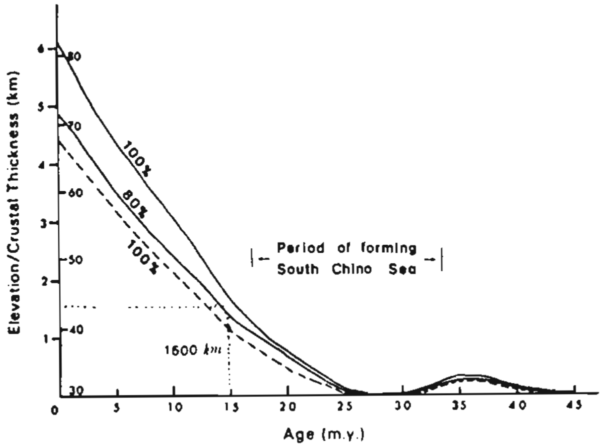
A Miocene flora from treeline in the summit region of the central Sierra Nevada south of Carson Pass is at 2.776 m (9,100 ft), and about 15 m above the granitic basement. Broadleaved evergreens (*Actinodaphne, Nectandra, Persea, Quercus*) and deciduous hardwoods (*Crataegus, Cyclocarya, Fagus, Liquidambar, Nyssa, Platanus, Populus, Quercus, Ulmus*) make up this well sampled flora. Conifers are not known from the assemblage. The flora suggests an environment like that now in the areas from northern Florida into south Carolina. Warmth of climate there ranges from *W* 15°-14°C. In view of the warmer ocean only 120 km west in the Middle Miocene, the absence of ice-caps, and the lack of major topographic barriers, climate was more equable than that now on the east coast. Hence warmth of climate probably was near *W* 14.5°, or lower. With a range of temperature near 12°C and a warmth of about 14.5°C, the distance to treeline is 12.5°C (Text-fig. 13), or approximately 2,288 m. Since the flora is now at 2766 m (9,100 ft), the data suggest an altitude near 478 m (i.e. 2,766-2,288 m), or about 1,570 ft in the Miocene. Hence, uplift in the area is on the order of 2,287 m (7,500 ft) since the Middle Miocene.



Text-fig. 13—Estimated altitudes of an Eocene flora, Nevada, and of two Miocene floras in the central Sierra Nevada based on paleotemperature, and its indication of the amount of uplift in the range. Stations in the Orizaban rainforest are: 1. Huachianago, 2. Jalapa, 3. Huatusco, 4. Orizaba.

This estimate is comparable to that indicated by the Mt. Reba flora (6-7 m.y.) situated 20 km south at an altitude of 2,620 m (8,600 ft) and about 30 m above the granodiorite basement (Axelrod, 1980b). The flora is dominated by evergreen oak (*Quercus*), tan-oak (*Lithocarpus*, Douglas fir (*Pseudotsuga*), and cypress that represent broadleaved sclerophyll forest. Mixed conifer forest taxa (*Abies, Pinus, Sequoiadendron*) are exceedingly rare. A few deciduous taxa, notably *Salix* and *Ulmus*, are also present. The relations imply a position at the upper margin of sclerophyll forest with mixed conifer forest on the bordering slopes. Allied vegetation is now in the Sierra Nevada to the northwest near 760 m (2,500 ft). The flora suggests mean annual temperature was near 13.4°C and the range was about 14.5°C, with warmth of *W* 13.7°C, or 174 days warmer than that (Text-fig. 13). This implies that the distance to the upper subalpine zone (*W* 10.5°C) was about 11.5°C or 2,105 m (7,100 ft). This is approximately the amount of uplift in the area since the close of the Miocene. The flora is overlain conformably by a thick, giant-boulder conglomerate at this site which is perched on a ridge crest overlooking Mokelumne River gorge where the river is now 1,360 m (4,500 ft) below the flora. This represents the amount of erosion that has occurred since 5-6 m.y. ago, and probably less.

As to the possible utility of the method, reference is made to the Middle Miocene Namling flora from the Tibetan Plateau west of Lhasa, and now at an altitude of 3,800 m. Represented by deciduous hardwoods chiefly,



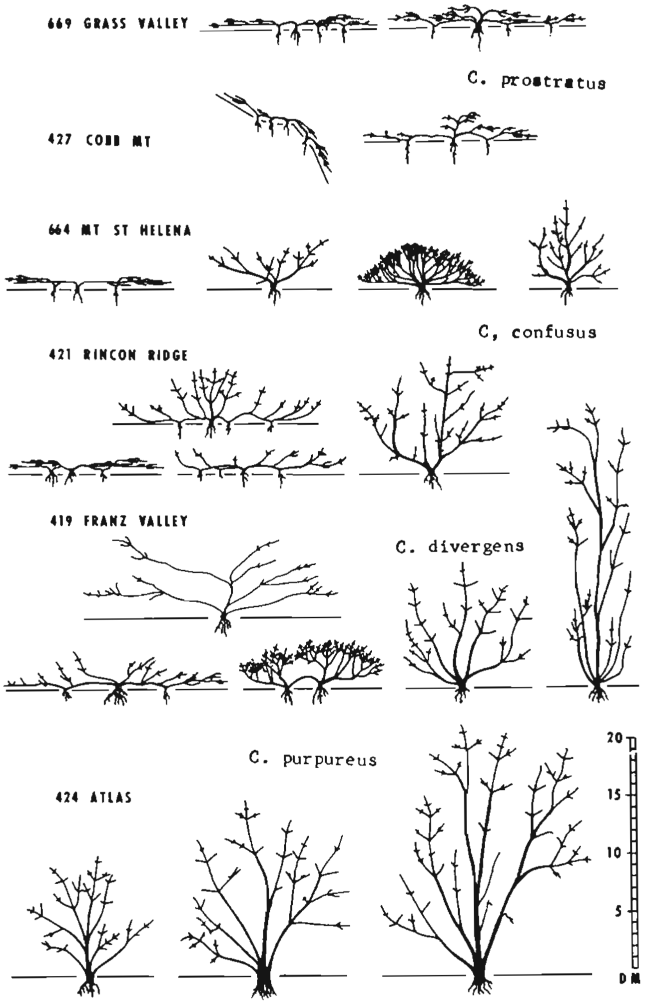
Text-fig. 14—Paleotemperature analysis of the Middle Miocene Namling flora, Tibet, suggested an altitude near 1,500 m (Axelrod, 1981a). This agrees with tectonic estimates of uplift of Tibet since the Middle Miocene (from Zhao & Morgan, 1985).

the flora certainly lived at a much lower altitude. Its thermal relations suggest an altitude of about 1,500 m (Axelrod, 1981a). This agrees closely with that estimated from plate tectonic history in south-east Asia (Text-fig. 14), including the opening of the South China Sea (Zhao & Morgan, 1985).

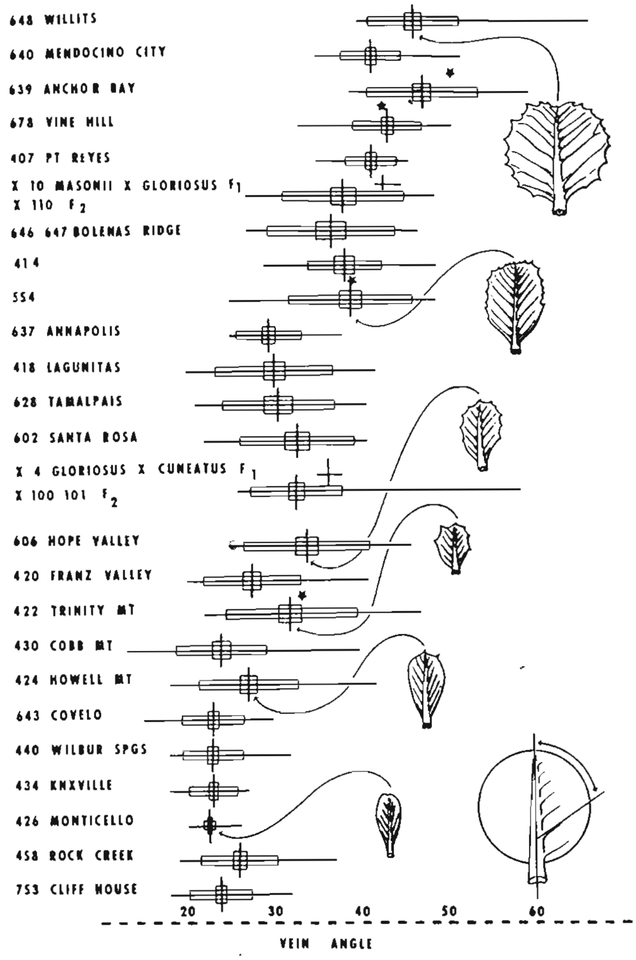
CENTERS OF ORIGIN

The local areas where taxa may have originated can rarely be determined apart from those of comparatively recent origin by hybridization, introgression, and other means from allied taxa in the nearby region. The problem of recognizing centres of origin is that taxa shift in area (altitude, latitude), as climate changes and taxa also change in time. This is the fallacy of pinpointing southeast Asia (eastern Himalayan region) as the center of angiosperm origin (Takhtajan, 1969). That area is a center of survival, one where climate is highly equable and with ample precipitation. The fossil record shows that a number of Magnolian taxa in that area have been recorded in regions distant from the east Himalayan region. Also, the Himalayan axis is very young, having been uplifted largely following the later Eocene. Prior to that the area was covered by ocean (see Smith *et al*, 1981), an environment scarcely conducive to the origin of angiosperms. The group originated in the tropics in pre-Cretaceous time and then migrated poleward (Axelrod, 1952, 1959). More recent evidence suggests that West Gondwanaland was the general region of early angiosperm evolution (Raven & Axelrod, 1974), and that this most probably took place on its drier margins and in drier sites (Stebbins, 1952, 1974; Axelrod, 1967).

The principal regions of Tertiary evolution were the areas of the major Geofloras, situated in tropical, temperate and subhumid-semiarid climates. Allied species now occur in the disjunct areas of the eastern and western hemispheres, indicating migration and diversification from a common boreal or austral source. However, the species commonly represent different tribes or sections, implying evolution following spread from a common center. In each region there have been local areas of diversification, as seen for the oaks and pines, with few taxa common to the eastern and western hemispheres (Axelrod, 1983b, 1986). In each hemisphere a number of taxa are restricted to the dry or temperate regions and have apparently been there throughout their history as judged from the known fossil record, for example, of the 250-odd species of oak only 10-12 species of the allied Subsects. Diversipilosae and Prionoide link America and Eurasia, a link that was already established by the Paleocene. Of the 90-odd species of *Pinus*, only species of the Strobi and Cembrae of Subg. Strobus are common to the northern continents,



Text-fig. 15—Rapid evolution is indicated for the *Ceanothus purpureus*—*C. prostratus* series in the north Coast Ranges, California. With a rise in altitude into the young volcanic mountains there is a comparable response in plant form, branching, leaf size, etc. (from Nobs, 1963).

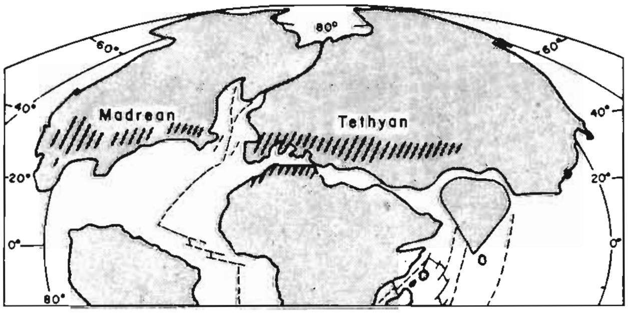


Text-fig. 16—Evolutionary change is also seen in moving from the inner Coast Ranges to the coastal strip in the series *C. cuneatus-gloriosus.* Not only is there a shift in leaf size, angle of departure of veins, teeth, etc. but in habit as well (from Nobs, 1963). In this case the older species (*cuneatus*) appears first in the interior.

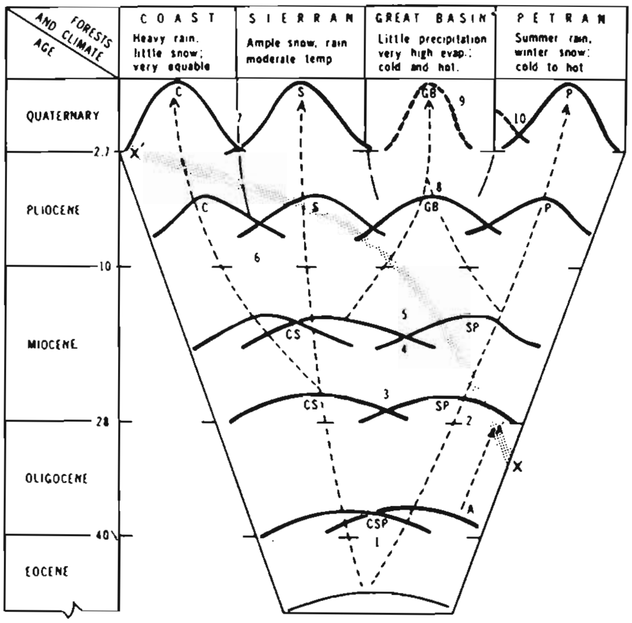
and in the Subg. *Pinus,* only members of Subsect. *Sylvestres* now link the northern continents. The remainder may well be of local origin. For example, the 8 species of Subsect. Cembroides evidently originated in areas of drier climate in southwestern United States and Mexico. The 12 species of Subsect. Ponderosae are chiefly Mexican today, though some ranged more widely to the north in the Miocene. The species of Subsect. Balfourianae are largely Rocky Mountain and Great Basin in origin, as judged from the fossil record. In Eurasia, Subsect. Canarienses, with *P. canarienses* and *P. roxburghii,* link the Canary Islands with the western Himalayas today, implying more widespread occurrences in the past. This is demonstrated by fossil pines allied to them in southwest Asia.

As the moist temperate and tropical floras retreated during the Tertiary, vegetation on their cold (Taiga, Tundra) and dry (savanna, thorn scrub, grassland and semidesert) margins gradually expanded. Hence, younger genera and species are often found in the more stressful areas when considered in terms of the world flora. But this is not to imply that there has been no change in the moist, more equable temperate or tropical regions; many new species originated there during the Tertiary.

There have been some very local centers of origin, areas where new opportunities have "suddenly" appeared. This is exemplified by the 8 species of *Ceanothus* (Subgenus *Cerastes*) in the Coast Ranges north of San Francisco Bay (Nobs, 1963). They apparently originated in this area following the accumulation of the Pliocene Sonoma Volcanics. The *C. purpureus-prostratus* series of several taxa shows a trend toward smaller size, less branching, and smaller leaves with fewer teeth to the north and at higher levels in the Coast Ranges (Text-fig. 15). The *C. gloriousus-cuneatus* series shows a shift to smaller size, less branching, and smaller leaves with few or no teeth from the coast toward the interior (Nobs. 1963) (Text-fig. 16). The genus *Arctostaphylos* in California includes some 40-odd species, most of which occur in the Coast Ranges that were elevated to their present heights at the close of the Pliocene and during the Quaternary. The rapid appearance of varied substrates and microclimates in the Coast Ranges facilitated the proliferation of numerous minor taxa in the major species groups. In Eurasia, the flora of the extended Tethyan region, situated in dry climate between the tropical and temperate geofloras has been a broad regional center of origin that extends from Portugal into the western Himalayas. There are a number of links with the Madrean vegetation of southwestern North America. These reflect migration across islands in the Atlantic before it was very wide (Text-fig. 17), chiefly during the Paleogene (Axelrod, 1975). The links were favored by the more nearly east-west orientation of the Atlantic coast of North America (prior to its counter-



Text-fig. 17—There are numerous floristic links between the Tethyan and Madrean regions. They apparently reflect Paleogene connections across the Atlantic when it was narrower, populated with now-sunken islands, and before North America was rotated counter-clockwise. Its former position provided more numerous south-facing warmer and drier sites on basement rocks suitable for sclerophyllous taxa of warm temperate requirements (from Axelrod, 1975).



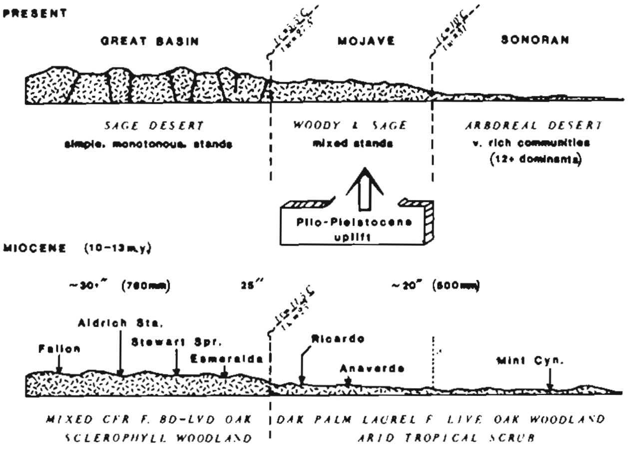
Text-fig. 18—Modernization of forests in western North America commenced in the central to southern Rocky Mountain region and thence spread coastward. Fossil· species allied to modern taxa that were associated in the past now largely contribute to forests of different composition in these more recently emerged climatic regions (from Axelrod, 1976).

clockwise rotation) that provided more numerous drier, warmer sites on south- and west-facing slopes. Links could not have been around the north Atlantic, as some have suggested, because that area was under cool temperate climate, as shown by the records of deciduous hardwoods and conifers there, not sclerophyllous taxa. The longer photoperiod there may also have been a factor in their restriction to middle latitudes.

VEGETATION CHANGES

Plants respond to changes in temperature and/or precipitation regimes which select some, segregate others to narrower relict areas, and eliminate some from areas they formerly occupied. During the Miocene, the present dry region east of the Cascade-Sierra Nevada axis, from British Columbia to south-central Nevada had ample rainfall and moderate temperature that supported a rich forest flora. It included species of *Acer, Betula, Castanea, Diospyros, Fagus, Ilex, Juglans, Liquidambar, Magnolia, Nyssa, Ostrya, Quercus, Sassafras, Taxodium* and *Ulmus* allied to species in the eastern United States. In addition, they were associated with species now represented by allied taxa in eastern Asia, distributed in *Acer, Alnus, Betula, Cercidiphyllum, Cinnamomum, Ginkgo, Metasequoia* and others. Further, a number of trees and shrubs that are now in the forests of the western United States are also recorded with them. These are distributed in *Abies, Picea, Pinus, Chamecyparis, Sequoia, Sequoiadendron, Alnus, Amelanchier, Betula, Crataegus, Fraxinus, Mahonia, Quercus, Sorbus, Rosa,* and many others. As mountains were elevated and rainshadows appeared, a more seasonal climate developed and rainfall over the interior gradually decreased. At the same time, progressively colder water was spreading into the middle latitudes, resulting in decreased summer precipitation. Both factors appear to account for the elimination of numerous forest taxa during the later Miocene and Pliocene that occur now in eastern North America and eastern Asia. Their associates, however, adapted to the present forest climates of the western United States, notably those of the Rocky Mountain axis, the Sierra-Cascade Range and the Coast Ranges (Text-fig. 18). Further environmental diversification resulted in the spread of new forest subzones, notably those of the Rocky Mountain axis, the Sierra-Cascade Range and the Coast Ranges (Text-fig. 18). Further environmental diversification resulted in the spread of new forest subzones, notably those of the lower, drier margins of forest, as well as those of the drier slopes where different local communities have been segregated from the richer forest of the Miocene and earlier times.

Sclerophyllous vegetation of the Madrean province dominated south of the forests of Arcto-Tertiary alliance. The transition between these dissimilar floras occurred in central and southern Nevada during the Miocene (Text-fig. 19). The ecotone included forest taxa that interfingered with sclerophyllous oaks, *Pinus* (aff. *monophylla-edulis*), *Juniperus, Lyonothamnus,* and many semiarid shrubs distributed in *Arctostaphylos, Ceanothus, Cercocarpus, Heteromeles, Peraphyllum, Schmaltzia* and others. Farther south woody legumes become abundant as do more numerous sclerophyllous oaks, thorn taxa, palm and many others indicative of generally frostless

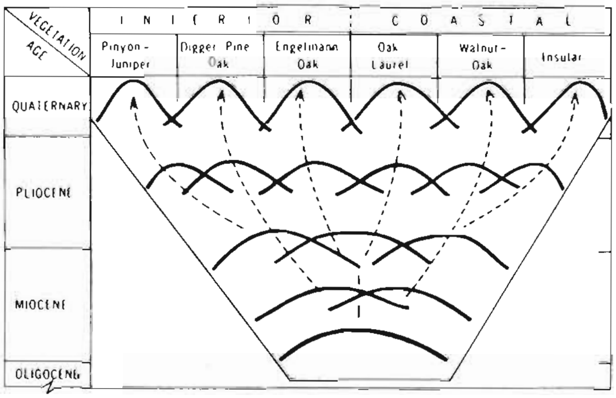


Text-fig. 19—Comparison of a north-south transect from the central Great Basin, western Nevada, into the Sonoran region, southern California, during the Miocene with that of today. The Mohave region represents an uplifted block with a flora transitional between the Sonoran and Great Basin desert floras.

climate. With decreasing summer rain and increasing cold sclerophyllous woodland taxa gradually retreated farther south. The surviving piñon-juniper woodland is relatively impoverished today, and occurs in a zone above the desert and sage-scrub belts. The preceding changes in woodland vegetation in the western United States are summarized in Text-fig. 20 and reviewed in detail elsewhere (Axelrod, 1977). It is amply clear that segregation of the rich Tertiary woodland in response to environmental changes during the middle and late Cenozoic shaped the present associations.

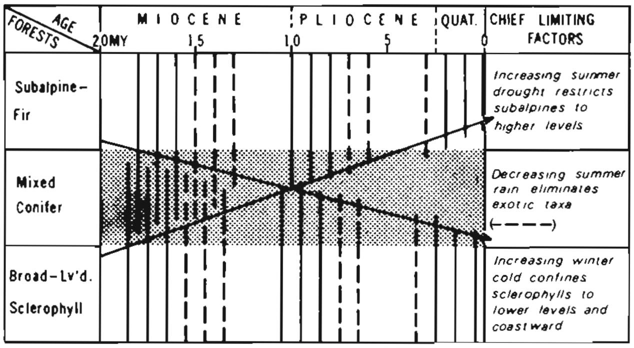
An additional vegetation change in the late Cenozoic has been the spread of wholly new zonal (regional) vegetation types. These notably include the grassland and desert environments, both of which are of post-glacial age in their present contexts (Axelrod, 1950, 1979a, 1979b, 1985). With respect to the tropical deserts, such as the Sonoran Desert of western North America, it has been the diversity of adaptive types of "peculiar" life form that has led to the notion that deserts are ancient earth features. Paleobotanical evidence shows that these diverse adaptive types represent taxa that persisted in the face of increasing dessication over the region. Earlier, they were members of woodland, thorn forest (scrub), and dry tropical forest and/or savanna vegetation. Some of them still enter these vegetation zones. These taxa were adapted to dry climate in the Eocene, and have further adapted to increased drought and heat more recently. This is certainly true of such unique taxa as *Fouquieria* (Fouquieriaceae), *Carnegiea* (Cactaceae), *Beaucarnea* (Liliaceae), and the leafless *Pedilanthus* (Euphorbiaceae). The occurrence of endemic families in the Sonoran area and on its borders is also consistent with gradual adaptation to drier climate later in the Tertiary and probably to their origin under subhumid climates in the Eocene and probably earlier.

Finally, mention must be made of the occurrence in Neogene floras of taxa whose modern derivatives are in the same region today, but are separated by fully 1,370-1,575 m (4,500-5,000 ft) in altitude. For example, *Populus* (cf. *tremuloides*) and *Picea* (cf. *breweriana*) occur in the Sonoma flora at sea level near Santa Rosa, California (Axelrod, 1944b). Their fossil associates were species of *Abies* (*grandis*), *Chamaecyparis* (*lawsoniana*), and *Sequoia* (*sempervirens*), as well as sclerophylls (*Lithocarpus, Heteromeles, Persea, Quercus, Umbellularia*), all of which indicate a lowland, mild climate with little frost. There is no evidence of nearby high mountains in the Sonoma region from which the upland species of aspen and spruce might have been derived. A comparable occurrence is seen in the presence of aspen with sclerophyllous oaks (cf. *Q. wislizenii, Q. douglasii*) and chaparral taxa (*Arctostaphylos, Heteromeles, Ribes*) in the low Sierran foot-hills in the early Pliocene (Axelrod, 1944a), yet these taxa are separated now from aspen by fully 1,575 m (5,000 ft) in the Sierra Nevada some 80 km to the east. Another example is provided by the presence of *Picea* (cf. *breweriana*) and *Abies (cf. magnifica)* in the Late Miocene (13 m.y.) Purple Mountain flora of western nevada together with sclerophyllous taxa, notably species of *Cercocarpus* (cf. *betuloides*) *Quercus* (cf. *chrysolepis*), *Heteromeles* (cf. *arbutifolia*) and others. The conifers are now at altitudes 1,200 —1,520 (4,000-5,000 ft) higher, well removed from the sclerophylls. Geological evidence certainly provides no evidence that the spruce and fir may have been derived from high mountains near at hand.



Text-fig. 20—Coastal and interior woodland associations were gradually segregated from the richer Madro-Tertiary woodland as summer rains decreased in the Neogene, and as areas of high equability were restricted coastward (from Axelrod, 1977).

These and other comparable occurrences seem to reflect the nature of Neogene climates. They were equable so that forest and woodland belts were closer in terms of altitude (see Text-figs 10, 12). Under these conditions, taxa were able to transgress their present



Text-fig. 21—Shifting associations of forest taxa in the Miocene and later. Vertical lines that shorten represent taxa whose ranges of tolerance were narrowed as climate changed. Increasing summer drought confined fir-subalpine taxa to higher, cooler levels, whereas increased winter cold restricted broadleaved evergreens to lower, warmer altitudes. It was this that gave rise to the modern, more distinct, less diverse associations than those of the Neogene. For clarity, taxa in the area of the mixed conifer forest (stippled) are now shown.

ecologic boundaries. In addition, there was summer rainfall, and it also provided conditions favorable for montane taxa at lower altitudes. This is seen today in the occurrence of aspen all through the forest belt in the eastern Great Basin and Rocky Mountains where it descends to meet the conifer woodland of *Pinus edulis* and *Juniperus* spp. together with its sclerophyllous chaparral taxa. It appears that as summer rains decreased in the west, montane taxa were confined to higher altitudes where lower evaporation rate compensated for the decrease (or absence) of summer precipitation. And as winters became more severe and snow frequency increased, taxa of the sclerophyll belt were gradually confined to lower altitudes (Text-fig. 21).

Some investigators have attempted to explain these and comparable occurrences by erecting high mountains in the nearby region from which the fossil remains might be carried to the lake basins or lowland floodplains. As noted, there is no geological evidence of high mountains in these areas. Those that may have been present were situated some 20-25 km (12-15 mi) south of the fossil sites (e.g. Mascall), areas from which it seems highly improbable that the abundant delicate winged seeds of spruce, fir and other taxa might have withstood transport without destruction.

The preceding review of some palaeobotanical problems certainly suggests that the present is not always the key to the past.

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Book Review

TAXONOMY of specimens of the Pennsylvanian age marattialean fern *Psaronius* from Ohio and Illinois—by James E. Mickle, Illinois State Museum Scientific Paper No. XIX, viii + 64 pages, 47 figures, 6 tables, 1984, 5 U. S. dollars.

Psaronius is one of the most dominant elements of the Late Pennsylvanian floras though its occurrences range from Late Namurian to as late as Bunter. It is an exclusive member of the Euramerican and Cathaysian floras. In Gondwanaland its only known occurrence is from Brazil.

Though the genus is known for 150 odd years, yet no acceptable system had been evolved so far for species delimitation in the genus. Early workers put great emphasis on the features of the vascular system. Later workers delimited the species on the basis of ground tissue characteristics. However, neither system was found to be completely satisfactory. James E. Mickle's doctoral dissertation contains results of investigation undertaken to understand the taxonomy and ontogenetic development of the species in this genus. For delimitation of the species the author has selected a number of independent parameters including those of Ground Tissue, Sclerenchyma Sheath, Vascular Anatomy and Morphology and Root Mantle. With this judicious approach he identifies four species in his collection of over 130 specimens from the Late Pennsylvanian deposits of the Appalachian and Illinois basins. Each species is described and illustrated in detail and the features are discussed with regards to its taxonomic status and evolutionary or genetic relationships. Salient features of other North American species of the genus are tabulated in an appendix. The author has also discussed ecological implications of *Psaronius* occurrences and has drawn tentative conclusions regarding environment of deposition.

There does seem to be an anomaly or two as far as typification of the species is concerned. For example, *Psaronius paucivaculosus*, a new species from Blickle's unpublished doctoral dissertation, is effectively published in this paper. Unexplicably, the holotype has been chosen from a new collection whereas specimen no. B-256, one of the three specimens studied by Blickle, has been relegated as a paratype. Similarly of the two specimens assigned to *Psaronius chasei* by Morgan, one is retained as holotype, but the other is not designated as paratype. On the whole this paper is a valuable supplement to earlier works on the genus *Psaronius*.

Hari K. Maheshwari

The Palaeobotanist **35**(2) : 131-135, 1986.

B.S.I.P.
Acc No 47621

Modern algae resembling fossil *Tetraporina*

Svenolov Lindgren

Lindgren, Svenolov (1987). Modern algae resembling fossil *Tetraporina*. *Palaeobotanist* **35**(2) : 131-135.

Specimens of *Tetraporina*, usually interpreted as algal microfossils, display similarities to several modern taxa of the Dinophyceae, Xanthophyceae and Chlorophyceae. The quadrangular and tetrahedral cell shape of algae and its variability due to ontogeny and environmental modifications, are reviewed in this article together with taxonomical problems in different classes of modern algae which are relevant to the taxonomy and botanical affinities of fossil *Tetraporina*.

Key-words—Algae, Dinophyceae, Xanthophyceae, Chlorophyceae, *Tetraporina* (Sweden).

Svenolov Lindgren, Department of Geology, University of Stockholm, S-10 691 Stockholm, Sweden.

सारॉंश

अश्मित टेट्रापोरीना-सदृश वर्तमान शैवाल

स्वेनोलॉव लिन्डग्रेन

टेट्रापोरीना के प्रादर्श जिनकी प्रायः सूक्ष्म-शैवालाश्मों की भाँति व्याख्या की जाती है डाइनोफ़ाइसी, जैन्थोफाइसी एवं क्लोरोफाइसी नामक कुलों के कई वर्तमान वर्गकों से समानता प्रदर्शित करते हैं। इस शोध-पत्र में शैवालों की चतुर्भुजी एवं चतुष्फलकीय आकार की कोशाओं में पादप-विकास एवं वातावरणीय परिवर्तनों के फलस्वरूप विभिन्नतायें विवेचित की गई हैं। इसी के साथ-साथ वर्तमान शैवालों के विभिन्न वर्गों में वर्गीकरणिक समस्याओं पर पुनर्विचार किया गया है। ये समस्यायें अश्मित टेट्रापोरीना की वनस्पतिक सजातीयताओं एवं वर्गिकी से सम्बद्ध हैं।

THE general morphology and the cell wall of *Tetraporina* indicate that these microfossils are of algal origin. The genus, however, may be made up out of specimens belonging to different natural taxa. The botanical affinities of fossil *Tetraporina* are discussed in Lindgren (1980, pp. 337-346).

Some specimens of modern algae may be difficult or impossible to assign to appropriate taxa without studying their ontogenetic variability in culture. The classification of fossil algae is further complicated by the restricted number of preserved diagnostic characters.

Modern algae displaying shapes similar to fossil *Tetraporina* occur in several groups, which are recorded in Table 1.

In this article are reviewed the distribution of quadrangular and tetrahedral cell shape in modern algae, and the variability of the cell shape due to ontogeny and environmental modifications, and taxonomical problems in different classes of modern algae which are relevant to the taxonomy of *Tetraporina*.

Table 1—Taxa of modern algae which include forms with shape similar to fossil *Tetraporina*

Class	*Order*	*Family*
Dinophyceae	Peridiniales	Ceratiaceae
	Dinococcales	Phytodiniaceae
Xanthophyceae	Mischococcales	Pleurochloridaceae
		Centritractaceae
Chlorophyceae	Volvocales	Tetrasporaceae
	Chlorococcales	Oocystaceae
		Micractiniaceae
		Hydrodictyaceae
		Coelastraceae
	Zygnematales	Zygnemataceae

MORPHOLOGY AND ONTOGENETIC VARIABILITY

Dinophyceae

Some species of *Ceratium* Schrank (Peridiniales) often occur in great quantities in lakes and ponds. At the end of the vegetation period they produce cysts which hibernate in the bottom sediment (Foot, 1959, p. 361). The spores are released through a burst in the cyst wall (Huber-Pestalozzi, 1950, pp. 259, 272). Some resting cysts of *Ceratium* have the same shape as *Tetraporina* and have been misinterpreted as species of the chlorophycean genus *Tetraedron* Kützing (Kovácik, 1975, pp. 384, 386).

Tetradinium Klebs (Dinococcales) comprises tetrahedral cells of the similar shape as *Tetraedron*. The existence of *Tetragonidium* Pascher as a genus comprising pyramidal and tetragonal cells attributed to the Cryptomonadaceae (Cryptophyceae) has been questioned by Fott (1959, p. 368).

Xanthophyceae

Tetraedriella and *Tetragoniella* (Pleurochloridaceae) were established by Pascher to comprise tetrahedral cells differing only in their size range. The monotypic genus *Tetragoniella* has been transferred into *Tetraedriella* since the size differences are not sufficient for distinguishing two genera (Smith, 1950, p. 385). The polymorph type species for *Tetraedron* Kützing (Chlorophyceae) has the diagnostic characteristics of *Tetraedriella* and has been transferred into this genus of the Xanthophyceae (Fott, 1967, p. 358).

Certain criteria used to distinguish modern algae from each other cannot be used on fossils since they are not preserved. Thus the modern algae *Tetraedriella* (Xanthophyceae) and *Tetraedron* (Chlorophyceae) can be distinguished from each other only by means of their chromatophors or food storage materials (Pascher, 1939, p. 586).

Species of the xanthophycean genera *Goniochloris* Geitler and *Pseudostaurastrum* Chodat have earlier been assigned to *Tetraedron* Kützing (Chlorophyceae). Some species described as *Tetraedron* are supposed to be misinterpreted representatives of the xanthophycean genera *Ophiocytium* Nägeli and *Tetraplektron* Fott (Kovácik, 1975, pp. 382, 383, 387).

Chlorophyceae

Volvocales

Porochloris Pascher, 1929 (Tetrasporaceae) comprises epiphytic, solitary algae with a thin to very thick cell wall which is distinctly resistant and impregnated by iron-hydroxide. In younger specimens the outline of the cell is round to elliptic whereas in older specimens it is quadrangular, square-shaped, rhomboidal or more or less round-shaped with four thickenings clearly marked on the cell wall.

The quadrangular shape of the cell, which in several instances may deviate, is defined by pores which break the cell wall at the corners. The aperture of the pore is slightly enlarged outwardly and often characterized by early iron-hydroxide precipitates. In one species, *P. filamentorum*, the pores can be seen only on strongly iron-impregnated specimens. From each pore extend hyaline threads of unknown function, emanating from the protoplast.

The reproduction occurs by zoospores which are released by bursting of the mother cell wall in either an appointed or an indefinite way. Aplanospores were observed as the only resting spores. They are in general larger than the vegetative cells and elliptical in outline. Their membrane is thick and smooth.

Chlorococcales

Tetraedron Kützing (Oocystaceae) originally comprised about 100 species (253 taxa) and represented a complex of various tetraedric algae. A great many of them have turned out to belong to other genera, mainly of the Xanthophyceae and Dinophyceae. Other cells which resemble *Tetraedron* in shape are either cysts or parts of the thallus of other unknown algae, or spores of aquatic hyphomycetes (Kovácik, 1975, p. 355). Many species which were previously referred to *Tetraedron* represent ontogenetic stages of other algae (Migula, 1907, p. 638).

A number of species originally assigned to other genera have been included in *Tetraedron* and many new taxa have been described.

Older investigators classified the algae primarily according to their shape, without recognizing their cytology. The descriptions of new taxa were frequently based on morphological features alone. The number of species, varieties, and forms of *Tetraedron* was reduced to six species (11 taxa) by Korsikov (1953) and later to four species by Kovácik (1975). Most of the remaining species were assumed to belong to the Xanthophyceae.

The type species of *Tetraedron* (*T. regulare* Kützing) has been transferred to *Tetraedriella* Pascher by Fott (1967, p. 358). For that reason the name *Tetraedron* is not valid for a chlorophycean genus. Korsikov (1953, p. 238) used *Tetraedron* exclusive of all xanthophycean species. The use of *Tetraedron* from the nomenclatural point of view is discussed in Komárek and Fott (1983, p. 696).

Despite that the variability of the shape was noticed as early as in 1894 by Lagerheim, and subsequently studied by Tanner (1923), Troitzkaja (1933), and Kovácik (1975), the present knowledge of the variability of the shape during the ontogeny of cells of most representatives of *Tetraedron* is still meagre.

In the quadrangular-shaped species of modern *Tetraedron* opposite cell sides have equally concave curvature or are flat. The curvature of the cell sides disappears with the ageing so that young cells with two deep and two shallow concavities develop slightly concave, flat or even convex sides with different curvature on neighbouring sides. Young cells are tetrahedral and flat, older cells are round or spherical. In *Tetraedron minimum* (Braun) Hansgirg the corners of the young cells have a papilla at the angles. With proceeding growth the angles become more rounded and papillae disappear so that older cells exhibit only their traces or a smooth surface. *Tetraedron incus* (Teiling) Smith have angular processes which are thin in young cells but thickening in older cells (Kovácik, 1975, pp. 364-368, 373).

The characteristic cell wall feature is the surface pattern network which is formed by the corrugation of the two outer cell wall layers. This structure changes during the ontogeny and the corrugated surface evens out with the cell ageing. "In young cells the periphery of the middle layer is abundantly folded and the network is very dense. In older cells the corrugated surface of the outer layers evens out, the network thins out and is composed of larger, often interlocked meshes. The middle layer is only slightly wavy. In old, large, rounded cells the network is reduced or the cell surface is completely smooth... The outer layer, although it forms the outer contours of the network, retains the same thickness throughout the whole process" while the thickness of the middle layer varies considerably. The disappearance of the surface structure of cell wall during ontogeny is supposed to be due to cell growth (Kovácik & Kalina, 1975, p. 438).

The release of autospores causes a rupture of the mother cell wall. In *Tetraedron minimum* var. *scrobiculatum* Lagerheim this rupture always occurs outside the deep concave indentations of the cell sides (Kovácik, 1975, p. 368).

In classifying fossil algae it must be born in mind that mutually different morphological types can be developed during the life cycles. *Tetraedron*-like stages will occur in several genera of the Chlorococcales, e.g. *Coelastrum* Nägeli, *Hydrodictyon* Roth, *Oocystis* Nägeli, and *Pediastrum* Meyen (Pringsheim, 1861, p. 781; Migula, 1907, p. 638; Wille, 1908, p. 816; Smith, 1950, p. 244; Kovácik, 1975, p. 386).

Plaesiodictyon mosellanum Wille, 1970 from the lower Keuper of Luxemburg was interpreted as a chlorophycean algae consisting of "plane, onelayered aggregations of a binary number of rectangular cells, which are arranged in a checker-board pattern". It has remarkable similarities to the modern genus *Pediastrum* (Wille, 1970, p. 283). The individual cells of *Plaesiodictyon* are cushion-shaped. Their angles are generally somewhat thickened as far as they are in contact with the margin of the coenobium and frequently growing into bud-shaped protuberances. There are no thickenings at the corners of the cells in the interior of the coenobium. The four corner cells of the coenobium are specially differentiated insofar as their free ends are most frequently prolonged into more or less distinct lobes.

Zygnematales

Some *Tetraporina*-like species assigned to the desmidiacean genera *Arthrodesmus* Ehrenberg, *Micrasterias* Agardh, and *Staurastrum* Meyen are misinterpreted representatives of *Tetraedron* and *Tetraedron*-like genera of the Xanthophyceae (Kovácik, 1975, pp. 367, 381, 384).

Strikingly *Tetraporina*-like fossils have been observed in a Bronze-Age settlement deposit in the Netherlands by Van Geel (1976, p. 337) and in Columbian Quaternary sediments by Van Geel & Van der Hammen (1978, p. 383), who have interpreted them as zygospores of *Mougeotia* Agardh (Zygnemataceae). Van Geel (1979, p. 467) has pointed out that spores related with those of the modern *Mougeotia* have been described as *Tetraporina*, *Tetrapidites* and *Tetraporopollenites*.

In the Zygnemataceae the ripe zygospore is quadrangular in the genera *Debarya* Wittrock, *Mougeotia* Agardh, *Temnogametum* West, and *Zygnemopsis* (Skuja) Transeau. For the identification and classification of modern taxa the shape, size and pigmentation of the zygospores and the ornamentation of the spore wall are main characters.

In almost all species the zygospores are constant in shape. The quadrangular zygospores show a number of variations in respect of the corners, the convexity and

Table 2—The characters of the corners in relation to different wall sculptures in the quadrangular zygnematacean zygospores with straight, concave, deeply concave or convex sides according to Randhawa (1959)

Wall sculpture	Corners
punctate	produced and truncate
	retuse
	rounded
	truncate
	with horn-like processes
scrobiculate	bulging
	obtuse
	produced into rounded horns
	produced and truncate
	retuse
	rounded
	truncate
smooth	apiculate
	produced and truncate
	retuse
	rounded
	truncate
	with horn-like processes
	with rounded process
	with thickened wall
verrucose	retuse
granulose	no record
reticulate	no record

concavity of the sides and the ornamentation of the spore wall. In most species the zygospores are smooth, reticulate, punctate or pitted while other kinds of ornamentation is rather uncommon (Randhawa, 1959, p. 100). Among the quadrangular forms the scrobiculate ornamentation is frequent but the pitted is absent. In the quadrangular zygnematacean zygospores with straight, concave, deeply concave or convex sides the characters of the corners in relation to different wall sculptures are recorded in Table 2.

In *Mougeotia* the zygospore wall is composed of an outer chitinous layer which is ornamented, and an inner transparent layer. In *Temnogametum* the spore wall consists of three layers of which the outer and inner are thin and hyaline, and the median is layered, chitinous, and ornamented (Randhawa, 1959, pp. 84, 87).

ENVIRONMENTAL MODIFICATION

The morphogenesis of algal cells is affected by nutritional and environmental factors such as chemical composition and temperature of the medium.

Nutritional influences

"Several inorganic elements or organic compounds trigger pronounced structural changes. For the inorganic nutrients the phenomena involved are : control of cell size and shape, wall ornamentation, unicell production, colony formation, sheath and mucilage formation...and auxospore formation. With organic compounds some organisms can form spines, produce unicells rather than colonies, or develop into a palmelloid state" (Trainor, 1970, p. 755).

The morphogenesis in strains of the acid resistant *Scenedesmus* Meyen under different environmental conditions has been studied by several authors. Forms which produce sporopollenins and have trilaminar wall sheaths are known in this genus (Atkinson *et al.*, 1972, p. 22; Staehelin & Pikett-Heaps, 1975, p. 167). The ratio between coenobia and unicells is affected by the phosphate uptake; the formation of unicells increases with an increase in the phosphate concentration of the medium (Overbeck & Stange-Bursche, 1965, p. 362). The development of bristles was shown to be due to influence of ammonia. When grown in the presence of ammonium at pH 8.5 or above the organism would be unicellular with numerous bristles like *Franceia* Lemmermann, but in a medium without ammonium spiny colonies were abundant (Trainor & Roskosky, 1967, p. 1661).

Soil bacteria can influence colonial or unicellular growth and the development of setae. A *Scenedesmus* culture isolated from soil developed colonies when grown in a soil extract medium. By addition of a soil bacteria the culture became unicellular (Trainor & Rowland, 1968, p. 315). Ovoid unicells with four or many setae, like *Chodatella*, were mostly developed when soil extract was added to a culture medium (Swale, 1967, p. 287), but without soil extract the same strain did not develop unicells (Trainor, 1970, p. 752). When thiamine was added to a dilute inorganic medium *Chodatella*-like unicells were formed (Trainor, 1970, p. 752). In media with low concentrations of iron and calcium, growth was promoted but spines were not formed on coenobia. Spines were formed when the level of either iron or calcium was increased (Trainor, 1969, p. 188).

It appears from the aforementioned examples that *Scenedesmus* is pleomorphic and that the pleomorphism can be developed under the influence of various nutritional factors. It is not known in detail how the development of the specimens of this and other algal genera is influenced or what controls the formation of the unicellular specimens in nature (Trainor & Rowland, 1968, p. 311). It does not seem to be any connection between the formation of spiny unicells and colonies lacking spines, both of which are produced by the same *Scenedesmus* culture (Trainor, 1969, p. 189).

Temperature influences

It has been shown that the morphology of algae is influenced by water temperature. In many cases an increase of temperature can be accompanied by decrease of size of the algae and production of unicells instead of coenobia (Grimas, 1974, p. 45). In other cases the situation is the other way round.

Scenedesmus quadricauda (Turpin) Brebisson develops larger coenobia at lower temperatures. Below 20°C normal four-cell coenobia and a great share of eight-cell coenobia are developed. At 30°C about 80 per cent of the coenobia are two-celled. *Ankistrodesmus falcatus* (Corda) Ralfs produced large colonies below 20°C but only unicells at higher temperatures. The shape and size of *Oocystis submarina* Lagerheim seem on the other hand to the independent of temperature (Grimas, 1974, p. 43).

The modification of shape and size is possibly an adaptation to the density of water, which is correlated to the temperature. The surface-to-volume ratio, morphology, size adaptation, and colony formation and their interactions with the physical environment are discussed by Tappan and Loeblich (1973, p. 211).

The approximate size range of some modern algae and fossil *Tetraporina* is listed in Lindgren (1980, p. 345, table 3).

CONCLUSION

Forms which are morphologically similar to fossil *Tetraporina* occur in several modern algal taxa. The origin of the *Tetraporina*-species can be sought for among unicellular forms, solitary forms which can also develop coenobia, coenobia which have disintegrated into individual cells, and resting spores.

It does not seem possible to assign the fossil form genus *Tetraporina* to any modern algal genus. The closest similarities seem to occur with cysts of the Dinophyceae, zygospores of the Zygnemataceae, individual cells of the coenobium of *Pediastrum*, and with specimens of *Porochloris, Tetradinium, Tetraedron* and *Tetraedriella*.

The great difficulties and diverse interpretations in classifying the modern quadrangular and tetrahedral algae demonstrates the impossibility of assigning their fossil counterparts to appropriate natural taxa, even at the rank of class.

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Lelstotheca Maheshwari, from the Barakar Formation of Raniganj Coalfield

Hari K. Maheshwari & A. K. Srivastava

Maheshwari, Hari K. & Srivastava, A. K. (1987). *Lelstotheca* Maheshwari, from the Barakar Formation of Raniganj Coalfield. *Palaeobotanist* **35**(2) : 136-140.

The genus *Lelstotheca*, known so far only from the Barakar Formation of Rajmahal Hills, Bihar is reported from the Barakar Formation of Raniganj Coalfield, West Bengal. The genus is represented by two species, viz., *L. robusta* (Feistmantel) Maheshwari and *L. striata* sp. nov. The new species is characterised by the presence of interconnecting striations running parallel to the median vein of the leaves. The taxonomic position of the genus and its records elsewhere are also discussed.

Key-words—*Lelstotheca*, Equisetales, Barakar Formation, Raniganj Coalfield (India).

Hari K. Maheshwari & A. K. Srivastava, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

सारॉंश

रानीगंज कोयला-क्षेत्र के बराकार शैल-समूह से लेल्सटोथीका माहेश्वरी

हरिकृष्ण माहेश्वरी एवं अश्विनी कुमार श्रीवास्तव

लेल्सटोथीका प्रजाति, जो कि अभी तक केवल राजमहल पहाड़ियों के बराकार शैल-समूह से ही ज्ञात थी, पश्चिम बंगाल में रानीगंज कोयला-क्षेत्र के बराकार शैल-समूह से भी अभिलिखित की गई है। यह प्रजाति दो जातियों अर्थात् ले. रोबस्टा (फ़ाइस्टमॅन्टॅल) माहेश्वरी तथा ले. स्ट्रिएटा नव जाति से निरूपित है। प्रस्तावित नव जाति पत्तियों की मध्य शिरा के समानान्तर विद्यमान अन्तरसंयोजी धारीयों से अभिलक्षणित है। इस प्रजाति की वर्गीकर्णिक स्थिति तथा अन्य स्थानों से इसके पूर्व-अभिलेखों का भी वर्णन किया गया है।

SURANGE and Prakash (1962) instituted the genus *Stellotheca* to include *Phyllotheca robusta* Feistmantel (1880) which Arber (1905) believed did not belong under *Phyllotheca*. Maheshwari (1972) considered the generic name *Stellotheca* to be an orthographic variant of the earlier *Stellatheca* (Danzé, 1956, p. 283) proposed for an ?osmundaceous fertile frond from the Westphalian C of Pas-de-Calais, France. Therefore, in accordance with articles 64 and 75 of the International Code of Botanical Nomenclature he proposed the name *Lelstotheca* to accommodate all forms placed under *Stellotheca* by Surange and Prakash (1962). However, according to interpretation of ICBN by Maithy and Mandal (1978) there is no justification for rejecting the generic name *Stellotheca*.

Article 64 of ICBN clearly states—A name is illegitimate and must be rejected if it is a later homonym that is if it is spelled exactly like a name previously and validly published for a taxon of the same rank based on a different type. Article 64 further notes that orthographic variants of the same name are homonyms when they are based on different types (see Articles 73, 75). Thus the remark of Maithy and Mandal (1978) that "the name *Stellotheca* can not be rejected because it has a different spelling from *Stellatheca*. Moreover, the former genus has been proposed for arthrophytes and the latter genus for ?Osmundaceous fertile frond" does not hold good. Examples cited by Maithy and Mandal (1978), i.e. *Symphyostemon* and *Symphostemon*, no doubt, can not be taken as orthographic variants. More such examples are given in Article 75 (ICBN, 1978, p. 64), viz., *Rubia* and *Rubus*, *Monochaite* and *Monochaetum*, *Peponia* and *Peponium*, *Iria* and *Iris*, *Desmostachys* and *Desmostachya*, *Gerrardinia* and *Gerrardiina*, *Durvillea* and *Urvillea*, *Peltophorus* and *Peltophorum*, etc. At the same time *Astrostemma* and *Asterostemma*, *Pleuropetalum* and *Pleuripetalum*, *Eschweilera* and *Eschweileria*, *Skytanthus* and *Scytanthus* are recognized as orthographic variants. The names *Stellatheca* and *Stellotheca* also fall into this category and hence the generic name *Stellotheca* was correctly replaced by *Lelstotheca*.

Outside India, the genus is known by *Stellotheca schtschurowskii* (= *Phyllotheca stschurowskii* Schmalhausen, 1879) Boureau (1964). However, the age of Zalessky's (1918, pl. 24, fig. 1) material collected from Kuznetsk Basin and included by Boureau is a matter of controversy. The material has been reinvestigated by Elias (1931), Neuberg (1948) and Radczenko (1956), who are of the opinion that the collection comprises Upper Palaeozoic and Lower Mesozoic forms. The specimens assigned to *Phyllotheca stschurowskii* by Zalessky have been found to be different from the type of the species illustrated and described by Schmalhausen (1879). In fact, one of the specimens (Zalessky, 1918, pl. 53, fig. 1, 1a) has been designated as holotype of *Annularia zalesskyii* Elias, 1931. Another specimen (Zalessky, 1918, pl. 38, fig. 2) has been transferred to *Pityophyllum noerdenskioldii* by Elias (1931, pl. 16, fig. 2). Zalessky (1933) himself transferred his *P. stschurowskii* specimens to the genus *Lobatannularia*. Neuberg (1948) transferred some of the specimens to *Schizoneura sibirica* and others to *Niazonaria*. *S. sibirica* was later transferred to a new genus *Paraschizoneura* by Radczenko (1956).

It would thus appear that *Phyllotheca stschurowskii* of Zalessky (1918) includes morphographically different forms and hence Boureau's (1964) transfer of these forms to the genus *Stellotheca* (*Lelstotheca*) needs to be examined afresh. Maithy and Mandal (1978) remarked that Arber (1905) and Elias (1931) wrongly spelled *stschurowskii*. The fact is that it is the original spelling as given by Schmalhausen (1879); it was later changed to *schtschurowskii* by Zalessky (1918).

The specimens for the present study were collected from the sandy carbonaceous shales associated with coals of Barakar Formation (Lower Permian) open cast projects of the Sangramgarh and Dalmia collieries in the West Raniganj Coalfield. None of the specimens is complete; these are preserved as compressions which have lost almost all their carbonified crust. Cellulose acetate pulls do not show cellular details, except for some faint impressions of longitudinal striations on the leaf surface. The specimens described by Surange and Prakash (1962) and Maithy and Mandal (1978) were also critically examined. All the figured specimens of the present study are deposited with the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

Genus—*Lelstotheca* Maheshwari, 1972

1962 *Stellotheca* Surange & Prakash, *Palaeobotanist 9*(1), p. 50, pl. 1, figs 1-7, text-figs 1, 2.
1964 *Stellotheca* Boureau, *Traité de Paléobotanique 3*, p. 287, figs 354, 355.
1966 *Stellotheca* Rigby, *Symp. Florist. & Strat. Gond.*, p. 51.
1966 *Stellotheca* Surange, *Indian Fossil Pteridophytes*, p. 49.
1978 *Stellotheca* Maithy & Mandal, *Palaeobotanist 25*, p. 279.

***Lelstotheca robusta* (Feistmantel) Maheshwari, 1972**

Pl. 1, figs 1, 2

1962 *Stellotheca robusta*, Surange & Prakash, *Palaeobotanist 9*, p. 50, pl. 1, figs 1-7, text-figs 1, 2.
1964 *Stellotheca robusta*, Boureau, *Traité de Paléobotanique 3*, p. 387, fig. 354.
1966 *Stellotheca robusta*, Surange, *Indian Fossil Pteridophytes*, p. 49, figs 27, 28.
1966 *Stellotheca robusta*, Rigby, *Symp. Florist. & Strat. Gond.*, p. 51, pl. 1, figs 1-3.
1978 *Stellotheca robusta*, Maithy & Mandal, *Palaeobotanist 25*, p. 279, pl. 1, figs 1-4, pl. 2, figs 5-9.
1981 *Stellotheca robusta*, Chandra & Rigby, *Geophytology 11*(2), p. 215, pl. 1, fig. 2.

The specimens are comparable in all respects with *Lelstotheca robusta* (Feistmantel) Maheshwari described by Feistmantel (1880), Surange and Prakash (1962) and Maithy and Mandal (1978).

Remarks—Feistmantel (1880) and Surange and Prakash (1962) considered that the leaves of a whorl of *L. robusta* are attached near the base in the form of a small cup or sheath. Maithy and Mandal (1978) observed the abaxially and adaxially preserved leaf whorls and found that the false union of leaves is visible in the adaxially preserved leaf whorl. However, our observation suggests that the false union as suggested by Maithy and Mandal (1978) is due to the swollen nature of node. The fine sediments deposited during the preservation give an impression of surrounding the cup-like depression (see pl. 1, fig. 2). Such depositional set up of the sediments around leaf whorl and axis has also been discussed by Walton (1936), while describing the factors which influence the external form of fossil plants with particular reference to *Annularia*, a comparative equisetale from the Northern Hemisphere.

Rigby (1966) described this species from New South Wales, Australia and included under it some of the forms earlier described under ?*Asterophyllites* (Clark, 1866), *Annularia australis* (Feistmantel, 1878; Wood, 1883; Feistmantel, 1890; Etheridge, 1891; Arber, 1905), *Annularia stellata* (Walkom, 1916) and *Phyllotheca robusta* (Walkom, 1922). *Stellotheca* sp. of Rigby (1966) and *Annularia* sp. (?*Stellotheca* sp.) of Lacey and Huard-Moine (1966) are not sufficiently well-preserved as to be properly identified and/or compared with known taxa.

Occurrence—Barakar Formation, grey shale above Seam no. B4, Dalmia Colliery, West Raniganj Coalfield, West Bengal.


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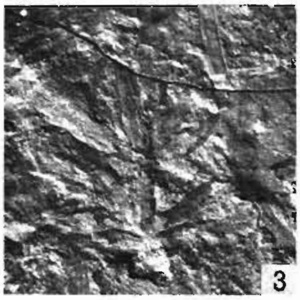
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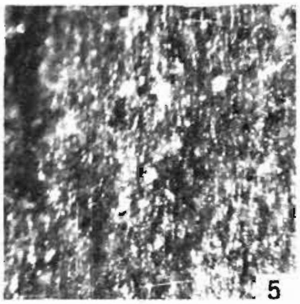
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PLATE 1

Lelstotheca striata sp. nov.
Pl. 1, figs 3-5

Diagnosis—Axis articulate, ribbed, leaves 8-12 in number, borne at nodes in a whorl, free up to base, linear-lanceolate in shape, apex sharply acute, base constricted, a single striated midvein entering each leaf and continuing up to apex; leaf surface showing fine interconnecting longitudinal striations; sometimes transverse thickenings present over leaf surface.

Holotype—BSIP Specimen no. 35850; Lower Permian, Barakar Formation, Coal Seam no. B4, Sangramgarh Open Cast Project, West Raniganj Coalfield, West Bengal.

Description—Of the three specimens in the collection, one specimen (no. 35850) shows two whorls of leaves attached to a slender axis. Preserved length of the axis is 11 mm which is 1.75 mm broad, articulate, with 8-12, fine, parallel, longitudinally running ribs in each internode; distance between two nodes is 10 mm, node smooth. At each node 8-12 leaves are arranged in a whorl, free up to base; leaves measure 5-8 mm in length and 1-1.5 mm in width at the widest, margin smooth, apex acute, base slightly constricted. A single, striated midvein enters each leaf at base and continues up to apex. Surface of each leaf shows 10-15, fine interconnecting longitudinal striations parallel to the midvein. The striae arise from the base of leaf and converge at the apex. Some of the leaves also show transverse thickenings/striations.

Comparison and discussion—The new species is comparable with the type species, *Lelstotheca robusta* in gross morphography. It can, however, be distinguished by the presence of fine, interconnecting longitudinal striations, over the surface of leaves. Transverse thickenings have also been observed in some of the leaves. Longitudinal striations over the leaf surface also occur in *Phyllotheca stschurowskii* (Schmalhausen, 1879, pp. 16-17, pl. 3, fig. 2b; pl. 4, fig. 4b; pl. 6, figs 2, 3) and *Annularia stellata* (Elias, 1931).

Striation/fibre/hair-like structures are quite common in the articulates. The leaves of *Phyllotheca sahnii, Raniganjia bengalensis, Lelstotheca robusta* and *Barakaria* (Meyen, 1969) show transverse striations. Walton (1936) reported some hair-like growth over the leaf surface in *Annularia sphenophylloides* Zenker, *A. galioides* Lindley & Hutton and *A. jongmansii* Walton. Transverse striations/fibres/hair have been observed over the leaf surface in *Annularia westphalica* Stür, *Carpannularia americana* Elias and *Annularia zalesskii* (Elias, 1931). Walton (1936, pl. 31, figs 16, 17) illustrated a specimen of *Annularia radiata* showing longitudinal striations oriented at right angles to the axis.

Many authors (Schmalhausen, 1879; Stür, 1887; Walkom, 1916; Zalessky, 1918; Thomas, 1911; Elias, 1931; Walton, 1936; Neuberg, 1964; Surange & Prakash, 1962; Pant & Kidwai, 1968; Rigby, 1966; Pant & Nautiyal, 1967; Maithy & Mandal, 1978) have expressed divergent views regarding the nature and importance of the striations. Some find them as mere lithological characters, though definite and regular presence of these structures over the leaf surface is indicative of an adaptive character.

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PLATE 1

1. *Lelstotheca robusta* (Feistmantel) Maheshwari, showing the nature of leaves and stem. BSIP Specimen no. 35848. × 1.5.
2. *L. robusta* leaf whorl showing false impression of cup-like depression formed due to fine sediments deposited during preservation. BSIP Specimen no. 35849. × 1.5.
3. *L. striata* sp. nov. Holotype, showing arrangement and attachment of leaves. BSIP Specimen no. 35850 × 1.5.
4. *L. striata* holotype enlarged to show the longitudinal and transverse striations over the surface of leaves. BSIP Specimen no. 35850. × 8.
5. *L. striata* leaf surface enlarged to show the fine parallel interconnecting longitudinal striations. BSIP Specimen no. 35850. × 30.

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The Palaeobotanist **35**(2) : 141-145, 1986.

Mesozoic plant remains from Samu, Barmer District, Rajasthan

Jayasri Banerji & Pankaj K. Pal

Banerji, Jayasri & Pal, P. K. (1987). Mesozoic plant remains from Samu, Barmer District, Rajasthan. *Palaeobotanist* **35**(2) : 141-145.

The plant assemblage includes pteridophytic as well as gymnospermic remains. Amongst the pteridophytes *Phlebopteris* is common with rare presence of *Cladophlebis*, whereas, of the gymnosperms *Otozamites* is frequent with rare occurrence of *Pachypteris*, *Pagiophyllum* and *Brachyphyllum*. The assemblage is somewhat similar to the fossil assemblage of Pariwar Formation, Jaisalmer District. On the basis of plant assemblage an Upper Jurassic age has been suggested for the Samu Hill Formation.

Key-words—Plant megafossils, Pteridophytes, Gymnosperms, Samu Hill Formation, Upper Jurassic (India).

Jayasri Banerji & P. K. Pal, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007 (India).

साराँश

राजस्थान के बाड़मेर जनपद में सारनु से मध्यजीवी पादप-अवशेष

जयश्री बैनर्जी एवं पंकज कुमार पाल

इस पादप-समुच्च्य में टेरीडोफ़ाइटी एवं अनावृबीजी दोनों ही प्रकार के पादप-अवशेष मिलते हैं। टेरीडोफ़ाइटीयों में क्लेडोफ्लेबिस की असामान्य उपस्थिति के साथ-साथ फ़्लीबॉप्टेरिस सामान्यतः मिलता है जबकि अनावृतबीजीयों में ओटोजमाइटिस प्रचुर संख्या में मिलता है तथा पेकिप्टेरिस, पेजियोफ़िल्लम् एवं ब्रेकिफ़िल्लम् अत्यन्त अल्प मात्रा में मिलते हैं। यह समुच्चय जैसलमेर जनपद के परिवार शैल-समूह से कुछ-कुछ मिलती-जुलती है। पादप-समुच्चय के आधार पर सारनु गिरि शैल-समूह की उपरि क्रीटेशी आयु प्रस्तावित की गई है।

THE sandstone-siltstone sequence interbedded with ferruginous shales exposed in the hilly range adjacent to the Samu Village (25° 40′N : 71° 47′E) has been named as Samu Hill Formation (Das Gupta, 1975; Baksi & Naskar, 1981). From this formation Baksi and Naskar (1981) have described *Phlebopteris athgarhensis* Jain, *Sphenopteris* sp. and *Ptilophyllum acutifolium* Morris. A number of specimens collected by one of us (J.B.) from the same locality is described below.

DESCRIPTION

Genus—*Phlebopteris* Brongniart

Phlebopteris sp. cf. *P. athgarhensis* Jain

Pl. 1, figs 1-5; Text-fig 1A-B

Description—Detached pinnae, largest available specimen 14 cm long, 7.4 cm wide. Pinna-rachis 2.5-3 mm wide, gradually narrowing towards apex. Pinnules opposite or subopposite, arising at an angle of 70°-90°, attached by entire base, linear, 0.35-3.5 cm long and 1.5-4 mm wide, gradually becoming shorter and narrower towards apex, often slightly bending downwards, margins entire, apex acute to obtuse. Midrib 0.5 mm wide, distinct up to apex; lateral veins arising at an angle of 50°-65°, mostly bifurcating 1-3 times, forming distinct polygonal meshes along both sides of midrib, veins 4-6 per mm near margin. Fertile pinnules more or less similar to the sterile ones; Sori arranged in rows, usually 1 mm apart on either side of midrib, number of sori in a row varies from 14 to 30, two rows of sori converging towards apex. Sorus almost circular, about 0.6 mm in diameter with a circular depression at the centre, other details obscure.

Remarks—Both sterile and fertile fronds are well represented. Out of 30 specimens in our collection none shows a bipinnate nature. Baksi and Naskar (1981) mentioned that the number of sporangia in a sorus is 5-7. But we were unable to find out any trace of sporangia in any of our specimens. In the Samu Hill specimens the sori are more contiguous than those in the type specimen of *Phlebopteris athgarhensis* Jain. Moreover, number of sporangia in a sorus is not known in the present specimens.

Genus—*Cladophlebis* Brongniart

Cladophlebis sp.

Pl. 1, fig. 6; Text-fig. 1C

Description—Detached pinnae, largest fragment 3.7 cm long, 1 cm wide, linear-lanceolate, pinna rachis 0.5 mm wide, finely striated, imparipinnate. Pinnules alternate or subopposite, arising at an angle of 60°-90°, often falcate, 1.5-6 × 1-2.5 mm in size, attached by broad base; margins entire, apex acute to broadly rounded. Midrib distinct, lateral veins simple or forked, mostly forking once.

Remarks—The collection includes only two imperfectly preserved specimens, out of which one (Pl. 1, fig. 7) has both part and counterpart. In gross morphography the specimens come closer to *Cladophlebis daradensis* described by Bose and Banerji (1984).

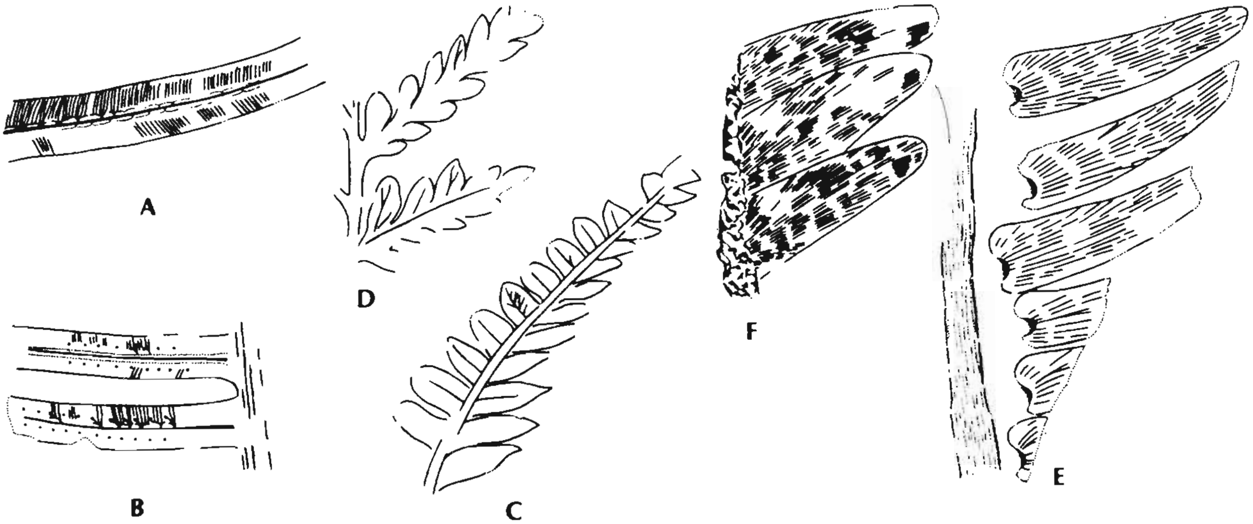
Genus—*Pachypteris* Brongniart

Pachypteris haburensis Bose, Kumaran & Banerji

Pl. 1, fig. 7; Text-fig. 1D

Description—Of two bipinnate fronds, the larger measured specimen 3 cm in length and 2.7 cm in width. Primary rachis 0.5 mm wide, medianly grooved. Pinnae alternate, emerging at an angle of 50°-60°, linear-lanceolate. Pinnules alternate-subopposite, attached at an angle of about 40°, lanceolate-obovate, 2-4 mm long and 1-1.5 mm wide (typically 2.5 × 1.2 mm), acroscopic margin towards base slightly constricted, basiscopic basal margin decurrent on the pinna-rachis; lateral margins entire; apex acute-obtuse. Veins rarely preserved; midrib distinct up to apex; secondary veins usually 1 or 2, rarely 3; mostly unforked, rarely in basal pinnules forking once.

Remarks—The two specimens in gross features and venation pattern of pinnules match exactly with *Pachypteris haburensis*.



Text-fig. 1 — **A,B.** *Phlebopteris* sp. cf. *P. athgarhensis* Jain : A, sterile pinnule showing venation, specimen no. BSIP 35898. × 2; B, part of a pinna with fertile pinnules showing single row of sori on either side of midvein, specimen no. BSIP 35809. × 2. **C**, *Cladophlebis* sp., specimen no. BSIP 35797. × 2. **D**, *Pachypteris haburensis* Bose *et al*, specimen no. BSIP 35797. × 2. **E**, *Otozamites* sp. cf. *O. imbricatus* Feistmantel, specimen no. BSIP 35810. × 2. **F**, *Otozamites* sp. B., specimen no. BSIP 35799. × 1.

PLATE 1

→

1-5. *Phlebopteris* sp. cf. *P. athgarhensis* Jain
1. Apical part of the sterile pinna; Specimen no. BSIP 35791 × 1.
2. Sterile pinna, Specimen no. BSIP 35792. × 1.
3-5. Fertile fronds showing sori; Specimen nos. BSIP 35793, 35795, 35796 × 1.
6. *Cladophlebis* sp. 1; Specimen no. BSIP 35797. × 1.
7. *Pachypteris haburensis* Bose *et al*; Specimen no. BSIP 35797. × 1.
8. *Otozamites* sp. B.; Specimen no. BSIP 35799. × 1.
9. *Otozamites* sp. A.; Specimen no. BSIP 35800. × 1.
10-12. *Otozamites* cf. *imbricatus* Feistmantel; Specimen nos. BSIP 35801, 35802, 35803 all. × 1.
13, 14. *Pagiophyllum* sp., Specimen nos. BSIP 35804 and 35805, both × 1.
15, 16. *Brachyphyllum* sp.; Specimen nos. BSIP 35806 and 35807, both × 1.
17. ?*Coniferocaulon* sp.; Specimen no. BSIP 35808. × 1.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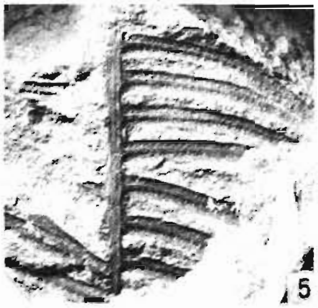
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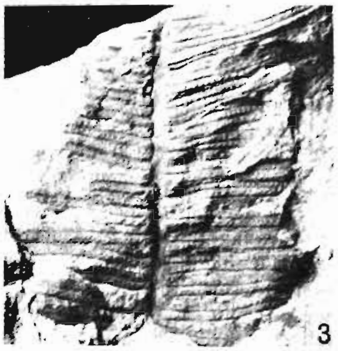
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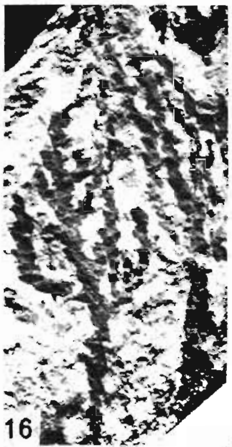
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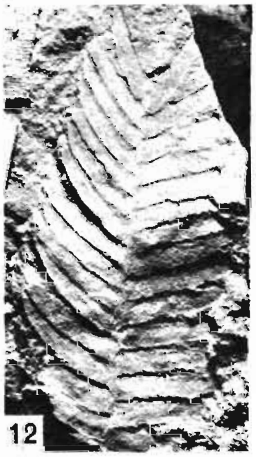
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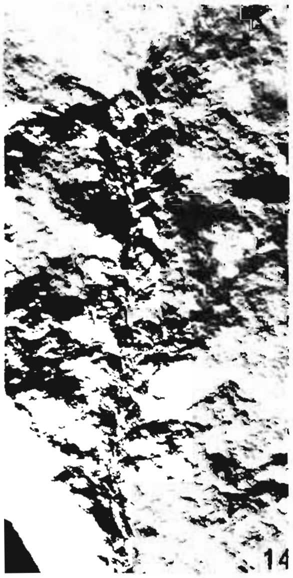
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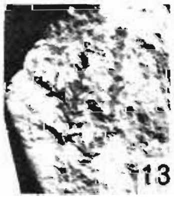
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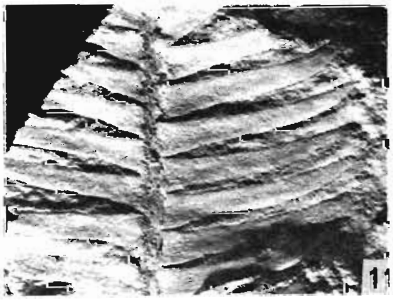
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PLATE 1

Genus—*Otozamites* Braun

Otozamites sp. cf. *O. imbricatus* Feistmantel

Pl. 1, figs 10-12; Text-fig. 1E

Description—Leaf imparipinnate, largest available specimen about 8.5 cm long, 2.7 cm wide, rachis 2.5-3 mm wide; pinnae arising at an angle of 60°-75°, alternate, contiguous, linear falcate, pinnae attached on upper surface of rachis slightly below middle of base, base distinct, arcuate, basal acroscopic margin slightly auriculate, basal basiscopic margin rounded, apex acute-subacute; rarely obtuse, margin entire. Pinnae 0.3-3.1 × 0.1-0.5 cm, typically 2 cm long, 4.5 mm wide, 7-12 veins radiating from pinna base, simple or forked 1-3 times at various levels.

Remarks—The species is common at Samu. In gross features the specimens match the specimens of *Otozamites imbricatus* Feistmantel described by Bose (1974, pl. 46, figs 1, 2).

Otozamites sp. A

Pl. 1, fig. 9

Description—Fragmentary pinnate leaves, rachis 1 mm wide, pinnae subopposite, attached on upper surface of rachis at an angle of 50°-70°, 5-7 × 2-3.5 mm, ovate-falcate, contiguous, basal acroscopic margin slightly auriculate, basal basiscopic margin somewhat curved inwards, lateral margins entire; apex obtuse. Veins 8-10 per pinnae nearer base, slightly diverging towards margin, veins unforked or once forked, forking at different levels.

Comparison—Only two specimens were collected. Out of them one clearly shows the asymmetrical nature of the base. In gross features the specimens resemble most *Otozamites kachchhensis* Bose & Banerji (1984).

Otozamites sp. B

Pl. 1, fig. 8; Text-fig. 1F

Description—Largest available fragment showing only three pinnae attached on one side of rachis at an angle of 70°-75°, oblong in shape, size 2.7 × 0.9 cm, margin entire, thick, basal acroscopic margin very slightly auriculate, apex obtuse, veins 35-40 per cm at base; slightly diverging at distal end, veins unforked-forked.

Comparison—In shape, size and concentration of veins *Otozamites* sp. B may be compared with *Otozamites graphicus* (Leckenby) Harris, *O. thomasii* Harris and *O. parallelus* Phillips described by Harris (1969).

Genus—*Brachyphyllum* Brongniart

Brachyphyllum sp.

Pl. 1, figs 15, 16

Description—Twigs profusely branched in all directions, largest specimen 4.7 cm in length, leaves spirally borne, appressed, closely placed; gradually becoming smaller and slightly spreading towards distal ends of twigs, triangular-rhomboidal, generally 1.5-2 × 1.5-2 mm in size; margin entire; apex acute; distinctly keeled.

Remarks—In gross features the specimens are not comparable with any of the species of *Brachyphyllum* so far known to us. However, refrain from assigning them to a new species because epidermal features are not known.

Genus—*Pagiophyllum* Heer

Pagiophyllum sp.

Pl. 1, figs 13, 14

Description—Branched shoot, 8.3 cm in length, leaves spirally attached, laterally spreading, ovate-falcate in shape, measuring 4-4.5 × 1.5-2 mm, margin entire; base decurrent; apex acute; distinctly keeled.

Comparison—The specimens resemble somewhat *Pagiophyllum* sp. A described by Bose *et al.* (1982). The specimens exhibit a wide range of variation in leaf-size. But altogether they appear to represent a natural population of continuous range of variations though the two extremities are distinct from each other.

DISCUSSION

In addition to plant fossils earlier described by Baksi and Naskar (1981) some more species have been described in this paper. Besides, our collection also includes a specimen doubtfully assignable to the genus *Coniferocaulon* Fliche (Pl. 1, fig. 17). The assemblage is dominated by *Phlebopteris* sp. cf. *P. athgarhensis* Jain and *Otozamites* cf. imbricatus Feistmantel. *Brachyphyllum* sp. is next in abundance. *Cladophlebis* sp., *Pachypteris haburensis* Bose *et al.* and *Pagiophyllum* sp. are rare.

The assemblage is somewhat similar to the assemblage described from the Pariwar Formation by Maheshwari and Singh (1976) and Bose *et al.* (1982). The assemblage from Habur also has forms like *Phlebopteris, Pachypteris, Otozamites, Pagiophyllum* and *Brachyphyllum*. However, so far *Taeniopteris, Pterophyllum* and *Anomozamites* have not been found at Samu. Baksi and Naskar (1981) have suggested a Lower Cretaceous age for the Samu fossiliferous beds. In the absence of any definite Cretaceous forms like *Weichselia* and *Onychiopsis*, it is difficult to say whether the Samu beds are exactly of Lower Cretaceous age. However, the overall assemblage is more suggestive of Upper Jurassic age.

ACKNOWLEDGEMENTS

We are highly indebted to Dr M. N. Bose for his keen interest during the course of the work and also for a good deal of suggestions after kindly going through the first draft. We are also thankful to Dr B. N. Jana for help during the field work.

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The Palaeobotanist **35**(2) : 146-149, 1986.

A new fossil dicot wood from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh

R. C. Mehrotra

Mehrotra, R. C. (1987). A new fossil dicot wood from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Palaeobotanist*, **35**(2) : 146-149.

A fossil dicotyledonous wood, *Euphorioxylon deccanense* sp. nov., of Sapindaceae has been described from the Deccan Intertrappean beds of Mehdwani, Mandla District. Small to medium-sized vessels, scanty paratracheal parenchyma, almost exclusively uniseriate xylem rays and non-septate fibres are the diagnostic features of the fossil wood.

Key-words—Xylotomy, Sapindaceae, *Euphorioxylon*, Deccan Intertrappean beds, Early Tertiary (India).

R. C. Mehrotra, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

सारॉंश

मध्य प्रदेश में मंडला जनपद की दक्खिन अन्तर्ट्रैपी संस्तरों से एक नवीन द्विबीजपत्री अश्मित काष्ठ

राकेश चन्द्र मेहरोत्रा

मंडला जनपद में महदवानी की दक्खिन अन्तर्ट्रैपी संस्तरों से सेपिन्डेसी कुल की यूफ़ोरिऑक्सीलॉन दक्खिनेन्से नव जाति की अश्मित काष्ठ वर्णित की गई है। लघु से मध्य-आकार की वाहिकायें, अत्यल्प परावाहिकी मृदूतक, प्राय: अत्यअधिक एकपंक्तिक दारु किरण एवं अपटी तंतु इस काष्ठाश्म के प्रधान लक्षण हैं।

A LARGE number of fossil plants, mostly in the form of petrified woods, have been described from various Deccan Intertrappean localities of Mandla District, Madhya Pradesh (Mehrotra, Prakash & Bande, 1984; Bande, Mehrotra & Prakash, 1986). Recently a new locality, Mehdwani (22° 54′ N: 80° 40′ E), was discovered in the same area, which lies about 70 km north-east of Mandla proper. A number of palm woods and a few dicotyledonous woods were collected from here. One of the dicotyledonous woods from this collection has been found to resemble certain xylotomically closely related genera of Sapindaceae and is being described here.

SYSTEMATIC DESCRIPTION

Genus—*Euphorioxylon* Awasthi, Guleria & Lakhanpal, 1982

Euphorioxylon deccanense sp. nov.
Pl. 1, figs 1, 3, 4, 6, 7

Material—A small piece of well preserved secondary wood about 2 cm in length and 1.7 cm in width.

Description—*Wood* diffuse-porous (Pl. 1, fig. 1). *Growth rings* indistinct. *Vessels* usually small to medium-sized, sometimes very small, t.d. 40-120 μm, r.d. 40-140 μm, mostly solitary, occasionally in radial multiples of 2-4, rarely in tangential pairs, circular to oval when solitary, with flat contact walls when in multiples, sometimes deformed due to compression, 9-23 per sq mm (Pl. 1, figs 1, 3); tyloses occasionally present; vessel members 180-330 μm long with oblique to horizontal ends; perforations simple (Pl. 1, fig. 4); intervessel pit-pairs bordered, alternate, 6-8 μm in diameter, circular to oval in shape with lenticular apertures (Pl. 1, fig. 7). *Parenchyma* scanty paratracheal (Pl. 1, fig. 3), parenchyma cells thin-walled, 24-60 μm in length and 16-20 μm in diameter. *Xylem rays* 7-10 per mm, almost exclusively uniseriate, sometimes with paired cells, usually made up of procumbent cells, sometimes with both procumbent and upright cells, 8-12 μm in width and 2-42 cells or 30-520 μm in height (Pl. 1, fig. 4); ray tissue heterogeneous, procumbent cells 12-20 μm in tangential height and 28-40 μm in radial length; upright cells 28-40 μm in tangential height and 8-12 μm in radial

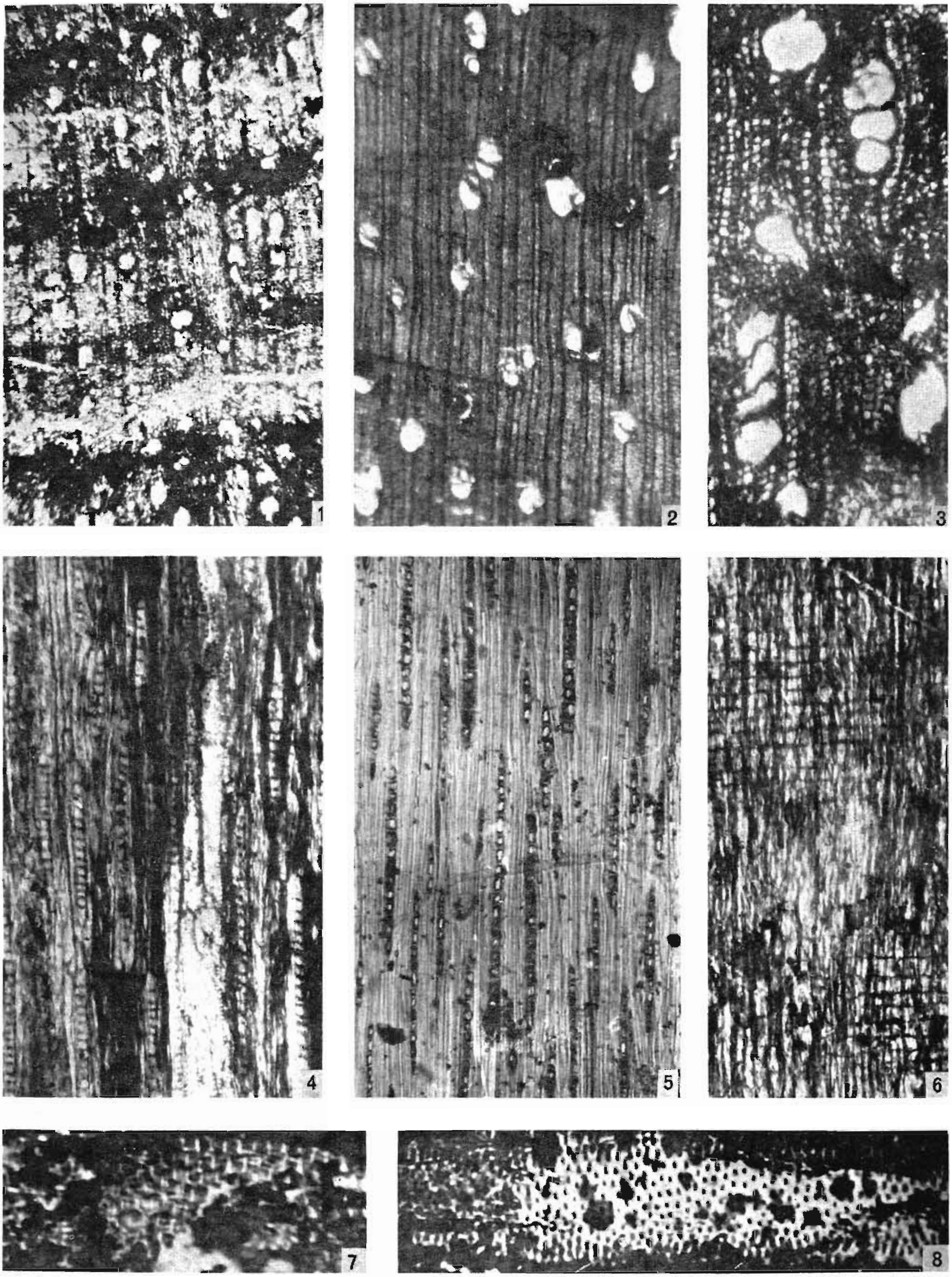

PLATE 1

length (Pl. 1, fig. 6). *Fibres* semi-libriform, oval to polygonal in cross section (Pl. 1, fig. 3), non-septate, 12-20 μm in diameter and 240-800 μm in length (Pl. 1, fig. 4).

Affinities—The important characters of the fossil wood are small to medium-sized vessels, scanty paratracheal parenchyma, almost exclusively uniseriate xylem rays, heterogeneous ray tissue and non-septate fibres. These characters are met with in the families Sonneratiaceae and Sapindaceae (Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Kribs, 1959; Miles, 1978). In Sonneratiaceae, only the genus *Sonneratia* L. shows some similarity with the fossil in gross features. However, the presence of vestured pitting and absence of parenchyma differentiate it from the present fossil (cf. Kazmi, 1982). As far as Sapindaceae is concerned, Ramesh Rao (1963, pp. 212-213) has given a key for separating different genera of this family on the basis of wood anatomy. A perusal of the key indicates that the fossil shows close resemblance with *Nephelium* Linn., *Schleichera* Willd. and *Xerospermum ferrugineum* C.E.C. Fisher. *Schleichera* can be differentiated from the fossil in having diffuse as well as terminal parenchyma and 1-2 seriate xylem rays while *Xerospermum ferrugineum* can be distinguished in possessing comparatively smaller number of vessels (4-9 per sq mm). Hence, the fossil shows maximum resemblance with *Nephelium* (sensu lato).

In its wider sense, *Nephelium* consists of about 30 species. However, according to Radlkofer (in Brandis, 1971) they should be grouped under four distinct genera—*Euphoria, Litchi, Otonephelium* and *Nephelium*. On the basis of xylotomy, *Nephelium*, in its restricted sense, can be differentiated from the other three genera by the amount of wood parenchyma which is best developed in the former and is rather sparse in the latter three.

Wood anatomy of *Euphoria, Litchi* and *Otonephelium* has been described by Ramesh Rao (1963) and according to him they are indistinguishable. Besides consulting the description of Ramesh Rao (1963, p. 226), the wood slides of *Euphoria longana, Litchi chinensis* and *Otonephelium stipulaceum* were also examined by the author who found that though there were some differences in a few anatomical characters of these three taxa, they were not significant enough to warrant a generic differentiation. However, it is felt that a critical examination of the wood slides of a larger number of species of these three genera would be desirable to establish generic identity on the basis of wood anatomy.

Thus, as known at present, on the basis of xylotomy the genera *Euphoria, Litchi* and *Otonephelium* form a complex whose components are impossible to differentiate. For the fossil woods assignable to this complex, Awasthi *et al.* (1982) had instituted the genus *Euphorioxylon*. Because of the closest resemblance of the present fossil with this complex, it has been placed under the same genus. In the generic diagnosis of *Euphorioxylon*, ray tissue was mentioned as homogeneous. However, due to the occasional presence of upright cells also in the present fossil wood, the ray tissue in its generic diagnosis should be emended as "homogeneous to heterogeneous".

So far the only record of *Euphorioxylon* is *E. indicum* Awasthi, Guleria & Lakhanpal (1982) which is known from the Cuddalore Series of Pondicherry and Kankawati Series of Kutch. This species differs from the present fossil in having homogeneous ray tissue and comparatively fewer vessels (9-14 per sq mm). In addition, vessel multiples are more frequent in it than in the present fossil wood.

As the present fossil is different from *Euphorioxylon indicum*, it has been placed under a new species *Euphorioxylon deccanense*, the specific name indicating its occurrence in the Deccan Intertrappean sediments.

Of the three living species resembling the fossil, *Euphoria longana* is distributed throughout the Western Ghats from the Konkan southwards, extending to Sri Lanka and ascending up to 900 m, Assam, South China, Burma and Malaya. *Litchi chinensis* is a native of China, cultivated in India for its fruits. *Otonephelium stipulaceum* is a handsome medium-sized tree being confined to the evergreen forests of Western Ghats from

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PLATE 1

1. *Euphorioxylon deccanense* sp. nov.—Cross section of the fossil wood in low power showing shape, size and distribution of the vessels. × 45; Slide no. B.S.I.P. 35895—I.
2. *Nephelium stipulaceum*—Cross section of the modern wood showing similar shape, size and distribution of the vessels. × 45.
3. *Euphorioxylon deccanense* sp. nov.—Magnified cross section of the fossil wood showing scanty paratracheal parenchyma and arrangement of the vessels. × 100; Slide no. B.S.I.P. 35895—I.
4. *Euphorioxylon deccanense* sp. nov.—Tangential longitudinal section of the fossil wood showing structure of xylem rays and fibres. × 120; Slide no. B.S.I.P. 35895—II.
5. *Nephelium stipulaceum*—Tangential longitudinal section of the modern wood showing similar structure of xylem rays and fibres. × 120.
6. *Euphorioxylon deccanense* sp. nov.—Radial longitudinal section of the fossil wood showing heterogeneous ray tissue. × 180; Slide no. B.S.I.P. 35895-III.
7. *Euphorioxylon deccanense* sp. nov.—Magnified intervessel pit-pairs of the fossil wood. × 400; Slide no. B.S.I.P. 35895—II.
8. *Nephelium stipulaceum*—Magnified intervessel pit-pairs of the modern wood. × 400.

the Nilgiris southwards, ascending up to 900 m (Ramesh Rao, 1963).

SPECIFIC DIAGNOSIS

Euphorioxylon deccanense sp. nov.

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* small to medium-sized, t.d. 40-120 μm , r.d. 40-140 μm, solitary and in radial multiples of 2-4, 9-23 per sq mm, tyloses occasionally present; perforations simple; intervessel pit-pairs bordered, alternate, medium-sized with lenticular apertures. *Parenchyma* scanty paratracheal. *Xylem rays* almost exclusively uniseriate, mostly made up of procumbent cells, 7-10 per mm, 8-12 μm in width and 2-42 cells or 30-520 μm in height; ray tissue heterogeneous. *Fibres* semi-libriform and non-septate.

Holotype—BSIP Museum specimen no. 35895 (the specimen was consumed while preparing the slides).

Locality & age—Deccan Intertrappean beds of Mehdwani, Mandla District, Madhya Pradesh; Early Tertiary.

ACKNOWLEDGEMENTS

The author is grateful to Dr B. S. Venkatachala, Director, BSIP, Lucknow for his constant encouragement. Sincere thanks are also due to Dr Ramesh Dayal, Forest Research Institute, Dehradun for providing the modern wood samples.

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The Palaeobotanist **35**(2) : 150-158, 1986.

Palynology of the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road Section, Jaintia Hills (Meghalaya) and Cachar (Assam). Part-VI. Palynostratigraphic zonation

R. K. Saxena, M. R. Rao & H. P. Singh

Saxena, R. K., Rao, M. R. & Singh, H. P. (1987). Palynology of the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road Section in Jaintia Hills (Meghalaya) and Cachar (Assam). Part-VI. Palynostratigraphic zonation. *Palaeobotanist* **35**(2) : 150-158.

Excellent exposures of Barail and Surma groups are developed along the sonapur-Badarpur Road Section in Jaintia Hills (Meghalaya) and Cachar (Assam). Frequency analysis and variation pattern observed in the palynoassemblage from these sediments provide ample evidence for their biostratigraphic zonation. On the basis of the first appearance, maximum development and decline of the various palynofossils, six cenozones have been recognized in the sequence. These are in ascending order: (i) *Polysphaeridium subtile* Cenozone, (ii) *Todisporites major* Cenozone, (iii) *Lygodiumsporites eocenicus* Cenozone, (iv) *Striatriletes sinuosus* Cenozone, (v) *Pinuspollenites foveolatus* Cenozone, and (vi) *Malayaeaspora costata* Cenozone. A formal description of each cenozone, as to their type section, lithology, thickness, nature of contacts, restricted and characteristic spore-pollen species and other salient features, if any, have also been given. The lateral extension of these cenozones has a potential in the correlation and demarcation of equivalent strata in other parts of this region.

Key-words—Palynostratigraphy, Barail-Surma groups, Oligocene-Lower Miocene, Meghalaya-Assam (India).

R. K. Saxena, M. R. Rao & H. P. Singh, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

जयन्तिया पहाड़ियों (मेघालय) एवं कछार (असम) में सोनपुर-बदरपुर मार्ग खंड के संग-संग विगोपित सूरमा (अधरि मध्यनूतन) एवं बैरेल (अल्पनूतन) अवसादों का परागाणविक अध्ययन. भाग 6—परागाणुस्तरिक मंडलन

रमेश कुमार सक्सेना, मलागलापल्ली रामचन्द्र राव एवं हरिपाल सिंह

जयन्तिया पहाड़ियों (मेघालय) एवं कछार (असम) में सोनपुर-बदरपुर मार्ग खंड के संग-संग बैरेल एवं सूरमा समूहों के सुस्पष्ट अनावरण विद्यमान हैं। इन अवसादों से उपलब्ध परागाणविक-समुच्चय में प्रेक्षित बारम्बारता विश्लेषण एवं विभिन्नता के ढंग से इनके जैवस्तरिकीय मंडलन हेतु पर्याप्त प्रमाण मिले हैं। प्रथम प्रादुर्भाव, अधिकतम् विकास एवं विभिन्न परागाणविकरूपकों के निम्नीकरण के आधार पर इस अनुक्रम में छः नवमंडल अभिनिर्धारित किये गये हैं। आरोही क्रम में ये (अ) पोलिस्फ़ेयरीडियम् सबटिल नवमंडल, (आ) टोडिस्पोराइटिस मेजर नवमंडल, (इ) लाइगोडियमस्पोराइटिस ईओसेनिकस नवमंडल, (ई) स्ट्आट्राइलिटीज़ साइनुओसस नवमंडल, (ए) पाइनसपोलिनाइटिस फ़ोविओलेटस नवमंडल, तथा (ऐ) मलायाइआस्पोरा कोस्टेटा नवमंडल हैं। प्रत्येक नवमंडल का एक संक्षिप्त विवरण दिया गया है जिसमें उनका प्रारूप खंड, शैलिकी, मोटाई, संस्पर्श प्रकृति, सीमित एवं लाक्षणिक जातियाँ तथा अन्य मुख्य लक्षण सम्मिलित हैं। इन नव-मंडलों के पार्श्व विस्तार से इस क्षेत्र के अन्य भागों में विद्यमान समतुल्य स्तरों के सहसम्बन्धन तथा परिसीमन में सहायता मिली है।

A FIELD study of the Tertiary sediments of north-eastern India reveals that various rock formations developed in this region are subjected to a large scale lateral variation and therefore lithological markers prove to be of limited value in stratigraphic correlation and demarcation of various levels therein. In such cases, biostratigraphic zones play an important role in demarcation and identification of stratal sequences and also in dividing them into finer units (zones). These are some of the important aspects of any palaeo-palynological study. A few efforts have so far been made in using the palynofossils for the above purpose by Baksi (1962), Dutta and Sah (1970), Banerjee, Misra and Koshal (1973), Sah and Dutta (1974) and Sah and Singh (1974),

B.S.I.P.

as far as the Tertiary sediments of north-eastern India are concerned.

The authors have studied the palynology of the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along the Sonapur-Badarpur Road Section in Jaintia Hills (Meghalaya) and Cachar (Assam). Systematic description of the palynofossils recovered from this section has been published by Rao (1983), Singh and Rao (1984), Saxena and Rao (1984), Rao *et al.* (1985), Rao (1986), Singh *et al.* (1986) and Rao and Singh (MS). The present paper deals with the palynostratigraphic zonation of the Barail-Surma sequence exposed along this section. These zones, when traced laterally, may prove to be helpful in correlation and demarcation of equivalent strata in other parts of north-eastern India.

The palynoassemblages recovered from the Barail (Oligocene) and Surma (Lower Miocene) groups are rich in pteridophytic spores and gymnospermous pollen grains, whereas the angiospermous pollen grains and algal and fungal remains are comparatively less represented. The assemblage consists of 62 genera and 112 species of palynomorphs. Of these, some species have a wide range of distribution while others are restricted to a small stratigraphic interval.

For the quantitative analysis of the assemblage, 200 specimens per sample were counted. However, in cases where the yield was poor, only 150 palynomorphs were counted. The frequencies of all the species per 100 specimens, were calculated and plotted in the range chart under the five slabs, viz., very rare (below 2%), rare (2-10%), common (11-20%), abundant (21-35%) and predominant (above 35%) (Text-fig. 1).

On the basis of the qualitative and quantitative analyses of the palynoflora, it seems possible to divide the Barail-Surma sequence of the present section into six cenozones. To establish and recognize these cenozones, parameters like the first and last appearance of various palynotaxa and their maximum development, decline, restricted occurrence and absence have been taken into consideration. Each cenozone has been formally instituted in accordance with the code of Stratigraphic Nomenclature of India (1971).

PALYNOSTRATIGRAPHY

The six cenozones established in the Barail-Surma sequence of Sonapur-Badarpur Road Section, are given below in the ascending order of stratigraphy.

(vi) *Malayaeaspora costata* Cenozone
(v) *Pinuspollenites foveolatus* Cenozone
(iv) *Striatriletes sinuosus* Cenozone
(iii) *Lygodiumsporites eocenicus* Cenozone
(ii) *Todisporites major* Cenozone
(i) *Polysphaeridium subtile* Cenozone

Polysphaeridium subtile Cenozone

Type section—Lower Laisong Formation exposed along Sonapur-Badarpur Road Section between 140 km and 142 km.*

Lithology—This zone is mainly composed of grey, very hard, thinly bedded, very fine to medium grained sandstones alternating with subordinate hard, sandy shale and intraformational conglomerate. Massive and moderately well bedded sandstones are also common. Generally the shales are carbonaceous. Thickness of this zone is ± 900 m.

Nature of contact—This cenozone constitutes the lower biostratigraphic unit of the Laisong Formation and conformably overlies the Kopili Formation (*Densiverrupollenites eocenicus* Cenozone, Tripathi & Singh, 1984). The upper limit of this cenozone is conformably overlain by the *Todisporites major* Cenozone, which is made up of thick sandstones intercalated with carbonaceous shale bands.

Species restricted to this cenozone—Adnatosphaeridium vittatum, Tricolpites sp.

Characteristic palynofossils—Adnatosphae-ridium vittatum, Polysphaeridium subtile, Cordosphaeridium inodes, Impletosphaeridium insolitum, Homotryblium floripes, Striatriletes susannae, Lygodiumsporites lakiensis, L. eocenicus, Cyathidites minor and *Pinuspollenites foveolatus* (Pl. 1, figs 1-9).

Remarks—The significant feature of this cenozone is that the dinoflagellate cysts are represented by 23 per cent. These cysts dominate in this zone while in the other zones they are insignificantly represented. *Polysphaeridium subtile* constitutes the major part (35%) of the dinoflagellate cysts and in some samples its percentage reaches up to 45 per cent or even more. The dominance of this taxon is, therefore, important and helps in distinguishing this cenozone from the overlying *Todisporites major* Cenozone. In addition, *Adnatosphaeridium vittatum, Cordosphaeridium inodes,* and *C. fibrospinosum* are also present in appreciable frequency. This cenozone is also rich in the pteridophytic (50%) and gymnospermous pollen grains (25%), while angiospermous pollen grains and fungal remains (2%) are insignificantly represented. Among the pteridophytic spores, *Striatriletes* is very abundant. Since this genus occurs in good frequency in all the cenozones, it can not be taken as marker taxon for any of them.

Todisporites major Cenozone

Type section—The upper part of the Laisong Formation, exposed along Sonapur-Badarpur Road Section between 142 km and 143.2 km.

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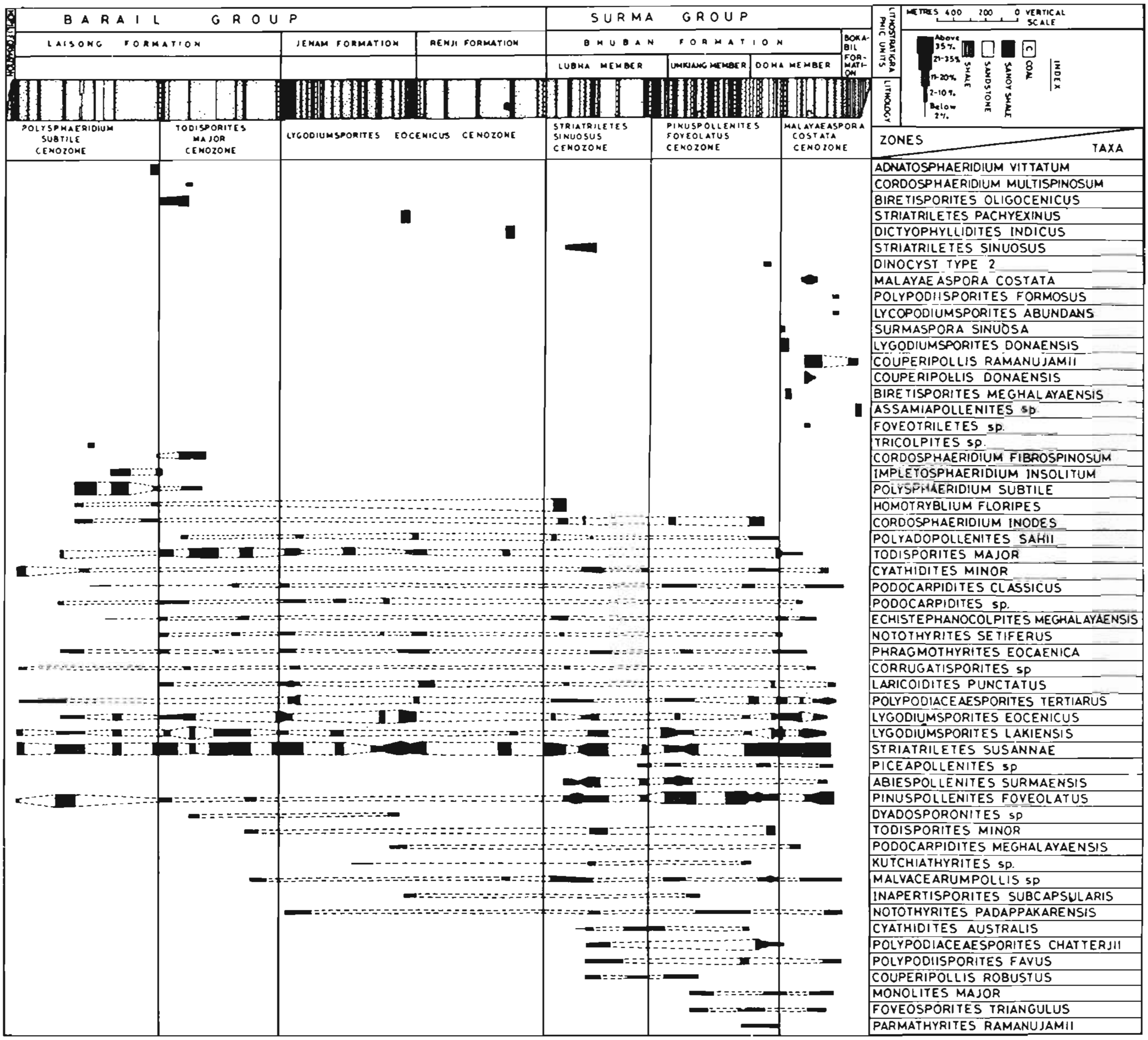
*The distances are given with reference to Shillong along Shillong-Silchar Highway (National Highway-44).



Text-fig. 1—Palynostratigraphic zonation of the Barail and Surma groups of Jaintia Hills (Meghalaya) and Cachar (Assam).

Lithology—The lithology mainly consists of grey, very hard, thinly bedded, very fine to medium grained sandstone alternating with carbonaceous shales. The thickness of this cenozone is ± 750 m.

Nature of contact—The upper part of this cenozone is composed of grey, medium grained sandstone which is conformably overlain by grey and carbonaceous shales of the basal part of the *Lygodiumsporites eocenicus* Cenozone.

Species restricted to this cenozone—Biretisporites oligocenicus and *Cordosphaeridium multispinosum.*

Characteristic palynofossils—Cordosphaeridium multispinosum, C. fibrospinosum, Polysphaeridium subtile, Striatriletes susannae, Biretisporites oligocenicus, Todisporites major, Lygodiumsporites lakiensis, L. eocenicus, Polyadopollenites sahii and *Echistephanocolpites meghalayaensis* (Pl. 1, figs 10-17).

Remarks—Pteridophytic spores are dominant (77%) in this cenozone. *Todisporites major* constitutes 30 per cent of the pteridophytic spores while in the underlying and overlying zones, its percentage is almost insignificant. Such a high frequency of this species has been taken as a reliable feature for the identification of this cenozone. Algal remains are represented by 5 per cent, fungal remains 8 per cent, gymnospermous pollen grains 8 per cent and angiospermous pollen grains 2 per cent.

Lygodiumsporites eocenicus Cenozone

Type section—Jenam and Renji formations exposed along Sonapur-Badarpur Road Section between 143.2 km and 147.5 km.

Lithology—The lower part of this zone is mainly argillaceous and consists of shales and sandy shales with fine to medium grained sandstones whereas the upper part is characterised by thickly bedded or massive, fine to medium grained, hard, ferruginous, occasionally cross-bedded sandstone with alternation of shales. Generally the shales are carbonaceous throughout this cenozone. The thickness of this cenozone is ± 1650 m.

Nature of contact—The contact of this cenozone with the overlying *Striatriletes sinuosus* Cenozone is unconformable. This contact coincides with Barail-Surma contact.

Species restricted to this cenozone—Striatriletes pachyexinus and *Dictyophyllidites indicus.*

Characteristic palynofossils—Striatriletes susannae, S. pachyexinus, Lygodiumsporites eocenicus, L. lakiensis, Todisporites major, Polypodiaceaesporites tertiarus, Podocarpidites meghalayaensis, Laricoidites punctatus and *Polyadopollenites sahii* (Pl. 1, figs 18-21).

Remarks—This cenozone is characterised by very high frequency of pteridophytic spores (82%). *Lygodiumsporites* constitutes the most dominant element (about 30%) of the assemblage and is represented by two species. Of these, *Lygodiumsporites eocenicus* constitutes 20 per cent of the assemblage, hence the zone is named after it. It is also characterised by the decline in gymnospermous pollen grains (8%) and *Todisporites major.* Besides, the dinoflagellate cysts are very rare in this cenozone. Fungal remains and the angiospermous pollen grains are represented by 6 per cent and 4 per cent respectively.

Striatriletes sinuosus Cenozone

Type section—Lubha Member, Lower Bhuban Formation, exposed along Sonapur-Badarpur Road Section between 147.5 km and 151.1 km.

Lithology—This zone consists of thin to fairly thick beds of fine to very fine grained, fawn, grey or brown sandstone with subordinate shales. The thickness of this cenozone is ± 650 m.

Nature of contact—The upper part of this cenozone is made up of sandstone bed which is conformably overlain by the carbonaceous shale of *Pinuspollenites foveolatus* Cenozone.

Species restricted to this cenozone—Striatriletes sinuosus.

Characteristic palynofossils—Cordosphaeridium inodes, Homotryblium floripes, Striatriletes sinuosus, S. susannae, Lygodiumsporites lakiensis, L. eocenicus, Cyathidites australis, Polypodiisporites favus, Polypodiaceaesporites chatterjii, Abiespollenites surmaensis, Pinuspollenites foveolatus, Couperipollis robustus, Polyadopollenites sahii, Echistephanocolpites meghalayaensis and *Malvacearumpollis* sp. (Pl. 2, figs 1-9).

Remarks—Striatriletes sinuosus Cenozone is characterized by the dominance of the genus *Striatriletes* (about 60%). Out of this, *Striatriletes sinuosus* represents 20 per cent of the assemblage and is restricted to this cenozone only. For this reason, the cenozone is named after this taxon. This cenozone also shows the comparative increase of gymnospermous pollen up to 20 per cent and the reappearance of dinoflagellate cysts. *Todisporites major* is conspicuous by its complete absence in this cenozone. Algal remains are represented by 10 per cent, fungal remains by 3 per cent and angiospermous pollen grains by 5 per cent.

Pinuspollenites foveolatus Cenozone

Type section—Umkiang and Dona (in part) members of Bhuban Formation of Surma Group, exposed along Sonapur-Badarpur Road Section between 151.1 km and 165.75 km.

Lithology—This zone consists of thick shale beds with brown, fine to medium and occasionally coarse grained, thinly bedded, lenticular sandstones and a few thin intraformational conglomerate in the lower part and grey and brown, very fine to medium grained, often argillaceous, fairly hard sandstone, alternating with thin sandy and carbonaceous shales in the upper part. The thickness of the cenozone is ± 800 m.

Nature of contact—The upper part of this cenozone is represented by sandy and carbonaceous shales which are conformably overlain by the basal sandstone bed of *Malayaeaspora costata* Cenozone.

Species restricted to this cenozone—Dinocyst type-2, *Parmathyrites ramanujamii.*

Characteristic palynofossils—Cordosphaeridium inodes, Dinocyst type-2, *Todisporites minor, Lygodiumsporites eocenicus, L. lakiensis, Striatriletes susannae, Polypodiaceaesporites tertiarus, P. chatterjii, Pinuspollenites foveolatus, Abiespollenites surmaensis* and *Malvacearumpollis* sp. (Pl. 2, figs 10-18).

Remarks—This cenozone is characterized by the dominance of gymnospermous pollen grains (33%). Among the gymnospermous pollen grains, *Pinuspollenites foveolatus* constitutes about 60 per cent of the assemblage and as such is a dominant taxon of this cenozone. In other cenozones it is sporadically represented.

This cenozone is also characterized by the dominance of *Polypodiaceaesporites tertiarus, P. chatterjii, Todisporites minor, Lygodiumsporites lakiensis* and *Malvacearumpollis* sp. Besides, the reappearance of *Todisporites major* and *Cordosphaeridium inodes* are among the other important features of this cenozone.

The algal remains are represented by 4 per cent, fungal remains 3 per cent, pteridophytic spores 57 per cent, and angiospermous pollen grains 3 per cent.

Malayaeaspora costata Cenozone

Type section—The upper part of Bhuban Formation (Dona Member) and Bokabil Formation exposed along Sonapur-Badarpur Road Section between 165.75 km and 180 km.

Lithology—The lower part of this cenozone mainly consists of grey and brown, very fine to medium grained, often argillaceous, fairly hard sandstone alternating with thin sandy and carbonaceous shales whereas the upper part is characterized by thick sandy shales with alternation of very fine grained laminated sandstones. The thickness of this cenozone is ± 550 m.

Species restricted to this cenozone—*Malayaeaspora costata, Surmaspora sinuosa, Lygodiumsporites donaensis, Lycopodiumsporites abundans, Foveotriletes* sp., *Biretisporites meghalayaensis, Polypodiisporites formosus, Couperipollis donaensis, C. ramanujamii* and *Assamiapollenites* sp.

Characteristic palynofossils—*Malayaeaspora costata, Lygodiumsporites eocenicus, L. lakiensis, L. donaensis, Biretisporites meghalayaensis, Striatriletes susannae, Polypodiaceaesporites tertiarus, P. chatterjii, Monolites major, Pinuspollenites foveolatus, Abiespollenites surmaensis, Assamiapollenites* sp., *Couperipollis donaensis, C. ramanujamii* and *Malvacearumpollis* sp. (Pl. 2, figs 19-27).

Remarks—Among the pteridophytic spores, *Malayaeaspora costata* constitutes about 20 per cent of the assemblage and is restricted to this cenozone only. For this reason, it is named after *M. costata, Lygodiumsporites donaensis, Surmaspora sinuosa, Lycopodiumsporites abundans, Couperipollis* spp. and *Assamiapollenites* sp. are also restricted to this cenozone. In addition, the percentages of angiospermous pollen is comparatively higher and *Lygodiumsporites eocenicus* and *L. lakiensis* again appear in it. The dinoflagellate cysts are absent. The assemblage also consists of fungal remains (3%), pteridophytic spores (63%), gymnospermous pollen grains (22%) and angiospermous pollen grains (12%).

DISCUSSION

The range and relative frequency of the various palynotaxa, as shown in the Text-fig. 1, reveal that a few miofloral changes can be marked in the Barail-Surma sequence of the present Sonapur-Badarpur Road Section. Some of these changes correspond with the physical features like unconformity and lithological boundaries.

The first such change was observed in the middle of the Laisong Formation dividing it into a lower *Polysphaeridium subtile* Cenozone and an upper *Todisporites major* Cenozone. The former is characterized by the rich representation of dinoflagellate cysts (23%), especially *Polysphaeridium subtile* and *Adnatosphaeridium vittatum* along with pteridophytic spores (50%), whereas in the latter dinoflagellate cysts

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PLATE 1 →

(All photomicrographs are enlarged *ca.* × 500. The coordinates of the specimens refer to the stage of Censico Microscope no. 13167).

Polysphaeridium subtile Cenozone

1. *Adnatosphaeridium vittatum* Williams & Downie *in* Davey *et al.*; Slide no. 8383, coordinates 75.1 × 120.0.
2, 3. *Cordosphaeridium inodes* (Klumpp) Eisenack, Slide no. 8370; coordinates 56.0 × 110.3, 75.6 × 117.5.
4. *Striatriletes susannae* van der Hammen emend. Kar; Slide no. 8387, coordinates 52.2 × 103.3.
5. *Impletosphaeridium insolitum* Eaton; Slide no. 8373, coordinates 42.0 × 110.5.
6. *Tricolpites* sp.; Slide no. 8745, coordinates 66.2 × 101.3.
7. *Lygodiumsporites lakiensis* Sah & Kar; Slide no. 9023, coordinates 73.5 × 105.7.
8. *Polysphaeridium subtile* Davey & Williams *in* Davey *et al.*; Slide no. 8369, coordinates 62.2 × 106.4.
9. *Pinuspollenites foveolatus* Rao; Slide no. 8400, coordinates 41.1 × 100.0

Todisporites major Cenozone

10. *Cordosphaeridium multispinosum* Davey & Williams *in* Davey *et al.*; Slide no. 8369, coordinates 35.6 × 103.4.
11. *Cordosphaeridium fibrospinosum* Davey & Williams *in* Davey *et al.*; Slide no. 8369, coordinates 53.3 × 101.6.
12. *Polyadopollenites sahii* Rao *et al.*; Slide no. 8758, coordinates 42.5 × 118.2.
13. *Striatriletes susannae* van der Hammen emend Kar; Slide no. 9503, coordinates 54.9 × 117.3.
14. *Todisporites major* Couper; Slide no. 8389, coordinates 48.1 × 98.7.
15. *Biretisporites oligocenicus* Rao & Singh; Slide no. 8388, coordinates 62.4 × 99.6.
16. *Lygodiumsporites lakiensis* Sah & Kar emend. Rao & Singh; Slide no. 8390, coordinates 49.1 × 110.3.
17. *Echistephanocolpites meghalayaensis* Rao *et al.*; Slide no. 8116, coordinates 54.2 × 112.3.

Lygodiumsporites eocenicus Cenozone

18. *Striatriletes pachyexinus* Rao & Singh; Slide no. 8391, coordinates 56.0 × 101.5.
19. *Dictyophyllidites indicus* Rao & Singh; Slide no. 8392, coordinates 69.2 × 108.6.
20. *Lygodiumsporites eocenicus* Dutta & Sah; Slide no. 8393, coordinates 48.8 × 109.1.
21. *Polyadopollenites sahii* Rao *et al.*; Slide no. 8396, coordinates 45.3 × 102.2.

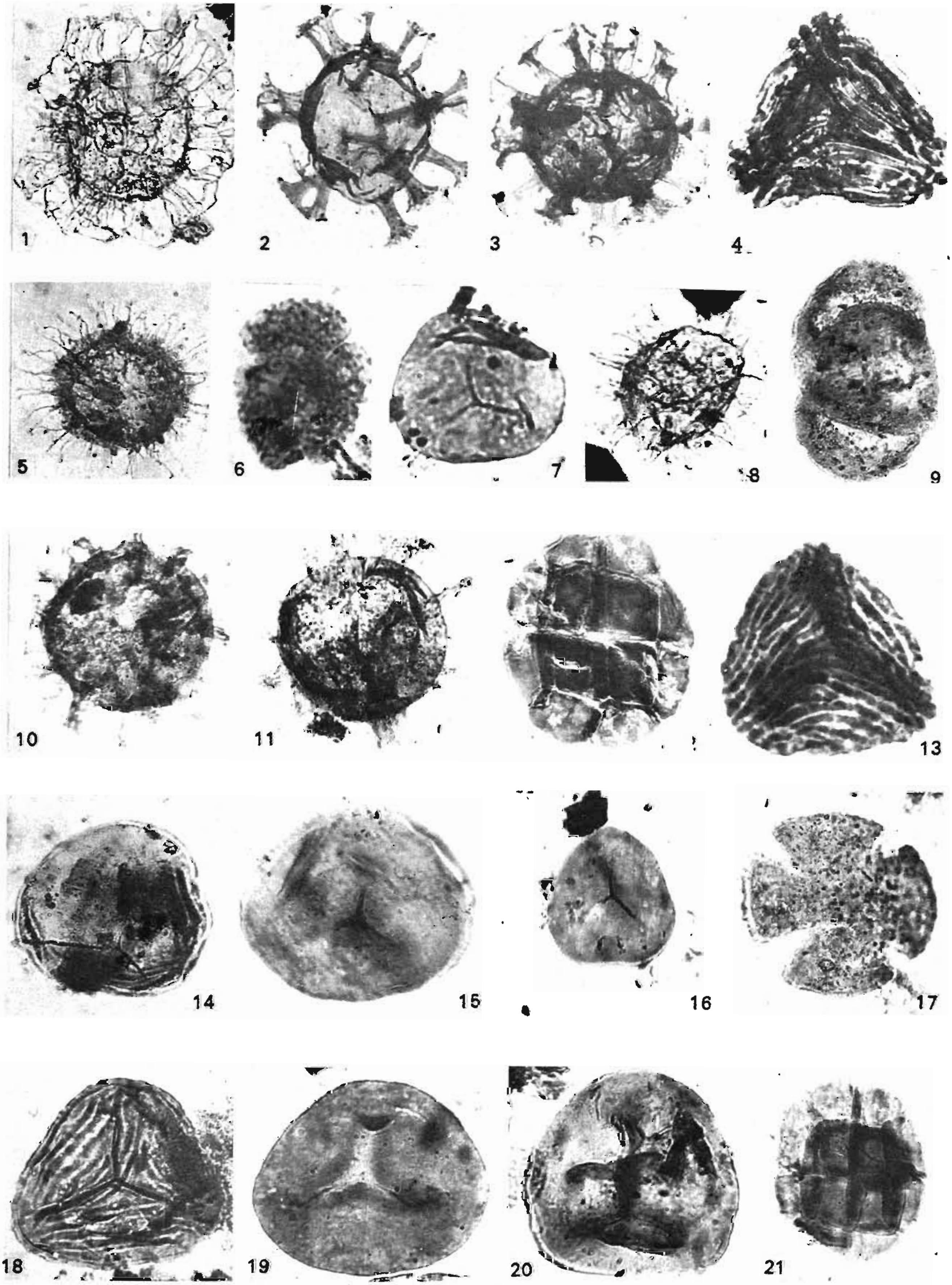

PLATE 1

decrease (5%) with corresponding increase in pteridophytic spores (77%). This miofloral change is not associated with any lithological boundary. The second miofloral change was marked between the *Todisporites major* and *Lygodiumsporites eocenicus* Cenozones, corresponding with the Laisong-Jenam boundary. While, both the zones are rich in pteridophytic spores, the latter is distinguished from the former by the high representation (30%) of *Lygodiumsporites* and restricted occurrence of *Striatriletes pachyexinus*. The *Lygodiumsporites eocenicus* Cenozone covers very thick sequence including both Jenam and Renji formations.

It is interesting to note that no floral change could be recognised at Jenam-Renji contact, though the two formations are well distinguishable on lithological grounds. The third miofloral change was recognized at the Barail-Surma contact and is thus associated with lithological boundary as well as with regional Oligo-Miocene unconformity. The cenozone across this boundary is named as *Striatriletes sinuosus* Cenozone and is characterized by 60 per cent representation of *Striatriletes*, restricted occurrence of *Striatriletes sinuosus* and increasing frequency (20%) of gymnospermous pollen grains. This cenozone corresponds with the Lubha Member of the Bhuban Formation. Its upper contact with the overlying *Pinuspollenites foveolatus* Cenozone marks the fourth miofloral change and is associated with a lithological boundary. In the *Pinuspollenites foveolatus* Cenozone, gymnospermous pollen show further increase (33%) with significant representation of *Pinuspollenites foveolatus* and decline in the pteridophytic spores, particularly *Striatriletes*. The fifth and the last change observed in the miofloral succession of the present section is at the contact of *Pinuspollenites foveolatus* and *Malayaeaspora costata* Cenozones dividing the Dona Member into two parts. The *Malayaeaspora costata* Cenozone covers the upper part of the Dona Member and Bokabil Formation and is characterized by rich representation (20%) and restricted occurrence of *Malayaeaspora costata* and also by the restricted occurrence of *Lygodiumsporites donaensis, Surmaspora sinuosa, Lycopodiumsporites abundans, Couperipollis* spp. and *Assamiapollenites* sp.

The above discussion also makes clear that the gymnospermous pollen grains increase in frequency in Surma Group as compared to Barail Group. These pollen might have migrated from the extra-peninsular region in the north which would have been sufficiently high during Lower Miocene to support coniferous flora.

It is significant that while no floral change has been observed in the entire Jenam-Renji sequence, finer units could be established in Laisong Formation (*Polysphaeridium subtile* Cenozone and *Todisporites major* Cenozone) and Bhuban Formation (*Striatriletes*

PLATE 2

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(All photomicrographs are enlarged *ca.* × 500)

Striatriletes sinuosus Cenozone

1. *Striatriletes sinuosus* Rao & Singh; Slide no. 8407, coordinates 66.9 × 95.9.
2. *Striatriletes susannae* van der Hammen emend. Kar; Slide no. 8385, coordinates 39.9 × 104.6.
3. *Polypodiisporites favus* Potonié; Slide no. 8401, coordinates 56.1 × 103.1.
4. *Couperipollis robustus* Saxena; Slide no. 8399, coordinates 63.0 × 105.1.
5. *Pinuspollenites foveolatus* Rao, Slide no. 8412, coordinates 56.9 × 110.9.
6. *Homotryblium floripes* (Deflandre & Cookson) Stover; Slide no. 8374, coordinates 73.5 × 110.5.
7. *Abiespollenites surmaensis* Rao; Slide no. 8407, coordinates 63.5 × 99.7.
8. *Lygodiumsporites lakiensis* Sah & Kar. emend. Rao & Singh; Slide no. 9025, coordinates 70.5 × 106.9.
9. *Polypodiaceaesporites chatterjii* Kar; Slide no. 8404, coordinates 74.5 × 101.3.

Pinuspollenites foveolatus Cenozone

10. Dinocyst type-2; Slide no. 8380, coordinates 52.9 × 97.7.
11. *Cordosphaeridium inodes* (Klumpp) Eisenack; Slide no. 8370, coordinates 60.2 × 110.5.
12. *Parmathyrites ramanujamii* Singh *et al.*; Slide no. 8109, coordinates 48.4 × 93.5.
13. *Malvacearumpollis* sp.; Slide no. 8403, coordinates 66.5 × 108.5.
14. *Lygodiumsporites lakiensis* Sah & Kar emend Rao & Singh; Slide no. 8405, coordinates 48.4 × 93.5.
15. *Polypodiaceaesporites tertiarus* Sah & Dutta; Slide no. 8411, coordinates 49.5 × 98.8.
16. *Pinuspollenites foveolatus* Rao; Slide no. 8999, coordinates 60.8 × 102.8.
17. *Todisporites minor* Couper; Slide no. 9029, coordinates 70.3 × 102.5.
18. *Polypodiaceaesporites chatterjii* Kar; Slide no. 9041, coordinates 74.7 × 102.5.

Malayaeaspora costata Cenozone

19. *Lygodiumsporites eocenicus* Dutta & Sah; Slide no. 8736, coordinates 99.2 × 105.7.
20. *Couperipollis ramanujamii* Rao *et al.*; Slide no. 8742, coordinates 67.4 × 93.1.
21. *Lygodiumsporites donaensis* Rao & Singh; slide no. 8408, coordinates 62.0 × 103.3.
22. *Couperipollis donaensis* Rao *et al.*; Slide no. 8409, coordinates 37.4 × 105.6.
23. *Assamiapollenites* sp.; Slide no. 8410, coordinates 66.0 × 102.8.
24. *Malayaeaspora costata* Trivedi *et al.*; Slide no. 8229, coordinates 60.9 × 105.6.
25. *Biretisporites meghalayaensis* Rao & Singh; Slide no. 8413, coordinates 43.5 × 104.5.
26. *Surmaspora sinuosa* Singh & Rao; Slide no. 8228, coordinates 69.5 × 118.8.
27. *Foveotriletes* sp.; Slide no. 9036, coordinates 57.0 × 100.5.


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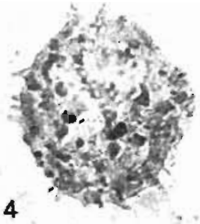
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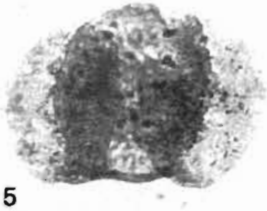
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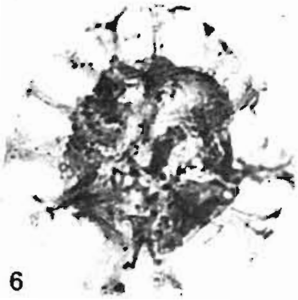
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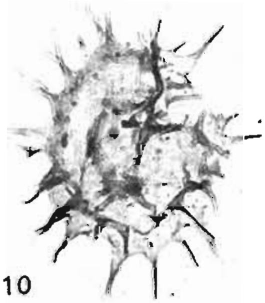
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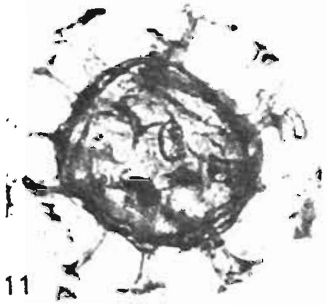
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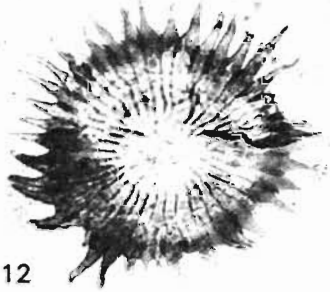
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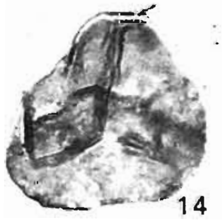
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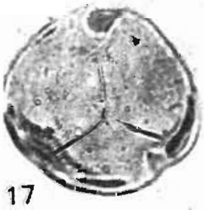
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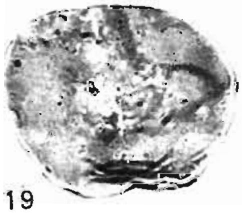
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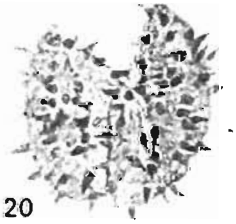
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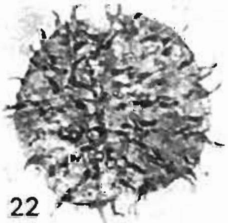
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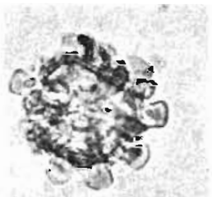
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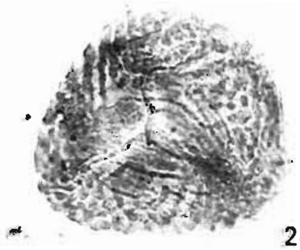
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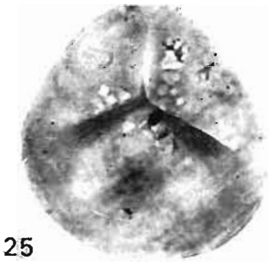
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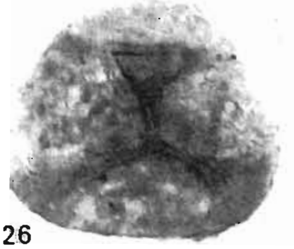
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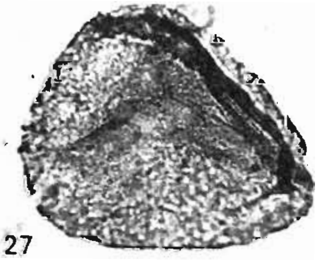
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PLATE 2

sinuosus Cenozone, *Pinuspollenites foveolatus* Cenozone and part of *Malayaeaspora costata* Cenozone). It is hoped that future palynological studies on Oligocene-Miocene sediments of this region may prove the lateral persistence of these cenozones and may further split them into subzones for more precise demarcation of the stratal units and finer biostratigraphic zonation.

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The Palaeobotanist **35**(2) : 159-164, 1986.

Glossopteris shailae, a new fossil leaf from Upper Permian (Raniganj Formation) of India

Usha Bajpai

Bajpai, Usha (1987). *Glossopteris shailae*, a new fossil leaf from Upper Permian (Raniganj Formation) of India. *Palaeobotanist* **35** (2) : 159-164.

A new species of *Glossopteris*, i.e. *G. Shailae* is reported from the Kumarpur Sandstone (Raniganj Formation), West Bengal. Morphologically the leaf is characterised by an evanescent midrib. The cuticular structure of the leaf is also different from those of known species of the genus *Glossopteris*.

Key-words—Morphology, Fossil leaf, *Glossopteris*, Upper Permian (India)

Usha Bajpai, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

सारांश

भारत के उपरि परमी कल्प (रानीगंज शैल-समूह) से एक नवीन अश्मित पत्ती, ग्लॉसॉप्टेरिस शैली

ऊषा बाजपेयी

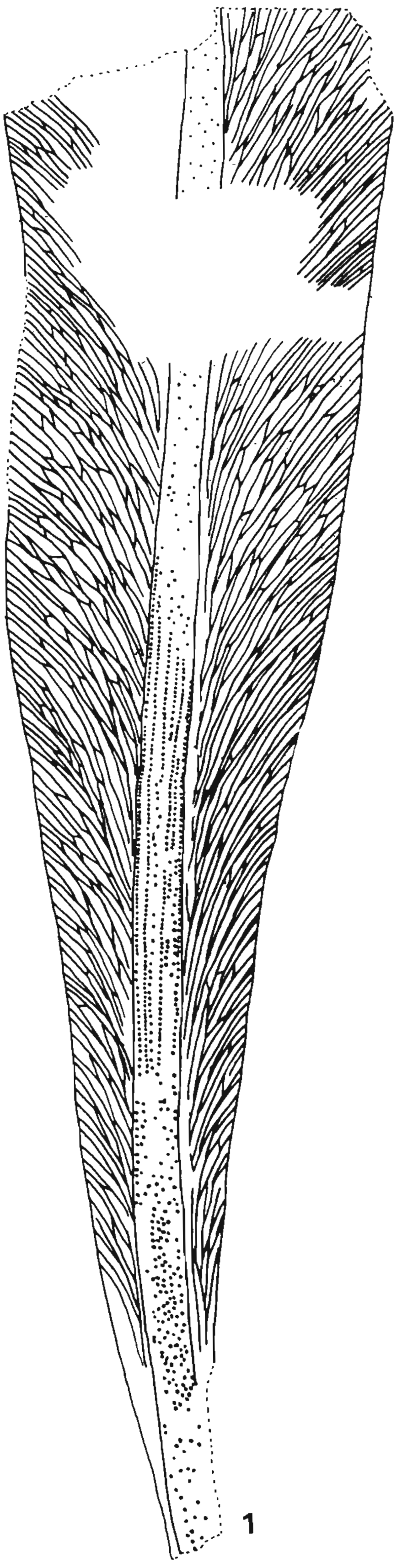
पश्चिम बंगाल में कुमारपुर बालुकाश्म (रानीगंज शैल-समूह) से ग्लॉसॉप्टेरिस की एक नव जाति, ग्लॉ० शैली वर्णित की गई है। आकारिकीय दृष्टि से यह पत्ती शीघ्रलोपी मध्यशिरा से अभिलक्षणित है। ग्लॉसॉप्टेरिस प्रजाति की अन्य ज्ञात जातियों से इस पत्ती की उपत्वचीय संरचना भी भिन्न पाई गई है।

THE Kumarpur Sandstone Member, the highest lithological unit of the Raniganj Formation, is very poor in shales and coal. Only one coal seam is reported from the base of this member. This seam outcrops in the Nonia Nala Section about 200 m upstream from the Technical College Bridge. A few pits have been dug here by local people to take out coal. The coal seam contains fragments of limonitic wood while the overlying grey shale contains an almost pure assemblage of leaves belonging to a *Glossopteris* species. Many of the specimens have a satisfactorily preserved carbonified crust. These leaves form the subject matter of this paper.

Material comprises more than 100 leaf compressions on a grey carbonaceous shale. The carbonified crust was processed by the usual nitric acid potassium hydroxide method for cuticles. For comparison and identification of the species, all available literature on *Glossopteris* leaves from the Raniganj Formation was consulted, particularly Feistmantel (1880), Arber (1905), Srivastava (1957), Maheshwari (1965), Pant and Gupta (1968, 1971) and Chandra and Surange (1971).

DESCRIPTION

More than 100 specimens referable to this species were collected from the Kumarpur Sandstone Member. However, most of the specimens are incomplete, though almost all have a carbonified crust preserved. For detailed investigation, therefore, only a dozen complete or almost complete specimens were selected, both for morphographical and epidermal studies. The leaves are simple, lanceolate to broad-lanceolate in shape, being widest in the middle region and tapering both towards the base and the apex. The apices of the leaves are obtuse or broadly rounded and the bases are attenuate; there being no sign of a petiole. The leaf margins are entire. The complete leaves measure 7-15 cm in length and 2-4 cm in width at the widest. A flat, 0.1-0.4 cm wide midrib runs through the leaf for about 2/3rd of its length and gradually becomes evanescent in the upper 1/3rd part. The midrib is characterised by longitudinally running striations the space between which in the lower half is dotted with more or less circular depressions. The



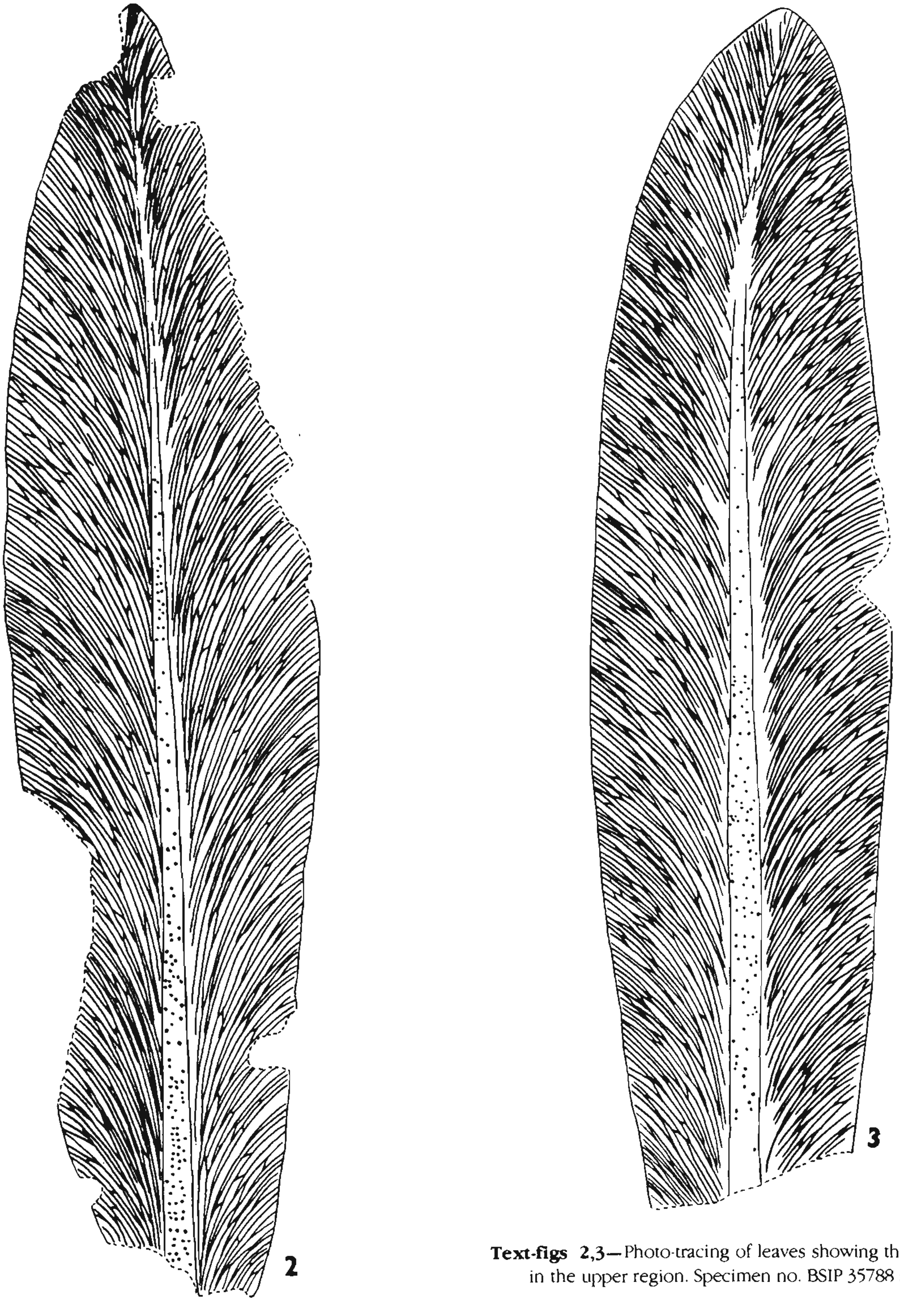
Text-fig. 1—Photo-tracing of the holotype showing venation. Specimen no. BSIP 35786. × ca 1.3.

midrib gives rise to secondary veins which apparently originated in the longitudinal striations of the midrib. Angle of emergence of secondary veins varies between 20°-35° After emergence the veins run straight for a short distance and then take a graceful curve and run straight to the leaf margin meeting it at an angle of 50°-55° Vein density ranges 8-14 per centimeter near the midrib and 16-26 per centimeter near the margin. During their course to the margin the secondary veins dichotomise and anastomose a number of times forming narrow elongate meshes. The vein dichotomies are mostly of *gamma* (γ) type and the anastomoses are of *lambda* (λ) type.

The carbonified crust, on acid-alkali processing, yields rather fragile hypostomatic cuticles. The upper cuticle is relatively thick; the vein and mesh areas are clearly decipherable. The cells over the veins are longish-rectangular, arranged end to end in 2-4 linear rows and measure 62-120 μm long × 25-43 μm wide. Cells in between the veins are polygonal, isodiametric or aniso-diametric in shape and measure 55-107 × 24-49 μm in diameter. Very rarely the cells are squarish. The cells over the lower surface are also similar in shape and arrangement. The cell walls, lateral-as well as end-walls, are relatively thin. Stomata are anomocytic, sunken, irregularly distributed and oriented in the mesh areas and are completely absent over the veins. The sunken thin-walled guard cells enclose a linear slit and measure 43 × 19 μm. The subsidiary cells are unspecialized, 5 (rarely 4 or 6) in number and form a definite ring demarcating the stomatal apparatus from the ordinary epidermal cells.

COMPARISON AND REMARKS

The midrib of the leaves, though flat and rather low, is easily identifiable through its longitudinally running striations and nonstomatiferous, thick-walled, squarish, end-to-end arranged cells. This fact along with the formation of meshes by the veins places the leaves in the genus *Glossopteris*. In having narrow elongate meshes the species compares favourably with *Glossopteris communis, G. decipiens, G. indica*; the closest resemblance being with *G. decipiens* in the evanescent nature of the midrib. Pant and Gupta (1968) have described morphologically more or less similar leaves under a number of specific epithets based on variations in the characters of the epidermis. Of the 8 species recorded by Pant and Gupta (1968), *G. waltonii, G. harissii, G. tenuifolia* and *G. zeilleri* differ in having wavy epidermal cells. The leaf of *G. petiolata* has a distinct petiole and the cells over the veins and the subsidiary cells have papillae. Some of the epidermal cells in *G. brongniartii* and *G. varia* are also papillate. *G. vulgaris* though morphologically very close, differs in being amphistomatic. *G. communis* differs in being almost spathulate in shape and in having a very



Text-figs 2,3—Photo-tracing of leaves showing the evanescent midrib in the upper region. Specimen no. BSIP 35788 and 35789. × ca 1.3.

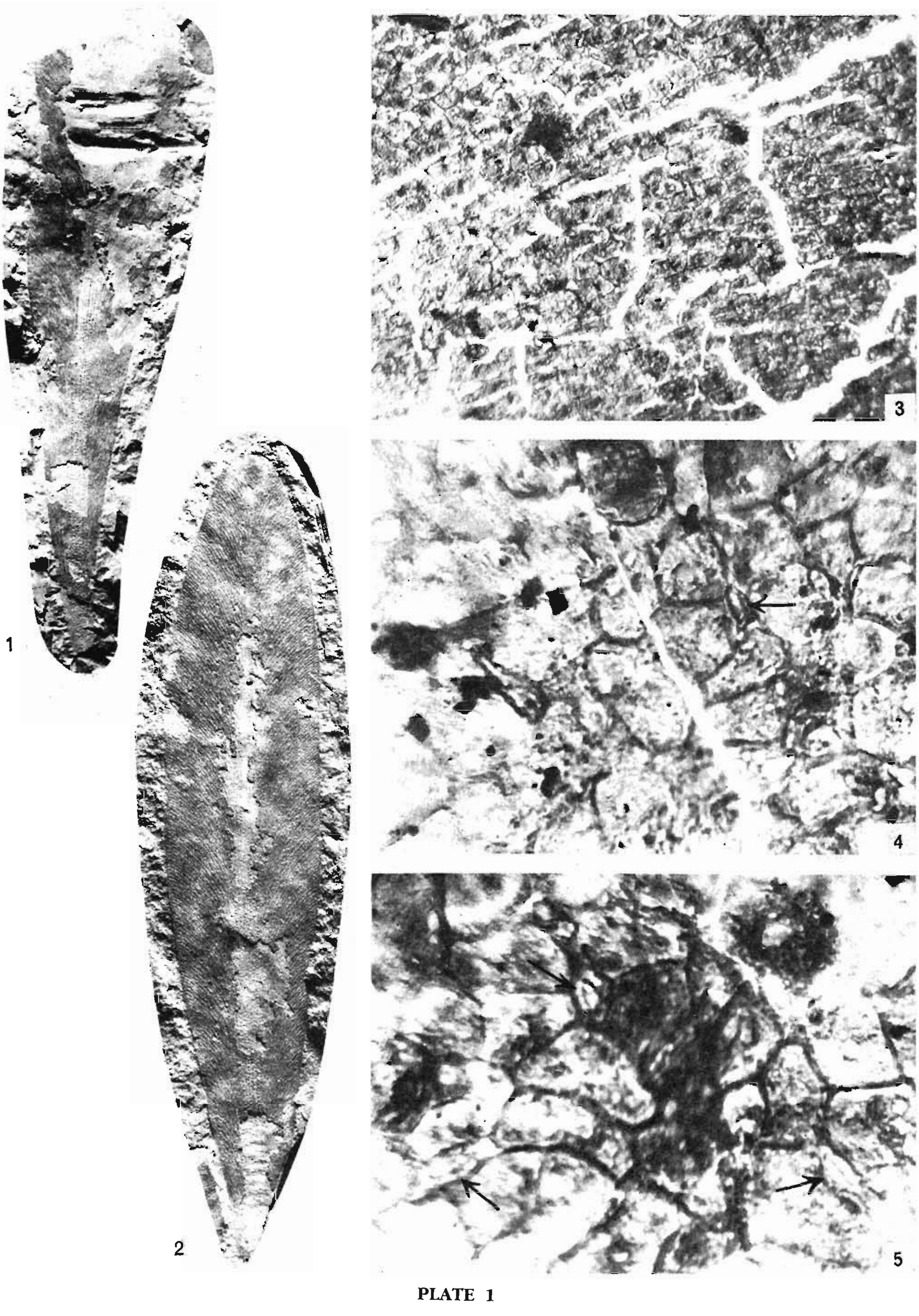
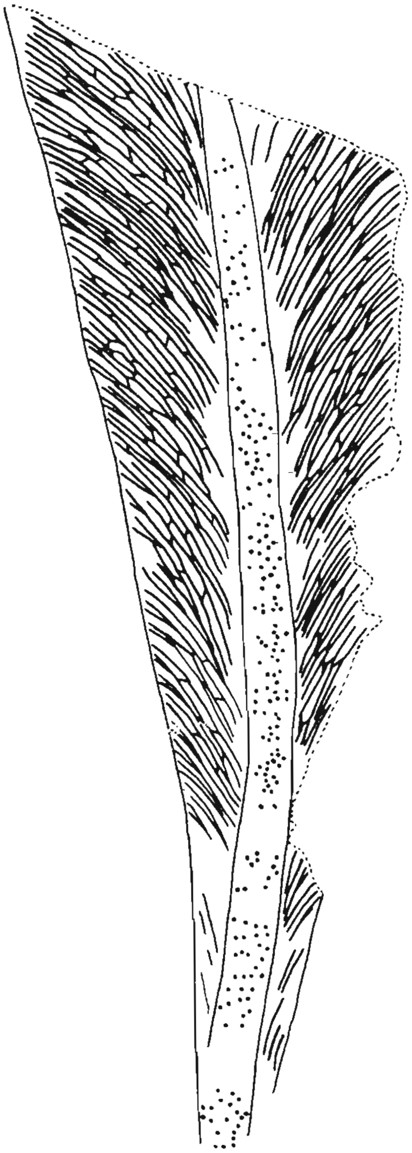


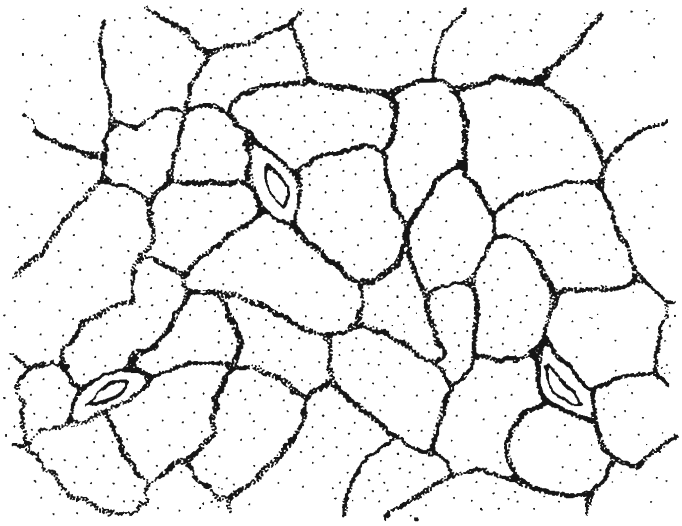
PLATE 1



Text-fig. 4—Photo-tracing of basal part of a leaf. Specimen no. BSIP 35790. × ca 1.3.

delicate stomatiferous cuticle. None of the species reported by Pant and Gupta (1971) are comparable.

In view of the characteristic features of the investigated specimens and the differences from the known comparable forms as enumerated above, the Kumarpur leaves have been given a new specific epithet, viz., *Glossopteris shailae* in honour of Dr Mrs Shaila Chandra, co-author of a monograph on the genus *Glossopteris*.



Text-fig. 5—Lower cuticle from the holotype. Slide no. BSIP 35786-1. × 425.

It is interesting to note that virtually all the leaf specimens collected from the Kumarpur Sandstone Member belong to a single species *G. shailae* as do the wood (*Araucarioxylon kumarpurensis* Bajpai & Singh, 1986) and megaspores (*Noniasporites harissii* Maheshwari & Bajpai, 1984). *Arberiella* type of sporangia (with striate-bisaccate pollen) have also been observed in the bulk macerates.

Glossopteris shailae sp. nov.

Diagnosis—Leaf simple; lanceolate to broad-lanceolate, apex obtuse or broadly rounded, base attenuate, margin entire. Length 7-15 cm, width 2-4 cm, midrib 0.1-0.4 cm wide, evanescent in upper part, with number of circular depressions allover, angle of emergence of secondary veins 20°-35°, vein dichotomies gamma type, anastomoses lambda type. Epidermis hypostomatic, upper cuticle relatively thick, stomata irregularly distributed and oriented.

←

PLATE 1

Glossopteris shailae sp. nov.

1. Holotype. Specimen no. BSIP 35786. × 1.
2. Leaf specimen no. BSIP 35787. × 1.5.
3. Upper cuticle of the leaf from the holotype showing epidermal cells. Slide no. BSIP 35786-1. × 100.
4. Lower cuticle of leaf from the holotype showing a stomata surrounded by 5 subsidiary cells. Slide no. BSIP 35786-1. × 425.
5. Lower cuticle of leaf showing irregularly distributed and oriented stomata. Slide no. BSIP 35786-1. × 425.

Holotype—Specimen no. BSIP 35786, Museum of Birbal Sahni Institute of Palaeobotany; Upper Permian, Raniganj Formation, Kumarpur Sandstone Member, Nonia Nala Section near Asansol, West Bengal.

ACKNOWLEDGEMENT

I express my gratitude to Dr H. K. Maheshwari for suggestions and for critically going through the manuscript.

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The Palaeobotanist **35**(2) : 165-170, 1986.

Fossil wood of *Gmelina* Linn. (Verbenaceae) from the Deccan Intertrappean beds of Nawargaon with comments on the nomenclature of Tertiary woods

Mohan B. Bande

Bande, Mohan B. (1987). Fossil wood of *Gmelina* Linn. (Verbenaceae) from the Deccan Intertrappean beds of Nawargaon with comments on the nomenclature of Tertiary fossil woods. *Palaeobotanist* **35** (2) : 165-170.

A fossil dicotyledonous wood collected from the Deccan Intertrapean beds of Nawargaon, District Wardha, Maharashtra has been described. It has been assigned to the extant genus *Gmelina* Linn. of Verbenaceae and has been described as a new species *Gmelina tertiara*. This is the first authentic record of the family Verbenaceae from the Deccan Intertrappean beds, which extends the antiquity of this family to the Palaeogene in the Indian Subcontinent. The problem of the nomenclature of Tertiary fossil woods has also been discussed.

Key-words—Xylotomy, *Gmelina*, Verbenaceae, Deccan Intertrappean beds, Palaeogene (India).

Mohan B. Bande, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

सारॉंश

तृतीयक युगीन काष्ठाश्मों की नामपद्धति पर टिप्पणियों सहित नवरगाँव के दक्खिन अन्तर्ट्रेपी संस्तरों से जिमॅलाइना लिन्नेयस (वर्बीनेसी) की काष्ठाश्म

मोहन बलवंत बाँडे

महाराष्ट्र के वर्धा जनपद में नवरगाँव के दक्खिन अन्तर्ट्रेपी संस्तरों से एकत्रित एक द्विबीजपत्री काष्ठाश्म को वर्बीनेसी कुल की वर्तमान प्रजाति जिमॅलाइना लिन्नेयस से नामाँकित किया गया है तथा जिमॅलाइना टर्शियॅरा नव जाति के नाम से इसका वर्णन किया गया है। दक्खिन अन्तर्ट्रेपी संस्तरों से वर्बीनेसी कुल का यह प्रमाणसिद्ध अभिलेख है जिससे भारतीय उपमहाद्वीप में पूर्व-तृतीयक युग में इस कुल की उपस्थिति इंगित होती है। इसके अतिरिक्त इस शोध-पत्र में तृतीयक युगीन काष्ठाश्मों की नामपद्धति की समस्या भी विवेचित की गई है।

ALTHOUGH the occurrence of fossil plants in the Deccan Intertrappean beds around Nawargaon (Wardha District, Maharashtra) was reported as early as 1916 by Haines (Shukla, 1946, p. 106), till about a decade ago only a few of them were described in detail. Shukla (1941) first recorded a fossil palm, *Palmoxylon nawargaoensis* from near Nawargaon and later on described one more species of *Palmoxylon*, *P. sclerodermum* Sahni from these beds (Shukla, 1946). Sahni (1964) also described a species of *Palmoxylon*, *P. intertrappeum* from the same area. The interest in the study of fossil plants of this region was revived after a gap of many years with the finding of a fossil wood comparable with the modern wood of *Aristolochia* by Kulkarni and Patil (1977b). Prakash and Ambwani (1980) and Ambwani (1981) described two more species of *Palmoxylon* from these beds of which one has been said to possess affinities with the modern genus *Livistona*. Similarly, Kulkarni and Patil (1977a) and Shete and Kulkarni (1980) have also described two palm peduncles *Palmocaulon costapalmatum* and *P. hyphaeneoides* from these beds of which affinities of the second species have been traced to the coastal branched palm *Hyphaene*. It is interesting to note that a fossil fruit showing a close similarity with the fruits of this genus has also been described from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh by Bande, Prakash and Ambwani (1982). Besides *Aristolochioxylon prakashii*, described by Kulkarni and Patil (1977b), the dicotyledonous plants so far described from these beds consist of fossil woods comparable to the modern genera *Evodia*, *Amoora*, *Aeschynomene*, *Sonneratia*, *Ardisia*, *Heterophragma* and *Phyllanthus* of the families Rutaceae, Meliaceae, Leguminosae, Sonneratiaceae, Myrsinaceae, Bignoniaçeae and Euphorbiaceae respectively (Shete & Kulkarni, 1982; Bande & Prakash, 1984; Prakash, Bande & Lalitha, 1986). All the plant fossils so far described from this area have been listed in Table 1 and to this list one more fossil wood is being added through this paper. It has been assigned to the modern genus *Gmelina* of Verbenaceae. The occurrence of such a variety of forms from these beds indicates that further work on the fossil flora of this area would be of great help in dealing with the problems of palaeovegetation, palaeoclimate, palaeogeography, etc.

in central India during the Deccan Intertrappean period.

Nawargaon (20°1′ and 78°35′ E) is a small forest village approachable from Wardha via Paunar, Sailu and Bordam. The Deccan Intertrappean beds are exposed on both the sides of the forest road which joins the villages Nawargaon and Sindhi Vihira. The fossil woods occur as stray pieces in the fields all along this road and also on slopes of the hills near the villages Nawargaon and Maragsur (Bande & Prakash, 1984, Maps 1, 2). The wood which is described here was collected from the base of one such hillock. However, before it is described in detail, the problem of the nomenclature of Tertiary fossil woods is discussed in detail.

Nomenclature—The nomenclature of fossil woods, especially Tertiary onwards, has always remained a matter of personal choice and also controversy Although different authors have used different names for describing them, the most common practice (followed by the present author also till recently) is to describe them under a new generic name coined by adding the ending *oxylon* or *inium* to the name of the nearest modern genus or the family. Sometimes they are also named after their rock formation or age. However, in the past few years the use of modern generic names without the ending-*oxylon* has become quite common when the generic affinities of the fossil wood are considered certain. This practice has been opposed by many workers and some of them have even gone to the extent of systematically adding the ending—*oxylon* to the names of those fossil woods described under modern generic names. This problem has been dealt with in great detail by Lakhanpal and Prakash (1980) and the salient points of their discussion as well as conclusions are summarised here for ready reference and also to explain the present author's shift from describing a fossil wood under a generic name ending with—*oxylon* to describing it under modern genus.

The main argument raised against describing a fossil wood as a species of a modern genus is that it is not possible to designate a fossil wood as a new species of an extant genus because the types of extant genera are entire plants; in the generic diagnosis (of the extant genera) no data about the wood structure are to be found. Therefore, one cannot place any species whose holotype is a wood in an extant genus. Whenever no connection with other organs can be demonstrated, a detached organ of a fossil plant can only be placed as a species of an organ genus, which frequently will have the characters of a form genus (Lakhanpal & Prakash, 1980, p. 201).

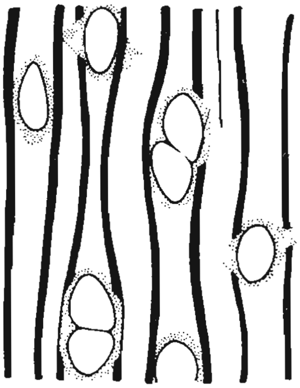
Lakhanpal and Prakash (1980, p. 202) have replied to these objections by quoting the observations made by Matten *et al.* (1977, p. 207) that....

"There does not appear to be anything in the 1972 International Code of Botanical Nomenclature which justifies such an approach to assigning names. According to the Article 9, the type of a species or a taxon below the rank of species is a single specimen or other element. If it is possible to have as the type of an extant species only part of an entire plant, as indicated by the word element, then why fossil (almost invariably detached organs) cannot be assigned to modern genera is unclear."*

Lakhanpal and Prakash (1980, p. 202) have further mentioned that there is a general aversion, especially on

Table 1—Fossil plants so far described from the Deccan Intertrappean beds of Nawargaon and nearby area

Fossil Species	*Comparable living Taxa*	*Reference*
PALMAE		
Palmoxylon nawargaoensis	Palmae	Shukla, 1941
P. sclerodermum	Palmae	Shukla, 1946
P. intertrappeum	Palmae	Sahni, 1964
P. livistonoides	*Livistona*	Prakash & Ambwani, 1980
P. arviensis	Palmae	Ambwani, 1981
Palmocaulon costapalmatum	Palmae	Kulkarni & Patil, 1977a
P. hyphaeneoides	*Hyphaene*	Shete & Kulkarni, 1980
RUTACEAE		
Evodinium indicum	*Evodia roxburghiana*	Bande & Prakash, 1984
E. intertrappeum	,,	Shete & Kulkarni, 1982
MELIACEAE		
Amooroxylon deccanensis	*Amoora rohituka & A. wallichii*	Bande & Prakash, 1984
LEGUMINOSAE		
Aeschynomenoxylon nawargaoensis	*Aeschynomene indica*	Shete & Kulkarni. 1982
SONNERATIACEAE		
Sonneratioxylon nawargaoensis	*Sonneratia* sp.	Bande & Prakash, 1984
S. caeseolarioides	*Sonneratia caeseolaria*	Shete & Kulkarni, 1982
MYRSINACEAE		
Ardisioxylon indicum	*Ardisia involucrata & A. paniculata*	Shete & Kulkarni, 1982
BIGNONIACEAE		
Heterophragmoxylon indicum	*Heterophragma adenophyllum*	Shete & Kulkarni, 1982
VERBENACEAE		
Gmelina tertiara sp. nov.	*Gmelina arborea*	
ARISTOLOCHIACEAE		
Aristolochioxylon prakashii	*Aristolochia* sp.	Kulkarni & Patil, 1977b
EUPHORBIACEAE		
Paraphyllanthoxylon palaeoemblica	*Phyllanthus emblica*	Prakash, Bande & Lalitha, 1986



Text-fig. 1 — *Gmelina tertiara*: Cross section showing vessels in radial pairs, paratracheal vasicentric to aliform parenchyma and xylem rays. × 85; Slide no. B.S.I.P. 35770/1.

the part of taxonomists dealing with living plants to accept species based on fossil material as belonging to extant genera. At the same time it is common knowledge that almost all plants of the Quaternary and most species of the Late Tertiary are structurally identical with extant plants even while only their dispersed organs are compared. Why they should not be included in the same genera, when the basis of identification is primarily morphological comparison? If fossil plants are deliberately kept apart from the living, it would be impossible to trace the appearance, distribution and evolution of modern taxa in the geological time, thus defeating the main objects of the study of fossil plants. They have, therefore, advocated that whenever there is a close similarity between the structure of a fossil (dicot woods included) with that of a modern genus, it should be assigned to the later.**

Before the present author was fully convinced about the above suggestion an argument which still remained unexplained was that before describing a fossil wood as a new species of a modern genus one must be sure that it differs from all the known species of the genus in its wood anatomy. However, it is usually a rare chance that all the modern species of a genus are available for comparison with the fossil. Further, these species may not be separable from each other on the basis of wood anatomy alone. How far, then, will it be justified to describe a fossil as a new species of a modern genus? By putting it under a different genus, i.e. by adding—*oxylon* we can avoid this mistake. The point was raised by the present author in a personal discussion with Dr Lakhanpal to which his reply was "by trying to avoid the mistake of creating a wrong species you are committing a bigger mistake of describing your fossil under a new genus!"

Another discrepancy pointed out by Lakhanpal and Prakash (1980, p. 203) is that though some advocates of compulsory organ genera say that they add *oxylon* to the name of the modern genus because they are sceptical about the generic identity of the fossil wood found detached from its parent plant, yet when they make palaeoecological deductions from these taxa, they tend to regard them in terms of their comparable modern genera. This sounds rather paradoxical. They make new organ genera by adding *oxylon* to the comparable extant genera and they derive ecological inferences on the basis of these extant genera, thus all the time admitting the affinity of the fossil with them. Why not describe these fossils as species of such extant genera where the structural similarity is definite? Why be afraid of a possible mistake in identification? A great advantage of the above proposal is that if such reference of a fossil wood to a modern genus is subsequently found to be erroneous, it can easily be transferred to another more appropriate modern genus, for which the International Code provides suitable rules. On the other hand, a fossil dicot wood referred to a new organ genus cannot be transferred to another organ genus even if its affinities are changed, warranting a change in the name, because Article 62 of the International Code of Botanical Nomenclature prohibits such a change. It says: "A legitimate name or epithet must not be rejected merely because it is inappropriate or disagreeable, or because another is preferable or better known, or because it has lost its original meaning". For example, the fossil wood of *Hopeoxylon indicum* Navale (1963), originally thought to be a wood of *Hopea* of the family Dipterocarpaceae, has now been found to belong to the genus *Sindora* of Leguminosae (Awasthi, 1977). As we are not allowed to change the name of the genotype even if its affinities are changed, we would always be using the name *Hopeoxylon* for the fossil wood of *Sindora* thus creating a lot of confusion. In the preamble of the International Code of Botanical Nomenclature it is said that "This code aims at the provision of a stable method of naming taxonomic groups, avoiding and rejecting the use of names which may cause error or ambiguity or throw science into confusion". Seeing the above example, the use of modern generic name in this ease would definitely have avoided the confusion created by the forced organ genera.

Lastly, quoting Lakhanpal and Prakash (1980, p. 203) again, : let us consider the proposition of Müller-Stoll & Mädel (1967) that a detached organ of a fossil plant can only be placed as a species of an organ genus because of the uncertainty of its representing one natural species or several. For this it must be admitted that the species of fossil woods or any other fossil organs referred to extant genera are species in a restricted sense, which may be termed as *organ species*. These organ species do not have the circumscription comparable with that of natural species. An organ species might very well include fossils

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*This statement holds true also with the 1983 edition of the International Code of Botanical Nomenclature, Sydney.

**It is worth to quote here article 13.3 of the code (1983 edn.) which says that whether a name applies to a taxon of fossil plants or of recent plants is decided by reference to the specimen that serves directly or indirectly as its nomenclatural type.

representing several natural species if the whole plants were known or it may have been produced by one extinct species of the genus living in the geological past. This understanding and recognition of the fact that the fossil species of a modern genus are organ species provides a reasonable solution to this issue. Thus, in agreement with the suggestions made by Lakhanpal and Prakash (1980, p. 204), the present author is also of the view that:

1. In those cases where anatomical details of fossil dicot woods are well preserved and it is possible to assign them to modern genera based on comparative studies of authentic modern woods, the fossil woods should be given modern generic names without adding the suffix *oxylon.*

2. In such cases where two or more modern genera of a family are anatomically indistinguishable and it becomes impossible to assign a fossil wood to any one of them, an organ genus with the suffix *oxylon* is preferred. The ending *oxylon* should be added to any one of the modern genera, preferably following the alphabetical priority.

3. In cases where a fossil wood is anatomically very similar to the mature wood of a modern genus and other structurally similar representatives but not identical to any of them then an organ genus should be coined by adding the suffix *oxylon* and the prefix *para* to the name of the modern genus showing closest similarity to the fossil wood.

4. In instances when it is only possible to identify fossil woods to the family or some other suprageneric level, the addition of *oxylon* to the fiamily or other relevant name is preferable and should be done with the addition of *oxylon* to the ending -ceae, -eae, -oideae, -inae, etc. (e.g. *Betulaceoxylon, Combretaceoxylon*).

5. When the wood anatomy is not uniform in a particular family the designation of the fossil woods after the family names is incorrect; attempts should be made to identify the fossil wood to the level of the sub-family, tribe or sub-tribe, which may be anatomically homogeneous and the name should be coined only after such an appropriate group.

6. Attempts to create new genera of morphologically similar woods only on stratigraphical grounds should be avoided.

7. In cases where it is not possible to identify fossil woods even up to family level due to bad preservation or lack of sufficient information then instead of naming it after the names of palaeobotanists, fossil localities or rock formations, etc. it is advisable to put them under the non-committal form genus *Dryoxylon* Schleiden (in Schmid, 1853) till their better preserved specimens are found or more information is available to determine their genus or family.

Genus—*Gmelina* Linn.

Gmelina tertiara sp. nov.

Topography—Wood diffuse porous. *Growth rings* indistinct. *Vessels* small to large, solitary and in radial multiples of 2-3, small clusters and in short tangential rows (Pl. 1, figs 1, 2), somewhat unevenly distributed, 8-15 per sq mm; tyloses present. *Parenchyma* paratracheal forming 1-2 seriate sheath around the vessels which may extend laterally to form thin wings of aliform to aliform-confluent parenchyma (Pl. 1, figs 1, 2). *Xylem rays* fine to moderately broad, closely spaced, 10-13 per mm, weakly heterogeneous, made up of mostly procumbent cells with 1-2 upright cells at the ends or on the margins, 1-4 seriate (uniseriates rare) or 16-50 μm in width and 4-35 cells or 80-950 μm in height (Pl. 1, figs 3, 4). *Fibres* arranged in radial rows in between the rays (Pl. 1, fig. 2).

Elements—Vessels circular to elliptical when solitary, with flat contact walls when in groups; t.d. 50-180 μm, r.d. 80-250 μm; vessel members 200-350 μm in length with oblique ends; perforations simple; intervessel pit-pairs bordered, alternate, polygonal with lenticular apertures, 8-10 μm in diameter (Pl. 1, fig. 6). *Parenchyma cells* thin walled, 15-20 μm in width and 40-70 μm in length. *Ray cells* thin-walled, procumbent cells 15-20 μm in tangential height and 40-60 μm in radial length; upright cells 15-20 μm in radial length and 40-60 μm in tangential height. *Fibres* polygonal in cross-section, semi-libriform with big lumen, septate, 10-25 μm in diameter and 400-600 μm in length.

Affinities—Important structural features of the present fossil such as small to large vessels with simple perforations and alternate bordered pits, paratracheal vasicentric to aliform to aliform-confluent parenchyma, 1-4 seriate weakly heterogeneous xylem rays and septate fibres clearly indicate its affinities to the family Verbenaceae (Metcalfe & Chalk, 1950, pp. 1031-1041; Pearson & Brown, 1932, pp. 781-812; Kribs, 1959, pp. 160-162). Amongst the various genera of this family the fossil shows a close similarity to the woods of *Gmelina* Linn. Wood slides of four species of this genus, viz., *Gmelina elliptica, G. fasiciculiflora, G. hainensis,* and *G. arborea* were available for study besides the the published description and photographs of *Gmelina arborea* (Pearson & Brown, 1932, pp. 798-803; Kribs, 1959, p. 160; Normand, 1960). The study indicates that the fossil is nearest in its anatomical details to the extant species *G. arborea.* The similarities can be observed in the shape, size and distribution of vessels, perforation plates and intervessel pit-pairs, distribution of parenchyma, structure of the xylem rays and fibres. The study also indicated that there is some variation in anatomical details amongst different wood samples of the extant species, especially in the distribution of vessels. Thus while in some cases the wood is diffuse-porous, in some it is semi-ring-porous and in others it is even ring-porous. Similarly, in some cases the smaller vessels are arranged in the form of tangential rows at the beginning of the growth ring and aliform-confluent parenchyma of these vessels looks like terminal parenchyma. Under the circumstances the fossil has been assigned to the extant genus *Gmelina* Linn. and has been

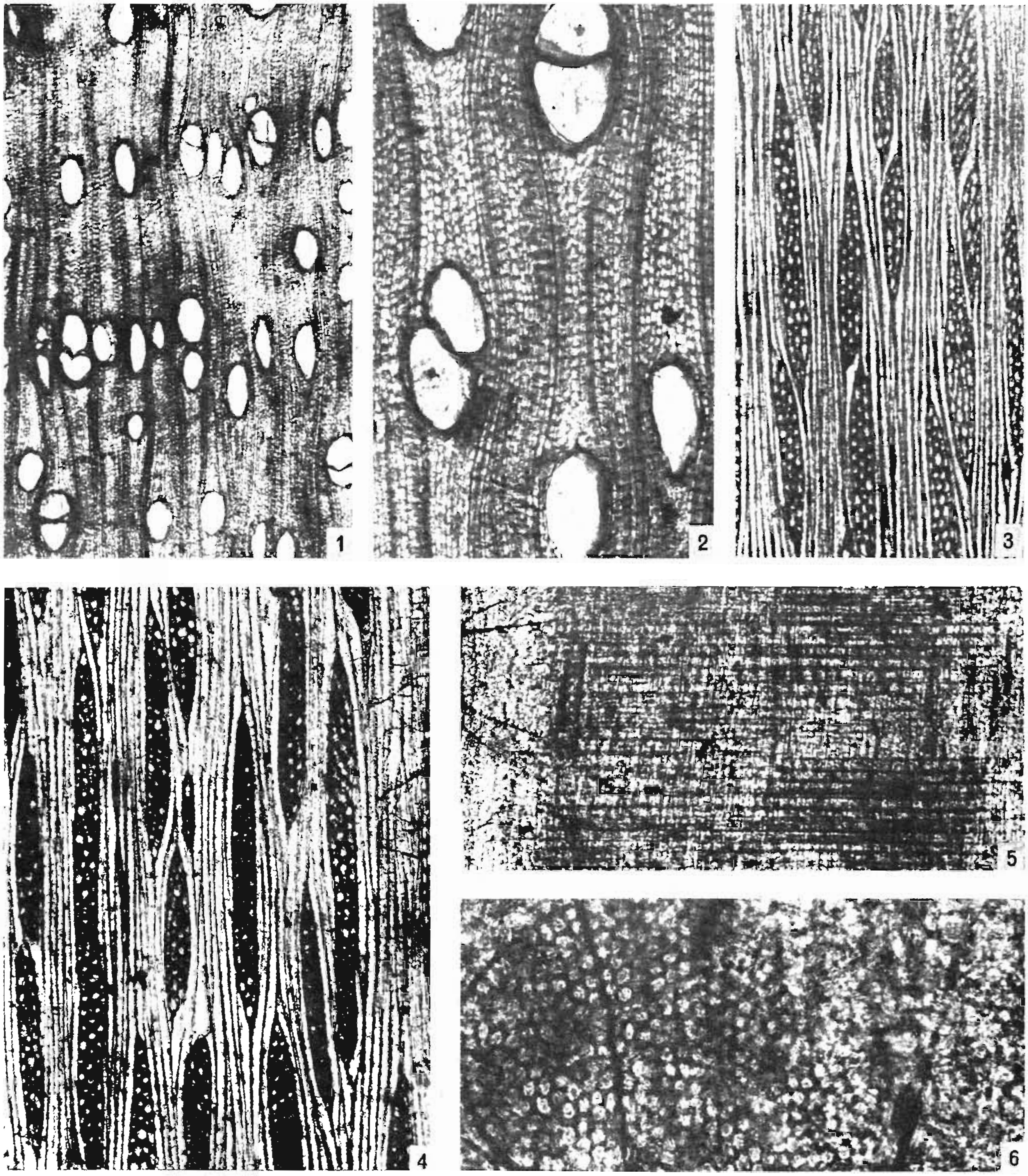

PLATE 1

Gmelina tertiara sp. nov.

1. Cross section showing shape, size and distribution of vessels, xylem rays and parenchyma. × 35; Slide no. B.S.I.P. 35770/1.
2. Cross section enlarged to show vessels in radial pairs, paratracheal parenchyma, xylem rays and semilibriform fibres. × 85; Slide no. B.S.I.P. 35770/1.
3, 4. Tangential longitudinal section showing 1-4 seriate, weakly heterogeneous xylem rays and septate fibres. × 85; Slide no. B.S.I.P. 35770/2.
5. Radial longitudinal section. × 85. Slide no. B.S.I.P. 35770/3.
6. Intervessel pit pairs. × 340. Slide no. B.S.I.P. 35770/2.

described as a new species *Gmelina tertiara* indicating its age.

Ingle (1972) had described a fossil wood said to possess affinities to the genus *Vitex* of Verbenaceae from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. However, the identification of this fossil has already been doubted by Prakash (1974) and thus, the present finding becomes the first authentic record of this family from the Deccan Intertrappean beds and extends its antiquity in India to the Palaeogene. The family Verbenaceae consists of about 75 genera almost all of which are tropical and subtropical in distribution. The genus *Gmelina* Linn. consists about 35 species, two of which occur in tropical Africa and the rest in East Asia, Indomalaya and Australia (Willis, 1973). In India the genus is represented by five species. *Gmelina arborea* to which the fossil bears nearest affinities is a moderate to large deciduous tree found throughout the deciduous and moist deciduous forests of India and Burma, in all Provinces, but nowhere common and very scarce in Uttar Pradesh and Punjab (Pearson & Brown, 1932, p. 799).

SPECIFIC DIAGNOSIS

Gmelina tertiara sp. nov.

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* small to large, t.d. 50-180 μm, r.d. 80-250 μm, solitary and in radial multiples of 2-3, small clusters and in short tangential rows, 8-15 per sq mm; perforations simple; intervessel pit-pairs bordered, alternate, polygonal with lenticular apertures, 8-10 μm in diameter. *Parenchyma* paratracheal, 1-2 seriate, vasicentric to aliform to confluent. *Xylem* rays 1-4 seriate, weakly heterogeneous, up to 35 cells in height. *Fibres* semilibriform, septate.

Holotype—B.S.I.P. Museum no. 35770; Deccan Intertrappean beds; ?Palaeocene.

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Neocouperipollis—A new name for *Couperipollis* Venkatachala & Kar

R. K. Kar & Madhav Kumar

Kar, R. K. & Kumar, Madhav (1986). *Neocouperipollis*—A new name for *Couperipollis*. *Palaeobotanist*, **35** (2) : 171-174.

Venkatachala and Kar instituted *Couperipollis* in 1969 selecting *Monosulcites perspinosus* Couper (1953) as the type species. Couper did not provide photograph for this species but instead gave a line drawing showing oval shape, well-developed colpus and spines with bulbous base and pointed tip. Later workers could not locate this or any other specimen from the slides made by Couper as per his diagram. Location of a pollen as per illustration of Couper from other localities of the same formation was also not fruitful and only polyporate forms comparable to extant Asteraceae or Malvaceae could be found *Couperipollis* recorded from Palaeocene-Eocene of India are monocolpate and spinose and are not related to Asteraceae or Malvaceae, so a new genus, viz., *Neocouperipollis* is proposed here to accommodate them.

Key-words—Palynology, *Neocouperipollis*, Palaeocene-Eocene, India.

R. K. Kar & Madhav Kumar, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

सारॉंश

काउपॅरिपॉलिस वेंकटाचाला व कर का एक नवीन नाम—निओकाउपॅरिपॉलिस

रंजीत कुमार कर एवं माधव कुमार

वेंकटाचाला एवं कर ने 1969 में मोनोसल्काइटिस पर्सपाइनोसस काउपर (1953) प्रारूप प्रजाति का चयन करके काउपॅरिपॉलिस स्थापित किया था। काउपर ने इस जाति का छायाचित्र नहीं दिया था बल्कि इसके बजाय उन्होंने एक अंडाकार, सुविकसित विदरक तथा कंदीय आधार एवं नुकीले अग्रभाग पर कंटक प्रदर्शित करते हुए एक रेखाचित्र दिया था। अन्य शोध-कर्त्ता काउपर द्वारा बनायी गई स्लाइड़ों से उनके रेखाचित्र के अनुसार इस प्रकार का प्रादर्श ढूंढने में असफल रहे। काउपर के चित्र के अनुसार इसी शैल-समूह के अन्य स्थानों से भी इस प्रकार का प्रादर्श उपलब्ध नहीं हो पाया है तथा वर्तमान ऍस्टॅरेसी अथवा माल्वेसी कुलों से तुलनीय केवल बहुमुखकी प्ररूप ही उपलब्ध हो सके हैं। भारत के पुरानूतन-आदिनूतन कल्प से अभिलिखित काउपॅरिपॉलिस कंटकयुक्त एवं एकमुखकी हैं तथा माल्वेसी अथवा ऍस्टरेसी कुलों से सम्बद्ध नहीं हैं अतएव इन प्ररूपों हेतु निओकाउपॅरिपॉलिस नामक एक नव प्रजाति प्रम्तावित की गई है।

MONOCOLPATE spinose pollen recovered from a bore core sample representing the Lower Eocene, (Naredi Formation), in Kutch formed the basis for the designation of *Couperipollis* by Venkatachala and Kar (1969). Comparable pollen had earlier been recorded by Couper (1953) from Lower Maxwell Formation of Pliocene age, New Zealand. Venkatachala and Kar (1969) instituted *Couperipollis* with the following diagnosis: "Pollen grains subcircular, oval or elliptical in shape. Monosulcate, sulcus well developed, mostly extending from one margin to other. Exine ornamented with verrucae, bacula and spines". *Couperipollis perspinosus* (Couper) Venkatachala & Kar was chosen by them as the type species. A detailed study of *Couperipollis* was made by Thanikaimoni, Caratini, Venkatachala, Ramanujam and Kar (1984) while preparing the atlas of "Selected Tertiary angiosperm pollens from India and their relationship with African Tertiary pollens". This note stems out from deliberations of this workshop.

Saxena (1980) recorded *Couperipollis* from Palaeocene while Venkatachala and Kar (1969) and Sah and Kar (1970) recovered them from Eocene of Kutch. Sah and Dutta (1966, 1968), Dutta and Sah (1970), Singh and Singh (1978) proposed several species of this genus from the Palaeocene of Meghalaya. Sah and Kar (1974) recorded the genus from Eocene of Rajasthan while Baksi and Deb (1981) recorded the genus from the Eocene sediments of Bengal.

Erdtman (1947) proposed *Monosulcites* for laevigate, monocolpate pollen but Couper (1953) emended this genus to include free, anisopolar, bilateral monosulcate pollen with elongate to subcircular shape and with variable exine thickness and sculpture.

This emendation of *Monosulcites* by Couper (1953) was not considered tenable because both the laevigate and spinose monocolpate forms are classed together. To circumvent this heterogeneity, Venkatachala and Kar (1969) erected a new genus *Couperipollis* with *Monosulcites perspinosus* (Couper) as the basionym of the type species *C. perspinosus* (Couper) Venkatachala & Kar. The type locality of *Monosulcites perspinosus* is Nukumaru beach, near Wangaui, Lower Maxwell Formation of Pliocene age. According to Couper (1953), the type specimen of *M. perspinosus* is L 43 but according to Norris (1962) and Pocknall and Mildenhall (1984) subsequent search in the type slide and other preparations made by Couper has not resulted into finding of the type specimen. The only spinose pollen that could be seen in the preparations are pollen comparable to extant Asteraceae or Malvaceae. Pocknall and Mildenhall (1984) remark that no original unprocessed material of Couper's collection remains and the sea has swallowed the exposures from where he originally collected the samples. While instituting the species, Couper (1953) did not illustrate his taxon with a photograph but instead provided a line drawing depicting the oval shape, well-developed colpus and spines with bulbous base and pointed tip.

Location of a pollen as per illustration of Couper from other localities, in the opinion of Pocknall and Mildenhall (1984), was also not fruitful. So they concluded that Couper's *Monosulcites perspinosus* could at best be a folded specimen with Malvaceae-like spines in which the pores are probably hidden in the folds. In such a case, even if *M. perspinosus* is subsequently found, *Couperipollis* then, in the opinion of Pocknall and Mildenhall (1984), would be a synonym of *Tubulifloridites* (Cookson) Potonié, *Malvacipollis* Harris or *Malvacearumpollis* Nagy. They therefore advocate that the genus *Couperipollis*, based on a drawing of a wrongly diagnosed specimen that no longer exists, should be abandoned. Abandoning the name of *Couperipollis* as suggested by Pocknall and Mildenhal (1984) alone would, however, not solve the taxonomic tangle. Some of the species of *Couperipollis* described from the Lower Tertiary of India are definitely monocolpate and spinose. They have no relation to the pollen grains of Asteraceae or Malvaceae but are closely akin to Arecaceae. These species are to be suitably accommodated either in an existing genus or a new one.

Mathur (1966) proposed *Echimonocolpites* for the spinose, monocolpate pollen and the hitherto known various species of *Couperipollis* should normally be placed within it. However, *Echimonocolpites* Mathur (1966) is a junior synonym of *Echimonocolpites* van der Hammen & de Mutis (1965). Prior to the proposition of *Echimonocolpites*, van der Hammen (1954) originally instituted *Monocolpites* for similar type of pollen and in 1956 he selected the pollen of *Orthrosanthus multiforus* Sweet an extant pollen as the lectotype for the genus. Since this species has already been named as the type species of *Orthrosanthus* Sweet the proposal of van der Hammen was regarded as invalid. Van der Hammen and de Mutis (1965) subsequently proposed *Echimonocolpites*—a new genus for those pollen and selected the type species from a new combination based on illegitimate *Monocolpites rudae*. This time, they however, validated it with a nomenclaturally acceptable holotype. This treatment is again not in accordance with the International Code of Botanical Nomenclature because this new combination does not provide full and direct reference to the basionym (Catalog Fossil Spores Pollen, vol. 34, p. 247). Nicolson (personal communication with Thanikaimoni) also corroborates that *Echimonocolpites* van der Hammen & de Mutis (1965) is validly published although the appropriate combination in *Echimonocolpites* has not (yet ?) been validated. Since a taxon name once rejected as illegitimate following the International Code of Botanical Nomenclature can not be used again for a new combination except by conservation, *Echimonocolpites* is regarded here as invalid.

Arengapollenites Kar (1985) resembles *Couperipollis* in monocolpate and spinose disposition but the spines in *Arengapollenites* are closely placed on two margins of the colpus in alternate fashion so that they interlock the aperture on invagination. This character is typical to the extant *Arenga* pollen and *Arengapollenites* was proposed by Kar (1985) to accommodate dispersed fossil pollen comparable to *Arenga*. In *Couperipollis*, the spines are not arranged in any special manner in apertural region and thus is easily distinguished from *Arengapollenites* Kar (1985).

As there is no suitable genus which could accommodate some of the species described under *Couperipollis*—a new name, viz., *Neocouperipollis* is proposed here with the following generic diagnosis made after an indepth study by Thanikaimoni, Caratini, Venkatachala, Ramanujam and Kar (1984).

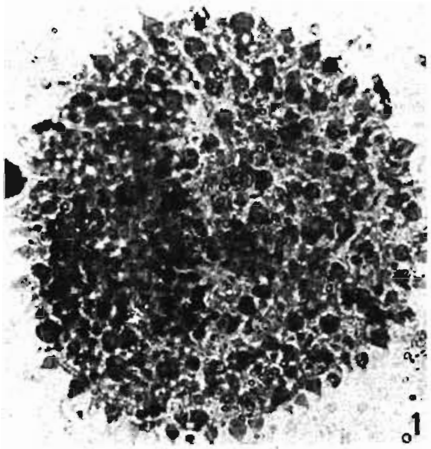
Genus—*Neocouperipollis* gen. nov.

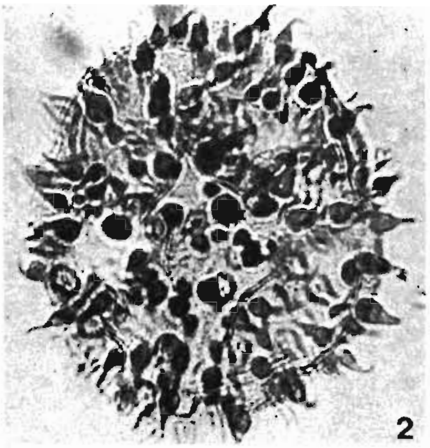
Type Species—*Neocouperipollis* (*Couperipollis*) *kutchensis* (Venkatachala & Kar) comb. nov.

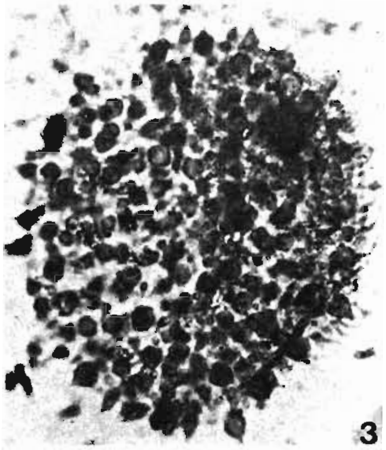
Diagnosis—Pollen grains more or less elliptical in polar view, monosulcate, echinate, sulcus extending from one end to the other along the longest axis, spines pointed with nexinal thickening at the base, exine more or less smooth between the spines.

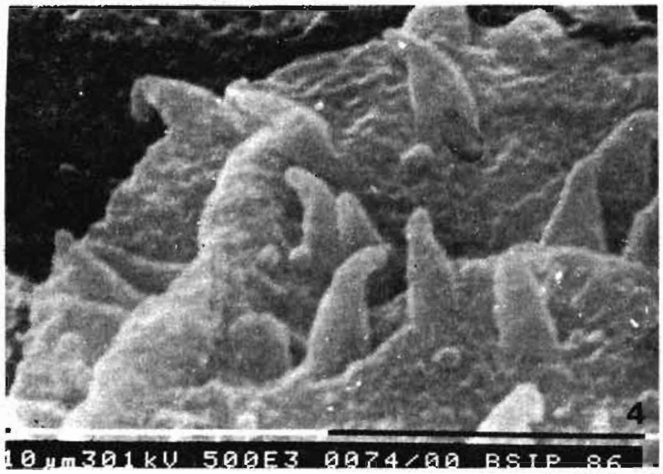
Neocouperipollis (*Couperipollis*) *kutchensis* (Venkatachala & Kar) comb. nov.

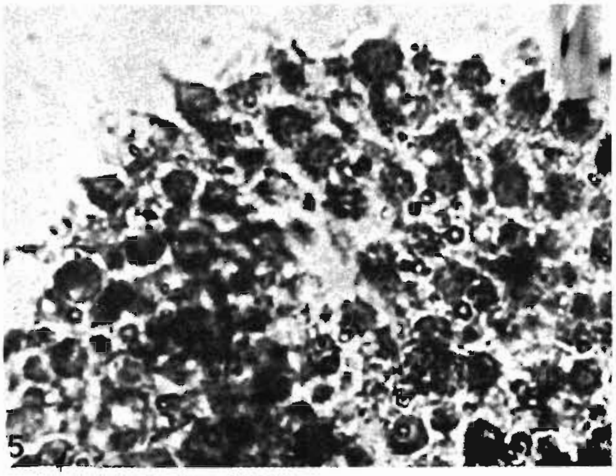
1969 *Couperipollis kutchensis* Venkatachala & Kar, p. 161, pl. 1, figs. 15-16.











Figures 1, 2, 5—*Neocouperipollis kutchensis* (Venkatachala & Kar) comb. nov. : 1, 5,Holotype, fig. 1 magnified to *ca.* × 1000 and fig. 5 *ca.* × 2000. Note the colpus in the middle region. Fig. 2 magnified to *ca.* × 1000.

Figure 3—*Neocouperipollis kutchensis* (Venkatachala & Kar) comb. nov. magnified to *ca.* × 1000. Note the spines with bulbous base and pointed tip.

Figure 4—SEM photograph of *Neocouperipollis kutchensis* (Venkatachala & Kar) comb. nov.

Emended Diagnosis—Pollen grains more or less subcircular to oval in shape, 35-65 × 30-60 µm. Monosulcate, exine spinose, spines strongly built with bulbous base and pointed tip, interspinal space more or less laevigate to granulose.

Holotype—Venkatachala and Kar, 1969, pl. 1, fig. 16, size 50 × 48 µm, slide no. 3315, V 34 (England Finder reading).

Remarks—Venkatachala and Kar (1969) mentioned the slide number of the holotype as 3314. However, the correct number of the slide is 3315.

Type Locality—Bore-hole core no. 14, Naredi Formation, Lower Eocene, Kutch.

The following species of *Couperipollis* were also emended by the authors and are here transferred to *Neocouperipollis*.

Neocouperipollis (*Couperipollis*) *achinatus*
(Sah & Kar) comb. nov.

Holotype—Sah and Kar, 1970, pl. 1, fig. 8, size. 42 × 30 µm, slide no. 3351.

Diagnosis—See Sah and Kar, 1970, pp. 130-131.

Neocouperipollis (*Monosulcites*) *magnus*
(Dutta & Sah) Kar & Kumar, 1986

Neotype—Kar & Kumar (1987), pl. 4, fig. 5, size 74 × 56 µm, slide no. 9357, g 34/2.

Diagnosis—See Dutta and Sah, 1970, pp. 28-29.

Neocouperipollis (*Couperipollis*) *spinorobustus*
(Kar & Kumar) comb. nov.

Holotype—Kar and Kumar (1986), size 65 × 48 µm, slide no. 9353, g 48.

Diagnosis—See Kar and Kumar (1986).

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The Palaeobotanist **35**(2) : 175-177, 1986.

An abnormal megaspore from Lower Permian Coal Measures near lake Tanganyika, Zaire

Hari K. Maheshwari & Usha Bajpai

Maheshwari, Hari K. & Bajpai, Usha (1987). An abnormal megaspore from Lower Permian Coal Measures near lake Tanganyika, Zaire. *Palaeobotanist* **35** (2) : 175-177.

An abnormal megaspore with a tetraradiate mark of cytokinesis is reported from the Lukuga Group of Zaire, Central Africa. The sporoderm of the megaspore shows effects of bio-degradation probably resulting due to bacteria.

Key-words—Palynology, Megaspore, Bacteria, Biodegradation, Permian (Zaire).

Hari K. Maheshwari & Usha Bajpai, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

तंगानयिका झील (ज़ायर) के समीपस्थ अधरि परमी कोयला-मेज़र्स से एक असाधारण गुरुबीजाणु

हरिकृष्ण माहेश्वरी एवं ऊषा बाजपेयी

केन्द्रीय अफ्रीका में ज़ायर के लुकुगा समूह से कोशिका द्रव्य-विभाजन के चतुर्ररिक चिन्ह से युक्त एक असाधारण गुरुबीजाणु की बीजाणुचर्म जैवनिम्नीकरण का प्रभाव व्यक्त करती है जो कि सम्भवतया जीवाणुओं के फलस्वरूप हो सकता है।

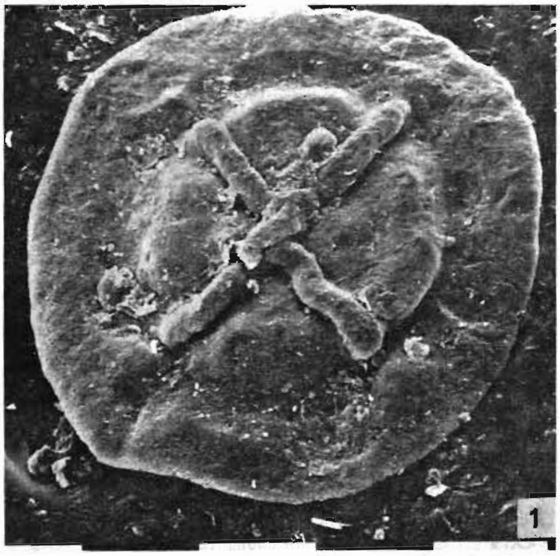
THE Permian Period in Zaire is represented by sediments of Lukuga Group which are mostly confined to the eastern part and outcrop from Irumu in the north-east up to almost the southern boundary of Katanga. Much work has been done on the palynostratigraphy of the group; almost all the formations are rich in microspores and pollen. However, megaspores have been recovered from only a few beds of Assise á couches de houille represented by Coal Measures near lake Tanganyika, south of Albertville (Bose & Maheshwari, 1968).

These megaspores are yet to be described and illustrated. One of the specimens from this assemblage shows an abnormal feature, that is, tetraradiate lines of cytokinesis. Though unusual attachment of spores and pollen in dyads and tetrads is known in a few species, e.g. *Glyptostrobus* sp. (Wodehouse, 1935), *Selaginella deflexa* Brack (Selling, 1945), *S. rupestris* Spring (Graustein, 1930), *S. selaginoides* (L.) Link (Erdtman, 1943), etc., the only report of an abnormal laesura known to us is by Devi and Khare (1985) who reported a circular laesura in *Pteris vittata* L. The tetraradiate megaspore is thus an unique find and is described and illustrated here.

DESCRIPTION

The megaspore is almost circular in proximo-distal view. The most unusual feature of the megaspore is the presence of tetraradiate lines of cytokinesis. Instead of the usual three 'letes' the megaspore has four 'letes'. All the 'letes' are equal in length and do not extend beyond the 'contact area'. Even though the arcuate ridges are not seen, the 'contact area' is well demarcated and slightly raised above the surface of the megaspore. The exospore is psilate at the light microscope level. Under the scanning electron microscope the sporoderm shows setting in of the biodegradational process.

Sandwiched between the tip of one of the 'letes' and the sporoderm is an ovoid body with rough surface. There are two other bodies lying on the sporoderm. One of the bodies is built up of irregular and broken ridges with mini and micro projections. The other body comprises a large number of ovoid to spherical structures, all with micro projections. These probably represent bacterial attack resulting in biodegradation of the sporoderm.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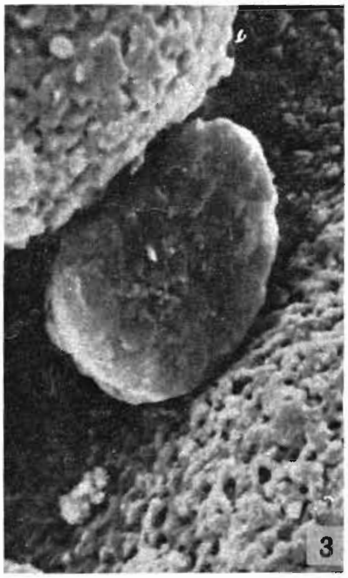
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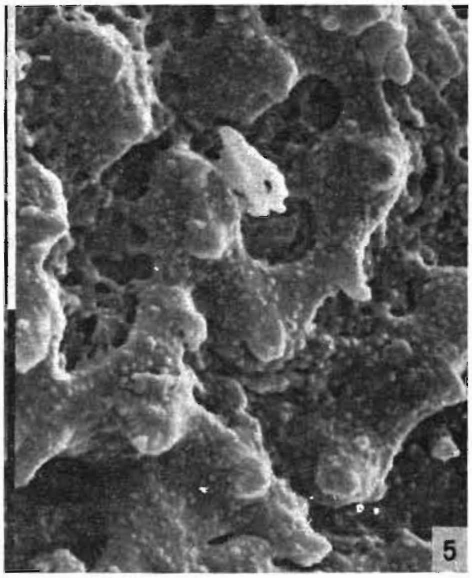
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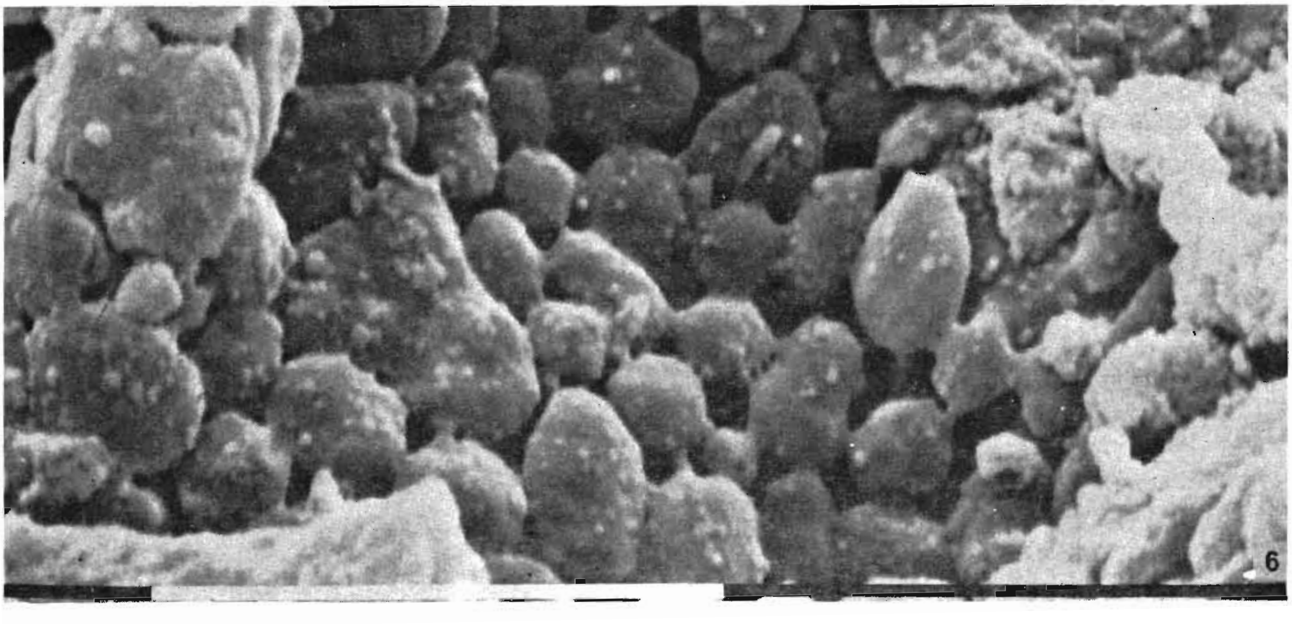
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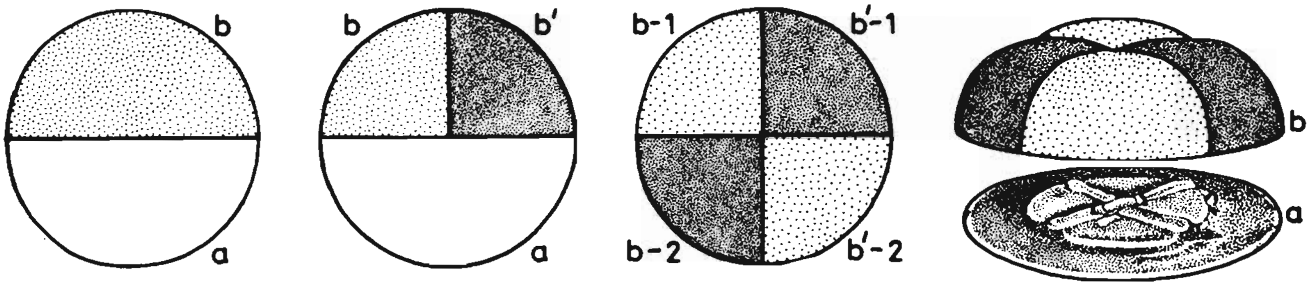
PLATE 1



Text-fig. 1—Presumed sequence of divisions in megaspore mother cell resulting in formation of abnormal megaspore (a).

The megaspore was recovered from the SEM stub and subjected to the differential maceration technique as outlined by Maheshwari and Bajpai (1984) to know the nature of mesosporium. However, only fragments of mesosporium could be recovered and because of this drawback the specimen could not be identified with the known megaspore taxa.

DISCUSSION

Pteridophytes regularly produce spores as direct products of meiosis. The meiocytes of heterosporous pteridophytes produce spores of two sizes. Some of the sporangia contain large number of small sporocytes, each of which gives rise to four microspores after meiosis. In other sporangia a regular and extensive degeneration of sporocytes takes place leaving only one or a few sporocytes to enlarge and undergo meiosis producing four large spores, the megaspores.

The micro- and megaspores of pteridophytes generally show 2 or 3 contact facets depending upon the type of tetrad, e.g. tetragonal or tetrahedral. The contact facets mark the lines of cytokinesis or cell plate formation within the spore mother cell. A megaspore with 4 contact facets, as in the present case, is an abnormality and its origin requires explanation. A possible sequence could be as follows:

In the megasporangium, the sporogeneous tissue segregates into individual cells which function as meiocytes. Usually all except one of the spore mother cells degenerate and the survivor undergoes cytokinesis through meiosis producing four spores arranged in a tetrad. In the present case it seems that after meiosis I, the cell plate was laid down forming a dyad. One of the member of the dyad did not divide further while the other one underwent two mitotic divisions to produce 4 cells arranged in a tetragonal tetrad. These 4 cells probably developed into abortive megaspores whereas the other member of the dyad acquired 4 'letes' marking the lines of contact between the functional megaspore and the 4 abortive megaspores. An attempt to reconstruct this sequence has been made in Text-figure 1.

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PLATE 1

1. Scanning Electron Micrograph of the megaspore showing four "letes" and raised contact areas. × 155.
2. A part of the megaspore magnified to show the rounded apex of one of the "letes". The reticle marks the presence of an oval foreign body. × 300.
3. The portion outlined by the reticle in figure 2 magnified further. × 2400.
4. Two foreign bodies lying in the angle between two "letes" × 810.

5, 6. The foreign bodies magnified further to show their nature and their biodegradational effect. 5. × 4100; 6. × 7600.

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Fossil woods of *Kingiodendron* and *Bauhinia* from the Namsang beds of Deomali, Arunachal Pradesh

Nilamber Awasthi & Uttam Prakash

Awasthi, Nilamber & Prakash, Uttam (1987). Fossil woods of *Kingiodendron* and *Bauhinia* from the Namsang beds of Deomali, Arunachal Pradesh. *Palaeobotanist* **35** (2) : 178-183.

Two fossil woods resembling those of *Kingiodendron* Harms and *Bauhinia* Linn. of the family Leguminosae are described from the Namsang beds (Mio-Pliocene) exposed along Namsang River at Deomali in Arunachal Pradesh. They have been named as *Kingiodendron prepinnatum* sp. nov. and *Bauhinia deomalica* sp. nov. respectively.

Key-words—Xylotomy, Leguminous woods, Namsang beds, Mio-Pliocene (India).

Nilamber Awasthi & Uttam Prakash, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

अरुणाचल प्रदेश में देवमाली की नामसाँग संस्तरों से किंगिओडेन्ड्रॉन एवं बॉहीनिआ की काष्ठाश्म

नीलाम्बर अवस्थी एवं उत्तम प्रकाश

अरुणाचल प्रदेश में देवमाली के पास नामसाँग नदी के संग-संग विगोपित संस्तरों (मध्य-अतिनूतन) से लैगूमिनोसी कुल के किंगिओडेन्ड्रॉन हार्म्स एवं बॉहीनिआ लिन्नॅयस से मिलते-जुलते काष्ठाश्म वर्णित किये गये हैं। इन काष्ठाश्मों को क्रमशः किंगिओडेन्ड्रॉन प्रीपिन्नाटम् नव जाति तथा बॉहीनिआ देवमालिका नव जाति से नामाँकित किया गया है।

IN continuation of our previous studies on the petrified woods from the Namsang beds which are exposed along the Namsang River at Deomali (Prakash, 1965, 1966; Prakash & Awasthi, 1970, 1971; Lakhanpal, Prakash & Awasthi, 1981), we have further investigated a large number of woods collected during our field excursions to this area in 1972, 1975 and 1978. In addition to several already known taxa, about sixteen new woods have been recognised. Of these, two have been described here. They show close resemblance with the modern woods of *Kingiodendron* and *Bauhinia* of Leguminosae.

SYSTEMATIC DESCRIPTION

Family—Leguminosae

Genus—*Kingiodendron* Harms

Kingiodendron prepinnatum sp. nov.

Pl. 1, figs 1, 2, 5, 7, 9; Pl. 2, fig. 1

Material—Single piece of well preserved decorticated secondary wood.

Description—*Wood* diffuse-porous. *Growth rings* present, delimited by narrow lines of parenchyma and narrow zone of thick-walled fibres. *Vessels* small to medium and occasionally large, mostly circular to oval or elliptical due to compression, solitary and in radial multiples of 2-4, evenly distributed, up to 250 μm in diameter, 6-12 vessels per sq·mm; perforations simple; vessel-members truncate, about 150-750 μm in length; intervessel pits medium to large, 6-12 μm in diameter, alternate, vestured, apertures small, linear to lenticular; tyloses not seen. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric, forming 2-3 cells wide sheath around vessels and occasionally aliform; apotracheal parenchyma occurring as fine lines of 2-3 cells in width delimiting the growth rings and also forming 3-6 cells wide sheath around gum canals, enclosing 1-3, sometimes up to 5 canals; parenchyma cells oval to angular, up to 44 μm in diameter. *Rays* 1-4 (mostly 3) seriate, about 3-18 cells in height, 7-9 per mm in cross section; ray tissue heterogeneous; rays homocellular to heterocellular; multiseriate rays consisting of procumbent cells and sometimes both procumbent and upright or square cells, the latter occurring as 1-2 marginal rows at one or both the ends, upright or square cells 30-60 μm in tangential height and 24-32 μm in radial length; procumbent cells 16-40 μm in tangential height and 48-160 μm in radial length. *Fibres* polygonal in cross-section, up to 32 μm in diameter, moderately thick-walled, non-septate. *Gum canals* abundant, normal, vertical, occurring singly or in pairs and sometimes aligned tangentially in small groups of 3-5, enclosed by 3-6 layers of parenchymatous tissue, oval, up to 400 μm in diameter.

Affinities—The above features of the fossil indicate that it is a leguminous wood. Presence of normal vertical gum canals is its most important character. Among the legumes such gum canals are known to occur in the secondary woods of *Copaifera, Detarium, Eperua, Sindora, Daniella, Gossweilerodendron, Oxystigma, Kingiodendron, Prioria* and *Pterygopodium.* In the first four genera the gum canals are in concentric rings while in the remaining six they are solitary or in pairs and sometimes in short tangential groups. Since in our fossil wood the gum canals are solitary or in pairs, it can be compared with those of the latter six genera. Among these the wood of *Kingiodendron pinnatum* Harms (Syn. *Hardwickia pinnata* Roxb.) shows close resemblance with our fossil wood. The other genera differ from it in some important features. In *Daniella* the xylem rays, parenchyma strands and vessel-members are storied (Normand, 1950, pl. 41, p. 109; Henderson, 1955, figs 193, 194, 201; Kribs, 1959, pp. 77-78) and in *Gossweilerodendron* the apotracheal parenchyma is also present in addition to vasicentric, aliform and confluent and the xylem rays are homogeneous (Kribs, 1959, pp. 81-82, fig. 196). *Oxystigma, Prioria* and *Pterygopodium* differ from the present fossil in having relatively higher frequency of uniseriate rays and the multiseriate rays often being longer.

Nomenclature—For naming the fossil woods new genera have generally been created by adding the suffix "Oxylon" or "inium" to extant genera with which the fossil woods show resemblance. But some palaeobotanists have used the modern generic names as such to designate the fossil woods. Besides, several other workers have also named the fossil dicotyledonous woods in various other ways without following any procedural uniformity. However, this problem was critically observed by Lakhanpal and Prakash (1980) who have given valid suggestions for naming the fossil dicot woods. One of the suggestions is that in those cases where anatomical details of fossil dicot woods are well preserved and it is possible to assign them to the modern genera based on a comparative study of authentic woods, the fossil should be given modern generic name without adding suffix "Oxylon". Since our fossil wood shows close resemblance with that of *Kingiodendron*, in accordance with the above suggestion, it is being placed under the same genus. Specifically it is named as *Kingiodendron prepinnatum* sp. nov. indicating the antiquity of the species *Kingiodendron pinnatum.*

Genus—*Bauhinia* Linn.

Bauhinia deomalica sp. nov.

Pl. 2, figs 2-6

Material—Two pieces of fairly well preserved silicified secondary wood, measuring 9 × 4 cm and 12 × 8 cm respectively.

Description—*Wood* diffuse-porous. *Growth rings* not clearly marked. *Vessels* small to mostly medium, sometimes large, round to oval, solitary and in radial mutiples of 2-3, occasionally up to 6, solitary and bigger vessels of radial multiples 60-160 μm in tangential diameter, 160-280 μm in radial diameter, uniformly distributed; vessel-members truncate, about 160-320 μm in length, storied; perforations simple; intervessel pits medium to large, about 8 μm in diameter, alternate to oval, vestured, aperture lenticular to circular. *Parenchyma* paratracheal, aliform-confluent to mostly banded, completely or partly enclosing the vessels, alternating with broader bands of fibres; parenchyma bands about 3-5 cells wide and 4-5 per mm, strands storied, some divided into several locules, each containing solitary crystals, cells about 20-40 μm in diameter. *Rays* very fine, almost exclusively uniseriate, 8-12 μm in width and 9-20 cells or 160-280 μm in height, closely spaced, 20-25 per mm, storied; ray tissue heterogeneous, rays homocellular to heterocellular, consisting of procumbent cells only or sometimes with a single row of upright cells at one or both the ends; upright or square cells 20-24 μm in tangential height, 16-12 μm in radial length, procumbent cells 8-12 μm in tangential height and 40-140 μm in radial length. *Fibres* polygonal in cross section, 10-24 μm in diameter, thick-walled, non-septate. *Ripple marks* present due to storied arrangement of vessel-members, parenchyma strands and xylem rays.

Affinities—The most important features of the fossil wood are: (i) ripple marks present due to storied arrangement of vessel-members, parenchyma strands and xylem rays; (ii) parenchyma aliform-confluent to mostly banded, and (iii) the xylem rays almost exclusively uniseriate. These features collectively indicate that the present fossil belongs to the family Leguminosae. Amongst legumes this combination of anatomical features is met with in *Bauhinia* and to some extent in *Dalbergia* and *Pterocarpus.* Although both *Dalbergia* and *Pterocarpus* resemble the fossil in gross features, they can be differentiated from it in some other significant characters. In *Dalbergia* the rays are 1-3 seriate and very short, their maximum height being up to 12 cells, whereas in the present fossil the rays are uniseriate with occasionally paired cells and 9-20 cells in height. Though the rays in *Pterocarpus* are also uniseriate yet they are comparatively much shorter than in the fossil. Moreover, the tylosis is absent in both *Dalbergia* and *Pterocarpus.*

From a detailed comparison of the fossil woods with the thin sections and published descriptions and illustrations of a number of species of *Bauhinia* Linn. particularly those occurring in the Indomalayan region (Moll & Janssonius, 1914, pp. 112-119, fig. 158; Pearson & Brown, 1932, pp. 417-425, figs 144-146; Metcalfe & Chalk, 1950, pp. 493-501; Ramesh Rao & Purkayastha, 1972, pp. 64-68, p. 172, figs 428-432, pl. 13, fig. 433) it was found that the fossil is very similar in all its anatomical characters with *Bauhinia foveolata* Dalz., and *B. racemosa* Lam. and also to some extent with *B. malabarica* Roxb.

Fossil woods and leaves of *Bauhinia* are of common occurrence in the Neogene deposits of India. The fossil wood described so far are: *Bauhinium miocenicum* Trivedi & Panjwani (1986) and *B. palaeomalabaricum* Prakash & Prasad (1983), both from the Siwalik beds of Kalagarh, Uttar Pradesh, and a fossil wood comparable to *Bauhinia* from the Cuddalore Series of South India (Ramanujam & Rao, 1966). All these differ markedly from the present fossil wood. In *Bauhinium miocenicum* the xylem rays are 1-3 (mostly 2) seriate and the vessels are medium-sized (t. d. 132-176 μm) whereas in our fossil the rays are almost exclusively uniseriate and the vessels are small to large (t.d. 60-160 μm, r.d. 16-280 μm). *Bauhinium palaeomalabaricum* Prakash & Prasad also differs from our fossil wood in possessing relatively broad, 3-9 seriate parenchyma bands and comparatively tall, 19-32 cells high xylem rays. In the present fossil the parenchyma bands are only 3-5 cells wide and the xylem rays are short, being about 9-20 cells in height. The fossil wood described by Ramanujam and Rao (1966) as *Bauhinia* is also different in having the vessels predominantly medium-sized (t.d. 125-175 μm), solitary to sometimes paired and the parenchyma bands broad up to 9 seriate; whereas in our fossil the vessels are small to large (t.d. 60-160 μm, r.d. 160-280 μm) and solitary as well as in radial multiples of 2-3, occasionally up to 6 vessels and the parenchyma bands are 3-5 seriate. Besides, Rawat (1964-65) reported a fossil wood of *Bauhinia* as *Bauhinioxylon indicum* from the Siwalik sediments of Mohand near Dehradun. But the author has not given any description and illustration of this fossil wood.

Since the present fossil wood is quite distinct from all the known fossil woods of *Bauhinia,* it is being described here as a new species, *Bauhinia deomalica* sp. nov.; the specific name indicating its occurrence in Arunachal Pradesh, India.

DISCUSSION

The genus *Kingiodendron* consists of four species, distributed in the Indomalayan region (Willis, 1973). In India *Kingiodendron* is represented by a single species, *Kingiodendron pinnatum* (Roxb.) Harms. It is a large tree occurring in the evergreen forests of Western Ghats from South Kanara to Kerala and Tirunelveli (Ramesh Rao & Purkayastha, 1972, pp. 79-81) mostly in association of *Vateria indica, Artocarpus hirsutus, Dysoxylum malabaricum, Dipterocarpus indicus, Filicium decipiens, Bischofia javanica, Toona ciliata* and *Elaeocarpus* species (Champion & Seth, 1968, p. 68). The other three species are known to occur each in Philippines, the Solomon and Fiji Islands.

Bauhinia is a large genus consisting of about 300 species distributed throughout the tropics of the world. About 30 species occur in India and Burma. Of the two species with which the fossil shows resemblance, *Bauhinia recemosa* Lam. occurs in sub-Himalayan tract ascending up to 1,500 m and throughout central, western and southern India in dry deciduous forest and also in dry regions of Burma and Sri Lanka. *Bauhinia foveolata* Dalz. grows in moist forests of Konkan and North Kanara at an elevation of 600 m (Ramesh Rao & Purkayastha, 1972, pp. 65, 66, 68).

→

PLATE 1

Kingiodendron prepinnatum sp. nov.

1, 2. Cross section showing distribution of vessels, parenchyma, gum canals solitary or in pairs (bigger ones) and growth ring (Fig. 2) delimited by apotracheal parenchyma line. × 40. Slide no. B.S.I.P. 35719-1.

Kingiodendron pinnatum

3. Cross section showing similar type and distribution of vessels, parenchyma, gum canals solitary or in groups of 2-3 and growth ring delimited by apotracheal parenchyma line. × 40.
4. Another cross section showing vessels and three gum canals together enclosed by parenchyma. × 50.

Kingiodendron prepinnatum sp. nov.

5. Tangential longitudinal section showing rays. × 90. Slide no. B.S.I.P. 35719-2

Kingiodendron pinnatum

6. Tangential longitudinal section showing rays similar to fossil. × 90.

Kingiodendron prepinnatum sp. nov.

7. Radial longitudinal section showing heterocellular xylem rays. × 90. Slide no. B.S.I.P. 45719-4.

Kingiodendron pinnatum

8. Radial longitudinal section showing heterocellular rays similar to fossil. × 90.


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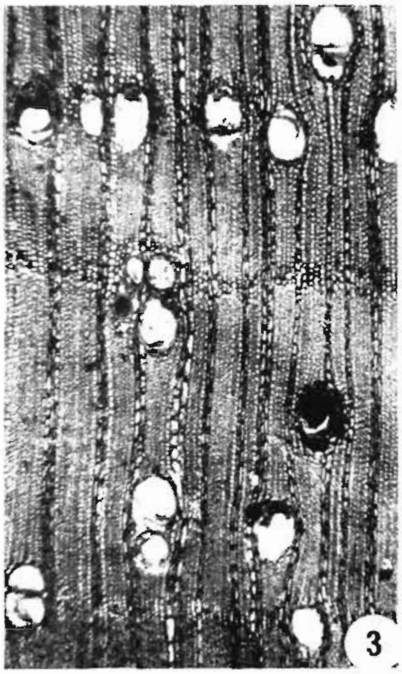
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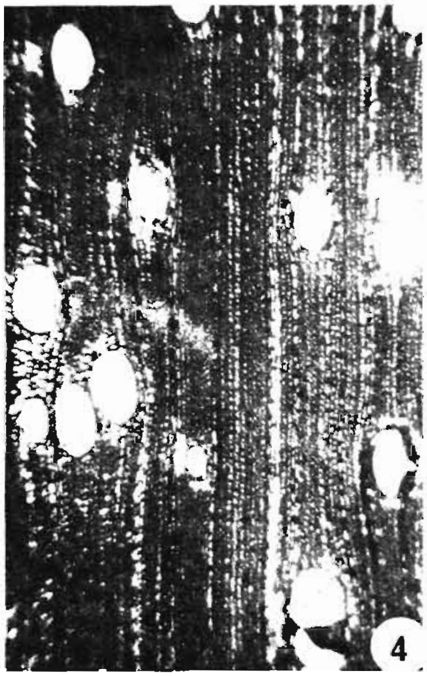
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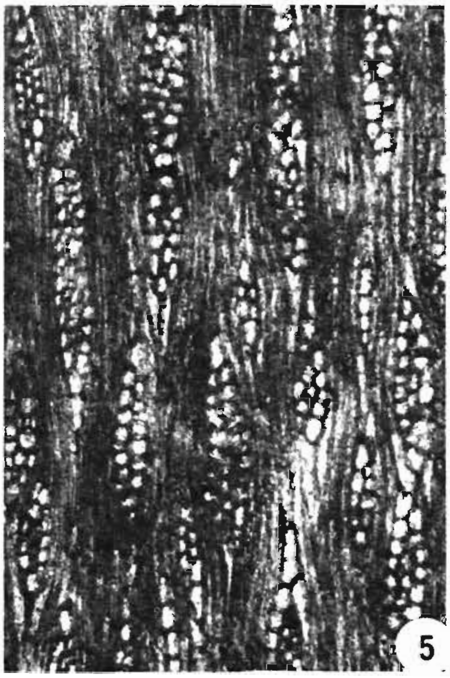
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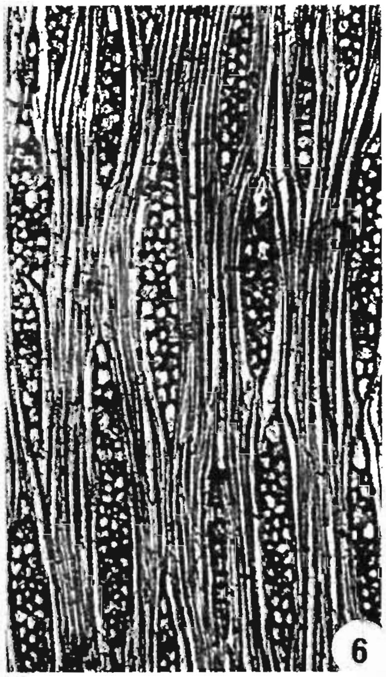
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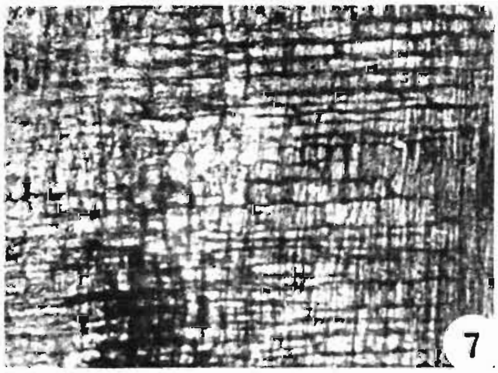
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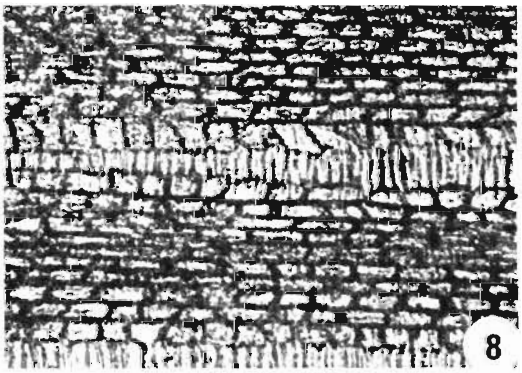
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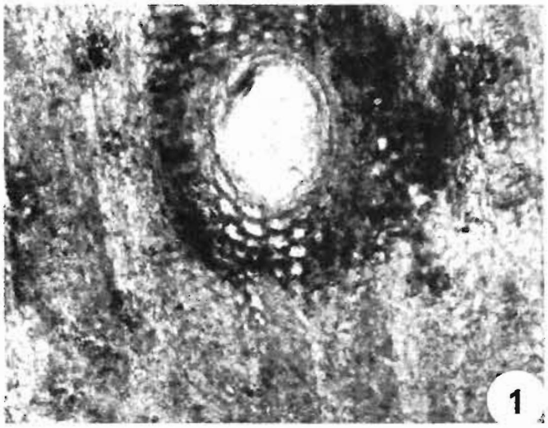
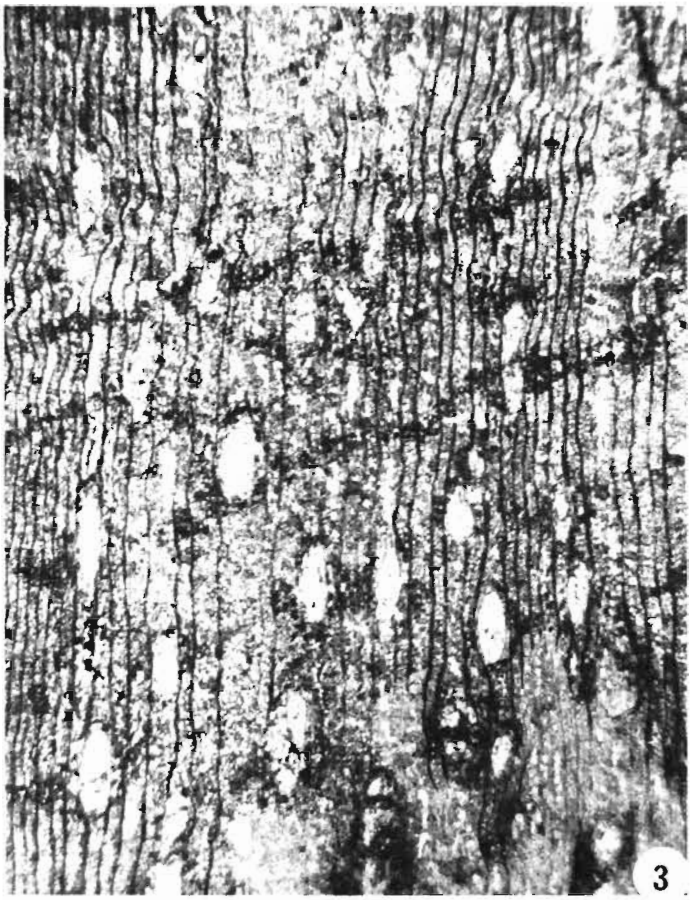
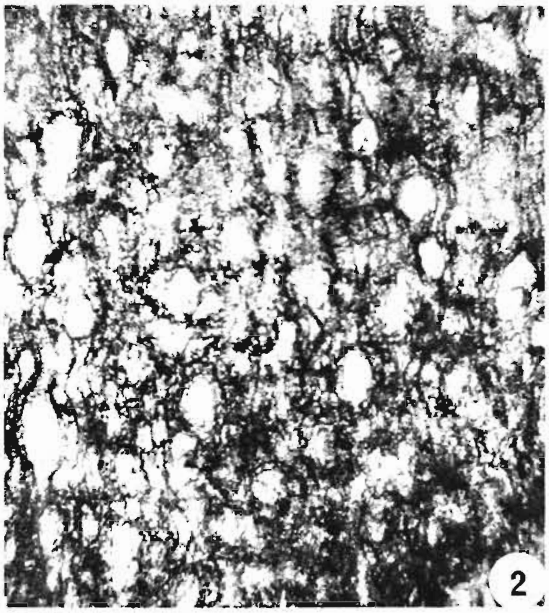
PLATE 1







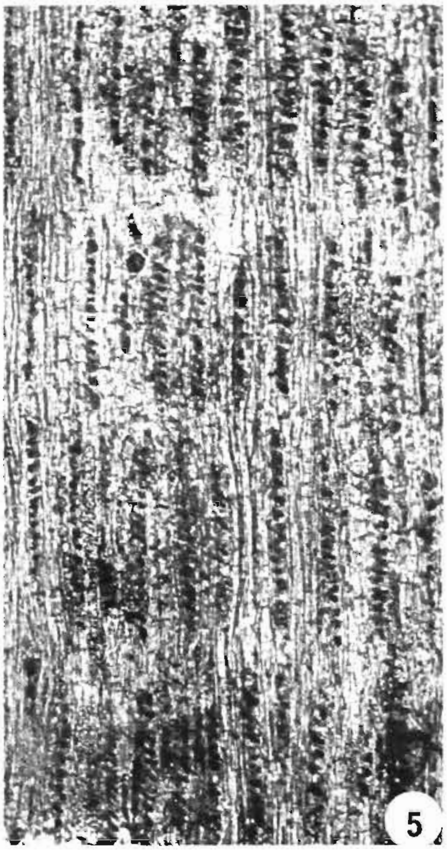


PLATE 2

Occurrence of leaves and woods of *Bauhinia* in the Neogene deposits of Northeast India and the Himalayan foot-hills (Lakhanpal & Awasthi, 1984; Rawat, 1965; Trivedi & Panjwani, 1986; Prakash & Prasad, 1984) indicates that this genus was widely distributed during the Neogene and continues to flourish luxuriently even today all along the North and Northeast India. Unlike *Bauhinia*, the genus *Kingiodendron* has completely vanished from this region as there is no record of its occurrence at present in North-east India, Burma and adjoining regions. Presumably there has been considerable change in the environmental conditions in Northeast India since the Neogene period when plants like *Kingiodendron* flourished here. Since a large number of fossil woods from this area are under investigation, a detailed account of the floristics, palaeoecology and phytogeography of this region will be published in due course.

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PLATE 2

Kingiodendron prepinnatum sp. nov.

1. Cross section magnified to show gum canal, with epithelial cells and 3-4 layers of parenchyma cells. × 90. Slide no. B.S.I.P. 35719-1.

Bauhinium deomalica sp. nov.

2. Cross section showing distribution of vessels and parenchyma bands. × 35. Slide no. B.S.I.P. 35720-1
3. Another cross section showing vessels and parenchyma bands. × 46. Slide no. B.S.I.P. 35721-1.
4. Cross section magnified to show tylosed vessels and vasicentric parenchyma. × 90. Slide no. B.S.I.P. 35721-2.
5. Tangential longitudinal section showing uniseriate and storied rays. × 120. Slide no. B.S.I.P. 355721-2.
6. Radial longitudinal section showing homocellular to heterocellular rays. × 175. Slide no. B.S.I.P. 35721-3.

The Palaeobotanist **35**(2) : 184-186, 1986.

Occurrence of Bamboo in the Siwalik beds near Ranital, Himachal Pradesh

R. N. Lakhanpal*, A. P. Tewari** & Nilamber Awasthi*

Lakhanpal, R. N., Tewari, A. P. & Awasthi, Nilamber (1987). Occurrence of Bamboo in the Siwalik beds near Ranital, Himachal Pradesh. *Palaeobotanist* **35** (2) : 184-186.

Impressions of leaves and culms of a bamboo have been described from the Lower Siwalik sediments near Ranital, district Kangra, Himachal Pradesh. Due to insufficiency of the preserved data it has not been possible to arrive at any definite identification of the bamboo.

Key-words—Leaf impressions, Culms, Bamboo, Siwalik beds, Tertiary (India).

**R. N. Lakhanpal & Nilamber Awasthi, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.*

***A. P. Tewari, Geological Survey of India, Pushpa Bhavan, Madangir Road, New Delhi, India.*

साराँश

हिमाचल प्रदेश में रानीताल के समीपस्थ शिवालिक संस्तरों में बाँस की उपस्थिति

राजेन्द्र नाथ लखनपाल, ए० पी० तिवारी एवं नीलाम्बर अवस्थी

हिमाचल प्रदेश के काँगड़ा जनपद में रानीताल के समीपस्थ अधरि शिवालिक अवसादों से बाँस के तने एवं पत्तियों की छापें वर्णित की गई हैं। अपर्याप्त परिरक्षित आँकड़ों के कारण बाँस का निश्चित अभिनिर्धारण सम्भव नहीं हो पाया।

A FEW years ago a party of geologists working with one of us (A.P.T.) collected some plant fossils from near Ranital, district Kangra, Himachal Pradesh, which is regarded as a locality of the Lower Siwalik sediments. In lithology these specimens are very much like those collected from Balu-Goloa, about 8 km east of Ranital and also considered as Lower Siwalik. While several kinds of plants have been described from Balu-Goloa (Lakhanpal, 1965, 1966, 1968, 1969; Lakhanpal & Dayal, 1966; Lakhanpal & Guleria, 1987), this is the first report from Ranital.

Description—There are eight specimens in the collection, which bear fragmentary plant remains showing obvious affinities with a bamboo. They consist of several leaf-impressions and two impressions of culms.

The leaves (Pl. 1, figs 1, 2) are linear, 2.0-3.5 cm broad with entire margin. The base and apex are not preserved in any specimen nor is any midrib discernible. Details of venation are not well preserved but one specimen shows the lamina bearing parallel longitudinal veins of two kinds: prominent veins placed at intervals of about 7 mm, each interval having a median vein with 7-8 finer interstitial veins on either side of it, without cross-veins.

The two fragments of culms are rather narrow, preserved width of one (Pl. 1, fig. 3) is about 2 cm and that of the other (Pl. 1, fig. 4) 3.4 cm. The former is about 8 cm and the latter about 10.5 cm in length. They represent the lower parts of the culms as both bear impressions of roots and vegetative buds at the nodes. The internodes are also short, about 2.5-3.5 cm in length. The impressions of roots are more or less oval, 1.5 × 3.0 to 3.0 × 5.0 mm across. The vegetative buds are broadly elliptic, measuring about 7.0 × 13.0 mm to 9.0 × 13.0 mm across. As preserved, there are up to 7 root scars in a row visible at the node. At some nodes, there is a thin linear impression of the junction of the sheath membrane, just below the row of root scars.

Discussion—The preservation of the present specimens is far from satisfactory for a definite identification with any known taxa of bamboos.

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4

However, the available data indicate that the Ranital bamboo had a narrow culm with short internodes, specially near the basal part. There were about a dozen root scars around the basal nodes, arranged in a single row. The vegetative buds were small and appeared broadly elliptic in outline. The leaves were of medium width and not very large.

Keeping the above features in view, an attempt was made to compare the fossil bamboo with those growing in the Arboretum of the Forest Research Institute, Dehradun. Four bamboos, viz., *Dendrocalamus strictus, D. longispathus, Melocanna baccifera* and *Neohouzeaua dullooa* are comparable to our fossil in the width of the stem. However, in characters of roots and buds *Melocanna* and *Neohouzeaua* are quite different, particularly *N. dullooa* in which the roots coming out in several circular rows form a sort of a band at the node. *Dendrocalamus strictus* and *D. longispathus* show more

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PLATE 1

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(All figures are of natural size)

1. A fragment of leaf-impression of a bamboo. B.S.I.P. specimen no. 35893 A.
2. Another specimen of a leaf-impression B.S.I.P. specimen no 35893 B.
3. An impression of a bamboo culm showing vegetative buds and a sheath membrane. B.S.I.P. specimen no. 35894.
4. Another impression of a culm clearly showing root scars and vegetative buds at the nodes. B.S.I.P. specimen no. 35893 C.

resemblance with the fossil. The size of the vegetative buds is similar in both. However, the internodes are shorter in *D. strictus* and longer in *D. longispathus*. The roots also seem more like those of the fossil in D. *strictus* than in *D. longispathus*. But in leaves, *D. longispathus* shows closer similarity than *D. strictus*.

The above comparisons are only tentative as our specimens are fragmentary and without enough characters warranting a definite identification. On the basis of the presently available information it can only be stated that a bamboo was growing around Ranital in the Lower Siwalik times. Its taxonomic affinities would be established only when better specimens are collected from this locality in future.

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The Palaeobotanist **35**(2) : 187-195, 1986.

Palynology of the Siwalik sediments of Kala Amb-Nahan area in Sirmaur District, Himachal Pradesh

R. K. Saxena & A. P. Bhattacharyya

Saxena, R. K. & Bhattacharyya, A. P. (1987). Palynology of the Siwalik sediments of Kala Amb-Nahan area in Sirmaur District, Himachal Pradesh. *Palaeobotanist* **35** (2) : 187-195.

The palynoflora recovered from the Lower Siwalik (Nahan) and Upper Siwalik sediments exposed along the road sections in Kala Amb-Nahan area in Sirmaur District consists of 18 genera and 25 species. Of these, two species are new. The diagnoses of two palynogenera, viz., *Inaperturopollenites* and *Inapertisporites*, have been emended. One new combination has also been proposed.

The Lower Siwalik (Nahan) palynoflora is represented by 13 genera and 17 species of fungal remains (13%), pteridophytic spores of Cyatheaceae and Polypodiaceae (5%), gymnospermous pollen of Pinaceae (73.5%), and angiospermous pollen of Liliaceae and Myricaceae (8.5%). On the other hand, the Upper Siwalik assemblage is represented by 11 genera and 15 species of fungal remains (14%), gymnospermous pollen of Pinaceae (67%), and angiospermous pollen of Potamogetonaceae, Palmae, Poaceae and Magnoliaceae (19%). A comparison of these Lower and Upper Siwalik assemblages with the known assemblages from the corresponding horizons has been made and it has been observed that the Lower Siwalik assemblage comes closest to that described from the Bhakra-Nangal Section in Himachal Pradesh, whereas the Upper Siwalik assemblage is comparable to the Pinjor assemblage near Chandigarh and Assemblage-1 of Hoshiarpur-Una Road Section assemblage.

Key-words—Palynology, Lower Siwalik, Upper Siwalik, Tertiary (India).

R. K. Saxena & A. P. Bhattacharyya, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

हिमाचल प्रदेश के सिरमौर जनपद में काला अम्ब-नाहन क्षेत्र के शिवालिक अवसादों का परागाणविक अध्ययन

रमेश कुमार सक्सेना एवं अनन्त प्रसाद भट्टाचार्य

सिरमौर जनपद के काला अम्ब-नाहन क्षेत्र में सड़क के संग-संग विगोपित अधरि शिवालिक (नाहन) एवं उपरि शिवालिक अवसादों से उपलब्ध परागाणुवनस्पतिजात में 18 प्रजातियाँ एवं 25 जातियाँ विद्यमान हैं। इनमें से दो जातियाँ नई हैं। दो प्रजातियों अर्थात् इनएँपर्चुरोपोलिनाइटिस एवं इनएँपर्टिस्पोराइटिस का निदान संशोधित किया गया है। एक नव संयोजन भी प्रस्तावित किया गया है।

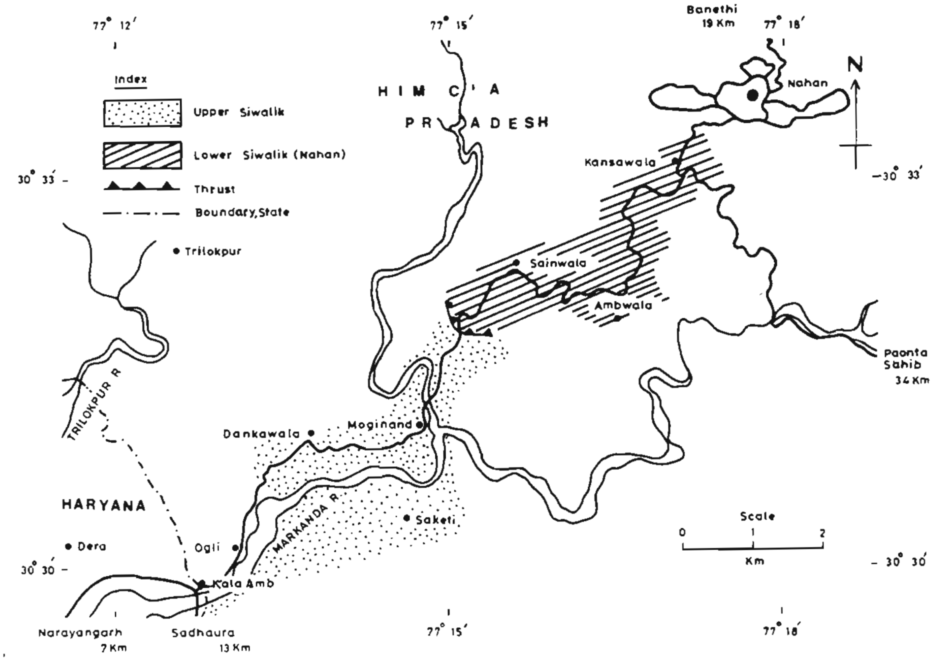
अधरि शिवालिक (नाहन) परागाणुवनस्पतिजात में कवकीय अवशेषों (13 प्रतिशत) टेरीडोफ़ाइटीयों में स्याथिएसी एवं पोलिपोडिएसी के बीजाणु (5 प्रतिशत), अनावृतबीजीयों में पाइनेसी के परागकण (73.5 प्रतिशत) तथा आवृतबीजीयों में लिलिएसी एवं मिरीकेसी के परागकणों (8.5 प्रतिशत) की 13 प्रजातियाँ एवं 17 जातियाँ मिलती हैं। दूसरी ओर उपरि शिवालिक समुच्चय में कवकीय अवशेषों (14 प्रतिशत), अनावृतबीजीयों में पाइनेसी के परागकण (67 प्रतिशत) तथा आवृतबीजीयों में पोटेमोजीटोनेसी, पाल्मी, पोएसी एवं मैग्नोलिएसी के परागकणों (19 प्रतिशत), की 11 प्रजातियाँ एवं 15 जातियाँ, विद्यमान हैं। इन अधरि एवं उपरि शिवालिक समुच्चयों की तुलना अन्य ज्ञात संस्तरों के समुच्चयों से की गई है तथा यह प्रेक्षित किया गया है कि अधरि शिवालिक समुच्चय हिमाचल प्रदेश में भाखड़ा-नाँगल खंड से वर्णित समुच्चय से घनिष्टता प्रदर्शित करता है, जबकि उपरि शिवालिक समुच्चय चंडीगढ़ के समीप पिंजौर समुच्चय तथा होशियारपुर-ऊना मार्ग खंड समुच्चय की समुच्चय-प्रथम से तुलनीय है।

THE palynological studies on the Siwalik Group started in late sixties. Banerjee (1968) published a short paper dealing with the palynoflora, palaeoclimate and environment of deposition of Lower and Middle Siwalik in Bhakra Nangal area of Himachal Pradesh. Thereafter, Lukose (1969), Nandi and Bandyopadhyay (1970), Venkatachala (1972), Nandi (1972), Mathur (1973) and Mathur and Venkatachala (1979) have made significant contributions to Lower and Middle Siwalik palynology. Nandi (1975) and Ghosh (1977) divided the Siwalik sequence of Jawalamukhi area, Himachal Pradesh into four informal zones, viz., Zones 1-4, on the basis of characteristic palynoassemblages recovered therefrom. Nandi (1980) provided a formal status to these zones as per requirements of the Code of Stratigraphic Nomenclature of India (1971) and tried to extend them in the various traverse sections of the Siwaliks in Uttar Pradesh, Punjab and Himachal Pradesh.

The palynological study of the Upper Siwalik sediments was started a little later. Singh *et al.* (1973) were the first to report the occurrence of *Pinus*-type, monosulcate-type and inaperturate (nonsaccate) pollen grains in the Pinjor Formation (Upper Siwalik) and to surmise subtemperate to temperate climate. Nandi (1975) and Ghosh (1977) reported the occurrence of *Cyathidites, Alsophilidites, Leptolepidites, Pinuspollenites, Podocarpidites, Monoporopollenites, Alnipollenites* and *Tetradomonoporites* in the basalmost part of Upper Siwalik and stated the remaining part of Upper Siwalik to be palynologically completely unfossiliferous. Thereafter, after a gap of few years, palynological studies on the Upper Siwalik were revived by Saxena and Singh (1980, 1981, 1982a, 1982b) and Singh and Saxena (1980, 1981). These assemblages are from the middle and upper parts of the Upper Siwalik, proving these horizons palynologically fossiliferous. Saxena *et al.* (1984) studied Lower, Middle and Upper Siwalik palynofloras of Bhakra-Nangal area, Himachal Pradesh. Saxena and Sarkar (1983) recorded several taxa of reworked Eocene dinoflagellate cysts from the five Siwalik sequences in Himachal Pradesh and Chandigarh, tracing their source in the Subathu Formation and interpreting a fluviatile environment for the deposition of these Siwalik sequences.

MATERIAL AND BRIEF GEOLOGY

The material for the present palynofloral investigation was collected from the Siwalik sequences exposed along the road between Kala Amb and Nahan and Kala Amb and Saketi in Sirmaur District of Himachal Pradesh (Map 1). The section exposes Upper Siwalik between Kala Amb and 6 km from Kala Amb where the uppermost part of Upper Siwalik, viz., Boulder Conglomerate is exposed. The Upper Siwalik consists of buff to rust coloured, fine to coarse grained sandstones with greyish siltstones and purple shales. The uppermost part of the Upper Siwalik is composed of massive boulder conglomerate beds alternated with grey and pinkish siltstones and coarse grained to gritty sandstone beds. The boulder conglomerate beds are composed of pebbles, cobbles and boulders ranging in size from few millimetres to 0.5 metre, embedded in a sandy matrix. 40 samples were collected from the Upper Siwalik (sample nos. 1-34 and 82-87). The Upper Siwaliks are overlain by Nahan (Lower Siwalik) at near 6 km from Kala Amb on Kala Amb-Nahan Road. The contact between the two is thrusted one (Markanda Thrust). The Nahan is composed of buff, compact, fine grained, massive, occasionally micaceous sandstone with subordinate purplish-grey siltstone and ferruginous, reddish to rust coloured shales. Fifteen samples (sample nos. 35-49) were collected from the Nahan sediments. Besides, 32 rock samples (sample nos. 50-81) were collected from the Kala Amb-Saketi Road cutting section exposing the Upper Siwaliks. Altogether, 87 samples from this area were collected, of which eleven samples proved to be palynologically



Map 1—Geological map of Kala Amb-Nahan area, Sirmaur District (Himachal Pradesh) showing the area of present study.

productive. The details of the samples, as to their lithology, location and productivity, are given in Table 1.

PALYNOFLORAL ASSEMBLAGE

Check-list of the Palynoflora

Lower Siwalik (Nahan)—Cyathidites minor Couper, *Intrapunctisporis, apunctis,* Krutzsch, *Monolites* sp., *Quadrangulosaccites himachalensis* Saxena & Singh, *Laricoidites magnus* (Potonié) Potonié *et al.*, *Inaperturopollenites punctatus* (Saxena) comb. nov., *I. ellipticus* sp. nov., *Inaperturopollenites* sp., *Araucariacites australis* Cookson, *Liliacidites major* Saxena, Monosulcate palynomorph-1, *Myricipites* sp., Polyporate palynomorphs 1 and 2, *Inapertisporites kedvesii* Elsik, *I. udarii* Gupta, *Staphlosporonites siwalikus* sp. nov., *Staphlosporonites* sp., *Polycellaesporonites bellus* Chandra *et al.*, *Spinasphaera robusta* Kar & Saxena.

Upper Siwalik—Pinuspollenites siwalikus Singh & Saxena, *Quadrangulosaccites himachalensis* Saxena & Singh, *Laricoidites magnus* (Potonié) Potonié *et al.*, *Inaperturopollenites punctatus* (Saxena) comb. nov., *I ellipticus* sp. nov., *Spinainaperturites* sp., Inaperturate palynomorph, *Palmidites* sp., *Pinjoriapollis magnus* Saxena & Singh, *P. lanceolatus* Saxena & Singh. *Pinjoriapollis* sp., Monosulcate palynomorph-2, *Monoporopollenites* sp., *Inapertisporites kedvesii* Elsik, *I. maximus* Singh & Saxena, *Staphlosporonites siwalikus* sp nov., and *Polycellaesporonites bellus* Chandra *et al.*

DESCRIPTION

Genus—*Monolites* Cookson, 1947 ex Potonié, 1956

Monolites sp.

Pl. 1, fig. 1

Description—Spore subcircular; size 52 × 48 μm; monolete; exine up to 1 μm thick, laevigate.

Genus—*Laricoidites* Potonié *et al.*, 1950 ex Potonié, 1958

Remarks—Since *L. magnus* (Potonié) Potonie *et al.* (1950), the type species of *Laricoidites*, has laevigate exine, it is recommended to retain this genus only for laevigate, inaperturate pollen grains.

Genus—*Inaperturopollenites* Pflug & Thomson in Thomson & Pflug, 1953 emended

Remarks—Pflug and Thomson in Thomson and Pflug (1953, p. 64) proposed this genus to accommodate

Table 1—Details of samples collected with their location, lithology and spore/pollen productivity

*Sample Number**	*Spore/pollen occurrence*	*Lithology*	*Locality*	*Rock Unit*
1-2	Unproductive	Pinkish Clay	Near Kala Amb Bus-stop	
3-4	„	Purple shale	1 km from Kala Amb near Terpentine factory	
5	Productive	„	1.1 km from Kala Amb	
6	Unproductive	„	„	
7-10	„	„	2.1 km from Kala Amb	
11-13	„	„	2.5 km from Kala Amb	
14-21	Unproductive	Purple shale in grey sandstone	3 km from Kala Amb	
22	Productive	„	„	
23-30	Unproductive	„	4 km from Kala Amb	
31	Productive	„	„	
32-34	Unproductive	„	5.75 km from Kala Amb	
82-84	„	Siltstones	6 km from Kala Amb	
85	Productive	„	„	
86-87	Unproductive	„	„	Upper
50-59	„	Purple shales	0.4-1.1 km from Kala Amb	Siwalik
60	Productive	„	„	
61-78	Unproductive	„	„	
79-80	Productive	„	„	
81	Unproductive	„	„	
		Markanda Thrust		
35	Productive	Reddish-rust coloured shales	1.6 km from Sainwala	
36-37	„	„	1.2 km from Sainwala	
38-41	Unproductive	„	0.2 km from Sainwala	
42-43	„	„	9 km from Kala Amb	
44-46	„	„	12.6 km from Kala Amb	Lower
47	Productive	„	„	Siwalik
48-49	Unproductive	„	„	(Nahan)

*Sample nos. 50-81 were collected from Kala Amb-Saketi Road Section and all other samples from Kala Amb-Nahan Road Section. Samples are not arranged in stratigraphic sequence.

"Pollen grains without or with indistinct germinal apparatus, original shape, spherical with a symmetry plane through the equator, sometimes tending to bilateral symmetry or lenticular, exine not cavate (no sacci or similar inflated structure)". Potonié (1958, pp. 77-78) emended the diagnosis as "equator circular, exine thin, infrapunctate, with many secondary folds, smaller, thinner and more strongly punctate exine than in *Laricoidites*".

Since, *Inaperturopollenites dubius* (Potonié & Venitz) Pflug & Thomson in Thomson & Pflug (1953), the type species of the genus, is infrapunctate (Thomson & Pflug, 1953, p. 65), Potonié's (1958), emended diagnosis seems to be more justified. However, much variations in shape and size have been observed by us in the grains of this genus. It is also recommended that this genus should be restricted only for punctate-infrapunctate, inaperturate pollen grains, and laevigate forms not to be included under it. The diagnosis of the genus is therefore emended as follows:

Emended diagnosis—Pollen grains highly variable in shape from circular to subcircular, oval, elliptical and of other irregular shapes. Size variable from small to large, inaperturate. Exine punctate-infrapunctate, irregularly folded.

Comparison—*Inaperturopollenites* closely resembles *Laricoidites* in shape, size and in having no aperture but can be distinguished by its punctate-infrapunctate exine while the latter is laevigate.

Inaperturopollenites punctatus (Saxena, 1979) comb. nov.

Pl. 1, figs 2, 3

Basionym—*Laricoidites punctatus* Saxena, 1979, *Palaeobotanist* **26**(2) : 131, pl. 1, fig. 2

Holotype—*Laricoidites punctatus* Saxena, 1979, pl. 1, fig. 2.

Description—Pollen grains circular-subcircular to oval, size range 68-84 × 54-72 μm, inaperturate. Exine 0.5 to 1.5 μm thick, infrapunctate.

Remarks—Since *Laricoidites* has been retained here only for laevigate-inaperturate grains, *L. punctatus* Saxena (1979) is transferred to *Inaperturopollenites*.

Inaperturopollenites ellipticus sp. nov.

Pl. 1, figs 4, 5

Holotype—Pl. 1, fig. 4, size 110 × 56
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Inaperturopollenites ellipticus sp. nov.

Pl. 1, figs 4, 5

Holotype—Pl. 1, fig. 4, size 110 × 56 μm; B.S.I.P. slide no. 8528, coordinates 7 × 100.

Type Locality—3 kilometre stone, Kala Amb-Nahan Road, Sirmaur District, Himachal Pradesh; Upper Siwalik.

Diagnosis—Pollen grains elliptical in shape, size range 82-135 × 42-76 μm, inaperturate. Exine up to 2 μm thick, infrapunctate, puncta closely and evenly distributed, exine sometimes folded.

PLATE 1

→

(All the photomicrographs are enlarged ca × 500. The coordinates of the specimens refer to the stage of Olympus Microscope no. 205838)

1. *Monolites* sp.; Slide no. B.S.I.P. 8521, coordinates 8 × 92.4.
2, 3. *Inaperturopollenites punctatus* (Saxena) comb. nov.; Slide no. B.S.I.P. 8526, coordinates 8.3 × 104.6; Slide no. B.S.I.P. 8527, coordinates 6 × 103.4.
4, 5. *Inaperturopollenites ellipticus* sp nov. : Slide no. B.S.I.P. 8528, coordinates 7 × 100 (Holotype), Slide no. B.S.I.P. 8528, Coordinates 11 × 93.
6. *Spinainaperturites* sp., Slide no. B.S.I.P. 8530, coordinates 3.7 × 78.3.
7. Monosulcate palynomorph-2; Slide no. B.S.I.P. 8533, coordinates 3.2 × 94 7.
8. *Pinjoriapollis magnus* Saxena & Singh; Slide no. B.S.I.P. 8531, coordinates 10 × 103.5
9. Polyporate palynomorph-1; Slide no. B.S.I.P. 8522, coordinates 7 × 115.5.
10. *Monoporopollenites* sp.; Slide no. B.S.I.P. 8532, coordinates 11.4 × 100.
11. *Palmidites* sp.; Slide no. B.S.I.P. 8528, coordinates 3 × 105.
12, 14. *Staphlosporonites siwalikus* sp. nov.; Slide no. B.S.I.P. 8536, coordinates 13 × 92.6 (Holotype); Slide no. B.S.I.P. 8538, coordinates 9 × 108.
13. Polyporate palynomorph-2; Slide no. B.S.I.P. 8535, coordinates 3.5 × 93.
15. *Inaperturopollenites* sp.; Slide no. B.S.I.P. 8529, coordinates 4 × 83.
16. *Pinjoriapollis* sp.; Slide no. B.S.I.P. 8532, coordinates 15.5 × 106.4.
17. *Myricipites* sp.; Slide no. B.S.I.P. 8534, coordinates 13.3 × 103.
18. *Staphlosporonites* sp.; Slide no. B.S.I.P. 8534, coordinates 9 × 108.
19. Inaperturate palynomorph; Slide no. B.S.I.P. 8528, coordinates 8 × 91.
20. Monosulcate palynomorph-1; Slide no. B.S.I.P. 8522, coordinates 16.3 × 107.8.


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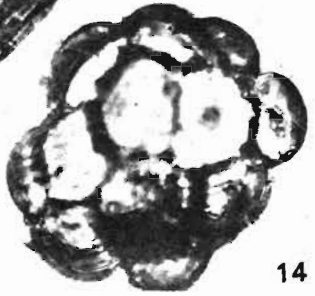
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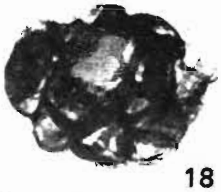
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PLATE 1

Comparison—The present species can easily be distinguished from *I. dubius* by its bigger size and elliptical shape. *I. ruptus* Potonié & Sah (1960) differs from the present species in being smaller in size. *I. punctatus* (Saxena, 1979) comb. nov. is circular-oval in shape.

Inaperturopollenites sp.

Pl. 1, fig. 15

Description—Pollen grain subcircular, size 66 × 63 μm, inaperturate. Exine 1.5 μm thick, faintly infrapunctate, many irregularly developed ridges present over the surface forming a coarse reticulum, some ridges prominent while others thin and incomplete.

Comparison—The present species differs from the other species by its irregularly developed ridges forming coarse reticulum.

Genus—*Spinainaperturites* Pierce, 1961

Spinainaperturites sp.

Pl. 1, fig. 6

Description—Pollen grain oval, size 68 × 53 μm, inaperturate. Exine up to 1 μm thick, ornamented with sparsely placed and irregularly distributed conate spinules.

Comparison—The present species differs from *S. magnificus* Ramanujam (1966) and *S. scabratus* Mathur (1966) in having sparsely placed and irregularly distributed conate spinules.

Inaperturate palynomorph

Pl. 1, fig. 19

Description—Elliptical palynomorphs, size 152 × 62 μm. No aperture visible, but a strong fold throughout the length of the longer axis present, suggesting the presence of a sulcus. Exine laevigate.

Genus—*Palmidites* Couper, 1953

Palmidites sp.

Pl. 1, fig. 11

Description—Pollen grain oval-elliptical in shape, size 88 × 53 μm. Monosulcate, sulcus not clearly discernible. Exine up to 1 μm thick, laevigate.

Genus—*Pinjoriapollis* Saxena & Singh, 1981

Pinjoriapollis sp.

Pl. 1, fig. 16

Description—Pollen grain elliptical, size 124 × 63 μm. Monosulcate. Exine 1 μm thick, infrapunctate.

Comparison—the present specimen differs from *P. magnus* and *P. lanceolatus* both described by Saxena and Singh (1981) in having infrapunctate exine.

Monosulcate palynomorph 1

Pl. 1, fig. 20

Description—Irregularly oval palynomorph, size 156 × 115 μm. Monosulcate, sulcus ± triangular in shape. Exine hyaline, laevigate.

Monosulcate palynomorph 2

Pl. 1, fig. 7

Description—Circular-oval palynomorphs, size range 62-77 × 52-62 μm. Monosulcate, sulcus wide, oval, conforming to the pollen margin. Exine up to 1.5 μm, psilate to weakly infrapunctate.

Genus—*Monoporopollenites* Meyer, 1956 emend. Potonié, 1960

Monoporopollenites sp.

Pl. 1, fig. 10

Description—Pollen grains circular to elliptical in shape, size range 66-140 × 60-62 μm. Monoporate, pore circular to oval, 11-28 × 9-11 μm. Exine laevigate.

Genus—*Myricipites* Wodehouse, 1933

Myricipites sp.

Pl. 1, fig. 17

Description—Pollen grain triangular, size 35 × 32 μm. Triorate, angulaperturate, interoral margin straight to ± convex. Exine 1.0 μm thick, granulose, grana closely placed and evenly distributed.

Comparison—The present specimen resembles *M. vulgaris* Dutta & Sah (1970) in having similar shape, size and exine ornamentation but in the latter ora are crassimarginate. *M. globatus* Kar & Saxena (1981) differs in having bigger size range (64-78 × 56-70 μm) and subcircular shape.

Polyporate palynomorph 1

Pl. 1, fig. 9

Description—Oval palynomorph, size 35 × 23 μm. Polyporate, pores 4 (or 5), equatorially placed. Exine 0.5 μm thick, laevigate.

Polyporate palynomorph 2

Pl. 1, fig. 13

Description—Subcircular palynomorph, size 54 × 47 μm. Polyporate, pores numerous, sparsely placed, periporate. Exine up to 1 μm thick, infrapunctate.

Remarks—The present specimen resembles the pollen grains of Chenopodiaceae/Amaranthaceae.

Genus—*Inapertisporites* van der Hammen, 1954 ex Rouse, 1959 emended

Remarks—Van der Hammen (1954) proposed this genus for reference to various inaperturate spores found in the Cretaceous and Tertiary sediments of Colombia without providing the generic diagnosis or type species. As such this genus remained invalid. Rouse (1959, p. 312) conserved this genus for inaperturate algal, fungal and possibly bryophytic spores and validated it by providing a generic diagnosis and nominating *I. pseudoreticulatus* Rouse (1959, pl. 2, figs 16-17) as its type species. Elsik (1968, p. 268) emended the generic diagnosis and restricted this genus only for inaperturate, psilate, unicellate and variable shaped fungal spores. Sheffy and Dilcher (1971, p. 27) again emended the diagnosis to include both algal and fungal spores of varied ornamentation. Sheffy and Dilcher (1971) stated the shape as 'globular or subglobular' and size range as 5-11 μm, which is not correct for most of the species of this genus. In the present emended diagnosis size and shape are therefore given as 'variable'.

Emended Generic Diagnosis—Inaperturate algal or fungal spores, unicellate, nonseptate. Shape and size variable, outline smooth or often uneven because of wrinkles or folds. Spore well ornamentation variable.

Genus—*Staphlosporonites* Sheffy & Dilcher, 1971

Staphlosporonites siwalikus sp. nov.

Pl. 1, figs 12, 14

Holotype—Pl. 1, fig. 12, size 61 × 52 μm; B.S.I.P. slide no. 8536, coordinates 13 × 92.6.

Type Locality—0.6 km from Kala Amb, Kala Amb-Saketi Road, Sirmaur District, Himachal Pradesh; Upper Siwalik.

Diagnosis—Fungal spores subcircular in shape, size range 61-77 × 52-70 μm. Multicellate, septa very thick, thicker than spore wall, individual cells circular-polygonal, small in size. Spore wall psilate.

Staphlosporonites sp.

Pl. 1, fig. 18

Description—Fungal spore subcircular to irregular in shape. Size 45-77 × 35-70 μm. Multicellate, cells irregularly arranged and vary in size, inaperturate. Spore wall dark brown in colour, psilate.

DISCUSSION

The palynofloral assemblage described here from the Lower Siwalik (Nahan) and Upper Siwalik sediments of Kala Amb-Nahan area in Sirmaur District, Himachal Pradesh, consists of 18 genera and 25 species of palynomorphs. These include fungal remains, pteridophytic spores, gymnospermous and angiospermous pollen grains and palynomorphs of uncertain affinity. Two new species and one new combination have been proposed. The number of palynomorphs per sample being very low, both in case of Lower and Upper Siwaliks, the quantitative analysis has been made on the basis of composite assemblages recovered from all the samples of Lower and Upper Siwaliks respectively. An analysis of the palynoflora is discussed ahead.

Lower Siwalik (Nahan) Assemblage

From the Lower Siwalik (Nahan) sediments a total of 15 samples were collected, of which only four samples yielded palynofossils. The assemblage consists of 13 genera and 17 species. Of these, three genera and five species are of fungal spores, three genera and three species of pteridophytic spores, four genera and six species of gymnospermous pollen, two genera and two species of angiospermous pollen and one genus and one species of uncertain affinity. The fungal spores constitute about 13 per cent of the assemblage, being represented by *Staphlosporonites, Inapertisporites* and *Polycellaesporonites.* The pteridophytic spores are comparatively poorly represented (5%) and may be related to Cyatheaceae and Polypodiaceae. The gymnospermous pollen grains showing affinity with the family Pinaceae constitute the bulk of the assemblage (73.5%). Amongst the gymnospermous pollen alone, inaperturate pollen share 96% (*Laricoidites* 46%; *Inaperturopollenites* 46% and *Araucariacites* 4%). The rest of the gymnospermous pollen are represented by bisaccate pollen grains. The angiospermous pollen grains are also insignificantly represented (8.5%) and have been assigned to Liliaceae and Myricaceae.

Upper Siwalik Assemblage

For the palynofloral investigation of the Upper Siwalik of this area, a total of 71 samples were collected, but only seven of them proved to be productive. The assemblage recorded from these samples consists of 11 genera and 15 species. The assemblage is represented by three genera and four species of fungal spores, four genera and five species of gymnospermous pollen grains and four genera and six species of angiospermous pollen grains. The fungal spores of this assemblage are qualitatively similar to those of the Lower Siwalik and constitute 14 per cent of the assemblage, being represented by *Inapertisporites, Staphlosporonites* and *Polycellaesporonites.* The assemblage is devoid of any positive evidence of bryophytic or pteridophytic spores. The gymnospermous pollen grains are comparatively less represented (67%) than those in the Lower Siwalik assemblage. The gymnospermous pollen are represented mainly by the inaperturate pollen grains (*Laricoidites* 28% and *Inaperturopollenites* 68%) while bisaccate pollen of *Quadrangulosaccites* share only 4%. All the gymnospermous pollen show affinity with Pinaceae. The angiospermous pollen are referable to Potamogetonaceae, Palmae, Poaceae and Magnoliaceae and share about 19 per cent of the assemblage.

PALYNOFLORAL COMPARISON

Lower Siwalik (Nahan)—The Lower Siwalik palynoassemblages have been described by Banerjee (1968), Venkatachala (1972), Mathur (1973), Nandi (1975), Ghosh (1977) and Saxena *et al.* (1984). Banerjee (1968) recovered pteridophytic spores belonging to Gleicheniaceae and Polypodiaceae, gymnospermous pollen of *Pinus* spp., *Disaccites* sp. and inaperturate types and angiospermous pollen of Compositae, Gramineae, Palmae, tricolpate, tetracolpate and polycolpate types from the Lower Siwalik sediments of Bhakra-Nangal area. This palynoflora compares with the present assemblage in common occurrence of monolete spores and inaperturate and bisaccate pollen grains. However, the present palynoflora is conspicuous in having poorly represented pteridophytic spores and bisaccate pollen grains, poor and less diversified angiospermous pollen grains and very high representation of inaperturate pollen and fungal spores. Venkatachala (1972) mentioned the occurrence of Palmae and Gramineae pollen and *Quercoidites, Haloragacidites, Cupuliferoipollenites, Sapotaceoidaepollenites* and *Araceoipollenites.* None of these taxa has been recorded in the present palynoflora. Mathur (1973) described a rich palynoflora consisting of 13 genera and 17 species from the Lower Siwalik sediments of Tharukhola-Chepang, northeast of Nepalgunge, Nepal. It has been observed that none of the species of this palynoflora is common to the present assemblage. In the Tharukhola-Chepang assemblage, angiospermous pollen grains are dominant followed by pteridophytic spores and gymnospermous pollen grains whereas the present assemblage is dominated by gymnospermous pollen grains and fungal spores with sporadic representation of pteridophytic spores and angiospermous pollen grains. Nandi (1975) and Ghosh (1977) mentioned the occurrence of 27 palynogenera in the Lower Siwalik of Jawalamukhi area of Himachal Pradesh. Of these, only *Cyathidites, Polypodiaceaesporites* (± = *Monolites*) and *Pinuspollenites* (± = *Quadrangulosaccites*) are common to the present assemblage. The Jawalamukhi assemblage is rich in pteridophytic spores and angiospermous pollen grains whereas the present assemblage is rich in fungal spores and gymnospermous pollen with subordinate representation of pteridophytic spores and angiospermous pollen grains. Saxena *et al.* (1984) recorded 23 genera and 28 species of palynomorphs from the Lower Siwalik of Bhakra-Nangal area of Himachal Pradesh. Of these, only five genera are common to the present Lower Siwalik assemblage. Quantitatively the two assemblages are comparable in the frequency of fungal remains and pteridophytic spores whereas inaperturate gymnospermous pollen dominate in the present assemblage in contrast to the angiospermous pollen in the Bhakra-Nangal assemblage.

Upper Siwalik—The Upper Siwalik palynofossils have so far been recorded by Singh *et al.* (1973), Nandi (1975), Ghosh (1977), Singh and Saxena (1980, 1981), Saxena and Singh (1980, 1982a, 1982b) and Saxena *et al.* (1984). Singh *et al* (1973) reported the occurrence of *Pinus* type, monosulcate type and inaperturate (nonsaccate) pollen grain. All these types have also been recorded from the present Upper Siwalik assemblage. Nandi (1975) and Ghosh (1977) recorded *Cyathidites, Alsophilidites, Leptolepidites, Pinuspollenites, Podocarpidites, Monoporopollenites, Alnipollenites* and *Tetradomonoporites* from the Upper Siwalik sediments of Jawalamukhi area of Himachal Pradesh. Of these, only *Pinuspollenites* and *Monoporopollenites* are common to both the assemblages. The present assemblage differs from Jawalamukhi assemblage in total absence of pteridophytic spores and rich representation of inaperturate pollen and fungal remains. Singh and Saxena (1980, 1981) recorded Upper Siwalik assemblage from Gagret-Bharwain Section in Una district of Himachal Pradesh. This assemblage largely compares with the present assemblage in common occurrence of *Pinuspollenites, Laricoidites, Monoporopollenites* (± = *Graminidites*) and *Inapertisporites.* A group-wise comparison of the two assemblages is given in Table 2.

Table 2—Group-wise comparison of the present Upper Siwalik assemblage with the Gagret-Bharwain Section assemblage of Una District, Himachal Pradesh

Group / *Assemblage*	*Upper Siwalik of Gagret-Bharwain Road Section, Himachal Pradesh (Singh & Saxena, 1981)*	*Upper Siwalik of Kala Amb-Nahan Road Section, Himachal Pradesh*
Fungal remains	28	14
Gymnospermous pollen	65	67
Angiospermous pollen	7	19
Reworked palynomorphs	Present	Absent

Saxena and Singh (1982a) reported Pinjor (Upper Siwalik) palynoflora from near Chandigarh. The present assemblage very much resembles this assemblage in common representation of *Pinuspollenites, Laricoidites-Inaperturopollenites, Palmidites, Pinjoriapollis, Monoporopollenites* (± = *Graminidites*) and *Inapertisporites.* Saxena and Singh (1982b) recorded Upper Siwalik palynoflora from the Hoshiarpur-Una Road Section in Punjab and Himachal Pradesh and established two informal zones. The present assemblage compares with the Assemblage-1 of the above section in the high frequency of inaperturate pollen grains and fungal remains. Saxena *et al.* (1984) recorded seven genera and nine species of palynomorphs from the Upper Siwalik of

Bhakra-Nangal Section in Himachal Pradesh. Of these, *Inapertisporites, Pinuspollenites* and *Graminidites* (± = *Monoporopollenites*) are also found in the present assemblage.

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Palynological study of Sutunga coal seam, Jaintia Hills, Meghalaya

J. Mandal

Mandal, J. (1987). Palynological study of Sutunga coal seam, Jaintia Hills, Meghalaya. *Palaeobotanist* **35** (2) : 196-199.

Palynological fossils recovered from Sutunga Colliery, Jaintia Hills, Meghalaya consist of 27 genera and 39 species. Pteridophytic spores and angiospermic pollen are more or less equally represented in the assemblage. The dominant species are: *Lycopodiumsporites parvireticulatus, Cyathidites minor, Lygodiumsporites lakiensis, Todisporites kutchensis, Proxapertites microreticulatus, Couperipollis brevispinosus* and *Tricolpites minutus.* A Palaeocene age is attributed to this assemblage.

Key-words—Palynology, Pteridophytes, Angiosperms, Sutunga Coal seam, Palaeocene (India).

J. Mandal, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

मेघालय की जयन्तिया पहाड़ियों में स्थित सुतुंगा कोयला-सीम का परागाणविक अध्ययन

जगन्नाथ प्रसाद मंडल

मेघालय की जयन्तिया पहाड़ियों में स्थित सुतुंगा कोयला-खान से उपलब्ध परागाणविक समुच्चय मंडल में 27 प्रजातियाँ एवं 39 जातियाँ हैं। टेरीडोफ़ाइटी बीजाणु एवं आवृतबीजी परागकण प्रायः समान मात्रा में मिलते हैं। लाइकोपोडियमस्पोराइटिस पार्विरेटिकुलेटस, स्याथिडाइटिस माइनर, लाइगोडियमस्पोराइटिस लाकीयेन्सिस, टोडिस्पोराइटिस कच्छेन्सिस, प्रोक्सापर्टाइटिस माइक्रोरेटिकुलेटस, काउपेरिपॉलिस ब्रेविस्पाइनोसस एवं ट्राइकॉल्पाइटिस माइन्यूटस प्रभावी जातियाँ हैं। इस समुच्चय की पुरानूतन आयु प्रस्तावित की गई है।

SOME of the Tertiary sedimentary deposits of Assam and Meghalaya have rich coal deposits. The coal comprises high sulphur content and is well known for its physiochemical properties. The coalfields of Khasi, Jaintia and Garo Hills are known to be formed along the southern fringe of Shillong Plateau on platform areas under stable shelf condition. In Jaintia Hills, a number of small coal bearing outliers are formed within the Lakadong Sandstone Member (Member of Sylhet Limestone Formation) and this coal is superior in rank to any other Tertiary coals of north-east India (Raja Rao, 1981).

Palynology of Palaeocene-Lower Eocene rocks of north-east India has been worked out by Biswas (1962), Baksi (1962), Sah and Dutta (1966), Dutta and Sah (1970), Salujha, Kindra and Rehman (1972), Singh (1977), Mehrotra (1983), etc. The present paper describes the results of palynological investigation of a coalfield situated on the left side of Jowai-Klheriaht Road (National Highway no. 44) near the village Sutunga. The coal seams extend over an area of one square kilometer, well exposed towards east and north of the village. Of the two coal seams, the top one varies from 0.1 to 0.2 m while the bottom one ranges from 0.3 to 1.07 m in thickness. In all, 30 samples were collected and macerated.

The assemblage comprises following 27 genera and 39 species:

Lycopodiumsporites parvireticulatus Sah & Dutta
L. umstewensis Dutta & Sah
L. palaeocenicus Sah & Dutta
Cyathidites minor Couper
Lygodiumsporites lakiensis Sah & Kar
Biretisporites bellus Sah & Kar
Intrapunctisporis apunctis Krutzsch
Dandotiaspora dilata (Mathur) Sah, Kar & Singh
D. telonata Sah, Kar & Singh
Todisporites kutchensis Sah & Kar
Schizaeoisporites phaseolus Delcourt & Sprumont
S. crassimurus Dutta & Sah
Polypodiisporites mawkmaensis Dutta & Sah
Laevigatosporites lakiensis Sah & Kar
Polypodiaceaesporites levis Sah

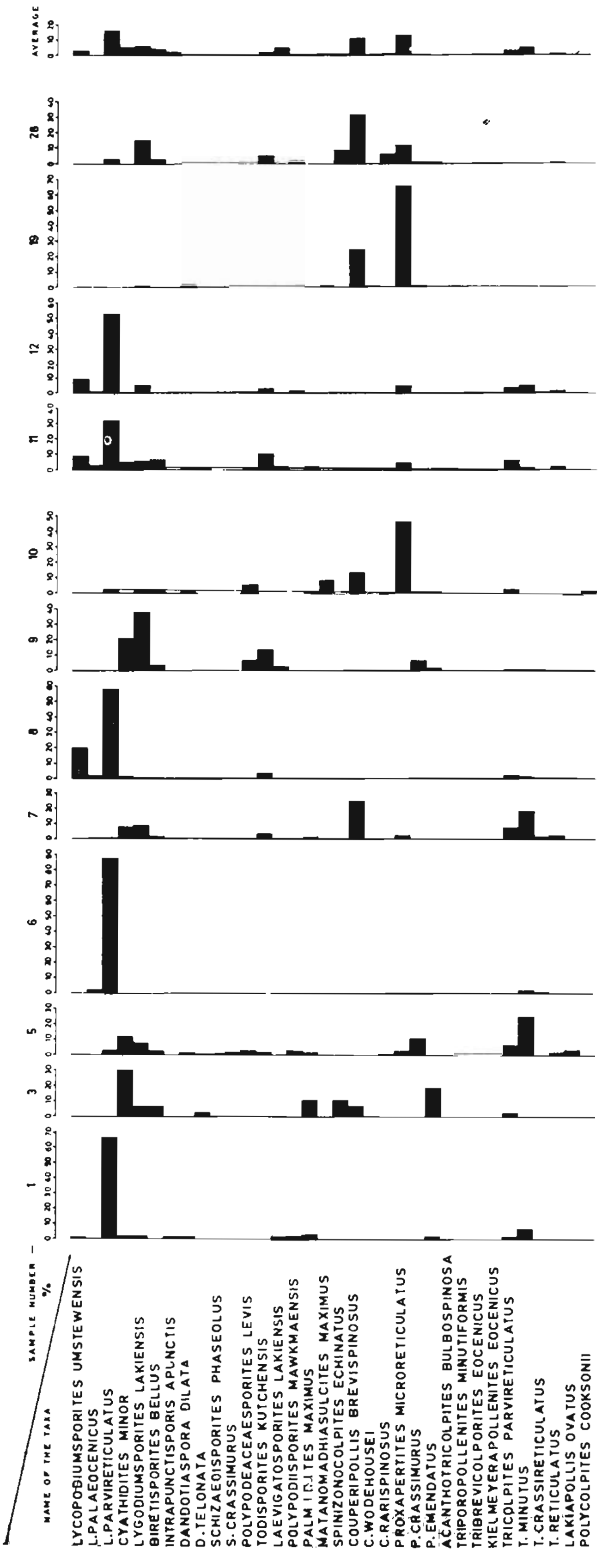
Palmidites maximus Couper
Matanomadhiasulcites maximus (Saxena) Kar
Spinizonocolpites echinatus Muller
Couperipollis brevispinosus (Biswas) Venkatachala & Kar
C. rarispinosus (Sah & Dutta) Venkatachala & Kar
C. wodehousei (Biswas) Venkatachala & Kar
Proxapertites microreticulatus Jain, Kar & Sah
P. emendatus (Singh) Kar & Kumar
P. crassimurus (Sah & Dutta) Jain, Kar & Sah
Acanthotricolpites bulbospinosa Kar
Triporopollenites minutiformis (Ramanujam) Saxena
Triorites bellus Sah & Kar
Polyadopollenites sp.
Tricolpites parvireticulatus Sah
T. minutus Sah & Kar
T. crassireticulatus Dutta & Sah
T. reticulatus Cookson
Lakiapollis ovatus Venkatachala & Kar
L. matanamadhensis Venkatachala & Kar
Kielmeyerapollenites eocenicus Sah & Kar
Retitrescolpites splendens Sah
Rhoipites kutchensis Venkatachala & Kar
Tribrevicolporites eocenicus Kar
Polycolpites cooksonii Sah & Dutta

GENERAL ASSESSMENT OF THE ASSEMBLAGE

The assemblage consists of 16 species and 11 genera of pteridophytes and 16 genera containing 23 species of angiospermic pollen. In the assemblage, both pteridophytic and angiospermic grains show more or less equal dominance. Gymnospermous grain and microplanktons are totally absent. The result of the qualitative analysis has been plotted in the Histogram 1.

The monolete is represented by four taxa, i.e. *Polypodiisporites, Polypodeaceaesporites, Laevigatosporites* and *Schizaeoisporites*. The significant trilete spores in the assemblage are *Lycopodiumsporites parvireticulatus* (16.3%), *L. umstewensis* (2.5%), *L. palaeocenicus* (1.7%), *Lygodiumsporites lakiensis* (9.8%), *Cyathidites minor* (6.3%), *Biretisporites bellus* (2.1%) and *Todisporites kutchensis* (4.6%); *Lycopodiumsporites* complex has the highest representation.

The angiospermic grains, on the other hand, are strongly dominated by sulcate grains represented by 9 species belonging to 5 genera. Other representative of non-sulcate forms are colpate (3 genera and 9 species), colporate (5 genera and 5 species), porate (2 genera and 2 species) and polycolpate by single taxa, viz., *Polycolpites cooksonii*. However, colporate, porate and polycolpate grains are poor in number and variety. The total percentage count of the pollen grains are *Palmidites maximus* (1.1%), *Proxapertites microreticulatus* (13%), *P. crassimurus* (1.7%), *P. emendatus* (2%),



Histogram 1—Histogram showing the pattern of miofloral behaviour in different samples.

Spinizonocolpites echinatus (1.7%), *Couperipollis brevispinosus* (10.6%), *C. rarispinosus* (1%), *Tricolpites reticulatus* (1%), *T. parvireticulatus* (2.6%) and *T. minutus* (4.6%), However, *Lycopodiumsporites*, *Proxapertites* and *Couperipollis* individually records up to 65 per cent in the samples.

DISCUSSION

The qualitative analysis shows that the assemblage is significantly represented by *Lycopodiumsporites parvireticulatus, Cyathidites minor, Lygodiumsporites lakiensis, Todisporites kutchensis* amongst the pteridophytes and *Proxapertites microreticulatus, Couperipollis brevispinosus* and *Tricolpites minutus* of angiospermous affinity.

It is observed that the pteridophytic spores are more dominant in the lower seam than the upper one. However, the behaviour of the pollen is just reverse of the spores. They increase gradually from base and dominate at the upper coal seam.

Comparison—Palynostratigraphic correlation of Lakadong Sandstone sequence with the Therria (=Cherra), Tura and Mikir formations has been discussed by Sah and Kar (1972), Sah and Singh (1974), Mehrotra (1981) and Sah and Dutta (1974). Sah and Dutta (1974) established three biozones in the Therria (=Cherra) Formation and also recorded significant break in between the assemblage of uppermost Cherra biozone (*Tricolpites reticulatus* Cenozone) and overlying assemblage of Lakadong Sandstone. The cenozones of Cherra and Lakadong in ascending order are *Proxapertites crassimurus* Cenozone, *Tricolpites reticulatus* Cenozone and Lakadong palynological zone.

Principal constituents of the Lakadong palynological zone are: *Retialetes dubius, Dandotiaspora* spp., *Couperipollis brevispinosus, C. rarispinosus, Palmaepollenites communis, P. eocenicus, Polycolpites cooksonii, Triorites communis, Cyathidites minor* and some microplanktons. Sutunga assemblage differs from the Cherra Cenozone described by Sah and Dutta (1966) in the total absence of microplankton and by equal dominance of pteridophytic spore and angiospermous pollen. The Lakadong Sandstone assemblage has angiospermous dominance over the pteridophytic remains. Another point of difference is the poor representation of *Dandotiaspora* spp. which has been replaced by *Lycopodiumsporites* in Sutunga.

Tura Formation—Sah and Singh (1974) distinguished four biozones in the Tura Formation of Garo Hills. They equated Cherra biozones with *Assamialetes emendatus* Cenozone, *Dandotiaspora telonata* Cenozone and *Palmidites plicatus* Cenozone respectively in ascending order, the basal three assemblage zones of Tura Formation. However, the uppermost biozone—*Proxapertites assamicus* Cenozone of Tura is characterised by *Proxapertites assamicus, Cicatricosisporites macrocostatus, Stephanocolpites tertiarus, Meliapollis ramanujamii, Polypodiisporites oligocenicus, Foveotriletes palaeocenicus, Palmidites plicatus, Liliacidites major* and *Lycopodiumsporites palaeocenicus*. A comparison with the present assemblage reveals that some of the marker species of Tura are present in Sutunga in insignificant percentage.

Mikir Formation—Palynoflora of the Mikir Formation which is the lateral equivalent of Therria (=Cherra) Formation in the Mikir and North Cachar Hills has been studied by Mehrotra (1981, 1983) and Mehrotra and Sah (1982). They have established five cenozones in Mikir Formation, which in the ascending order are *Assamialetes macroluminus* Cenozone, *Dandotiaspora dilata* Cenozone, *Palmidites plicatus* Cenozone, *Foveotriletes palaeocenicus* Cenozone and *Palmaepollenites eocenicus* Cenozone. The Sutunga assemblage compares well with the Mikir Formation in the presence of following common taxa: *Foveotriletes palaeocenicus, Dandotiaspora dilata, D. telonata, Assamiasporites tertiarus, Proxapertites assamicus, Palmidites plicatus, P. maximus, Lycopodiumsporites palaeocenicus* and *Polypodiisporites oligocenicus*. Gymnospermous pollen and dinoflagellates are absent in both the assemblages. The uppermost Mikir Cenozone, the *Palmaepollenites eocenicus* Cenozone, is characterised by *Palmaepollenites eocenicus, P. communis* and microplankton. These forms are totally absent in Sutunga.

Bengal Basin—Baksi (1972) proposed seven palynological cenozones as Bengal Palynological Zones (I-VII) for the Upper Cretaceous—Tertiary sequence. The Bengal palynological zone I ranges from Middle to Upper Cretaceous in age and characterised by frequent occurrence of non-aperturate grains (both tectate and non-tectate), pteridophytic grains particularly by *Lycopodiumsporites*, frequent occurrence of *Mulleripollis bolpurensis;* occurrence of *Spinizonocolpites* is rare and there is also definite occurrence of massulae of *Azolla*. Baksi (1972) noticed some similarity between the constituents of Palynological Zone-I with the Langpar Formation of South Shillong Front. The present assemblage does not closely resemble Palynological Zone I as the characteristic forms like *Mulleripollis* and *Aquilapollenites* are totally absent.

The upper assemblage zone of Baksi (1972) and Baksi and Deb (1981) is *Proxapertites operculatus* zone of Bengal Palynological Zone-II which is characterised by frequent to abundant occurrence of *Proxapertites*, restricted occurrence of probable Lycopodiales, *Granulatisporites, Leiotriletes, Proteacidites* and more frequent presence of *Spinizonocolpites baculatus* and other tricolpate and tricolporate grains. A comparison with the Sutunga assemblage shows that a few genera like *Proxapertites, Spinizonocolpites* and triletes are common but quantitatively they are distinct from one another.

Matanomadh Formation—In Kachchh Basin Matanomadh Formation represents the basal lithostratigraphic unit of the Tertiary succession. Palynology of this unit has been extensively worked out by Mathur (1966), Kar and Saxena (1976) and Saxena (1978, 1979). Sah and Singh (1977) mentioned four distinct biozones and those zones in the ascending order are: Barren Zone, *Dandotiaspora dilata* Cenozone, *Couperipollis brevispinosus* Cenozone and Sponge Zone respectively. However, comparison with the Sutunga assemblage indicates that Matanomadh assemblage is more rich in quality as well as in quantity.

A survey of the literature (Sah & Kar, 1972; Sah & Singh, 1974, 1977; Saxena, 1980; Mehrotra, 1981) shows that the miofloras of Therria (=Cherra) Formation of Khasi and Jaintia Hills, Tura Formation of Garo Hills, Mikir Formation of Mikir and North Cachar Hills and Matanomadh Formation of western India are homotaxial with minor differences probably due to local factor. Sah and Kar (1972) and Sah and Singh (1974, 1977) favoured Lower Eocene age for the coal bearing Lakadong Sandstone Member which overlies the marine Lakadong Limestone on the basis of palaeontological, palynological and geological evidences. However, Sah and Singh (1974) mentioned that the appearance of *Cicatricosisporites, Margocolporites, Stephanocolpites* and *Meliapollis* in Lakadong Sandstone zone is indicative of Lower Eocene age. But none of these forms are present in Sutunga assemblage. Rather the assemblage is characterised by *Lycopodiumsporites, Cyathidites, Lygodiumsporites, Dandotiaspora dilata, Todisporites, Couperipollis, Proxapertites, Palmidites, Tricolpites* and *Polycolpites*. The significant percentage of marker species like *Dandotiaspora dilata, Proxapertites, Triorites, Polycolpites* (with more than 5 colpi) and *Proteacidites* seems to characterise to be Palaeocene assemblage. The Sutunga assemblage compares closely with other known Palaeocene assemblages recovered from India. So it is obvious that this assemblage is also of Palaeocene in age. It may be mentioned here that Jain (1982) also dated Lakadong Limestone Member and Lakadong Sandstone Member as Palaeocene on the basis of dinoflagellate cysts.

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Bacteria from the Archaean Banded Iron-Formation of Kudremukh region, Dharwar Craton, South India

B. S. Venkatachala*, Mukund Sharma*, R. Srinivasan**, Manoj Shukla* & S. M. Naqvi**

Venkatachala, B. S., Sharma, Mukund, Srinivasan, R., Shukla, Manoj & Naqvi, S. M. (1987). Bacteria from the Archaean Banded Iron Formation of Kudremukh region, Dharwar Craton, South India. *Palaeobotanist* **35** (2) : 200-203.

Scanning electron microscopic study of the Archaean (> 2.6 Ga old) banded iron-formation of the Bababudan Group, Dharwar Supergroup reveals the presence of coccoid and rod-shaped bacteria in syngenetic pyrite grains of the Kudremukh iron-formation. These resemble sulphur reducing bacteria.

Key-words—Bacteria, Banded Iron-Formation, Dharwar Craton, Archaean (India).

**B. S. Venkatachala, Mukund Sharma & Manoj Shukla, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.*

***R. Srinivasan & S. M. Naqvi, National Geophysical Research Institute, Hyderabad 500 007, India.*

सारॉँश

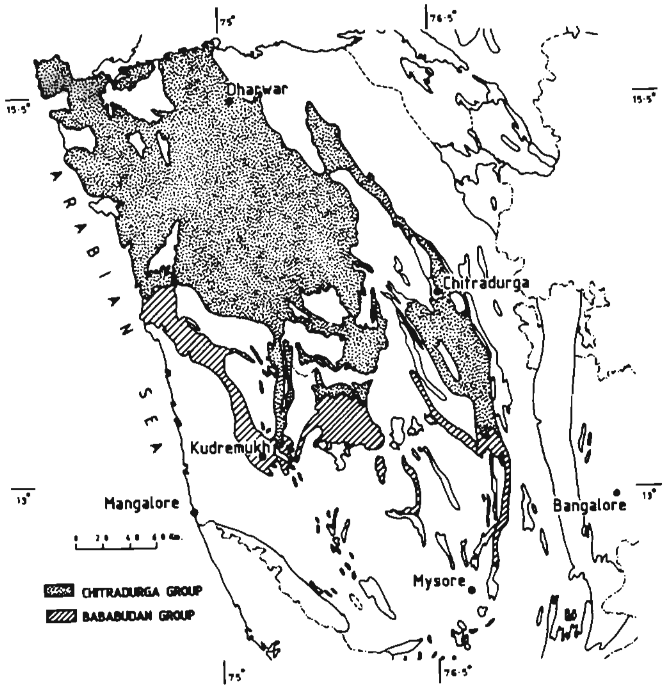
दक्षिण भारत में धारवाड़ क्रेटन के कुद्रेमुख क्षेत्र की आर्कियन युगीन पट्टित लौह शैलों से जीवाणु

बेंगलूर श्रीनिवासा वेंकटाचाला, मुकुन्द शर्मा, आर० श्रीनिवासन, मनोज शुक्ला एवं ऍस० ऍम० नक्वी

धारवाड़ महासमूह में बाबाबुदान समूह के आर्कियन (लगभग 2.6 जी.ए.) युगीन पट्टित शैलों के क्रमवीक्ष्ण सूक्ष्मदर्शीय अध्ययन से कुद्रेमुख लौह शैलों के सहजनित पाइराइट कणों में कोकॉयड एवं दंडाकार जीवाणु मिले हैं। ये जीवाणु गंधक अवकारक जीवाणुओं से सजातीयता व्यक्त करते हैं।

THERE has been intensive research in the area of Early Precambrian (Archaean) palaeobiology during the last two decades (see Schopf, 1975, 1983; Nagy *et al.*, 1983). These studies are oriented towards understanding of the antiquity of biological processes on the Earth and the influence they have had on the evolution of the unique atmospheric, hydrospheric and biospheric environment that characterises our planet. The iron-formations were dominantly deposited during the Precambrian. The magnitude on which they were deposited during the Precambrian has not repeated itself in the later part of Earth's history (James, 1983). The Precambrian iron-formations have been considered as large scale sinks for the oxygen evolved during the early part of the Earth's history (Cloud, 1973, 1976). Photosynthesis and photodissociation are considered to have contributed oxygen to the Earth's ecosystem. It has been known that some bacteria preferentially precipitate iron. In an effort to look for the influence of organic activity on the precipitation of iron, palaeobiologists have searched for organic signatures in the Precambrian banded iron formations (BIF) for over three decades which have yielded fruitful results (Tyler & Barghoorn, 1954; Schopf *et al.*, 1965; Walter & Hofmann, 1983).

Extensive deposition of iron took place during the Archaean in India (see James, 1983; Radhakrishna *et al.*, 1986). These rock formations are well-developed in the Archaean supracrustal belts of South India, where they are designated as Dharwar schist belts (Map 1). The Dharwar sequence has been classified by Swami Nath and Ramakrishnan (1981) into Lower Bababudan Group and Upper Chitradurga Group. Banded iron-formation occurs extensively at the top of the Bababudan Group. The iron-formation of the Bababudan Group is well developed in the Bababudan schist belt and in the Kudremukh-Kodachadri schist belt of the Western Ghat mountain ranges of South India. Deep drilling investigations have been carried out in the Kudremukh area in connection with prospecting for iron ore. Some of the drill cores from these bore-holes have not been affected by the post-Precambrian weathering processes. Examination of some of the unweathered cores have



Map 1—Showing the locality (After Swami Nath *et al*, 1981).

shown the presence of unoxidized pyrite grains within them. One such core from the bore-hole no. 6N/195 taken from a depth of about 63 m during the course of our investigations has disclosed the presence of coccoid and rod-shaped bacteria in pyrite grains.

The petrological work has been carried out by NGRI and the palaeobiological work by the Sahni Institute. Stubs containing the figured bacteria and hand specimens showing isoclinal fold are deposited in the Sahni Institute's repository.

GEOLOGICAL SETTING

The Kudremukh banded iron-formation belongs to the Bababudan Group of Dharwar Supergroup. Available geochronological data (Taylor *et al*, 1984) have substantiated that the Dharwar Supergroup is older than 2.6 Ga confirming their Archaean age. The Kudremukh iron-formation is intimately associated with metabasalts (amphibolites) whose age on the basis of Sm-Nd geochronology has been suggested to be 3.2 ± 0.23 Ga (Drury *et al*, 1983). The rock formations of the Dharwar craton have been metamorphosed under conditions varying from green schist to upper amphibolite facies. The last major episode of metamorphism which has affected the region is considered to be 2.6 Ga. In the Kudremukh region the grade of metamorphism falls in the almandine-amphibolite facies as indicated by the garnetiferous nature of the amphibolites, as well as, the development of cummingtonite, grunerite and magenesio-riebeckite in the iron-formation.

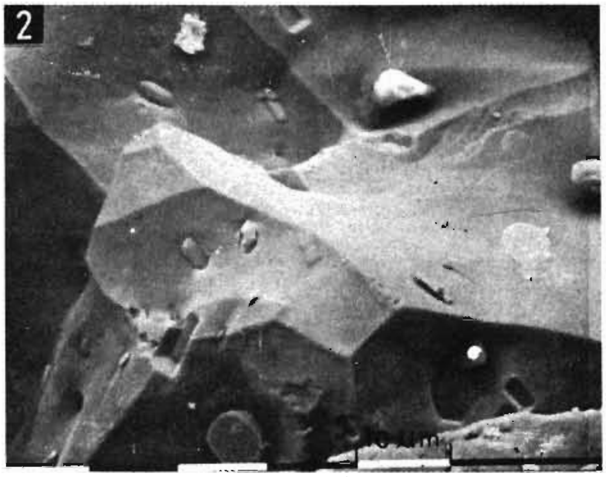
The Kudremukh iron-formation consists of magnetite, variety of iron silicates, iron carbonates and pyrite. The common occurrence of metamorphic silicate minerals in the Kudremukh banded iron-formation along with the presence of relict carbonate bands and pyrite rich layers indicates that the primary iron-formation of Kudremukh consisted of non-oxide type beds (Srinivasan, in preparation). The pyritic and carbonate layers are co-fold with the chert and iron rich layers indicating that they are syngenetic sedimentary bands (Pl. 1, fig. 1). The ore minerals, both the oxides as well as the sulphides, are euhedral and appear to have undergone metamorphic recrystallisation accompanying isoclinal folding in the area. Some of the pyrite grains are broken and sheared. Archaean iron-formations of Kudremukh have been subjected to enrichment of iron by post depositional weathering processes. It is believed by most workers that this enrichment is due to post-Cretaceous lateritic weathering.

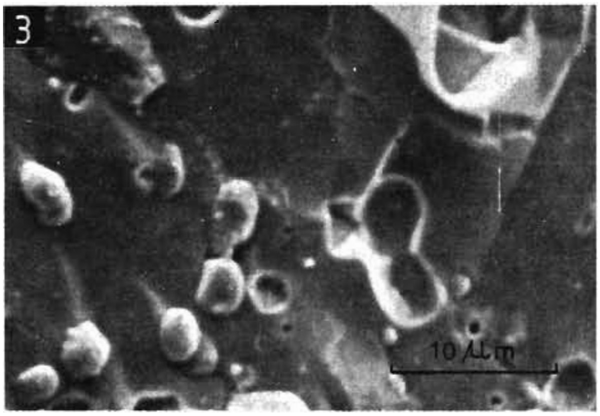
TECHNIQUES OF STUDY

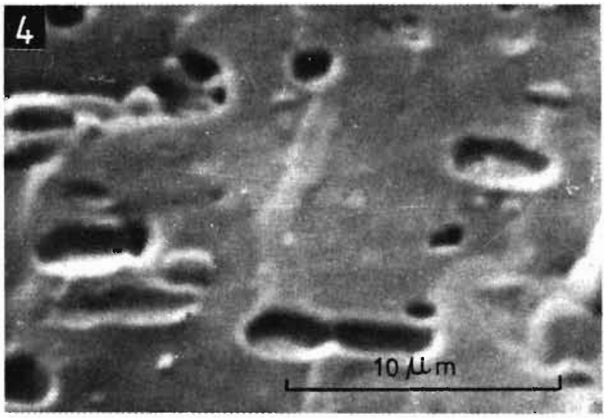
Scanning electron microscopy was carried out on pyrite using the following method: The bore-hole samples were washed with dilute hydrochloric acid for 30 seconds and then 2 mm cubes were cut from different portions of the core sample. They were repeatedly washed with reagent grade acetone. The washed pieces were transferred to small glass bottles which were also cleaned with acetone. The bottles containing the specimens were subjected to ultrasonic (Bransonic 221) treatment for six minutes. Then the specimens were repeatedly washed in acetone. After thorough drying they were mounted on the stubs. Gold-Palladium coating was given on a horizontal stage in vacuum evaporator for 165 seconds (on 1.4 KV and 15 MA) resulting into a coating thickness of 34650 Å. The material was then studied on PHILIPS 505 SEM. In all, nine stubs gave positive results. Six of them are preserved at the Birbal Sahni Institute of Palaeobotany, Lucknow.

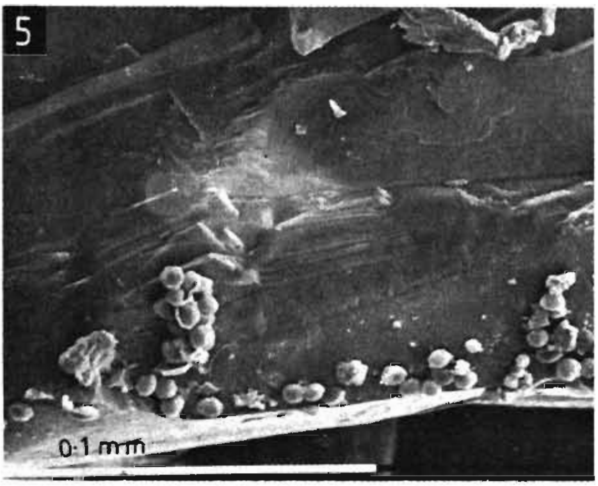
DESCRIPTION OF BACTERIA

Biota that are included in this communication consist of bacteria embedded in pyrite grains. Bacteria that rest on pyrite as well as recrystallised chert laminae are also recorded. Bacteria found within pyrite are considered syngenetic with the host pyrite as they are seen ingrained in the mineral (Pl. 1, fig. 2). They have also left behind their impressions on the pyrite grains (Pl. 1, figs 3, 4). The bacteria resting on pyrite and chert which are not included in the mineral need further study to authenticate their syngenecity; therefore the latter are only illustrated here (Pl. 1, figs 5, 6) and are excluded from the main discussion of this paper.









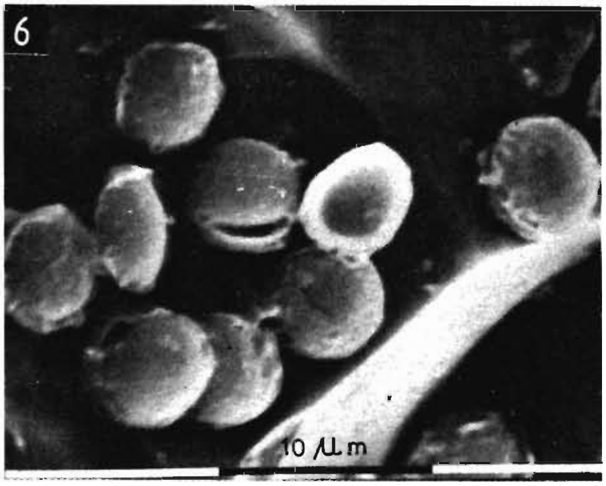


PLATE 1

1. Isoclinal fold in banded iron-formation showing pyrite layers (white) co-folded with iron rich (dark) and silica rich (grey) laminae. Note that some pyrite grains have developed euhedral outline due to metamorphic recrystallisation.
2. Subspherical to elliptical-shaped coccoid bacteria and rod-shaped bacteria embedded in pyrite grain.
3. Coccoid bacteria and their negative impression left on pyrite.
4. Negative impression of rod-shaped bacteria in pyrite. Note constriction in the middle indicating possible division of bacteria.
5. Coccoid bacteria resting on chert-layer.
6. Detail of saucer-shaped bacteria resting on chert. Note the horizontal division of cell and equatorial mucilaginous sheath. These resemble *Thiovulum*.

SYNGENETIC BACTERIA

The syngenetic bacteria are represented by two morphological types (i) coccoid and (ii) rod-shaped.

Coccoid bacteria—The coccoid bacteria are nearly spherical. Their diameter varies from 2-4 μm (Pl. 1, fig 3). They occur as individuals or in group of two or three surrounded by some sheath-like material which may be relicts of original mucilaginous matter (not illustrated here). These sheaths can be studied only under very high magnification. It is proposed to take up such studies later for a detailed account.

Rod-shaped bacteria—The rod-shaped bacteria embedded in pyrite are illustrated in Pl. 1, fig. 4. They are 1-2 μm long and 0.5 μm broad. Some of them show constriction in the middle which may be indicative of division of bacteria.

DISCUSSION AND CONCLUSION

The presence of syngenetic carbonate and pyrite layers in the Kudremukh iron-formation coupled with the ubiquitous development of metamorphic iron silicates suggests that the Kudremukh iron-formation is composed of beds which were deposited as nonoxide type iron-formation. The nature of the Kudremukh iron-formation or atleast some beds in them were therefore of the nature of mixed carbonate and sulphide types. Such iron-formations are known to have accumulated under reducing conditions (James, 1954; Klein, 1983).

The presence of pyrite in non-detrital sedimentary rocks is considered to be a consequence of interaction of microbiologically generated H_2S with iron compound leading to the formation of pyrite (Ehrich, 1981). It has been found that some bacteria, such as the members of the family Siderocapsaceae and *Thiobacillus* play an important role in metabolically concentrating iron compounds.

The morphology and size parameters of the coccoid and rod-shaped bacteria found in the Kudremukh iron-formation compare well with members of Siderocapsaceae and *Thiobacillus* respectively (Bergey's Mannual of Determinative Bacteriology, eds. Breed *et al.*, 1957, pp. 89-217). Some species of *Thiobacillus* are known to thrive and precipitate iron under reducing condition.

Schopf (1965) reported bacteria similar to the Siderocapsaceae from the 2.0 Ga old Gunflint cherts. Occurrence of similar bacteria in the iron-formation of Kudremukh indicates that such bacteria were also present as far back as the Archaean. Elemental analysis of this material is planned as further confirmatory studies.

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Palynostratigraphy of Subathu Formation (Eocene) in the Banethi-Bagthan area, Sirmaur District, Himachal Pradesh

H. P. Singh & Samir Sarkar

Singh, H. P. & Sarkar, Samir (1987). Palynostratigraphy of Subathu Formation (Eocene) in the Banethi-Bagthan area, Sirmaur District, Himachal Pradesh, India. *Palaeobotanist*, **35** (2) : 204-210.

On the basis of the qualitative and quantitative distribution of the recovered palynoflora five distinct palynological assemblage zones have been recognised within the Subathu Formation in the Banethi-Bagthan area of Himachal Pradesh. In ascending order of stratigraphy the palynological assemblage zones are: *Todisporites* spp. Assemblage Zone, *Subathua sahnii* Assemblage Zone, *Cordosphaeridium inodes* Assemblage Zone, *Homotryblium* spp. Assemblage Zone, and *Cleistosphaeridium* spp. Assemblage Zone.

Key-words—Palynostratigraphy, Palynological zonation, Subathu Formation, Eocene (India).

H. P. Singh & Samir Sarkar, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

सारांँश

हिमाचल प्रदेश में सिरमौर जनपद के बनेठी-बगथान क्षेत्र में सुबाथु शैल-समूह (आदिनूतन) का परागाणुस्तरविन्यास

हरिपाल सिंह एवं समीर सरकार

हिमाचल प्रदेश के बनेठी-बगथान क्षेत्र में सुबाथु शैल-समूह से उपलब्ध परागाणुवनस्पतिजात के गुणात्मक एवं परिमाणात्मक विश्लेषण के आधार पर पाँच विभिन्न समुच्चय मंडल बनाये गये हैं। स्तरविन्यास के आरोही क्रम ये टोडिस्पोराइटिस जाति समुच्चय मंडल, सुबाथुआ साहनाई समुच्चय मंडल, कोर्डोस्फ़ेयरिडियम् इनॉड्स समुच्चय मंडल, होमोट्राइब्लियम् जाति समुच्चय मंडल, एवं क्लिस्टोस्फ़ेयरीडियम् जाति समुच्चय मंडल हैं।

MEDLICOTT (1864) for the first time used the term Subathu as "Subathu Series" for the Palaeogene sediments of Simla Hills. He named them after the town Subathu (30°59′ : 77°1′) where its type locality is situated.

Since then difference of opinion prevailed among the geologists regarding the exact stratigraphic status of this rock sequence. Different authors have treated the status of the Subathu sediments differently as Subathu Series (Pilgrim & West, 1928; Chaudhri, 1968), Subathu Group (Medlicott, 1864; Pascoe, 1964; Raiverman & Seshavataram, 1965; Karunakaran & Ranga Rao, 1979), Subathu Stage (Pascoe, 1964), Subathu beds (Krishnan, 1960; Mathur, 1968) and Subathu Formation (Pascoe, 1964). Considering the recommendations of the International Commission of Stratigraphic Terminology Khanna (1978) formally instituted the Subathu Formation on the evidences provided by the lithostratigraphy and biostratigraphy.

Subathu Formation represents the lowermost marine sequence of the Tertiary rocks in Himachal Pradesh. It is conformably overlain by the Dagshai Formation. The status of the Subathu Formation in the present paper is followed after the concept of Khanna (1978). The Subathu Formation is exposed as a discontinuous outcrop along the narrow belt running right from Jammu in the west to the west of Dehradun in the east. The rocks of this formation are mainly characterised by the presence of calcareous, pale-olive, greenish-grey shales, limestone and siltstone bands. Palynological information from these rock sediments was scantily known until the last decade. Few noteworthy contributions during that period have been made by Mathur (1963, 1964, 1965) and Salujha *et al.* (1969). Only in the last decade a number of publications, viz., Mathur and Venkatachala (1979), Khanna (1978), Singh & Khanna (1978), Singh *et al.* (1978), Khanna *et al.* (1979) and Khanna and Singh (1979) have come out.

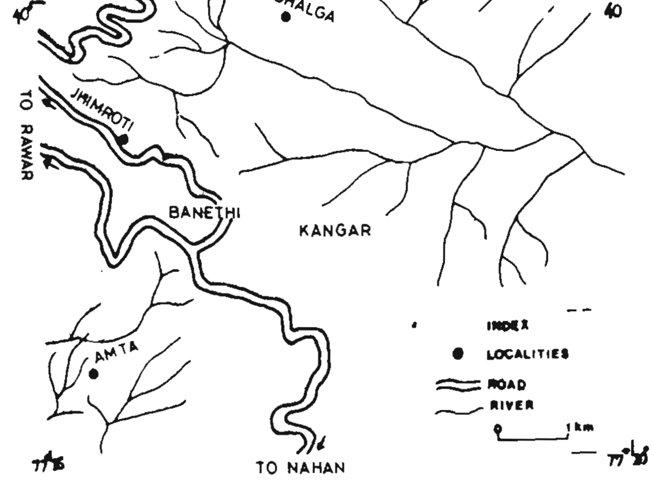
Singh *et al.* (1978) recognised seven distinct palynozones along with one barren zone within the Subathu Formation at its type locality (Subathu). Lateral extension of these palynozones has also been traced out in 7 other localities of Kalka-Simla area. In ascending order of stratigraphy the palynozones are: (8) *Todisporites* spp. Cenozone, (7) *Subathua sahnii* Cenozone, (6) *Cordosphaeridium multispinosum* Cenozone, (5) *Homotryblium* spp. Cenozone, (4) *Hexagonifera* spp. Cenozone, (3) *Cleistosphaeridium* spp. Cenozone, (2) Barren Zone, and (1) *Cyclonephelium* spp. Cenozone.

In the present paper an effort has been made to analyse the palynological data qualitatively and quantitatively from the Subathu sediments of Banethi-Bagthan area. On the basis of the available evidence, five palynological assemblage zones have been established.

AREA UNDER INVESTIGATION

The present palynological investigation was carried out near Nahan in the Sirmaur District of Himachal Pradesh (Map 1). It covers an area measuring about 48 sq km between 30°38'25" and 30°43'20" north latitude and 70°17'45" east latitude. It falls in the Survey of India toposheet map no. 53/F/6. This area is covered by a dense forest with rugged topography. The average height of the area is around 1200 m from M.S.L. The main drainage is towards southeast. The Jalal River with a number of tributaries (the most important being Ghambar Ka Nala) follows the south-eastern direction.

Several traverses were undertaken at different localities to find out the well-developed suits of Subathu sediments in this area. Efforts were also made to understand the exact order of superposition of strata including the thickness of various lithotypes with a view to observe the lower and upper contacts of the Subathu Formation. On the basis of these observations four geological sections were selected for measurement by using standard Brunton-tape method. Collection of rock samples for palynological studies was made from these sections. The lower contact of Subathu Formation has not been observed in any one of the sections whereas its upper contact is marked by the conformably overlying Dagshai Formation.



Map 1

BIOSTRATIGRAPHIC ZONATION OF SUBATHU FORMATION

On the basis of qualitative and quantitative analyses of the recovered palynoassemblages, five distinct assemblage zones are proposed within the Subathu sediments of the present area of investigation. The upper and lower limits of the assemblage zones have been established considering the variation patterns observed within the spore-pollen and microplankton assemblages. In most of the cases the lithological boundaries coincide with the palynological boundaries and no major floral break seems to have occurred in any of the studied geological sections. From the distributional pattern of different palynofloral elements, it is apparent that the change in palynofloral composition from one assemblage zone to another is recognizable. Three most reliable parameters have been taken into consideration for the recognition of different assemblage zones, viz., the first appearance, the maximum development and lastly the decline of the various taxonomic entities. The concept of the assemblage zone strictly follows the Code of Stratigraphic Nomenclature proposed by the American Commission on Stratigraphic Nomenclature (1961).

Quantitative analysis of each productive sample has been carried out after counting about 200 palynomorphs. The characteristic species of each assemblage zone have been plotted against the lithology of the standard section. The mean value of the spore, pollen and microplankton frequencies has been plotted under five different suites, viz., very rare, rare, common, abundant and predominant. The probable occurrence has been shown by the dotted line. The following five assemblage zones have been recognised in ascending order of stratigraphy, viz., (5) *Todisporites* spp. Assemblage Zone, (4) *Subathua sahnii* Assemblage Zone, (3) *Cordosphaeridium inodes* Assemblage Zone, (2) *Homotryblium* spp. Assemblage Zone, and (1) *Cleistosphaeridium* spp. Assemblage Zone.

As prescribed by the Code of Stratigraphic Nomenclature each assemblage zone together with necessary palynostratigraphic data is given below:

Cleistosphaeridium spp. Assemblage Zone

Localities—Bagthan-Savar Road Section; Dagalaghat Village—Banethi-Bagthan Road Section.

Lithology—This assemblage zone is characterised by mostly laminated dark brown, calcareous shales and dark brown to greenish, ferruginous splintery shales. At Dagalaghat Section, some grey to blackish siltstone bands are present within the shales. The thickness of this assemblage zone varies from 34 to 50 m.

Lower contact—This assemblage zone forms the lowermost palynostratigraphical unit of the Subathu Formation exposed in the present area of investigation. The appearance of thinly laminated brown calcareous shales over light brown buff coloured clays mark the lower contact of this zone.

Upper contact—The upper part of the ferruginous green to purple shale, laminated with clays forms the upper contact of the *Cleistosphaeridium* spp. Assemblage Zone. It is overlain by hard, compact purple splintery shales intermixed with thin band of limestone at Bagthan which contains *Homotryblium* in abundance. At Dagalaghat Section the upper part is generally composed of pale olive shale over slightly ferruginous siltstone.

Significant species of this assemblage zone—*Cleistosphaeridium diversispinosum, C. flexuosum, Lingulodinium macherophorum, Operculodinium centrocarpum, Glaphyrocysta exuberans, Hystrichosphaeridium tubiferum, Subathua sahnii, Graminidites media* and *Podocarpidites couperi* are the significant species of this assemblage zone. While *Adnatosphaeridium vittatum, A. multispinosum, Hystrichokolpoma salacium* and *H. cinctum* are the restricted species to this cenozone.

Remarks—In this assemblage zone mostly marine forms have been recorded along with a few land derived elements. *Cleistosphaeridium diversispinosum* and *C. flexuosum* are the most dominant forms represented by about 25 per cent of the total assemblage. Many other dinoflagellate cyst species present here are below 2 per cent. These are *Homotryblium abbreviatum, H. tenuispinosum, H. latirictum, Glaphyrocysta divaricata, Subathua spinosa, Podocarpidites couperi* and *Todisporites rarus* which mark their first appearance in this assemblage zone. The presence of *Pediastrum* spp. is also noteworthy.

Homotryblium spp. Assemblage Zone

Localities—Bagthan-Savar Road Section; Dagalaghat Village—Banethi-Bagthan Road Section.

Lithology—This assemblage zone mostly consists of hard compact, dark purple splintery shales or grey

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PLATE 1

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(All photomicrographs are enlarged ca. × 500 unless otherwise mentioned)

1. *Biretisporites crassus* Sarkar & Singh; B.S.I.P. Slide no. 6862, coordinates 14.9 × 109.5.
2. *Spiniferites ramosus* (Ehrenberg) Loeblich & Loeblich; B.S.I.P. Slide no. 6896, coordinates 4.5 × 94.5.
3. *Cleistosphaeridium flexuosum* Davey *et al.*; B.S.I.P. Slide no. 6922, coordinates 5.5 × 85.5.
4. *Dapsilidinium pasteilsii* (Davey & Williams) Bujak *et al.*; B.S.I.P. Slide no. 6917, coordinates 21 × 113.5.
5. *Pediastrum angulatus* Singh & Khanna; B.S.I.P. Slide no. 8424, coordinates 6 × 87.5.
6. *Graminidites media* Cookson; B.S.I.P. Slide no. 6860, coordinates 21.2 × 118.
7. *Biretisporites* sp. B.S.I.P. Slide no. 6862, coordinates 15.5 × 93.
8. *Amtaspora indica* Sarkar & Singh; B.S.I.P. Slide no. 6862, coordinates 15.5 × 93.
9. *Amtaspora pseudostriata* Sarkar & Singh; B.S.I.P. Slide no. 6862, coordinates 15.5 × 93.
10. *Monolites* sp.; B.S.I.P. Slide no. 6861, coordinates 8.2 × 79.
11. *Dictyophyllidites* sp.; B.S.I.P. Slide no. 6860, coordinates 11 × 110.5.
12. *Biretisporites potoniaei* Delcourt & Sprumont; B.S.I.P. Slide no. 6860, coordinates 1.5 × 79.
13. *Hystrichokolpoma cinctum* (Klumpp) Damassa; B.S.I.P. Slide no. 6895, coordinates 14 × 107.
14. *Polysphaeridium zoharei* (Wall) Bujak; B.S.I.P. Slide no. 6917, coordinates 20.2 × 104.2.
15. *Podocarpidites decorus* Sarkar & Singh; B.S.I.P. Slide no. 6925, coordinates 14.5 × 82.3.
16. *Todisporites rarus* Sarkar & Singh; B.S.I.P. Slide no. 6861, coordinates 21.8 × 97.8.
17. *Operculodinium centrocarpum* (Deflandre & Cookson) Wall; B.S.I.P. Slide no. 6917, coordinates 19.5 ×
17. *Operculodinium centrocarpum* (Deflandre & Cookson) Wall; B.S.I.P. Slide no. 6917, coordinates 19.5 × 84.8.
18. *Striatriletes susannae* (Van der Hammen) Kar, B.S.I.P. Slide no. 6928, coordinates 7.4 × 115.
19. *Palmidites noviculatus* Sarkar & Singh; B.S.I.P. Slide no. 6925, coordinates 14.5 × 82.3.
20. *Couperipollis capitatus* Sarkar & Singh; B.S.I.P. Slide no. 6927, coordinates 13 × 83.
21. *Todisporites major* Couper, B.S.I.P. Slide no. 6860, coordinates 20 × 77.
22. *Sentusidinium rioultii* (Sarjeant) Sarjeant & Stover, B.S.I.P. Slide no. 6905, coordinates 8.2 × 79.
23. *Adnatosphaeridium multispinosum* Williams & Downie, B.S.I.P. Slide no. 6923, coordinates 10 × 86.5.
24. *Glaphyrocysta intricata* (Eaton) Stover & Evitt; B.S.I.P. Slide no. 6923, coordinates 14.5 × 102.
25. *Thalassiphora velata* (Deflandre & Cookson) Eisenack & Gocht; B.S.I.P. Slide no. 6907, coordinates 19.5 × 84.8.
26. *Homotryblium pallidum* Davey & Williams; B.S.I.P. Slide no. 6919, coordinates 19.5 × 78.5.
27. *Subathua sahnii* Khanna & Singh; B.S.I.P. Slide no. 6908, coordinates 12.5 × 92.
28. *Thalassiphora pelagica* (Eisenack) Eisenack & Gocht; B.S.I.P. Slide no. 6909, coordinates 14.5 × 98.8.
29. *Cordosphaeridium inodes* (Klumpp) Morgenroth; B.S.I.P. Slide no. 6923, coordinates 13 × 117.
30. *Multicellaesporites* sp.; B.S.I.P. Slide no. 6923, coordinates 13 × 117.

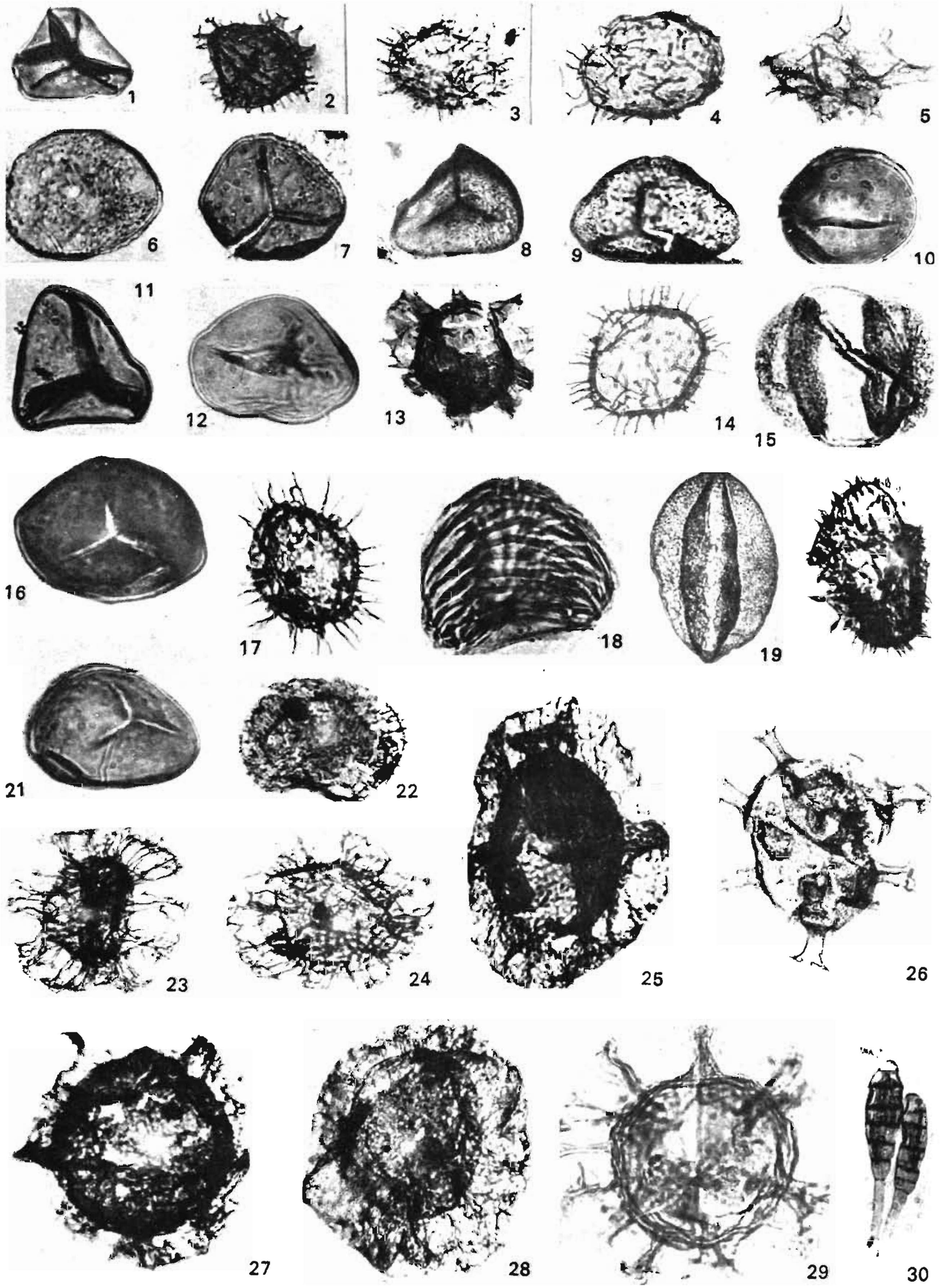
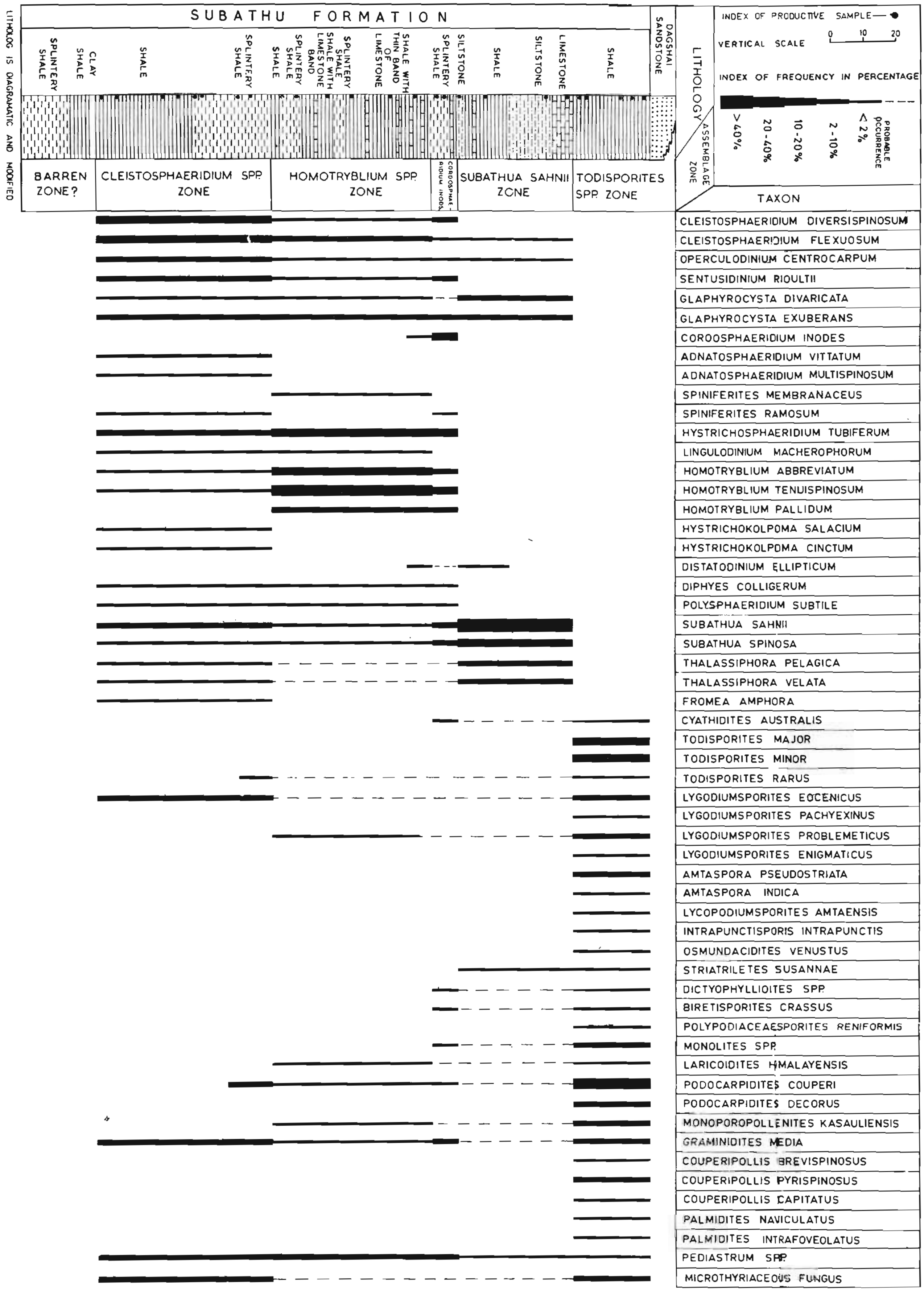


PLATE 1


LITHOLOG IS DIAGRAMATIC AND MODIFIED
SUBATHU FORMATION
SPLINTERY SHALE
CLAY SHALE
SHALE
SPLINTERY SHALE
SHALE
SPLINTERY SHALE
SHALE WITH LIMESTONE BAND
SPLINTERY SHALE
SHALE WITH THIN BAND OF LIMESTONE
SPLINTERY SHALE
SILTSTONE
SHALE
SILTSTONE
LIMESTONE
SHALE
DAGSHAI SANDSTONE
LITHOLOGY
ASSEMBLAGE ZONE
BARREN ZONE?
CLEISTOSPHAERIDIUM SPP. ZONE
HOMOTRYBLIUM SPP. ZONE
COROOSPHAERIDIUM INODES
SUBATHUA SAHNII ZONE
TODISPORITES SPP. ZONE
INDEX OF PRODUCTIVE SAMPLE
VERTICAL SCALE
0
10
20
INDEX OF FREQUENCY IN PERCENTAGE
>40%
20-40%
10-20%
2-10%
< 2%
PROBABLE OCCURRENCE
TAXON
CLEISTOSPHAERIDIUM DIVERSISPINOSUM
CLEISTOSPHAERIDIUM FLEXUOSUM
OPERCULODINIUM CENTROCARPUM
SENTUSIDINIUM RIOULTII
GLAPHYROCYSTA DIVARICATA
GLAPHYROCYSTA EXUBERANS
COROOSPHAERIDIUM INODES
ADNATOSPHAERIDIUM VITTATUM
ADNATOSPHAERIDIUM MULTISPINOSUM
SPINIFERITES MEMBRANACEUS
SPINIFERITES RAMOSUM
HYSTRICHOSPHAERIDIUM TUBIFERUM
LINGULODINIUM MACHEROPHORUM
HOMOTRYBLIUM ABBREVIATUM
HOMOTRYBLIUM TENUISPINOSUM
HOMOTRYBLIUM PALLIDUM
HYSTRICHOKOLPOMA SALACIUM
HYSTRICHOKOLPOMA CINCTUM
DISTATODINIUM ELLIPTICUM
DIPHYES COLLIGERUM
POLYSPHAERIDIUM SUBTILE
SUBATHUA SAHNII
SUBATHUA SPINOSA
THALASSIPHORA PELAGICA
THALASSIPHORA VELATA
FROMEA AMPHORA
CYATHIDITES AUSTRALIS
TODISPORITES MAJOR
TODISPORITES MINOR
TODISPORITES RARUS
LYGODIUMSPORITES EOCENICUS
LYGODIUMSPORITES PACHYEXINUS
LYGODIUMSPORITES PROBLEMETICUS
LYGODIUMSPORITES ENIGMATICUS
AMTASPORA PSEUDOSTRIATA
AMTASPORA INDICA
LYCOPODIUMSPORITES AMTAENSIS
INTRAPUNCTISPORIS INTRAPUNCTIS
OSMUNDACIDITES VENUSTUS
STRIATRILETES SUSANNAE
DICTYOPHYLLIDITES SPP.
BIRETISPORITES CRASSUS
POLYPODIACEAESPORITES RENIFORMIS
MONOLITES SPP.
LARICOIDITES HIMALAYENSIS
PODOCARPIDITES COUPERI
PODOCARPIDITES DECORUS
MONOPOROPOLLENITES KASAULIENSIS
GRAMINIDITES MEDIA
COUPERIPOLLIS BREVISPINOSUS
COUPERIPOLLIS PYRISPINOSUS
COUPERIPOLLIS CAPITATUS
PALMIDITES NAVICULATUS
PALMIDITES INTRAFOVEOLATUS
PEDIASTRUM SPP.
MICROTHYRIACEOUS FUNGUS

laminated shales (calcareous in nature) intermixed with purplish grey shaly limestone. Minor partings of white limestones have also been observed in Bagthan Section. In Dagalaghat Section this zone is mainly characterised by pale olive to purplish shales together with greyish brown siltstone bands. The thickness of this assemblage zone varies from 27 to 38 m.

Lower contact—In Dagalaghat Section, pale olive and slightly ferruginous siltstone grades into the purplish shales forming the lower contact of this assemblage zone, whereas in Bagthan Section the purple splintery shales overlie the greenish splintery shales marking its lower contact.

Upper contact—The top layers of the shale which are purplish to pale olive in colour form the upper contact of this assemblage zone. Minor partings of white limestone have been found in the Bagthan Section.

Significant species of this assemblage zone—*Homotryblium tenuispinosum, H. abbreviatum, H. pallidum, Hystrichosphaeridium tubiferum, Cleistosphaeridium flexuosum, C. diversispinosum, Glaphyrocysta exuberans* and *Graminidites media* are significant species of this assemblage zone. *Spiniferites membraneous* is the only restricted species to this assemblage zone.

Remarks—This assemblage zone is overwhelmingly dominated by various species of the genus *Homotryblium* (47%) whereas the abundance of *Cleistosphaeridium* sharply declines from 25 per cent to 7 per cent. The distribution of many forms is less than 2 per cent. These forms are *Sentusidinium rioultii, Operculodinium centrocarpum, Glaphyrocysta divaricata, Polysphaeridium subtile, Subathua sahnii, S. spinosa, Lygodiumsporites problematicus, Laricoidites himalayensis, Monoporopollenites kasauliensis* and *Pediastrum* spp. Forms like *Cordosphaeridium inodes, Distatodinium ellipticum, Lygodiumsporites problematicus, Laricoidites himalayensis, Monoporopollenites kasauliensis* show their first appearance in this assemblage zone. Another interesting feature of this assemblage zone is the presence of relatively high percentage of different species of *Pediastrum* (16%).

Cordosphaeridium inodes Assemblage Zone

Localities—Bagthan-Savar Road Section, Dagalaghat Village—Banethi-Bagthan Road Section.

Lithology—This assemblage zone mainly consists of splintery purplish shales intercalated with shaly siltstone and its thickness varies from 4 to 15 m.

Lower contact—The appearance of splintery shales over the purplish shales with limestone partings marks the lower contact of this assemblage zone.

Upper contact—The upper part of the purplish shale with siltstone bands form its upper contact. It is overlain by a limestone band which contains *Subathua* in abundance.

Significant species of this assemblage zone—*Cordosphaeridium inodes, Homotryblium tenuispinosum, H. abbreviatum, H. pallidum, Sentusidinium rioultii, Hystrichosphaeridium tubiferum, Subathua sahnii, S. spinosa* and *Graminidites media* are the significant species to this assemblage zone.

Remarks—In this assemblage zone *Cordosphaeridium inodes* is the most dominant element which appears for the first time in the upper part of the *Homotryblium* spp. Assemblage Zone and sharply rises from 2 to 17 per cent. The distributional frequency of some dinoflagellates forms, viz., *Spiniferites ramosus, Glaphyrocysta exuberans, Cleistosphaeridium divarsispinosum, C. flexuosum* and *Polysphaeridium subtile* is less than 2 per cent. Forms like *Biretisporites crassus* and *Monolites* sp. make their first appearance in this assemblage zone.

Subathua sahnii Assemblage Zone

Localities—Bagthan-Savar Road Section; Dagalaghat Village—Banethi-Bagthan Road Section, Jhimroti-Banethi Road Section.

Lithology—This assemblage zone is mainly composed of argillaceous limestone with massive development of grey shales with intercalation of thin bands of purple shales and grey siltstone. The thickness of this assemblage zone varies from 5 to 26 m.

Lower contact—The appearance of argillaceous limestone band over the siltstone of *Cordosphaeridium inodes* Assemblage Zone forms the lower contact of this assemblage zone.

Upper contact—The uppermost part of the argillaceous limestone band where the limestone is mostly compact and yellowish green in colour form the upper contact of this assemblage zone.

Significant species of this assemblage zone—*Subathua sahnii, S. spinosa, Thalassiphora pelagica, T. velata, Glaphyrocysta divaricata* and *G. exuberans* are significant species of this assemblage zone.

Remarks—Not a single species has been found to be restricted in this assemblage zone. It is mostly dominated by various members of the family *Thalassiphoraceae*, viz., *Thalassiphora pelagica, T. velata*, etc. The other species present in this zone are: *Cleistosphaeridium flexuosum, Operculodinium centrocarpum, Distatodinium ellipticum* and *Striatriletes susannae*. Each of these species are present in very small quantity and their percentage in terms of frequency is never more than 2.5 per cent each. The spores of *Striatriletes susannae* show their first appearance in this assemblage zone.

Todisporites spp. Assemblage Zone

Localities—Bagthan-Savar Road Section; Dagalaghat Village—Banethi-Bagthan Road Section; Jhimroti-Banethi Road Section; Amta-Surla Briddle Path Section.

Lithology—This assemblage zone mainly consists of alternation of calcareous grey and purple shales. Limestone is completely lacking in this assemblage zone. The thickness of this assemblage zone varies from 6 to 59 meters.

Lower contact—The appearance of purple shales over the limestone band marks the lower contact of this assemblage zone.

Upper contact—The base of the overlying Dagshai sandstone forms the upper contact of this assemblage zone and in most of the cases the shales are highly purplish in nature.

Significant species of this assemblage zone—Todisporites major, T. minor, Lygodiumsporites pachyexinus, L. enigmaticus, Amtaspora pseudostriata, A. indica, Lycopodiumsporites amtaensis, Intrapunctisporis intrapunctis, Osmundacidites venustus, Polypodiaceaesporites reniformis, Podocarpidites decorus, Couperipollis brevispinosus, C. pyrispinosus, C. capitatus, Palmidites noviculatus and *P. intrafoveolatus* are the significant species of this assemblage zone.

Remarks—At the base of this assemblage zone a few microplanktons, viz., *Homotryblium tenuispinosum, H. pallidum, H. abbreviatum, Hystrichosphaeridium tubiferum, Glaphyrocysta divaricata, Polysphaeridium subtile, Operculodinium centrocarpum, Cleistosphaeridium flexuosum, Subathua sahnii* and *S. spinosa* have been recorded. Each of these species is present in very meagre quantity and their percentage in terms of frequency is never more than one per cent. Most probably they denote a coastal transitional environment in between the *Subathua sahnii* and *Todisporites* spp. assemblage zones. At the top of this assemblage zone the dinoflagellate cysts completely disappear and the palynofloral assemblage is totally replaced by a trilete rich spore assemblage. A noteworthy feature of this assemblage zone is the sharp fall in the percentage of *Pediastrum* (less than 2% of the total assemblage). Some of the samples belonging to this assemblage zone have yielded bisaccate gymnospermous pollen.

CONCLUSIONS

On the basis of the frequency of various palynofossils in different stratigraphical horizons the Subathu Formation is divided into five distinct assemblage zones which in the ascending order of stratigraphy are: (5) *Todisporites* spp. Assemblage Zone, (4) *Subathua sahnii* Assemblage Zone, (3) *Cordosphaeridium inodes* Assemblage Zone, (2) *Homotryblium* spp. Assemblage Zone, and (1) *Cleistosphaeridium* spp. Assemblage Zone.

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FOURTEENTH BIRBAL SAHNI MEMORIAL LECTURE

The mixed Permian Cathaysia-Gondwana flora

Li Xingxue

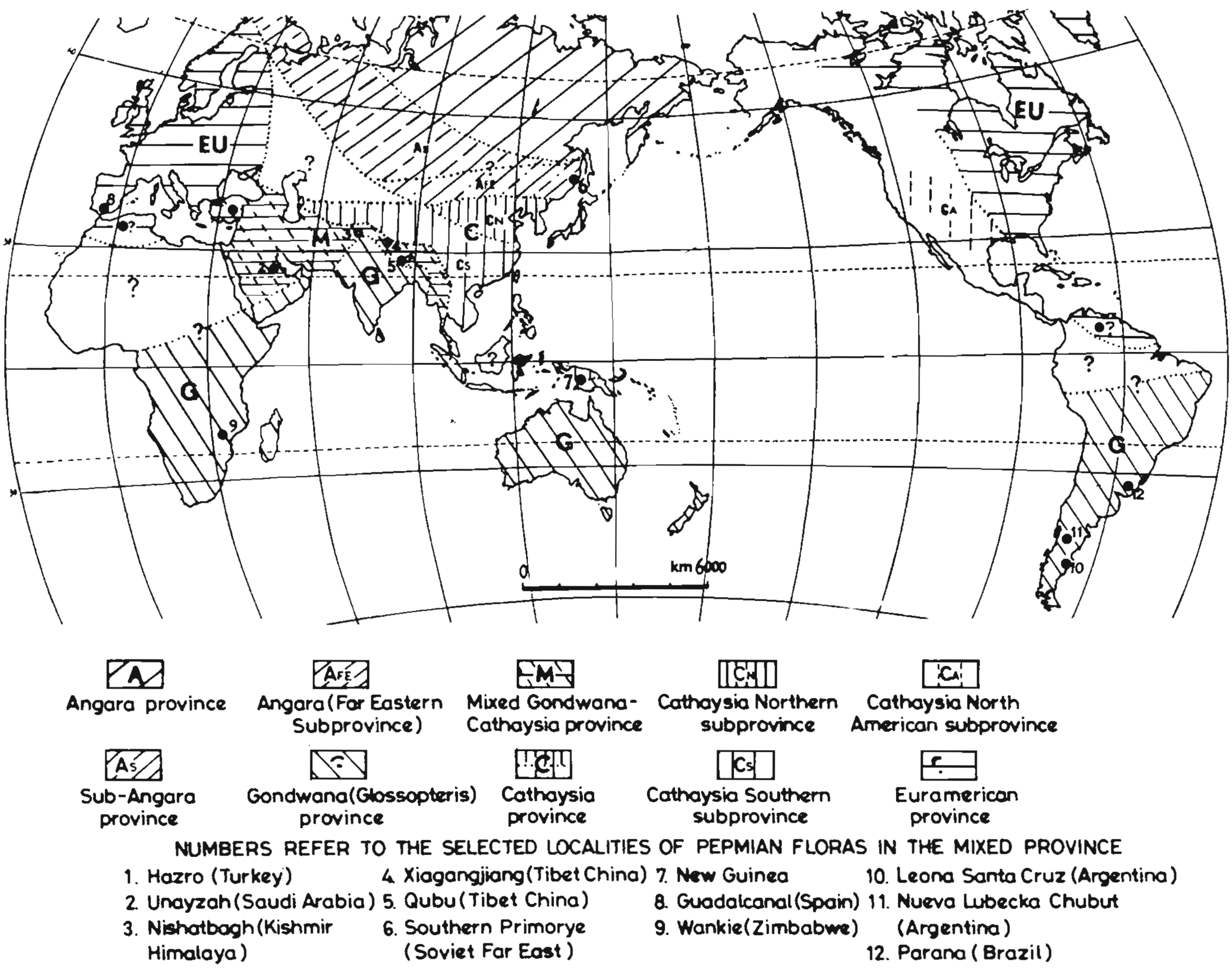
Nanjing Institute of Geology and Palaeontology, Academia Sinica, Nanjing 21008, China

THE reasons for my talking about the mixed flora problem here are threefold; first, as you are well aware, early in the middle of thirties, late Professor Birbal Sahni (1935, 1936) had furnished elaborate explanations about the formation of the sub-continent of South Asia and the Qinghai-Xizang (Tsinghai-Tibet) Plateau as well as the subdivision of palaeophytogeographical provinces of East Asia. Second, it is a very interesting problem relating to many branches in geology, geography and biology and deserves special attention and further study. And third, some important new ideas were put forward during the last decade on the Qinghai-Xizang Plateau through investigations made by Chinese and foreign scientists. Therefore, I consider it appropriate to summarize the relevant data available with the hope that it might throw some light on this obscure problem and stimulate new researches. However, because the mixed flora problem concerns with many complicated subjects and has long been in dispute, some scholars even deny the occurrence of any mixed flora during geological times. Thus, what I am submitting here is preliminary and far from complete.

BRIEF REVIEW OF RELATED MIXED FLORAS OUTSIDE CHINA

Hazro flora (Turkey)—The Hazro flora of Anatolia in Turkey (Map 1) has been one of the most attractive known mixed floras (Wagner, 1959, 1962). There is little dispute to the remarkable Cathaysia nature of this flora; some authors, however, doubt identification of some specimens as *glossopteris*, a representative of the Gondwana flora. Archangelsky and Wagner (1983) re-investigated the original collection and complementary specimens obtained from the same locality. The plant remains originally assigned to *Glossopteris* cf. *stricta* has been identified as *Glossopteris anatolica* sp. nov.; and another genus *Botrychiopsis*, also a common member of the Gondwana flora, was recognized with certainty. Now it seems acceptable that the Hazro flora is a mixed flora with double aspects of both Cathaysian flora and Gondwana flora.

Unayzah flora (Saudi Arabia)—The Unayzah flora was found in the central part of Saudi Arabia and also attracted much attention among those who are interested in the research of mixed flora. The earliest account (El-Khayal *et al.*, 1980) suggested that it was a typical Euramerican flora without any reliable elements of Cathaysian flora or Gondwana flora. But subsequent study (Lemoigne, 1981) demonstrated that it is really a mixed flora, containing such important Cathaysian representatives as *Annularis mucronata* Schenk, *Lobatannularia* cf. *heianensis* (Kod.), *Fascipteris hallei* (Kaw.), etc. associated with "Northern" elements. The memoir of a comparatively systematical study for this flora by Wagner and others (pers. comm., 1984) has been sent to press. Although the detailed content we do not know, yet my colleague Dr. Zhou tells me that he had an opportunity to observe the Wagner collection from the same locality at Sheffield University. He recognized with confidence the presence of Cathaysian elements, e.g. *Gigantonoclea*, etc. in this flora. Of course, there are other northern elements in the flora. At present, it is difficult to judge whether this flora contains Gondwana elements? The specimen with loose reticulate venation identified by Lemoigne (1981) as *Zamiopteris* (?) sp. is a doubtful plant. Considering the presence of *Glossopteris* in the Hazro flora north to the Unayzah flora, I think it highly possible that Gondwana elements may be found in the Unayzah flora. Now it would seem that the traditional view to regard the Arabian Peninsula as a part of the Gondwanaland has lost its basis, as the occurrence of the mixed Permian flora in this area is beyond doubt. The presence of some Cathaysian elements in Central Saudi Arabia is not unexpected, because several Permian Cathaysian species, e.g.



Map 1—World map showing distribution of Permian floral provinces (dotted lines indicate only the approximate boundary of floral provinces).

Plagiozamites oblongifolius Halle have been also discovered in Iraq (Ctyroky, 1973), a neighbouring country to the Hazro flora of Turkey as mentioned above. Consequently, a question in front of us is that what kind of flora occupied the vast area of northern Africa to the west of the Red Sea?

Mamal flora (Kashmir)—According to Singh, Maithy and Bose (1982) in this flora some representatives of the Cathaysian flora, i.e. *Lobatannularia ensifolia* Halle, *Rajahia mamalensis* sp. nov. and *Sphenophyllum thonii* var. *minor* Sterzel, are found in association with typical elements of the Gondwana flora, i.e. *Trizygia speciosa* Royle, *Glossopteris intermittens* Feistmantel and *G. angustifolia* Brongn. Below the strata containing the Mamal mixed flora and separated by the Panjal Volcanic Series is the Nishatbagh Formation containing Glossopteris flora; beneath the Nishatbagh Formation is the Agglomerate Slate Formation which is widely spread in Kashmir Himalayas and possibly of late Carboniferous age.

The discovery of the Mamal mixed flora and the stratigraphical succession in the Nishatbagh area is very interesting and significant to the study of stratigraphy and palaeontology of the central and southern parts of Tibet and I will touch it again later.

Mixed flora of the Soviet Far East—The discovery of mixed Permian flora in a place near Vladivostok, southern Primorye of the Soviet Far East is a matter of great interest (Zimina, 1967, 1969, 1983). The most prominent feature is that this flora includes many typical Gondwana plants, such as *Glossopteris*, several new forms of *Gangamopteris* and *Palaeovittaria* and another known species, *Euryphyllum whittanium* Feistmantel. Secondly, it is interesting that this flora includes such Cathaysian species as *Labatannularia heianensis* (Kod.) and *Pecopteris* (*Asterotheca*) *orientalis* (Shenk) in association with some Angaran and Euramerican elements. This flora is divided into three—upper, middle and lower assemblages, occurring in about 3,000 m thick marine-continental intercalated deposits. The lower assemblage is mainly composed of Angaran of Early Permian age. The middle assemblage is dominated by taxa of the Gondwana flora associated with a few Cathaysian elements and is dated as late Early Permian to early Late Permian. The upper assemblage is distinguished by a few Cathaysian elements but without any Gondwana taxon.

The age determination of these assemblages and the presence of Cathaysian elements seem reliable because Burago (1973) also reported the discovery of floras equivalent to those of the Upper and Lower Shihhotse formations of North China in the same district (not far from the north to Vladivostok). Why almost all the Gondwana elements in this flora are new species? Why this mixed flora occurs in the very north-eastern Asia, and why a vast area separates this place from the currently known distribution of Glossopteris flora? All these phenomena need reflection.

Flora of Western Guinea—Jongmans (1940) first reported the occurrence of a mixed flora in New Guinea. Subsequently, Visser and Hermes (1962) reported the presence of *Glossopteris* and *Vertebraria* associated with a few Cathaysian elements in the east of western New Guinea, while Asama and others (1975) doubt the presence of latter. Recently I received from Dr J. Rigby two photos of fossil plant fragments obtained from western New Guinea which he suspects are Cathaysian elements associated with Gondwana elements. I believe they can be identified as *Gigantonoclea* sp. and *Fascipteris* sp.; thus the presence of Cathaysia Gondwana mixed Permian flora in this area is proved, though I am not very clear about the geological relations of the fossil site.

Guadalcanal Flora of Southeastern Spain—This flora, through the palaeobotanical and palynological study made recently by Broutin (1981, 1982), is considered to be mixed flora containing Angara, Cathaysia, Gondwana and Euramerica elements. This area refers formerly to the Euramerican floristical province, so that the Euramerican elements need not to be listed. The remarkable feature of this flora is the presence of Cathaysian elements, i.e. *Protoblechnum wongii* Halle cf. *Fasicpteris* (*Validopteris*) *robusta* Gu et Zhi *Sphenopteris pseudogermanica* Halle and *Lobatannularia*—type, etc. The species that is more or less comparable with the Gondwana Permian element is *Ginkgophytopsis* sp. cf. *G. kidstonii*-type cf. *Entsovia* sp. shows some affinity with the Angara flora. In addition, there are *Rhipidopsis baetica, R. ginkgoides, Phyllotheca* sp. and *Psygmophyllum* spp. which are common components of the above mentioned three floras.

The palynological result coincides quite well with that of the macroflora study as to the nature of the flora. In this paper, Broutin simply mentioned a similar mixed flora found from Algeria in northern Africa. A formal article for the flora by Doubinger is in press.

There seems to be little doubt that Guadalcanal flora has some Cathaysian elements; however, the presence of Angara or Gondwana elements in the flora has not yet been proved. One can hardly judge such plants as *Rhipidopsis ginkgoides* and *Psygmophyllum* belonging to any phytogeographical province, and the determination of these plant taxa is often difficult.

Wankie flora in Zimbabwe—The Wankie flora has been well known as a mixed Permian flora consisting of elements of both southern and northern Hemisphere types (Walton, 1929). Teixeira (1949, 1952), Lacey and Huard-Moine (1966), Lacey and Smith (1972) and others successively went to the original locality in Zimbabawe, and also investigated the equivalent strata in Mozambique and Malawi in some detail. Although some additions or changes about the composition and identification of the Wankie flora were made by these authors, however, there is no dispute about the nature of flora which is dominated by Gondwana elements and mixed with quite a number of northern hemisphere elements, including Cathaysian ones. Some "northern" elements which Walton originally mentioned without confidence, are also confirmed by Lacey and others; for example, they recognized the presence of *Pecopteris arcuata* Halle in this flora. The Wankie material, both sterile and fertile, under this designation, in my opinion, differs in venation and fructification of the typical specimens of Halle's species described from China.

Mixed floras of South America—The mixed Permian floras have a wider distribution in South America (Archangelsky, 1958, 1970, 1971; Archangelsky & Sota, 1960; Archangelsky & Arrondo, 1975). Nueva Lubecka of Chubut, Leona of Santa Cruz, and Central Patagonia in Argentina, and the Parana Basin in southern Brazil are among the more famous localities. One of the most prominent features of the Glossopteris flora in these area is that in addition to many Euramerican elements, e.g. *Sphenophyllum thonii* Mahr, *S.* cf. *oblongifolium* (Germ. et Kaulf.) and *Pecopteris unita* Brongn., there are a few representatives of the Cathaysian flora, e.g. *Pecopteris* (*Asterotheca*) *anderssonii* Halle in the Lubecka Formation of Argentina and *Chiropteris reniformis* Kaw. in the Tubaro Formation (or Tatui Formation of Rigby, 1970), Parana Basin of Brazil. The composition of these floras in South America is largely the same as that of the Wankie flora in South Africa, and the present geographical position of both areas is widely separated by the Atlantic Ocean. Lacey and Huard-Moine (1966) suggested that both show a close affinity with the Cathaysian flora of East Asia. Archangelsky and others (1975), on the other hand, are inclined to combine floras in South America and South Africa with the coeval floras in Australia, and inlay the relevant ancient plates together as shown in their new Paleofloristic Province—Austroafroamerican—which has characters of its own. However, these assumptions seem to deserve further consideration.

RECENT STUDIES ON THE MIXED FLORAS OF XIZANG, CHINA

1. *The Xiagangjiang mixed flora in Central Xizang*—This interesting flora has been recently studied by Li *et al.* (in press). It is most probably latest Early Permian in age. It is situated approximately at 32°26'N—84°15'E, a locality about 120 km southeast to the Gerze city (Map 2). The plant-bearing horizons and generalized stratigraphic columnar section of Xiagangjiang area are shown in Text-fig. 1.

The plant remains are all preserved as impressions and seldom well preserved enough for a specific determination. Attempts at cuticular preparation and palynological analysis for the material have been made, but yield no results. The identification of 17 species or types of the flora listed in the following is based merely on their macroscopic features.

Phyllotheca sp. (cf. *P. australis* group)
?*Schizoneura* sp. (cf. *Schizoneura gondwanensis* Feistmantel)
Indeterminable arthrophytic leaves
Sphenopteris xiagangjiangensis sp. nov.
Sphenopteris sp.
Pecopteris aff. *arcuata* Halle
Pecopteris sp. 1 (? sp. nov.)
Pecopteris sp. 2
Pecopteris sp. 3
?*Alethopteris* sp.
Noeggerathiopsis hislopii (Bunbury)
Noeggerathiopsis sp.
?Squamous leaf
?*Plagiozamites oblongifolius* Halle
Cardiocarpus sp. 1
Cardiocarpus sp. 2
Carpolithus sp.

At the first glance, the Xiagangjiang flora does not show a close relationship with any known Permian flora. However, in the dominance of strongly ribbed arthrophytic stem-casts *Phyllotheca* sp. and ?*Schizoneura* sp., and cordaitalean leaves, i.e. *Noeggerathiopsis* spp., bears a striking resemblance to that of the Glossopteris flora; they are very rarely found in the Permian Cathaysian flora. Another distinctive feature of the flora is the relatively rich occurrence of Pecopterids and Sphenopterids, which remind us also of a floral aspect of the Permo-Carboniferous of northern hemisphere. Of particular interest among these forms is a specimen named *Pecopteris* aff. *arcuata* Halle which distinguishes itself by a venation of *P. unita*-type. Pecopterid plants with this type of venation have never been found in the typical Glossopteris flora. In this connection, it seems appropriate to point out that a specimen from southern Xizang (Tibet) described by Hsü (1976) as *Dichotomopteris qubuensis* bears also the venation of *P. unita*-type, which, in my opinion, probably is conspecific with *P.* aff. *arcuata* of the Xiagangjiang flora. Another specimen from Xiagangjiang, i.e. ?*Plagiozamites oblongifolius* Halle might show a certain relationship with the Cathaysian flora, too.

In the tectonic region in the nearby area, where the Xiagangjiang flora occurs, some Blaini type glacial deposits and cold water invertebrate assemblages such as *Eurydesma* fauna have been found (Liu *et al.*, 1983). Furthermore, the stratigraphic succession, mainly of the Permian, in the Xiagangjiang area corresponds rougly to that of the Mamal mixed flora in the Nishatbagh area of Kashmir. The Xiagangjiang flora is thus considered to be a mixed Permian flora, although the total absence of either typical Gondwana genera such as *Glossopteris* and *Gangamopteris* or the Cathaysian gigantopterids, *Lobatannularia* and *Tingia* in the Xiagangjiang area is a noteworthy feature.

2. *The Qubu flora of southern Xizang (Tibet)*—This flora has attracted much attention due to its importance in geo-tectonics and palaeobotany (Hsü, 1973, 1976, 1978, 1981). It was thought to be typical Glossopteris flora. However, Singh and others (1982) transferred the specimens originally identified as *Raniganjia qubuensis* Hsü to *Lobatannularia*, an important Cathaysian genus; they also pointed out that the Mamal mixed flora found in Kashmir "show close similarity with the assemblages described by Hsü (1973, 1976) from... southern Xizang". Obviously, they doubted somewhat the typical nature of Glossopteris flora of Qubu. In 1983, I published a paper "Notes on the three new species of the Glossopteris flora from Qubu Formation, *S.* Xizang", with the conclusion that this flora should be dated as late Early Permian instead of early Late Permian as originally advocated. Besides, as has been mentioned above, the so-called *Dichotomopteris qubuensis* in the Qubu flora is probably conspecific with *Pecopteris* aff. *arcuata* in the Xiagangjiang flora. In the following, a discussion will be made on the close similarity between several specimens originally identified as *Dizeugotheca qubuensis* Hsü of the Qubu flora and some specimens of the Wankie mixed flora from Zimbabwe in South Africa. Thus, whether the Qubu flora is a typical Glossopteris flora or a mixed flora must be reconsidered. I think the latter assumption is more probable. But due to the true nature of this flora having great influence upon the approaches of geo-tectonics and palaeobiogeography, for caution's sake, I think it wiser not jumping at conclusion about this problem at this moment.

SOME REMARKS ON THE MIXED FLORAS

The preceding review of the relevant mixed floras indicates that one of the most remarkable features is that Wankie flora of south Africa and its corresponding mixed floras of South America appear to show a closer affinity with the Cathaysian than with Euramerican flora. However, this depends on the reliability in identification of some relevant plant taxa. Therefore, some remarks should be made here to certain significant or debatable species listed in Table 1 (Numbers in brackets refer to those shown in the Table):

1. Specimens described by Archangelsky (1960) as *Sphenophyllum thonii* from Chubut of Santa Cruz, Patagonia of Argentina, are found by Srivastava and Rigby (1983) to be distinct from the Euramerican plant. They are placed under a new species *S. archangelskii.*
2. Forms described under *Sphenophyllum thonii* var. *minor* Sterzel by Walton (1929) from the Wankie District of Zimbabwe, by Teixeira (1946) as *S. thonii* from Mozambique, and by Arrondo (1972) as *S. thonii* from Argentina are considered by Srivastava and Rigby (1983) to be a new species *S. waltonianum.*
3. It seems to be doubtful whether the form *Pecopteris* (*Asterotheca*) *anderssonii* found in Argentina has any real affinity to Cathaysian species. The type-specimens of the latter are distinguished by the slightly lobed based pinnules and more divided lateral veins.
4. The Xiagangjiang form, *Pecopteris* aff. *arcuata* with a venation of *Pecopteris unita*-type, in my opinion, is probably identical with the specimen described by Hsü (1976) as *Dichotomopteris qubuensis* and also more or less resembles the specimen named *P. unita* by Walton (1929) from the Wankie flora.
5. Both the sterile and fertile specimens of the Wankie flora regarded by Lacey and others (1966) as *Pecopteris arcuata* Halle and those originally assigned by Walton (1929) to *P. unita* from *emarginata* (Goepp.) resemble so strongly in shape, size and venation the material described by Hsü (1976) as *Dizeugotheca qubuensis* from the Qubu flora that they may be of specific identity with one another and represent a new form of *Pecopteris.* The Qubu specimens have been later named *Pecopteris qubuensis* (Hsü) Li (1983, p. 138).
6. Rigby (1970) has expressed the opinion about the Brazil form described as *Chiropteris reniformis* Kaw. that its specific identity is probably not entirely free from doubt.

Judging from the above remarks, one can see that the true relationship between the southern and northern floras as indicated by the presence of Cathaysian or "Northern" elements in South Africa and South America is somewhat doubtful. Then how about the view point for the mixed floras concerned that has held by some palaeobotanists should be? Is it groundless? I don't think we can arrive at this conclusion for the time being,

Table 1—Some significant Cathaysian and "Northern" elements of the mixed Permian floras.

REGION	Turkey	Saudi Arabia	Kishmir Area	Xizang, China South	Xizang, China Central	Soviet Far East	W. New Guinea	S. Spain	Zimbabwe etc.	Chubut.etc. Argentina	Parana, S. Brazil	Remarks
FLORA or FORMATION	Hazro	Unayzah	Mamal	Qubu	Jianzhanong Fm. Xiagangjiang	Barabash-kaya Fm. Pospelovka Fm.	Irian Jaya	Guadalca-nal	Wankie (U. Ecca)	Lubeckense	Itararé & Guata	
SPECIES / AGE	P_2^2	P_2 or P_1^2	P_1^2	P_1^2	? P_1^2	P_1 & P_2	P_2	P_1^2	P_1	P_1	P_1	
Annularia mucronata		x										(1)– (6) See explanations in the text
Lobatannularia ensifolia			x									
Lobatannularia heianensis	x	cf.				x						
Lobatannularia sp. (or type)				x				x				
Sphenophyllum thonii									x	x(1)		
Sphenophyllum thonii var. *minor*			x						x(2)			
Sphenophyllum cf. *koboense*	x											
Sphenophyllum cf. *oblongifolium*								x	x	x	cf.	
Sphenophyllum cf. *verticillatum*								x	x			
Pecopteris (*Asterotheca*) *anderssonii*										x(3)		
Pecopteris (*Asterotheca*) *orientalis*					?	x						
Pecopteris (*Asterotheca*) *hemitelioides*		cf.							x	x		
Pecopteris (*Ptychocarpus*) *arcuata*				?(4.5)	aff.(4)				x(5)			
Pecopteris unita								x	x(4)	x		
Rajahia (*Pecopteris*) *mamalensis*			x		?							
Fascipteris hallei	x	x										
Fascipteris sp.							x	x				
Chansitheca cf. *kidstonii*									x			
Chiropteris reniformis											x(6)	
Gigantonoclea hallei	x											
Gigantonoclea sp.		x					x					
Plagiozamites oblongifolius					?							
Psygmophyllm cf. *multipartitum*								x				
References	Wagner, 1962; Archangelsky & Wagner, 1983	EL-Khayal et al., 1980; Lemoigne, 1981; Pers. comm., 1984	Singh et al., 1982	Hsü 1976; Singh et al. 1982; Li, 1983	Li et al., (in press)	Zimina, 1967, 1969, 1983	Pers. Comm. 1983	Broutin, 1981, 1982	Walton, 1929; Lacey et al., 1966	Archangelsky, 1957, 1960, 1971; Archangelsky & Arrondo, 1967, 1975, etc.	Dolianiti, 1952; Archangelsky, 1960; Rigby, 1970, etc.	

because the distribution pattern of these elements, the close resemblance in floral composition among different sites as well as the presence of some species closely similar to those of northern hemisphere all point to the fact that these characteristics cannot be considered to be from any accidental event. Even judging only from morphological features of the megafossil plants is not meaningless. For example, a commonly presented pecopterid plant with a venation of *Pecopteris unita*-type, the widely distributed *Sphenophyllum thonii* or *S. thonii* var. *minor* of northern hemisphere and the superficial likeness of some other arthrophytic plants—all of these have not been found in the typical Glossopteris flora indeed, and appear to indicate a special aspect of mixed flora. The importance of these elements thus should not be overlooked.

Besides, another pecopteroid form (not listed in Table 1), i.e. the socalled "*Pecoteris phegopteroides* (Feistmantel) has been found in the Hazro and Unayzah floras. The likeness between this plant and *Dizeugotheca phegopteroides* of Gondwanaland seems to be superficial. The specimens of the Hazro flora have recently been transferred to *Pecopteris nitida* Wagner (Archangelsky & Wagner, 1983, p. 89). The Unayzah specimens seem probably to have nothing to do with true *Asansolia* (*Pecopteris*) *phegopteroides* (Feistmantel) Pant & Lata, 1976, either.

It should be mentioned here that the occurrence of many species of *Sphenophyllum* in the mixed floras of South Africa and South America, represented by *S. thonii* and *S.* cf. *oblongifolium*, etc. was once considered to be a curious phenomenon by Lacey and others (1966, p. 24) and they wrote: "The curious assemblage of *Sphenophyllum* alone suggests that the affinity of the Wankie flora is closer to the Cathaysian than the Euramerican flora."

Of course, more emphasis should be laid on the presence of such plants as *Lobatannularia, Gigantonoclea* and *Fascipteris* which indicate a true affinity with the Cathaysian flora; especially the important genus *Lobatannularia* which is not only widely distributed in the Permian floras of Hazro, Unayzah, Mamal, Qubu, Guadalcanal and the Soviet Far East, but often occurs in the Nanshan (Qilianshan) mixed flora of Cathaysia-Angara type and in the southern belt of the Far East subprovince of the Angara flora (e.g. the Dzungaria Basin in Xinjiang and Ichun in Heilungjiang, China). It appears that this kind of arthrophyte has a high adaptability* to different ecological environments: it possibly often played a pioneer role as a representative of the Cathaysian flora when the floras migrated or mixed together with the change of ecological conditions. Thus, in some mixed floras they are found as individual "stray elements" of the Cathaysian flora.

One can see from the above discussion that although the identification of some taxa among the mixed floras is doubtful, the significance of their being taken as indicators of a given flora should not be strongly reduced. Some plants mentioned above, i.e. *Sphenophyllum waltonianum, S. archangelskii, Pecopteris* aff. *arcuata* (or *P. qubuensis*) and "*Pecopteris phegopteroides*", might be taken as indicators of the mixed Permian Cathaysia Gondwana floras.

DISTRIBUTION AND ORIGIN OF THE MIXED FLORAS

The Permian floras of the Wankie District of Zimbabwe, of Santa Catherina, Argentina and the Parana Basin, southern Brazil have long been accepted as mixed floras dominated by Gondwana elements in association with northern elements. However, little discussion has been given to their distribution area, mutual relation and origin.

Since the sixties, different assumptions have been put forward by many scientists, e.g. Wagner (1962), Chaloner and Meyen (1973), Plumstead (1973), Lemoigne (1981), Archangelsky (1975) and Broutin (1981) on the palaeophytogeography of the southern and northern floras to the migration direction of the relevant floras and the formation of the mixed floras during Permian time. However, most of those assumptions are too simple to explain such complicated problem.

The Permian phytogeographical distribution is shown in Map 1 (including the mixed floras). This is based on the previous works combined with the data derived from Qinghai-Xizang Plateau of China during the last decade. It also attempts to discuss respectively the origin of the mixed floras according to different areas or different geographical position.

Asia and its neighbouring areas

As shown in Map 1, the distribution area of the mixed floras in Asia would be largely restricted to the presumed Median Plate supposed by Li Chun-yu and others* (1982, 1983). If we reconstruct the Qinghai-Xizang Plateau, the Himalayan ranges and the Indian Shield into their original manner during Permian, this belt or the Median Plate approximately would lie in an east-west direction between the Gondwanaland and the Eurasian Plate. And judging from the plentiful data about the sedimentary facies and invertebrate faunas in the Qinghai-Xizang Plateau and Himalayas, the severe cold climate in Gondwanaland had been persistently prevailing till the beginning of the Asselian-Sakmarian epochs. The climate became warmer towards the end of

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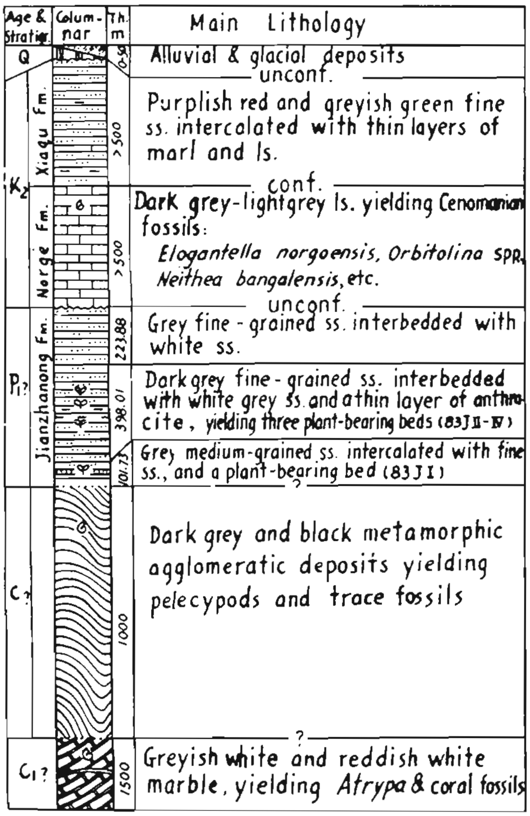
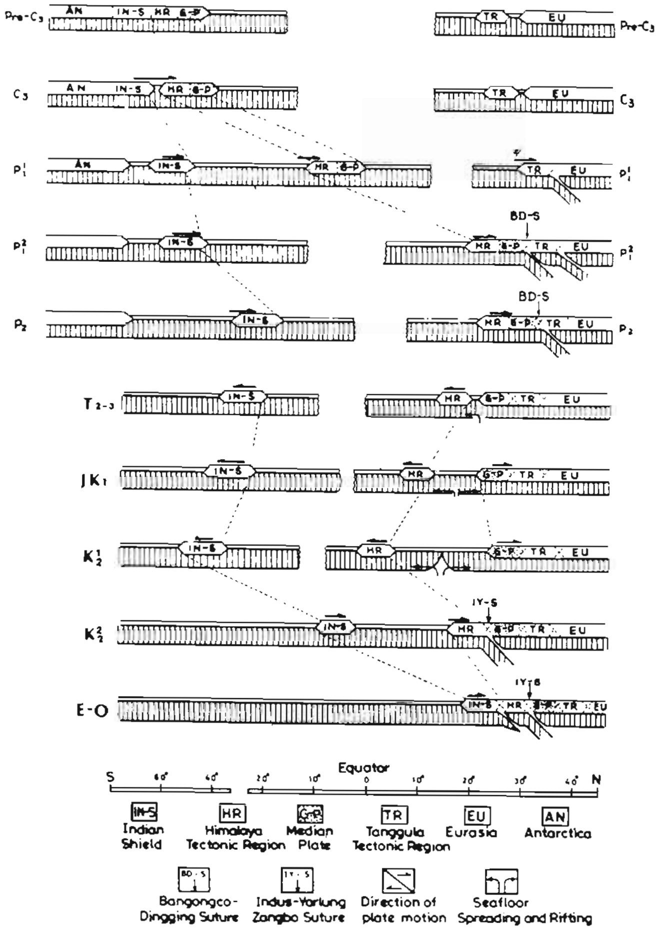
*It does not resemble those continental plates which are usually composed of one or some nuclei, but consists of a cluster of microcontinents separated from Gondwanaland and then welded together through interactions of Eurasian and Arabian-Indian Plates (after Li Chun-yu *et al.*, 1982).



Text-fig. 1—Generalised columnar stratigraphic section on the Xiagangjiang area of Gerze and Cogen counties, Xizang (Tibet).



Text-fig. 2—Schematic cross section from North Antarctica to Xizang (Tibet) mainly illustrating activity of Plates in Tethys-Himalaya Tectonic Domin.

Sakmarian. Since then, warm water faunas abundantly flourished at the Artinskian epoch, while cold water faunas only occasionally developed—these indicate that a warm or subtropical climate prevailed in the Median Plate area. The background leading to this change is the global regression at the end of Early Permian on the one hand and, on the other, the start of the drift of Indian Subcontinent (once a part of the Gondwanaland) and the southern part of the Qinghai-Xizang Plateau since Late Carboniferous from the main body of Gondwanaland which drifted successively northwards to the warm-subtropical area.

Such ecological environment and time-space relations provide natural conditions for the formation of mixed floras through mutual connection and migration of some elements came from essentially different floras of the southern and northern continents during Permian Period.

Based on these considerations, here I first attempt to give an explanation for the formation process of the mixed floras of Tibet and its neighbouring areas (Map 2; Text-fig. 2).

1. The Bangongco-Dingqing Suture Zone is tentatively considered by the writer to represent the Palaeo-Tethys lying between Gondwanaland and ancient Eurasia. All tectonic regions south of this Zone formed, together with the Indian Shield, parts of Gondwanaland which was situated near the Antarctic Region in Late Palaeozoic.

2. They drifted northwards in Late Carboniferous, crossed the Equator in earliest Permian and finally, highly probably, collided with the Tanggula Tectonic Region in Late Early Permian.

3. After the collision, the Permian flora that originally flourished in the Cathaysian South Subprovince might have migrated southwards across the Bangongco-Dingquing Suture Zone first to meet the Glossopteris flora in some places, such as Xiagangjiang in central Xizang, where the latter flora had flourished.

4. Meanwhile or slightly later, the successive and continuous southward migration of the Cathaysian flora and its intermingling with the local flora of southern Xizang produced the Qubu Glossopteris flora; but only a few forms of the Cathaysian flora survived in the Qubu flora. This was either due to somewhat severe natural conditions, or because the Qubu area stands so far away south of the original sites of the Cathaysia flora that only those forms with highly adaptive ability were able to arrive here and survive.

5. As for the Indus-Yarlung Zangbo Suture Zone it has now become relatively clear that it started from the Middle-Late Triassic onward. A great fracture occurred with the expansion of the sea floor and a Mesozoic Ocean or Mesotethys was progressively formed; from the Late Cretaceous onward, this ocean began to reduce and the crust plate quickly drifted northward resulting in subduction. This suture zone did not come into being until both crustal plates, to the north and south of this line, collided in the latest Late Cretaceous or the earliest Tertiary. In short, this suture was formed only after the existence of the mixed Permian flora in the Himalayan-Southern Xizang Region.

As mentioned above, the Kashmir Mamal mixed flora lies in or very near to the Indus-Yarlung Zangbu Suture Zone; the formation of this flora could naturally be explained by the same plate tectonic history as that of Xizang (Tibet). Singh *et al.* (1982, p. 220) expressed a somewhat similar view to the Median Plate assumption in explaining the origin of the Mamal mixed flora. They wrote: "This naturally raises the question whether there was a separate landmass between the Cathaysia on the north and the Gondwanaland on the south".

Western Asia and South-western Europe

The mixed floras in this area include those found from Hazro in Turkey, Unayzah in Saudi Arabia and Guadalcanal in southwestern Spain. Either in geographical position or in the main floral composition, these floras stand very close. Wagner (1962, fig. 1) is inclined to call the area which covers Turkey, Spain and North Africa next to the Mediterranean Sea—the Permo-Carboniferous Equatorial Belt. Now the Unayzah mixed flora has been found in the Arabian Peninsula, the southern boundary of Wagner's belt naturally can be extended southward. Accordingly, the whole North Africa could be regarded as a part of the Mixed Floral Province. The background of the formation of the mixed floras in this area is possibly similar to that occurring in Tibet-Himalayas. Of course, the concrete process can not be inferred until the tectonic situation and the type of plate movement is understood.

The Soviet Far East

Zimina (1983) attempted to explain the migration route of *Glossopteris* and *Gangamopteris* etc. of the flora of Soviet Far East through the Cathaysian floral Province in the mainland China. This is obviously very difficult and unacceptable.

I consider we could explain this puzzle—why *Glossopteris*, etc. are present in the northeastern corner of Asia in another way according to Plate Tectonic Theory and some geological and palaeontological phenomena observed from Japan Isles.

Using the Plate Tectonic theory and palaeomagnetic data, McElhinny *et al.* (1981) inferred that the Asian Continent was quite different in Permian from what it appears today. It was composed of several isolated palaeo-blocks distributed in different positions in the Tethys or Proto-Pacific (cf. McElhinny's fig. 1). The "Sikhote Alin" block, where the mixed flora under discussion existed, lies in a place around 30°N, as shown in their Late Permian phytogeographical map. To the west of, and not far from, it was the "Tarim" (including the Dzungarian basin) palaeoblock in Xinjiang, China; while to the east was the "Southeast Asia" palaeoblock (south China included) separated by sea.

If my explanation about the formation of the mixed flora in Tibet and Himalayan Kashmir could be applied here, and the "Sikote Alin" palaeoblock be presumably extended back to Middle-Late Carboniferous, then this block together with northeastern Africa and Arabian Peninsula would be a part of the Gondwanaland in Late Permian resulting in a situation as shown in McElhinny's figure 3. In this case, the "Sikhote Alin" palaeoblock possibly the Late Permian Angara Far East subprovince belonging to the "Tarim" Dzungaria block on the one hand and stood close to came into contact with some Cathaysian elements migrated from the "Southeast Asia" palaeoblock on the other; consequently, a peculiar mixed flora with three aspects of Gondwana-Cathaysia-Angara floras took shape. The "Sikhote Alin" block continuously drifted northward in Mesozoic and finally to the present position in Cenozoic and conjugated with the Asia mainland into a huge mass along the folded belts formed in Late Mesozoic. In this regard, the paper given by McElhinny and others also mentioned that Japan and Southeast Asia were also connected together in Permian and positioned near the Equator; subsequently it moved northward progressively until arriving at the present position.

It should be pointed out that the concept "Japan" as used by McElhinny and others is much encompassing for explaining its geological history. As currently recognized, the Permo-Carboniferous strata of Japan are mainly marine and hence unfavourable for preservation of fossil plants; only a few Cathaysian elements of late Early Permian to Late Permian age were occasionally found. However, the Mesozoic floras and related strata of Japan are well documented through detailed investigation; based on which the Japan Isles can be divided palaeobiogeographically and tectonically into two distinct zones: the Inner Zone (near the Asia mainland) and the Outer Zone (toward the Pacific Ocean). Taking the Late Jurassic Early Cretaceous floras as an example, here we have an Inner Zone Tectori-type flora and an Outer "Ryoseki"-type flora, and they are entirely different either in floral composition or in the source material of the plant bearing strata. It was thought that this difference was due to age discrepancy, now it has become clear that it is not the case. Other assumptions do not lead to a reliable result either. Recently some

Japanese scientists (e.g. T. Kimura, pers. comm., 1982) are also inclined to rely the data given by McElhinny and others, and suggest that the Outer Zone was originally a fragment of the Gondwanaland at the beginning of Permian and then it drifted northward and conjugated with the Inner Zone which once existed as the marginal part of the main continent. This background thus leads to the great difference geologically and palaeontologically between the Inner and Outer Zones. This difference is clearly shown in the map "Floral Provinces of 'Tectori'-type flora and 'Ryoseki'-type flora during Late Jurassic-Early Cretaceous prepared by Kimura (1979, 1980). More interesting is that a locality with 'Ryoseki'-type flora inserted strangely into a place near Vladivostok where it seemed to belong to the Inner Zone. This is quite similar to the mixed flora of the Soviet Far East under discussion. It is very likely that both of them belong to the 'Sikote Alin' palaeoblock. Of course, the presumption here I present needs to be verified in the future.

Western New Guinea

This is a very complex place where several big plates and some tectonic fracture zones were passing through or conjugated together. The regional geology related to the mixed flora is not yet clear and so any inference must be premature. However, this site is not very far from Djambi in Sumatra which has yielded a Cathaysian flora and stands as its southern most reach adjacent to the northern part of the Australian Plate. Furthermore, if the Qinghai-Xizang Plateau and the Indian shield be reconstructed to the earlier situation, i.e. prior to their northern subduction, compression and folding, then New Guinea would possibly belong to the eastern extension of the Li's Median Plate. In this kind of transitional belt the Gondwana-Cathaysia mixed flora is not unexpectable. Rigby (pers. comm., 1983) is inclined to explain the occurrences of this mixed flora that the only way this could have happened is based on the reconstructions (Plate 6) given by Carey (1982) for the expanding earth theory.

South-eastern Africa

Lacey *et al.* (1966, p. 23) wrote "The nearest comparison of the Wankie flora is certainly with the Cathaysia flora of Shansi in China, described by Halle (1927)". Discussing the close similarity between the Wankie flora and the contemporaneous mixed floras of Santa Cruz, Argentina they pointed out again, "The curious assemblage of *Sphenophyllum* species alone suggests that the affinities of the Wankie flora are closer to the Cathaysia than the Euramerica flora". On the other hand, another fact should not be overlooked that is in the South Asia Subcontinent proper which is near to the northern Cathaysian flora province; no Cathaysian elements have been reported here in the *Glossopteris* flora. Such curious relations like a Chinese saying, "far and wide for what lies close at hand" how did it happen? In discussing the development history of the Wankie flora in South Africa, naturally one can not avoid answering this question.

I don't know the detail of the geological history of south-eastern Africa but from Map 1 we can see that the Arabian Peninsula, which has the Unayzah flora with many Cathaysian elements, is separated from the northeastern Africa only by the recently formed rift of the Red Sea. Many Cathaysian and/or other "Northern" elements in the Unayzah flora, under favourable conditions, naturally could move southward to Zimbabwe and its neighbouring areas to intermingle with the local Glossopteris flora. This might be how the Wankie type mixed flora happened.

Besides, one can see from the "Late Permian Continental Reconstruction" by Scotese and others (1979; see Condie, 1982, p. 192, figs 9, 7) that the Arabian Peninsula is close next to the northwestern corner of Africa, while India and Madagascar insert obliquely between the main Gondwanaland (through conjugation of South Africa and South America) and Antarctica. There is a quite wide ocean between India and Tibet plus Turkey-Iran palaeoblock. If these tectonic units or blocks which are the components of Li's Median Plate began to be separated from Indian Plate in Late Carboniferous, as some new data indicated and drift quickly to the Equator and then to the northern subtropical temperate zone, the distance between these units and India would be progressively bigger with the change in time and place. Consequently, the chance for elements of the Cathaysian flora intermingling with those of the Gondwana flora in the Subcontinent of south Asia became little and little. That is why the Wankie flora shows a much more close affinity with the Cathaysia flora than other floras.

South America

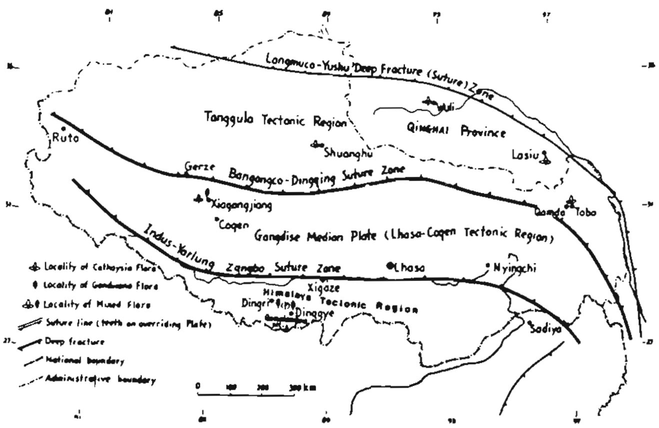
The mixed floras of Argentina and southern Brazil in South America and the Wankie mixed flora in South Africa have long been considered to resemble each other in a certain floristic composition. As already mentioned above, based on the Plate Tectonic Theory Archangelsky and Arrondo (1975) conjugated these floras on both sides of the Atlantic Ocean into a specially named "Austroafroamerican Floristical Province".

However, though some *Sphenophyllum* species in the mixed flora of South America are largely the same as those in the Wankie flora, the associated so-called Cathaysian elements in the former are different from and rarer than those in the Wankie flora. Therefore, I think both floras possibly have different origin. As for South America, it concerns with the true relationship of its flora with *Gigantopteris* flora *sensu lato* found in Kansas and Oklahoma of the southwestern United States. Especially after the preliminary report of the discovery of Cathaysian flora in Venezuela (Wagner, 1978*), this possible relation becomes more reasonable. However, the question is that the known presumed Cathaysian elements in the mixed flora of South America have not yet been found in the "Gigantopteris" flora of North America. So it seems attractive that the mixed flora or some of its components in South America migrated through the route passing the Guadalcanal flora in Spain and the Hazro flora in Turkey if there was a real relationship between the mixed flora of South America and that of East Asia. The occurrence of the Atlantic Ocean is a later event in geological time; during Permian this distributional belt of mixed floras along Turkey, southeastern Spain and possibly northern Africa extended westward just pointing to Venezuela where the presence of Cathaysian flora is thus not unexpectable. However, this will meet with a difficult problem again because the mixed floras around the present day Mediterranean Sea, being nearly all of Late Permian are younger than that of mixed floras of South America. I am still puzzled over these mixed floras having Cathaysian elements associated with the Glossopteris flora.

CONCLUSION

Agreeing with the view that mixed floras were really present in the geological past, the present paper deals with the origin and distribution of the mixed Permian Cathaysia-Gondwana floras and other problems.

In Asia, except for the Soviet Far East, almost all the known mixed floras are distributed in the same geographical belt which roughly corresponds to the Turkey-Iran-Gandize Median Plate named by Chinese scientists. This correspondence is not a mere accident but is difficult to explain by some theories such as Parallelism in evolution, etc. Using some relevant achievements resulting from the recent researches based mainly on the Plate Tectonic Theory, especially that concerned with Tibet I attempt to apply the Median Plate supposition to explain the distribution and formation of mixed floras. And for this purpose, a comprehensive map showing the distribution of Permian floristical provinces in the world and model of schematic cross-sections mainly illustrating the activity of Plates in Himalayas-Tibet Tectonic Domain have been tentatively made which, I hope, might somewhat be useful to further researches on this subject.



Map 2—Showing fossiliferous localities of Permian plants and main structure pattern in Xizang (structure pattern after Li Chun-yü & others, 1982).

The composition of a given mixed flora, except those species descending from its parent floras (s), most probably includes some newly evolved endemics. It could not be produced in isolation, nor is one of the parent floras simply intermingled with another. A certain number of new plants might have evolved characteristics of their own, either from the native parent flora or any flora(s) originating in some other places, which is intimately related with time and space in migration process of its parent floras as well as the ecological conditions. Such new forms as *Pecopteris* cf. *P. unita*—type and *Sphenophyllum waltonianum*, both known from southeastern Africa and Kashmir Himalayas and Tibet, may be regarded as diagnostic plants of the related mixed flora. The same perhaps holds good for explaining the presence of some new glossopteroid plants found in the mixed floras in Hazro, Turkey and the Soviet Far East area near Vladivostok.

Of course, the reliability of the assumption explaining the mixed flora problem needs the big premise, i.e. some tectonic maps and palaeophytogeographical reconstructions for a particular geological period, are trustworthy. This question still exists in the present paper.. Furthermore, objections would be lodged against my interpretation for it just based on the morphologic features of plant megafossils and a few taxa in particular, without any evidence of fructification and cuticular structures. But, I just confined my discussion on objective material that I could gather, though my interpretation naturally includes some assumptions: I hope this would be missible and excused.

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*See IOP Newsletter 8 (Jan., 1979), p. 16.

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SIXTEENTH BIRBAL SAHNI MEMORIAL LECTURE

Our oldest rocks and the early record of life

B. P. Radhakrishna

The Geological Society of India, Bangalore-560 019, India

NEARLY fifty years ago, while still a student, I had the privilege of hearing Professor Birbal Sahni, one of the greatest scientists India has produced. I remember him as a most charming personality who thrilled the audience with his exposition of the theory of drifting continents. Professor Sahni's interest was largely centred round the study of extinct plants and this lead him on to take a keen interest in geology. His contributions to the Indian geology are as profound as those to Botany. The twin sciences of geology and botany suffered a grievous loss in the untimely death of this distinguished scientist.

I am grateful to the Director of this Institute for the honour he has done in inviting me to deliver the Founder's Day lecture. The subject I have chosen for my talk is on 'Our oldest rocks and the early record of life.' It is one of great interest to both geologists and botanists. Rapid advances are being made in this multi-disciplinary field in which geologists, biologists, organic chemists, and geochronologists are working together to unveil the mystery of the origin of life. It will be my object to unfold this fascinating story as best as I can. The story of the origin of life is inseparably tied up with the early evolution of the planet Earth itself. It is inevitable, therefore, that to gain a correct understanding of the beginnings of life, we should go back into Earth history and understand how Earth emerged as a separate entity in the solar system and how it evolved through time. An understanding of how the atmosphere and hydrosphere initially developed is also a necessary part of such a study. Evidences for constructing the early history of Earth, the recognition of the major events which led to the beginning of life have to be looked for in our oldest rocks.

There are, however, serious limitations to such studies. Rocks older than 3800 m.y. have not come to light. We really do not know what happened during the first 1,000 m.y. of the birth of the earth as it is shrouded in mystery. Secondly, the oldest sedimentary rocks that could have preserved traces of life are in a highly altered and metamorphosed state. We have to work with such fragmentary data in order to piece together scraps of information and try to construct a history of past events.

Schopf, one of the most active palaeobiologists of the present day has suggested classifying all available evidences relating to early life into four categories: (i) compelling evidence, (ii) presumptive evidence, (iii) Evidence of permissive or possible category, and (iv) Evidences that are completely missing. As we go along tracing the early history of the Earth we will see that the evidences which have so far come to light on the vexed question of the origin of life are only of the permissive or possible category. A great deal of further search for the missing evidence has to continue before we are in a position to quantify our evidence as compelling.

We in India are in an advantageous position to carry out palaeobiological studies. Nearly a third part of our country is covered by the oldest rocks. Every part is easily accessible. Some of the largest Proterozoic sedimentary basins of the world containing sediments which have not suffered from subsequent metamorphism are to be found in India. We have, therefore, rocks ranging in age from 3,800 to 600 m.y —the entire Precambrian—the period during which life evolved and diversified. This country, then, should be capable of contributing substantially to the evidence that is being gathered from all parts of the world to trace the beginnings of life on this planet.

In spite of such excellent opportunities, palaeobiological research in India has not made much headway. Text books and monographic studies on Early Life which have appeared in recent years do not make even a mention of India or of Indian material. This is surprising since possibly the first record of fossil stromatolite came from the Indian Precambrian. There is urgent need to intensify study of our oldest rocks and bring to light evidences that lie hidden in them—evidences so compelling as to make the rest of the world take notice and give due credit.

EVOLUTION OF THE PLANET EARTH

Our story begins with the origin of the Earth. Latest advances in astronomy point to a time when there was no Sun, Earth or any of the other planets of the Solar System It is said, at the very beginning, there was some primordial substance which burst with a big bang 13,000 m.y. ago and released elementary particles into empty space. These elementary particles later combined to form a variety of atoms of heavier nucleii of which the simplest and the most abundant are hydrogen and helium. Over 95 per cent of the universe is made up of two elements—hydrogen and helium. The rest of the elements are believed to have evolved out of hydrogen through a series of complex thermo-nuclear reactions at high temperature and pressure. Hydrogen burned to produce helium and helium produced carbon and oxygen. At still higher temperature silicon and other heavier elements like iron and nickel were produced. Such reactions took place in the supernovae long before the accretion of the Earth.

The Solar System as such came into being through gravitational collapse of an interstellar cloud of gas and dust. The Earth formed through accretion of planetissimals made up of a mixture of silicate and metal particles similar to the present day chondritic meteorites. The meteorites falling from outer space reflect the composition of planetissimals which gathered together to form the primitive earth.

EVOLUTION OF THE ATMOSPHERE

The Earth when it was first formed was devoid of an atmosphere and was also waterless and lifeless. There was no differentiation into continents and oceans. The outer surface of the mantle itself formed the crust. This was bombarded by meteorites which destroyed this crust and allowed for differentiation to take place. Great floods of lava erupted and covered the surface of the earth.

As the planet further evolved, the gases originally trapped inside the earth were released to form the earth's initial atmosphere. The gases so released initially were lighter, like hydrogen, helium and argon. These being light did not stick to the earth but escaped into outer space. A secondary atmosphere developed which was rich in methane, ammonia and water vapour. Even this was transitional and changed to one of carbon dioxide and nitrogen. Such a stage had been reached by 3,800 m.y. ago. The inner planets like Venus and Mars, however, have been observed to preserve such an atmosphere even today. On Earth, there was a further change as a result of photosynthesis. Oxygen was produced by green algae (cyanobacteria). Carbon dioxide got fixed in photosynthetic algae and carbonate rocks. Oxygen content which was originally nil or present only in minor amount in the atmosphere steadily increased through time. Oxygen and nitrogen, it should be remembered, form 99 per cent of the present day atmosphere. Biological activity, therefore, played a decisive role in the build up of oxygen in the atmosphere on Earth. No other planet in the Solar System has either free water or free oxygen in their atmosphere except the Earth. The formation of oxygen-rich atmosphere is a landmark in the history of the planet Earth, as it formed the starting point for the diversification of life forms.

The rock record confirms many of these changes. The lack of oxygen in the early atmosphere is supported by the occurrence of fresh unaltered grains of uraninite and pyrite in the oldest conglomerates of the Archaean (~ 3,000 m.y.). The beginning of life and the first release of oxygen is documented by the deposition of banded iron formation rich in oxide minerals of iron. The steady increase of oxygen in the atmosphere and the onset of processes of oxidation and weathering is confirmed by the first appearance of continental red beds around 2,000 m.y. ago.

EVOLUTION OF THE HYDROSPHERE

We have already noted that the first billion years of Earth's existence witnessed profuse degassing of water vapour from the earth's interior. This vapour condensed and poured out as rain on Earth's surface and collected to form the first water bodies on Earth. There were no real oceans to start with but only shallow warm seas developed around hydrothermal vents. Whether this happened gradually as a result of continuous volcanic outgassing or whether it was sudden and catastrophic, happening at an early stage in the history of the earth, is not clear. The oceans are believed to have reached their present volume 2,000 m.y. ago and since then there has not been much of a change. The early seas were probably more acidic because of dissolved carbon dioxide.

OUR OLDEST ROCKS

Although the age of the earth is put down at 4,500 m.y. on the basis of radiometric data, oldest rocks so far identified on earth do not go beyond 3,800 m.y. Such old rocks are extremely rare. They were till recently known only from Greenland (Moorbath *et al.*, 1973), but several occurrences have come to light in recent years. Rock strata described as Older Metamorphics in the Singhbhum region of Bihar (India) may prove to be still older, as the gneisses intruding them have given an age of 3,800 m.y. (Basu *et al.*, 1981). It is claimed that unpublished work in progress is indicative of rocks of still older ages existing in the Dharwar Craton of Peninsular India (Monrad *et al.*, 1982). The Indian Precambrian shield, therefore, may prove to be one of the oldest continental fragments of the world.

The oldest dated rock in South India is a migmatitic gneiss giving an age of 3,358 ± 66 m.y. (Beckinsale *et al.*, 1980). These gneisses are intrusive into still older sediments including graphitic schists originally of the nature of carbonaceous shales to which the name 'Sargur Supracrustals' has been given (Swami Nath & Ramakrishna). No direct estimation of the age of the sediments has yet been made. They are in all probability older than 3,400 m.y.

There have been recently claims of still older ages of 4,200 m.y. for zircon grains in a 3,100 m.y. old gneisses from Pilbara, Western Australia (Froude *et al.*, 1983). These older ages, however, have not been accepted (Moorbath, 1983; Sharer & Allegre, 1985). Rocks dated at 3,800 m.y., therefore, are the oldest so far known and it has not been possible to extend earth history, as recorded in rocks, beyond 3,800 m.y. The search for identifying still older rocks, however, will continue, but the success ratio is going to be limited. So far as geological record is concerned the first billion years (the missing billion), remains blank and evidence of what happened during this period probably has to be pieced together from a study of other planets.

CONDITIONS 3,800 m.y. AGO AS REVEALED BY THE ROCK RECORD

Prior to 4,000 m.y. ago we may presume that conditions on earth were not particularly hospitable to life. The temperature was high. There was neither atmosphere nor hydrosphere.

The study of oldest known sediments indicates the existence of shallow oceans. Continental masses at that period were probably very few. Processes of erosion, transport and deposition had no doubt set in, and deposition of clastic and chemical sediments had just started. The atmosphere was deficient in oxygen and particularly enriched in carbon dioxide and nitrogen. Volcanism was active with release of abundant gases. The landscape was studded with volcanoes belching smoke and lava. The seas were warm and acidic. Sediments that were being deposited were mostly immature mixtures of crustal and volcanic material. These were the conditions under which life on earth appears to have made its beginning.

LIFE IN OUTER SPACE—COSMIC ORIGIN OF LIFE?

Carbonaceous meteorites are known to contain not only amorphous carbon but also various hydrocarbons. The earth too must have contained hydrocarbons from the very beginning and could have formed the basic material for the origin of life.

Modern thinking appears to be in favour of considering the origin of life as involving a lengthy process of chemical evolution which first generated simple organic compounds in the early atmosphere. These primary products became increasingly complex culminating in the evolution of polymeric structure, i.e. number of repeated basic units held together by chemical bonds having capabilities of self-replication (Chang *et al.*, 1983). Chemical evolution is thus believed to have preceded biologic evolution. The energy available for promoting these chemical reactions was probably that provided by sunlight, electric discharges, thunder and lightening. Proteins and nucleic acids must have been synthesized in such an environment. Such transformation probably took place in the atmosphere and the seas of that period and in their boundary with the land surface. The preservation of abundant carbonaceous material in earliest Archaean sediments lends support to this view. Organic matter thus started gathering and accumulated in the shallow oceans of that period. Life appears to have got cooked in such a primitive broth of organic compounds (Sylvester Bradley, 1972).

The idea that life originated in outer space is now being put forward forcefully. Hoyle and Wickramsinghe (1986) have projected the idea that a swarm of comet-like bodies were present towards the outer margins of the Solar System in its early history and were the sites of early biological replication. They feel that such bodies are more favourable venues for the development of life than the initially sterile surface of a small planet like the earth. Following this idea, they predicted that dust expelled from Halley comet would be organic in composition. Surprisingly, astronomers have reported material from comet Halley which looks organic like coaltar. Since Earth is perpetually embedded in a halo of cometary material, bacteria from outer space could have landed softly on earth without being destroyed by heat. These observations add a new dimension to the origin of early life.

HOW DID LIFE ORIGINATE 3,800 m.y. AGO

While there may be organic particles of carbon and hydrocarbons in other planets and in space, it is only on earth structures which have the capacity to replicate and transmit genetic characteristics to their descendents are found. The initial life forms were microscopic, mostly unicellular, in the form of minute spheres probably indistinguishable from carbon particles of non-biological origin (Schopf, 1978).

Microscopic carbonaceous objects resembling filamentous bacteria have now been found in a chert barite unit from North Pole, western Australia (Groves *et al.*, 1981). These are undoubtedly fossils, but it has not been possible to definitely prove that they were original and not contaminants. After five years of intense searching, the authors have admitted of their failure to discover more reliable evidence of life at North Pole. They do not deny that life existed before 3,500 m.y. ago but affirm that unequivocal evidence of its existence has probably not been preserved.

A recent discovery of some importance is the identification of giant clams at a depth of 5,640 m on the steep inner wall of the Japanese trench. Similar clams have been noted close to hot springs. This is very significant as it points to development of ecosystems on geothermal rather than on solar energy (Jennesch & Mottl, 1985). This lends support to the hypothesis that early life probably originated first near hydrothermal vents.

The division between life and non-life is stated to be an artificial one. According to Ponnamperuma the animate and inanimate are to be seen as lying in a continuum rather than as being one or the other. On such a scale, a virus which cannot replicate on its own would be somewhere near the middle as might some unknown proto cell that became the ancestor of life on earth.'

Growing crystals of clay are stated to have formed the first replicating evolving systems and ushered in the age of organic cells. The earliest known organisms are considered by Schopf to be similar to the type of bacteria known today—blue green algae, that unlike other bacteria produce oxygen through photosynthesis.

According to Margulis, the story of life on earth is overwhelmingly a story of bacteria, microscopic cells that lack nuclei. For two billion years, i.e. more than half the time that life has been on earth, the bacteria or prokaryotes had the planet to themselves. They altered the atmosphere and evolved all of life's miniaturised chemical systems—achievements that so far humanity has not approached.

THE NATURE OF THE EARLY LIFE FORMS

Schopf (1983) a leading palaeobiologist of the present day speculates that early life inhabited an aqueous and presumably benthonic environment, the muds and silts of bottom sediments beneath wave base where organic detritus could accumulate. The early life forms were morphologically simple, undifferentiated, non-mobile, non-colonial and presumably spheroid organisms. It is one of the marvels of nature that the diversity of life forms of the present day started from such humble beginnings. All life on earth, from bacteria to the banyan tree, or even man, evolved originally from a single ancestral cell!

STROMATOLITES

Stromatolites are organo-sedimentary structures produced by the trapping of sediments by metabolic activity of micro-organisms. They thus represent the only undisputed fossils in Archaean rocks (Walter, 1983; Krumbein, 1983). Their first appearance in the geological record is a pointer to the presence of photosynthetic bacteria. They are not regular fossil organisms but are related to the algae in the same way as coral reefs are related to coral organisms. Surrounding environment had a significant role to play in the growth of stromatolitic structure. A number of varieties are now recognised such as mound-shaped stromatolites, branched columnar stromatolites (Baicalia) and conically laminated stromatolites (Conophyton). These have formed in a variety of depositional settings and provide an opportunity for studying palaeoenvironmental conditions and identifying ancient shore lines.

Stromatolitic structures were first identified in the Proterozoic Vindhyan rocks as early as 1872 (King, 1872, p. 164). The algal character of such structure was pointed out by Srinivasa Rao (1943). A list of earlier references to stromatolitic structure in the Proterozoic of India is given by Raha and Sastry (1982). Reports of Archaean stromatolites, however, are rare. Rarity of these structures is attributed to their obliteration through metamorphism.

Many more structures are likely to be identified in the coming years through careful field work. These stromatolites, when identified, have to be subjected to a careful study of their microbiota, since it is the microbe community which generated layered, domed and columnar structures so characteristic of stromatolites. Such studies are likely to provide valuable clues to the early evolution of life forms and to the mode of their preservation.

The Late Archaean and Early Proterozoic witnessed a change from a mobile environment to one of stable platforms in which bulk deposition of carbonate sequences became possible. These carbonates appear to have favoured the development of stromatolites. There was at that time a marked invasion and perhaps more effective utilization of such an environment (Walter, 1976). Stromatolitic structures have been found to be ubiquitous components of carbonate facies environments throughout the world (Schopf & Walter, 1983). A gradual but marked increase in mean diameter and size range and taxonomic diversity has been noticed during the Proterozoic (Schopf, 1977).

Russian geologists have made extensive studies and have used stromatolites to classify the Late Proterozoic and erect stromatolite biostratigraphy. Raha and Sastry (1982) have made a preliminary attempt in this direction for the Proterozoic sequences in India. Study of stromatolites, their morphology, morphogenesis and microbiology should, however, gain in momentum in this country. The need for improving descriptive methods and making use of numerical techniques has to be emphasized. Significant changes in microfossil assemblages have been noted at boundaries between Early, Middle and Late Proterozoic. Stromatolites of differing ages were probably formed by distinctively differing microbiota and could be stratigraphically useful. The Proterozoic sedimentary basins of India contain a rich harvest of stromatolites awaiting detailed examination. For a country of the size of India and with such abundant material available, there are very few palaeontologists who are interested in the study of early life, compared to the large number of geochemists, structural geologists and the like.

ARCHAEAN MICROBIOTA

There have been several sporadic attempts at identifying microfossils in rocks of Archaean age. Most of these finds on critical examination have been found to be not genuine. Schopf and Walter (1983) have formulated a set of criteria which have to be satisfied before the authenticity of Archaean microfossils can be accepted. These are:

Geological age—That the rocks containing microfossils are to be precisely dated and shown to be Archaean in age.

Syngenetic character—That the fossil-like objects are demonstrably syngenetic, physically imbedded in the rock and not extraneously induced contaminants.

Biogenicity—That the fossils are actually biogenic and not laboratory produced artifacts.

The last criterion is the most difficult to satisfy since a wide variety of non-biologic objects can imitate biologic microbiota. Cloud (1973) and Schopf (1975) are of the opinion that the bulk of the Precambrian microfossils are either artifacts of non-biologic origin or recent bacterial contaminants. Only two occurrences have so far been accepted as satisfying the above criteria: (i) microbiota from bedded stromatolitic cherts of the 3,500 m.y. old Warrawoona Group, Pilbara Block of Western Australia (Walter *et al.*, 1980), and (ii) the 2,800 m.y. old Fortescue Group of Hamersley Basin, also in Western Australia.

The Warrawoona microfossils, as described, are structurally complex, more advanced and indicate that the beginnings of life on earth must have occurred very much earlier. Recently well-preserved stromatolites from 3,300 to 3,500 m.y. old rocks in chert layers within the Fig Tree Group of Swaziland Supergroup in South Africa have been reported (Byerley *et al.*, 1986), which are morphologically complex but biogenically convincing. They are stated to be morphologically advanced. They are described as stratiform growing on a substrate of komatiitic lava and sediments deposited on the lava surface and covered by later komatiitic flows. Abundant fine-grained tourmaline included in the fine-grained laminae is suggestive of an environment dominated by boron-rich hot spring emissions and evaporite brines. Chert layers in between komatiitic flows elsewhere, should be carefully searched for stromatolite structure and Archaean microbiota. It is conjectured that life when it first appeared diversified rapidly and in all probability explored and occupied most, if not all, habitable ecological zones (Awramik, 1986).

We in India have to give more attention to the study of Archaean microbiota. Exposures are in no way inferior to those of Western Australia and South Africa. There is scope for making important discoveries in the older rocks after taking all due precautions.

CHRONOLOGY OF THE BEGINNINGS OF LIFE

Evidence from the geological record points to the presence of spheroidal prokaryotes as the earliest forms of life. Their energy requirement was probably met by fermentation of organic material of non-biologic origin—a stage reached during chemical evolution. Oxygen producing photosynthetic cells probably appeared earlier than 3,000 m.y. ago. These are believed to have lived in mat-like communities in shallow water and gave rise to the first stromatolite columns.

Filamentous fossil bacteria have been identified in thin sections of the laminated carbonate cherts from the Fortescue Group, Western Australia (Awramik *et al.*, 1983). These are claimed, as of today, the oldest undoubted fossils known in the geological record. The complexity of these forms indicates that life must have appeared much earlier.

The oldest stromatolites reported from India are those from the Karnataka (Dharwar) Craton. One is from Sandur (Murthy & Krishna Reddy, 1984) and the other from Dodguni by Boral (1986). Suresh (1982) has reported microfossils from Dodguni cherts.

The rate of change of biota during the first 1,000 to 1,500 m.y., after the first appearance of life was so slow that not much of a change in evolutionary pattern is noticed. Since 1,500 m.y. however, evolutionary changes have been rapid leading to increased taxonomic diversity (Schopf, 1975). Characterization of the fossil record in the period of approximately 900 m.y. prior to Cambrian time, and its ordering into biochronologic sequence is going to be a major challenge to palaeontologists in the comming years (James, 1981).

Schopf (1978) says that the style and tempo of evolution in the Precambrian was distinctly different from that of the later Phanerozoic era. The Precambrian was an age in which the dominant organisms were microscopic and prokaryotic, and until near the end of the era, the ratio of evolutionary change was limited by the absence of advanced sexual reproduction. It was an age in which the bench-marks in the history of life were the result of biochemical and metabolic innovations rather than morphological changes.

MAJOR STEPS IN THE EVOLUTION OF LIFE

Eight major steps have been recognised in the early evolution of life (Cloud, 1983). These are:

1. Origin of life around 3,800 m.y. ago.
2. Appearance of first stromatolites pointing to the

existence of some type of microbial life forms around hydrothermal vents feeding on sulphur ($>$3,500 m.y. ago).

3. Photosynthesis: Further development of stromatolites, precursors of blue-green algae, producing molecular oxygen as a result of photosynthesis (3,000 m.y. ago).
4. Appearance of enlarged cells and oxygen tolerating blue-green algae. Continental red beds pointing to presence of free oxygen in the atmosphere (2,000 m.y. ago).
5. Eukaryotic cells: Development of larger cells with nucleus (1,400 m.y. ago).
6. Appearance of Metazoa: Ediacara fauna—first appearance of multicellular aquatic animals.
7. Appearance of metazoa with shells—dawn of the Cambrian (550 m.y. ago).
8. Fully oxic conditions (100%)—the first appearance of fish and land plants. Biospheric evolution to the present day world—life filling almost all parts of the planet. It should be noted that in the first two stages oxygen was deficient. There was a gradual build up in oxygen content in atmosphere from 1 per cent around 3,000 m.y. ago to 100 per cent by 500 m.y. ago.

ECONOMIC IMPORTANCE OF PALAEOBIOLOGICAL STUDIES

Petroleum exploration—The study of palaeobiology is not without economic interest. For example, it has an important bearing on petroleum exploration. Kerogen is a geochemically altered organic matter present in sedimentary rocks formed millions of years ago. It is conjectured that oil or gas originated from kerogen. Petroleum is found in source beds which contained organic matter and the oil later migrated to reservoir rocks. The attention of petroleum geologists has been concentrated mostly on reservoir rocks and little attention has been given to the study of organic matter in source rocks. Organic matter has now been traced to the most ancient rocks. It is but right, therefore that attention should be turned to the study of life forms trapped in the oldest rocks and trace the changes in composition that have occurred as a function of time and temperature.

Petroleum source rocks have now been identified in the Precambrian of McArthur Basin, North Australia ranging in age from 1,400 to 1,700 m.y. (Jackson *et al.*, 1986). The rock types consist of stromatolitic and evaporitic carbonates and inter-bedded carbonaceous shales. Because of their low degree of thermal alteration they provide a valuable resource for the study of primitive biota. The hydrocarbon composition of the oil in these strata is stated to be consistent with a derivation from organic matter of prokaryotic origin. This opens up possibilities of striking oil in middle Proterozoic sediments so well represented in the sedimentary basins of India.

Another interesting development may be noted. Liquid oil has now been reported or trapped in fluid inclusions in calcite veins cutting across a cupriferous shale deposit at White Pine, Michigan (Kelley & Nishioka, 1985). Oil is known to have impregnated all rock types. The hydrocarbon content of None such shales is stated to be similar to those of Phanerozoic source rocks. A Precambrian age and indigenous origin is ascribed for the oil on the basis of chemical similarity. These are stray evidences, no doubt, but indicate biological activity in Precambrian leading to the production of hydrocarbons similar to those formed in more recent sediments.

Mention should be made here of the other extreme view held by Gold (1980, 1982) and some of the Russian geologists challenging the 'fossil fuel' theory and holding to the belief that hydrocarbon gases are abiogenic in origin, produced through the hydrolysis of metal carbides trapped in the Earth's mantle (Zvi Sofar, 1985). According to these authors gas is being formed in other planets and that primordial materials cooking near the planets cores have slowly seeped upward through cracks in the crust. Important accumulations of oil, according to them, can accumulate in regions of continental faulting. Very little is known about this aspect yet. A 3 to 5 km deep hole is being drilled by the Swedish Power Board to test whether abiogenic methane is being expelled from the mantle to produce gas fields where satisfactory cap rocks exist. Some of the test wells drilled have indeed showed evidences of the presence of methane. Progress on this subject is being watched with interest.

Recent news reports (The Times, London, 17th September 1986) point to the discovery of solid methane hydrate (a bluish ice-like substance)—a new kind of gas deposit, in some of the deep holes being drilled in the Arctic. The methane hydrate is described as a chemically bound mixture of methane gas and water that occur as vast sheets or lenses. It is stable when cold but readily decomposes on warming. A cubic yard of hydrate is stated to be capable of yielding 5,000 cubic feet of natural gas. This will be a new energy source for the future.

In these matters it would appear not wise to be over conservative and blind to understanding of what still remains unknown. If what Gold predicted comes true, the implications are startling. We can then expect huge gas reserves in regions affected by deep crustal faults. Regions which are presumably written off now as barren of oil may prove to be rich. The importance of carrying out research in this field at once becomes apparent (Radhakrishna, 1984).

MICROORGANISMS AND HEAVY METAL CONCENTRATION

Study of the metal content of living organisms of almost all types shows large concentration factors for a very wide range of metals. Microorganisms are known to interact with heavy metals and play an active part in the mobilization, transportation and deposition of metals like gold, uranium and iron The Precambrian is known for its rich accumulation of gold, uranium and iron in stratified deposits. Fossils of earliest living forms have been traced in rocks formed just before the deposition of iron formations. The appearance of stromatolites in the geological record is indicative of the presence of oxygen producing cyanobacteria and the dominant role played by them in the deposition of iron. An array of organisms are now known to precipitate minerals (Lowenstem, 1980). The processes by which biological heavy metal transfer, transportation and accumulation can take place has recently been reviewed by Dexter Dyer *et al.* (1984). Biological processes presumably have played a major role in differential enrichment of specific metals. Gold contained in trace amounts in volcanic rocks of komatiitic composition which dominated in the Archaean was removed in solution during the weathering process. Its precipitation close to the edge of the sedimentary basin of deposition was aided by biological activity (Reimer, 1984). Degradation of organic matter, has been shown to dissolve gold, enrich it in the biological system and redeposit in a concentrated form. Similarly, uranium concentration in sediments has been shown to be related to biological activity. Experiments continue to be conducted to test enrichment of uranium by micro-organisms as a method of concentrating it from low-grade ores. These experiments are expected to throw new light on the origin of uranium deposits and open up new pathways for exploration.

FUTURE STUDIES

Although not a palaeontologist, you will pardon me if I venture to make a few suggestions regarding the direction in which future studies should be pursued. First and foremost, interest in palaeontological studies has to be revived. The weakest section in many of our university geology departments is the Palaeontology wing and suffers both from want of qualified men and equipment. These should be strengthened and young intelligent scholars attracted to join. We have some of the largest sedimentary basins in India ranging in age from 3,000 m.y. to the present. A careful search in the older sedimentary basins is sure to reveal a whole range of fossil remains to reconstruct the early history of life on earth.

Study of microbiota from stromatolitic structures is likely to show local peculiarities and some apparent evolutionary trends which can be made use of in stratigraphic correlations. More concentrated search for stromatolites especially in rocks older than 2,500 m.y. should be undertaken.

Carbon isotopic ratios have indicated the biological nature of carbon in ancient sediments as old as 3,800 m.y. These sediments should be searched for evidence of primitive life forms.

Unmetamorphosed banded iron formations and associated cherts require to be more intensively studied. The relation of photosynthetic oxygen to the deposition of banded iron formation should be evaluated. The following major biological innovations have been identified: (i) origin of life (> 3,800 m.y. ago), (ii) bacterial photosynthesis (> 3,400 m.y. ago), (iii) appearance of eukaryotes (2,000 to 1,300 m.y. ago), and (iv) dawn of Metazoa (~ 600 m.y. ago). Evidences in support of this chronology from the Indian geological record have to be collected. There should be sustained search for evidence of fossil remains in our oldest rocks. In my opinion two specialist groups should be constituted, one for Archaean microbiota and the other for the stromatolites of Proterozoic.

Micropalaeontological study of the Precambrian is one of the most rapidly developing branches of current research. Such studies have yet to gain in tempo in India. This Institute which bears the honoured name of Professor Birbal Sahni should specialise in all inter-disciplinary studies in which Biology and Earth Sciences are concerned and give a lead to micropalaeontological research in the country. Sedimentologists, geochronologists, geochemists, palaeontologists, organic chemists and molecular biologists should shift their attention to the Archaean-Proterozoic record. They should together make a supreme effort at understanding the process of early evolution of biological system on Earth.

There is still a long way to go in solving the mystery of the origin of life. The emergence of life we have seen is only one stage in the larger history of cosmic changes and the result of constant assembly of matter since it was created with a big bang. The broad goal is to arrive at an intellectually satisfying account of how living forms emerged step by step from inanimate matter (Dickenson, 1978).

There emerges from these studies an increasing awareness of the supreme truth embodied in our ancient texts—*the Upanishads* that there is a thread which runs through all things and holds them together and that the universe is the result of a gradual unfolding of the creative power inherent in the primordial substance.

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DR. G. THANIKAIMONI
(1938-1986)

Dr. G. Thanikaimoni, an eminent palynologist and a botanist passed away on 5th September, 1986 in the tragic hijack event in Karachi. Dr Thanikaimoni, a man of Peace, fell a prey to the cruel hands of terrorism.

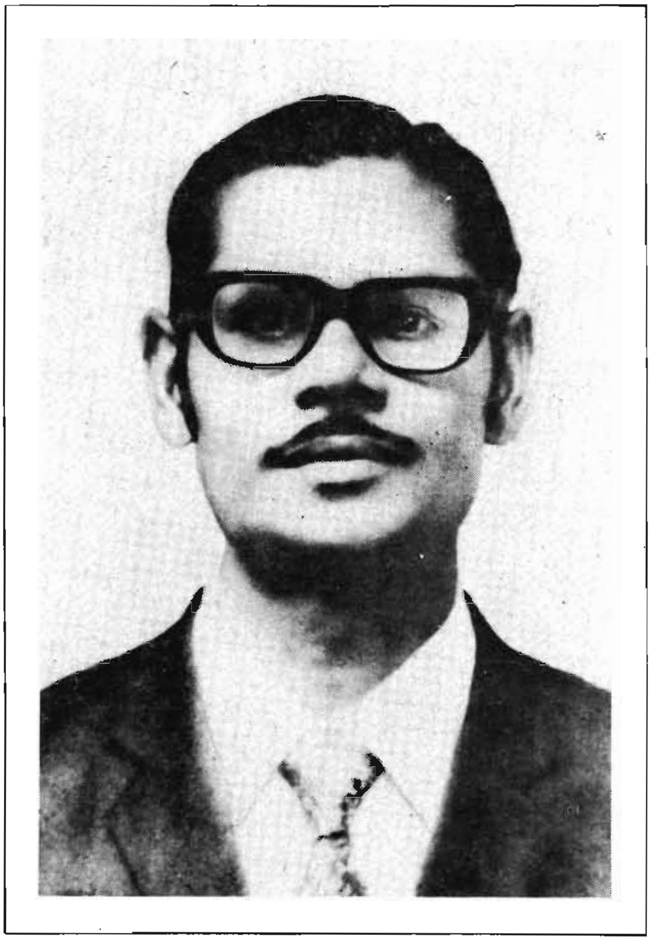
'*Thani*'—as he was known to his large circle of friends had acquired international reputation as a versatile palynologist in the scientific community. He was snatched away from our midst while on his way to U.S.A. to attend the Second International Conference on Palaeo-oceanography at Woodshole. He was to present at this conference the results of a regional programme on the Mangroves of Asia and Pacific and a state-of-art report on marine palynology.

Thani did his Master of Science from the University of Madras and joined the French Institute, Pondicherry in 1962 where he persued his scientific carrier. In 1970, he was awarded the Doctor of Science (Doctorat d' Etat) Degree for his work on 'Palynology and Systematics of the palms' by the University of Montpellier. This work was noted for his original ideas on the large family Palmae. In the framework of evolutionary systematics, he revised several predominantly tropical families and proposed biogeographic evolution of the species. He was the head of the Palynology Department at the French Institute and trained many young botanists.

His contribution to the understanding of vegetational history of southern India and the evolution of mangroves are significant. He also investigated the pollen spectra of the archaeological sites of Borobudur (Indonesia), Laong Speom (Kampuchea) and Stingpra (Thailand) reconstructing their past environmental histories.

He was a noted pollen morphologist who maintained wide and active collaborations with specialists from all over the world. He was a member of the International Working Group on the Terminology. He was invited by the Linnean Society of London to present the synthesis of his excellent findings on the form and function of pollen apertural types in 1983. He combined ecology with palynology to bring out a synthesis of the two disciplines.

Thanikaimoni built up a large reference collection of pollen grains of over 20,000 extant species—the largest in the world for tropical plants, which has been frequently consulted by palynologists both from India and overseas. He also served as a Member of the Scientific Advisory Council of the Birbal Sahni Institute of Palaeobotany, Lucknow and a member of the Editorial Advisory Committee of The Palaeobotanist.



His monumental Bibliographic Index on the Morphology of Pollen Grains of Angiosperms, which he began in 1972, in five volumes stands a testimony to his memory. It includes 9,000 genera covering 5,300 publications. Indubitably, Dr Thanikaimoni brought Indian Palynology to the forefront of the world scene.

He leaves behind his wife, a son, a daughter and a vast circle of friends and fellow-scientists throughout the world who will remember him for ever. Dr Thanikaimoni possessed an untiring energy for work, an insatiable thrust for knowledge, an indomitable zeal to explore new avenues of research and unusual power of self adaptation with different types of people. The community of palynologists will ever miss their dear friend—**Thani**

B.S.I.P.

DEPT. OF
GONDWANA PALYNOSTRATIGRAPHY

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Evolutionary trends in gymnospermous wood structures during Mesozoic—Protopinaceous woods in the German Jurassic

Wolfgang R. Mueller-Stoll

Mueller-Stoll, Wolfgang R. (1987). Evolutionary trends in gymnospermous wood structures during the Mesozoic-Protopinaceous woods in the German Jurassic. *Palaeobotanist* **35**(3) : 233-235.

This paper contains the establishment for the opinion that in German Jurassic the Protopinaceae against the modern pitted (abietoid) woods are not so frequent as hitherto supposed. According to our estimations the relations between protopinaceous woods and modern pitted ones are different from those believed earlier.

Key-words—Evolution, Gymnospermic woods, Protopinaceae, Jurassic (Germany).

Wolfgang R. Mueller-Stoll, Am Drachenberg 1, DDR-1570 Postdam, East Germany.

साराँश

मध्यजीवी कल्प में अनावृतबीजी काष्ठ संरचनाओं में विकासीय प्रवृत्तियाँ–जर्मन जूराई कल्प में प्रोटोपाइनेसीय काष्ठ

वुल्फाँग आर० मुलर-स्टोल

यह शोध-पत्र इस मत की पुष्टी करता है कि जर्मन जुराई कल्प में प्रोटोपाइनेसी वर्तमान गर्त्त युक्त (ऐंबीटॉयडी) काष्ठों की तुलना में उतनी प्रचुर नहीं है जैसा कि अभी तक माना जाता था। हमारे अनुमान के अनुसार प्रोटोपाइनेसीय तथा वर्तमान गर्त्त युक्त काष्ठों के सम्बन्ध पूर्व अनुमानित तथ्यों से भिन्न हैं।

WOOD structures comparable with the secondary wood of recent Conifers essentially appear not earlier than the Cretaceous as (Kraeusel, 1949) ascertained. These younger, especially Tertiary, fossil woods may be compared, as a rule, closely to recent genera, groups of genera or families of the Conifers. The Mesozoic woods differ distinctly from younger wood forms; in general, they may be compared with recent forms at most in single characteristics but not in their total structure. Many of the Mesozoic woods may belong to the Conifers; for the most part, however, this cannot be stated with certainty. Many of these woods may have belonged to different other gymnosperms, an abundant variety of which existed during the Mesozoic.

The Mesozoic woods show a characteristic evolutionary trend. In the Triassic the ancient wood types of the Palaeozoic still prevail. The extensive collective-genus *Dadoxylon*, the tracheids of which having araucarioid pits, includes secondary wood of Conifers and other gymnosperms as well as of non-gymnosperms, while the Araucariaceae in their recent sense are not yet represented. Nevertheless, the name *Araucarioxylon* Kraus 1882 is usually considered as synonymous with *Dadoxylon* Endlicher 1847 (for discussion see Maheshwari, 1972; Lepekhina, 1972). Only since the Cretaceous it is probable and can partly be proved, that the woods of *Dadoxylon*-type belong to the Araucariaceae. From the nomenclatural point of view it is immaterial that the Palaeozoic Dadoxyla certainly are not Conifers, the younger ones, however, are probably Araucariaceae, since both groups cannot be differentiated by secondary wood alone. Primary structures of numerous Palaeozoic *Dadoxylon* of southern hemisphere, for example, those studied by Kraeusel (1956 a-c), show that they are not related to Conifers, because there is centripetal wood adjoining the path, being very wide in some of these forms.

PROTOPINACEAE IN MESOZOIC

Wood forms distinguishing in particular the Mesozoic belong to the Protopinaceae. Their tracheids show pits which represent an intermediate state between the ancient araucarioid pitting type of *Dadoxylon* and the modern abietioid pitted woods. If we concede the Protopinaceae-woods an intermediate position between the Palaeozoic *Dadoxylon* and modern woods, this is to be understood to concern the phylogeny of features and not the phylogeny of taxonomic tribes.

There has been some discussion and misunderstanding about the position of the Protopinaceae. It must be kept in mind that the Protopinaceae are not a natural group in the sense of Neobotany, but only an anatomical wood-type which may include quite different Gymnosperms. This type appears sporadically during the Triassic, reaches its great diversification in the Jurassic, and dies in the Cretaceous. Grambast (1952) reports a protopinaceous wood said to be of Early Eocene age. The question now whether the Protopinaceae are the only wood-type in Middle Mesozoic besides few representatives of araucarioid structure and certain isolated types like *Xenoxylon*. Recent investigations on extensive material of Jurassic woods have shown that beside different genera of Protopinaceae there have existed already many woods with abietioid, i.e. modern pitting of the tracheids. Those woods have not yet acquired the features of the woods of later periods. They are built up very simply throughout, and give a rather uniform impression. Their anatomical differences are as yet lesser than in the recent Gymnosperms. Only one of our samples contained resin ducts, and two showed structures like cross-tracheids along the ray borders; spiral thickening nowhere could be found. It is striking that the horizontal and tangential walls of the ray cells are never pitted. These ray structures appear in extant Gymnosperms chiefly the Araucariaceae and Podocarpaceae, with abietioid pitted tracheids sufficiently well-preserved they could be assigned to the genera *Podocarpoxylon, Phyllocladoxylon, Cupressinoxylon* and *Circoporoxylon*. Possibly there are also woods with taxodioid cross-field pitting to be considered as primitive forms of *Taxodioxylon*. Woods of these genera have existed during the German Jurassic with certainty already in greater number besides the Protopinaceae genera—*Protocupressinoxylon* Eckhold, *Protopodocarpoxylon* Eckhold, *Protophyllocladoxylon* Kraüsel and *Araucariopitys* Jeffrey. Moreover, *Protocedroxylon* Gothan and *Protopolyporoxylon* Vogellehner have been proved in German Jurassic, but they are not present in our material. The other genera of Protopinaceae, namely *Protopiceoxylon* Gothan and *Prototaxodioxylon* Vogellehner are hitherto not found in German Jurassic (Vogellehner, 1968). The driving woods, so-called "Treibhoelzer", from the Upper Lias (Jurassic), Posidonia-schists of Holzmaden, South Germany, were investigated by Vogellehner (1962). He found *Protocupressinoxylon* and *Cupresinoxylon* and for the first time in the Posidonia-schists *Protophyllocladoxylon* and *Phyllocladoxylon*; those woods are habitats for marine animals, mostly sea-lilies (*Seirocrinus subangularis*).

PORTION OF PROTOPINACEAE IN THE JURASSIC PERIOD

Among 76 specimens of our material, usable for diagnoses, we found 5 *Dadoxylon* (6.6%), 11 *Xenoxylon* (14.5%), 24 Protopinaceae (31.6%), and 36 Abietioid pitted woods (47.3%). Therefore, the relation of protopinaceous against modern pitted woods is strongly moved against the abietioid pitted types; the relation amounts 24 to 36 specimens, i.e. 40 to 60 per cent. If the values, calculated by us, are not correct at all, because some of these woods in reality may belong to the Protopinaceae, the opinion that in German Jurassic the number of protopinaceous woods is greater than that of the modern has to be droped. This result was not to be expected as Kraeusel (1949, p. 102) calculated for the Jurassic Period in the whole world a relation of protopinaceous against modern pitted woods of 60 to 40 per cent, having considered all known findings till 1945. He pointed out that the share of Protopinaceae probably might be too small, because parts of protopinaceous woods hitherto classified to the Lower Cretaceous really may be older.

One can say that the Protopinaceae have appeared approximately at the same time as the simple structured abietioid pitted woods, or atmost a little later, as Protopinaceae is scarce in the Triassic. During the Lower Jurassic (Lias) at any rate both groups existed almost side by side. Since intermediate pitting of protopinaceous type is not rare in root-wood of recent Conifers, it could be presumed that the Protopinaceae represent samples of roots, while the modern (abietioid) pitted samples are the remains of stem-wood. However, this argument is not valid because in this case woods with intermediate pitting should be found in the Tertiary, too, but they are practically absent there. It must be stated that the Protopinaceae being a specific anatomical wood-type cannot be doubted; one must concede, however, that there need not be a featural-phylogenetic chain of tree links, namely woods with araucarioid pitted tracheids, followed by woods with intermediate pitted tracheids (Protopinaceae), and finally followed by woods with abietioid pitted tracheids (modern Conifers). The Protopinaceae should not be considered as a necessary link in the evolutionary line, because the first abietioid pitted woods, still simply structured may have developed also directly from araucarioid pitted ancestors, because in the Triassic both wood types, i.e. protopinaceous and modern pitted woods exist side by side, like a modern pitted wood, e.g. *Podocarpoxylon triassicum* from the Keuper of Frankonia has demonstrated (Sel-Meier & Vogellehner, 1968). In the German Jurassic the Protopinaceae have their greatest extension, in the Cretaceous they declined. Therefore, woods with modern tracheids are direct descendants of araucarioid pitted forms, but only in anatomical sense. Both types, protopinaceous and modern, have their origin in the same time period. Therefore, the Protopinaceae also originated from the araucarioid stock.

Mueller-Stoll (1960) stated that the fossil with enlarged pith named *Reticulopitys suevica* from Lias of Schwaebisch Gmuend, South Germany, has a secondary wood like *Protophyllocadoxylon*; on his table 2, fig. 9 this is clearly discernible. The pores in cross-field in tangential direction are single, large, oblique-elliptical, acute on both corners, so called "Eiporen", but Schultze-Motel (1961) critisized this, because in text-fig. 1 on p. 171 the cross-field pores are round like *Circoporoxylon*, but it is only apparent because of bad preservation.

It is certain that during the Cretaceous Period the modern tracheidal pitting finally predominates, and the Protopinaceae gradually disappear. Thus the question arises: Do these woods belong to dying tribes and their particular wood structure disappeared with them, or we face a progressive evolution of the original forms whereby the secondary wood, too, has lost its ancient features? At present we can only raise this question, but cannot clearly answer it. The difficulties lie in the fact that the wood fossils are very rarely found in organic connection with other plants parts. It is usually impossible to classify them in accordance with the taxonomic system which is built up upon the structure of the reproductive organs.

While within the Protopinaceae a progressive evolution and transition to modern woods is possible and up to a certain extent probably, we also know wood types in the Mesozoic, which represent blind-ending of evolutionary lines. This concerns the genus *Xenoxylon* that existed from Triassic to Cretaceous, with maximum expansion during Jurassic, or *Circoporoxylon*, a podocarpoid wood, which appeared in Jurassic and continued beyond Cretaceous in the Tertiary. What kind of plants possessed such wood we do not know for the above mentioned reasons. *Xenoxylon* probably does not belong to true Conifers, but to some other Gymnosperms.

On the southern hemisphere wood structures developed quite differently than on the northern one, corresponding to the development of the entire gymnospermous group. The genus *Dadoxylon* (syn. *Araucarioxylon*) retained much greater importance, and contains during Cretaceous already genuine Araucariaceae. From a more extensive material of South-African Cretaceous Schultze-Motel (1966) proved that these woods show a specific anatomical feature which occurs only in some recent Araucariaceae, especially in some species of *Agathis*. There are so called "marginal cells" looking like low cell rows accompanying the ray borders.

For araucarian woods with such distinguishing features the new genus *Dammaroxylon* was established (Schultze-Motel, 1966). *Podocarpoxylon* also occupies an important share in Cretaceous Period of South Africa. We must remember that at present, too, the Podocarpaceae and Araucariaceae are specific Conifers of southern floras, a fact that became clearly obvious by the end of Mesozoic. During earlier epochs Podocarpaceae was distributed also in the northern hemisphere. These woods have more definite evidences than many dubious leaf remains. Podocarpoid woods may be traced in Central Europe with certainty back to the Jurassic.

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Sphenopsids from the Barakar Formation of Hura Tract, Rajmahal Hills, Bihar

V. K. Singh, A. K. Srivastava & Hari K. Maheshwari

Singh, V. K., Srivastava, A. K. & Maheshwari, Hari K. (1987). Sphenopsids from the Barakar Formation of Hura Tract, Rajmahal Hills, Bihar. *Palaeobotanist*, **35**(3) : 236-241.

Sphenopsids from Lalmatia Incline (Lalmatia Top Seam, Barakar Formation), Rajmahal Hills, Bihar, belong to *Sphenophyllum gondwanensis* sp. nov., *Lelstotheca* sp. and equisetalean axes. Previous records of northern species of *Sphenophyllum* in Lower Gondwana sediments are reviewed and reassessed.

Key-words—Sphenophyllales, *Sphenophyllum*, Barakar Formation, Rajmahal Hills (India)

V. K. Singh, A. K. Srivastava & Hari K. Maheshwari, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

सारांश

राजमहल पहाड़ियों (बिहार) में हुरा क्षेत्र के बराकार शैल-समूह में स्फ़ीनॉप्सिड

विनय कुमार सिंह, अश्विनी कुमार श्रीवास्तव एवं हरिकृष्ण माहेश्वरी

बिहार में राजमहल पहाड़ियों में लालमटिया आनति (लालमटिया शिखर सीम, बराकार शैल समूह) से प्राप्त स्फ़ीनॉप्सिड स्फ़ीनोफ़िल्लम् गोंडवानेन्सिस नव जाति, लेल्सटोथीका जाति एवं इक्वीसिटेली अक्ष से सम्बन्धित हैं। अधरि गोंडवाना अवसादों में स्फ़ीनोफ़िल्लम् की उत्तरी जातियों का अवलोकन तथा पुनर्निर्धारण किया गया है।

TRIZYGIA Royle (1839), one of the commonest Sphenopsids of the Lower Gondwana, is represented by foliage shoots whose slender, articulate axes have at each node a verticil of six leaves arranged in 3 pairs (two pairs of larger leaves and one pair of much smaller leaves). Most of the later workers, however, did not recognize the independent identity of the genus *Trizygia* and included the solitary species *T. speciosa* under the genus *Sphenophyllum*. Maheshwari (1968) argued that the trizygoid leaf arrangement and the epidermal features are significant characters to retain the independent identity of the genus *Trizygia*. It is not that the genus *Sphenophyllum* does not occur in Lower Gondwana; it has been reported from South America, Africa as well as India (*see* Archangelsky, 1958; Lacey & Huard-Moine, 1966; Arrondo, 1972; Maithy, 1978; Srivastava & Rigby, 1983, etc.).

We record some more specimens of *Sphenophyllum* from the Barakar Formation of Rajmahal Hills, Bihar. The collection also includes a large number of glossopterid leaves, axes, scale leaves, seeds, sporangia and a few sterile pteridophylls. *Trizygia speciosa*, surprisingly, has not been found. Thin carbonified crust sometimes covers the fossils but cellulose pulls did not reveal cellular details.

Previous collections of *Sphenophyllum* available at Birbal Sahni Institute of Palaeobotany have also been examined.

Genus—*Sphenophyllum* Brongniart 1828

Sphenophyllum gondwanensis sp. nov.

Pl. 1, figs 1-5; Text-fig. 1a-d

1958 *Sphenophyllum thonii* Mahr : Archangelsky, *Acta geol. Lilloana* **2** : 29-31, figs 4,7.

1966 *Sphenophyllum thonii* Mahr : Lacey & Huard-Moine, *Symposium on Floristics and Stratigraphy of Gondwanaland, Lucknow* : 15,16; pl. 1, fig. 1.

1972 *Sphenophyllum thonii* Mahr : Arrondo, *Rev. Mus. Plata* (n.s.), **7** : 36-38, pl. 1, fig. 1.

1982 *Parasphenophyllum thonii* var. *minor* (Sterzel) Asama : Singh, Maithy & Bose. *Palaeobotanist* **30** : 204, pl. 6, figs 38-40; text-figs 7 A-B.

Diagnosis—Sterile shoots, axes articulate, internodes with longitudinally running ribs, nodes with a whorl of six leaves each. Leaves cuneate, obovate or subtriangular in shape, do not form a leaf sheath. Leaves of younger whorl small, with finely denticulate distal margin; leaves of older whorl comparatively large, with fine to deeply incised, dentate distal margin. A single vein enters leaf base, dichotomises five to eight times, side veins radiate towards lateral margin, median veins go straight up, each ultimate veinlet terminates in a denticulation of distal margin.

Holotype—Specimen no. BSIP 35866; Middle Permian; Barakar Formation; Lalmatia Top Seam, Lalmatia Incline Colliery, Rajmahal Hills, Bihar.

Description—The collection has ten specimens, some with counterparts. A number of fragments of leaf whorls and scattered leaves are also present. The specimens represent sterile shoots. The shoot axis in flattened condition is 2 to 3 mm broad, articulate, ribbed, internodes being 0.8 to 2 cm long, nodal distance decreasing from basal to apical part. The nodes are slightly swollen, each node has a whorl of six leaves similar in size and shape. Leaves of successive whorls may differ in size and distal margin. Leaves of younger whorl are 0.5 to 1.5 cm long, 0.2 to 1 cm wide and show fairly crenulate distal margin. Leaves of older whorl are larger, 1 to 2.5 cm long, 0.5 to 1 cm broad and possess deeply crenulate/denticulate distal margin, latter sometimes being elongate, sharp and teeth-like which measure up to 3 mm.

One of the specimens (Pl. 1, figs 1, 2; Text-fig. 1a) shows remnants of 6 leaf whorls and an occasional internode. At least two or more leaves are preserved completely or partly in every whorl. Although, only two middle whorls are connected by the axis, all the whorls belong to the same foliage shoot, the intervening portions of the axis either lie unexposed in the rock or are covered by the overlying leaves. There is a gradual change in leaf size and distal margin (apex) from one end of the axis to other. The leaves of lower whorls are large, and have crenulate or denticulate apices. Those of upper whorls are comparatively small with finely crenulate apices. Leaves within a whorl, however, are isophyllous.

A single vein enters the leaf base and dichotomises 5 times or more. The ultimate veins radiate and diverge slightly towards the lateral margins of the lamina; the median veins run straight. Sometimes 2 or more veins seen entering the leaf base but a careful observation reveals that the single vein dichotomises immediately after entering the leaf and gives an appearance as if two veins are entering the leaf base.

Though the leaves are arranged in a whorl at nodes of shoot axis, in fossil state they are found preserved in one plane. Sometimes, a part of whorl may lie in a different plane, often leaves of a whorl overlap the leaves of another whorl (Pl. 1, fig. 4; Text-fig. 1d) and so also the intervening internode hair, hooks or spines are lacking.

Comparison—The new species, *Sphenophyllum gondwanensis*, is characterised by the presence of heterophyllous leaf whorls. A similar variation in distal margin of leaves is already known in a number of northern species of the genus *Sphenophyllum*. *Lilpopia*, a genus which has leaves similar to *Sphenophyllum*, also shows heterophylly. Batenburg (1981) has worked in detail the leaf morphology of *Sphenophyllum* and according to him "heterophylly is not a peculiarity of a few species but a feature of the genus on a whole with the main exception of the older primitive forms with lacineat leaves only".

Thus, it appears that heterophylly is quite common in the species of *Sphenophyllum* and *S. gondwanensis* reports from the Lower Gondwana Formation of India enhances the possibility of the occurrence of heterophylls forms of *Sphenophyllum* other than the northern hemisphere.

Among the heterophyllous forms, *S. miravallis* (Hetterscheid & Batenburg, 1984, pl. 2, fig. 1) is distinct in having asymmetrical pairs of leaf whorls; in *S. gondwanensis* all the six leaves of whorl are similar in size and shape. Further *Bowmanites cupulatus* Hetterscheid & Batenburg, 1984, a fertile part attributed to *S. miravallis*, is not known to occur so far in Indian Lower Gondwanas. Vegetative heterophyllous leaves of *Lilpopia raciborskii* (Kerp, 1984) resemble the leaves of *S. gondwanensis* but the former species characteristically has sporangiate cones coming up at the nodes, a character so far not known to occur in the genus *Sphenophyllum*.

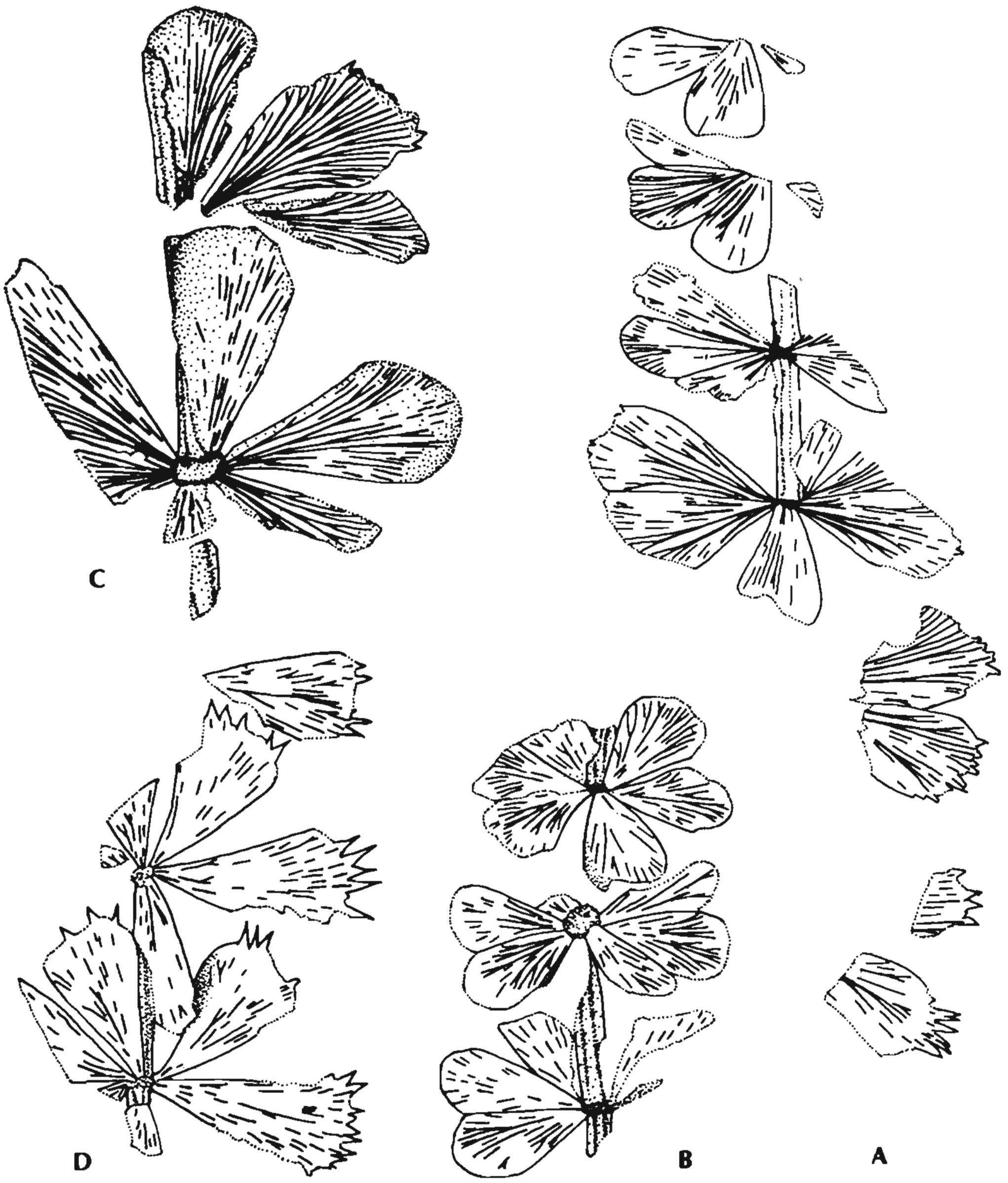
S. thonii Mahr (1968) has larger leaves and fine, dense venation, the latter resulting in fine and numerous fringes which continue downwards on the lateral sides also. *S. archangelskyii* Srivastava & Rigby, 1983 differs in having elongate-obovate leaves with deeply incised distal margin and relatively dense distribution of lateral veins. In *S. waltonianum* Srivastava & Rigby, 1983 the leaves have a teeth-like serration and a median notch on the distal margin. Individual leaves of *S. sakoense* Appert; 1977 are comparable with *S. gondwanensis* but differ in showing considerable reduction in leaf size in a whorl.

Genus—*Lelstotheca* Maheshwari 1972

Lelstotheca sp.

Pl. 1, fig. 6

Description—There are twelve pieces of foliage shoots in the collection. The leaves are arranged in star-shaped verticils at the swollen nodes which are 1—1.5 cm apart. The leaves are linear in shape 1—3.5 cm long and 1—2.5 mm wide, the lateral sides being parallel to each other except near the apices, which are acute. Each leaf has a persistent midrib.



Text-figure 1—A-D. *Sphenophyllum gondwanensis* sp. nov., **A**, holotype, fragments of 6 leaf whorls, two whorls show attachment with an articulate stem; leaves of younger whorl show fine crenulate distal margin; leaves of older whorl show deeply incised dentate distal margin. Specimen no. BSIP 35866 × 4 (see also Pl. 1, figs 1-2). **B**, remains of 3 younger leaf whorls showing leaves with smooth/crenulate distal margins, arranged around a node. Specimen no. BSIP 35867 × 4 (see also Pl. 1, fig. 3). **C**, a fragment of two leaf whorls showing crenulate to dentate distal margin and venation pattern. Specimen no. BSIP 35868. × 4 (see also Pl. 1, fig. 5). **D**, showing leaves of older whorl with deeply dentate distal margin. Specimen no. BSIP 35866. × 3 (see also Pl. 1, fig. 4).

PLATE 1

→

1. *Sphenophyllum gondwanensis* sp. nov. Holotype, showing six leaf whorl fragments, two whorls show attachment with a slender axis. Leaves of younger whorl show fine crenulate distal margin and leaves of older whorl show deep incised, dentate distal margin. Specimen no. BSIP 35866. Natural size.
2. *S. gondwanensis* holotype, enlarged to show the details of venation pattern and distal margin. × 2.
3. *S. gondwanensis* showing detached fragments of older and younger leaf whorls. Older whorl shows 4 leaves with dentate distal margin, younger fragment shows three whorls of smaller leaves with fine crenulate distal margin. Specimen no. BSIP 35867. × 2.
4. *S. gondwanensis* showing a fragment of older leaf whorls with deeply incised dentate distal margin. Specimen no. BSIP 35866. × 2.
5. *S. gondwanensis* showing a fragment of two leaf whorls with fine dentate to crenulate distal margin. Specimen no. BSIP 35868. × 2.
6. *Lelstotheca* sp. showing detached fragments of leaf whorls. Specimen no. BSIP 35869. × 0.8.

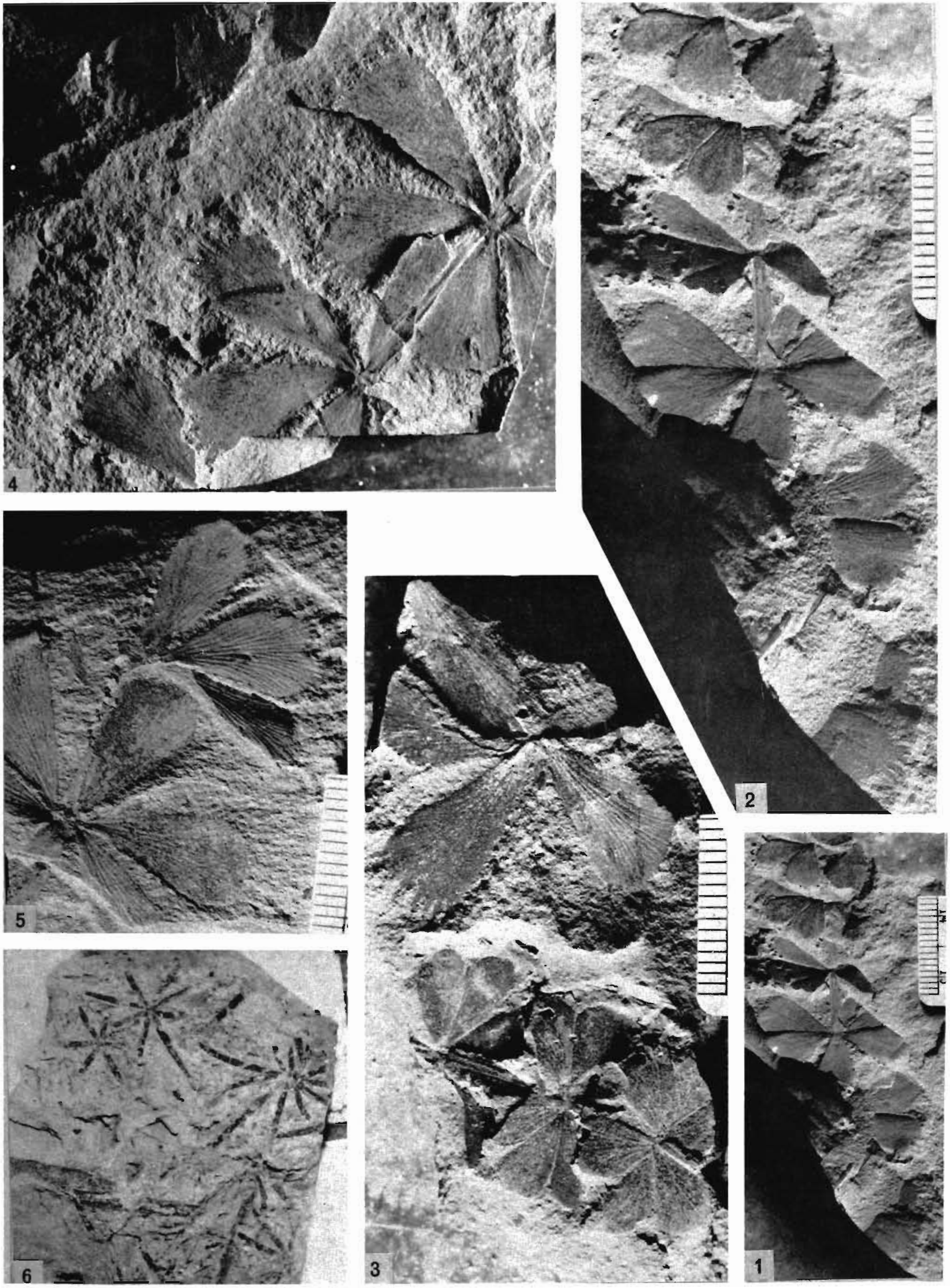


PLATE 1

Comparison—The specimens show a general resemblance to *Lelstotheca robusta* (Feistmantel) Maheshwari. The leaves in typical species of *L. robusta* are widest near the base gradually taper towards the apex, whereas in the present specimens the leaves are equally broad all along and abruptly turn into an acute apex.

Somewhat similar shoots have earlier been reported from Zimbabwe by Huard-Moine (1965, pl. 1, fig. 4) and Lacey and Huard-Moine (1966, pl. 1, fig. 8) as doubtful records of *Annularia*. Rigby (1966a, pl. 1, fig. 4) has reported comparable specimens as *Stellotheca* sp. from New South Wales, Australia.

EQUISETALEAN AXES

Description—Compressions of leafless, articulate axes showing ridges and furrows in successive internodes occur abundantly in our collection. The axes are 4-15 cm long and 0.1-2 cm wide, generally with swollen nodes. The length of internodes varies from 1-5.5 cm. The ridges are about 1-2 mm apart, parallel to each other and always continuous in successive internodes.

Discussion—Leafless, articulate axes have been reported from different formations of Lower Gondwana as equisetalean axes or sphenopsid axes or have been assigned to the genus *Phyllotheca* or *Schizoneura* on grounds of their associations or close similarity with the stems having attached leaf-sheaths of the respective sphenopsid. Rigby (1966a) introduced the genus *Paracalamites* Zalessky in Lower Gondwanas for such axes. *L. robusta* was reportedly found attached to *Paracalamites*.

GENERAL DISCUSSION

The genus *Sphenophyllum* Brongniart, 1828 is a common sphenopsid in the Permian-Carboniferous of Northern Hemisphere. Till recently typical *Sphenophyllum* forms were not adequately known from the Lower Gondwana of India though such forms were documented from Lower Gondwana of South America, Australia and Africa (Arber, 1905; Walton, 1929; Teixeira, 1947; Archangelsky, 1958, 1960; Lacey & Huard-Moine, 1966; Rigby, 1966b; Arrondo, 1972; Appert, 1977). Now Maithy (1978), Chandra and Rigby (1981), Singh, Maithy and Bose (1982), Srivastava and Rigby (1983) and Pant, Srivastava and Das (1985) have reported some typical forms of *Sphenophyllum* from India. It would thus seem that *Sphenophyllum*, though a rare plant in the Lower Gondwana, was of wide occurrence. However, the genetic relationship between the typical Sphenophyllums of Northern Hemisphere and similar looking forms from Gondwanaland is yet unknown.

The sphenophyll species which occur in the Permian sediments of the Gondwanaland fall into two basic categories, viz., the trizygoid and symmetrical (Asama, 1966), represented by the genera *Trizygia* and *Sphenophyllum* respectively.

The stratigraphic distribution of the various species of *Sphenophyllum*/*Trizygia* in the Gondwana sediments shows that of the trizygoid species, four species, viz., *S. oblongifolium, S. verticillatum, S. wankianum* and *T. maithyiana* are present in the Lower Permian and only one species, *T. speciosa*, is frequent in the Upper Permian. Similarly, amongst the non-trizygoid species, four, i.e. *S. gondwanensis, S. churulianum, S. waltonianum* and *S. rhodesii* are restricted to Lower Permian and only one, *S. crenulatum*, occurs in the Upper Permian. Though, the sphenophylls were comparatively less abundant in the Lower Permian Gondwana, yet the number of species was relatively very high. Eight species are so far known from the Lower Permian of Gondwana as compared to only two from the Upper Permian of Gondwana. This shows that the sphenophylls were evolving rather fast in the Lower Permian and had stabilized by the Upper Permian.

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Role of spore-pollen species in demarcating the Permo-Triassic boundary in Raniganj Coalfield, West Bengal

Vijaya & R. S. Tiwari

Vijaya & Tiwari, R. S. (1987). Role of spore-pollen species in demarcating the Permo-Triassic boundary in Raniganj Coalfield, West Bengal. *Palaeobotanist* **35**(3) : 242-248.

An attempt is made to delimit Permo-Triassic boundary in Raniganj Coalfield on the basis of selected palynofossils. *Densipollenites invisus, D. indicus* and *D. densus* decline while *D. magnicorpus* and *Gondisporites raniganjensis* disappear at the close of Raniganj Formation; *Densoisporites contactus, Lundbladispora microconata, L. brevicula, Playfordiaspora cancellosa, Lunatisporites ovatus, L. diffusus* and cf. *L. pellucidus* appear at Lower Panchet. Lithological and palynological changes at Raniganj/Panchet boundary help to draw the Permo-Triassic boundary at this level.

Key-words—Palynology, Raniganj Coalfield, Permo-Triassic Boundary (India).

Vijaya & R. S. Tiwari, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

पश्चिम बंगाल में रानीगंज कोयला-क्षेत्र में परमी-त्रिसंघी सीमा के परिसीमन में बीजाणु-परागकणों की भूमिका

विजया एवं राम शंकर तिवारी

कुछ छाँटे गये अश्मित बीजाणु-परागकणों के आधार पर रानीगंज कोयला-क्षेत्र में परमी-त्रिसंघी सीमा परिसीमित करने का प्रयास किया गया है। रानीगंज शैल-समूह के अन्त में डेन्सीपोलिनाइटिस इन्वीसस, डे० इन्डिकस और डे० डेन्सस की संख्या कम हो जाती है जबकि डे० मैग्नीकॉर्पस एवं गोंडिस्पोराइटिस रानीगन्जेन्सिस विलुप्त हो जाते हैं; डेन्सोइस्पोराइटिस कॉन्टेक्टस, लुन्ब्लाडिस्पोरा माइक्रोकोनेटा, लु० ब्रेविकुला, प्लेफ़ोर्डियास्पोरा कैन्सेलोसा, ल्यूनाटिस्पोराइटिस ओवेटस, ल्यू० डिफ़्यूसस एवं सजातीय ल्यू० पेल्यूसिडस अधरि पंचेत में आविर्भूत होने लगते हैं। रानीगंज/पंचेत सीमा पर शैलिकीय एवं परागाणविक परिवर्तन परमी-त्रिसंघी सीमा को सुनिश्चित करने में सहायता प्रदान करते हैं।

EFFORTS during the last decade to delimit Permo-Triassic boundary in Peninsular India on the basis of palynological studies have proved successful (Tiwari & Singh, 1986). Palynological boundary demarcations were, so far, based on generic distinctions. The present work has been undertaken to achieve a finer and precise boundary demarcation on the basis of distribution pattern of significant species which could be used as marker taxa.

AREA OF STUDY

Subsurface material from the eastern most part of Raniganj Coalfield have been used for the present study. Recent palynological investigations of bore-core samples in this area (Rana & Tiwari, 1980; Singh & Tiwari, 1982; Tiwari & Singh, 1983; Tiwari & Rana, 1984) have demonstrated palynofloral changes marking the Raniganj/Panchet sequences (Table 2). Following samples have been used for this study (Table 1), allowing a lateral comparative distributional pattern of species.

Quantitative determination of miospores at generic level has revealed the sequential arrangement of palynological assemblages at Raniganj/Panchet boundary (Table 2; after Tiwari & Singh, 1986).

EVALUATION OF SPORE-POLLEN SPECIES FOR ZONATION

Quantitative determinations for palynological assemblage at generic level in bore-holes NCRD-6 (Bharadwaj & Tiwari, 1977), RAD-2 (Singh & Tiwari,

Table 1—List of samples studied representing the sequence encompassing the Raniganj/Panchet boundary in various bore-holes in Raniganj Coalfield

S. No.	Depth in m	Lithology	Lithological boundary	Miofloral zones (Tiwari & Singh 1986)
I	*B.H. NCRD-6 (Bharadwaj & Tiwari, 1977)*			
1.	215.00	Greenish Shale		P-II B
2.	280.00	Greenish Shale	Raniganj/Panchet	
3.	287.30	Greenish Shale		R-IB
II	*B.H. RAD-2 (Singh & Tiwari, 1982)*			
1.	430.00	Greenish Shale		P-IVA
2.	450.47	Sandstone	Raniganj/Panchet	
3.	460.00	Sandstone		P-IIIB
4.	545.00	Sandstone with coal		R-IB
5.	550.00	Carbonaceous Shale	R-IA	
III	*B.H. RAD-5 (Tiwari & Singh, 1983)*			
1.	481.00	Greenish shale+Sandstone		P-IIB
2.	493.50	Sandstone	Raniganj/Panchet	
3.	505.00	Greenish shale+Sandstone		P-IA

Table 2—Showing the quantitative change-over in palynological assemblages at Raniganj-Panchet boundary (modified after Tiwari & Singh, 1986)

LOWER PANCHET	*Assemblage* P-I	*Striatopodocarpites* *Klausipollenites*	P-IB	*Striatopodocarpites*, cf. *Lunatisporites, Klausipollenites, Chordasporites, Inaperturopollenites, Crescentipollenites, Lundbladispora*
			P-IA	*Striatopodocarpites-Klausipollenites, Alisporites, Nidipollenites, Verrucosisporites, Densipollenites, Playfordiaspora, Satsangisaccites*
BOUNDARY				
UPPER RANIGANJ	*Assemblage* R-I	*Striatopodocarpites* *Densipollenites*	R-IB	*Striatopodocarpites-Crescentipollenites, Densipollenites, Scheuringipollenites, Klausipollenites*, cf. *Lunatisporites, Gondisporites, Lundbladispora*
			R-IA	*Striatopodocarpites-Densipollenites, Faunipollenites, Crescentipollenites, Gondisporites, Lundbladispora, Playfordiaspora*, cf. *Lunatisporites.*

1982) and RAD-5 (Tiwari & Singh, 1983), exhibit definite change at Raniganj-Panchet level. It has been observed that a large number of taxa, which qualify the Lower Raniganj Formation continue to occur even at the closing phase of the Raniganj Formation; although a few genera, viz., *Densipollenites* and *Crescentipollenites*, gain abundance at this younger level, apiculate trilete genera proliferate in variety, while a few cavate-taeniate pollen appear at the close of Raniganj. The most significant change is observed in the frequency of *Densipollenites* which suddenly records its prominence in the Upper Raniganj. It is thus obvious that except the two genera, i.e. *Densipollenites* and *Crescentipollenites*, none of the other genera exhibits striking variability in their occurrence within the Raniganj palynological succession because of their percentage frequency which is more or less similar throughout this sequence. The genus *Densipollenites* gets further significance due to the characteristic behaviour of its species.

Consequently, for the record of specific variations, it was preferred to search thoroughly the occurrence pattern of certain species in *Striatopodocarpites-Densipollenites/ Crescentipollenites* palynozone (i.e. R-1 of Tiwari & Singh, 1986), which is the youngest zone at the close of Raniganj palynoflora. It is difficult to evaluate various species for the use of boundary delimitation because most of the species have a long range distribution throughout the Permian. For this reason striated pollen (including *Crescentipollenites*) and apiculate trilete spores have been excluded from the present determination.

The presence of *Ephedripites* and *Weylandites* is also not always consistent at this level; they may or may not be present in *Densipollenites/Crescentipollenites*-Phase. Parallel to this change-over *Gondisporites* plays an effective role by its sudden prominence and subsequent decline at the Raniganj/Panchet boundary level. Therefore, the genera thus remain for determination of boundary delimitation by virtue of the change in their species are—*Densipollenites* and *Gondisporites.* Beside these significant indicators, few species of cavate spores and monosaccate and taeniate pollen signify the younger aspect within the Raniganj palynoflora because these taxa virtually qualify the Lower Panchet horizons. Such genera are *Densoisporites, Lundbladispora, Playfordiaspora* and *Lunatisporites.*

On the basis of such an evaluation supported by a thorough search for the incidence of species, the following species are considered important for boundary demarcation :

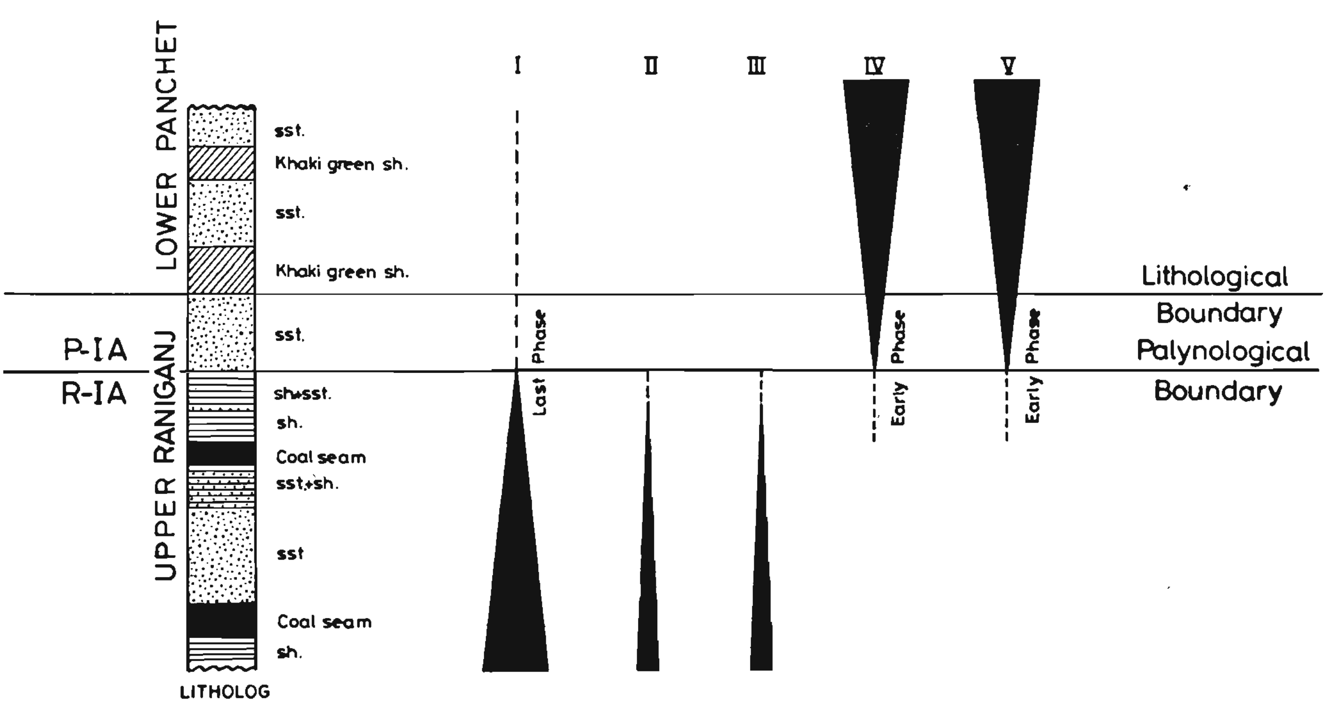
- *Densipollenites* Bharadwaj 1962
    - *D. indicus* Bharadwaj 1962
    - *D. invisus* Bharadwaj & Salujha 1964
    - *D. densus* Bharadwaj & Srivastava 1969
    - *D. magnicorpus* Tiwari & Rana 1981
- *Gondisporites* Bharadwaj 1962
    - *G. raniganjensis* Bharadwaj 1962
- *Densoisporites* Weyland & Krieger emend. Dettmann 1963
    - *D. contactus* Bharadwaj & Tiwari 1977
- *Lundbladispora* Balme emend. Playford 1965
    - *L. brevicula* Balme 1963
    - *L. microconata* Bharadwaj & Tiwari 1977
- *Playfordiaspora* Maheshwari & Banerji 1975
    - *P. cancellosa* (Playford & Dettmann) Maheshwari & Banerji 1975
- *Lunatisporites* Leschik emend. Scheuring 1970
    - *L. ovatus* Maheshwari 1975
    - *L. diffusus* Bharadwaj & Tiwari 1977 cf. *L. pellucidus* Maheshwari & Banerji 1975

These species can be indentified on the basis of characters as *Densipollenites* includes monosaccate alete non-striate pollen where saccus envelops the central body loosely from all the sides and is attached at one point, the saccus being intrareticulate, variously folded and usually with radiating folds from the point of attachment among its species; *D. indicus* has a thin, small circular central body with distinct outline; *D. invisus* possesses a very thin body with almost ill-defined outline; *D. densus* exhibits a small dark brown, dense and well demarcated body, while in *D. magnicorpus* a big, dark brown and well-defined body occupies more than half the area of pollen. *Gondisporites raniganjensis* includes roundly triangular to subcircular, trilete spores with denticulate equatorial ridge, surrounding a large central body with granulose as well as sparsely spinulate or baculate exine. In *Densoisporites contactus* broadly triangular, cavate, cingulate, trilete spores are incorporated which have distinct contact area and finely micropunctate unsculptured exine. *Lundbladispora brevicula* includes roundly triangular, cavate, cingulate, trilete spores, exine being 2-3 μm thick, finely spongy, distally bearing ± 2 μm wide, 2-4 μm long spines; *L. microconata* has been circumscribed for broadly triangular, cavate, cingulate trilete spores whose exine is finely spongy, distally bearing 1×1 μm short, rare coni. In *Playfordiaspora cancellosa* more or less circular monosaccate pollen are included which enclose dense brown central body with trilete mark; its rays are body radius long and saccus is regularly intrareticulate forming honey-comb pattern. *Lunatisporites ovatus* includes bisaccate pollen, central body being distinct, vertically oval and proximally bearing 4-6 taeniae; distally, saccus attachment are accompanied with wide lunar folds. *L. diffusus* are bisaccate pollen, central body being diffused but apparently rhomboidal; proximally bearing unevenly wide 6-8 taeniae, distally narrow lunar folds along the zone of saccus attachment present. cf. *Lunatisporites pellucidus* includes bisaccate pollen, with vertically oval to rhomboidal central body, which proximally bearing 4-6 taeniae; distally, lunar folds absent.

DISTRIBUTION PATTERN OF SIGNIFICANT SPECIES

Determination of Raniganj-Panchet boundary on the basis of percentage frequency of spores and pollen (Tiwari & Singh, 1986) has revealed prominence of *Densipollenites/Crescentipollenites* combination at the closing phase of Raniganj Formation. Transitional trend is marked by the incoming of *Lundbladispora, Lunatisporites, Densoisporites* and *Playfordiaspora* at the top most assemblage in Raniganj Formation. Quantitative change in the assemblage at this level is distinct, and it corroborates with the change in lithology where carbonaceous and sandstone facies die out while khaki-green shales come in to prominence (Tiwari & Singh, 1983).

Relative positioning of the lithological boundary and the palynological boundary (based on percentage frequency of pollen & spore genera) have been depicted in Text-fig. 1. Keeping the objective of the present work of refinement and precision the marking of Permo-Triassic boundary on the basis of spore-pollen distribution, it has been found that the taxa listed on p. 000 shows greater degree of



Text-figure 1—Species behaviour pattern. Index : I—*Densipollenites invisus, D. indicus, D. densus*; II—*Densipollenites magnicorpus*; III—*Gondisporites raniganjensis*; IV—*Lundbladispora microconata, L. brevicula, Densoisporites contactus, Playfordiaspora cancellosa*; V—*Lunatisporites ovatus, L. diffusus, L. pellucidus.*

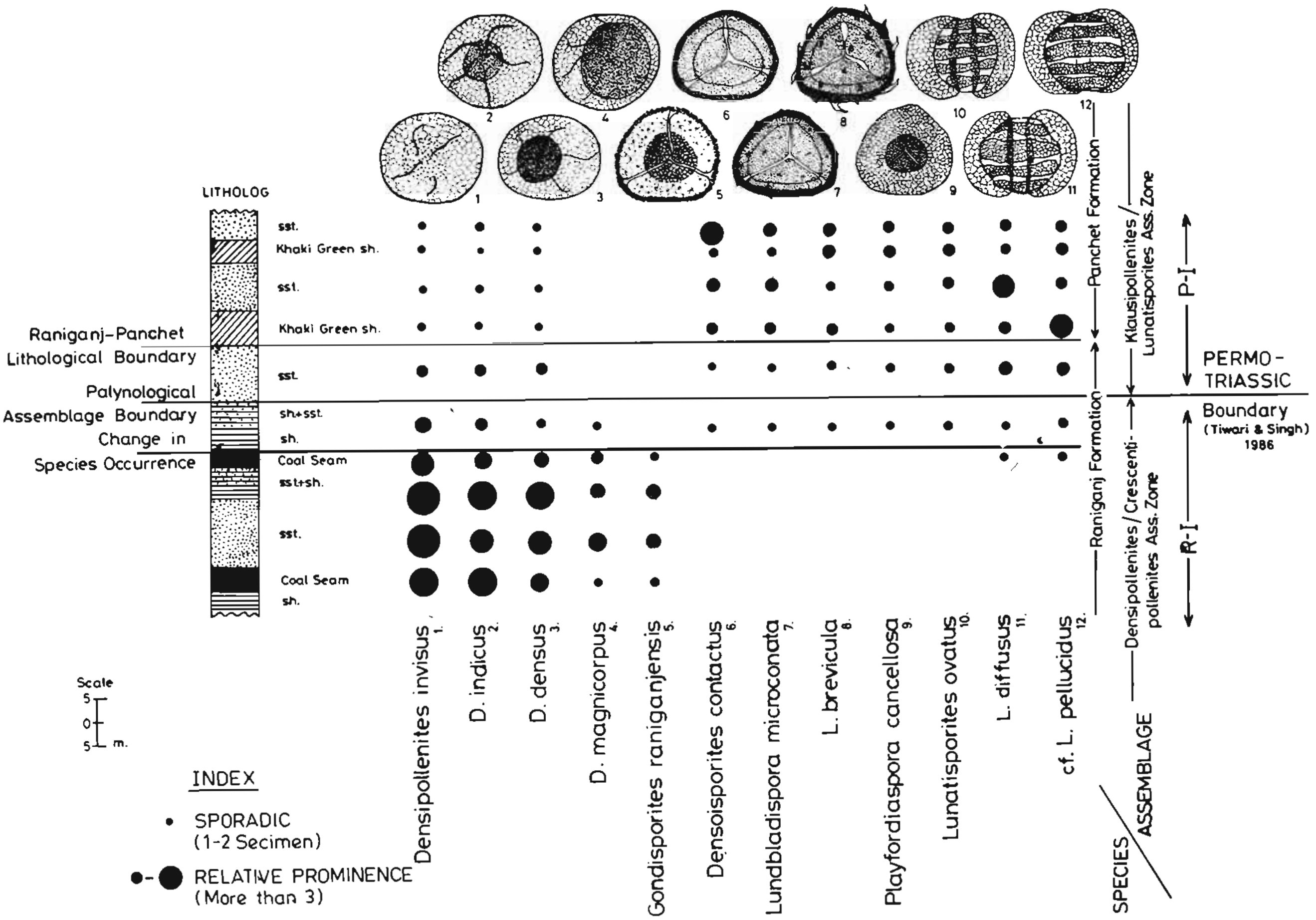
certainity and hence could be utilized in determination of this boundary.

Range of individual representative species is shown in a standard profile through Raniganj-Panchet boundary (Text-fig. 2) exhibiting lithological succession composed of coal seams, carbonaceous shale and sandstone beds (classified in Raniganj Formation) followed by khaki-green shale and sandstones (Panchet Formation). This profile has been compiled on the basis of lithologs prepared by Geological Survey of India from a number of bore-holes in this area and represents a generalized section for Raniganj-Panchet transitional level.

The distribution pattern of selected species through this profile was finalised after a thorough search of fossil taxa in scores of slides of each sample. Absence of any species at any particular level was put on record only when a number of samples in the entire series in the log were thoroughly checked. Thus, the absence is effectively considered a positive evidence. The behaviour pattern is as follows :

1. *Densipollenites*—This genus exhibits maximum species diversity at close to the Raniganj-Panchet transition as expressed by the fair record of *D. indicus, D. invisus, D. densus* and *D. magnicorpus*, in assemblage zone R-I of Tiwari and Singh (1986) which qualifies the uppermost part of Raniganj Formation. The first three species are also recorded from still older assemblages of the Lower Gondwana. Further search in the succeeding younger assemblage (i.e. in the shale and sandstone unit above the topmost coal seam of the Raniganj Formation) shows a sudden decline in the frequency of these species (Text-fig. 2), although the presence of these species of *Densipollenites* continues in the lowest bed of the khaki-green shales of Lower Panchet Formation, where they are scanty as well as sporadic. *D. magnicorpus* has been identified to be the most important species because its prominence is recorded only in the Raniganj Formation and not in the younger sequences. As it is evident from the Text-fig. 2, decline in the frequency of *Densipollenites* spp. on one hand and emergence of certain species (viz. of cavate spores and taeniate pollen) characteristic of Panchet assemblage on the other, are concurrent. Although three species of the genus *Densipollenites* are transgressive, the palynological boundary drawn on the basis of generic dominance, their qualified occurrence (i.e. sporadicity and inconsistency) further supportingly depicts a definite change at this time plane.

2. *Gondisporites*—*G. raniganjensis* is found in Raniganj palynoflora, within R-I and R-II assemblage zones proposed by Tiwari and Singh (1986). Extensive search for this species in the R-I assemblage zone reveals its sporadic presence in the sequence up to the top most coal seam of Raniganj Formation; it hardly crosses the shale unit above this



Text-figure 2—General lithological section at Raniganj/Panchet Boundary and variation in species occurrence.

seam (Text-fig. 2). In Panchet sediments it has not been recorded. Evidently, its extinction is significant at the palynological boundary (i.e. R-I/P-I zone) already drawn on the basis of percentage frequency of spore-pollen genera.

Beside the above discussed taxa, there are certain other species (given below) which are quanti-tatively significant in Panchet palynoflora. These show their first appearance almost at the begining of Panchet and get diversified (Text-fig. 2).

3. Densoisporites—It is an important genus of Panchet palynoflora and is represented by two species—*D. playfordii* and *D. contactus*. An extensive search of these species in R-I assemblage zone (Tiwari & Singh, 1986) revealed the presence of only one species, i.e. *D. contactus* in the shale and sandstone unit (above the topmost coal seam), and not below it. But in the younger strata above this lithological unit, other species of *Densoisporites* also start making their appearance (Text-fig. 2). Evidently the incidences of *D. contactus* in the topmost sandstone shale bed of the Raniganj Formation indicates a Panchet affinity for this level.

4. Lundbladispora—Its maximum specific diversification is identified in the Panchet palynofloras (Tiwari & Singh, 1986). The species generally met within the Panchet are : *L. willmotti, L. brevicula, L. microconata, L. densispinosa, L. raniganjensis* and *L. warti.* Within R-I assemblage zone of Raniganj palynoflora, presence of this genus is recorded by the species *L. brevicula* and *L. microconata* only. All the more, their occurrence is restricted only to the shale and sandstone unit, above the topmost coal seam of the Raniganj Formation (Text-fig. 2). Again, its occurrence indicates a Panchet affinity for this level. It is, therefore, clearly evidenced that the species of *Lundbladispora* can play a deciding role in deciphering the Raniganj-Panchet boundary.

5. Playfordiaspora—This genus usually makes its appearance in the Lower Panchet (khaki-green shale unit) but, however, very sporadically and sparingly it has been recorded in the shale and sandstone unit above the topmost coal seam of the Raniganj Formation. Till now two species—*P. cancellosa* and *P. annulata* are identified. An extensive search in the topmost coal seam of Raniganj Formation and above has revealed the presence of *P. cancellosa* in shale and sandstone bed overlying the topmost coal seam. It is not recorded in the topmost coal seam of the Raniganj Formation (Text-fig. 2). Obviously, *Playfordiaspora* can be relied upon as a good indicator of the Raniganj/Panchet transition along with other floral elements.

6. *Lunatisporites*—This taeniate-disaccate pollen is an important component of Triassic palynofloras (Tiwari & Singh, 1986). When an immense search for the occurrence of its species was made through Raniganj-Panchet transitionary zone, only three species, i.e. *L. diffusus* cf. *L. pellucidus* and *L. ovatus*, stood out to show their qualified occurrence. *L. ovatus* generally appear above the topmost coal seam of the Raniganj Formation and gradually acquires a better numerical importance in younger horizons. However, sporadic and inconsistent occurrence of *L. diffusus* and cf. *L. pellucidus* has been recorded in the topmost coalseam of Raniganj Formation but hardly below it (Text-fig. 2). These three species, therefore, demarcate a level of change at the close of R-I (*Densipollenites/Crescentipollenites*) Assemblage zone.

REMARKS

Distribution pattern of the species discussed (Text-fig. 2) brings out two major events at Raniganj/Panchet boundary. The first is the declination of *Densipollenites* phase (Text-figs 1, 2), above the coal facies of Raniganj Formation and the second is the simultaneous appearance of species of *Lundbladispora, Densoisporites, Playfordiaspora* and *Lunatisporites* heralding a new phase in the palynoflora associated with a change in lithofacies. Change in species distribution occurs in shale/sandstone unit on the top of uppermost coal seam (Text-figs 1, 2). Other noteworthy record is the occurrence of nonstriate-bisaccate taxa, assignable to *Satsangisaccites* and *Nidipollenites*, in the shale and sandstone unit above the topmost coal seam. Beside the well-logged data from bore-cores discussed above, the occurrence of certain taxa of importance (viz. *Lundbladispora, Playfordiaspora, Densoisporites*) has been reported from the outcrop sections in Hoharo River, Machkanda Jhor and Nonia Nala sections (Bharadwaj, Tiwari & Anand Prakash, 1979). These taxa at places, appear to occur in the older strata than what has been determined in the subsurface of above account. However, more precise study of measured section in the outcrop of this type is needed for ascertaining their distribution.

DISCUSSION

The Raniganj/Panchet boundary based on lithological change has been established at the top of sandstone which overlies the topmost coal seam. Thus, the sandstone/khaki-green shale marks the boundary. Palynological boundary drawn on quantitative determination of palynotaxa precedes this line of lithological boundary (Tiwari & Singh, 1986). The search for the role of palynotaxa at species level in determining the boundary has revealed a definite pattern of occurrence. The change in species starts in shale/sandstone unit above the topmost coal seam of Raniganj Formation (Text-fig. 2). This analysis reveals that the various boundary lines could be drawn in the following order : lithology, generic assemblage and spore pollen species. These events represent Permian/Triassic time boundary.

Palynological boundary always precedes lithological boundary (Tiwari & Singh, 1986). The boundary based on species distribution, i.e. the first appearance/ extinction or declination in frequency precedes to the palyno-assemblage boundary. The dwindling of already present species and simultaneous appearance of certain new species at the level of change is important (Text-fig. 2).

CONCLUSIONS

Following conclusions have been drawn from the present study:

1. All species in a palynological assemblage are not suitable for precise palynological age determination, particularly with regard to age boundaries. In order to find the qualifying species, intensive search is needed involving in recording trace occurrence, on both the sides of the expected boundary level. It is not the first appearance of a species which provides a clue to demarcate boundary but the package of their behaviour pattern including extinction patterns.
2. In the area understudy, considering the stratal sequences from older to younger units particularly with regard to the Raniganj-Panchet boundary, the incoming as well as disappearance of certain species has been recorded at the earliest level; the demarcation in palynological assemblages is evidenced after a time-lapse and subsequently the change in lithology is the last factor to become evident.
3. Lithological and biostratigraphical boundaries are marked at a close range of each other. This level is in the sandstone unit which is subjacent to the khaki-green shale. This is considered to demarcate the Permo-Triassic time boundary.
4. Sudden decline of *Densipollenites invisus, D. indicus* and *D. densus* and disappearance of *D. magnicorpus* and *Gondisporites raniganjensis* heralds the close of Permian. Simultaneously, the incoming of *Densoisporites contactus, Lundbladispora microconata, L. brevicula, Playfordiaspora cancellosa, Lunatisporites ovatus, L. diffusus* and cf. *L. pellucidus* ushers a new floral phase

signifying the Triassic. This trend in species occurrence (i.e. just above the topmost coal seam of Raniganj Formation) definitely foreshadows the time boundary because it is an expression of benchmark change at this level.

5. The change in species behaviour at Raniganj/Panchet boundary is an important evolutionary event. Remarkable change in the percentage frequency of palynoflora alongwith substantial incoming of newer one, marks the palynological boundary. It indicates a clear cut change in the quality of floral elements and its major genetic as well as ecological alteration. This biological boundary closely precedes the lithological boundary which denotes the change in regional tectonic set up and the area of provinence. The change in certain species—appearance or disappearance is, however, first to occur. Obviously, these three indications of a change over are suggestive of definite time boundary, i.e. Permo-Triassic boundary at this level of events.
6. The coal facies ceases to develop in this basin at Raniganj/Panchet boundary when the area became tectonically static and subsequently khaki-green shales appear as the major dominating lithology. The species distributional design imparts a figurative appearance of two patterns of cluster, one is decreasing and the other is increasing (Text-fig. 1) pattern. In the declining cluster pattern, the group of species *Densipollenites indicus, D. invisus, D. densus, D. magnicorpus* and *Gondisporites raniganjensis* is projected which qualify the Permian palynofloras. These die out gradually. Other cluster pattern which is reversed and emerges at the side of the first one, depicts a slow but continuous progressive increase of Triassic species, such as—*Densoisporites contactus, Lundbladispora microconata, L. brevicula, Playfordiaspora cancellosa, Lunatisporites diffusus* and *L. pellucidus*. These two cluster patterns are complementary to each other and therefore is suggestive of a major change at this level.

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Significant palynozones of Subathu Formation (Himachal Pradesh) and their bearing on stratigraphy

H. P. Singh & Samir Sarkar

Singh, H. P. & Sarkar, S. (1987). Significant palynozones of Subathu Formation (Himachal Pradesh) and their bearing on stratigraphy. *Palaeobotanist* **35**(3) : 249-257.

The distribution of the Subathu Formation palynozones (Upper Palaeocene-Upper Eocene) in the area of Kalka-Simla and Banethi-Bagthan (Himachal Pradesh) has been discussed. The comparative study of these palynozones shows that they are correlatable which has been inferred from the evidence of lateral distribution of the Subathu assemblages studied from widely separated areas.

Key-words—Palynostratigraphy, Correlation, Subathu Formation, Palaeocene-Eocene (India).

H. P. Singh & Samir Sarkar, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

सुबाथु शैल-समूह (हिमाचल प्रदेश) के विशिष्ट परागाणविक मंडल तथा स्तरविन्यास में इनका महत्व

हरिपाल सिंह एवं समीर सरकार

इस शोध-पत्र में कालका-शिमला एवं बनेठी-बगथान (हिमाचल प्रदेश) क्षेत्र में सुबाथु शैल-समूह के परागाणविक मंडलों (उपरि पुरानूतन-उपरि आदिनूतन) का वितरण विवेचित किया गया है। परागाणविक मंडलों के तुलनात्मक अध्ययन से व्यक्त होता है कि इनमें पारस्परिक सम्बन्ध है। यह अनुमान अलग-अलग विस्तृत क्षेत्रों में अध्ययन किये गये सुबाथु समुच्चयों के पार्श्व वितरण के प्रमाणों के आधार पर लगाया गया है।

THE term Subathu was first used by Medlicott (1864) for a conformable sequence of Palaeogene sediments exposed in the Simla Hills, after the town Subathu situated south-west of Simla. Later in 1879, the term 'Sirmur Series' was given to the same stratal sequence by Medlicott himself and the term Subathu was restricted to its lowermost marine sequence. Since then Eocene marine sediments of the Himalayan foothills have been designated as "Subathus".

The rocks of this formation occur as a discontinuous outcrop along the narrow belt in the extrapeninsular region of the Indian subcontinent extending from Jammu in the west to the west of Dehradun in the east. Its maximum development has been observed in the north western region, i.e. Jammu and Kashmir area which thins out south-eastwardly. In Simla Hills, they are conformably overlain by the Dagshai sediments which, in turn, are overlain by the Kasauli succession. The Subathu Formation is mainly characterized by the predominance of calcareous olive green (oily looking), pale-olive, grey, black and purple shales with subordinate lenticular bands of limestones, siltstones and occasional sandstones. Coaly layers have also been observed at the lowermost horizons at certain places.

Different disciplines have been utilized for the correlation of Subathu sediments of Himachal Pradesh such as animal fossils, lithological variation, mineral content of the rocks, etc. But it is not possible to correlate the entire outcrop of the Subathu Formation on the basis of a single discipline. Moreover, the lithofacies of Subathu Formation varies considerably from place to place which creates problems in correlation. Besides, sediments of this formation are much disturbed due to tectonic activity associated with the Great Himalayan uplift thus complicating the problem of correlation.

Table 1—Lithological comparison between Subathu Formation exposed in Kalka-Simla (Solan District) and Banethi-Bagthan area (Sirmaur District) of Himachal Pradesh

Kalka-Simla area		*Banethi-Bagthan area*		
Palynological zones	Lithology	Palynological zones	Lithology	Remarks
Todisporites spp. Cenozone	Pale olive-green shales, generally arenaceous in nature, siltstone bands present, intercalation of purple shales also observed. Limestones are totally absent.	*Todisporites* spp. Assemblage Zone	Alternation of calcareous grey and purple shales, generally calcareous in nature. Limestones are completely lacking in this assemblage zone.	In Banethi-Bagthan area purple shales are highly developed as compared to the Kalka-Simla area, otherwise both the horizons have the same lithological features.
Subathua sahnii Cenozone	Massive to nodular pale olive-green shales with siltstone bands. Shales are slightly arenaceous in nature. In the lower part intercalation of grey shales and in upper part intercalation of purple shales have been observed.	*Subathua sahnii* Assemblage Zone	Argillaceous limestone with massive developments of grey shales with intercalation of thin bands of purple shales and grey siltstone.	Argillacious limestone bands have been observed in Banethi-Bagthan area which are completely lacking in Kalka-Simla area. It may be of local importance only. In Kalka-Simla area, the shales are mostly nodular in nature and arenaceous.
Cordosphaeridium multispinosum Cenozone	Shales of various colours, viz., grey greenish-grey, olive-green, needle like to splintery to nodular in nature. Siltstone bands occassionally present, bands or lenses of limestone or impure shaly limestone have also been observed.	*Cordosphaeridium inodes* Assemblage Zone	Splintery, purplish shales intercalated with siltstone	In Kalka-Simla area lenses of limestones or impure shaly limestone have been found which are absent in the Banethi-Bagthan area. In other characters rocks of both the places are identical.
Hexagonifera spp. Cenozone	Olive-green, calcareous splintery shales, greenish grey splintery shales with more pockets and veins of calcite.			In Banethi-Bagthan area *Hexagonifera* spp. Cenozone not encountered in any of the sections.
Homotryblium spp.	Olive-green, calc cenozone splintery shales, containing streaks and veins of calcite lenses, siliceous limestones are common.	*Homotryblium* spp. Assemblage Zone	Compact, dark purple splintery shales, grey laminated shales intermixed with purplish grey, shaly limestone. Minor partings of white limestone have also been observed in Bagthan section. In Dagalaghat pale olive to purplish shales together with greenish brown siltstone bands are present.	In lithological characters, Subathu sediments of both the areas are almost similar. In Banethi-Bagthan area siltstone bands are present in the shales which are less developed in Kalka-Simla area.
Cleistosphaeridium spp. Cenozone,	Greenish-grey thinly bedded calc. splintery shales with lenses of limestone, sometimes nodular. At Kumarhatti shales are pale olive-green in colour.	*Cleistosphaeridium* spp. Assemblage Zone	Laminated dark brown calc. shales dark brown greenish, ferruginous splintery shales. At Dagalaghat some grey to blackish siltstone bands present.	Overall characters of rocks in both the areas resemble closely excepting in the presence of lenses of limestone in the Kalka-Simla area.
Barren Zone	Massive black shales associated with carbonate bands and at times intercalations of purple shale facies.			This horizon has not been observed in the Banethi-Bagthan area.

(*Continued*)

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Cyclonephelium spp. Cenozone	Alternations of shaly limestone, limestone, carbonaceous shales intercalated with small coal bands.		Subathu sections of Banethi-Bagthan area do not expose the entire thickness of the formation. Therefore we have not found these rock types in our present area of investigation.

Table 2—Palynofloral comparison between Kalka-Simla area (Solon District) and Banethi-Bagthan area (Sirmaur District), Himachal Pradesh

Kalka-Simla area, Palynological zones with characteristic species	*Banethi-Bagthan area, Palynological zones with characteristic species*
Todisporites spp. Assemblage Zone	*Todisporites* spp. Assemblage Zone
Todisporites dagshaiensis, T. kotiensis, T subathuensis, Lycopodiumsporites pattamorensis, L. crossii, L. singhii, Intrapunctisporis intrapunctis Lygodiumsporites barogensis, Podocarpidites kumarhattiensis, Cyathidites cooksonii, etc.	*Todisporites major, T. minor, T rarus, Amtaspora pseudostriata, A. indica, Podocarpidites couperi, P. decorus, Graminidites media, Couperipollis pyrispinosus, C. capitatus, Monoporopollenites kasauliensis, Palmidites noviculatus* and *P. intrafoveolatus*

Remarks—In palynofloral composition this horizon is very much diversified in Banethi-Bagthan area than Kalka-Simla area. Many new forms have been recovered from the horizon of Banethi-Bagthan area, but the general composition of the palynoflora clearly indicates homotaxial relation between these two assemblages.

Subathua sahnii Assemblage Zone	*Subathua sahnii* Assemblage Zone
Subathua sahnii, Thalassiphora velata, I. pelagica, Cyclonephelium indicum, Oligosphaeridium complex, Cleistosphaeridium diversispinosum, C. disjunctum, C. parvum, Homotryblium tenuispinosum and *Hystrichosphaeridium granulatum*	*Subathua sahnii, S. spinosa, Thalassiphora pelagica, T. velata, Glaphyrocysta divaricata, G. exuberans, Cleistosphaeridium flexuosum, Operculodinium centrocarpum, Distatodinium ellipticum* and *Striatriletes susannae*

Remarks—The palynofloral composition of two localities are almost similar.

Cordosphaeridium multispinosum Assemblage Zone	*Cordosphaeridium inodes Assemblage Zone*
Cordosphaeridium multispinosum, C. fibrospinosum, C. exilimurum, Subathua sahnii, T. dagshaiensis, T. kotiensis, Lygodiumsporites barogensis, Thalassiphora velata, Cyclonephelium spinetum, and *Hexagonifera sahnii.*	*Cordosphaeridium inodes, Homotryblium tenuispinosum, H. abbreviatum, H. pallidum, Sentusidinium rioultii, Hystrichosphaeridium tubiferum, Subathua sahnii, S. spinosa* and *Graminidites media.*

Remarks—Cordosphaeridium multispinosum occurs abundantly in the strata of Kalka-Simla area which is replaced by *C. inodes* in Banethi-Bagthan area. The overall composition of palynoflora resembles very closely each other.

Hexagonifera spp. Assemblage Zone	
Hexagonifera reticulata, H. chlamydata, H. vermiculata, H. sahnii, Subathua sahnii, Homotryblium abbreviatum, H. tenuispinosum, etc.	

Remarks—One of the most interesting features of Banethi-Bagthan palynoflora is the complete absence of the genus *Hexagonifera.*

Homotryblium spp. Assemblage Zone	*Homotryblium* spp. Assemblage *Zone*
Homotryblium tenuispinosum, H. abbreviatum, Cyclonephelium spinatum, Tenua kutharensis, Oligosphaeridium complex, Cleistosphaeridium diversispinosum, Hystrichosphaeridium granulatum, and *Thalassiphora velata.*	*Homotryblium tenuispinosum, H. abbreviatum, H. pallidum Hystrichosphaeridium tubiferum, Cleistosphaeridium flexuosum, C. diversispinosum, Glaphyrocysta exuberans, Graminidites media,* and *Spiniferites membranaceous.*

Remarks—In palynofloral composition this horizon is very much similar to both the areas.

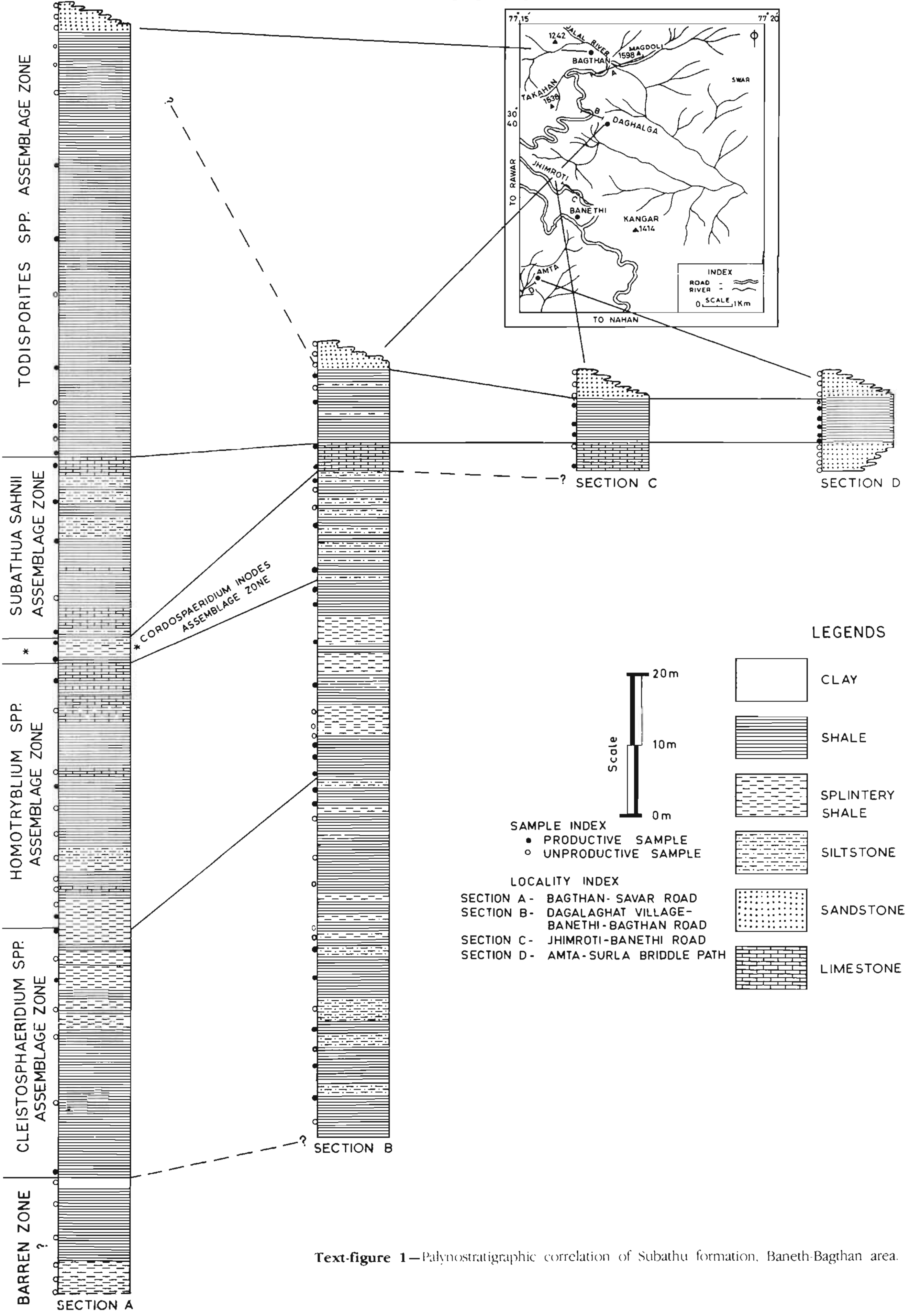
Cleistosphaeridium spp. Assemblage Zone	*Cleistosphaeridium* spp. Assemblage Zone
Cleistosphaeridium diversispinosum, C. disjunctum, Cyclonephelium compactum, C. spinetum, Tenua simlaensis, Trichodinium hirsutum, Oligosphaeridium complex, Hystrichokolpoma unispinum, and *Todisporites dagshaiensis.*	*Cleistosphaeridium diversispinosum, C. flexuosum, Lingulodinium macherophorum, Operculodinium centrocarpum, Glaphyrocysta exuberans, Hystrichosphaeridium tubiferum, Subathua sahnii, Graminidites media* and *Podocarpidites couperi.*

Remarks—Although major forms of this assemblage zone are common to both the places but the Kalka-Simla assemblage is much more diversified than Banethi-Bagthan area.

Cyclonephelium spp. Assemblage Zone	
Cyclonephelium compactum, C. spinatum, C. divaricatum, Tenua simlaensis, T kutharensis, Trichodinium hirsutum, Oligosphaeridium complex, Cleistosphaeridium diversispinosum, C. disjunctum, etc.	

Remarks—This assemblage zone has not been observed in any of the sections of Banethi-Bagthan area. Lithological data also supports this view.

Realizing these limitations, systematic palynological investigations of this succession were started at the Birbal Sahni Institute of Palaeobotany, Lucknow about a decade ago. Very detailed palynostratigraphical investigations were carried out in the Kalka-Simla area of Simla Hills, Himachal Pradesh and a number of papers have been published. Important contributions have been made by Singh *et al.* (1978), Khanna *et al.* (1979), Khanna and Singh (1981), etc. On the basis of qualitative



Text-figure 1—Palynostratigraphic correlation of Subathu formation, Baneth-Bagthan area.

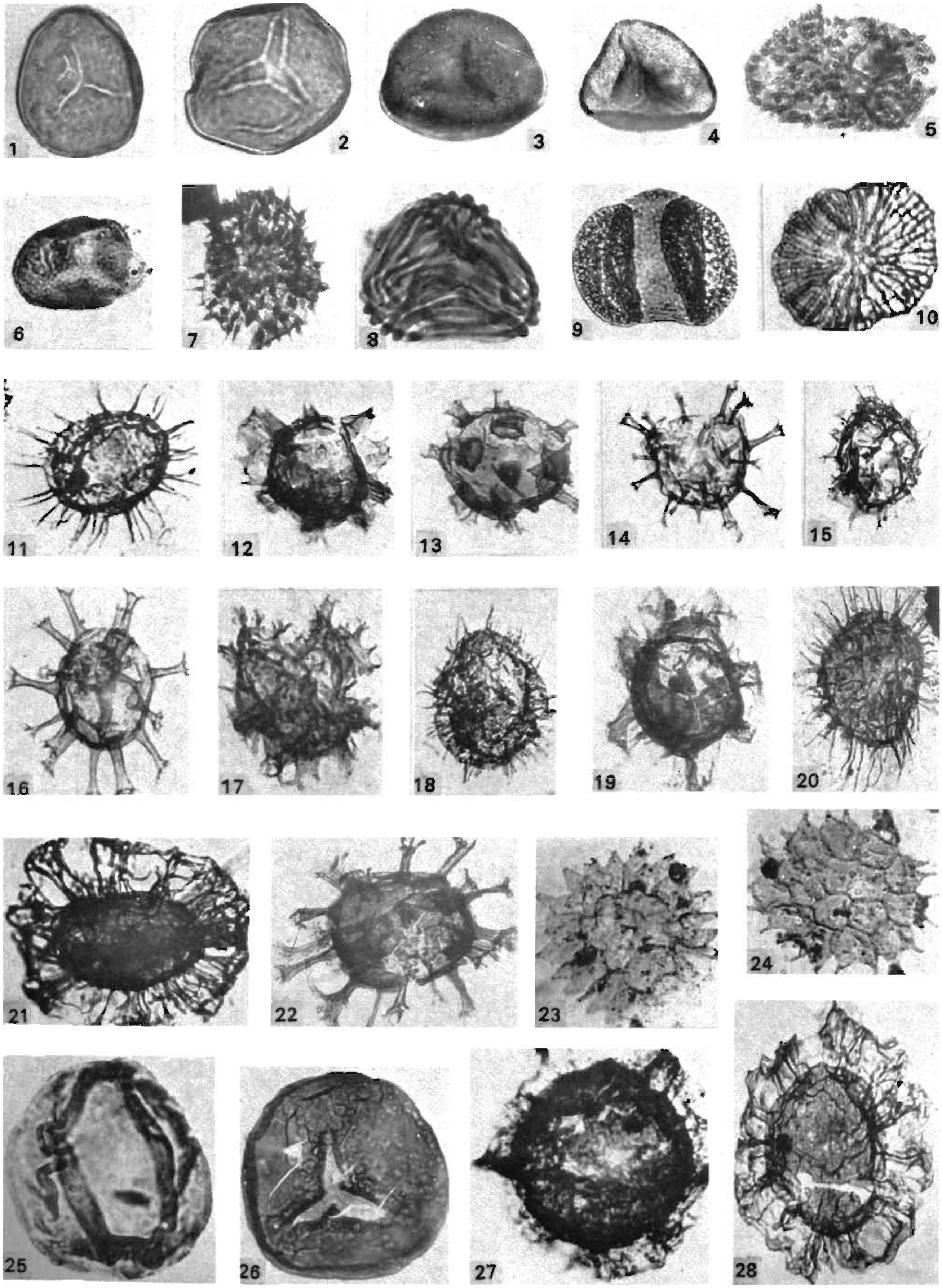


PLATE 1

and quantitative analyses of the palynological data, the following seven cenozones and one barren zone have been established (Singh *et al.*, 1978) in Subathu Section. Their ascending order of stratigraphy is as under:

8. *Todisporites* spp. Cenozone
7. *Subathua sahnii* Cenozone
6. *Cordosphaeridium multispinosum* Cenozone
5. *Hexagonifera* spp. Cenozone
4. *Homotryblium* spp. Cenozone
3. *Cleistosphaeridium* spp. Cenozone
2. Barren zone
1. *Cyclonephelium* spp. Cenozone

Singh *et al.* (1978) have also recognized two subzones, viz., *Pediastrum* spp. subzone, *Hystrichokolpoma* spp. subzone in one section. Kuthar nala section near the Subathu town has been designated as the standard reference section. Khanna *et al.* (1978) correlated eight measured sections of Subathu Formation in the Kalka-Simla area on the basis of distinctive palynological assemblages. They have traced lateral continuity of the palynological zones of the standard reference section in the different sections located from north-east to south-west in the Simla Hills, viz., Kummarhatti, Dagshai, Dharampur A, Dharampur B, Dharampur C, Jabli and Koti. Dharampur A section has been correlated with the stratigraphic horizon of the type section designated as *Todisporites* spp. Cenozone whereas the Dagshai Section represents the upperpart of the *Cordosphaeridium multispinosum* Cenozone, *Subathua sahnii* Cenozone and *Todisporites* spp. Cenozone. The Kumarhatti Section possesses all the cenozones of the standard reference section excepting the *Hexagonifera* spp. Cenozone. Lithostratigraphically the cenozones of this section are comparatively thinner but biostratigraphic horizon corresponds to its equivalent horizon with reference to the standard reference section. Lower part of Dharampur B section has been equated with the upper part of the *Cordosphaeridium multispinosum* Cenozone of the type section. Likewise Dharampur C section represents two palynological zones, viz., *Cleistosphaeridium* spp. Cenozone and *Homotryblium* spp. Cenozone whereas Koti Section is represented only by the *Cordosphaeridium multispinosum* Cenozone of the standard reference section. The Jabli Section has been equated with the palynological zones, viz., *Cleistosphaeridium* spp. Cenozone, *Homotryblium* spp. Cenozone, *Cordosphaeridium multispinosum* Cenozone, *Subathua sahnii* Cenozone and *Todisporites* spp. Cenozone. The *Hexagonifera* spp. Cenozone has not been observed in this section. They have established two subzones, viz., *Pediastrum* spp. subzone and *Hystrichokolpoma granulata* subzone but it is assumed that they are of local significance because

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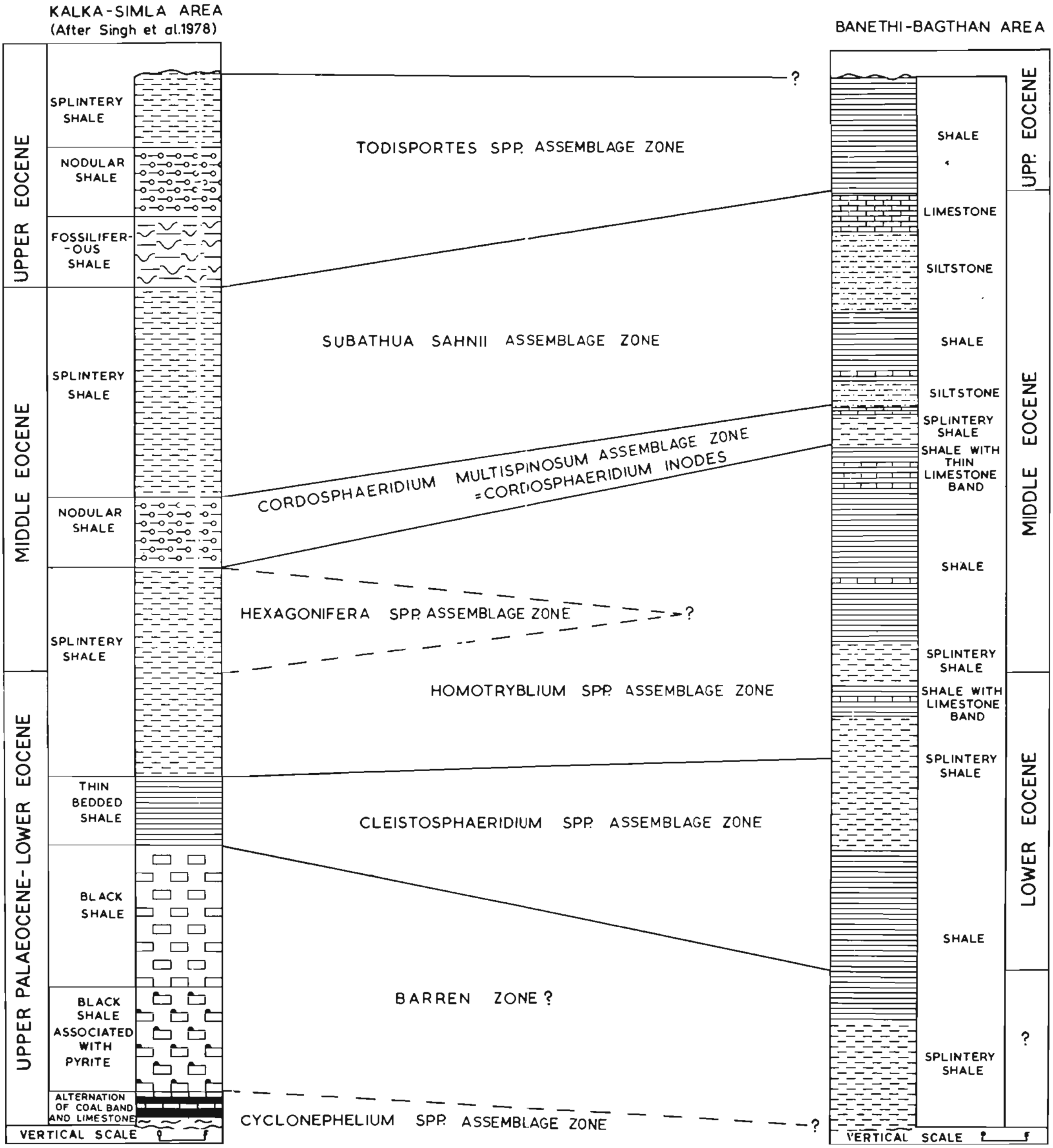
PLATE 1

(All photomicrographs are enlarged Ca. × 500 unless otherwise mentioned).

1. *Todisporites minor* Couper; Slide no. BSIP 6860; Coordinates 5 × 69.
2. *Todisporites rarus* Sarkar & Singh; Slide no. BSIP 6860; Coordinates 21 × 96.5.
3. *Amtaspora pseudostriata* Sarkar & Singh; Slide no. BSIP 6861; Coordinates 20.4 × 110.5.
4. *Amtaspora indica* Sarkar & Singh; Slide no. BSIP 6860; Coordinates 21 × 96.5.
5. *Couperipollis pyrispinosus* Sarkar & Singh; Slide no. BSIP 6861; Coordinates 15 × 74.
6. *Osmundacidites mollis* (Cookson & Dettmann) Dettmann; Slide no. BSIP 8423; Coordinates 14.5 × 118.2.
7. *Couperipollis pyrispinosus* Sarkar & Singh; Slide no. BSIP 6861; Coordinates 2.1 × 85.8.
8. *Striatriletes susannae* (van der Hammen) Kar; Slide no. BSIP 6928; Coordinates 10 × 81.5.
9. *Podocarpidites couperi* Sarkar & Singh; Slide no. BSIP 6915; Coordinates 21.5 × 102.2.
10. *Phragmothyrites eocaenica* Edwards; Slide no. BSIP 6921; Coordinates 5.8 × 104.
11. *Operculodinium centrocarpum* (Deflandre & Cookson) Wall; Slide no. BSIP 6917; Coordinates 21 × 80.
12. *Hystrichokolpoma cinctum* (Klumpp.) Damassa; Slide no. BSIP 6895; Coordinates 14 × 107.
13. *Homotryblium abbreviatum* Eaton; Slide no. BSIP 6911; Coordinates 11.8 × 116.
14. *Homotryblium pallidum* Davey & Williams; Slide no. BSIP 6917; Coordinates 5.8 × 83.6.
15. *Spiniferites membranaceus* (Rossignol) Sarjeant; Slide no. BSIP 6903; Coordinates 7 × 102.
16. *Homotryblium tenuispinosum* Davey & Williams; Slide no. BSIP 6903; Coordinates 19.5 × 78.5.
17. *Spiniferites supparus* (Drugg) Sarjeant; Slide no. BSIP 6826; Coordinates 3 × 101.
18. *Cleistosphaeridium flexuosum* Davey *et al.*; Slide no. BSIP 6926; Coordinates 15.5 × 117.8.
19. *Hystrichokolpoma cinctum* (Klumpp) Damassa; Slide no. BSIP 6896; Coordinates 15 × 101.5.
20. *Cleistosphaeridium diversispinosum* Davey *et al.*; Slide no. BSIP 6898; Coordinates 7.8 × 108.2.
21. *Adnatosphaeridium vittatum* Williams & Downie; Slide no. BSIP 6924; Coordinates 15 × 73.5.
22. *Hystrichosphaeridium arborispinum* Davey & Williams; Slide no. BSIP 6924; Coordinates 4 × 99.
23. *Pediastrum diffusus* Singh & Khanna; Slide no. BSIP 8422; Coordinates 6 × 77.8.
24. *Pediastrum wilsonii* Singh & Khanna; Slide no. BSIP 8421; Coordinates 14.5 × 106.2.
25. *Laricoidites himalayensis* Sarkar & Singh; Slide no. BSIP 6925; Coordinates 5.2 × 89.
26. *Todisporites major* Couper; Slide no. BSIP 6927; Coordinates 15 × 73.5.
27. *Subathua sahnii* Khanna & Singh; Slide no. BSIP 6907; Coordinates 5 × 117.5.
28. *Glaphyrocysta exuberans* (Deflandre & Cookson) Stover & Evitt; Slide no. BSIP 6923; Coordinates 105 × 85.



Text-figure 2—Palynostratigraphical correlation of Subathu sediments of Kalka-Simla and Banethi-Bagthan area, Himachal Pradesh.

they are not laterally traceable.

Prompted by the successful application of palynological fossils in correlating different sections of Sabathu Formation in Kalka-Simla area the present authors have carried out an extensive palynostratigraphical investigation in the Benethi-Bagthan area of Sirmaur District, Himachal Pradesh in order to find out the potentialities of the established palynozones of Kalka-Simla area. On the basis of recovered palynofossils five distinct palynological zones have been established in this area. In ascending order of stratigraphy they are: *Cleistosphaeridium* spp. Assemblage Zone, *Homotryblium* spp. Assemblage Zone, *Cordosphaeridium inodes* Assemblage Zone, *Subathua sahnii* Assemblage Zone and *Todisporites* spp. Assemblage Zone. Four measured sections, viz., Dagalaghat Village-Banethi-Bagthan Road Section, Jhimroti-Banethi Road Section, Bagthan-Savar Road Section and Amta-Surla Briddle Path Section, have been correlated. Among these sections, Bagthan-Savar Road Section has been designated as the standard reference section because it is the thickest among all the four studied sections. Besides, it contains all the assemblage zones established in the present area of investigation. Considering the Bagthan-Savar Road Section as the standard reference section and on the basis of recovery of various palynological assemblages, it has been possible to equate different parts of the Subathu sediments with the stratigraphic horizons of this section.

The Dagalaghat Village—Banethi-Bagthan Road Section represents *Cleistosphaeridium* spp. Assemblage Zone, *Homotryblium* spp. Assemblage Zone, *Cordosphaeridium inodes* Assemblage Zone, *Subathua sahnii* Assemblage Zone and *Todisporites* Assemblage Zone in ascending order of stratigraphy. The assemblage zones of this section have been correlated with the corresponding assemblage zones of the standard reference section. However, the *Subathua sahnii* Assemblage Zone is associated with a comparatively thinner strata.

The Subathu sediments represented in the Jhimroti-Banethi Road Section have yielded two types of palynological assemblages which are similar to the assemblages of *Subathua sahnii* and *Todisporites* spp. Assemblage zones. Therefore, the stratigraphic horizons of this section containing *Subathua* and *Todisporites* rich assemblages have been correlated with the *Subathua sahnii* and *Todisporites* spp. Assemblage zones of the Bagthan-Savar Road Section. It is also proposed that the lower part of this section is equivalent to the upper part of the *Subathua sahnii* Assemblage zone of the standard reference section.

The Amta-Surla Briddle path section represents only a part of the Subathu sediments and the palynological information from the sediments allows its correlation with the *Todisporites* spp. Assemblage zone of the standard reference section. Palynostratigraphic scheme of correlation of four measured sections of the Subathu Formation is presented in Text-fig. 1.

Palynostratigraphic correlation of the Subathu sediments of Banethi-Bagthan and Kalka-Simla areas of Himachal Pradesh (Text-fig. 2) shows that the Subathu Formation is conformably overlain by the Dagshai Formation in the Kalka-Simla area. Similar situation is maintained in all four sections of the Subathus presently investigated in the Banethi-Bagthan area. It is interesting to note that the lithological similarity of the Subathu sediments in both the areas is very striking (Table 1) as is exhibited by the presence of calcareous green, purple or grey coloured splintery shale, carbonaceous shale, siltstone and limestone bands separated from each other by the shales and siltstones. In the uppermost part of the Subathu shales tend to become purplish in colour. However, the basal horizons of the Subathu Formation of Kalka-Simla area are characterized by having mostly alternation of shaly limestones, carbonaceous shales intercalated with small coal bands. Few older corresponding horizons have not been found in the Banethi-Bagthan area. The lower most Subathu palynological assemblage of Kalka-Simla area possesses the *Cyclonephelium* spp. Cenozone. This palynozone has not been encountered in the Banethi-Bagthan area. Palynological investigations show that out of the seven palynostratigraphical zones established within the Subathus (Singh *et al.*, 1978) of Kalka-Simla area, only five have been located in the Banethi-Bagthan area. The palynological composition of each zone within the Subathu Formation of Kalka-Simla area is also reflected in the corresponding zones of the Banethi-Bagthan area (Table 2).

The lowermost palynological zone of the Subathu succession in the Banethi-Bagthan area is the *Cleistosphaeridium* spp. Assemblage Zone. It shows a close palynofloral similarity with the *Cleistosphaeridium* spp. Assemblage Zone of the Subathus in the Kalka-Simla area. *Glaphyrocysta divaricata* (= *Cyclonephelium divaricata*), *Cleistosphaeridium diversispinosum, Lingulodinium macherophorum,* (= *C. disjunctum*), *Homotryblium tenuispinosum, Oligosphaeridium complex* and *Subathua sahnii* are the important taxa common to both the assemblages.

Homotryblium spp. Assemblage Zone, the next palynozone of Subathu Formation (Banethi-Bagthan area) shows a close correspondence in palynofloral composition with the *Homotryblium* spp. Cenozone of the Kalka-Simla area. The stratigraphically important forms common to both the palynozones are *Cleistosphaeridium diversispinosum, Homotryblium tenuispinosum, H. abbreviatum, Hystrichosphaeridium tubiferum* and *Subathua sahnii.* In ascending order of stratigraphy, the third palynological zone of the Subathu Formation in Banethi-Bagthan area is *Cordosphaeridium inodes* Assemblage Zone. This assemblage zone has been equated with the *Cordosphaeridium multispinosum* Cenozone of the Kalka-Simla area on the basis of identical lithology and overall similar palynofloral composition. The corresponding levels of the Subathu Formation at both the places have abundant occurrence of the genus *Cordosphaeridium*. *Homotryblium tenuispinosum, H. abbreviatum* and *Subathua sahnii* are common to both the assemblages. *Hexagonifera* spp. Cenozone in between the *Homotryblium* spp. Cenozone and *Cordosphaeridium multispinosum* Cenozone of the Subathu succession in Kalka-Simla area has not been located in the present area of investigation.

The fourth palynological zone of the Subathu Formation in the Banethi-Bagthan area is *Subathua sahnii* Assemblage Zone. This assemblage zone has been correlated with the *Subathua sahnii* Cenozone of the Kalka-Simla area on the basis of the dominance of *Subathua sahnii, S. spinosa* and *Thalassiphora pelagica*, etc.

The next assemblage zone of the Subathu Formation is represented by *Todisporites* spp. Assemblage Zone in both the areas together with similar composition of palynofossils. This assemblage zone at both the places is characterized by having exclusively pteridophytic spores, gymnospermous and angiospermous pollen grains. Thus it is quite apparent from the above facts that the five palynological zones of the Banethi and Bagthan areas have a close relationship with the five palynofloral zones of the middle and upper part of Subathu Succession of Kalka-Simla area of Simla Hills. On all possible counts they can be assumed to be representing the lateral continuation of the Kalka-Simla palynozones. Based on their close resemblance these palynozones have been correlated as given below:

Kalka-Simla area	Banethi-Bagthan area
Todisporites spp. Cenozone	= *Todisporites* spp. Assemblage Zone
Subathua sahnii Cenozone	= *Subathua sahnii* Assemblage Zone
Cordosphaeridium multispinosum Cenozone	= *Cordosphaeridium inodes* Assemblage Zone
Homotryblium spp. Cenozone	= *Homotryblium* spp. Assemblage Zone
Cleistosphaeridium spp. Cenozone	= *Cleistosphaeridium* spp. Assemblage Zone

From the foregoing discussion it is evident that lateral continuation of the Subathu palynozones over widely separated areas in Himachal Pradesh is a significant phenomenon which can reliably be used in palynological correlations.

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The Palaeobotanist **35**(3) : 258-262, 1986.

Fossil leaves of *Dipterocarpus* from the Lower Siwalik beds near Jawalamukhi, Himachal Pradesh

R. N. Lakhanpal & J. S. Guleria

Lakhanpal, R. N. & Guleria, J. S. (1987). Fossil leaves of *Dipterocarpus* from the Lower Siwalik beds near Jawalamukhi, Himachal Pradesh. *Palaeobotanist* **35**(3) : 258-262.

Leaf impressions resembling those of the modern *Dipterocarpus turbinatus* Gaertn. f. and *D. tuberculatus* Roxb., have been described from the Lower Siwalik beds of Balu-Goloa, near Jawalamukhi (Himachal Pradesh) as *Dipterocarpus siwalicus* sp. nov. Their occurrence indicates that a moist tropical forest was growing near Jawalamukhi during the Middle Miocene times.

Key-words—Megafossil, Fossil leaves, *Dipterocarpus*, Lower Siwalik, Middle Miocene (India).

R. N. Lakhanpal & J. S. Guleria, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

सारॉंश

ज्वालामुखी (हिमाचल प्रदेश) के समीपस्थ अधरि शिवालिक संस्तरों से डिप्टेरोकार्पस की अश्मित पत्तियाँ

राजेन्द्र नाथ लखनपाल एवं जसवन्त सिंह गुलेरिया

ज्वालामुखी (हिमाचल प्रदेश) के समीपस्थ बालु-गोलो की अधरि शिवालिक संस्तरों से वर्तमान डिप्टेरोकार्पस टर्बिनेटस गेयर्टन० ऍफ़० एवं डि० ट्यूबरकुलेटस रॉक्सबरो की पत्तियों से मिलती-जुलती पर्ण-छापों को डिप्टेरोकार्पस शिवालिकस नव जाति के नाम से वर्णित किया गया है। इनकी उपस्थिति से व्यक्त होता है कि मध्य-मध्यनूतन युग में ज्वालामुखी के समीप एक नम उष्णकटिबन्धीय वन विद्यमान था।

A NUMBER of angiospermic leaf-impressions belonging to *Berchemia, Ficus, Fissistigma, Lagerstroemia, Smilax* and *Ziziphus* and a fruit of *Dalbergia* were described from the Jawalamukhi area in district Kangra, Himachal Pradesh (Lakhanpal, 1965, 1966, 1968, 1969; Lakhanpal & Dayal, 1966). These fossils came from the Lower Siwalik beds (Sahni & Mathur, 1964; Karunakaran & Ranga Rao, 1979) exposed near the village Balu-Goloa (31° 57′N : 76°16′ E), about 12 km northwest of Jawalamukhi. From the same area, though not from Balu-Goloa, Mathur (1978) described leaf-impressions of *Mallotus* and the artificial genera *Papilionoid* and *Poacites*. In addition, a fossil wood, *Anisopteroxylon jawalamukhi*, had also been described by Ghosh and Ghosh (1958) from the Middle Siwalik exposures near the village Khundian (31°56′N : 76°23′ E).

The occurrence of leaf-impressions resembling those of *Dipterocarpus* in the Siwalik sediments of the Jawalamukhi area had already been reported by Lakhanpal (1970, p. 683; 1974, p. 34). They were collected from near Balu-Goloa and are being described in the present paper. These impressions are preserved on compact, fine-grained sandstones of the Lower Siwalik horizon.

DESCRIPTION

Family—Dipterocarpaceae

Genus—*Dipterocarpus* Gaertn. f.

Dipterocarpus siwalicus sp. nov.

Fig. 1; Fig. 2 A-C

The species is represented by more than a dozen well preserved impressions of small to large leaves. Leaves seemingly symmetrical, ovate to elliptic, lamina 8.5-21.5 cm in length and 6.0-11.0 cm in width; apex acute to slightly attenuate; base more or less round to cordate; margin entire or slightly undulate; texture thick chartaceous; petiole not preserved; venation pinnate, eucamptodromous;

primary vein (1°) moderate, more or less straight to slightly curved; secondary veins (2°) usually alternate, rarely a few secondaries oppositely arranged, angle of divergence acute, 25°-80° (mostly 40°-60°), decreasing from base towards apex, course straight to uniformly curved, unbranched, intersecondary veins absent; tertiary veins (3°) with angle of origin about 70°-80°; pattern percurrent, course somewhat wavy, unbranched, running obliquely in relation to mid-vein, arrangement

Figure 1—*Dipterocarpus siwalicus* sp. nov. × Natural size. Specimen no. BSIP 35859.

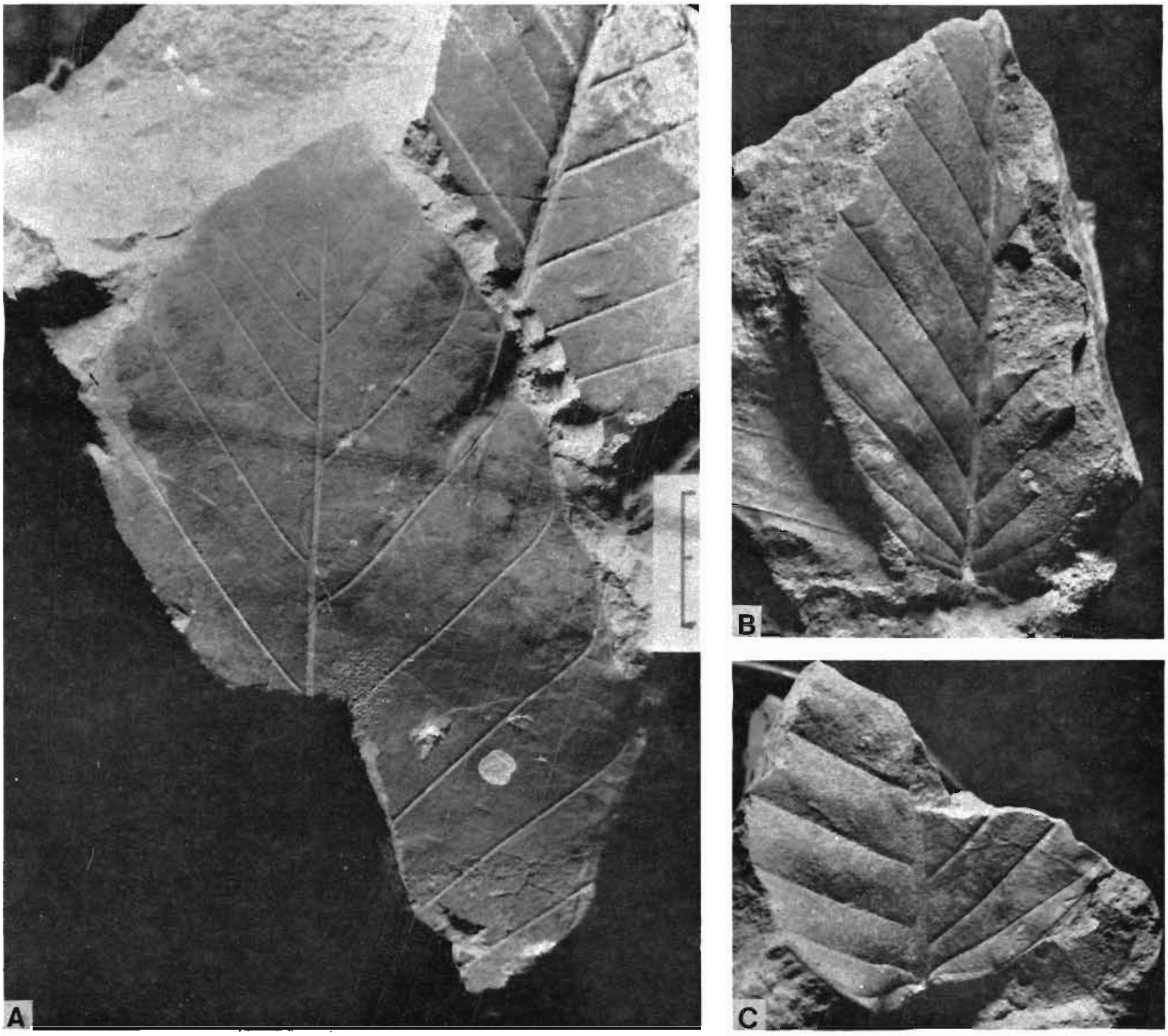

Figure 2A-C—*Dipterocarpus siwalicus*, leaves showing variation in size and shape—Natural size. Specimen nos. BSIP 35860-35862.

mostly alternate, usually close, rarely distant; higher order venation not seen.

Holotype—Specimen no. BSIP 35859.

Paratypes—Specimen nos. BSIP 35860-35862.

Locality—Near Balu-Goloa (31°57′ N : 76°16′ E), about 12 km north-west of Jawalamukhi, district Kangra, Himachal Pradesh.

Horizon & Age—Lower Siwalik; Middle Miocene

DISCUSSION

The main features of the fossil leaves are : (i) broadly ovate shape, (ii) medium to large size, (iii) acute to slightly attenuated apex, (iv) broadly obtuse to rounded base, sometimes also cordate, (v) thick texture, (vi) secondaries coming off straight from the midrib and curving up near the margin, (vii) angle of divergence of the secondaries decreasing from base towards the apex, and (viii) tertiaries in slanting cross-ties. Considered collectively, they clearly indicate that these leaves belong to the family Dipterocarpaceae. Very close comparison is offered by the genera *Shorea* and *Dipterocarpus*. However, in *Shorea* there is very often a prominent branching of some of the secondaries, which is not found in any of the present leaf-impressions. Thus the fossil leaves can be assigned to the genus *Dipterocarpus* Gaertn. f.

There are many living species of *Dipterocarpus*, but some have much larger or thicker and stiffer leaves while in others the leaves are smaller. In 3-4 species there is an occasional inter-secondary between adjacent secondaries. In almost all the characters and range of size, the closest resemblance is shown by the leaves of *Dipterocarpus turbinatus* Gaertn. f. However, in one feature there is some difference. In *D. turbinatus* the leaf base is broadly obtuse to almost rounded and the same is found in most of the fossil specimens. But in two or three impressions the leaf base is cordate. Such a base is found in the leaves of *D. tuberculatus* Roxb., which are usually larger in size than those of *D. turbinatus*. Thus the present fossil combines almost all the features of the leaves of *D. turbinatus* with one found in those of *D. tuberculatus*. Most probably it represents an ancestral form from which these two species have evolved. As far as we are aware, there are 19 records of fossil leaves referred to Dipterocarpaceae as listed below, giving relevant information about their provenance, age and comparable modern taxa.

It is not our intention here to evaluate the correctness and validity of all these records but to consider those that can be compared with the Balu-Goloa leaves for taxonomic relationship. Going by the identifications given by the previous workers, the following six records merit discussion as far as their affinity with *Dipterocarpus* is concerned:

1. *Dipterocarpus antiquus* Heer
2. *D. atavinus* Heer
3. *D. labuanus* Geyler
4. *D. nordenskiöldi* Geyler
5. *Dipterocarpus* sp. Geyler
6. *Phyllites dipterocarpoides* Crié.

About *Dipterocarpus antiquus* and *D. atavinus* Edwards (1923, p. 161) remarked that these two species might belong to the family Dipterocarpaceae, particularly *D. atavinus*, but did not comment about their generic identification with *Dipterocarpus*. Earlier Brandis (1895, p. 4) had also accepted *D. atavinus* as belonging to Dipterocarpaceae but considered it as a species of *Shorea* rather than *Dipterocarpus*. Thus these two species are not definitely assignable to the genus *Dipterocarpus*. Edwards (1923, p. 162) had examined the original specimens of *Dipterocarpus labuanus, D. nordenskiöldi* and *Dipterocarpus* sp. of Geyler in the Stockholm Museum and was not convinced about the certainty of their attribution as according to him these specimens were not definitely identifiable. According to Brandis (1895, p. 4) these fossils "show no characters which warrant their reference to the Dipterocarpaceae". Bancroft (1933, p. 82) agreed with the above opinions and suggested that these records of Geyler should be left out of any account of the geological history of the Dipterocarpaceae.

Phyllites dipterocarpoides has been compared with the leaves of the modern species *Dipterocarpus baudii* and as such can be considered the only authentic fossil record of a *Dipterocarpus* leaf. Leaves of *D. baudii* (synonym of *D. duperrianus*) are very thick, large and hairy and quite distinct from those of *D. turbinatus* or *D. tuberculatus* with which our fossils are closely comparable. Therefore, we are assigning the Balu-Goloa leaves to a new species, *Dipterocarpus siwalicus*, named after the Siwalik beds from which they were collected.

Dipterocarpus turbinatus, with which *D. siwalicus* shows the closest resemblance, is a lofty tree, 37-46 m, high, distributed in Assam, Andamans,

Name	*Author*	*Locality*	*Age*	*Comparable modern taxa*
Anisoptera thurifera	Merrill (1923)	Luzon (Philippines)	Pliocene	*Anisoptera*
Dipterocarpaceophyllum sumatrense	Kräusel (1929)	Sumatra	Tertiary	Dipterocarpaceae, genus indeterminate
Dipterocarpophyllum gregoryi	Edwards (1923)	Burma	Tertiary	Dipterocarpaceae, genus indeterminate
D. humei	Seward (1935)	Egypt	?Tertiary	*Shorea*
D. zeraibense	Seward (1935)	Egypt	?Tertiary	*Shorea*
Dipterocarpus antiquus	Heer (1883)	Sumatra	Tertiary	*?Dipterocarpus*
D. atavinus	Heer (1883)	Sumatra	Tertiary	*?Dipterocarpus*
D. labuanus	Geyler (1887)	Labuan	Tertiary	*?Dipterocarpus*
D. nordenskiöldi	Geyler (1887)	Labuan	Tertiary	*?Dipterocarpus*
Dipterocarpus sp.	Geyler (1887)	Labuan	Tertiary	*?Dipterocarpus*
Doona? chaneyi	Wolfe (1977)	Alaska (U.S.A.)	Eocene	*Doona*
Hopea fagifolia	Schuster (1911)	Java	Pleistocene	*Hopea*
Parashorea chasmanensis	Wolfe (1977)	Alaska (U.S.A.)	Eocene	*Parashorea*
P. pseudogoldiana	Wolfe (1977)	Alaska (U.S.A.)	Eocene	*Parashorea*
Phyllites dipterocarpoides	Crié (1888)	Java	Pliocene	*Dipterocarpus*
P. (Hopea) praecursor	Geyler (1875)	Borneo	Eocene	*Hopea*
Shorea guiso	Merrill (1923)	Luzon (Philippines)	Pliocene	*Shorea*
S. polyspermum	Merrill (1923)	Luzon (Philippines)	Pliocene	*Shorea*
Vatica lancifolia	Schuster (1911)	Java	Pleistocene	*Vatica*

Bangla Desh, Burma, Cochin-China and Thailand. The tree is not typically gregarious though sometimes it approaches that condition in patches. It is found in the forests of the moister tropical type, evergreen or semi-evergreen, where it towers over the rest of the associates, often with an undergrowth of palms, canes and climbers. In its natural habitat the absolute maximum shade temperature varies from 37°-41°C and the absolute minimum from 7°-16°C. The rainfall varies from 1,500-5,000 mm.

The other comparable modern species, *D. tuberculatus*, is a large deciduous tree, 30-37 m high, growing gregariously in Burma, Cochin-China and Thailand. From Burma it also extends into the borders of Assam and Bangla Desh. It is found in localities where the absolute maximum shade temperature varies from 37.5°C to 43°C and the absolute minimum shade temperature from 4.5°-10°C. The normal rainfall varies from about 900-3050 mm.

The climatic requirements of the above two species closely comparable with *D. siwalicus*, indicate that a rich, moist tropical forest must have been growing around the fossil locality during the Middle Miocene times when the Lower Siwalik sediments were deposited there.

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Characters and homologies of ancient angiosperms as related to their origin

Ludwig Rüffle

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Morphogenetics and interpretative morphology of ancient angiosperms, as evidenced by pollen and leaves from the Middle and Lower Cretaceous, are discussed. The similarity of pollen in Chloranthaceae and *Austrobaileya* shows close relationship which confirms Meeuse's Anthocorm Theory. General morphology of Monimiaceae and Piperaceae is investigated to find some morphological peculiarities of their organs concerning their phylogenetic ambiguity. The flowers of Monimiaceae resemble those of *Whittleseya* and the inflorescences of Piperales (Saururales) resemble some so-called teratologies in modern hybrids of certain Rosaceae. The lack of petals in *Neviusia* as well as certain inflorescences of Bennettitales need consideration.

Key-words—Angiosperms, Origin, Morphogenetics, Monimiaceae, Piperaceae.

Ludwig Rüffle, Palaeontologisches Museum, Museum für Naturkunde, Humboldt Universitat, D.D.R.-1040 Berlin, West Germany.

सारॉंश

प्राचीन आवृतबीजीयों के उद्भव से सम्बद्ध इनके संलक्षण एवं समजाततायें

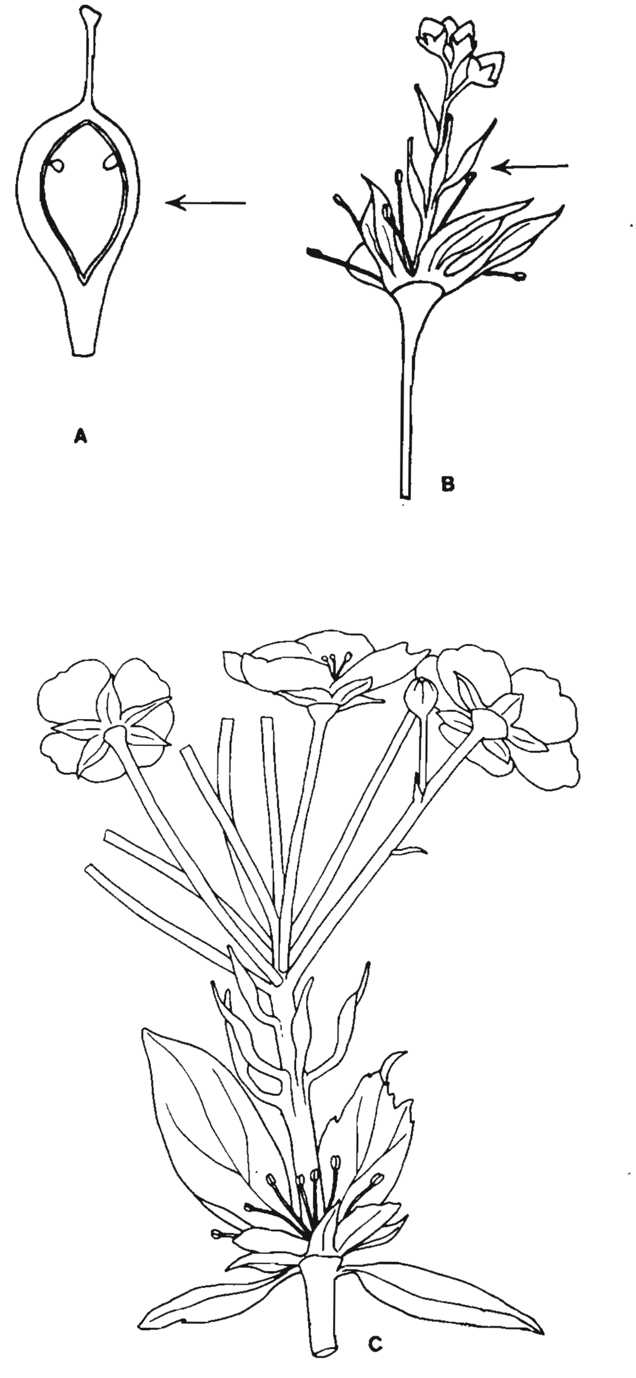
लुडविग रफ़ले

मध्य एवं अधरि क्रीटेशी काल से उपलब्ध अश्मित परागकणों एवं पत्तीयों के प्रमाणों के आधार पर प्राचीन आवृतबीजीयों का संरचनाविकास तथा इनकी व्याख्यात्मक आकारिकी विवेचित किये गये हैं। क्लोरेन्थेसी एवं ऑस्ट्रोबैलया के परागकणों की परस्पर समानता से इनका घनिष्ठ सम्बन्ध व्यक्त होता है जिससे मीयूस के एँन्थोकॉर्म सिद्धान्त की पुष्टी होती है। मोनीमिएसी एवं पाइपरेसी नामक कुलों के सम्बद्ध अंगों की जातिवृत्तीय संदिग्धता अन्वेषित करने हेतु इनकी सामान्य आकारिकी का अध्ययन किया गया है। मोनीमिएसी कुल के पुष्प व्हिटलेसिआ से समानता प्रदर्शित करते हैं तथा पाइपरेल्स (सोरुरेल्स) के पुष्पक्रम रोज़ेसी कुल के कुछ वर्तमान संकरों से सजातीयता व्यक्त करते हैं। नेवियूसिआ एवं कुछ बेन्निटाइटेल्स के पुष्पक्रमों में दलपुंज की अनुपस्थिति विचारणीय है।

AFTER Zimmermann's (1966) view of "Hologeny" qualitative new organs (characters) in plant phylogeny can be developed by a certain heterobathmic composition ("mosaic") of partial multiplications and partial stability of older ones. While some organs and characters remain in ancient stature and shape, an other part becomes comparably smaller and increases in quantity. The combination of all these parts by fusion forms a new organ (character). Referring to this there seem to be no differences between genetics and phylogenetics. Some examples of hybrids and so-called teratologies show the same (Guédès). If reduction in the above mentioned manner becomes evident in a high degree, this mode of phylogenetic evolution would be called neoteny by Takhtajan. As far as an organism may be reduced or not, paleobotanical record can demonstrate.

It seems that the more principles of neoteny became acknowledged by botanists, the more was it possible to judge ontogenetical (and some teratological?) events in connection with phylogenesis and last but not least with paleobotany. Enlargement of organisms by new organs does not take place in continuity as well in phylogeny as in ontogeny.

It seems to be of importance that most of the higher plants [particularly angiosperms



Text-figure 1—A-C, *Spiracea* van Houttei ZBI. (hybrid of species) : Prolification of flower, ca × 10, ca × 20, ca × 30 respectively.

(Magnoliophyta) in a high degree] are similar in cotyledonar and reproductive (floral) regions: shape of foliar appendages, gonophylls, semaphylls ("bracts, petals"), venation, marginal meristems, trichotomy, dichotomy (particularly in default of buds), central steles, dedifferentiation of adaxial and abaxial surfaces (particularly in some monocots) Rüffle (1969, 1980). The higher coordinations and differentiations as angiosperm phylogeny has produced them, seem to be a heterobathmic mixture of intermediate programs of several morphogenetic events resembling loops of computers. If any loop lacks, regeneration of morphogeny becomes neoteny. New characters of organisms cannot simply be added terminally in ontogenesis or phylogenesis at least. This may be the main reason that for derivation of angiosperms (Magnoliophyta) from ancient groups, comparisons (and definitions) with flowers only are insufficient; paleobotany needs more or less parts in connection or the whole plant for reconstruction of ontogeny. Knowledge of modern plants can make it easy. It seems that in angiosperms many buds (perhaps certain flowers), intercalary growth of leaves and shoots (Doyle & Hickey) and secondary thickening or the whole stem of trees from cotyledons to the reproductive region are such inter-mediated programs, characterized rather by many postgenital adnations.

Hagemann has shown that in *Helleborus* (and obviously in *Platanus, Dewalquea* (Fagaceae) and Araceae too) the pedate shape of foliar leaves originates from a secondary meristem which is arranged across the petiole. The leaves though compound are homologous to any other simple leaf of Ranunculaceae (Platanaceae, Fagaceae, Araceae). But the more leaves are compound in the pedate manner, the so-called leaflets are at the same time homologous with simple leaves concerning the groups mentioned above. In view of phylogeny (and neoteny) each homology seems to be ambiguous.

Obviously plant organs can produce more plant organs close to the former by neotenic regeneration. The present author postulates that the median prolifications in the flowers of some hybrids in *Spiracea* or *Geum* producing small clusters of new flowers instead of carpels, etc. are not only teratological, they are atavisms resembling the inflorescences of Piperales (Saururales), which are regarded by Kuprianova and Meeuse to be one of the oldest angiosperm families close to Araceae. For *Peperomia* Leinfellner has found out that the hypopeltate bracts within the spica resemble the mode of growth of the so-called "Querzone" of angiospermous carpels and some cotyledons. To the present author it seems possible to interpret the inflorescences of Piperales nearly as an inflorescence as well as only one cone-like flower. The basal bracts seem to be petals. This recalls the anthocorm theory with a small correction: The inflorescences of Piperales (Saururales) seem to be homologous pro parte to the flowers of *Magnolia* (holanthocormoid) but the single flowers of Piperales (anthoid) likewise pro parte.

This could explain many premises of the anthocorm theory (theory of polyaxis in floral region). Meeuse (1976) draws the attention also to

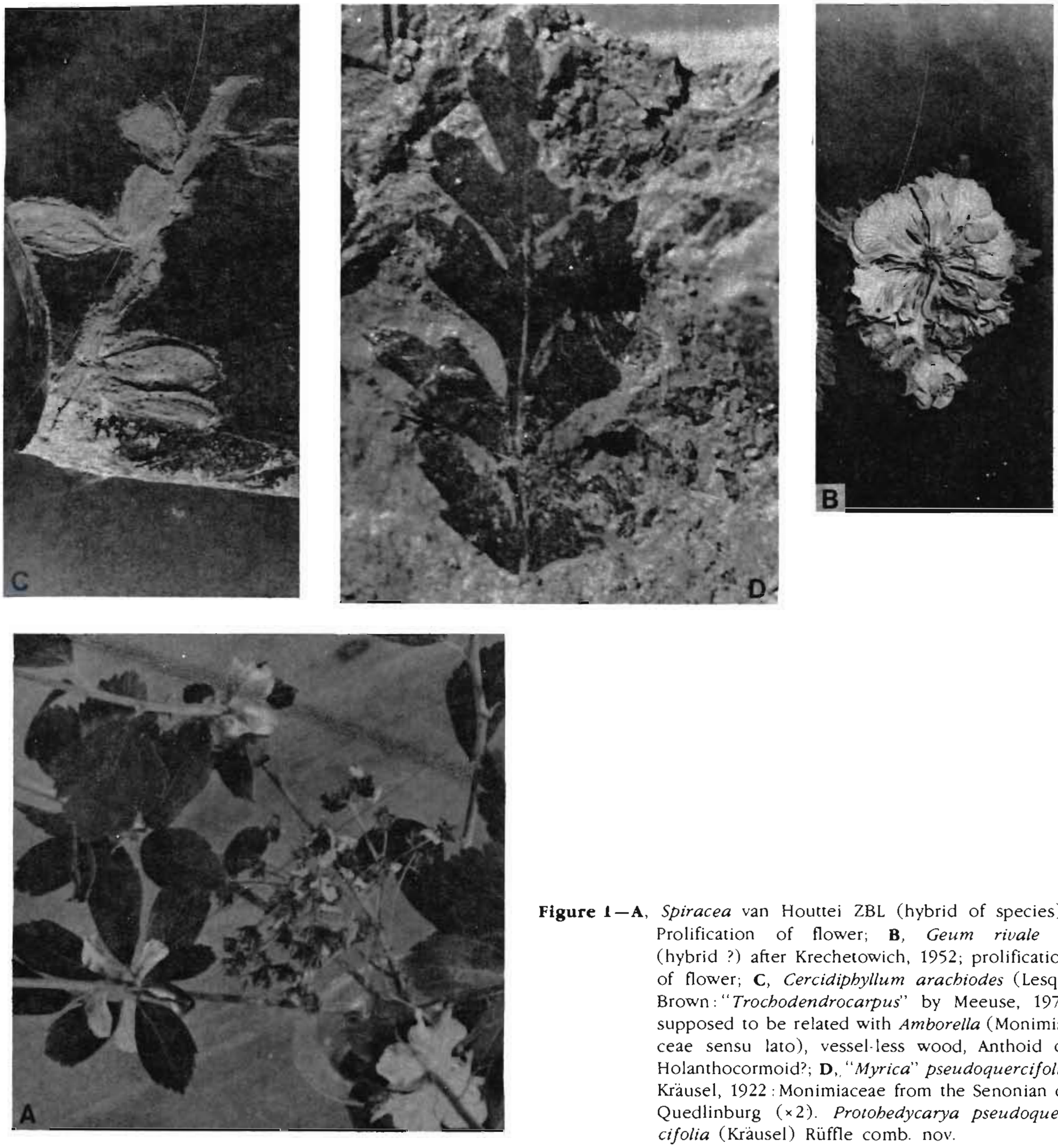
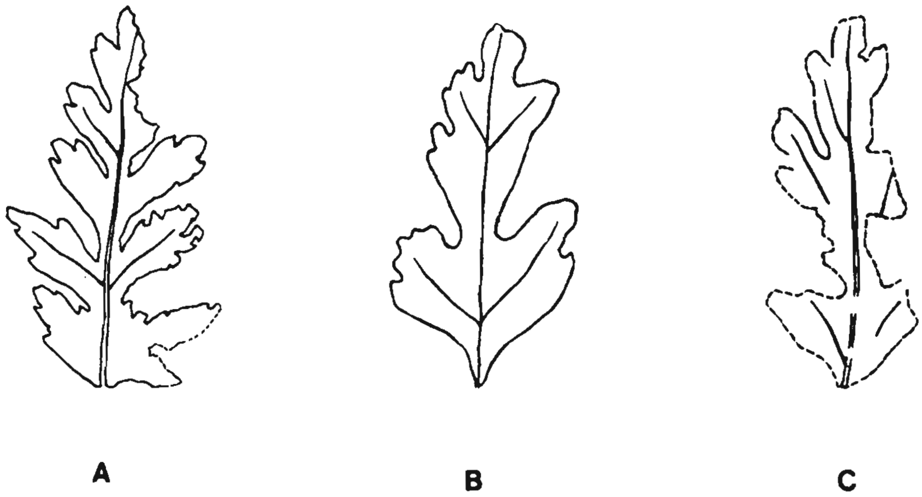


Figure 1—A, *Spiracea* van Houttei ZBL (hybrid of species): Prolification of flower; **B**, *Geum rivale* L. (hybrid ?) after Krechetowich, 1952; prolification of flower; **C**, *Cercidiphyllum arachiodes* (Lesq.) Brown: "*Trochodendrocarpus*" by Meeuse, 1974 supposed to be related with *Amborella* (Monimiaceae sensu lato), vessel-less wood, Anthoid or Holanthocormoid?; **D**, "*Myrica*" *pseudoquercifolia* Kräusel, 1922: Monimiaceae from the Senonian of Quedlinburg (×2). *Protohedycarya pseudoquercifolia* (Kräusel) Rüffle comb. nov.

Monimiaceae, particularly the similarity between *Trochodendrocarpus* and *Amborella* fructifications. The present author wants to emphasize that the flowers of *Amborella* and some Monimioideae harmonize very well with Meeuse's anthocorm theory: In Europe some Upper Cretaceous leaves of Monimioideae with cuticles ("*Myrica*" *pseudoquercifolia*) Kräusel (1922), Rüffle (1965), Knappe & Rüffle (1975, figure 5) are close to some Cissites ("*Cissus tavaredensis*" Teixeira) from Aptian and Albian (Potomac flora) in shape and morphology, particularly in the broad undulated margin. The nearly anemochore diclinic flowers of *Amborella* and some Monimioideae (Monimiaceae) and their fossil and extant distribution could demonstrate that in fact this family would be one of the oldest angiosperms on the whole as well as Piperales. This corresponds to the anthocorm theory (in both being homoxylous woods). Perhaps Magnoliaceae arose much later (see inflorescences of Bennettitales).



Text-figure 2—A, Protohedycarya pseudoquercifolia (Kräusel) Ruffle comb. nov.; **B**, *Cissites tavaredensis* Teixeira, 1948 from Aptial/ Albian, Portugal; **C**, *Cissites* sp. after Lebedev, 1974 from Aptian/Albian, Siberia (**B** and **C** are supposed to be related with *Protohedycarya pseudoquercifolia* (Krausel) Rüffle comb. nov. based on cuticles.

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Palynology of the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road Section, Jaintia Hills (Meghalaya) and Cachar (Assam). Part-III. Pteridophytic spores

M. R. Rao & H. P. Singh

Rao, M. R. & Singh, H. P. (1987). Palynology of the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road Section, Jaintia Hills (Meghalaya) and Cachar (Assam). Part-III. Pteridophytic spores. *Palaeobotanist* **35**(3) : 267-280.

The present paper deals with the systematic description of pteridophytic spores recovered from the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road Section, Meghalaya and Assam. The pteridophytic spores are represented by 18 genera and 32 species. Quantitative analysis of the assemblage reveals that the pteridophytic spores are the dominant (63%) elements of the assemblage. Palynological data reveals that tropical-subtropical humid climate prevailed during the deposition of the sequence of sediments.

Key-words—Palaeopalynology, pteridophytic spores, Oligocene-Lower Miocene (India).

M. R. Rao & H. P. Singh, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

जयन्तिया पहाड़ियों (मेघालय) एवं कछार (असम) में सोनपुर-बदरपुर मार्ग खंड के संग-संग विगोपित बैरेल (पश्चनूतन) एवं सूरमा (अधरि मध्यनूतन) अवसादों का परागाणविक अध्ययन. भाग 3—टेरीडोफ़ाइटी बीजाणु

मुलागलापल्ली रामचन्द्र राव एवं हरिपाल सिंह

प्रस्तुत शोध-पत्र मेघालय एवं असम में सोनपुर-बदरपुर मार्ग खंड के संग-संग विगोपित बैरेल (पश्चनूतन) एवं सूरमा (अधरि मध्यनूतन) अवसादों से उपलब्ध टेरीडोफ़ाइटी बीजाणुओं के वर्गीकृत वर्णन से सम्बन्धित है। उपलब्ध टेरीडोफ़ाइटी बीजाणु 18 प्रजातियों एवं 32 जातियों से निरूपित हैं। समुच्चय के परिमाणात्मक विश्लेषण से व्यक्त होता है कि टेरीडोफ़ाइटी बीजाणु इस समुच्चय में प्रभावी (63 प्रतिशत) हैं। परागाणविक आँकड़ों से यह भी इंगित होता है कि इन अवसादों के निक्षेपण के समय उष्णकटिबन्धीय-उपोष्णकटिबन्धीय नम जलवायु विद्यमान थी।

THE Barail-Surma sediments are excellently exposed in between Sonapur-Badarpur Road Section (National Highway-44) located at south east of Shillong. The Barail Group is represented by Laisong, Jenam and Renji formations. The Renji Formation is unconformably overlain by the Surma Group. This group is divided into lower Bhuban and upper Bokabil formations. The Bhuban Formation is again divided into Lubha, Umkiang and Dona members. The lithostratigraphy of this section has been published by Saxena and Tripathi (1982). The details of rock samples from different formations and the palynological studies by different workers on the Tertiary sediments of north-eastern India have been discussed by Saxena and Rao (1984).

In all, 288 rock samples were collected from the Barail-Surma sediments of Sonapur-Badarpur Road Section, out of them 216 samples proved to be palynologically productive. The palynofossils recovered from these samples include dinoflagellate cysts, fungal remains, spore-pollen and micro remains of obscure origin. The present paper deals exclusively with the systematic description of 18 pteridophytic spore genera and 32 species, which constitutes only a part of the study. Six species belonging to different genera have been established as new. In addition, the diagnosis of *Lygodiumsporites lakiensis* has been emended. The systematic description of the dinoflagellate cysts

(Saxena & Rao, 1984) and fungal remains (Singh *et al.*, 1986) have already been published.

For the recovery of palynofossils, samples were treated with HCl, HF and HNO_3. The digestion period of samples varied from 7 to 10 days. The samples were then washed with distilled water and then treated with 5% KOH solution for about 5-10 minutes. The material was finally washed through 400 mesh sieve. The slides were prepared in polyvenyl alcohol and mounted in DPX Mountant. All slides and negatives were deposited in the repository of Birbal Sahni Institute of Palaeobotany, Lucknow.

The present palynological assemblage has been arranged following the classification proposed by Potonié and Kremp (1954, 1955, 1956) and subsequently modified by Potonié (1956, 1958, 1960, 1966, 1970) and Dettmann (1963).

SYSTEMATIC DESCRIPTION

Genus—*Cyathidites* Couper 1953

Type species—*Cyathidites australis* Couper 1953.

Cyathidites australis Couper 1953
Pl. 1, fig. 1

Distribution—*Cyathidites australis* Couper (1953) is widely distributed in the Upper Mesozoic and Tertiary strata of India.

Occurrence—Bhuban Formation, Surma Group.

Affinity—Cyatheaceae (Couper, 1953).

Cyathidites minor Couper 1953
Pl. 1, fig. 2; Pl. 2, fig. 16

Remarks—The miospores of *C. minor* reported from the Barail and Surma (Oligocene-Miocene) sediments of Sonapur-Badarpur Road Section, Meghalaya and Assam are slightly bigger in size (up to 52 μm) than those described by Couper (1953) from New Zealand.

Distribution—*C. minor* Couper (1953) is reported both from the Mesozoic and Tertiary sediments of India.

Occurrence—Laisong Formation, Barail Group; Lubha and Dona members, Bhuban Formation, Surma Group.

Affinity—Cyatheaceae (Couper, 1953, 1958).

Genus—*Lygodiumsporites* (Potonié, Thomson & Thiergart) Potonié 1956

Type species—*Lygodiumsporites adriennis* (Potonié & Gelletich, 1938) Potonié, Thomson & Thiergart 1950.

Lygodiumsporites lakiensis Sah & Kar 1969 emend.
Pl. 1, figs 3, 4

Emended diagnosis—Miospores triangular to subtriangular in equatorial view, apices broadly rounded, interapical sides convex. Size range 50-56 μm. Trilete mark distinct, Y-rays reaching 2/3-4/5 of the spore radius, labra distinct, enclosing the suture, ray-apex and vertex raised, broader near the apex, gradually narrowing towards the ray-ends. Proximal face convex, distal face almost flat. Exine 1.5 μm thick, laevigate. *Extrema lineamenta* smooth.

Remarks—The restated diagnosis of *L. lakiensis* is based on the study of about 25 specimens which have been recovered from the present assemblage. The presence of thick labra in the illustration of the type specimen of *Lygodiumsporites lakiensis* is clearly discernible though it has not been mentioned by Sah and Kar (1969, pl. 1, figs 15-17).

Distribution—Palaeocene, Eocene and Oligocene of Kachchh, Gujarat (Sah & Kar, 1969; Saxena, 1978; Kar, 1979).

Occurrence—Barail and Surma groups.

Affinity—Schizaeaceae.

Lygodiumsporites eocenicus Dutta & Sah 1970
Pl. 1, figs 5, 10

Restated diagnosis—Miospores subtriangular to triangular in equatorial view, apices broadly rounded, interapical sides usually convex. Size range 53-77 μm. Trilete mark distinct, Y-rays extending 2/3 of the spore radius, ray-apex conspicuously raised over a small area, ray-vertex almost flat and tapering towards the ray-ends. Exine 1-2 μm thick, laevigate often heavily folded. Proximal face of the exine almost flat, distal face deeply convex. *Extrema lineamenta* smooth.

Remarks—Most of the specimens of *Lygodiumsporites eocenicus* from the present assemblage possess very distinct trilete rays, extending usually 2/3 of the spore radius together with a flat proximal and deeply convex distal face in contrast to the observations of Dutta and Sah (1970). According to these authors the proximal face of *L. eocenicus* appears to be almost convex. This fact has not been confirmed by our observations on the specimens studied from the present assemblage as well as those illustrated by the original authors.

Distribution—Lower Eocene of South Shillong Plateau, Meghalaya (Dutta & Sah, 1970); Palaeocene-Eocene sediments of Tura Formation, Meghalaya (Singh, 1977); Palaeocene of Kachchh, Gujarat (Saxena, 1978).

Occurrence—Laisong and Jenam formations, Barail Group; Bhuban Formation, Surma Group.

Affinity—Schizaeaceae.

Lygodiumsporites donaensis sp. nov.
Pl. 1, figs 7, 16

Holotype—Pl. 1, fig. 7, size 60 μm; BSIP slide no. 8408.

Type locality—166.5 km-stone (from Shillong), Sonapur-Badarpur Road Section, Meghalaya

Type Horizon—Dona Member, Bhuban Formation, Surma Group, Lower Miocene.

Diagnosis—Miospores triangular to subtriangular. Size range 65-85 μm. Trilete mark distinct, Y-rays reaching ± half of the radius accompanied by thickened exine all along the Y-mark. Ornamentation laevigate-scabrate.

Description—Miospores mostly subtriangular in equatorial view, interapical sides straight to convex. Trilete mark distinct, Y-rays straight, tapering, reaching ± half of the radius accompanied by thickened exine in the vicinity of the Y-mark, thickening usually diffused but almost of uniform width. Exine uniformly thick, 1.5 μm. Ornamentation laevigate to finely scabrate. *Extrema lineamenta* smooth.

Comparison—*Lygodiumsporites donaensis* sp. nov. resembles *L. eocenicus* Dutta & Sah (1970) by its shape and general characters but can be distinguished by the presence of thickened exine all along the trilete mark. *L. adriennis* (Potonié & Gelletich) Potonié, Thomson & Thiergart (1950) possesses infrapunctate structure and hence it is not comparable. *L. lakiensis* Sah & Kar (1969) is distinguished by its smaller size (up to 60 μm). *L. padapakkarensis* Rao & Ramanujam (1978) can be distinguished by having intrapunctate exine. *L. pachyexinus* Saxena (1978) is different as it possesses thicker exine.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Affinity—Schizaeaceae.

Genus—*Todisporites* Couper 1958

Type species—*Todisporites major* Couper 1958

Todisporites major Couper 1958

Pl. 1, fig. 8

Remarks—The miospores assignable to *Todisporites major* Couper (1958) reported from this assemblage possess larger size (65-105 μm) than the forms of *T. major* (52-78 μm) described by Couper (1958).

Distribution—*Todisporites major* Couper, 1958 is a long ranging species which is distributed in the Mesozoic and Tertiary sediments of both the hemispheres.

Occurrence—Barail Group and Dona Member, Bhuban Formation, Surma Group.

Affinity—Osmundaceae.

Todisporites minor Couper 1958

Pl. 1, fig. 6

Distribution—It is widely distributed in the Mesozoic and Tertiary sediments of both the hemispheres.

Occurrence—Laisong Formation, Barail Group; Lubha and Dona members, Bhuban Formation, Surma Group.

Affinity—Osmundaceae.

Genus—*Biretisporites* (Delcourt & Sprumont) Delcourt, Dettmann & Hughes 1963

Type species—*Biretisporites potoniaei* Delcourt & Sprumont 1955.

Biretisporites oligocenicus sp. nov.

Pl. 1, figs 17, 15

Holotype—Pl. 1, fig. 15, size 88 μm; BSIP slide no. 8388.

Type locality—142 km-stone (from Shillong), Sonapur-Badarpur Road Section, Meghalaya.

Type Horizon—Laisong Formation, Lower Oligocene, Barail Group.

Diagnosis—Miospores subcircular to subtriangular. Size range 70-88 μm. Trilete mark distinct, Y-rays reaching 2/3 of the radius, commissures raised, enclosed within the extension of the upturned exine. Exine 2-4 μm thick, scabrate.

Description—Miospores mostly subcirular in equatorial view, apices bluntly rounded, interapical sides ± convex. Trilete mark distinct, Y-rays reaching 2/3 of the radius surrounded by thick labra, broader at the centre of the Y-mark and narrower at the ray-ends, enclosed within the extension of the upturned exine. Exine 2.5 μm thick, scabrate. Few folds present.

Comparison—*Biretisporites oligocenicus* sp. nov. compares with *B. meghalayaensis* sp. nov. by its raised trilete mark which lies within the extension of the upturned exine. However, the former can be distinguished in having thicker exine (4 μm thick) and broader labra at the centre which narrows down at the ray-ends and is usually straight. *B. potoniaei* Delcourt & Sprumont (1955) differs by having longer trilete rays, extending up to the periphery. *B. convexus* Sah & Kar (1969) is different in having smaller size (65 μm) and uniform thickening along the Y-mark. *B. spectabilis* Dettmann (1963) possesses conspicuous lips and extension of the trilete mark up to the equator, hence it is not comparable. *B. bellus* Sah & Kar (1970) and *B. singularis* Salujha, Kindra & Rehman (1974) are smaller in size. *B. crassisexinus* Venkatachala & Rawat (1973) possesses finely granulose ornamentation and hence it is not comparable.

Occurrence—Laisong Formation, Barail Group.

Affinity—?Hymenophyllaceae.

Biretisporites meghalayaensis sp. nov.

Pl. 1, figs 9, 13

Holotype—Pl. 1, fig. 9, size 61 μm; BSIP slide no. 9030.

Type Locality—169 km-stone (from Shillong), Sonapur-Badarpur Road Section, Meghalaya.

Type Horizon—Dona Member, Bhuban Formation, Surma Group, Lower Miocene.

Diagnosis—Miospores subtriangular. Size range 60-88.5 μm. Trilete mark distinct. Y-rays reaching 3/4 of the radius, enclosed within the extension of the upturned exine. Exine laevigate to finely scabrate.

Description—Miospores subtriangular in equatorial view, apices broadly rounded, interapical sides straight to convex. Trilete mark distinct, Y-rays reaching 3/4 of the radius, enclosed within the upturned extension of the exine, extension mostly spathulate in form with wavy margin. Exine 1 μm thick, sometimes finely scabrate otherwise laevigate.

Comparison—The present species closely compares with *Biretisporites convexus* Sah & Kar (1969) in shape and general characters but can be distinguished from the latter by having continuous extension of the upturned exine with wavy margin around the trilete. *B. potoniaei* Delcourt & Sprumont (1955) possesses a thicker exine (up to 5 μm thick) and trilete rays extending up to the periphery and hence, it is not comparable. *B. spectabilis* Dettmann (1963) is different by its conspicuous lips and the extension of trilete mark up to the equator. *B. bellus* Sah & Kar (1970) and *B. singularis* Salujha, Kindra & Rehman (1974) are smaller in size. *B. crassisexinus* Venkatachala & Rawat (1973) can be distinguished from the present species by its finely granulose ornamentation.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Affinity—?Hymenophyllaceae.

Genus—*Surmaspora* Singh & Rao 1984

Type species—*Surmaspora sinuosa* Singh & Rao 1984.

Surmaspora sinuosa Singh & Rao 1984

Pl. 2, fig. 6

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Affinity—Unknown.

Genus—*Gleicheniidites* (Ross) Skarby 1964

Type species—*Gleicheniidites senonicus* Ross 1949.

Gleicheniidites senonicus Ross 1949

Pl. 2, fig. 17

Distribution—Palaeocene of Kachchh, Gujarat (Saxena, 1978).

Occurrence—Laisong Formation, Barail Group.

Affinity—Gleicheniaceae.

Genus—*Dictyophyllidites* Couper 1958

Type species—*Dictyophyllidites harrisii* Couper 1958

Remarks—The genus *Dictyophyllidites*, as diagnosed by Couper (1958), was emended by Dettmann (1963). She described even the ornate forms under the same genus. This has enlarged the original circumscription of the genus more than necessary a treatment to which we donot agree. In the present treatise *Dictyophyllidites* is understood *sensu stricto* Couper (1958).

Dictyophyllidites indicus sp. nov.

Pl. 1, figs 18-20

Holotype—Pl. 1, fig. 18, size 75 μm; BSIP slide no. 8392.

Type locality—146.25 km-stone (from Shillong), Sonapur-Badarpur Road Section, Meghalaya.

PLATE 1

→

(All photomicrographs are enlarged *ca.* × 500. Coordinates of the specimen refer to the stage of the Censico Microscope no. 13167).

1. *Cyathidites australis* Couper, slide no. BSIP 8739, coordinates 67.2 × 106.5.

2. *Cyathidites minor* Couper, slide no. BSIP 9024, coordinates 73.5 × 105.7.

3, 4. *Lygodiumsporites lakiensis* Sah & Kar emend. slide nos. BSIP 8390, coordinates 49.10 × 110.3; BSIP 9025, coornates 70.5 × 106.9.

5, & 10. *Lygodiumsporites eocenicus* Dutta & Sah, slide nos. BSIP 8736, coordinates 99.2 × 105.7; BSIP 8393; coordinates 48.8 × 109.10.

6. *Todisporites minor* Couper, slide no. BSIP 9029, coordinates 70.3 × *102.5*.

7 & 16. *Lygodiumsporites donaensis* sp. nov. slide nos. BSIP 8408, coordinates 62.0 × 103.3 (Holotype); BSIP 8408, coordinates 70.3 × 112.5.

8. *Todisporites major* Couper, slide no. BSIP 8389, coordinates 48.10 × 98.7.

9 & 13. *Biretisporites meghalayaensis* sp. nov., slide nos. BSIP 9030, coordinates 52.2 × 114.5 (Holotype); BSIP 8414, coordinates 54.9 × 108.9.

11 & 15. *Biretisporites oligocenicus* sp. nov., slide nos. BSIP 9031, coordinates 52.0 × 105.6; BSIP 8388, coordinates 62.4 × 99.6 (Holotype).

12. *Corrugatisporites* sp., slide no. BSIP 9034, coordinates 54.0 × 110.3.

14. *Garotriletes* sp., slide no. BSIP 9033, coordinates 54.0 × 110.3.

17. *Polypodiaceaesporites chatterjii* Kar, slide no. BSIP 9041, coordinates 74.7 × 102.5.

18-20. *Dictyophyllidites indicus* sp. nov., slide nos. BSIP 8392, coordinates 69.2 × 108.6 (Holotype); BSIP 9032, coordinates 59.5 × 100.8; BSIP 9032, coordinates 65.2 × 115.2.

21. *Foveosporites* sp., slide no. BSIP 9039, coordinates 43.5 × 95.10.

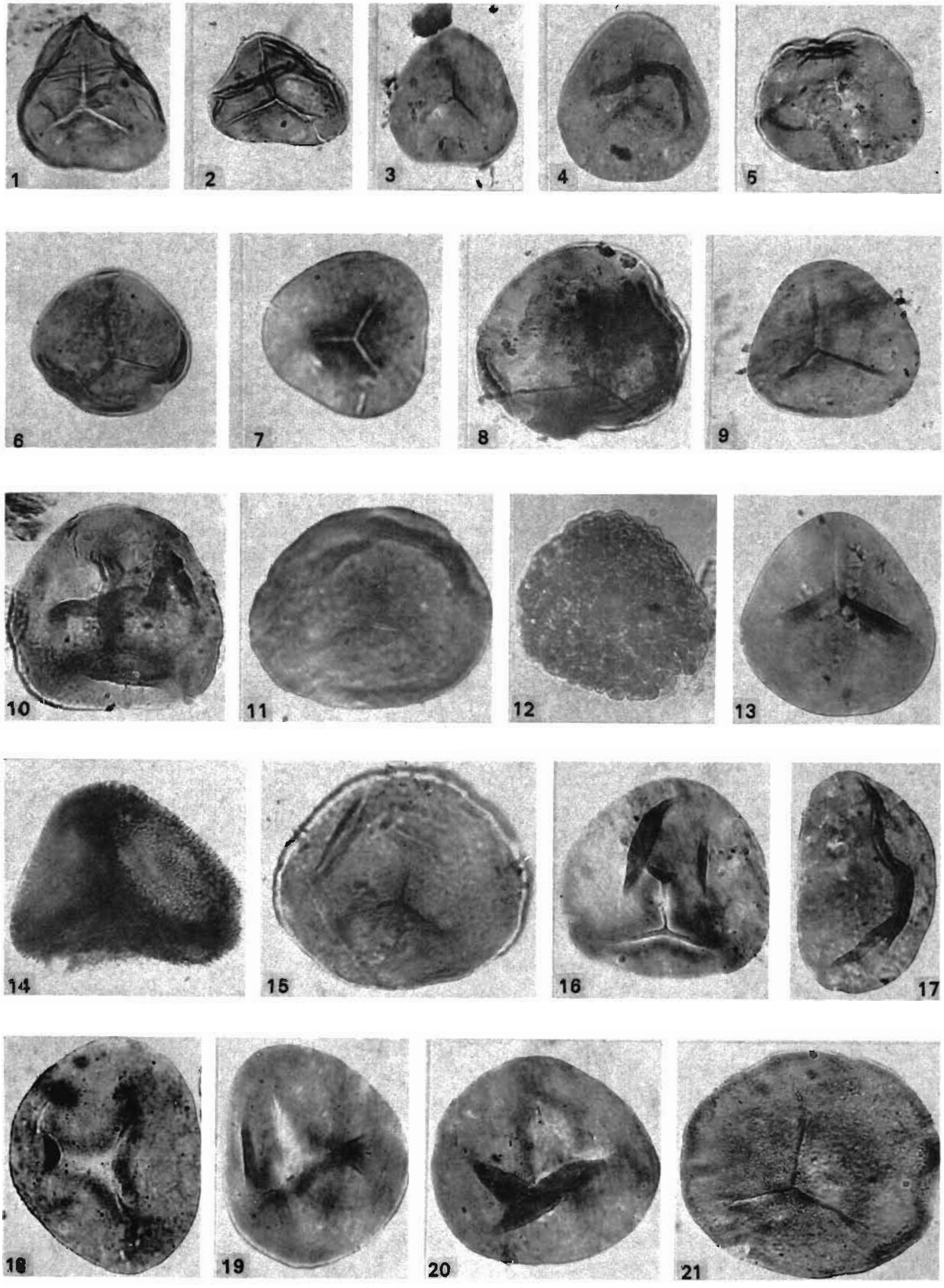

PLATE 1

Type Horizon—Renji Formation, Upper Oligocene, Barail Group.

Diagnosis—Miospores subtriangular to subcircular, size range 75-95 μm. Trilete mark distinct, Y-rays reaching more than half of the radius, commissures raised, flanked by distinct thick arcuate margo. Exine laevigate.

Description—Miospores mostly subcircular to subtriangular in equatorial view, apices bluntly rounded, interapical sides straight to convex. Trilete mark distinct, usually laesurae straight, accompanied by a distinct and thick, arcuate margo lying in close proximity to the Y-rays following an interradial pathway leaving a longer part of the exine as unthickened. Exine up to 1.5 μm thick, laevigate. Distal face of the exine distinctly convex, proximal face being plane to slightly convex. *Extrema lineamenta* smooth.

Comparison—Dictyophyllidites harrisii Couper (1958) is distinguished from the present species by its smaller size (up to 56 μm) and longer Y-rays, ± extending up to the equator. *D. pectinataeformis* (Bolkhovitina) Dettmann (1963) is different by its granulose exine and may perhaps have to be excluded from the limits of the genus *Dictyophyllidites. D. crenatus* (1963) is distinct from *D. indicus* sp. nov. in having sinuous laesurae and thicker exine (3.5 μm thick). *D. cymbatus* Venkatachala & Goczan (1964) possesses kyrtomic folds hence it is not comparable. *D. granulatus* Saxena (1978) is different by having thicker exine (5 μm) and granulose ornamentation, thus it is not comparable.

Occurrence—Renji Formation, Barail Group.

Affinity—? Matoniaceae.

Genus—*Garotriletes* Singh & Singh 1978

Type species—*Garotriletes assamicus* Singh & Singh 1978.

Garotriletes sp.

Pl. 1, fig. 14

Description—Miospore triangular in equatorial view, apices broadly rounded, interapical sides ± straight. Size ± 77 μm. Trilete mark distinct, reaching more than 3/4 of the radius, ray-ends bifurcated, labra around the trilete mark thick, ± globular at one of the ray-ends. Exine up to 3.5 μm thick, foveolate, foveolae compactly placed appearing foveo-reticulate in surface view.

Comparison—The present specimen is closely comparable to *Garotriletes assamicus* Singh & Singh (1978) in its shape and foveo-reticulate ornamentation of the exine. But the former is bigger in size (77 μm) and can also be distinguished by having distinct labra which is thick and almost encloses the Y-mark.

Occurrence—Laisong Formation, Barail Group.

Affinity—Not known.

PLATE 2

→

(All photomicrographs are enlarged *ca* × 500. Coordinates of the specimen refer to the stage of the Censico Microscope no. 13167).

1 & 13. *Striatriletes susannae* van der Hamnen emend. Kar, slide nos. BSIP 8385, coordinates 40.3 × 105.6; BSIP 8387, coordinates 54.4 × 104.2.

2-3. *Striatriletes sinuosus* sp. nov., slide nos. BSIP, 8397, coordinates 44.4 × 104.2; BSIP 8407, coordinates 66.10 × 95.10 (Holotype).

4-5. *Malayaeaspora costata* Trivedi *et al.*, slide nos. BSIP 8228, coordinates 43.10 × 100.7; BSIP 8229, coordinates 60.9 × 105.6.

6. *Surmaspora sinuosa* Singh & Rao, slide no. BSIP 8225, coordinates 69.5 × 118.8.

7 & 10. *Striatriletes pachyexinus* sp. nov. slide nos. BSIP 9040, coordinates 54.5 × 99.7; BSIP 8391, coordinates 56.0 × 101.5 (Holotype).

8 & 12. *Foveosporites triangulus* Sah & Dutta, slide nos. BSIP 8132, coordinates 53.2 × 105.5; BSIP 9037, coordinates 52.5 × 100.5.

9. *Foveotriletes* sp. B., slide no. BSIP 9036, coordinates 57.0 × 100.5.

11. *Foveotriletes* sp. A., slide no. BSIP 9035, coordinates 60.5 × 113.3.

14. *Cingutriletes* sp., slide no. BSIP 8112, coordinates 42.4 × 104.3.

15. *Lycopodiumsporites abundans* Salujha *et al.*, slide no. BSIP 8103, coordinates 47.6 × 105.3.

16. *Cyathidites minor* Couper, slide no. BSIP 9023, coordinates 65.8 × 104.8.

17. *Gleicheniidites senonicus* Ross, slide no. BSIP 8383, coordinates 40.4 × 96.10.

18. *Foveosporites miocenicus* Ramanujam, slide no. BSIP 8746, coordinates 64.7 × 106.8.

19. *Polypodiisporites speciosus* Sah, slide no. BSIP 8122, coordinates 40.0 × 118.2.

20. *Polypodiaceaesporites chatterjii* Kar, slide no. BSIP 8404, coordinates 74.5 × 102.2.

21, 27. *Polypodiaceaesporites tertiarus* Sah & Dutta, slide no. BSIP 8386, coordinates 70.7 × 105.2; BSIP 8411, coordinates 49.5 × 98.8.

22. *Polypodiisporites tuberculensis* (Baksi) comb. nov., slide no. BSIP 9045, coordinates 42.3 × 106.8.

23. *Polypodiisporites favus* (Potonié) Potonié, slide no. BSIP 9044, coordinates 51.7 × 110.8.

24, 25. *Monolites major* (Cookson) Potonié, slide nos. BSIP 8123, coordinates 40.3 × 98.8; BSIP 9042, coordinates 60.0 × 113.4.

26. *Polypodiisporites formosus* Salujha *et al.*, slide no. BSIP 9043, coordinates 49.2 × 111.3.

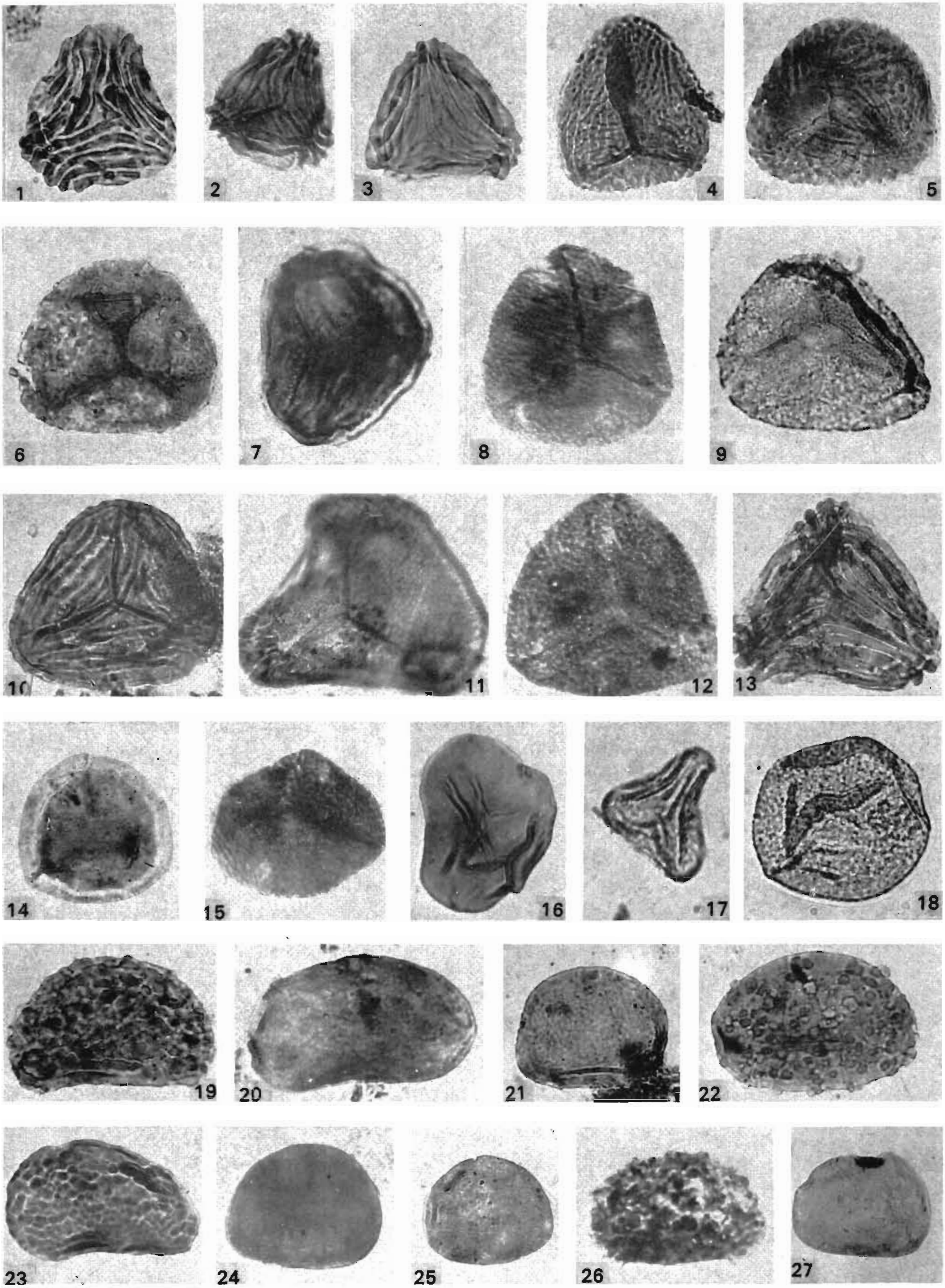

PLATE 2

Genus—*Corrugatisporites* (Thomson, Pflug & Ibrahim) Weyland & Griefeld 1953

Type species—*Corrugatisporites solidus* (Potonié) Thomson & Pflug 1953.

Remarks—Thomson and Pflug (1953) described three species under the genus *Corrugatisporites*, viz., *C. solidus, C. multivallatus* and *C. paucivallatus*. They presumed that the genus was instituted by Ibrahim (1933). Later, Weyland and Griefeld (1953) assigned a new species to the same genus, viz., *Corrugatisporites toratus*. Then it was observed that Ibrahim did not publish any genus with the name *Corrugatisporites*. Therefore Potonié (1956) proposed *C. toratus* as the type species for the genus *Corrugatisporites* and restated its diagnosis. But Jansonius and Hills (1976) in "*Genera file of fossil spores*" cited *C. solidus* as the type species for the genus *Corrugatisporites* because this species was placed first in order of its publication as described by the original authors (Thomson & Pflug, 1953). In the present treatise, systematic treatment as given by Jansonius and Hills (1976) of *Corrugatisporites* has been followed.

Corrugatisporites sp.

Pl. 1, fig. 12

Description—Miospores subtriangular, apices broadly rounded, interapical sides ± convex. Size up to 72 μm. Trilete mark not distinct due to heavy ornamentation. Exine 1.5 μm thick, verrucose, verrucae laterally fused both on the proximal and distal sides forming variously shaped small, irregular channels. Outline undulate.

Comparison—*Corrugatisporites* sp. compares closely to *C. terminalis* Sah & Dutta (1968) by its verrucose exine but the latter can be distinguished in having distinct trilete mark and different exine ornamentation on the proximal and distal surfaces.

Occurrence—Laisong and Jenam formations, Barail Group; Bhuban Formation, Surma Group.

Affinity—Not known.

Genus—*Foveotriletes* van der Hammen ex Potonié 1956

Type species—*Foveotriletes scrobiculatus* (Ross) Potonié 1956.

Foveotriletes sp. A

Pl. 2, fig. 11

Description—Miospore triangular in equatorial view, apices broadly rounded, interapical sides ± convex. Size 92 μm. Trilete mark distinct, Y-rays reaching almost up to the equator, ends bifurcated. Exine 4 μm thick, foveolate, foveolae compactly placed, bigger at the apices and smaller towards the Y-mark. Surface view foveoreticulate.

Comparison—*Foveotriletes* sp. closely compares with *F. scrobiculatus* (Ross) Potonié (1956) in having foveolate exine but the former can be distinguished by its bigger size (92 μm). *F. miocenicum* Ramanujam (1966, 1967) possesses an ill-developed trilete mark and smaller size (48.5 μm) thus it is not comparable. *F. pachyexinus* Dutta & Sah (1970), *F. bifurcatus* Rao & Ramanujam (1978) are distinguished by their smaller size. *F. microreticulatus* Couper (1958) differs by its raised commissures.

Occurrence—Laisong Formation, Barail Group.

Affinity—Not known.

Foveotriletes sp. B

Pl. 2, fig. 9

Description—Miospore triangular in equatorial view, apices broadly rounded, interapical sides ± convex. Size ± 77 μm. Trilete mark distinct, Y-rays reaching 3/4 of the spore radius. Exine 1.5 μm thick, foveolate, foveolae small, compactly placed. Surface view finely foveo-reticulate.

Comparison—*Foveotriletes* sp. A can be distinguished from *Foveotriletes* sp. B in possessing differential foveolate ornamentation at the apices and near the Y-mark.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Affinity—Not known.

Genus—*Foveosporites* Balme 1957

Type species—*Foveosporites canalis* Balme 1957.

Foveosporites triangulus Dutta & Sah 1970

Pl. 2, figs 8, 12

Remarks—The specimens of *Foveosporites triangulus* Dutta & Sah (1970) reported from the Sonapur-Badarpur Road Section (Middle Bhuban Formation, Surma Group) in the present study are bigger in size (up to 75 μm) than those (35-48 μm) described by Dutta & Sah (1970) from the Cherra Formation, Meghalaya.

Distribution—Lower Eocene of South Shillong Plateau, Meghalaya (Dutta & Sah, 1970).

Occurrence—Umkiang and Dona members, Bhuban Formation, Surma Group.

Affinity—*Lycopodium phlegmaria* (Lycopodiaceae).

Foveosporites miocenicus Ramanujam 1972

Pl. 2, fig. 18

Remarks—*Foveosporites miocenicus* Ramanujam (1972) is reported from the Upper Bhuban Formation, Surma Group. Its size ranges up to 62 μm.

Distribution—Miocene sediments around Warkalli Lignite, South India (Ramanujam, 1972).

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Affinity—Unknown.

Foveosporites sp.

Pl. 1, fig. 21

Description—Miospore circular, size ± 99 μm. Trilete mark distinct, strongly built with bifurcated ends. Exine 2.5 μm thick, foveolate, foveolae small rounded, compactly placed. Surface view foveo-reticulate.

Comparison—*F. canalis* Balme (1957) differs from the present species by its smaller size and also in possessing coalescent foveolae.

Occurrence—Laisong Formation, Barail Group.

Affinity—Not known.

Genus—*Lycopodiumsporites* (Thiergart) Delcourt & Sprumont 1955

Type species—*Lycopodiumsporites agathoecus* (Potonié) Delcourt & Sprumont 1955.

Lycopodiumsporites abundans Salujha, Kindra & Rehman 1972

Pl. 2, fig. 15

Remarks—The present specimens of *Lycopodiumsporites abundans* are bigger in size (up to 60 μm) than those reported by Salujha *et al.* (1972) from the Palaeogene of Garo Hills (52 μm).

Distribution—Palaeogene of Garo Hills, Meghalaya (Salujha, Kindra & Rehman, 1972).

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Affinity—Lycopodiaceae.

Genus—*Striatriletes* van der Hammen 1956 emend. Kar 1979

Type species—*Striatriletes susannae* van der Hammen 1956 emend. Kar 1979.

Striatriletes susannae van der Hammen 1956 emend. Kar 1979

Pl. 2, figs 1, 13

Remarks—In the diagnosis of *Striatriletes susannae* van der Hammen emend. Kar (1979) has mentioned that the exine of the miospores is ± laevigate. But in the present investigation some forms referable to *S. susannae* have imperceptibly punctate-microverrucose exine. Even such spores have also been included in the same species.

Distribution—Palaeogene of Garo and Khasi-Jaintia Hills (Salujha *et al.*, 1972, 1974); Oligocene of Kachchh (Kar, 1979).

Occurrence—Barail and Surma groups.

Affinity—*Ceratopteris thalictroides* (L) Brongn.

Striatriletes sinuosus sp. nov.

Pl. 2, figs 2, 3

Holotype—Pl. 2, fig. 3, size 55 μm; BSIP slide no. 8407.

Type locality—150.1 km-stone (from Shillong), Sonapur-Badarpur Road Section, Meghalaya.

Type Horizon—Lubha Member, Bhuban Formation, Surma Group, Lower Miocene.

Diagnosis—Miospores triangular to subtriangular. Size 50-70 μm. Trilete mark distinct, sinuous, strongly built, Y-rays reaching 3/4 of the radius. Exine 1-2.5 μm, costate, costate, arising at ray-ends, 4-6 in each concentric ring, very closely placed, laevigate.

Description—Miospores triangular, apices more or less pointed, interapical sides straight to more or less convex. Trilete-mark distinct, sinuous, strongly built, Y-rays tapering, reaching 3/4 of the radius, length of the ray ranges from 18 to 25 μm. Exine 1.5 μm thick, costate, costae mostly 4 in number at each ray-end and 4 in each concentric ring on the distal side opposite to each inter-ray area, sometimes branching of costae on the distal face evident, resulting in increase in number, 6 costae in each concentric ring, 2.5-3.5 μm wide and 2-3 μm high, closely placed, flat to well-developed, parallely arranged. Costae and intervening spaces between them laevigate.

Comparison—*Striatriletes sinuosus* sp. nov. is distinguished from all known species of *Striatriletes* (van der Hammen, 1956) Kar (1979) by its strongly built and tapering trilete mark. Also the Y-rays are longer reaching up to 3/4 of the spore radius together with a smaller size range (50-70 μm).

Occurrence—Lubha Member, Bhuban Formation, Surma Group.

Affinity—Parkeriaceae.

Striatriletes pachyexinus sp. nov.

Holotype—Pl. 2, fig. 10, size 70 μm; BSIP slide no. 8391.

Type locality—145.4 km-stone (from Shillong), Sonapur-Badarpur Road Section, Meghalaya.

Type Horizon—Jenam Formation, Upper Oligocene, Barail Group.

Diagnosis—Miospores subtriangular. Size range 60-70 μm. Trilete mark distinct, Y-rays strongly built, reaching 3/4 of the spore radius. Exine 2.5-3.5 μm thick, costate, costae ill-developed, ± laevigate.

Description—Miospores subtriangular in equatorial view, apices broadly rounded, interapical sides ± convex. Trilete mark distinct, commissures strongly built, Y-rays reaching 3/4 of the spore radius. Exine 3.5 μm thick, costate, costae ill-developed, nature of the costae on the distal side not clearly discernible. Costae and intervening spaces between them ± laevigate, outline undulate.

Comparison—*Striatriletes susannae* (van der Hammen, 1956) Kar 1979 is distinguished from *S.*

pachyexinus sp. nov. in having well-developed costae and bigger size range (77-115 μm). *S. pachyexinus* sp. nov. differs from *S. sinuosus* sp. nov. by its well developed commissures and thicker exine. *S. microverrucosus* Kar & Saxena (1981) possesses microverrucose costae and hence it is not comparable. *S. multicostatus* Kar & Saxena (1981) is distinguished by having more number of distinct costae (6-9) and shorter rays reaching only up to half of the radius. *S. pseudocostatus* Singh & Tripathi (1983) is distinct from *S. pachyexinus* by its ill developed, flat and unevenly wide costae. *S. attenuatus* Singh & Tripathi (1983) differs in possessing a thick and raised trilete mark, in having less number of costae with a lesser curvature and in possessing dilate costae ends.

Occurrence—Jenam Formation, Barail Group.

Affinity—Parkeriaceae.

Genus—*Malayaeaspora* Trivedi, Ambwani & Kar 1981

Type species—*Malayaeaspora costata* Trivedi, Ambwani & Kar 1981.

Malayaeaspora costata Trivedi, Ambwani & Kar 1981
Pl. 2, figs 4, 5

Distribution—Tertiary coal of Malaya (Trivedi *et al.*, 1981.

Occurrence—Dona Member, Bhuban Formation, Surma Group.

Affinity—?Schizaeaceae.

Genus—*Cingutriletes* (Pierce) Dettman 1963

Type species—*Cingutriletes congruens* Pierce 1961.

Cingutriletes sp.
Pl. 2, fig. 14

Description—Miospores subtriangular, apices rounded, interapical sides ± convex. Size ± 55 μm. Trilete mark distinct, slightly raised, Y-rays extending up to the equator. Cingulate, cingulum up to 8.5 μm thick. Exine 1.5 μm thick, laevigate.

Comparison—*Cingutriletes* sp. closely compares with *C. congruens* Pierce (1961) which can be distinguished by its smaller size (26 μm) and proximally smooth and distally punctate exine.

Occurrence—Umkiang and Dona members, Bhuban Formation; Bokabil Formation, Surma Group.

Affinity—Unknown.

Genus—*Polypodiaceaesporites* (Thiergart) ex. Potonié 1956

Type species—*Polypodiaceaesporites haardti* (Potonié & Venitez) Thiergart 1938.

Polypodiaceaesporites tertiarus Sah & Dutta 1968
Pl. 2, figs 21, 27

Remarks—The exine seems to be thinner at the polar region as compared to the peripheral area, a character which is seen in the illustration of the type species as given by the original authors though not mentioned in the systematic description.

Distribution—Tertiary Succession of Assam (Sah & Dutta, 1969); Lower Eocene of South Shillong Plateau, Meghalaya (Dutta & Sah, 1970).

Occurrence—Laisong and Jenam formations, Barail Group and Surma Group.

Affinity—Polypodiaceae.

Polypodiaceaesporites chatterjii Kar 1979
Pl. 1, fig. 17; Pl. 2, fig. 20

Distribution—Oligocene of Kachchh, Gujarat (Kar, 1979).

Occurrence—Lubha and Dona members, Bhuban Formation, Surma Group.

Affinity—Polypodiaceae.

Genus—*Monolites* (Cookson) Potonié 1956

Type species—*Monolites major* (Cookson) Potonié 1956.

Monolites major (Cookson) Potonié 1956
Pl. 2, figs 24, 25

Remarks—The specimens of *Monolites major* (Cookson) Potonié (1956) recorded from the present material have thicker exine (2.5 μm thick) as compared to those described by Cookson (1947).

Distribution—Lower Tertiary of Kerguelen (Cookson, 1947).

Occurrence—Umkiang and Dona members, Bhuban Formation, Surma Group.

Affinity—Polypodiaceae.

Genus—*Polypodiisporites* (Potonié) Potonié 1956

Type species—*Polypodiisporites favus* Potonié 1931 ex Potonié, 1956.

Polypodiisporites favus Potonié 1931 ex Potonié 1956
Pl. 2, fig. 23

Distribution—Eocene Germany (Potonié, 1931).

Occurrence—Bhuban Formation, Surma Group.

Affinity—Polypodiaceae.

Polypodiisporites speciosus Sah 1967
Pl. 2, fig. 19

Distribution—Upper Neogene profile from Rusizi Valley (Burundi) by Sah (1967); Tertiary Succession of Assam (Sah & Dutta, 1968); Palaeogene of Garo and Khasi-Jaintia Hills, Meghalaya (Salujha *et al.*, 1972, 1974).

Occurrence—Laisong Formation, Barail Group; Bhuban Formation, Surma Group.

Affinity—Polypodiaceae.

Polypodiisporites formosus Salujha, Kindra & Rehman 1972

Pl. 2, fig. 26

Distribution—Palaeogene of Garo Hills, Meghalaya (Salujha *et al.*, 1972).

Occurrence—Umkiang Member, Bhuban Formation, Surma Group.

Affinity—Polypodiaceae.

Polypodiisporites tuberculensis Baksi (1962) comb. nov.

Pl. 2, fig. 22

1962 *Polypodiaceaesporites tuberculensis* Baksi, *Bull. geol. Min. metall. Soc. India* **26** : 1-21, 19.

Description—Miospores oval, bean-shaped, extremities broadly rounded. Size range 45-60 μm. Monolete mark distinct, extending 2/3 along the longer axis. Exine up to 1.5 μm thick, verrucose, verrucae sparsely placed, 2-3 μm in diameter.

Remarks—Baksi (1962) published a new genus *Polypodiaceaesporites* from the Simsang River Tertiaries, South Shillong Front, Assam with a single species *P. tuberculensis*. *Polypodiaceaesporites* Baksi (1962) is a junior homonym of *Polypodiaceaesporites* Thiergart ex Potonié (1956). The characters of *Polypodiaceaesporites* Baksi (1962) do not conform with those of *Polypodiaceaesporites* Thiergart ex Potonié (1956). However, *Polypodiaceaesporites tuberculensis* Baksi (1962) falls within the generic circumscription of *Polypodiisporites* (Potonié) Potonié, 1956 and hence has been transferred to the latter as a new combination.

Occurrence—Jenam Formation, Barail Group.

Affinity—Polypodiaceae.

DISCUSSION

The pteridophytic spores described in this paper from the Barail and Surma groups (Oligocene-Lower Miocene) are represented by 18 genera and 32 species. Of these, *Biretisporites oligocenicus*, *B. meghalayaensis*, *Striatriletes pachyexinus*, *S. sinuosus*, *Dictyophyllidites indicus* and *Lygodiumsporites donaensis* have been established as new species. The distribution of different species is as follows :

PALYNOTAXA	Barail Group			Surma Group			
	Laisong Formation	Jenam Formation	Renji Formation	Bhuban Formation			Bokabil Formation
				Lubha Member	Umkiang Member	Dona Member	
Gleicheniidites senonicus	+	—	—	—	—	—	—
Biretisporites oligocenicus	+	—	—	—	—	—	—
Foveosporites sp.	+	—	—	—	—	—	—
Foveotriletes sp. A	+	—	—	—	—	—	—
Garotriletes sp.	+	—	—	—	—	—	
Striatriletes pachyexinus	—	+	—	—	—	—	—
Polypodiisporites tuberculensis	—	+	—	—	—	—	—
Dictyophyllidites indicus	—	—	+	—	—	—	—
Striatriletes sinuosus	—	—	—	+	—	—	—
Polypodiisporites formosus	—	—	—	—	+	—	—
Foveotriletes sp. B	—	—	—	—	—	+	—
Malayaeaspora costata	—	—	—	—	—	+	—
Surmaspora sinuosa	—	—	—	—	—	+	—
Lygodiumsporites donaensis	—	—	—	—	—	+	—
Biretisporites meghalayaensis	—	—	—	—	—	+	—
Lycopodiumsporites abundans	—	—	—	—	—	+	—
Foveosporites miocenicus	—	—	—	—	—	+	—
Monolites major	—	—	—	—	+	+	—
Foveosporites triangulus	—	—	—	—	+	+	—
Cingutriletes sp.	—	—	—	—	+	+	—
Polypodiaceaesporites chatterjii	—	—	—	+	—	+	—
Polypodiisporites favus	—	—	—	+	+	+	—
Cyathidites australis	—	—	—	+	+	+	—
Corrugatisporites sp.	—	+	—	+	+	+	—
Todisporites major	+	+	+	—	—	+	—
Cyathidites minor	+	—	—	+	—	+	—
Todisporites minor	+	—	—	+	—	+	—
Polypodiisporites speciosus	+	—	—	+	+	+	—
Lygodiumsporites eocenicus	+	+	—	+	+	+	—
L. lakiensis	+	+	+	+	+	+	+
Striatriletes susannae	+	+	+	+	+	+	+
Polypodiaceaesporites tertiarus	+	+	—	+	+	+	+

The diagnosis of *Lygodiumsporites lakiensis* has been emended. *Lygodiumsporites lakiensis* Sah & Kar, 1969, from the present assemblage possesses very distinct trilete mark, reaching 2/3-4/5 of the spore radius, labra distinct, enclosing the suture, ray-apex and vertex raised, broader near the apex, gradually narrowing towards the ray-ends. The presence of thick labra in the illustration of the type specimen is clearly discernible though it has not been mentioned by Sah and Kar (1969). *Lygodiumsporites eocenicus* (Dutta & Sah, 1970) as studied possess trilete mark distinct, rays extending 2/3 of the spore radius, ray-apex conspicuously raised over a small area, ray-vertex almost flat and tapering towards the ray-ends. Proximal face of the exine almost flat, distal face deeply convex. Besides, the genus *Dictyophyllidites* as diagnosed by Couper (1958) was emended by Dettmann (1963). She described even the ornate forms under the genus. This has enlarged the original circumscription of the genus more than necessary. The miospores of *Striatriletes susannae* described by van der Hammen emend. Kar (1979) posses laevigate exine, but in the present study, some forms belonging to this species have imperceptibly punctate-microverrucose exine. So such spores have also been included in the same species. In *Polypodiaceaesporites tertiarus* Sah & Dutta (1968), the exine seems to be thinner at the polar region as compared to the peripheral area, a character which is seen in the illustration of the type species as given by the original authors though not mentioned in the systematic description.

On the basis of the possible affinities of the dispersed pteridophytic spores studied the presence of the following families is inferred. Taxa of uncertain botanical affinity are also listed below :

Taxon	*Family*
Cyathidites australis	Cyatheaceae
C. minor	Cyatheaceae
Lygodiumsporites lakiensis	Schizaeaceae
L. eocenicus	"
L. donaensis	"
Todisporites major	Osmundaceae
T. minor	"
Biretisporites meghalayaensis	?Hymenophyllaceae
B. oligocenicus	"
Surmaspora sinuosa	Unknown
Gleicheniidites senonicus	Gleicheniaceae
Dictyophyllidites indicus	?Matoniaceae
Garotriletes sp.	Unknown
Corrugatisporites sp.	Unknown
Foveotriletes sp. A	Unknown
Foveotriletes sp. B	Unknown
Foveosporites triangulus	Lycopodiaceae
F. miocenicus	Unknown
Foveosporites sp.	Unknown
Lycopodiumsporites abundans	Lycopodiaceae
Striatriletes susannae	Parkeriaceae
S. pachyexinus	"
S. sinuosus	"
Malayaeaspora costata	?Schizaeaceae
Cingutriletes sp.	Unknown
Polypodiaceaesporites tertiarus	Polypodiaceae
P. chatterjii	"
Monolites major	"
Polypodiisporites favus	"
P. speciosus	"
P. formosus	"
P. tuberculensis	"

These families possibly indicate tropical-subtropical humid climate during the sedimentation of the present sequence.

An analysis of the assemblage reveals that the pteridophytic spores dominate the Surma Group as compared to the Barail Group. The presence of *Biretisporites oligocenicus, Dictyophyllidites indicus, Striatriletes pachyexinus, Gleicheniidites senonicus, Foveosporites* sp. A, *Foveotriletes* sp. A, *Garotriletes* sp. and *Polypodiisporites tuberculensis* is restricted to the Barail Group, whereas *Striatriletes sinuosus, Malayaeaspora costata, Surmaspora sinuosa, Lygodiumsporites donaensis, Biretisporites meghalayaensis, Cyathidites australis, Foveosporites triangulus, F. miocenicus, Lycopodiumsporites abundans, Monolites major, Foveotriletes* sp. B, *Cingutriletes* sp., *Polypodiaceaesporites chatterjii* and *Polypodiisporites favus* are restricted to the Surma Group. The forms in common between the Barail and Surma groups are *Todisporites major, T. minor, Lygodiumsporites lakiensis, L. eocenicus, Striatriletes susannae, Cyathidites minor, Corrugatisporites* sp., *Polypodiaceaesporites tertiarus* and *Polypodiisporites speciosus.*

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Palynological correlation of coal seams in Godavari Graben, Andhra Pradesh, India

Suresh C. Srivastava

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The palynological study of various coal seams from Yellandu, Kothagudem, Belampalli, Ramakrishnapuram and Ramagundam coalfields of Godavari Graben has been done. The distributional pattern of various palyno-taxa has suggested the occurrence of six miospore assemblages. Miospore Assemblage E is marked by the association of *Parasaccites* and *Scheuringipollenites*. Assemblage D is characterised by the dominance of *Brevitriletes*. In assemblages C1, C2 and C3, *Brevitriletes* is associated with *Hennellysporites*. *Indotriradites*, although rare, occurs only in this assemblage. *Horriditriletes* and *Latosporites* characterise Assemblage B in association with *Brevitriletes*. *Primuspollenites* gains significance only at this stage of palynofloral succession. In the youngest Assemblage A all the triletes decrease appreciably giving way to nonstriate-disaccates, *Scheuringipollenites*, so as to take up the dominance. The sporological succession shows only one change after Assemblage E (Upper Karharbari) was deposited. Miospore assemblages D to A represent the Lower Barakar palynoflora.

Key-words—Palynology, Coal seams, Correlation, Godavari Graben, Lower Barakar (India).

Suresh C. Srivastava, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

आँध्र प्रदेश (भारत) में गोदावरी द्रोणिका के कोयला-सीमों का परागाणविक सहसम्बन्ध

सुरेश चन्द्र श्रीवास्तव

गोदावरी द्रोणिका के येल्लान्डु, कोठागुदेम, बेलमपल्ली, रामकृष्णपुरम एवं रामागुँडम् नामक कोयला-क्षेत्रों से प्राप्त विभिन्न कोयला-सीमों का परागाणविक अध्ययन किया गया है। विभिन्न वर्गकों के वितरण के ढंग से छः मिओबीजाणु समुच्चयों की उपस्थिति प्रस्तावित होती है। मिओबीजाणु समुच्चय ई० में पैरासेक्काइटिस एवं श्यौरिंजीपोलिनाइटिस का साहचर्य है। सी-1, सी-2 एवं सी-3 सुमच्चयों में ब्रेविट्राइलिटीस तथा हेनेलिस्पोराईटिस साथ-साथ विद्यमान हैं। इंडोट्राइरेडाइटिस, यद्यपि अत्यल्प है, केवल इसी समुच्चय में मिलता है। होरिडीट्राइलिटीज़ एवं लाटोस्पोराईटिस ब्रेविट्राइलिटीज़ के साहचर्य में समुच्चय-बी० को अभिलक्षणित करते हैं। प्राइमसपोलिनाइटिस परागाणुवनस्पतिजातीय अनुक्रम के केवल इसी चरण पर अपना महत्व प्रदर्शित करता है। अल्पतम् आयु वाली समुच्चय ए० में सभी त्रिअरीय परागकण काफ़ी कम हो जाते हैं तथा इनके स्थान पर अरेखीय-द्विकोष्ठीयों एवं श्यौरिंजीपोलिनाइटिस की बाहुल्यता बढ़ जाती है। समुच्चय ई० (उपरि करहरबारी) के निक्षेपण के पश्चात् बीजाणविक अनुक्रम केवल एक परिवर्तन प्रदर्शित करता है। मिओबीजाणु समुच्चय (डी० से ए० तक) अधरि बराकार परागाणुवनस्पतिजात का निरूपण करते हैं।

THE Godavari Graben forms a south-eastward extension of the large stretch of Gondwana formations of the Wardha Valley coalfields. It extends in total length of about 350 km and 55 km in breadth. This tract includes many small and important coal-bearing areas which crop out from below the Kamthi Formation. Thus, the coal measures are met with to a small extent and only at intervals, chiefly along the western margin of the main stretch of Gondwana sediments. The areas north of the Godavari River, known as North Godavari coalfields, include Tandur, Mandamari-Somagundum and Ramakrishnapuram coalfields. The main coalfields south of the Godavari River are Ramagundam, Yellandu, Manuguru and Kothagudem.

The discovery of coal in Godavari Valley dates back to 1872 by King near Yellandu and since then extensive surveys have been done with the result a number of coal seams have been proved. However, the study of miospores from these areas attracted the attention of geoscientists in recent years. Ghosh (1962, 1963) studied the palynological contents of different coal types of Tandur area. Chatterjee *et al.* (1964) studied the petrographic characters of the coals from this area, while Banerjee (1964) studied the petrographic characters of the Queen Seam in Yellandu area. Ramana Rao and his associates (1965, 1966) studied the chemical characters of the coals from Kothagudem Coalfield. Moiz and Rao (1968) have described in short the sporae dispersae of the Kothagudem Coalfield. Tiwari and Moiz (1971) have described five new genera of miospores from the coal-bearing horizons of the Godavari Graben. Recently, Navale, Misra and Anand-Prakash (1983) have also studied the petrographic constituents of the working coal seams of the Godavari Graben. Although a number of coal seams have been proved in different areas of the Godavari Basin, little attempt has been done to correlate them. As the coal seams are occurring so widely apart, palynology seems to be the only possible means to attempt their correlation. In the present investigation the palynofloral assemblages in the coals of different areas of Godavari Graben has been studied with a view to establish a palynological succession and a possible correlation of the coal seams.

GEOLOGY

The Lower Gondwana sediments in Godavari Graben stretch in a north-west to south-east linear belt and are exposed along both the margins of the graben. The general stratigraphic setting of the Lower Gondwana sediments in the mainland area is shown in Table 1.

The basement for the deposition of Gondwana sediments has been provided by the Archaeans in the southern part while Pakhals and Sullavai group of rocks constitute the basement north of Mailaram High. The Barakar Formation, overlying Talchir and underlying the Barren Measures formations, occurs as discontinuous patches along the basin margins. The continuity of these sediments has been proved along the western limb of the basin and shows considerable variation in its thickness. However, the continuity of coal seams in axial region has yet to be proved. The coal horizons are restricted to limited number of sub-basins each having its own depositional history. A brief description of the coal-bearing areas investigated is as follows:

Yellandu area—This area is named after the village Singareni and is 22.5 km long and 3.2 km wide aligned in NNW-SSE direction. The area is formed of a Gondwana outlier and workable coal seams occur in the northern part of the area below the Kamthi sandstones. Two prominent coal seams, viz., King Seam (2.4 m) and Queen Seam (9.7-30.4 m), are being worked in this area. The Queen Seam overlies the King Seam with a parting of about 61 m. The Queen Seam varies in thickness from 9.7 to 30.4 m but only the lower 3 meters are extensively developed and are being worked in Polampalli Incline and 20 and 22 Inclines. The King Seam splits into top (0.9 m) and bottom (1 m) towards the northern part of the coalfield.

Table 1—Showing stratigraphic succession of Lower Gondwana sediments in the mainland basin area of Godavari Valley Coalfields

Age	Group	Formation	Thickness (m)	Lithology
Upper Permian to Lower Triassic	LOWER GONDWANA	Kamthi	500 m	*Upper Member*: Coarse grained sandstone with clay clasts and pebbles and subordinate violet cherty siltstones and pebbly beds.
			600 m	*Middle Member*: Alternating sequence of medium-grained white to greenish grey white sandstones and buff to greenish grey clays.
			200 m	*Lower Member*: Medium to coarse-grained, greenish white calcareous sandstones with a few coal seams.
Upper Permian		Barren Measures	500 m	Medium to coarse grained greenish grey to greenish white felspathic sandstone with subordinate variegated clays and micaceous siltstones.
Upper part of Lower Permian		Barakar	300 m	*Upper Member*: Coarse white sandstone with subordinate shale and coal seams.
				Lower Member: Coarse-grained sandstones with lenses of conglomerates subordinate shales/clays and few thin bands of coal.
Lower Permian		Talchir	350 m	Fine-grained sandstone, splintery green clays, shales, chocolate coloured clays, pebble beds and tillite.
				................Unconformity....................
Upper Proterozoic				Sullavai/Pakhal

Kothagudem area—The area is located nearly 39 km east of Yellandu Coalfield. The Barakar sediments containing the coal seams are mostly concealed below the Barren Measures. The Kothagudem coal belt stretches to about 18 km from Kothagudem in the north to Pengadapa in the south. The exploration of the coal is confined only to the King Seam, of which the average thickness ranges from 2.1 to 31.3 m. The seam is being worked up to 3.33 m in Incline no. 2 but the thickness of the seam increases towards south splitting into two and depending upon the local conditions it is being worked in convenient sections with the names of 'Red', 'Blue' and 'Green'.

The general sequence of coal seams in the area as established by Kothagudem Collieries Co. Ltd., is as follows:

Top (Queen) Seam	6.7 to 13.5 m
Parting	42 m
King Seam	2.1 to 31.3 m
Parting	0.91 to 6.3 m
Bottom (Green) Seam	4.2 to 8.4 m

Ramagundam area—This area is situated south of the Godavari River extending up to Ladnapuram in the south for about a stretch of 16 km and forms the most important coal bearing part of the Godavari Graben. The sequence of coal seams established (Ramanamurty, 1977) in the area is as follows:

Strata	*Thickness*
Barren Measures Formation	
Sandstone	11.71-30.12 m
No. 1A seam (highly shaly coal)	0.45- 6.15 m
Sandstone	24.39-34.28 m
No. I seam	5.09- 9.71 m
Sandstone	14.73-26.35 m
No. II seam	1.75- 6.17 m
Sandstone	32.72-62.77 m
No. II/A seam	0.75- 3.00 m
Sandstone	46. 5-73.00 m
No. III seam	4.65-10.35 m
Sandstone	0.00-15.10 m
No. IV seam	1.06- 3.81 m
Sandstone	35.98-76.59 m
No. IV A seam	0. 5- 1.00 m
Sandstone	71.24 m
Talchir Formation	

Out of the seven coal seams, No. I, II, III and IV are being worked as they are persistent and economically significant while the rest three coal seams are either developed mostly to a local extent or contain low grade coal.

Belampalli area—The area is situated north of Godavari River and extends over a strike length of about 45 km from Khairagura in the north-west up to Belampalli in the south-east. The Barakars in the area are overlain by Barren Measures Formation and include four coal seams but at present only two coal seams, the Salarjung Seam and Ross Seam, are being worked out.

The general sequence of the coal seams in the area is as follows:

Strata	*Thickness*
Barren Measures Formation	
Parting	30.00- 40.00 m
No. I Seam	0.02- 4.35 m
Parting	10.00- 46.90 m
No. II Seam	1.00- 6.03 m
Parting	70.00- 80.00 m
Salarjung Seam/No. III Seam	1.05- 12.00 m
Parting	24.00- 40.00 m
Ross Seam/No. IC Seam	0.5 - 5.07 m
Sandstone	95.00-110.00 m

The lowermost coal seam is named as Ross Seam in Belampalli area while in other areas it is known as No. IV Seam. In the southern part around Shanti Khani it splits into two with a parting of 5.5 m sandstone.

Seam no. III or the Salarjung Seam remains almost uniform in Belampalli area but in Golet area it splits up into two sections.

Mandamari-Ramkrishnapuram area—The coal measures of this area form a part of the Somagudem-Mandamari - Ramkrishnapuram - Srirampur - Indaram coal belt traceable from Somagudem in the north to Indaram in the south. The sequence of coal seams as established by Ramana, Ramanamurthy and Dawood (1974) is as follows:

Strata	*Thickness*
Barren Measures Formation	
Parting-Sandstone	10.00- 20.00 m
No. I A seam with shale band	3.06- 5.04 m
Parting	15.00- 20.00 m
No. I seam with shale band	2.01- 5.05 m
Parting	9.45- 16.08 m
No. II B Seam	1.6 - 2.13 m
Parting	10.00- 14.6 m
No. II A Seam	1.1 - 3.4 m
Parting	8.00- 10.00 m
No. II Seam	1.2 - 6.9 m
Parting	22.7 - 33.8 m
No. III A	1.5 - 1.8 m
Parting	12.1 - 24.2 m
No. III Seam	0.7 - 12.2 m
Parting	6.1 - 29.17 m
No. IV Seam	1.5 - 5.7 m
Parting	8.00- 10.00 m
No. V Seam	0.3 - 1.8 m
Parting	8.7 - 18.00 m
No. VI Seam	0.61- 1.22 m

Parting 80.00-100.00 m
Talchir Formation

In general, the Barakars of Tandur area are believed to have been repeated due to south westerly down throw fault and No. III and No. IV seams are correlatable with Salarjung and Ross seams of Belampalli area respectively.

PALYNOFLORAS

The sporae dispersae distributed among the coal seams investigated (Table 2) from Godavari Graben has been assigned to 48 genera (*sensu* Bharadwaj, 1962; Bharadwaj & Salujha, 1964; Bharadwaj & Srivastava, 1969; Tiwari, 1964; Tiwari & Moiz, 1971) which are listed below:

Leiotriletes, Callumispora, Hennellysporites, Cyclogranisporites, Lophotriletes, Brevitriletes, Lobatisporites, Horriditriletes, Godavarisporites, Microbaculispora, Lacinitriletes, Pseudoreticulatispora, Indotriradites, Calamospora, Latosporites, Parasaccites, Crucisaccites, Divarisaccus, Caheniasaccites, Potonieisporites, Virkkipollenites, Cuneatisporites, Platysaccus, Lueckisporites, Striatites, Primuspollenites, Lahirites, Striatopodocarpites, Faunipollenites, Striapollenites, Distriatites, Illinites, Vesicaspora, Scheuringipollenites, Ibisporites, Tiwariasporis, Kingiacolpites, Distriomonocolpites, Maculatasporites, Pilasporites, Hemisphaerium, Peltacystia, Brazilea, Balmeella, Tetraporina, Greinervillites, Leiosphaeridia and *Globulisphaeridium.*

The percentage distribution of various miospore genera is given in Table 3a and b in which the genera, viz., *Hennellysporites, Brevitriletes, Horriditriletes, Parasaccites* and *Scheuringipollenites* are characteristically present among all the samples and hence form the dominant components of palynoflora of the different coal seams in Godavari Graben.

Besides, the genera—*Leiotriletes, Indotriradites, Latosporites, Striatites, Lahirites, Striatopodocarpites, Faunipollenites, Illinites, Vesicaspora* and *Ibisporites*—are also associated significantly with the dominant components.

The other genera are rather inconsistently present but in very low percentages. The behaviour of alete miospores is also not consistent throughout the palynofloral spectrum although in some samples they are present in significant amounts. However, their presence among the mioflora have been ignored as their affinity, occurrence and significance in the stratigraphy is not precisely known. The

Table 2—Showing details of coal samples investigated from Godavari Valley coalfields, Andhra Pradesh

Coal seam	Colliery	Location
King Seam	Kothagudem Collieries	No. 2 Incline
King Seam (Red)	Khammam District	Venkatesh Khani Incline 6 & 7
King Seam (Blue)	Khammam District	Venkatesh Khani Incline 6 & 7
Bottom Seam (Blue)	Khammam District	Venkatesh Khani Incline 6 & 7
Blue Seam	Khammam District	No. 9 and 10 Incline
Green Seam	Khammam District	No. 9 and 10 Incline
Top 1 Seam	Khammam District	No. 9 and 10 Incline
Top 2 Seam	Khammam District	No. 9 and 10 Incline
Queen Seam	Yellandu Collieries	Pollampalli Incline
King Seam	Yellandu Collieries	No. 20 Incline
D Seam	Yellandu Collieries	No. 20 Incline
Queen Seam	Yellandu Collieries	No. 22 Incline
D Seam	Yellandu Collieries	No. 22 Incline
Seam 3	Ramagundam Collieries, Karim Nagar District	No. 1 Incline
Seam 4	Ramagundam Collieries, Karim Nagar District	No. 1 Incline
Seam 1	Ramagundam Collieries, Karim Nagar District	Godavari Khani Incline No. 3
Seam 2	Ramagundam Collieries, Karim Nagar District	Godavari Khani Incline No. 3
Seam 3	Ramagundam Collieries, Karim Nagar District	No. 7 Incline
Seam 3	Ramakrishnapuram Collieries, Adilabad District	Ramkrishna Khani
Seam 3	Ramakrishnapuram Collieries, Adilabad District	Ramkrishna Khani
Seam 4	Ramakrishnapuram Collieries, Adilabad District	Ramkrishna Khani
Seam 2	Ramakrishnapuram Collieries, Adilabad District	Motilal Khani
Seam 3	Mandamari area	Kalyani Khani
Seam 4	Mandamari area	Kalyani Khani
Top Seam	Belampalli area	Shanti Khani Incline
Middle Seam	Belampalli area	Shanti Khani Incline
Bottom Seam	Belampalli area	Shanti Khani Incline
Salarjung Seam	Belampalli area	Morgan pit
Ross seam	Belampalli area	Morgan pit
Salarjung Seam	Belampalli area	85 Dip
Ross Seam	Belampalli area	85 Dip

Table 3a—Percentage composition of various palynotaxa in different coal seams of Godavari Graben

Genera/Overall sample no.	1	2	3	5	6	6B	6+6B	7	7C	7+7C	8	9	10C	11	12	13A
PTEROPSIDS																
Lieotriletes	2.5	3.0	3.5	3.0	1.0	2.0	1.5	2.0	0.5	1.4	4.0	3.5	—	5.0	2.5	3.0
Callumispora	1.5	—	3.0	3.0	8.0	10.0	9.0	—	—	—	3.0	—	5.0	2.0	2.0	1.0
Hennellysporites	4.0	2.0	2.0	0.5	2.0	6.0	4.0	1.5	1.0	1.4	1.5	7.0	1.0	10.0	0.0	2.0
Cyclogranisporites	—	—	—	—	1.0	0.5	0.8	—	—	—	1.0	—	—	—	0.5	—
Verrucosisporites	—	—	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—
Lophotriletes	3.0	—	1.5	0.5	—	—	—	1.5	—	0.9	1.0	—	0.5	0.5	2.0	3.0
Brevitriletes	24.5	28.0	29.5	34.0	40.0	29.0	34.5	20.0	25.0	22.5	15.0	14.0	13.5	10.0	19.0	11.0
Lobatisporites	1.0	—	1.5	2.0	—	—	—	0.5	0.5	0.5	—	—	—	—	—	—
Horriditriletes	4.0	4.0	11.0	3.0	4.0	7.0	5.5	3.0	4.0	3.5	7.0	2.5	—	1.0	25.0	17.0
Godavarisporites	0.5	7.5	—	4.0	3.0	4.0	3.5	—	—	—	1.0	1.0	—	3.0	3.0	—
Pseudoreticulatispora	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.0	—
Lacinitriletes	—	—	—	—	—	—	—	—	—	—	—	—	—	1.5	2.0	—
Microbaculispora	—	—	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—
Calamospora	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Latosporites	1.5	—	—	—	—	—	—	1.5	1.0	1.4	13.0	7.5	0.5	—	5.5	9.0
LYCOPSID																
Indotriradites	—	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	1.0
GYMNOSPERM																
Parasaccites	5.5	6.0	6.5	15.0	8.0	11.0	9.5	4.0	2.0	3.0	5.5	2.0	24.0	8.0	0.5	4.0
Crucisaccites	—	—	—	—	—	—	—	—	—	—	—	—	0.5	—	—	—
Divarisaccus	—	—	—	0.5	—	—	—	—	—	—	0.5	—	—	0.5	—	—
Cabeniasaccites	—	—	0.5	—	—	—	—	—	—	—	—	—	—	0.5	—	—
Potonieisporites	—	—	2.0	2.0	—	—	—	1.0	—	0.5	—	—	—	0.5	—	—
Cuneatisporites	—	—	—	—	—	—	—	—	—	—	—	—	—	2.5	0.5	0.5
Platysaccus	1.0	2.0	2.0	—	—	—	—	8.0	9.0	8.5	2.5	3.5	0.5	1.0	4.0	8.5
Lueckisporites	—	—	—	—	—	—	—	—	0.5	0.4	—	—	—	—	—	—
Striatites	3.0	2.0	1.0	—	2.0	—	1.0	2.0	2.0	2.0	1.5	0.5	0.5	1.0	1.5	4.0
Primuspollenites	—	—	—	—	—	—	—	—	—	—	3.0	8.0	—	0.5	2.0	1.0
Labirites	7.0	5.0	2.0	2.0	2.0	—	2.0	5.0	3.0	4.0	6.0	3.0	2.5	2.0	2.5	1.0
Striatopodocarpites	6.0	5.0	5.0	1.5	2.0	2.0	2.0	1.0	5.0	3.0	6.0	10.0	6.5	5.0	1.0	3.0
Striapollenites	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Faunipollenites	8.0	3.0	6.0	2.5	3.0	3.0	3.0	2.0	2.0	2.0	3.5	4.5	2.0	7.0	2.0	2.0
Distriatites	—	—	—	—	—	—	—	—	0.5	0.4	—	—	—	—	—	—
Illinites	7.0	2.0	—	1.0	2.0	3.0	1.5	—	—	—	1.0	4.5	5.5	10.0	—	1.0
Vesicaspora	2.0	3.0	1.5	1.0	—	—	—	0.5	0.5	0.5	—	1.0	4.0	4.0	1.5	5.0
Scheuringipollenites	11.0	7.5	12.0	10.0	5.0	2.0	3.5	25.0	25.0	25.0	10.0	14.0	18.5	12.0	12.5	12.0
Ibisporites	0.5	—	0.5	0.5	1.0	—	0.5	—	4.0	2.0	0.5	3.0	3.0	2.0	0.5	1.0
Tiwariasporis	1.0	2.0	1.0	1.0	1.0	—	0.5	5.5	3.0	4.4	9.0	0.5	3.5	0.5	2.0	3.0
Kingiacolpites	—	2.0	2.0	1.5	—	1.0	0.5	1.0	1.5	0.9	—	3.0	1.5	2.0	—	2.0
Distriomonocolpites	—	—	0.5	—	—	1.0	0.5	—	—	—	—	—	—	—	—	—
PHYTOPLANKTON																
Maculatasporites	—	—	—	—	0.5	—	0.5	—	—	—	—	0.5	—	—	0.5	—
Pilasporites	2.5	5.0	2.5	4.0	3.0	5.0	4.0	4.0	1.5	2.7	1.0	1.5	3.0	4.0	1.5	1.0
Hemisphaerium	—	3.0	—	0.5	2.0	5.0	3.5	3.5	0.5	2.0	—	0.5	—	2.0	—	—
Brazilea	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Balmeella	0.5	2.0	—	0.5	—	0.5	0.2	—	—	—	0.5	—	1.0	—	—	—
Leiosphaeridium	2.0	5.0	1.0	6.0	9.0	8.0	8.5	5.0	7.0	6.0	4.0	4.0	1.0	2.0	4.0	4.0
Greinervillites	—	—	—	—	—	—	—	—	0.5	0.4	—	—	—	—	—	—
Globulisphaeridium	—	1.0	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—
Tetraporina	—	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—
Peltacystia	—	—	—	—	—	—	—	1.0	1.5	0.7	—	—	1.0	—	—	—

Kothagudem Collieries : No. 2 Incline—1. King Seam; Nos. 6, 7 Incline—2. King Seam (red), 3. King Seam (blue); Nos. 9, 10 Incline—5. Blue Seam, 6, 6B. Green Seam; 6×6B. Average; 7, 7C. Top Seam; 7×7C. Average. *Yellandu Collieries* : Polampalli Incline—9. Queen Seam; 20 Pit Incline—10C. King Seam, 11. D Seam; 22 Pit Incline—12. Queen Seam, 13. A, D Seam

Table 3b—Percentage composition of palynotaxa in different coal seams in Godavari Graben

Genera Samples nos.	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
PTEROPSIDS																	
Leiotriletes	6.0	3.0	3.0	6.0	3.0	3.0	1.0	0.5	—	2.0	0.5	4.0	1.0	6.0	11.0	2.0	4.0
Callumispora	1.0	1.5	1.0	—	1.0	4.0	6.0	2.0	—	—	1.0	—	0.5	1.0	2.5	—	—
Hennellysporites	11.0	12.0	2.0	4.0	4.0	6.0	4.0	4.0	3.0	3.0	3.0	8.0	14.5	1.0	24.0	4.0	21.0
Cyclogranisporites	1.0	3.0	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lophotriletes	—	0.5	—	—	—	—	—	—	—	—	—	2.0	—	—	—	—	—
Brevitriletes	14.5	25.0	10.0	11.0	12.0	21.0	26.0	25.0	16.0	18.0	16.0	21.0	23.0	20.0	16.0	15.0	16.5
Horriditriletes	5.0	3.0	5.0	2.0	3.5	0.5	2.0	2.0	—	1.0	1.5	2.0	1.0	5.0	4.0	6.0	5.0
Godavarisporites	0.5	3.0	2.0	1.0	0.5	0.5	5.0	2.0	1.0	1.0	—	5.0	4.0	5.0	3.0	1.0	0.5
Pseudoreticulatispora	—	—	—	—	—	—	—	—	—	—	—	0.5	—	—	—	—	—
Lacinitriletes	—	2.5	0.5	0.5	—	—	—	0.5	—	—	—	—	—	—	—	—	—
Microbaculispora	—	—	—	—	—	—	—	—	—	—	—	—	0.5	—	—	1.0	0.5
Latosporites	0.5	—	3.0	6.0	1.0	0.5	1.5	1.0	—	—	—	1.5	0.5	—	—	—	—
LYCOPSID																	
Indotriradites	—	4.5	—	—	—	0.5	—	0.5	—	—	—	0.5	0.5	5.0	6.5	1.0	0.5
GYMNOSPERMS																	
Parasaccites	5.0	5.0	0.5	1.5	6.0	9.0	8.0	4.0	4.0	6.0	1.0	6.0	9.5	3.0	4.5	2.0	4.5
Divarisaccus	—	—	—	—	—	0.3	—	—	—	—	—	—	—	—	—	—	0.5
Potonieisporites	—	—	—	—	—	—	—	—	2.0	—	—	0.5	—	—	—	—	—
Cuneatisporites	3.5	—	—	1.0	0.5	—	—	—	1.5	1.5	0.5	—	—	2.0	0.5	—	—
Platysaccus	2.5	1.0	3.0	5.0	3.0	—	—	1.5	2.0	1.5	4.5	1.0	0.5	3.0	2.0	4.0	2.0
Lueckisporites	—	—	0.5	1.5	—	—	—	—	—	—	—	—	—	—	—	—	—
Striatites	3.0	1.0	3.5	1.5	2.0	2.0	0.5	1.5	4.0	2.0	1.0	1.5	1.0	6.0	1.5	7.0	1.0
Primuspollenites	—	0.5	3.0	6.5	—	—	—	—	—	—	0.5	1.5	—	—	—	0.5	—
Labirites	5.5	0.5	5.0	3.0	6.0	—	—	3.0	8.0	6.0	3.0	6.0	3.0	6.0	1.0	5.0	2.5
Striatopodocarpites	5.5	5.5	5.0	3.0	7.0	6.0	5.0	5.0	4.0	4.0	2.0	6.5	7.0	3.0	3.0	3.0	4.0
Striapollenites	—	—	—	—	—	—	—	—	0.5	—	—	—	—	—	—	—	—
Faunipollenites	5.5	1.0	7.0	4.0	4.0	4.5	0.5	8.0	9.0	8.0	4.0	1.5	4.0	2.0	0.5	5.0	3.0
Distriatites	—	—	—	—	—	—	—	—	—	0.5	—	—	—	—	—	—	—
Illinites	6.5	2.0	2.5	4.0	3.0	2.0	3.0	3.0	2.0	8.0	—	3.5	2.0	3.0	1.0	8.0	5.0
Vesicaspora	5.0	1.0	1.0	2.0	8.0	7.0	0.5	4.0	5.5	7.0	3.5	3.5	1.0	6.0	3.0	4.0	3.0
Scheuringipollenites	9.5	12.0	23.0	23.0	18.0	11.0	12.0	16.0	22.5	14.0	29.0	8.5	10.0	8.0	6.0	15.0	7.0
Ibisporites	2.5	—	2.0	4.0	5.0	1.5	2.0	2.0	7.5	1.0	6.5	2.5	1.0	—	1.0	2.0	1.0
Tiwariasporis	2.2	2.0	3.0	5.0	1.5	1.0	3.0	1.0	2.5	3.0	4.5	6.0	1.5	3.0	0.5	5.5	0.5
PHYTOPLANKTON																	
Kingiacolpites	2.0	2.0	3.0	0.5	4.0	3.0	1.0	0.5	2.5	—	0.5	0.5	0.5	—	0.5	0.5	3.0
Maculatasporites	—	—	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pilasporites	1.5	3.0	3.0	1.0	3.0	8.0	8.0	6.5	2.0	9.5	5.0	4.0	7.0	4.0	7.0	2.5	10.0
Hemisphaerium	—	2.0	2.0	—	1.0	0.5	6.0	2.5	—	0.5	2.0	—	4.0	—	—	—	1.0
Brazilea	—	—	—	—	—	—	—	—	—	—	1.0	—	—	—	—	—	—
Balmeella	—	—	0.5	—	—	1.5	—	—	—	0.5	—	1.0	1.0	—	—	—	—
Leiosphaeridium	1.0	3.5	4.0	2.0	3.0	6.0	5.0	3.0	1.0	1.5	6.0	2.0	2.0	2.0	1.0	1.0	4.0
Tetraporina	—	—	0.5	—	1.0	0.5	—	1.5	—	—	1.0	0.5	—	—	—	—	—

Ramagundam Collieries : No. 1 Incline—14. Seam 3, 15. Seam 4; No. 3 Incline—16. Seam 1, 17. Seam 2, No. 7 Incline—18. Seam 3. *Ramakrishnapuram Collieries* : Ramkrishna Khani 1-19. Seam 3, 20. Seam 4; Motilal Khani 1-21. Seam 2. *Mandamari Area* : Kalyani Khani—22. Seam 3, 23. Seam 4. *Belampalli Collieries* : Shanti Khani—24. Top Seam, 25, Middle Seam, 26. Bottom Seam; Morgan Pit—27. Salarjung Seam, 28. Ross Seam; 85 Dip—29. Salarjung Seam, 30. Ross Seam.

qualitative association of palynospores as well as their quantitative representation in different areas of the Godavari Graben has been discussed separately as each of them are situated wide apart and as such their mutual relationships are unknown. The assemblages bear the same designation.

Yellandu area

The general behaviour of the dominant components and their variation in individual coal seams is shown in Table 3a. *Parasaccites* is present up to its maximum only in the King Seam of No. 20 Incline while in the leader 'D' seam lying above it decreases considerably. On the contrary *Hennellysporites* records a reverse trend, i.e. it is low in the King Seam but becomes high in the 'D' seam of No. 20 Incline and also in the Queen Seam of Polampalli Incline. In No. 22 Incline the Queen and the 'D' seams are marked by the dominance of *Horriditriletes, Scheuringipollenites* and *Parasaccites* continues to decrease from No. 20 to Polampalli to No. 22 Inclines. *Latosporites* increases steadily in the same direction. *Primuspollenites* and *Illinites* are present significantly in Queen Seam of Polampalli Incline.

The distinctive distribution of all the dominant constituents and their percentage frequency suggests segregation of the samples into sporologically three different assemblages. The percentage of inconsistently occurring genera have been merged into those occurring consistently in order to represent the pollen spectrum more uniformly rather than irregularly.

Assemblage E—This assemblage is characterised by the dominance (Table 4a) of *Parasaccites* (18%) and *Scheuringipollenites* (16%). *Brevitriletes* (12%) occur subdominantly and is associated with *Hennellysporites* (6%), *Striatopodocarpites* (6%) and *Illinites* (8%). The total percentage of laevigate + apiculate triletes amounts to 14 per cent (Table 5), varitriletes 12 per cent, monosaccate 18 per cent, nonstriate-disaccate 32 per cent and striate disaccate up to 15 per cent. Thus the overall percentage is largely shared by the nonstriate disaccate pollen grains. Such an assemblage is present in the King Seam and D Seam of No. 20 Incline (sample Nos. 10 & 11).

Assemblage B1—The Queen Seam of Pollampalli Incline contains Assemblage Bl. This is characterised by the combined dominance of *Brevitriletes* (14%) and *Scheuringipollenites* (14%). *Striatopodocarpites* (10%) closely follows along with *Primuspollenites* (8%) and *Hennellysporites* (7%). Monosaccates have reduced to 2 per cent. Thus the Queen Seam of Polampalli Incline contains mioflora quite different from the Assemblage E of King Seam. The total percentage of laevigate + apiculate triletes amounts to 14 per cent and the varitriletes 14 per cent. Nonstriate-disaccate (26%) show a slight decrease in their percentage. The monolete miospores (8%) and reticuloid disaccate (8%) record their appearance for the first time in this assemblage.

Assemblage B2—*Horriditriletes* dominates the assemblage up to 21 per cent. The dominant components of Assemblage E reduce to subdominance. *Latosporites* increases to 7 per cent. The average total of laevigate + apiculate triletes rises to the maximum (32%). Nonstriate-disaccates are present up to 23 per cent. Such a mioflora is contained in the Queen Seam and D Seam (sample nos. 12 & 13) of No. 22 Incline. This coal seam shares its resemblance with the Queen Seam of Pollampalli Incline in respect of *Latosporites* and *Primuspollenites* but differs in having high percentage of *Horriditriletes* and *Striatopodocarpites.* In Polampalli Incline Queen Seam is being worked out only partly and such differences may occur due to incomplete representation of the entire thickness of the coal seam. It may also indicate variations in the lateral extension of the same seam. Keeping in view the above facts the palynofloras of the Queen Seam from two inclines are described in the same but a different sub-assemblages.

Kothagudem area

The main working coal seam in this area is the King Seam which is being worked out partly in convenient sections of Red and Blue. This coal seam has been collected from Venkatesh Khani Group of inclines Nos. 6 and 7. From Nos. 9 and 10 Inclines Blue Seam and Green Seam have been collected along with Top 1 and Top 2 seams. King Seam in this area is marked by the dominance of *Brevitriletes.* This character is in sharp contrast with the King Seam of Yellandu area. The genera *Parasaccites* and *Sheuringipollenites* which were dominant in the latter, have reduced considerably in Kothagudem area. *Parasaccites* decreases steadily in the younger coal seams of No. 9 and 10 Inclines while *Scheuringipollenites* becomes maximum in Top 1 Seam. *Latosporites* and *Primuspollenites* attains significance in Top 2 Seam only. Thus the eight samples collected from the Kothagudem area can be segregated into three distinct miospore assemblages.

Assemblage D—This assemblage is characterised by the dominance of *Brevitriletes* (30%) in the King Seam (Red & Blue) of No. 6 Incline, Blue and Green Seams of No. 9 and 10 Inclines, and King Seam of No. 2 Incline. *Parasaccites* (10%), and *Sheuringipollenites* (9%) are present subdominantly. The laevigate + apiculate triletes total up to 19 per cent, varitrilete 30 per cent, nonstriate-disaccate and striate disaccate are present up to 14 per cent each. The variations among different genera in the lateral extension of the King Seam in Kothagudem area are negligible. Monosaccate and varitrilete are highest in 9 and 7 Incline to No. 2 Incline. Striate and nonstriate-disaccates occur in the reverse order.

Table 4a—Showing percentage composition of different assemblages in various collieries of Godavari Graben

Assemblages	E			D									
Collieries	Yellandu			Kothagudem								Ramakrishnapuram	
Incline/Pits	20			2	6&7			9&10				Ramakrishna Khani	
Coal Seam	King	D	Average	King	King Red	King Blue	Average	Blue	Green	Average	Average	Seam 4	Seam 3
Genera / Sample no.	10	11	10+11	1	2	3	2+3	5	6	5+6	1+ (2+3) +(5+6)	20	19
Leiotriletes	0.8	7.0	4.0	3.2	4.7	4.3	4.5	4.3	3.5	4.5	4.2	5.1	2.0
Hennellysporites	1.8	11.0	6.5	4.6	3.7	3.8	3.5	1.8	5.0	3.5	3.2	7.4	6.0
Horriditriletes	0.8	2.0	1.5	5.6	5.7	11.8	8.5	6.3	7.5	7.0	7.6	2.1	4.0
Brevitriletes	14.4	11.0	12.5	25.2	29.7	30.3	30.0	35.3	36.5	35.5	31.6	22.4	28.0
Latosporites	1.4	1.0	1.5	2.2	1.7	1.1	1.5	1.3	2.0	1.5	1.8	2.1	3.5
Parasaccites	25.4	11.0	18.0	6.2	7.7	7.8	7.5	16.5	11.5	14.0	9.9	10.4	10.0
Platysaccus	1.4	5.0	3.0	1.6	2.7	2.8	3.5	1.3	2.0	1.5	1.8	2.1	3.5
Striatites + Labirites	4.6	5.0	5.0	11.4	9.7	4.5	7.0	4.6	7.0	5.5	7.6	5.2	4.5
Striatopodocarpites	7.4	6.0	6.5	6.6	6.7	5.8	6.5	2.8	4.0	3.5	5.8	7.6	7.0
Faunipollenites	2.8	8.0	5.5	8.6	4.7	6.8	5.5	3.8	5.0	4.5	5.8	5.8	2.5
Illinites	6.4	11.0	8.5	7.7	3.7	2.8	3.5	4.3	3.5	4.0	4.6	3.6	5.0
Vesicaspora	4.8	5.0	5.0	2.5	4.7	2.3	3.5	2.3	2.0	2.0	1.8	8.4	2.5
Scheuringipollenites	19.4	13.0	16.0	12.7	9.2	12.8	11.0	11.3	5.5	8.5	10.5	12.6	14.0
Ibisporites	4.3	3.0	3.5	1.2	1.7	1.3	1.5	1.8	2.5	2.0	1.5	3.1	4.0
Tiwariasporis	4.3	1.0	3.0	1.7	3.7	1.8	2.5	2.3	2.5	2.5	1.5	2.6	5.0

Assemblage B1—*Brevitriletes* though reduced considerably in To 2 seam of No. 9 and 10 Inclines yet it dominates the assemblage. *Latosporites* distinguishes this seam by its presence up to 13 per cent. *Scheuringipollenites* (10%) and *Horriditriletes* (7%) closely follow the above genera. *Primuspollenites* is present up to 3 per cent. In this respect it shows resemblance with the Queen Seam of Polampalli Incline in Singareni area. The total percentage of laevigate + apiculate trilete miospores remain at 19 per cent but varitrilete and nonsaccate-decrease persistently. Striate disaccate increase to 26 per cent. In this manner the Top 2 Seam shows a palynoflora distinctly different from the King Seam.

Assemblage A—It is found in the Top 1 Seam of No. 9 and 10 Inclines. This is marked by the dominance of *Scheuringipollenites* (25%). *Brevitriletes* (22) also rises to subdominance. *Platysaccus* increases to 9 per cent. The total percentage of laevigate + apiculate triletes (8%), monoletes (1%), monosaccates (3%) and striate-disaccate decreases considerably while the nonstriate-disaccate share the maximum percentage (37%) of the palynoflora. In this respect the Top 1 Seam differs from all the underlying coal seams.

Ramagundam area

Five samples from three different inclines were collected. The genus *Hennellysporites* is present significantly in the two older coal seams but reduces in the younger ones. *Parasaccites* and *Brevitriletes* also behave likewise (Table 3b). *Indotriradites*, although rare, is present in Seam 4 only. *Latosporites* and *Primuspollenites* are present in very small amounts in Seam 3 and 4 while in Seam 2 and 1 they are present significantly. *Scheuringipollenites* increases gradually in the younger coal seams reaching its maximum in Seam 1 of No. 3 Incline.

The quantitative distribution of various miospores genera distinguishes two distinct miofloral assemblages as follows:

Assemblage C1—Seam No. 4 of No. 1 Incline contains the dominance of *Brevitriletes* (26%, Table 4a). *Hennellysporites* (12%) and *Scheuringipollenites* (12%) occur next to it. *Indotriradites* (4.5%) is characteristically associated with this seam only which indicates an older aspect of the coal seam to which it is associated. The total percentage of laevigate + apiculate trilete (25%) and varitrilete (26%) characterise the assemblage in close association with nonstriate-disaccate (23%).

Assemblage C2—The genus *Brevitriletes* (15%) reduces considerably in this assemblage while *Scheuringipollenties* (15%) increases slightly. Their combined dominance is associated with *Hennellysporites* (8%), *Latosporites* (5%), *Parasaccites* (6%), *Striatites* (9%) and *Striatopodocarpites* (7%). *Indotriradites*, which was

(Table 4a contd......)

			C												
			C1				C2						C3		
		Mandamari	Ramagundam							Belampalli					
Motilal Khani		Kalyani Khani	1	7			Morgan Pit	85 Dip		Shanti Khani	85 Dip	Morgan Pit		Shanti Khani	
Seam 2	Average	Seam 4	Seam 4	Seam 3	Seam 3	Average	Ross Seam	Ross Seam	Average	Bot.	Salarjung	Salarjung	Average	Middle	Total Average
21		23	15	14	18	14+18	28	30	28+30	26	29	27	27+29	25	C1+C2 +C3
1.2	2.7	2.8	7.0	6.0	3.3	5.0	12.0	5.0	8.5	2.5	2.7	7.0	4.8	5.0	5.5
5.2	6.2	4.0	13.5	11.5	4.7	8.0	25.8	22.0	23.9	15.5	9.0	8.0	8.5	9.0	13.0
13.2	3.1	2.0	4.5	5.5	4.4	5.0	5.3	6.0	5.6	2.5	6.0	6.0	6.2	3.0	4.5
26.2	25.5	18.8	26.0	15.0	12.7	15.0	17.2	18.2	17.6	24.5	15.7	21.0	18.2	22.0	20.5
2.2	2.6	1.0	1.5	1.0	1.8	1.3	1.0	1.2	1.1	1.5	0.7	1.0	1.1	2.5	1.5
6.0	8.8	7.0	6.5	5.5	6.8	6.0	5.8	6.0	5.9	10.5	2.0	4.0	3.0	7.5	6.5
1.2	1.8	3.8	2.5	6.0	4.4	5.0	3.8	3.0	3.4	1.5	4.7	6.6	5.3	2.5	3.4
7.0	5.5	9.6	4.5	9.5	9.8	9.0	5.0	6.9	5.9	6.5	13.4	14.0	13.7	9.5	8.2
6.2	6.9	4.8	7.0	6.0	7.7	6.7	4.3	5.0	4.1	8.5	3.7	4.0	3.8	7.5	6.2
9.2	5.8	8.8	2.5	6.0	4.7	5.0	1.8	4.0	4.9	5.0	5.0	3.0	4.0	2.5	3.9
4.2	4.2	8.8	3.5	7.0	3.7	5.0	2.3	6.0	4.1	3.0	8.0	4.0	6.0	5.0	4.4
5.2	5.3	8.0	2.5	5.5	8.7	7.0	4.3	4.0	4.1	2.0	4.7	7.0	5.8	4.5	4.3
17.2	14.6	14.8	13.5	10.0	18.7	15.0	7.3	8.0	7.1	11.5	15.7	10.0	12.8	8.5	11.4
3.2	3.4	2.0	1.5	3.0	5.8	4.0	2.3	2.5	2.4	2.5	2.7	1.0	1.8	3.5	3.0
2.2	3.6	3.8	3.5	2.5	2.4	3.0	1.8	2.2	2.0	2.5	6.0	4.0	5.0	7.5	4.0

present in Assemblage C2 is absent in this assemblage. The total percentage of laevigate and apiculate trilete amounts to the tune of 18 per cent and nonstriate-disaccate to 37 per cent. Varitrilete and striate-disaccate are present in 15 per cent and 20 per cent respectively. The coal seam 3 of No. 1 Incline and Seam 3 of No. 7 Incline, in which Assemblage C2 is distributed, compare very closely to each other in the distribution pattern of their palynoflora. However, the trend of variation of the dominant components in Seam 3 of No. 7 Incline shows a slight increase in the percentage of *Scheuringipollenites* thus increasing the total representation of nonstriate-disaccate slightly higher than those of Seam 3 of No. 1 Incline. *Hennellysporites* is also slightly reduced in No. 7 Incline while it increases in No. 1 Incline. Although the differences are marked out only slightly yet the general behaviour of rest of the genera compare very closely with that of Seam 3 of No. 1 Incline and hence it is preferred to retain the same in Assemblage C2. The differences, however, represent only the lateral variations within the same seam.

Assemblage A—Seam 2 and Seam 1 of Godavari Khani Incline No. 3 is marked by the dominance of *Sheuringipollenites* (23%, Table 4b). *Brevitriletes*, which was dominant in Assemblage C1, has reduced considerably along with *Hennellysporites* and *Parasaccites*. On the other hand, *Latosporites* and *Primuspollenites* mark a slight increase in their percentage. This character is in sharp contrast with the older assemblage described above. While the total representation of laevigate and apiculate trilete (13%), varitrilete (10%) and monosaccates (1%) have reduced considerably, the monolete miospores (5%), nonstriate, reticuloid and striate-disaccate (37%, 5%, 20% respectively) mark a significant increase in their percentages.

Ramkrishnapuram area

As shown in Table 3b the three coal seams collected from two different Inclines (Seam nos. 2, 3, 4) show a close similarity in qualitative as well as quantitative occurrence of various miospore genera. In view of their similarities all the three coal seams have been grouped together to represent the same miospore Assemblage D (Table 4a) of the Ramkrishnapuram area.

Assemblage D—Brevitriletes (25%) in general dominates over the genus *Scheuringipollenites* (13%) and thus characterises the assemblage. These two genera continue to increase in their percentage from oldest to the youngest seam while *Hennellysporites* and *Parasaccites* record a reverse trend. The overall representation of laevigate and

Table 4b—Showing percentage composition of different assemblages in various collieries of Godavari Graben

Assemblages			B						A				
		B1		B2									
Collieries	Yella-ndu	Kotha-gudem	Aver-age	Yella-ndu	Aver-age	Total Average	Kotha-gudem	Mande-mari	Belam-palli	Ramagundam			
Incline/Pits	Polam-palli	9 & 10		No. 22				9 & 10	Kalyani Khani	Shanti Khani		Godavari Khani	Aver-age	Total Average
Coal Seam	Queen	Top 2		Queen	D		B1+ B2	Top 1	Seams 3	Top	Seam 2	Seam 1		
Genera Samples nos.	9	8	9+8	12	13	12+13		7	22	24	17	16	16+17	7+22+24 +16+17
Leiotriletes	4.7	5.0	4.6	5.0	4.0	4.5	4.5	2.3	0.4	1.5	7.0	4.8	5.9	2.5
Hennellysporites	8.3	2.0	5.0	2.2	3.0	2.6	4.0	2.3	3.4	6.5	4.5	3.3	3.9	4.5
Horriditriletes	3.7	8.0	5.6	26.0	18.0	22.0	14.0	4.8	0.4	2.5	4.5	5.3	5.5	3.3
Brevitriletes	15.3	16.0	15.6	20.0	12.0	16.0	16.0	23.3	16.4	17.0	11.0	11.3	11.3	17.0
Latosporites	8.7	14.0	11.3	6.6	10.0	8.3	10.0	2.3	0.4	1.0	6.5	4.3	5.5	2.3
Parasaccites	3.3	7.0	5.3	1.6	5.0	3.3	4.0	3.8	6.4	2.0	2.0	1.8	1.9	3.5
Platysaccus	4.3	3.0	3.5	5.6	9.0	7.3	5.4	9.8	3.4	5.5	8.0	4.8	6.5	6.3
Striatites+ Labirites	4.9	9.0	7.0	6.2	7.0	6.6	7.5	7.6	12.6	6.0	7.5	11.1	9.5	8.9
Striatopodocarpites	11.3	7.0	9.0	2.0	4.0	3.0	6.0	3.8	4.4	3.5	3.5	6.3	4.9	4.0
Faunipollenites	5.7	4.0	4.8	3.0	3.0	3.0	4.0	3.3	9.4	5.5	4.5	8.3	6.5	6.0
Illinites	5.7	2.0	5.3	1.0	1.0	1.0	3.0	1.4	4.4	1.5	4.5	3.8	4.4	3.0
Vesicaspora	2.3	1.0	1.5	2.6	6.0	4.3	3.0	1.4	5.9	4.5	2.5	2.3	2.5	3.6
Scheuringipollenites	15.3	11.0	13.0	13.6	13.0	13.3	13.1	25.8	22.7	30.0	23.5	24.0	23.7	25.5
Ibisporites	4.3	1.0	2.7	1.6	2.0	1.8	2.0	2.3	7.4	7.5	4.5	3.3	3.9	5.1
Tiwariasporis	1.7	10.0	5.8	3.0	3.0	3.0	3.0	5.3	2.4	5.5	5.5	4.3	4.9	4.5

apiculate triletes totals to 14 per cent whereas varitrilete and nonstriate-disaccate are present up to 24 per cent and 22 per cent respectively. The percentge of monosaccate pollen is still maintained on an average up to 7 per cent.

Mandamari area

The two coal seams, viz., Seam 4 and Seam 3, collected from Kalyani Khani in Mandamari Division show distinctly different palynofloras with each other (Table 3b). *Brevitriletes* decreases from below to become maximum in the youngest seam. On this basis both the seams have been placed in two different miospore assemblages (Table 4a, b).

Assemblage D—Coal Seam 4 of Kalyani Khani Incline shows the dominance of *Brevitriletes* (18%) while *Scheuringipollenites* (14%) along with *Faunipollenites* and *Illinites* (8% each) and *Vesicaspora* (7%) are represented subdominantly. The average percentage of laevigate and apiculate triletes total up to 7 per cent; varitrilete ranges up to 18 per cent; nonstriate and striate disaccate are present up to 33 per cent and 23 per cent respectively.

Assemblage A?—The dominant genus *Brevitriletes* of Assemblage D declines to subdominance in Assemblage A? *Scheuringipollenites* rises to dominance being represented up to 23 per cent. *Faunipollenites* (9%), *Parasaccites* (6%) and *Ibisporites* (7%) occur next to the subdominant genus *Brevitriletes.* The laevigate and apiculate triletes as well as varitriletes as compared to Assemblage D, declines to 4 per cent and 6 per cent respectively while the population of nonstriate and striate-disaccates increases to 43 per cent and 28 per cent respectively. This assemblage is associated with coal seam No. 3 of Kalyani Khani Incline.

Belampalli area

The Tandur collieries, situated 2.5 km north-east of Belampalli Railway Station, comprises a large group of collieries. Coal samples were collected from the working faces of the coal seams in Shanti Khani Incline, Morgan pit and 85 Dip. Salarjung Seam and Ross Seam is being worked out in the latter two inclines while in Shanti Khani Incline the Top, Middle and Bottom Seams are being worked. *Hennellysporites* is associated with all the older seams of the above inclines but it reduces in the younger coal seams. *Leiotriletes* and *Parasaccites* (Table 3b) behave similar to *Hennellysporites. Brevitriletes* occurs uniformly in the Salarjung and Ross seams but in Shanti Khani Incline it reduces from older to younger seams. Similarly *Indotriradites* is uniformly present in all the coal seams of Morgan pit, 85 Dip and older two coal seams of Shanti Khani Incline. *Scheuringipollenites,* on the other hand, increases from the older towards the younger seams. Such a distribution of the above taxa segregates the palynoflora into three distinct miofloral assemblages.

Assemblage C2—The Ross Seam of Morgan pit and 85 Dip contain Assemblage C2 in which *Hennellysporites* is represented to its maximum of 23 per cent (Table 4a). *Brevitriletes* follows next to it. *Leiotriletes* and *Scheuringipollenites* occur next to *Brevitriletes. Indotriradites* is present in the Ross Seam but only lowly. The average percentage of the laevigate and apiculate triletes total up to 38 per cent, varitrilete 16 per cent and zonate trilete 4 per cent. The nonstriate-disaccate like varitrilete are present up to 16 per cent but striate-disaccate (9%) are present in low amounts.

However, the mioflora of the Bottom Seam of Shanti Khani Incline shows a different picture. The general dominance is marked by the genus *Brevitriletes* unlike that of Ross Seam palynoflora. On the contrary, *Hennellysporites* (14%) shows a slight decrease in its percentage. The total representation of laevigate and apiculate trilete (21%) and zonate trilete (1%) show a slight decline from the normal trend whereas varitrilete (23%), monosaccate (9%) and striate-disaccate (16%) tend to increase. Thus, the differences in the Bottom Seam become quite apparent yet the higher presence of *Hennellysporites* closely alienates it with Ross Seam mioflora. The trend of variation of rest of the taxa from Bottom Seam to Middle Seam in Shanti Khani Incline also bears a great parallelism with that observed in Ross Seam to Salarjung Seam. In view of the above facts it has been preferred to retain the Bottom Seam of Shanti Khani Incline in Assemblage C2.

Assemblage C3—The Assemblage C3 of the Salarjung Seam in Morgan pit and 85 Dip is marked by the dominance of *Brevitriletes* (18%) and *Scheuringipollenites* (12%) while *Hennellysporites,* which was a dominant genus of Assemblage C2, has reduced to subdominance. The percentage of *Indotriradites* is almost similar to Assemblage C2. Although the general behaviour of the important constituents of Assemblage C3 compare very closely to Assemblage C2, the differences increases manyfolds when their overall representation of the group of miospores is taken into account. The laevigate and apiculate triletes reduces to 21 per cent while the percentages of varitrilete and zonate trilete remain almost similar to Assemblage C2. The percentage of nonstriate and striate-disaccate increases significantly (28% & 23% respectively) thus distinguishing the Salarjung Seam from Ross Seam.

The Middle Seam of Shanti Khani Incline is marked by the dominance of *Brevitriletes* (21%) similar to the Salarjung Seam of Morgan pit. In this respect it also shares its resemblance with the underlying Bottom Seam except the lower percentage of *Hennellysporites* (8%). *Indotriradites* is also slightly reduced. While the percentage of laevigate and apiculate trilete, varitrilete and zonate trilete spores in Middle Seam resembles with the Bottom Seam, the total representation of striate and nonstriate-disaccate pollen grains remain similar to Salarjung Seam. Thus, the lower percentage of *Hennellysporites* and the general dominance of *Brevitriletes* coupled with higher amounts of striate-disaccate pollen emplaces the Middle Seam into the palynospore Assemblage C3.

Assemblage A—The Top Seam of Shanti Khani Incline contains Assemblage A which is characterised by the dominance of *Scheuringipollenites* (29%). *Brevitriletes* (16%) which was dominant in Assemblage C1 has reduced to subdominance. The average total of laevigate and apiculate triletes reduces to 8 per cent. Varitrilete spores also have reduced to 16 per cent. The striate-disaccate pollen grains (20%) increases only slightly but the nonstriate-disaccates (40%) rise appreciably. Thus, the palynoflora in the Top Seam of Shanti Khani Incline is quite different from the Middle Seam.

CORRELATION

The variation of different genera, qualitative and quantitative both, in coal seams of different areas of Godavari Graben, has been discussed already. The correlation of coal seam based on their quantitative variance within each area is discussed hereunder separately.

Yellandu area—The oldest coal seam of the Singareni Coalfield is the King Seam of No. 20 Incline as it contains the maximum percentage of radial monosaccates, chiefly *Parasaccites*. Radial monosaccate pollen grains occur right from the glacial phase of the Talchir Stage and continue up to the Upper Karharbari Stage (Bharadwaj & Srivastava, 1973) of the Lower Gondwanas of India. This is a transitional zone which is marked by the dying phase of *Parasaccites* and other radial monosaccates while *Scheuringipollenites* continues to rise so as to gain dominance in the younger sediments. In other words it represents the end of the monosaccates rich palynaflora of Talchir Series.

Palynologically Queen Seam of No. 22 Incline is different from King Seam and represents a much younger stage in the miofloral succession. The seam is characterised by the dominance of apiculate triletes mainly *Horriditriletes* and a good percentage of monolete miospores. In Queen Seam of Polampalli Incline, however, the apiculate spores declines suddenly while reticuloid and striate-disaccate pollen compensate the loss. Barring these the other groups tend to cohere the two seams more closely. Assemblage B of Sohagpur Coalfield (Bharadwaj & Srivastava, 1971) resembles with Queen Seam of No. 22 Incline in view of the dominance of *Horriditriletes* + *Brevitriletes* but tends to differ in having more monolete spores. This assemblage has been placed in the Middle Barakar Stage of the Sohagpur Coalfield. It is therefore, evident that the King Seam and Queen Seam were deposited at two different levels significantly differentiated from each other. The succession of palynoflora in Yellandu area is as follows:

Assemblage B2	D Seam Queen Seam	No. 22 Incline
Assemblage B1	Queen Seam	Polampalli Incline
Assemblage E	King Seam	No. 20 Incline

Kothagudem area—The King Seam of this area contains abundance of varitriletes (*Brevitriletes*) and laevigate + piculate triletes (Assemblage D). As compared to the King Seam of Yellandu area, the monosaccate pollen grains tend to decline slightly. Nonstriate-disaccate pollen are also higher in Yellandu area comparatively. Thus the King Seam of the above two areas share only few points in common rather their marked differences. Palynofloral assemblages dominant in *Brevitriletes* are known in Sohagpur Coalfield (Assemblage E) but the same is differentiated by its association with *Microbaculispora* and *Indotriradites*. In Mohpani Coalfield (Bharadwaj & Anand-Prakash, 1972) *Brevitriletes* is associated with high *Scheuringipollenites* and *Indotriradites*. Assemblage-D of Bisrampur (Bharadwaj & Srivastava, 1970) and Assemblage A of Talcher Coalfield (Bharadwaj & Srivastava, 1969) also contains the dominance of *Brevitriletes* but in all these assemblages *Parasaccites* is present in very small percentages. In this respect the palynofloral assemblage of King Seam shows an older aspect.

Top 2 Seam of No. 9 and 10 Inclines shows further decline in *Parasaccites* and *Brevitriletes* which were the characteristics of the King Seam. Instead, *Latosporites* and striate-disaccate rise significantly. The palynoflora differs entirely from the King Seam. On the other hand, Top 2 Seam compares microfloristically very closely with Queen Seam of Yellandu area (Pollampalli Incline) in view of monolete and striate-disaccate pollen although *Horriditriletes* is too low. The overall behaviour of all the genera compares with the assemblage B1.

Top 1 Seam, overlying the Top 2 Seam, represents another phase of palynofloral succession.

Table 5—Showing percentage of miospore groups in different assemblage in Godavari Valley Coalfield

Group of miospores	Collieries	Yellandu			Kothagudem			Ramagundam		Ramakrishanpuram		Mandamari	Belampalli				
													Morgan Pit		Shanti Khani		
	Assemblage	E	B1	B2	D	B1	A	C1	C2	A	D	D	C2	C3	C2	C3	A
Laevigate + Apiculate trilete		14.5	13.5	32.0	19.0	18.5	8.0	25.0	18.0	13.5	14.2	7.3	38.0	21.0	20.5	21.0	8.0
Varitrilete		12.5	13.5	15.0	30.0	15.0	22.0	26.0	15.0	10.5	24.0	18.0	16.0	17.5	23.0	21.0	16.0
Zonate		—	—	0.5	—	—	—	—	—	—	0.5	—	3.5	3.5	1.0	1.0	—
Monolete		0.5	7.5	7.0	0.5	13.0	1.5	1.5	1.3	4.5	1.0	—	—	—	0.5	1.5	—
Monosaccate		17.5	2.5	2.5	10.0	6.0	3.0	6.5	6.0	1.5	7.0	6.0	4.5	2.5	9.0	6.5	1.0
Nonstriate Disaccate		32.0	26.5	23.5	14.5	14.0	37.0	23.0	37.0	36.5	21.6	33.0	15.5	28.0	14.5	19.5	43.5
Reticuloid Disaccate		—	8.5	2.0	—	3.0	—	—	—	4.5	—	0.5	—	—	—	—	0.5
Striate Disaccate		15.5	18.5	10.5	14.0	26.0	16.0	20.0	20.7	13.1	—	23.5	28.0	22.5	16.5	21.5	15.5
Alete		7.5	9.5	7.0	12.0	4.5	12.0	—	—	9.0	18.6	12.0	13.5	5.0	15.0	8.5	14.5

This is characterised by assemblage A in which *Brevitriletes* rises once again and *Scheuringipollenites* attains its maximum development. Compositely the assemblage is characterised by the abundance of varitrilete spores and nonstriate-disaccate pollen. Striate-disaccate pollen and monolete spores decline sharply. This character is in sharp contrast with the underlying Top 2 Seam. Three stages of the palynoflora succession have been recognised in Kothagudem area.

Assemblage A	Top 1 Seam	No. 9 and 10 Incline
Assemblage B1	Top 2 Seam	No. 9 and 10 Incline
Assemblage D	Blue and Green Seams	No. 9 and 10 Incline
	King Seam	No. 6 and 7 Incline
	King Seam	No. 2 Incline

Ramagundam area—The oldest coal seam of Ramagundam area (Seam No. 4) contains Assemblage C1 in which the dominance of *Brevitriletes* is associated with *Hennellysporites.* In this way the pteridophytic spores form the bulk of the total percentage. In younger Seam 3 of No. 1 Incline *Brevitriletes* decreases appreciably. *Hennellysporites* remains almost similar to Seam 4 and thus shows its older affiliation. However, the total percentage of nonstriate-disaccate increased to distinguish it separately. In the mioflora of Seam 3 of No. 7 Incline (Assemblage C2) the percentage of nonstriate disaccate increases further high and in this respect the Coal Seam 3 of both the Inclines have been put in one assemblage (Assemblage C2). Both the assemblages described here appear more quantitative rather than qualitative and resemble very closely to each other in view of its association with *Hennellysporites.* The flora of Seam 3 of No. 1 Incline represents a transition in between Seam 4 of the same Incline and Seam 3 of No. 7 Incline. Assemblage C of Chirimiri Coalfield (Bharadwaj & Srivastava, 1969) contains *Hennellysporites* in similar percentages as has been observed here but in Chirimiri they are associated with the dominance of *Microbaculispora.* In Sohagpur Coalfield *Hennellysporites* occurs alongwith *Brevitriletes* (Assemblage E, Bharadwaj & Srivastava, 1969) and compares very closely to the Assemblages C1 and C2 of Ramagundam area. However, in Sohagpur Coalfield it is associated with *Indotriradites* and *Microbaculispora.*

In Seam 1 and Seam 2 of No. 3 Incline *Scheuringipollenites* rises to its maximum while *Brevitriletes* reduces next to it. This assemblage (Assemblage A) is quite distinct from the older seams described above. Similar dominance is described from Giridih Coalfield (Srivastava, 1973), Korba Coalfield (Bharadwaj & Tiwari, 1964—Assemblage E; Bharadwaj & Srivastava, 1973—older subzone of Zone no. 3). However, the coal seams marked by the dominance of *Scheuringipollenites* in the Giridih Coalfield are associated appreciably with reticuloid and striate-disaccate pollen. In Korba Coalfield the older phase of Zone No. 3 resembles very closely with Seam 1 of Ramagundam area. Thus the collation of these three assemblages in this area is as follows:

Assemblage A +	Coal Seam 1	No. 3 Incline
	Coal Seam 2	
Assemblage C2 –	Coal Seam 3	No. 7 Incline
	Coal Seam 3	No. 1 Incline
Assemblage C1 +	Coal Seam 4	No. 1 Incline

Ramkrishnapuram area—Coal seams 2, 3 and 4 of this area show a very coherent palynoflora (Assemblage D) being characterised by the dominance of *Brevitriletes. Scheuringipollenites* occurs as

Table 6—Absolute percentage frequency of gymnospermous pollen grains in various coal seams of Godavari Graben

Genera Sample no.	1	2	3	5	6	7	8	9	10	11	12	13	14
Parasaccites	10.5	15.7	21.2	45.5	38.8	6.0	12.2	3.4	33.7	16.1	1.6	8.4	8.6
Cuneatisporites	—	—	—	—	—	—	—	—	—	4.2	1.6	1.0	6.2
Platysaccus	1.9	5.0	4.8	—	—	15.0	5.2	4.4	0.6	1.7	13.5	17.7	4.3
Striatites	5.7	5.0	2.4	—	4.4	4.0	3.0	1.8	0.6	1.7	4.9	8.4	5.1
Primuspollenites	—	—	—	—	—	—	6.2	13.9	—	0.8	6.5	2.0	—
Labirites	13.4	12.7	4.8	5.5	8.1	7.0	12.2	5.2	3.6	3.4	8.2	2.0	9.5
Striatopodocarpites	11.0	12.7	11.8	3.5	8.1	5.3	12.2	17.4	8.9	8.4	3.2	6.3	9.5
Faunipollenites	15.0	7.6	14.2	6.5	12.2	4.5	7.2	7.8	3.7	11.8	6.5	4.5	9.5
Illinites	13.4	5.0	—	2.5	6.1	—	2.0	7.8	7.6	16.9	—	2.0	11.2
Vesicaspora	3.7	7.6	3.6	2.5	—	0.9	—	1.7	5.5	7.0	4.9	10.4	8.6
Scheuringipollenites	21.0	18.9	28.2	25.5	15.3	44.0	21.4	24.4	25.5	20.4	41.0	25.0	16.4
Ibisporites	1.0	—	1.0	2.5	2.0	4.2	—	5.2	4.3	3.4	1.6	2.0	4.3
Tiwariasporis	1.9	5.0	2.3	2.5	2.0	7.6	18.4	1.8	4.8	0.8	6.5	6.2	3.4
Kingiacolpites	—	5.0	5.8	3.5	3.0	1.5	—	5.2	2.4	3.4	—	4.1	3.4

Kothagudem Collieries : No. 2 Incline—1. King Seam; Nos. 6,7 Incline—2. King Seam (red), 3. King Seam (blue); Nos. 9, 10 Incline—5, Blue Seam, 6. Green Seam, 7. Top 1 Seam, 8. Top 2 Seam. *Yellandu Collieries* : Polampalli Incline—9. Queen Seam; 20 Pit Incline—10. King Seam, 11. D Seam; 22 Pit Incline—12. Queen Seam, 13. D Seam. *Ramagundam Collieries* : No. 1 Incline—14. Seam 3, 15. Seam 4; No. 3 Incline—16. Seam 1, 17. Seam 2; No. 7 Incline—18. Seam 3. *Ramakrishnapuram Collieries* : Ramakrishna Khani 1—19. Seam 3, 20. Seam 4; Motilal Khani 1—21. Seam 2. *Mandamari Area* : Kalyani Khani—22. Seam 3, 23. Seam 4. *Belampalli Collieries* : Shanti Khani—24. Top Seam, 25. Middle Seam, 26. Bottom Seam; Morgan Pit—27. Salarjung Seam, 28. Ross Seam; 85 Dip—29. Salarjung, 30. Ross Seam.

subdominant genus closely followed by *Parasaccites.* The variation in different genera within different coal seams both vertically and laterally are rather negligible and all the three coal seams contain nearly identical palynofloras.

Assemblage D	Seam 2 Motilal Khani
	Seam 3 Ramkrishna Khani
	Seam 3 Kalyani Khani
	Seam 4 Ramkrishna Khani

Mandamari area—Palynoassemblage D characterises the Coal Seam 4 of Kalyani Khani Incline. The dominance is marked by *Brevitriletes* and is subdominantly associated with *Scheuringipollenites.* In coal Seam 3 of the same incline *Brevitriletes* decreases only slightly but *Scheuringipollenites* records a significant increase till it reaches the dominance. However, the general trend of variation of rest of the components compare each other, except the above two genera. The cause of such differences could not be ascertained. The coal seams are being worked in partly convenient sections and the entire thickness of the coal seams is usually not available. Such factors may cause such abnormal variations. As has been observed in other area, *Scheuringipollenites* has a tendency to increase in the younger coal seams. Keeping in view the above factors Coal Seam 3 has provisionally been placed along with Coal Seam 4.

Assemblage D?	Coal Seam 3 Kalyani Khani Incline
	Coal Seam 4 Kalyani Khani Incline

Belampalli area—The two workable coal seams, Ross Seam (3 m) and Salarjung Seam (about 8 m) are separated by a sandstone band of about 30 m in thickness in the Morgan pit and 85 dip area. Salarjung Seam is being mined only partly while Ross Seam is being worked in its entire thickness. Ross Seam is characterised by the dominance of *Hennellysporites* while *Brevitriletes* and *Scheuringipollenites* occur next to it (Assemblage C2). In Salarjung Seam *Hennellysporites* decreases to subdominance while *Brevitriletes* rises to dominance (Assemblage C3). The former coal seam is rich in laevigate + apiculate triletes while the latter contains higher amounts of nonstriated and striated-disaccates. In fact, the palynoflora of the Salarjung and Ross seams contains similar group of pollen qualitatively and shows greater resemblance with each other. In view of this fact they have been designated as Assemblage C2 and C3. However, the quantitative variation of individual genera and the total representation of various group of miospores together distinguishes the two coal seams distinctly from each other.

Ghosh (1968) studied the distribution of miospores in the coal types of above coal seams. According to his observations also the Ross Seam and Salarjung Seam bear closer relationship with each other qualitatively and they can only be differentiated quantitatively. He recorded higher occurrence of *Parasaccites* (=*Nuskoisporites*) and *Leiotriletes* in Ross Seam and *Hennellysporites* in Salarjung Seam which, however, differ from our observations.

In Shanti Khani Incline the coal seams of Morgan pit area split into two each. These coal seams are also being worked here in only partly convenient sections. The mioflora similar to Ross

Table 6 contd.....

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
14.4	0.8	2.5	8.8	20.0	22.5	8.0	8.0	9.5	1.6	13.5	23.6	6.0	18.0	3.6	13.5
—	—	1.5	0.7	—	—	—	2.0	2.3	0.8	—	—	4.0	2.0	—	—
3.0	4.9	7.7	4.4	—	—	3.0	2.5	2.4	7.3	3.0	2.2	7.0	8.0	6.5	5.4
3.0	6.4	4.5	3.0	4.3	1.4	3.0	5.0	3.0	1.6	3.0	2.4	13.3	6.0	11.3	2.7
1.4	4.9	10.0	—	—	—	—	—	0.8	2.4	—	—	—	—	0.8	—
1.4	8.0	4.5	8.8	—	—	6.0	10.3	9.5	4.8	12.6	7.3	13.3	4.0	8.1	7.0
16.6	8.0	4.5	10.3	12.6	14.0	10.0	5.0	6.3	3.6	13.5	17.0	7.0	12.0	4.8	10.7
3.0	11.4	6.0	6.0	9.5	1.4	16.0	12.2	13.3	6.5	3.2	9.7	4.1	2.0	8.1	8.0
6.0	4.0	6.0	4.4	4.3	8.5	6.0	2.5	12.7	—	7.2	5.0	7.0	4.0	13.0	13.5
3.0	1.6	3.0	11.7	15.0	1.4	8.0	7.3	11.0	5.7	7.2	2.4	13.3	12.0	6.5	8.0
36.0	37.0	35.4	26.4	23.0	34.0	32.0	29.0	22.8	47.1	18.0	24.4	18.0	24.0	24.4	20.0
—	3.2	6.0	7.3	3.0	5.8	4.0	9.8	1.6	10.5	5.2	2.4	—	4.0	3.6	2.7
6.1	4.9	7.7	2.2	2.0	8.0	2.0	3.2	4.8	7.3	12.6	2.4	7.4	2.0	9.0	1.3
6.1	4.9	0.7	6.0	6.3	3.0	1.0	3.2	—	0.8	1.0	1.2	—	—	0.8	8.0

Seam is found in the Bottom Seam of Shanti Khani Incline. Similarly the Middle Seam is equivalent to Salarjung Seam palynologically. Thus the above two seams extend laterally into the Shanti Khani area, and the behaviour of various palynotaxa in the lateral extent of the each seam is well evident. The mioflora of Salarjung Seam is consistent throughout the entire length of the seam. In Ross Seam *Brevitriletes* increases slightly in the Shanti Khani area and is separated from the Middle Seam by nearly 7 meters sandstone parting. The Top Seam of the Shanti Khani area shows a palynoflora quite different from the above two seams. This coal seam contains the dominance of *Scheuringipollenites* (Assemblage A) and is associated with other nonstriate-disaccate pollen :

Assemblage A	Top Seam	Shanti Khani area
Assemblage C3	Salarjung Seam	Morgan pit
	Salarjung Seam	85 dip
	Salarjung Seam	Shanti Khani
Assemblage C2	Ross Seam	Morgan pit
	Ross Seam	85 dip
	Bottom Seam	Shanti Khani Incline

BIOSTRATIGRAPHY AND INTER-AREA CORRELATION

The oldest palynofloral assemblage is encountered in the King Seam of Yellandu area and is characterised by *Parasaccites* and *Scheuringipollenites* (Assemblage E). The Gondwana sediments of the Yellandu area occur in the form of an outlier from the main Gondwana strata of the Godavari Valley. The equivalence of King Seam of this area is not found in other areas.

The next younger coal seam is accosted in Assemblage D which is characterised by the dominance of *Brevitriletes.* This miofloral assemblage is associated with the King Seam of Kothagudem area. It may be mentioned here that the King Seam is the oldest working coal seam in Yellandu and Kothagudem areas but the palynofloras of the two show a definite discordance. The genus *Parasaccites* decreases from Yellandu to Kothagudem area while *Brevitriletes* increases inversely. Thus the monosaccates and nonstriate-disaccate pollen record sharp decline while varitrilete spores increase proportionately in Kothagudem area. The palynoflora similar to the King Seam of Kothagudem area is also encountered in Seam 2, 3 and 4 of Ramkrishnapuram and Seam 3 and 4 of Mandamari areas.

Assemblages C2 and C3 are associated within the Ross and Salarjung seams of the Tandur area respectively. Their equivalence is also observed in Seam 3 of Ramagundam area (Assemblage C2). Seam 3 and Seam 4 of Ramagundam area are normally correlated with the Salarjung and Ross seams of Belampalli area, which, however, agree only partly palynologically with Seam 4 of Ramagundam area. It shows an intermediate position between the King Seam of Kothagudem area and Ross Seam of Belampalli area.

The Queen Seam of Pollampalli Incline is characterised by a combined dominance of *Brevitriletes* and *Scheuringipollenites* (Assemblage B1) and in this respect it compares Top 2 Seam (No. 9 & 10 Incline) of Kothagudem area.

The seam represented by Assemblage B2, which contains high percentage of *Horriditriletes,* is present in the Queen Seam and D Seam of Yellandu area (No. 22 Incline). The mioflora of Queen Seam has not been encountered in Belampalli and Ramagundam areas.

The youngest palynological assemblage is encountered in Top 1 Seam of Kothagudem area and is characterised by the dominance of *Scheuringipollenites* (Assemblage A). Seam 1 and Seam 2 of

Ramagundam area and Top Seam of Shanti Khani Incline, Belampalli area also contains similar palyoflora. Thus the inter-area correlation of Godavari Valley is summarised as follows:

Assemblage A		Top 1 Seam	Kothagudem area
		Seam 1	Ramagundam area
		Seam 2	Ramagundam area
		Top Seam	Belampalli area (Shanti Khani Incline)
Assemblage B	B1	Queen Seam	Yellandu area
		Top 2 Seam	Kothagudem area
	B2	Queen Seam	Pollampalli Incline, Yellandu area
Assemblage C	C3	Salarjung	Morgan pit, Belampalli area
		Mid. Seam	Shanti Khani
	C2	Ross Seam	Morgan pit, Belampalli area
		Bott. Seam	Shanti Khani
		Seam 3	Ramagundam area
	C1	Seam 4	Ramagundam area
Assemblage D		King Seam	Kothagudem area
		Seam 2, 3, 4	Ramkrishnapuram area
		Seam 3, 4	Mandamari area
Assemblage E		King Seam	Yellandu area

The palynological investigations suggest the occurrence of six palynoassemblages in the Godavari Graben. The average representation of various genera reveal that palynological succession was influenced by one palynofloral change during the course of deposition of the coal seams studied in the present investigation. The oldest palynoflora is associated with the King Seam of Yellandu area containing Assemblage E.

The absolute percentages of gymnospermous pollen grains have been re-calculated after redistributing the percentages of pteridophytic and alete spores and have been shown in table 6. It shows that *Parasaccites* and *Scheuringipollenites* occur either as dominant or subdominant unit throughout the spectrum. In King Seam of Yellandu area the overall dominance of *Parasaccites* documents its comparison with the known Upper Karharbari palynofloras but the additional presence of *Scheuringipollenites* indicates a younger aspect. The overall dominance of *Parasaccites* in King Seam of Kothagudem collieries also allienates it with King Seam of Yellandu area but the presence of apiculate spores in King Seam of Kothagudem area shows a distinct Lower Barakar aspect. In Korba Coalfield (Bharadwaj & Srivastava, 1973) similar transition has been observed at the boundary of Upper Karharbari and Lower Barakar formations obviously subtending the present observation. Assemblages D-B represent various stages of palynological succession within the Lower Barakar palynofloras. The assemblage changes considerably after the deposition of Assemblage B where nonstriate-disaccate become dominant over the pteridophytic spores. Striate-disaccate pollen grains also mark slight increase. Assemblage A represents the Middle Barakar palynoflora.

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Further observations on *Cycadinorachis omegoides* Sharma from the Rajmahal Formation, India

O. P. Suthar, D. R. Bohra & B. D. Sharma

Suthar, O. P., Bohra, D. R. & Sharma, B. D. (1987). Further observations on *Cycadinorachis omegoides* Sharma from the Rajmahal Formation. *Palaeobotanist* **35**(3) : 297-300.

A petrified *Cycadinorachis omegoides* is reported from Sonajori in the Rajmahal Hills, Bihar. The number of bundles in the omega gradually reduces while the distinction of centripetal and centrifugal xylems increases towards the apex of the rachis (leaf). The ground tissue possesses mucilage ducts. The lamina has parallel veins and a more or less homogeneous mesophyll. Tracheids possess scalariform and contiguous bordered pits. Relationship of *Cycadinorachis* with allied extinct and extant plants is discussed.

Key-words—Gymnosperms, Morphology, Anatomy, *Cycadinorachis*, Rajmahal Formation (India).

O. P. Suthar, D. R. Bohra & B. D. Sharma, Department of Botany, University of Jodhpur, Jodhpur 342 001, India

साराँश

राजमहल शैल-समूह (भारत) से प्राप्त साइकेडिनोरेकिस ओमॅगॉयडिस शर्मा पर कुछ और प्रेक्षण

ओ० पी० सुथार, डी० आर० बोहरा एवं बी० डी० शर्मा

बिहार में राजमहल पहाड़ियों में सोनाझोड़ी से अश्मीभूत साइकेडिनोरेकिस ओमॅगॉयडिस अभिलिखित किया गया है। ओमॅगा में बंडलों की संख्या क्रमशः कम होती जाती है जबकि प्राक्ष में ऊपर की ओर अभिकेन्द्री एवं अपकेन्द्री दारू में भिन्नता बढ़ जाती है। भरण उतक में श्लेष्मक नाल विद्यमान है। स्तरिका समानान्तर शिराओं तथा प्रायः एक समांगी मध्यमपर्ण से युक्त है। वाहिनिकाओं में सोपानवत् एवं संलग्न परिवेशित गर्त विद्यमान हैं। इसके अतिरिक्त सम्बन्धित विलुप्त एवं वर्तमान पौधों से साइकेडिनोरेकिस की बन्धुता भी विवेचित की गई है।

SHARMA (1973) described an isolated petrified rachis—*Cycadinorachis omegoides* Sharma bearing mesarch bundles arranged in an omega from the fossiliferous locality of Amarjola. The species is now reported in a chert from Sonajori near Pakur.

DESCRIPTION

Each of the three specimens of *Cycadinorachis omegoides* has 2-5 rachides or portions of leaves embedded in different planes. The largest specimen is nearly 10 cm long and has a portion of lamina attached to it. The lamina is lateral and has parallel, simple or branched veins. The thickest portion of rachis is 7 mm in diameter. It has 23 collateral, conjoint and mesarch bundles arranged in an omega-shaped manner (Pl. 1, figs 1-3; Text-fig. 1). The xylem is more or less triangular (Pl. 1, fig. 4) with the phloem (unpreserved) towards the outer (centrifugal) side. The direction of phloem varies with the change in positions of the bundles in the omega (Pl. 1, fig. 2). The centarch xylem comprises compactly arranged tracheids (Pl. 1, fig. 3). In addition to main bundles there are 3-4 smaller bundles in a line in the cavity of omega, i.e. medullary vascular bundles (Pl. 1, fig. 4). The ground tissue is parenchymatous with a few mucilage ducts (Pl. 1, fig. 6). The hypodermis patches are distinct, sclerenchymatous and 5 to 7 cells thick.

A cross section of the rachis from the level little above than the one described in Plate 1, fig. 1 shows reduction in the number of bundles (Pl. 1, fig. 2; Text-fig. 1B) and this continues towards the apex of the frond (rachis). The reduction in bundles is due to the fusion of adjacent bundles in the rounded

Text-figure 1A-C—*Cycadinorachis omegoides*: **A**, cross section through basal portion of rachis with omega-shaped arrangement of bundles. × 24; **B**, cross section of rachis little above the base. × 24; and **C**, cross section of the upper portion showing fusion of central bundles. × 24.

portion of the omega (Text-fig. 1C). The bundles thus produced are larger in size and show differentiation of centripetal and centrifugal xylems (Pl. 1, fig. 5). The tracheids of the former are comparatively wide. The medullary strands disappear in the upper portion of rachis.

Laminae arise on either side of the upper portion of rachis (Text-fig. 1C) and a 3-5 cells thick layer of parenchyma develops outside the hypodermis on the dorsal surface (Pl. 1, fig. 6). The neck of the omega disappears and the bundles in the open arms are arranged more or less in a straight line to supply the laminae. A cross section through the veins of the lamina shows distinction of upper and lower epidermis. The latter possesses stomata. The mesophyll is homogeneous and undifferentiated into spongy and palisade tissues. The bundles are enclosed by a sheath and are connected with the upper and lower epidermis by sclerenchyma strands (Pl. 1, fig. 7). Details of the bundles are not preserved. In between the bundles there are transversely elongated, large cells which probably acted as transfusion cells, similar to those found in *Dioon spinulosum* (Bierhorst, 1971) and *Cordaites* (Coulter & Chamberlain, 1910).

REMARKS

In the present material the bundles are collateral, conjoint and mesarch while in holotype of *Cycadinorachis omegoides* Sharma these were described as concentric with mesarch protoxylem. The medullary vascular strands and mucilage ducts in the ground tissue also could not be seen in the type specimen. Some of these minor differences may be due to preservational factors in Amarjola material.

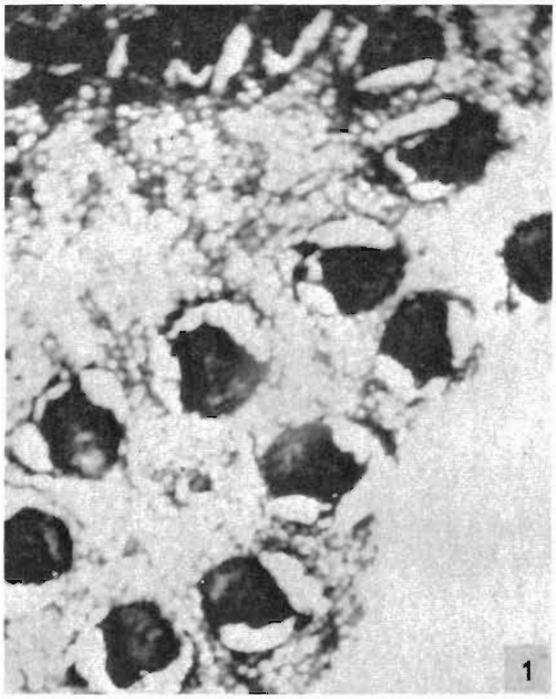
The omega-shaped arrangement of bundles in the petiole/rachis has been described in *Cycas* and *Dioon* (Mettenius, 1861). The present specimens differ in the structure of the bundles and existence of medullary bundles. The mucilage ducts are ill-defined which are quite distinct in the extant genera. The anatomy of the lamina is identical to that of *Dioon spinulosum* (Bierhorst, 1971; fig. 20-4D). The vascular bundles hang in the undifferentiated mesophyll by sclerenchyma bands from both the surfaces.

None of the cycadean fronds from Rajmahal Formation is known in petrifaction and hence the comparison with the present specimens is not possible. Petrified material of *Taeniopteris spatulata* collected from Nipania (Rao, 1943) were associated with the Pentoxyleae and named as *Nipaniophyllum raoi* Sahni (1948). The midrib of petrified leaves of *Nipaniophyllum raoi* from Nipania (Rao, 1943; Sahni, 1948) possesses diploxylic bundles arranged in a differently shaped simple arc unlike the omega of the present material.

→

PLATE 1

1. Cross section of rachis from base with omega-shaped arrangement of bundles × 24.
2. Cross section above the base. × 24.
3. Cross section showing a few bundles enlarged to show mesarch protoxylem. × 120.
4. Cross section showing bundles and a medullary strand. × 120.
5. Cross section showing upper portion of rachis with lateral laminae and origin of parenchyma layer dorsal to hypodermis. × 24.
6. Section showing presence of mucilage ducts in ground tissue × 120.
7. Cross section of the lamina with two bundles and homogeneous mesophyll. × 120.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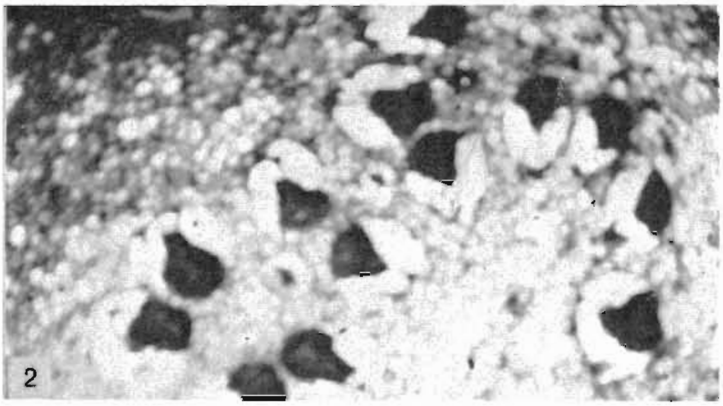
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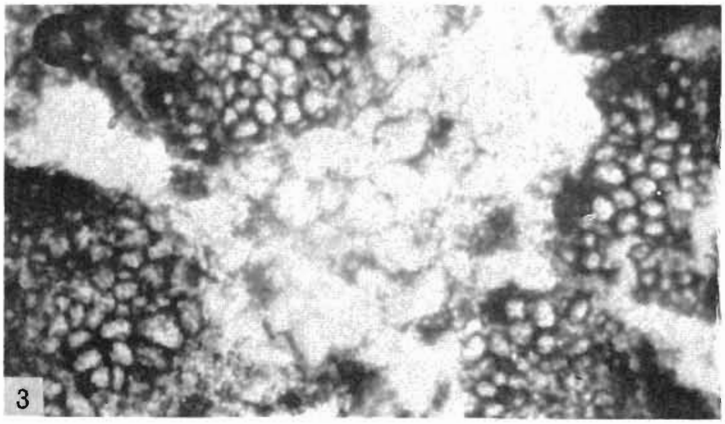
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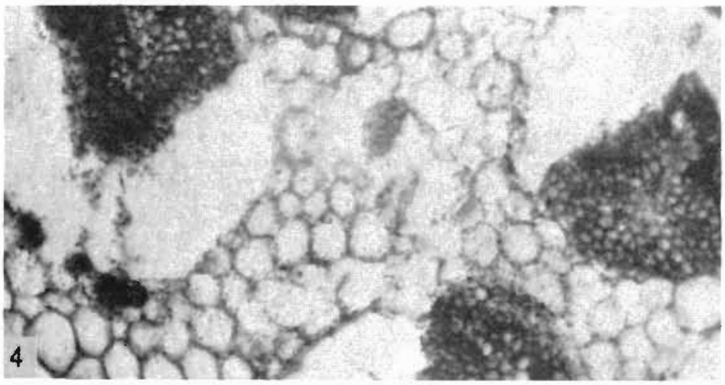
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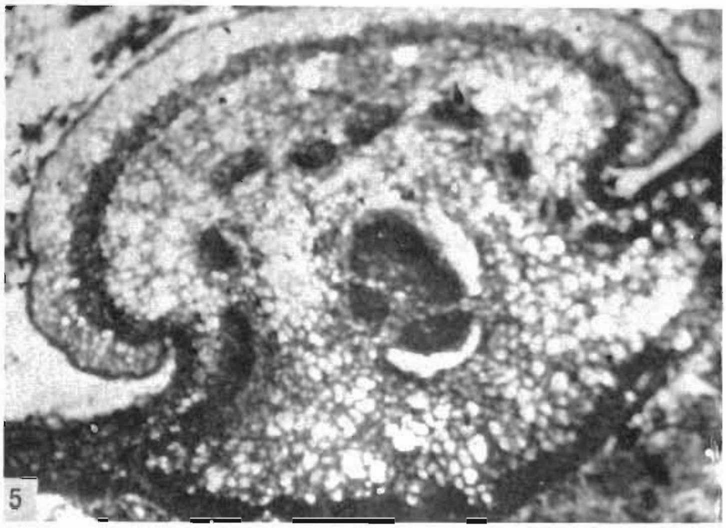
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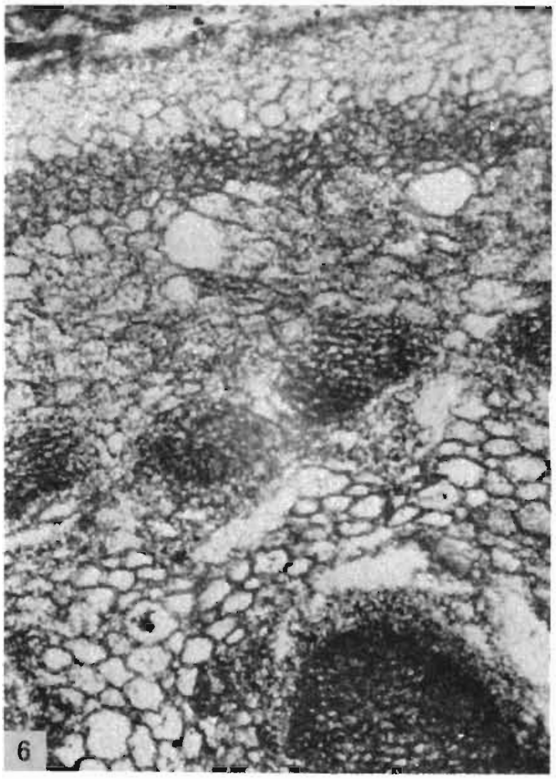
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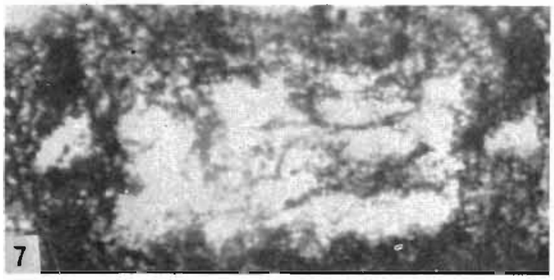
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PLATE 1

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The Palaeobotanist **35**(3) : 301-313, 1986.

Palynology of the Jaintia Group (Palaeocene-Eocene) exposed along Jowai-Sonapur Road, Meghalaya, India (Part II). Data analysis and interpretations

H. P. Singh & S. K. M. Tripathi

Singh, H. P. & Tripathi, S. K. M. (1987). Palynology of the Jaintia Group (Palaeocene-Eocene) exposed along Jowai-Sonapur Road, Meghalaya, India (Part II). Data analysis and interpretations. *Palaeobotanist* **35**(3) : 301-313.

The palynoflora recovered from the Jaintia Group (Palaeocene-Eocene) exposed along the road between Jowai and Sonapur, Jaintia Hills has been dated and compared with various Lower Tertiary palynological assemblages. The present studies support tropical to subtropical vegetation during the Palaeocene-Eocene times. It has also been inferred that the Jaintia Group sediments were deposited under shallow marine conditions.

Key-words—Palynology, Stratigraphy, Jaintia Group, Palaeocene-Eocene (India).

H. P. Singh & S. K. M. Tripathi, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

मेघालय (भारत) में जोवई-सोनपुर मार्ग के संग-संग विगोपित जयन्तिया समूह (पुरानूतन-आदिनूतन) का परागाणविक अध्ययन. भाग 2—आँकड़ों का विश्लेषण एवं व्याख्या

हरिपाल सिंह एवं सूर्यकान्त मणि त्रिपाठी

जयन्तिया पहाड़ियों में जोवई और सोनपुर के बीच में सड़क के संग-संग विगोपित जयन्तिया समूह (पुरानूतन-आदिनूतन) से उपलब्ध परागाणु-वनस्पतिजात का कालनिर्धारण किया गया है तथा विभिन्न अधरि तृतीयक युगीन परागाणविक समुच्चयो से इसकी तुलना की गई है। प्रस्तुत अध्ययन पुरानूतन-आदिनूतन काल में उष्णकटिबन्धीय से उपोष्णकटिबन्धीय वनस्पति की उपस्थिति प्रमाणित करता है। यह भी निष्कर्ष निकाला गया है कि जयन्तिया समूह के अवसाद छिछली समुद्री परिस्थितियों में निक्षेपित हुए थे।

THE sediments of Jaintia Group are exposed along National Highway 44, connecting Shillong (Meghalaya) and Badarpur (Assam). These sediments belong to the shelf facies and are exposed between Jowai and Sonapur, southeast of Shillong. The Jaintia Group is divided into three formations, which in the ascending order are : Therria Formation, Sylhet Limestone and Kopili Formation. At Jowai, the Shillong Group (Precambrian) is unconformably overlain by the Therria Formation. Further south-ward, the Therria Formation is overlain by the Sylhet Limestone which in turn is succeeded by the Kopili Formation (Map 1). Detailed geological information and a geological map of the area have been published by Saxena and Tripathi (1982).

Therria Formation (about 100 m thick) is constituted by monotonous white-brown and pale-red, medium to very coarse-grained, often gritty, cross-bedded, ferruginous sandstone, alternating with subordinate shale and fine-grained carbonaceous sandstone. The shale is mostly bentonitic and without megafossils. The carbonaceous sandstones are generally associated with thin coal seams.

The Sylhet Limestone (about 500 m thick) is made up mainly of limestone with thin alternations of sandstone and consists of five members. Kopili Formation, the youngest stratigraphic unit of the Jaintia Group, is made up of grey, fine to very fine grained, massive to laminated, compact sandstone, alternating with shales. The shales represent ellipsoidal structures showing laminae like successive layers of onion. Kopili Formation is about 500 m thick.

Sein and Sah (1974) on the basis of palynological study, mostly at generic level, demarcated the Eocene and Oligocene sediments exposed along the road between Lumshnong and Sonapur. Later, Dutta and Jain (1980) described acritarch and dinoflagellate assemblages from the Sylhet Limestone and Kopili Formation in the Lumshnong area and pointed out their biostratigraphic potential. However, palynostratigraphical information available so far from this area is meagre and the results are based on study of limited number of samples.

The present analysis of palynological data is based on 318 rock samples which were collected from stratigraphically measured sections. Of these, 160 samples proved to be productive, yielding a rich palynofloral assemblage constituted by algal, fungal, pteridophytic and angiospermic remains. Systematic palynology alongwith critical observations has already been dealt with by Singh and Tripathi (1983), Tripathi and Singh (1984a), Tripathi and Singh (1985), Singh and Tripathi (1986) and Tripathi (in Press).

A paper on palynostratigraphical zonation and correlation of the Jaintia Group sediments, exposed along Jowai-Sonapur Road, Meghalaya has also been published by Tripathi and Singh (1984b). In the present paper a comparative account of the assemblages known from the stratigraphically equivalent horizons is given and palynological data has been analysed qualitatively and quantitatively to reflect upon palaeogeography, palaeoclimate, palaeoecology and age of the sediments.

PALYNOFLORAL COMPOSITION AND ITS QUALITATIVE ANALYSIS

The Jaintia Group (Palaeocene-Eocene) sediments exposed along the road between Jowai and Sonapur, Meghalaya have yielded 59 genera and 92 species. Out of these, 15 genera and 25 species represent the pteridophytes, 20 genera and 29 species represent the angiosperms, 13 genera and 26 species represent the algae and 11 genera and 12 species represent the fungi.

Qualitatively angiospermous pollen grains exhibit their dominance over other plant groups but quantitatively pteridophytic spores constitute the major part of the assemblage (30%). The dinoflagellate cysts (algae) constitute 29% of the total palynofloral assemblage, while the angiosperms share 20% of it. The fungal remains are represented by 2% only. Gymnospermous pollen grains are conspicuously absent in the present palynofloral assemblage. The presence of various palynotaxa in the three formations is as follows:

	FORMATION		
	THERRIA	SYLHET	KOPILI
Cyathidites australis	+		
Intrapunctisporis densipunctis	+		
Dandotiaspora dilata	+		+
D. telonata	+	+	+
Dandotiaspora sp.	+		
Biretisporites sp.	+		
Lygodiumsporites eocenicus	+		+
L. meghalayaensis	+		
L. khliehriatensis	+		
L. marginiplicatus	+		
L. psilatus	+		
Todisporites major	+		+
Osmundacidites sp.			+
Corrugatisporites sp.			+
Foveotriletes pachyexinous	+		
Foveotriletes sp.	+		
Striatriletes susannae			+
S. paucicostatus			+
S. attenuatus			+
Cingutriletes sp.	+		
Monolites mawkmaensis	+		
M. discordatus	+		
Polypodiisporites mawkmaensis	+		
Verrucatosporites sp.			+
Schizaeoisporites sp.	+		
Sciadopityspollenites sp.	+		+
Trifossapollenites constatus	+		
Couperipollis brevispinosus	+	+	
C. meghalayaensis	+		
C. wodehousei	+		
C. robustus	+		
C. rarispinosus	+		
Couperipollis sp.			+
Liliacidites microreticulatus	+		
L. giganticus	+	+	
L. major	+		
Collospermumpollis laevigatus	+		
Palmidites plicatus	+		+
P. obtusus	+	+	+
P. maximus	+		
Palmaepollenites communis	+		
Pinjoriapollis magnus			+
Proxapertites assamicus	+		
Assamialetes emendatus	+		
Ladakhipollenites elongatus	+		
Tricolpites alveolatus	+	+	
Trisynocolporites angularis	+		
Retitrescolpites sp.			+
Tricolporopollis rubra	+	+	+
Densiverrupollenites eocenicus			+
Lakiapollis assamicus			+
Myricipites vulgaris	+		
Graminidites maximus	+		
Polyporina sp.		+	
Gonyaulacysta sp.			+
Apteodinium sp.	+		+
Turbiosphaera filosa			+
T proximata			+
Apectodinium homomorphum	+		
A. parvum	+		
Apectodinium sp. cf. *A. hyperacanthum*	+		

Homotryblium tenuispinosum	+		
H. oceanicum	+		
H. plectilum			+
Cordosphaeridium exilimurum	+		+
C. multispinosum	+		+
C. valiantum	+		
Cordosphaeridium sp.		+	
Prolixosphaeridium conulum	+		
Impletosphaeridium sp.	+		
Polysphaeridium subtile	+		+
P. giganteum			+
P. ornamentum			+
Operculodinium centrocarpum	+		+
O. israelianum	+		
O. major	+		+
Adnatosphaeridium vittatum	+	+	
A. robustum	+		
Codoniella langparensis	+		
Eocladopyxis sp.	+		
Callimothallus pertusus			+
Phragmothyrites eocenica	+		+
Phragmothyrites sp.			+
Paramicrothallites sp.	+		+
Microthallites sp.			+
Cucurbitariacites bellus	+		
Pluricellaesporites psilatus	+		
Dicellaesporites popovii	+		
Dicellaesporites minutus	+		
Diporisporites sp.	+		+
Diporicellaesporites sp.	+		
Inapertisporites sp.	+		

Botanical affinity of studied fossil spores and pollen grains has been inferred by comparing their morphographic features with those of the living ones. Mostly the published information on the morphology of spores and pollen grains has been used for this purpose. In most of the cases the affinity could be traced only up to family level, however, in some cases it has been possible to compare them up to the generic level as well. The pteridophytes are represented by the following families:

Lycopodiaceae

Foveotriletes pachyexinous and *Foveotriletes* sp. are comparable to the spores found in some members of the family Lycopodiaceae. This family is presently found in tropical to temperate regions and favours moist and shady places.

Polypodiaceae

The family Polypodiaceae is represented by *Monolites mawkmaensis, M. discordatus, Polypodiisporites mawkmaensis* and *Verrucatosporites* sp. The present day distribution of this family is cosmopolitan.

Matoniaceae

Biretisporites and *Dandotiaspora* are doubtfully related to the fern family Matoniaceae.

Schizaeaceae

Schizaeoisporites sp. appears to be related to this family due to the comparable spore morphology. This family is chiefly distributed in the tropical and subtropical regions of the world. *Lygodiumsporites* and *Intrapunctisporis* also show affinity with this family.

Cyatheaceae

Cyathidites australis resembles the spores of the family Cyatheaceae. Presently plants of this family are found mainly in the tropical and subtropical areas of the world.

Osmundaceae

Todisporites major and *Osmundacidites* sp. resemble the spores of the family Osmundaceae.

Parkeriaceae

The genus *Striatriletes* is quite similar to the spores found in *Ceratopteris* (Parkeriaceae). This is a water fern and is distributed in the tropical and subtropical regions of the world.

The angiosperms are represented by the following families:

Palmae

Palmidites, Palmaepollenites and *Couperipollis* resemble the pollen grains of the family Palmae. The present day distribution of this family is restricted to tropical and subtropical regions of the world.

Liliaceae

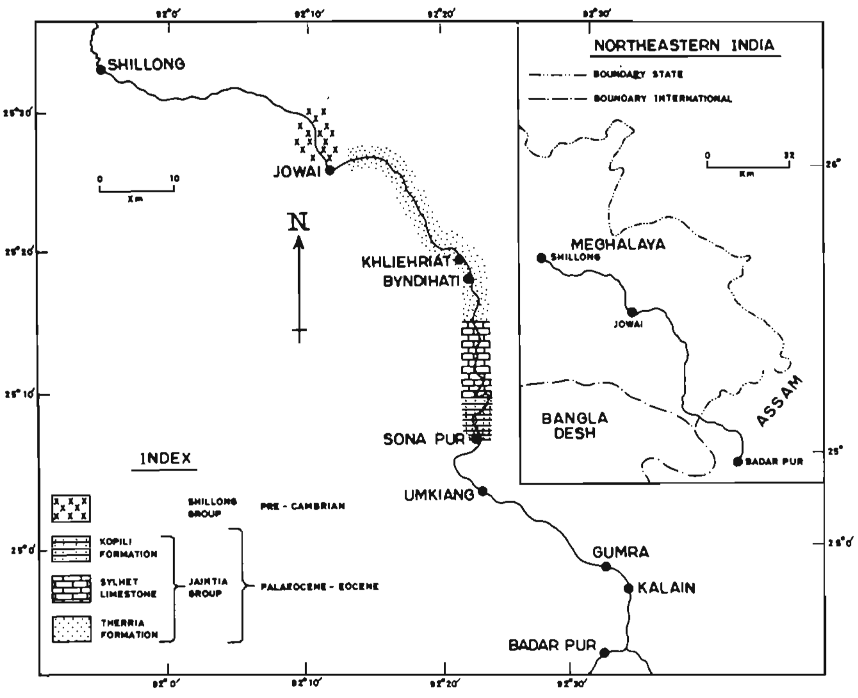
Liliacidites and *Collospermumpollis* are closely comparable to the pollen grains of the family Liliaceae. This family is cosmopolitan in the present day distribution.

Graminae

Graminidites maximus resembles the pollen grains of the family Graminae. This family is cosmopolitan in the present day distribution.

Nymphaeaceae

This family appears to be represented by the pollen grains of *Proxapertites assamicus.* The present day distribution of this family is mainly restricted to the tropical regions. It is an aquatic family.



Map 1—Showing the area of investigation.

Nelumboniaceae

Pollen grains assignable to *Assamialetes emendatus* resemble the pollen grains of this family. This family is also aquatic and is restricted to the tropical regions of the world.

Cruciferae

Ladakhipollenites elongatus resembles the pollen grains of the family Cruciferae. This family is cosmopolitan in the present day distribution and it grows in diverse conditions. However, pollen grains of similar morphology are also found in the family Polygonaceae.

Oleaceae

The family appears to be represented by the pollen grains assignable to *Retitrescolpites* sp. The present day geographical distribution of this family is restricted to tropical and warm temperate regions of the world.

Labiatae

Trifossapollenites constatus doubtfully represents this family. The family is cosmopolitan in the present day distribution.

Chenopodiaceae

The family is represented by *Polyporina* sp. However, similar pollen grains are also found in the family Amarantaceae.

Euphorbiaceae

Tricolporopollis rubra and *Lakiapollis assamicus* are comparable to the pollen grains of the family Euphorbiaceae. The present day distribution of this family is cosmopolitan. Pollen grains of similar morphology are also found in the family Araliaceae.

Myricaceae

Myricipites vulgaris shows affinity with the family Myricaceae. The present day distribution of this family is restricted to subtropical to temperate regions of the world. *Myricipites vulgaris* is abundantly found in the Indian Tertiary sediments but during the present study its frequency was found to be extremely low.

Magnoliaceae

This primitive family is probably represented in the assemblage by *Pinjoriapollis magnus*. The present day distribution of this family is in the temperate regions of the world.

?Aristolochiaceae

The genus *Sciadopityspollenites* may doubtfully be related to the family Aristolochiaceae. The affinities of *Tricolpites alveolatus* and *Densiverrupollenites eocenicus* are uncertain.

Palynofloral assemblage recovered from the Palaeocene-Eocene sediments of Jowai-Sonapur Road section, Meghalaya reflects a tropical to subtropical type of vegetation; however, a few temperate elements were also encountered.

PALYNOFLORAL COMPARISON

Punjab Basin

Palynological studies on the Subathu Formation have been carried out by Mathur (1963, 1966); Salujha, Srivastava and Rawat (1969) and Singh and Khanna (1980). The Subathu palynological assemblage described by Salujha, Srivastava and Rawat (1969) comprises 28 genera and 45 species. Of these, 10 genera belong to pteridophytes, 1 to gymnosperms, 12 to angiosperms and 5 to microplanktons. The palynofossils are poorly preserved precluding a close comparison. However, *Todisporites (Scabratriletes), Dandotiaspora (Psilatriletes lobatus), Osmundacidites (Scabratriletes* sp. A), *Couperipollis (Echinomonoletes)* and *Palmaepollenites (Retimonocolpites)* appear to be common to both the assemblages. Forms restricted to the Subathu Formation are: *Lycopodiacidites, Polypodiaceaesporites, Granodiporites, Anacolcidites, Triorites, Nyssapollenites, Polycolpites, Microhystridium, Canno-sphaeropsis*, etc. The palynofossils restricted to the Therria Formation but not reported from the Subathu Formation are: *Intrapunctisporis densipunctis, Foveotriletes, Monolites, Liliacidites, Assamialetes*, etc.

Recently Singh, Khanna and Sah (1978) and Singh and Khanna (1980) carried out a detailed palynostratigraphic study of the Subathu Formation and recovered a rich palynofloral assemblage. The assemblage recorded by Singh and Khanna (1980) consists of 15 dinoflagellate genera, 4 pteridophytic genera, 2 gymnospermic genera and 5 angiospermic genera. The palynotaxa common to the Subathu and Therria formations are: *Cordosphaeridium, Homotryblium, Gonyaulacysta, Polysphaeridium, Lygodiumsporites, Todisporites, Cyathidites, Proxapertites, Couperipollis, Tricolpites* and *Palmidites.* Palynotaxa restricted to the Subathu Formation are: *Hystrichosphaeridium, Oligosphaeridium, Spiniferites, Cleistosphaeridium, Cyclonephelium, Thalassiphora, Subathua, Araneosphaera, Achilleoidinium, Tenua, Hexagonifera, Verrutricolpites* and *Podocarpidites.* The palynotaxa represented in the Therria Formation but absent in the Subathu Formation are *Turbiosphaera, Apectodinium, Operculodinium, Adnatosphaeridium* and *Codoniella.* Besides, many angiospermous pollen grains, pteridophytic spores and fungal remains have been recovered from the Therria Formation, which are not present in the Subathu Formation.

A comparative study of the palynological assemblages from the Therria and Subathu Formation reveals that the former is dominated by the pteridophytic spores and angiospermic pollen grains, while the latter is characterized by the abundant occurrence of dinoflagellate cysts. A few dinoflagellate cyst genera are common between the two formations, but most of the elements are not comparable. Singh, Khanna and Sah (1978) assigned an Upper Palaeocene-Upper Eocene age to the Subathu Formation.

Rajasthan

Bose (1952), Singh and Natrajan (1950) and Jain, Kar and Sah (1973) investigated the Barmer Sandstone of Rajasthan palynologically. The palynoflora described by Jain, Kar and Sah (1973) comprises 36 genera and 43 species, of which *Proxapertites, Tricolpites, Palmaepollenites*, etc. are common between the two assemblages. The following Barmer Sandstone forms are absent in the present assemblage: *Araliaceoipollenites, Proteacidites, Extratriporopollenites* and *Triorites.* Many palynofossils present in the Therria Formation are absent in the Barmer Sandstone. The Barmer Sandstone has been assigned a Palaeocene age (Jain *et al.*, 1973).

Rao and Vimal (1950, 1952) and Sah and Kar (1974) made palynological studies on the Palana beds, Rajasthan. The palynological assemblage described by Sah and Kar (1974) is richly diversified and consists of 32 genera and 47 species. The palynotaxa common between the Palana beds, Rajasthan and Therria Formation, Meghalaya are: *Todisporites, Osmundacidites, Dandotiaspora dilata, Schizaeoisporites, Palmaepollenites, Liliacidites, Couperipollis, Tricolpites*, and *Callimothallus.* The forms present in the Palana beds but absent in the Therria Formation are: *Dictyophyllidites, Laevigatosporites, Cheilanthoidspora, Retipilonapites, Cupuliferoipollenites, Rhoipites, Caprifoliipites, Hippocrateacidites, Margocolporites, Verrutricolpites, Verrucolporites, Platoniapollenites, Calophyllumpollenites, Kielmeyerapollenites, Polybrevicolporites, Pseudonothofagidites*, etc.

The following palynotaxa of the Therria Formation are not present in the Palana Bed, Rajasthan: *Intrapunctisporis, Lygodiumsporites,* *Foveotriletes, Monolites, Polypodiisporites, Palmidites, Proxapertites, Assamialetes, Tricolporopollis, Densiverrupollenites*, etc. In addition to this the Therria assemblage possesses many dinoflagellate cysts. The palynofloral assemblages of Palana beds and Therria Formation have very few elements in common. Sah and Kar (1974) assigned a Lower Eocene age to the Palana beds.

Kutch

Palynological studies on the Lower Tertiary sediments of Kutch have been carried out by Mathur (1963, 1966), Venkatachala and Kar (1968, 1969a, 1969b), Sah and Kar (1969, 1970), Kar and Saxena (1976), and Saxena (1978, 1979).

Saxena (1978, 1979) reported a rich palynological assemblage from the Matanomadh Formation, Kutch (Palaeocene), comprising 45 genera assignable to 86 species. Of these, 14 genera and 27 species belong to pteridophytes, 3 genera and 3 species belong to gymnosperms and 28 genera and 56 species belong to angiosperms. Palynofossils common between the Matanomadh and Therria formations are: *Cyathidites australis, Lygodiumsporites eocenicus, Todisporites major, Dandotiaspora dilata, D. telonata, Intrapunctisporis, Osmundacidites, Polypodiisporites mawkmaensis, Couperipollis wodehousei, C. brevispinosus, C. robustus, Liliacidites, Palmidites maximus, Palmaepollenites, Proxapertites* and *Tricolpites*.

The palynotaxa present in the Matanomadh Formation but absent in the Therria Formation are: *Dictyophyllidites, Leptolepidites, Foveosporites, Lycopodiumsporites, Cicatricosisporites, Polypodiaceaesporites, Dracaenoipollis, Verrutricolpites, Psilastephanocolpites, Striatricolporites, Meliapollis, Triorites, Triporopollenites, Sonneratioipollenites* and *Pseudonothofagidites*. The palynofossils which are present in the Therria Formation but absent in the Matanomadh Formation are: *Assamialetes emendatus, Tricolporopollis, Foveotriletes, Monolites*, etc. In addition to this many dinoflagellate cyst genera occurring in the Therria Formation are also not represented in the Matanomadh assembalge. A comparative study reveals that the palynofloral assemblages from Therria and Matanomadh Formation are closely comparable.

The palynological assemblage from the Naredi and Harudi formations, Kutch (Lower-Middle Eocene), described by Kar (1978), is also not closely comparable to the present assemblage. Very few elements, viz., *Cyathidites, Polypodiisporites, Palmaeopollenites, Couperipollis, Proxapertites* and *Dandotiaspora* are common among the Naredi, Harudi and Therria assemblages.

Jain and Tandon (1981) described a palynological assemblage from the Middle Eocene sediments of Kutch establishing five informal zones within it. This assemblage is not closely comparable to the present one as only a few elements, viz., *Operculodinium centrocarpum, Homotryblium plectilum, Adnatosphaeridium vittatum, Polysphaeridium subtile* and *Cordosphaeridium* are common to both the assemblages.

Cambay Basin

The palynological reports from the Cambay Basin have been published by Varma and Dangwal (1964), Venkatachala and Chowdhary (1977), Rawat, Mukherjee and Venkatachala (1977), Mathur and Chowdhary (1977) and Mathur, Juyal and Chopra (1977). The palynofloral assemblage from the Kadi Formation, Cambay Basin (Venkatachala & Chowdhary, 1977) is not closely comparable to the present assemblage. However, the following elements are common to both the assemblages: *Lygodiumsporites, Biretisporites, Verrucatosporites, Schizaeoisporites, Palmaepollenites, Liliacidites, Proxapertites* and *Tricolpites*. The palynotaxa present in the Kadi Formation but absent in the present assemblage are: *Polypodiaceaesporites, Arecipites, Mauriidites, Spinizonocolpites, Psilodiporites, Retitricolpites, Margocolporites, Rhoipites, Cupuliferoipollenites* and *Marginipollis*. The palynofossils present in the Therria and Kopili assemblages but not recorded from the Kadi Formation are: *Cyathidites, Intrapunctisporis, Couperipollis, Assamialetes, Tricolporopollis, Todisporites, Palmidites* and *Lakiapollis*. Besides, many dinoflagellate cyst genera recorded in the present assemblage are also absent in the Kadi Formation. Venkatachala and Chowdhary (1977) assigned a Lower Eocene age to the Kadi Formation.

The palynological assemblage from the Kalol Formation, Cambay Basin (Mathur & Chowdhary, 1977) is also not much comparable to the present assemblage. The following palynotaxa are common to both the assemblages: *Lygodiumsporites, Polypodii-sporites, Schizaeoisporites, Osmundacidites, Striatriletes (Magnastriatites), Palmaepollenites, Retitrescolpites, Proxapertites* and *Liliacidites*. The palynotaxa present in the Kalol Formation but not represented in the present assemblage are: *Gleicheniidites, Alsophilidites, Lycopodiumsporites, Baculatisporites, Mauritidites, Psilatricolpites, Anacolcidites, Cupuliferoipollenites, Bombacacidites, Rhoipites, Acanthacidites, Araliaceoipollenites, Margocolporites*, etc. Forms recorded in the present assemblage but absent in the Kalol assemblage are: *Intrapunctisporis, Todisporites, Assamialetes, Tricolporopollis, Couperipollis, Palmidites, Tricolpites*, etc.

Cauvery Basin

The palynological studies on the Palaeocene-Eocene sediments of the Cauvery Basin have been carried out by Venkatachala and Rawat (1972). The following palynotaxa are common to both the assemblages: *Lygodiumsporites, Schizaeoisporites, Proxapertites, Couperipollis, Palmaepollenites, Liliacidites, Tricolpites* and *Myricipites*. The palynotaxa present in the Cauvery basin but absent in the present assemblage are: *Laevigatosporites, Spinainaperturites, Psilodiporites, Marginipollis, Palaeocaesalpiniaceaepites, Margocolporites, Rhoipites, Caprifoliipites*, etc.

The palynotaxa occurring in the present assemblage but absent in the Cauvery Basin assemblage are: *Cyathidites, Intrapunctisporis, Dandotiaspora, Todisporites, Osmundacidites, Assamialetes, Palmidites, Tricolporopollis, Lakiapollis*, etc.

Bengal Basin

Baksi (1972) carried out a detailed palynostratigraphic work on the Upper Mesozoic and Tertiary succession of the Bengal Basin dividing it into seven palynological zones.

The sediments in the Bengal Basin range from Middle Cretaceous to Plio-Pleistocene in age. The Zone II and Zone III are of Palaeocene to Early Eocene and Middle to Late Eocene ages respectively. The Zone II and Zone III have some palynofossils which also occur in the present assemblage. These are: *Assamialetes emendatus, Palmaepollenites* and *Couperipollis*. A comparative study reveals that the Bengal Basin palynoassemblage is not comparable to the present assembalge except for the common occurrence of a few elements.

Assam Basin

The palynological studies in the Lower Tertiary sediments of Assam and Meghalaya have been carried out by Biswas (1962), Baksi (1962), Sah and Dutta (1966, 1968, 1974), Dutta and Sah (1970), Sah, Kar and Singh (1970), Salujha, Kindra and Rehman (1972, 1974), Salujha, Rehman and Kindra (1973), Sah and Singh (1974), Sein and Sah (1974), Singh (1977a, 1977b), Singh and Tiwari (1979), Dutta and Jain (1980) and Mehrotra (1981). Dutta and Sah (1970) described a rich palynological assemblage from the Cherra Formation, Meghalaya. It comprises 49 genera assignable to 103 species. Out of this 18 genera and 34 species belong to pteridophytes, one genus and one species to gymnosperm and 27 genera and 68 species belong to angiosperms. The following palynotaxa are common between the Cherra and Therria assemblages: *Cyathidites, Lygodiumsporites eocenicus, Foveotriletes pachyexinous, Dandotiaspora dilata, Polypodiisporites, Monolites mawkmaensis, Schizaeoisporites, Assamialetes emendatus, Couperipollis brevispinosus, C. wodehousei, Liliacidites microreticulatus, Palmaepollenites communis, Proxapertites assamicus, Tricolpites, Sciadopityspollenites, Tricolporopollis rubra*, etc.

The palynotaxa recorded in the Cherra Formation but absent in the present assemblage are: *Stereisporites, Lycopodiumsporites, Sestrosporites, Retipilonapites, Polycolpites, Nyssapollenites, Triporopollenites, Meliapollis, Foveosporites, Microreticulatisporites, Foraminisporis*, etc. The palynomorphs present in the Therria Formation but not represented in the Cherra Formation are: *Intrapunctisporis, Dandotiaspora telonata, Todisporites, Palmidites plicatus*, etc. Besides these many dinoflagellate cyst genera recovered from the Therria Formation are also absent in the Cherra Formation. It is observed that the Therria and Cherra assemblages are closely comparable. The Cherra Formation is of Palaeocene age (Dutta & Sah, 1970).

The palynological assemblage from the Tura Formation, Meghalaya described by Singh (1977a) comprises 53 spore-pollen genera referable to 89 species. Out of these, 19 genera and 29 species belong to pteridophytes and 34 genera and 69 species belong to angiosperms. The palynotaxa common to the Tura and Therria assemblages are: *Cyathidites, Lygodiumsporites eocenicus, Foveotriletes pachyexinous, Dandotiaspora dilata, D. telonata, Monolites discordatus, Monolites mawkmaensis, Assamialetes emendatus, Couperipollis brevispinosus, C. wodehousei, Liliacidites microreticulatus, Palmaepollenites communis, Proxapertites assamicus, Liliacidites major, L. giganticus, Palmidites maximus*, etc. The palynotaxa occurring in the Tura Formation but absent in the Therria Formation are: *Stereisporites, Lycopodiumsporites, Retipilonapites, Polycolpites, Nyssapollenites, Triporopollenites, Triorites, Meliapollis, Droseridites, Pseudonothofagidites*, etc. The palynomorphs present in the Therria Formation but absent in the Tura Formation are: *Intrapunctisporis, Sciadopityspollenites, Tricolpites alveolatus, Retisyncolporites, Tricolporopollis rubra*, etc. It is apparent from the above mentioned comparative study that the Tura and Therria assemblages are closely comparable. Sah and Singh (1974) assigned a Palaeocene age to the lower part of the Tura Formation.

Dutta and Jain (1980) recorded a rich dinoflagellate cyst assemblage from the Upper Palaeocene-Upper Eocene sediments of the Jaintia Hills, Meghalaya. The forms common to both the assemblages are as follows: *Turbiosphaera, Cordosphaeri-*

dium exilimurum, C. multispinosum, Operculodinium centrocarpum, O. major, Homotryblium plectilum, Apectodinium homomorphum and *A. parvum*. The dinoflagellate cysts occurring in the assemblage described by Dutta and Jain (1980) but absent in the present assemblage are: *Thalassiphora Distatodinium, Samlandia, Araneosphaera, Hystrichokolpoma, Spiniferites* and *Glaphyrocysta*. The dinoflagellate cysts occurring in the present assemblage but absent in the assemblage described by Dutta and Jain (1980) are: *Gonyaulacysta, Apteodinium, Prolixosphaeridium, Polysphaeridium, Adnatosphaeridium* and *Codoniella*. A comparative study shows that the two assemblages are closely comparable.

Dandot (Pakistan)

Vimal (1952) described a palynological assemblage from Dandot Lignite, Pakistan comprising 29 spore/pollen types assignable to 10 genera. The forms appearing to be common between the two assemblages are: *Dandotiaspora dilata* (=*Trilites* spm. 6), *Dandotiaspora telonata* (=*Trilites* spm. 6) and *Lygodiumsporites eocenicus* (=*Trilites* spm. 4). The common occurrence of these forms favours the dating of Dandot Formation as Palaeocene.

Australia and New Zealand

The Lower Tertiary palynological assemblage of New Zealand (Couper, 1953, 1958) and Australia (Cookson, 1946, 1947; Cookson & Pike, 1954) are dominated by the pollen grains of *Nothofagus, Cupenidites, Podocarpus*, etc. These forms are absent in the present assemblage. However, some pollen grains, viz., *Palmidites maximus, Cyathidites australis, Tricolpites alveolatus, Couperipollis* and *Liliacidites* are common between the New Zealand and Therria assemblages. Wilson (1967) described *Apectodinium (Wetzeliella)* from the Palaeocene-Eocene strata of New Zealand. This form has also been recorded in the Therria assemblage. The Australian Palaeocene-Eocene dinoflagellate cyst assemblages are dominated by *Apectodinium (Wetzeliella)* and *Deflandrea*. The genus *Deflandrea* is not present in the present assemblage.

A world wide palynofloral comparison of the Palaeocene-Eocene assembalges reveals that the present assemblage is partially comparable to the palynoflora of south-east Asian countries, Austrialia, New Zealand and western European countries. The dinoflagellate cyst assemblage is strikingly similar to the one described from the London Clay (Eocene) of Britain.

QUANTITATIVE ANALYSIS OF THE PALYNOFLORA

The percentage frequency of various palynotaxa has been determined by counting 200 palynofossils per sample but in some cases where the yield was poor 150 palynofossils were counted. Out of 59 genera and 92 species, 26 genera assignable to 48 species were found to be stratigraphically significant.

The quantitative analysis of the palynofloral assemblage reveals that the lower part of the Therria Formation is dominated by the pteridophytic spores, particularly the genus *Lygodiumsporites*. The middle part of the Therria Formation is characterized by the predominance of angiospermic pollen grains, whereas its upper part is richly dominated by the dinoflagellate cysts. The Sylhet Limestone has yielded very few palynofossils, hence, it has not been possible to observe any palynofloral change within this formation.

In the Kopili Formation the lower part is dominated by the dinoflagellate cysts while the upper part is characterized by the high frequency of pteridophytic spores. The genus *Striatriletes* is characteristically associated with this Formation.

On the basis of qualitative and quantitative analyses of the palynoflora recovered from the Palaeocene-Eocene sediments exposed along the road between Jowai and Sonapur, Meghalaya, Tripathi and Singh (1984b) established five palynozones which are given below in ascending order of stratigraphy (Text-fig. 1).

KOPILI FORMATION:

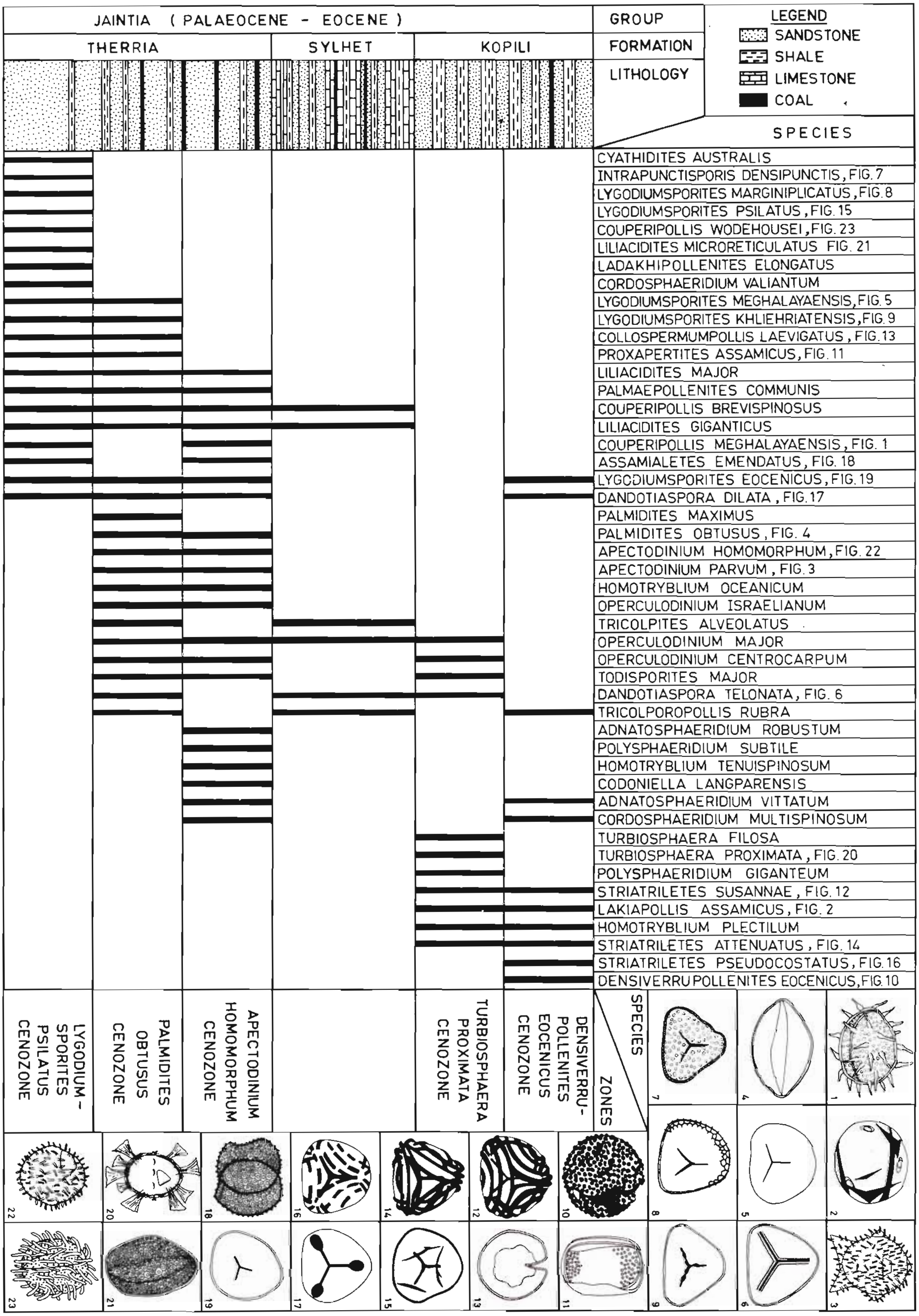
5. *Densiverrupollenites eocenicus* Cenozone Tripathi & Singh (1984b)
4. *Turbiosphaera proximata* Cenozone Tripathi & Singh (1984b)

THERRIA FORMATION:

3. *Apectodinium homomorphum* Cenozone Tripathi & Singh (1984b)
2. *Palmidites obtusus* Cenozone Tripathi & Singh (1984b)
   Lygodiumsporites psilatus Cenozone Tripathi & Singh (1984b)

PALAEOECOLOGY, PALAEOGEOGRAPHY AND ENVIRONMENT OF DEPOSITION

The palynological assemblage recovered from the Palaeocene-Eocene sediments, exposed along the road between Jowai and Sonapur, Meghalaya is represented by many pteridophytic and angiospermic families which are presently restricted to the tropical to subtropical regions of the world.



Text-figure 1—Palynological zonation of the Palaeocene-Eocene strata (Jawai-Sonapur), Meghalaya (Litholog not to the scale).

These families are: Lycopodiaceae, Polypodiaceae, Schizaeaceae, Cyatheaceae, Parkeriaceae, Palmae, Liliaceae, Nymphaeaceae, Nelumboniaceae, Oleaceae and Myricaceae. Besides, other families represented in the assemblage are cosmopolitan in the present day distribution.

Lakhanpal (1970), on the basis of the palaeobotanical evidences, envisaged that the Palaeogene flora in the Indian Subcontinent was predominantly tropical. The fact that tropical to subtropical vegetation was existing in the nearby areas of Assam and Meghalaya has been confirmed by the palynological studies (Dutta & Sah, 1970; Sah & Singh, 1974; Singh, 1977a, b). The present palynological evidences also indicate that the area in the vicinity of Meghalaya was supported by a tropical to subtropical flora.

The climate during the deposition of the investigated Palaeocene-Eocene sediments of Meghalaya was warm and humid. This view is supported by the presence of many fungal remains in the palynological assemblage recovered from this area. Amongst fungal remains the fruiting bodies like *Callimothallus, Phragmothyrites* and *Paramicrothallites*, belonging to the epiphyllous fungi, are very common. The frequent occurrence of these fruiting bodies suggests that a warm and humid climate prevailing during that period supported a vegetation favourable for the growth of the epiphyllous fungi. A similar palaeoclimate has been deduced for the Cherra (Dutta & Sah, 1970) and Tura formations (Sah & Singh, 1974).

As mentioned earlier the Tertiary sediments in the area of investigation rest unconformably over the Precambrian Shillong Group. This indicates that the area remained a high ground during the Palaeozoic and Mesozoic times but finally got submerged into the water by the close of the Mesozoic Era paving a way for the deposition of Tertiary sediments.

Singh (1977b) mentioned that the Garo, Khasi, Jaintia and Mikir Hills, comprising the Assam autochthon, were initially a north-easterly extension of the Peninsular India and they got detached from the mainland sometimes during the Cretaceous Period. The break up of the Gondwanaland during that time upset the isostatic balance of the region causing various earth movements. The Dauki Tear Fault, which crosses the Jowai-Badarpur Road near Sonapur, appears to be attributed to one of these movements. These earth movements also seem to be responsible for the subsidence of the southern slopes of the Garo, Khasi and Jaintia Hills (Singh, 1977b).

It appears that the gradual sinking of the southern slope of the Jaintia Hills, Meghalaya was probably associated with the rise of the Shillong Plateau. This caused the invasion of the sea in the southern part of the Jaintia Hills. Simultaneously the area started withdrawing from the Shillong Plateau (Singh, 1977b). The continued subsidence of the southern slope of the Shillong Plateau is indicated by the huge thickness of the strata exhibited by the Sylhet Limestone and Kopili formations. The transgression of the sea in this area is evidenced by the presence of dinoflagellate cysts in these sediments. The Palaeocene-Eocene sediments exposed along the road between Jowai and Sonapur, Meghalaya appear to have been deposited under the brackish water to shallow marine environments.

The oldest sediments of the Therria Formation, represented by the *Lygodiumsporites psilatus* Cenozone, is characterized by the dominance of the pteridophytic spores (47%) and angiospermic pollen grains (38%). The dinoflagellate cysts are represented by 7 per cent of the total assemblage of the cenozone. The *Palmidites obtusus* Cenozone of the Therria Formation is dominated by the angiospermic pollen grains (47%) and pteridophytic spores (24%). The dinoflagellate cysts are represented by 25 per cent of the total cenozone assemblage. The youngest palynological zone of the Therria Formation, viz., *Apectodinium homomorphum* Cenozone is dominated by the dinoflagellate cysts (78%). Here the angiospermic pollen grains and the pteridophytic spores are represented by 17 per cent and 4 per cent respectively.

Therefore, it is clear that the older sediments of the Therria Formation exhibit comparatively low percentage frequency of the dinoflagellate cysts while, its younger sediments are characterized by a very rich representation of the dinoflagellate cysts. This perceptible change in the palynological spectrum of the Therria Formation indicates that the sediments representing the *Lygodiumsporites psilatus* and *Palmidites obtusus* cenozones were deposited under the brackish water estuarine conditions, whereas the sediments representing the *Apectodinium homomorphum* Cenozone were deposited under shallow marine conditions.

In the Kopili Formation the older *Turbiosphaera proximata* Cenozone is characterized by the dominance of the dinoflagellate cyst assemblage (44%). The pteridophytic spores and angiospermic pollen grains are collectively represented by 16 per cent of the total assemblage. The youngest palynozones of the Kopili Formation, viz., *Densiverrupollenites eocenicus* Cenozone exhibits the dominance of the pteridophytic spores (40%) and angiospermic pollen grains (7%) over the dinoflagellate cysts (10%).

The palynological spectrum of the Kopili Formation indicates that the sediments representing the *Turbiosphaera proximata* Cenozone were deposited under shallow marine conditions, while the sediments representing the *Densiverrupollenites eocenicus* Cenozone were deposited under brackish water estuarine conditions. The Kopili Formation sediments appear to have been deposited under the shallow sea which was subjected to frequent oscillations. This view is supported by the alternate deposition of the shales and sandstones in this formation (Dutta & Jain, 1980).

Coastal conditions prevailing during the time of deposition of the investigated Palaeocene-Eocene sediments is proved by the rich representation of the pollen grains resembling those of the family Palmae. These pollen grains are: *Palmidites maximus, P. obtusus, P. plicatus, Palmaepollenites communis, Couperipollis brevispinosus, C. meghalayaensis, C. wodehousei* and *C. rarispinosus*. The fresh water elements represented in the palynoassemblage, viz., *Proxapertites assamicus* and *Assamialetes emendatus* appear to have been transported to the near-shore areas through the fresh water channels which might have had connections with the sea then. The coastal vegetation seems to have been followed by the swamp vegetation. The presence of swamp vegetation is supported by the pollen grains of the family Chenopodiaceae, viz., *Polyporina* sp.

AGE OF THE THERRIA FORMATION

The earlier workers like Oldham (1863), Medlicott (1869), La Touche (1887), Medlicott and Blanford (1893), and Pinfold (1919) assigned a Cretaceous age to the Tura Formation (=Therria and Cherra formations). Evans (1932), while dealing with lithostratigraphy of Tertiary sediments in Assam assigned a Lutetian (Middle-Eocene) age to most of the Jaintia Group sediments. The basal sediments of this group are represented by Therria Formation. Fox (1936) also expressed the view that the Tura Formation (=Therria Formation) may belong to the Lower Tertiary age. The Tertiary age for these sediments was later confirmed by Jacob (1949) and Pascoe (1963), Sah and Dutta (1966, 1968) and Dutta and Sah (1970).

Langpar Formation, which represents lowermost Tertiary sediments in Assam Basin, is overlain by a coal measure sequence. This sequence has been named as Therria Formation along the Umshoryngkew River, Cherra Formation in Cherrapunji Plateau, Tura Formation in Garo Hills and Mikir Formation in Mikir Hills. Dutta and Sah (1970) and Sah and Dutta (1974) recovered a rich palynological assemblage from Cherra Formation and proposed Palaeocene age for it. The Palaeocene age for this formation was indicated by these authors on the basis of the following evidences.

1. Cherra Formation is disconformably underlain by Langpar Formation which is supposed to be Danian in age. It shows the presence of foraminifera like *Globigerina pseudobulloides* and *Globigerina triloculinoides*, etc. These forms are characteristic of the Danian age.
2. Cherra Formation is conformably overlain by the Lakadong Limestone Member of the Sylhet Limestone. This member has yielded typical Ranikot (Lower Eocene) fossils like *Nummulites thalicus, N. sindensis, Lockhartia hamei, Miscellania miscella, M. meandrina, Operculina* cf. *canalifera, Alveolina* sp., *Orbitospiphon tibetica* and *Discocyclina ranikotensis*.

Therefore, the Cherra Formation between the underlying Langpar Formation (Danian) and overlying Lakadong Limestone Member (Lower Eocene) was dated by Dutta and Sah (1970) as Palaeocene. The palynofossils common to the Therria Formation and Cherra Formation are: *Cyathidites australis, Lygodiumsporites eocenicus, Corrugatisporites, Foveotriletes pachyexinous, Monolites mawkmaensis, Polypodiisporites mawkmaensis, Schizaeoisporites, Sciadopityspollenites, Assamialetes emendatus, Trifossapollenites constatus, Couperipollis (Monosulcites) brevispinosus, C. (monosulcites) rarispinosus, Liliacidites microreticulatus, Proxapertites (Schizosporis) assamicus, Retitrescolpites, Myricipites* and Formation, *Polyporina*.

It is apparent from comparisons of the palynofloras of Therria and Cherra formations that many spore and pollen genera are common between the two. Hence, it is logical to assume that both these formations are time equivalents. Therefore, on the basis of the palynological similarities between the Cherra and Therria formations, Palaeocene age has been assigned to the Therria Formation.

Palaeocene dating of Therria Formation is further supported by the fact that, its youngest palynozone, viz., *Apectodinium homomorphum* Cenozone is characterized by the presence of *Apectodinium homomorphum* and *A. parvum*. These forms are considered to be characteristic of Upper Palaeocene age (Harland, 1979). The presence of these palynofossils in various Upper Palaeocene sediments has been reported by Cookson (1967), Wilson (1967) and Chateauneuf and Gruas-Cavagnetto (1978).

Sah and Singh (1974) correlated three lower palynozones of Tura Formation, viz., *Assamialetes emendatus* Cenozone, *Dandotiaspora telonata* Cenozone and *Palmidites plicatus* Cenozone with the three palynozones of Cherra Formation, viz., *Proxapertites crassimurus* Cenozone, *Araliaceoipollenites reticulatus* Cenozone and *Tricolpites reticulatus* Cenozone respectively and assigned a Palaeocene age to these Tura sediments.

AGE OF KOPILI FORMATION

As mentioned earlier no detailed palynostratigraphical work has been carried out on the Kopili Formation, Meghalaya, on the basis of which any precise date could be given to this formation. Samanta (1968) on the basis of presence of small foraminifera like *Pellatispira* and absence of characteristic Middle Eocene forms like *Assilina, Alveolina, Dictyoconoides* and *Lockhartia* confirmed an Upper Eocene age for this formation. Sein and Sah (1974) and Dutta and Jain (1980) did not assign any age to Kopili Formation. Their palynological assemblages lack any Upper Eocene stratigraphical marker. The present Kopili assemblage also lacks any Upper Eocene marker form. Archangelsky (1969) described *Turbiosphaera* from the Rio-Turbio (Lower Eocene-Upper Eocene) of Santa Cruz Province, Argentina. This form has also been recovered from Lower palynological zone of Kopili Formation, viz., *Turbiosphaera proximata* Cenozone Therefore, occurrence of *Turbiosphaera* in Kopili Formation may prove helpful in its dating at a later date by carrying out detailed study of this genus up to the specific level. However, Kopili Formation is dated as Eocene on palaeontological evidences.

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Fossil wood of *Xanthophyllum* from the Cuddalore Sandstone near Pondicherry

Nilamber Awasthi

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A fossil dicot wood from the Cuddalore sandstones exposed at Murattandichawadi near Pondicherry has been described. In all its anatomical features the fossil shows resemblance with the woods of the genus *Xanthophyllum* of Polygalaceae and hence named as *Xanthophyllum cuddalorense* sp. nov.

Key-words—Xylotomy, *Xanthophyllum*, Polygalaceae, Cuddalore Sandstone, Mio-Pliocene (India)

Nilamber Awasthi, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

पॉण्डिचेरी के समीपस्थ कुडलोर बालुकाश्म से ज़ैन्थोफ़िल्लम् की अश्मित काष्ठ

नीलाम्बर अवस्थी

पॉण्डिचेरी के समीपस्थ मुरट्टंडीचावड़ी में विगोपित कुडलोर बालुकाश्म से प्राप्त एक अश्मित काष्ठ का वर्णन किया गया है। सभी शारीरीय लक्षणों में यह काष्ठ पोलीगैलेसी कुल के ज़ैन्थोफ़िल्लम से समानता दर्शाती है अतएव इसे ज़ै० कुडलोरेन्से नव जाति से नामांकित किया गया है।

THE Cuddalore Sandstone exposed around the village Murattandichawadi about 8 km north-west of Pondicherry is well known for rich deposits of petrified angiospermous and gymnospermous woods. The woods studied so far belong to Podocarpaceae, Palmae and nearly 15 tropical dicotyledonous families. They have been reviewed by Awasthi (1974), who subsequently described more dicotyledonous woods from the same area (Awasthi, 1975a, 1975b, 1977a, 1977b, 1979, 1980, 1981a, 1981b; Awasthi *et al.*, 1982). Some of them are phytogeographically significant as their modern counterparts presently occur in the evergreen forests of Malaya, Java, Sumatra and neighbouring Islands. The wood of *Xanthophyllum* being described here is the first authentic report of the occurrence of Polygalaceae in India in the geological past.

DESCRIPTION

Genus—*Xanthophyllum* Roxb.

Xanthophyllum cuddalorense sp. nov.

Pl. 1, figs 1-5

Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to medium, t.d. 100-180 μm, r.d. 120-280 μm, typically solitary, very rarely in radial multiples of two, circular to oval, mostly oval due to lateral compression before fossilization, irre-gularly distributed, sometimes crowded at places (Pl. 1, fig. 1) as well as very few (Pl. 1, fig. 2), about 2-10 vessels per sq mm; perforations simple, transverse to slightly oblique; vessel-members about 250-750 μm in height; intervessel pits not well-preserved, seemingly small; tylosis-like structure occasionally seen in some vessels. *Parenchyma* paratracheal and apotracheal, paratracheal parenchyma usually scanty and limited to a few cells around vessels forming narrow or incomplete sheath (Pl. 1, fig. 3); apotracheal parenchyma diffuse or continuous or broken 1-2 seriate lines, irregularly and closely placed (Pl. 1, figs 2, 3), about 10-15 lines per mm; strands up to 8 cells; cells bigger than the usual size, oval radially, about 40 μm in diameter. *Rays* fine, 1-2 seriate, about 12-18 per mm in cross-section, 6-40 cells in height, heterogeneous, consisting of procumbent cells in the middle portion and one to

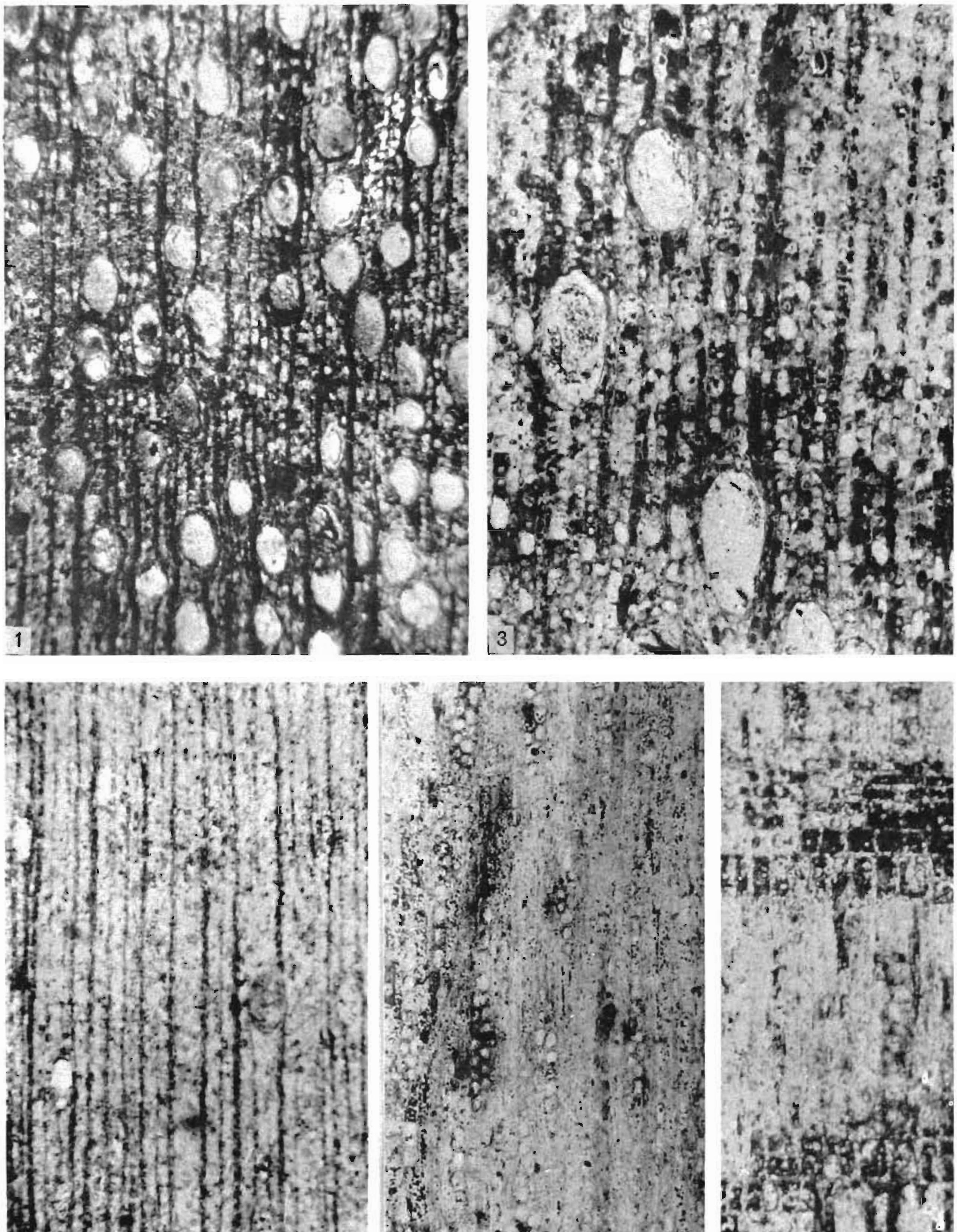

PLATE 1

several uniseriate marginal rows of upright or square cells at both the ends, end to end fusion common; upright cells 20-48 μm in tangential height and 40-100 μm in radial length; crystals present. *Fibres* aligned in radial rows, 12-32 μm in diameter, thick-walled, walls 4-6 μm in thickness, nonseptate, pits not satisfactorily preserved, rarely seen, small, bordered, about 4 μm in diameter.

AFFINITIES

In having the important as well as characteristic features, such as medium to large-sized solitary vessels, vasicentric and closely placed 1-2 seriate apotracheal parenchyma lines, 1-2 seriate heterocellular xylem rays and nonseptate thick-walled fibres with small bordered pits—the fossil wood is comparable with the woods of *Xanthophyllum* of the family Polygalaceae. According to Metcalfe and Chalk (1950, p. 135) *Xanthophyllum* is the only genus of Polygalaceae which is characterised by apotracheal parenchyma occurring as 1-2 seriate and closely spaced continuous or broken lines in addition to scanty paratracheal ones. This further confirms the identification of the fossil wood as *Xanthophyllum*. Amongst the various species of *Xanthophyllum* thin sections of the woods of *Xanthophyllum glaucum, X. andamanicum, X. flavescens, X. griffithii, X. virense* and *X. affini* were critically examined for identification of the fossil up to specific level. It was observed that the fossil resembles all these species in gross features. However, the nature and distribution of vessels, amount and distribution of parenchyma and width and height of rays show that the fossil wood appears to be closer to *Xanthophyllum flavescens*, though the frequency of vessels in the former is relatively more than in the latter.

Regarding the nomenclature of fossil wood the recommendation of Lakhanpal and Prakash (1980) has been followed. Accordingly the fossil wood is assigned the modern generic name *Xantho-phyllum*. As pointed out above, the fossil wood slightly differs from *Xanthophyllum flavescens* in size and frequency of vessels, hence a new specific name *Xanthophyllum cuddalorense* is given to it. The specific name indicates its occurrence in the Cuddalore Sandstone.

Holotype—Specimen no. BSIP 35854; Murattandichavadi near Pondicherry; Cuddalore Sandstone; Miocene-Pliocene.

DISCUSSION

The genus *Xanthophyllum* Roxb. consists of about 60 species distributed in the Indo-Malayan region (Willis, 1973, p. 1229). *Xanthophyllum flavescens* seemingly the nearest living counterpart of the fossil, is found in the evergreen forest of Western Ghats, Burma and elsewhere in the Malayan region. In the Western Ghats, India, it occurs in the evergreen forest of the Nilgiris southwards up to 1300 m. In the high level evergreen forest of Palghat (Kerala) it is found in association with *Myristica laurifolia, Hydnocarpus laurifolius, H. alpina, Euphoria longana, Lansium anamalayanum, Garcinia spicata, Elaeocarpus serratus, Epiprinus mallotiformis., Gomphandra polymorpha, Gordonia obtusa, Syzygium* sp., *Baccaurea courtallensis, Glochidion malabaricum, Canthium diococcum, Scolopia crenata, Nothopodytes foetida, Actinodaphne hookeri*, etc. (Champion & Seth, 1968, p. 67).

A large number of taxa, most of which are the important elements of the evergreen to semi-evergreen forests, viz., *Anisoptera, Dryobalanops, Dipterocarpus, Shorea, Hopea, Sterculia, Gluta, Mangifera, Calophyllum, Mesua, Euphoria, Afzelia, Cassia, Cynometra, Sindora, Duabanga, Sonneratia, Barringtonia, Chrysophyllum* and *Diospyros* are already known from the Cuddalore sandstones near Pondicherry (Awasthi, 1974, 1977a, 1977b, 1979, 1980, 1981a, 1981b; Awasthi *et al.*, 1982). Occurrence of *Xanthophyllum* too in the same deposits further indicates prevalence of excessive humid conditions in this region during the Miocene-Pliocene.

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PLATE 1

Xanthophyllum cuddalorense sp. nov.

1. Cross section showing nature and distribution of vessels and parenchyma. × 47. Slide no. BSIP 35854-I.
2. Another cross section showing uneven distribution of vessels. × 45. Slide no. BSIP 35854-II.
3. Cross section magnified to show the vessels and diffuse parenchyma. × 112. Slide no. BSIP. 35854-II.
4. Tangential longitudinal section showing rays. × 112. Slide no. BSIP 35854-III.
5. Radial longitudinal section showing heterocellular rays. × 112. Slide no. BSIP 35854-IV.

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Palynology of Kamthi Formation from Ramagundam-Mantheni Area, Godavari Graben, Andhra Pradesh, India

D. C. Bharadwaj,* Suresh C. Srivastava, B. V. Ramanamurty** & Neerja Jha

Bharadwaj, D. C., Srivastava, Suresh C., Ramanamurty, B. V. & Jha, Neerja (1987). Palynology of Kamthi Formation from Ramagundam-Mantheni Area, Godavari Graben. *Palaeobotanist* **35**(3) : 318-330.

Palynological study of the Kamthi Formation from the Ramagundam-Mantheni area of Godavari Graben reveals that the palynoflora of Kamthi Formation is uniformly dominated by striate-disaccate (about 50%) and the subdominant groups differ. Thus Lower Member of the Kamthi Formation is characterised by the subdominance of nonstriate-disaccates while Middle Member is characterised by the subdominance of *Striasulcites* in the older part and *Densipollenites* in the younger part. The palynoflora is by and large comparable with the Raniganj palynoflora of Damodar Valley except a few differences. The palynoflora in the upper part of the cored Middle Member of Kamthi Formation exhibits close proximity towards Permian-Triassic (Panchet) transition. Obviously, only the Lower and partly Middle members of the Kamthi Formation are homotaxial with Raniganj Formation of Damodar Basin.

Key-words—Palynology, Striate-disaccates, Kamthi Formation, Godavari Graben (India).

Suresh C. Srivastava & Neerja Jha, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.
**D. C. Bharadwaj, C-131, Mahanagar, Lucknow 226 006, India.*
***B. V. Ramanamurty, Singareni Collieries Co. Ltd., Belampalli, 504 251, India.*

साराँश

आँध्र प्रदेश (भारत) में गोदावरी द्रोणिका के रामागुँडम्-मन्थेनी क्षेत्र से कामथी शैल-समूह का परागाणविक अध्ययन

दिनेश चन्द्र भारद्वाज, सुरेश चन्द्र श्रीवास्तव, बी वी रमनमूर्ति एवं नीरजा झा

गोदावरी द्रोणिका के रामागुँडम्-मन्थेनी क्षेत्र से कामथी शैल-समूह के परागाणविक अध्ययन से व्यक्त होता है कि कामथी शैल-समूह का परागाणुवनस्पतिजात रेखीय-द्विकोष्ठीय परागकणों (लगभग 50 प्रतिशत) से समान रूप से प्रभावी है तथा उपप्रभावी समूह भिन्नता प्रदर्शित करते हैं। अतएव कामथी शैल-समूह का अधरि सदस्य अरेखीय-द्विकोष्ठीयों के उपप्रभाव से लक्षणित है जबकि बीच का सदस्य पुराने भाग में स्ट्रिआसल्काइटिस तथा अल्पायु वाले भाग मे डेन्सीपोलिनाइटिस के उपप्रभाव से अभिलक्षणित है। कुछ विभेदों को छोड़कर परागाणुवनस्पतिजात रानीगंज परागाणुवनस्पतिजात से बहुत कुछ तुलनीय है। कामथी शैल-समूह के मध्य-क्रोड़ सदस्य के ऊपरी भाग का परागाणुवनस्पतिजात परमी-त्रिसंघी (पंचेत) परिवर्तन की ओर घनिष्ठ निकटता इंगित करता है। वस्तुतः कामथी शैल-समूह के केवल अधरि तथा आँशिक रूप से मध्य सदस्य तथा दामोदर द्रोणिका के रानीगंज शैल-समूह समकालक्रमी हैं।

LOWER Gondwana sediments representing Talchir, Barakar, Barren Measures and Kamthi formations are well developed in Godavari Graben (16° 38′ & 19° 32′; Longitude 79° 12′ & 81° 39′; Map 1). Amongst these the Kamthi Formation has the maximum thickness. The rocks of Kamthi Formation are exposed extensively in Wardha-Godavari Valley in Maharashtra and Andhra Pradesh. However, the name Kamthi was given by Blanford, W. T. (1868) to these distinctive rocks after the erstwhile military station of Kamthi (20°10′ : 79°15′) close to Nagpur. The entire Gondwana sediments in Godavari Valley overlying the Barakar Formation and underlying the Maleri Formation were previously included within the Kamthi Formation by King (1881). But Sengupta (1970) for the first time identified Iron Stone Shale in Bheemaram area. Recently, Ramanamurty (1979) has reported the occurrence of 400 m thick sediments as Barren Measures Formation in Ramagundam area on the basis of lithological characteristics. Hence, the rocks overlying the Barren Measures Formation and underlying the Maleri

Formation are referred to here as Kamthi Formation.

The palynoflora of the Kamthi Formation has been hitherto unknown except a brief mention of few genera of pteridophytic spores and disaccate pollen by Ramanamurty (1979). Recently, occurrence of megaspores in the Kamthi Formation has been reported by Jha and Srivastava (1984) from Ramagundam-Mantheni and Chelpur areas of Godavari Graben. In the present paper the palynostratigraphy of the Kamthi Formation has been given in detail.

GEOLOGY

The oldest rocks in the area are the Archeans which are overlain by unfossiliferous Pakhal Limestone and shales and Sullavai Sandstone. Based on subsurface data, the stratigraphy and lithology of Lower Gondwana sediments of Ramagundam area (Ramanamurty, 1979) are as follows:

FORMATION	LITHOLOGY
Kamthi	Predominantly fine to medium-grained sandstone with subordinate shales and few shaly coal seams.
	Gradational Contact
Barren Measures	Predominantly medium to coarse-grained, greenish grey and greyish white felspathic sandstones with subordinate shales and clays.
	Gradational Contact
Barakar	Predominantly medium to gritty greyish white sandstones with shales and well developed coal seams
	Gradational contact
Talchir	Fine-grained greenish to greenish grey sand and siltstones and clays with few pebble beds

Lithology of Kamthi Formation

In the type area the rocks of Kamthi Formation consist of conglomerates of pebbles, grits, sandstone and shales. A typical member of the group is the fine, massive and homogeneous mudstone, yellow when fresh but becoming red on exposure. This member passes into red shales. Kamthi Formation of Godavari Graben (Map 2) has been subdivided into three units (Sengupta, 1970). The Lower Member consists of greyish white, calcareous sandstone and a few coal seams (Ramanamurty, 1979). The Middle Member consists of alternating sequence of medium grained grey-white sandstone and shale/variegated clays. The sandstone and shales exhibit a greenish tint at places. This member is remarkably devoid of any coaly horizon. The shales are characterised by nodules and concretions of calcareous material. The Upper Member comprises coarse-grained sandstone with bands of ferruginous sandstone and brick red bands of pebbles or conglomerate and have innumerable clasts of white, violet and yellow shales as well. Hard and compact violet claystone is associated with this member. The Kamthi Formation is succeeded by Upper Gondwana sediments progressively represented by the Maleri, Kota and Chikiala beds consisting of sandstones, intercalations of red and white clays, fine-grained grey sandstones and thin limestone beds.

Chikiala beds		
Kota Formation		
Maleri Formation		
Kamthi Formation	Upper	Coarse-grained sandstone with bands of ferruginous sandstone and brick red siltstone
	Middle	Alternation of medium-grained grey white sandstone and shale, variegated clay, devoid of coal. Sandstone exhibit greenish tint at places
	Lower	Medium-grained greyish white calcareous sandstone and few coal seams
Barren Measures Formation		Gradational contact.

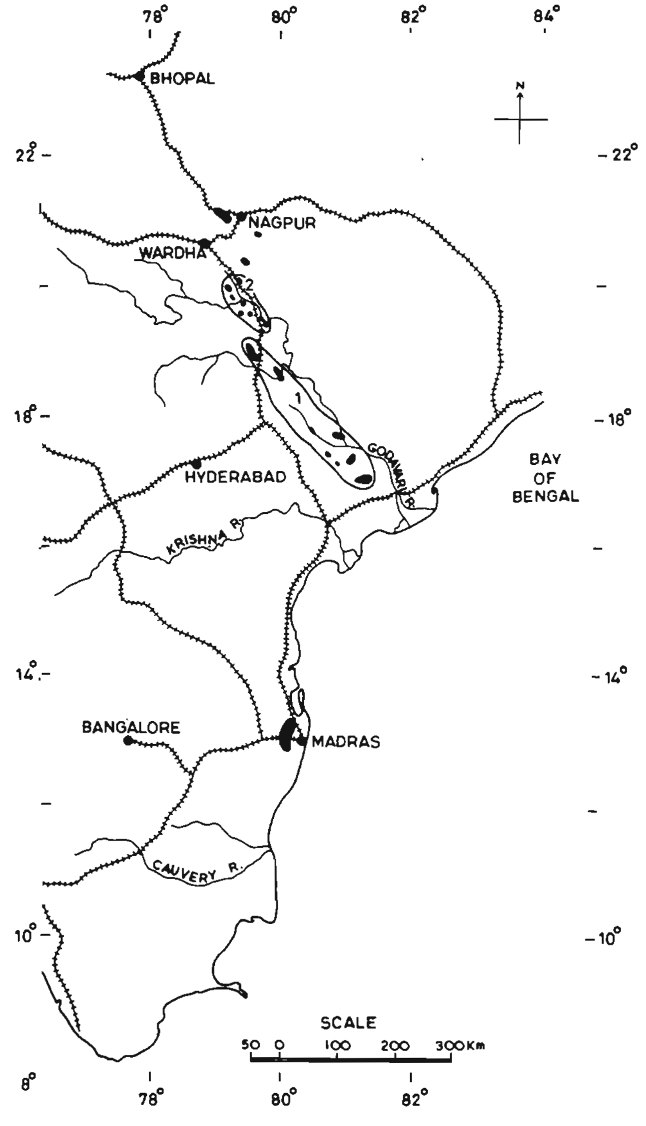
MATERIAL AND METHOD

The material has been obtained from bore-hole GGK-20 and GGK-27 in Ramagundam-Mantheni area of Godavari Graben. About 40 samples from these bore-holes representing Lower and Middle members of the Kamthi Formation were macerated. The samples containing silica were first treated with hydrochloric acid and hydrofluoric acid followed by nitric acid and KOH, if necessary. The samples have yielded a rich palynoflora. The details of the samples have been given in Tables 1 and 2. Location of the bore-holes has been shown in Map 2.

OBSERVATIONS

The sediments of Kamthi Formation have been studied from the subsurface of Ramagundam area where it attains maximum thickness in Godavari Graben. The sporae dispersae have been assigned to following 53 genera :

Laevigate trilete—*Callumispora.*
Apiculate trilete—*Lophotriletes, Horriditriletes, Osmundacidites, Verrucosisporites, Microbaculispora, Brevitriletes.*
Cingulate/Zonate trilete—*Gondisporites, Lundbladispora*
Monolete—*Laevigatosporites, Polypodiidites*
Alete monosaccate—*Densipollenites*
Radial monosaccate—*Parasaccites, Virkkipollenites,*



Map 1—Location map of Pranhita-Godavari Valley coalfields.

Caheniasaccites, Potonieisporites, Striomonosaccites
Nonstriate-disaccate—*Platysaccus, Alisporites, Vitreisporites, Falcisporites, Vesicaspora, Paravesicaspora, Aurangapollenites, Ibisporites, Scheuringipollenites, Cuneatisporites*
Reticuloid disaccate—*Primuspollenites, Schizopollis*
Striate-disaccate—*Striatites, Circumstriatites, Lahirites, Faunipollenites, Striatopodocarpites, Crescentipollenites, Verticipollenites, Hindipollenites, Distriatites, Strotersporites*
Taeniate disaccate—*Lunatisporites, Corisaccites, Guttulapollenites, Hamiapollenites*
Colpate—*Weylandites, Striasulcites, Marsupipollenites, Praecolpatites, Pretricolpipollenites, Distriamonocolpites*
Alete—*Leiosphaeridia, Pilasporites, Inaperturopollenites, Singraulipollenites*

The qualitative and quantitative distribution of various palynotaxa have been evaluated and it has been found that *Densipollenites, Faunipollenites, Striatopodocarpites, Striasulcites, Scheuringipollenites, Alisporites, Falcisporites* and *Vesicaspora* show characteristic variation at various levels of the Kamthi Formation.

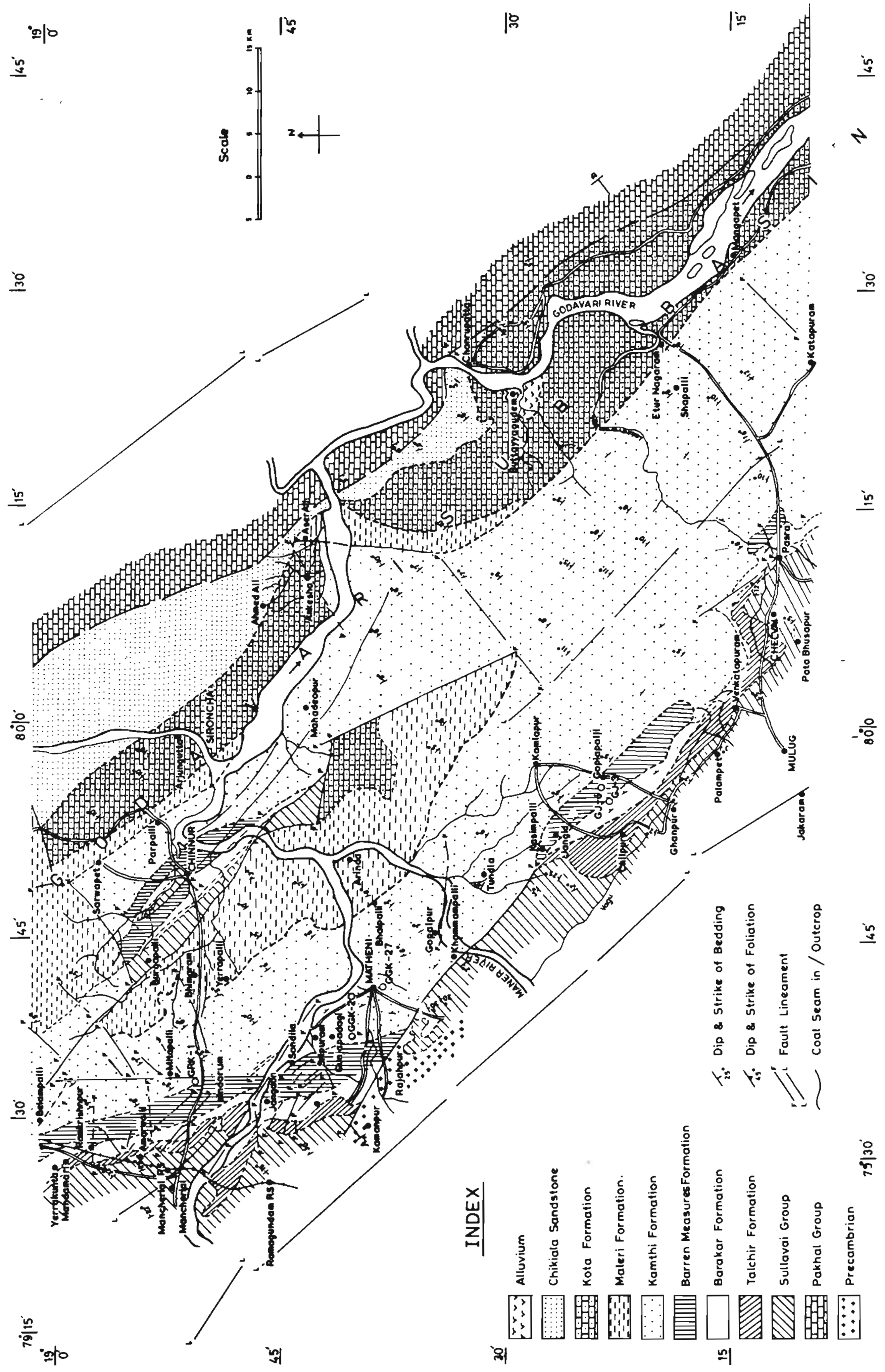
The trend of occurrence of palynofossils in two bore-holes studied has been given below. Out of the two bore-holes, GGK-27 has yielded more diversified palynoflora and has been described first.

Bore-hole no. GGK-27, Ramagundam-Mantheni Area (Map 1, sample nos. 32-1, depth 841-54.0 m, Histogram 1)—This bore-hole was drilled near Mantheni Village south-east of Ramagundam Railway Station. It has penetrated through the Middle and Lower members of the Kamthi Formation and was closed at 851.15 m.

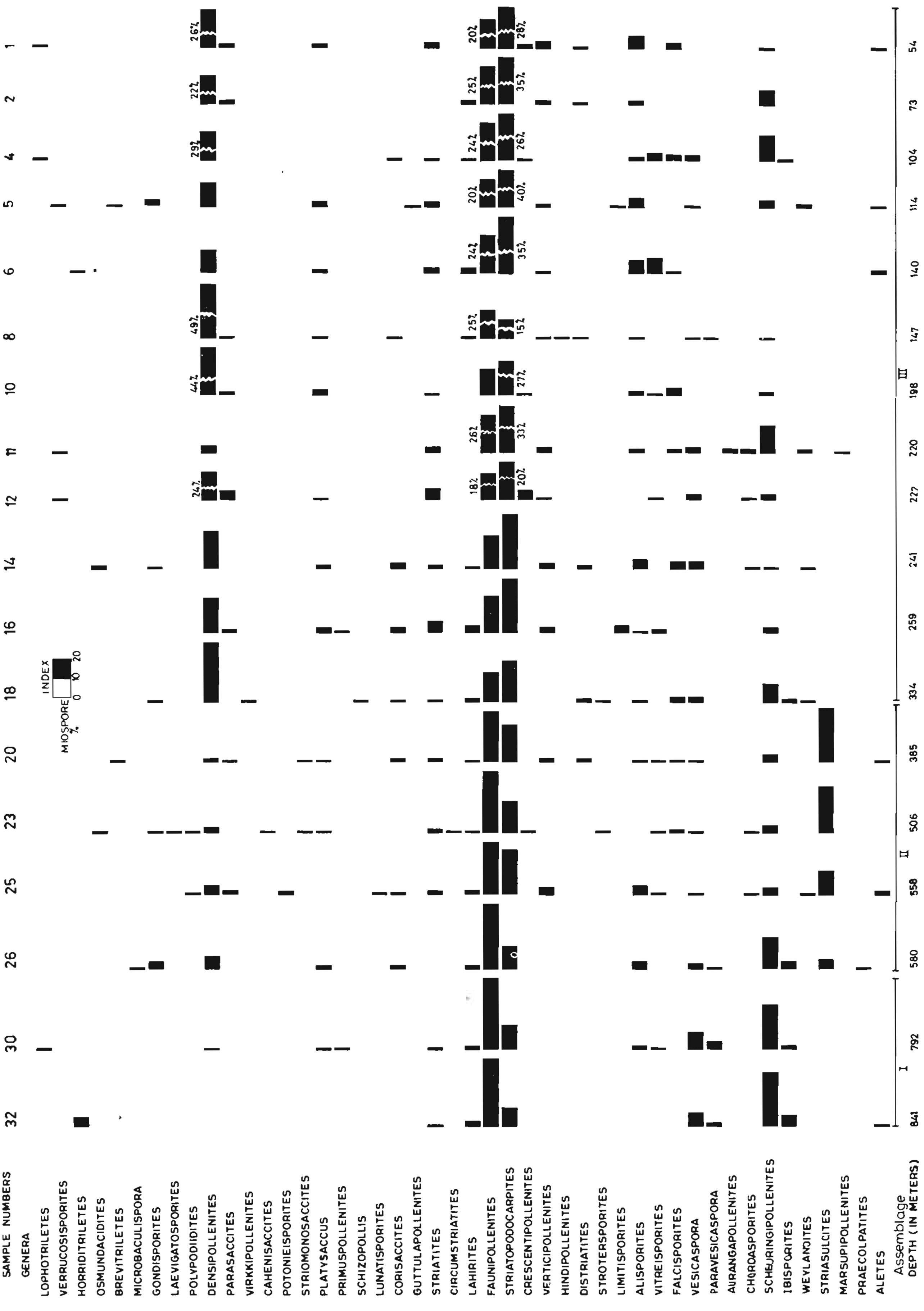
The Lower Member is coal-bearing containing the workable Sondila coal seam. Quantitatively, the older sediments (sample nos. 32, 30) are characterised by the abundance of striate-disaccates, chiefly *Faunipollenites* (36 to 38%). Nonstriate-disaccate *Scheuringipollenites* (24 to 29%) occurs next in order of dominance. *Striatopodocarpites* (10 to 13%) ranks next to the above and is followed by *Vesicaspora* (9-14%). Other disaccates represented are *Striatites* (1%), *Lahirites* (2-3%), *Vitreisporites* (1%), *Platysaccus* (1%) and *Primuspollenites* (1%). Triletes are quite low in percentage and are represented by *Horriditriletes* and *Lophotriletes.*

In comparatively younger sediments (sample nos. 26 to 1) representing the Middle Member of the Kamthi Formation, the overall dominance of striate-disaccates is maintained. *Striatopodocarpites* increases in the younger sequence and ultimately increases over *Faunipollenites. Scheuringipollenites* which was associated subdominantly in the Lower Member of the Kamthi Formation is reduced considerably in these sediments. *Striasulcites* on the other hand appears for the first time in sample no. 26 (5%) and increases to its maximum (29%) in sample no. 20 to represent the subdominant taxon next to *Faunipollenites.* In further younger samples *Striasulcites* disappears.

Densipollenites, already having made its appearance in sample no. 30, attains dominance in sample no. 18. The epibole of this genus with its maximum percentage (44-49%) lies in sample nos. 10 (198 m) and 8 (148 m). Though it shows a decline in younger sediments, still maintains subdominance. *Faunipollenites* on the other hand records a decline from sample no. 18 giving way to *Striatopodocarpites* which overrides ultimately in younger samples. The percentage frequencies of *Alisporites, Vitreisporites, Falcisporites, Vesicaspora, Paravesicaspora, Chordasporites, Gondisporites,*



Map 2—Geological map of Pranhita-Godavari Valley coalfields showing location of bore-holes GGK-20 and GGK-27.



Histogram 1—Showing percentage frequency of miospores genera in bore-hole GGK-27.

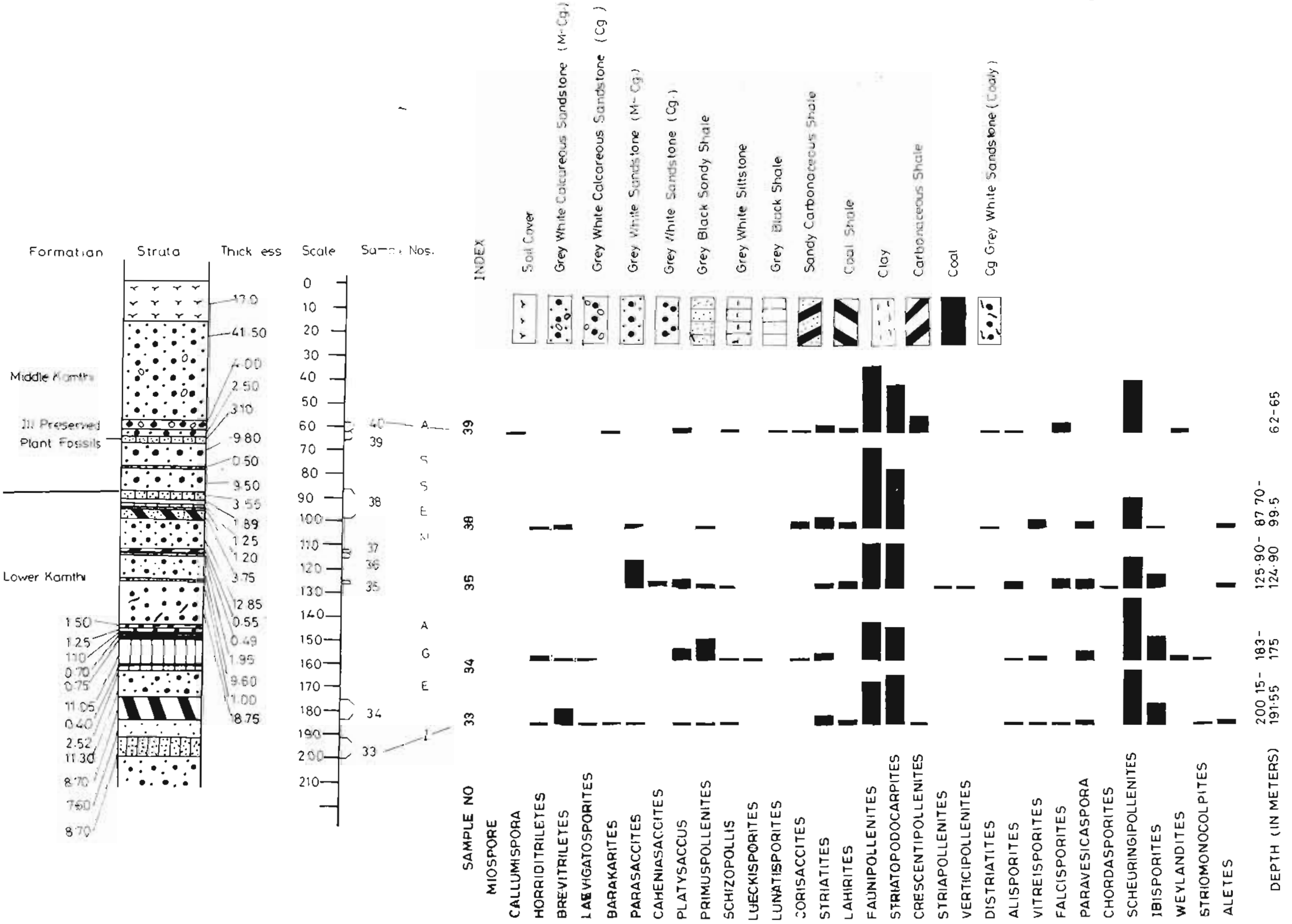
Polypodiidites, Osmundacidites, Crescentipollenites, Verticipollenites, Hindipollenites, Lunatisporites, Corisaccites and *Guttulapollenites* are quite low but these are persistent in occurrence, hence, significant. In general, the triletes are low in percentage.

Bore hole GGK-20, Ramagundam Area (Map 1, sample Nos. 33-40, depth 191-55-58.50 m, Histogram 2)—It was drilled north-west of the bore-hole GGK-27. This bore-hole also traversed the Lower and Middle members of the Kamthi Formation up to approximately 200 m. Further below, the sediments represent the Barren Measures Formation. In this sequence the sediments, appertaining lithologically to the Middle Member of the Kamthi Formation, show the continuation of Lower Kamthi palynoflora. Sample nos. 33 to 39 have yielded a palynoflora dominated by striate-disaccates. *Faunipollenites* (16-34%) and *Striatopodocarpites* (14-25%) together maintain the overall dominance although *Scheuringipollenites* records a higher percentage in sample nos. 33 and 34. *Primuspollenites* is present up to 9 per cent in sample no. 9 only and similarly *Parasaccites* is present up to 12 per cent in sample no. 35. Other notable genera, rare but persistent in occurrence, are *Lunatisporites* (0-1%), *Corisaccites* (1-3%), *Vitreisporites* (1-4%), *Falcisporites* (1-4%), *Crescentipollenites* (1-7%), *Chordasporites* (0-1%) and *Alisporites* (1-3%). Triletes are poorly represented.

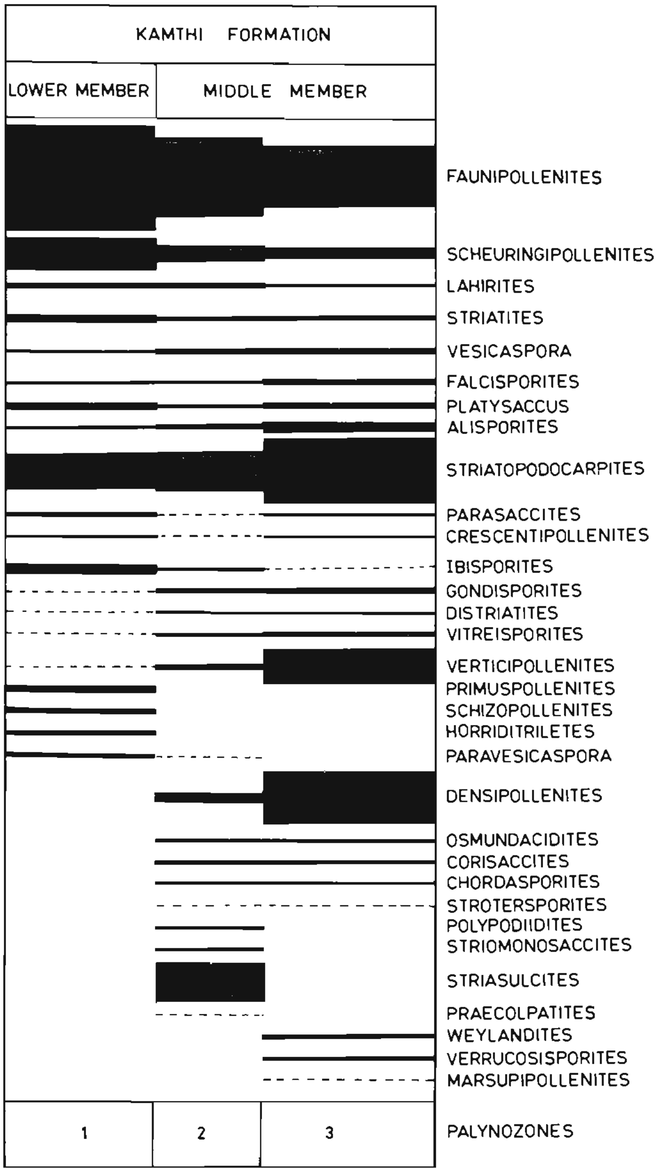
PALYNOASSEMBLAGES

The quantitative and qualitative distribution of palynotaxa as discussed here shows that the palynological succession within the Kamthi Formation has undergone two changes, one between the Lower and Middle Members and the other within the Middle Member. In this way the palynoflora is divisible into the following three assemblages (Text-fig. 1).

Assemblage I—It is characterised by the dominance of striate-disaccates chiefly *Faunipollenites* and *Striatopodocarpites*; *Scheuringipollenites* remains as subdominant element. *Densipollenites* is very low or virtually absent in this assemblage. An important feature of the assemblage is appearance of elements like *Alisporites, Falcisporites, Vitreisporites, Lunatisporites, Corisaccites, Chordasporites* and *Crescentipollenites*. These elements are rare but ± persistently present throughout the assemblage. Triletes are quite low in percentage.



Histogram 2—Showing percentage frequency of miospore genera in bore-hole GGK-20.



Text-figure 1—Showing average distribution of various taxa in Kamthi Formation, Ramagundam area, Godavari Graben.

In bore-core of hole GGK-27, Assemblage I has been encountered in samples 32 and 30 from the levels of 841 m and 792 m respectively. According to the stipulation of one of us (Ramanamurthy) Lower Member of the Kamthi Formation starts unlikely (or ends) at 776.70 m. In the bore-core of the hole GGK-20 the youngest productive sample containing Assemblage I comes from 62.00-65.00 m level out of a dark greenish grey, medium to coarse grained argillaceous sandstone and the oldest from 200.15 m level. This sequence of strata as well as about 50 m of micaceous and calcareous sandstone topping may be considered as the zone of Assemblage I. However, this does not conform with the lithological separation of top 87.97 m strata as Middle Member of the Kamthi Formation.

Assemblage II—This is also characterised by the dominance of striate-disaccates among which *Faunipollenites* is more than *Striatopodocarpites. Scheuringipollenites* being subdominant in the beginning loses place to *Striasulcites* which is restricted to this zone only. Although *Densipollenites* also appears simultaneously in this assemblage, it remains low in percentage. *Falcisporites, Vesicaspora, Paravesicaspora, Vitreisporites, Chordasporites, Gondisporites, Polypodiidites, Osmundacidites, Crescentipollenites, Verticipollenites* and *Lunatisporites* though low in percentage, are persistent in occurrence and hence significant. Triletes are low in percentage. Important feature of this assemblage is the presence of *Striasulcites* in high percentage and *Densipollenites* in low percentage.

In the hole GGK-27, the oldest evidence of Assemblage II is found at 580 m level; the three samples (29-27) from the underlying strata up to 776.60 m do not yield any palynoflora. The youngest occurrence of this assemblage is known from 385 m level. With the oldest occurrence of Assemblage III recorded from sample no. 18 at 334 m the upper limit of Assemblage II should lie between 385 and 334 m levels. At 366.70 m level there is a lithological change (Histogram 1) which could as well be the level of assemblage change.

Assemblage III—In this assemblage the general dominance of striate-disaccates remains unaltered but *Striatopodocarpites* mostly exceeds *Faunipollenites* presumably at the cost of the latter. *Densipollenites* increases to overall subdominance which is collated with the total exit of *Striasulcites.* Genera like *Alisporites, Vitreisporites, Falcisporites, Vesicaspora, Paravesicaspora, Chordasporites, Verticipollenites, Lunatisporites, Guttulapollenites* and *Hindipollenites* increase only slightly. These pollen grains are low in percentage but are persistent in occurrence. Trilete spores are also low in occurrence.

Assemblage III is observed in whole of the sequence overlying 366.70 m and up to 54 m depth from the surface. There is no lithological uniqueness in 43 m thick overlying strata. Hence, presumably the Assemblage Zone III continues right up to the surface soil cover.

COMPARISON

Assemblage I compares very well with the palynoflora of Jhingurdah Seam in Singrauli Coalfield (Tiwari & Srivastava, 1984) both having younger elements like *Falcisporites, Gondisporites, Lunatisporites* and *Corisaccites* besides dominant striate-disaccates and subdominant nonstriate-disaccates (excluding percentages of cryptogamic

Table 1—Showing details of samples, limits and characters of assemblages and biozones in bore hole GGK-27 (*Sample numbers with asterisk denotes yielding samples which could be counted).

Sample	Depth	Lithology	Lithological succession	Assemblage	Characteristic forms	Remark	Biozones
1*	54	Green sandstone					
2*	73	Carb. shale					
3*	85	Carb. shale					
4*	104	Carb. Shale					
5*	114	Carb. shale					
6*	140	Carb. shale		III	*Striatopodocarpites, Faunipollenites, Densipollenites* (high), rare forms like *Alisporites, Falcisporites, Lunatisporites Chordasporites Guttulapollenites* etc.	*Densipollenites* Phase	Upper part of Middle Member
7	147	Greenish siltstone					
8*	156	Carb. shale					
9	188	Carb. shale					
10*	198	Carb. shale	KAMTHI FORMATION				
11*	220	Grey shale					
12*	222	Grey shale					
13	240	Grey shale slightly micaceous					
14*	241	Carb. shale slightly micaceous	MIDDLE MEMBER				
15	248	Grey shale					
16*	259	Grey shale		II	*Faunipollenites, Striatopodocarpites, Densipollenites* (low) *Striasulcites* + Rare forms like *Falcisporites, Vesicaspora, Chordasporites, Gondisporites Osmundacidites, Polypodiidites* etc.	*Striasulcites* Phase	Lower part of Middle Member
17	306	Greenish shale					
18*	334	Carb. shale					
19	357	Grey shale					
20*	385	Grey siltstone slightly micaceous					
21	420	Carb. shale					
22	450	Slightly greenish siltstone					
23*	506	Carb. shale					
24	525	Grey siltstone					
25*	558	Greenish siltstone					
26*	580	Carb. shale					
27	625	Grey siltstone					
28	650	Carb. shale	LOWER MEMBER	I	*Faunipollenites, Striatopodocarpites* + *Scheuringipollenites* + Rare forms like *Alisporites, Falcisporites, Chordasporites, Lunatisporites* etc.	Striate disaccate rich phase Appearance of rare forms	Lower Member
29	749	Carb. shale					
30*	792	Carb. shale					
31	793	Carb. shale					
32*	841	Carb. shale					

Table 2—Showing details of samples, limits and characters of assemblages and biozones in bore hole GGK-20 (*Sample numbers with asterisk denotes yielding samples which could be counted).

Sample no.	Depth	Lithology	Lithological succession	Assemblage	Characteristic forms	Remark	Biozone
40	62.50-58.50	Coarse grained grey white Calc. sst.	MIDDLE				
39*	65-62	Dark greenish grey micaceous arg. sst.	KAMTHI FORMATION				
38*	99.5-87.70	Grey Carb. shale			*Faunipollenites* + *Stripatopodocarpites* + *Scheuringipollenites* + Rare forms like *Falcisporites, Vitreisporites, Lunatisporites, Corisaccites Chordasporites* & *Crescentipollenites*	Absence of Middle Member *Densipollenites*	
36	112-113	Coal					
37	113-115	Shale	LOWER				
35*	124.90-125.90	Grey shale					
34*	175-183	Coal fine grained micaceous sst. with Coal lenticles.					
33*	191.55-200.15	Grey black, Coaly & Sandy shale					

spores in Jhingurdah Seam). *Densipollenites* is characteristically almost absent in both.

Assemblage I can also be compared with the Raniganj palynoflora of Auranga Coalfield (Lele & Srivastava, 1979), Assemblage I of bore-hole RAD-2 (Singh & Tiwari, 1982), Assemblage 2 of bore-hole RNM-3 (Rana & Tiwari, 1980) and Assemblage II of bore-hole RNM-2 (Tiwari & Rana, 1984) from East Raniganj Coalfield in having dominant striate-disaccates. However, some younger forms which appear in Lower Kamthi Member of Godavari Valley are absent. Besides, *Densipollenites* is positively better represented in Assemblage-2 of RNM-3 and Assemblage II of RNM-2 in East Raniganj Coalfield.

The association of *Striasulcites* (Assemblage II) with dominant striate-disaccates has not been reported so far from any other coalfield excepting the Hutar Coalfield (Shukla, 1983). But therein *Striasulcites* is associated with the dominance of *Scheuringipollenites* and it has been recovered from upper part of Barakar Formation. The positive presence of *Densipollenites* in this assemblage is very significant.

Assemblage III, i.e. *Densipollenites* rich phase of Kamthi Formation in Godavari Graben bears a close correspondence with Assemblage 3 of bore-hole RNM-3 (Rana & Tiwari, 1980), with Assemblage III of bore-hole RAD-2 (Singh & Tiwari, 1982), with Group I of bore-hole RAD-5, with Group A of bore-hole RAD-4 (Tiwari & Singh, 1983) and Assemblage III of bore-hole RNM-2 (Tiwari & Rana, 1984) in East Raniganj Coalfield in having dominant striate-disaccates, high percentage of *Densipollenites* and presence of younger forms such as *Lunatisporites, Chordasporites, Klausipollenites, Alisporites, etc. Densipollenites* rich palynoflora of Upper Raniganj is also known from Nonia Nala (Banerji & Maheshwari, 1974), Noniakhal and Machkanda Jhore in Raniganj Coalfield (Bharadwaj, Tiwari & Anand-Prakash, 1979) and from Gopad River (Maheshwari, 1967). Thus, *Densipollenites* appears as one of the significant elements of palynoflora during the Middle Member of Kamthi Formation in Godavari Graben as is also known from upper part of Raniganj Formation of Damodar Basin. But the genera having younger aspect are relatively better represented in Godavari Graben than in other known *Densipollenites* rich assemblages in Damodar Basin—a condition similar to that in Bijori Formation of Satpura Gondwana Basin (Bharadwaj, Tiwari & Anand-Prakash, 1978). The present palynoflora also shows paucity of trilete spores while in Damodar Valley triletes are comparatively higher in representation in the Raniganj Formation.

COMPARISON OF PALYNODATA WITH LITHODATA

Bore-hole GGK-20—Lithologically, the Lower Member of Kamthi Formation in bore-hole GGK-20 has been marked between 200.15 to 87.90 m levels and Middle Member above this level (Histogram 2). But the palynoflora shows no change in the sequence and thus palynologically the whole sedimentary sequence in bore-hole GGK-20 above 200.15 m belongs to Lower Member of the Kamthi Formation. Lithologically also, the beds above 87.90 m level do not exhibit appreciable difference but for lack of coaly facies. However, the occurrence of plant fossils at 68.10 m level suggests that carbonaceous nature continued well above the coaly facies.

PLATE 1

→

(All photomicrographs magnified × 500)

1. *Guttulapollenites hannonicus*, negative no. 32/9, slide no. BSIP 9324; Coordinates 104 × 12.6
2. *Hamiapollenites* sp., negative no. 26/14, slide no. BSIP 9325; Coordinates 7.6 × 108.3
3. *Lueckisporites* sp., negative no. 32/14, slide no. BSIP 9334; Coordinates 89.5 × 17.5
4. *Chordasporites australiensis*, negative no. 21/20, slide no. BSIP 9330; Coordinates 3.4 × 103.0
5. *Paravesicaspora nilssoni*, negative no. 37/6, slide no. BSIP 9336; Coordinates 12.6 × 90.0
6. *Falcisporites nuthallensis*, negative no. 28/21, slide no. BSIP 9329; Coordinates 19.2 × 96.4
7. *Crescentipollenites densus*, negative no. 27/28, slide no. BSIP 9331; Coordinates 106 × 13.3
8. *Lunatisporites ovatus*, negative no. 22/10, slide no. BSIP 9332; Coordinates 113.9 × 11.5
9. *Striasulcites ovatus*, negative no. 37/3, slide no. BSIP 9338; Coordinates 3.0 × 82.7
10. *Lueckisporites microgranulatus*, negative no. 23/7, slide no. BSIP 9327; Coordinates 10.7 × 84.8
11. *Strotersporites* sp., negative no. 37/11, slide no. BSIP 9339; Coordinates 13.7 × 93.9
12. *Strotersporites crassiletus*, negative no. 37/1, slide no. BSIP 9340; Coordinates 13.3 × 83.2
13. *Densipollenites kamthiensis*, negative no. 24A/7, slide no. BSIP 9324; Coordinates 10.3 × 100.0
14. *Verticipollenites debilis*, negative no. 35/3, slide no. BSIP 9328; Coordinates 2.8 × 91.0
15. *Vitreisporites pallidus*, negative no. 28/35, slide no. BSIP 9324; Coordinates 19.8 × 95.7
16. *Striatopodocarpites multistriatus*, negative no. 20B/8, slide no. BSIP 9329; Coordinates 19.0 × 98.7

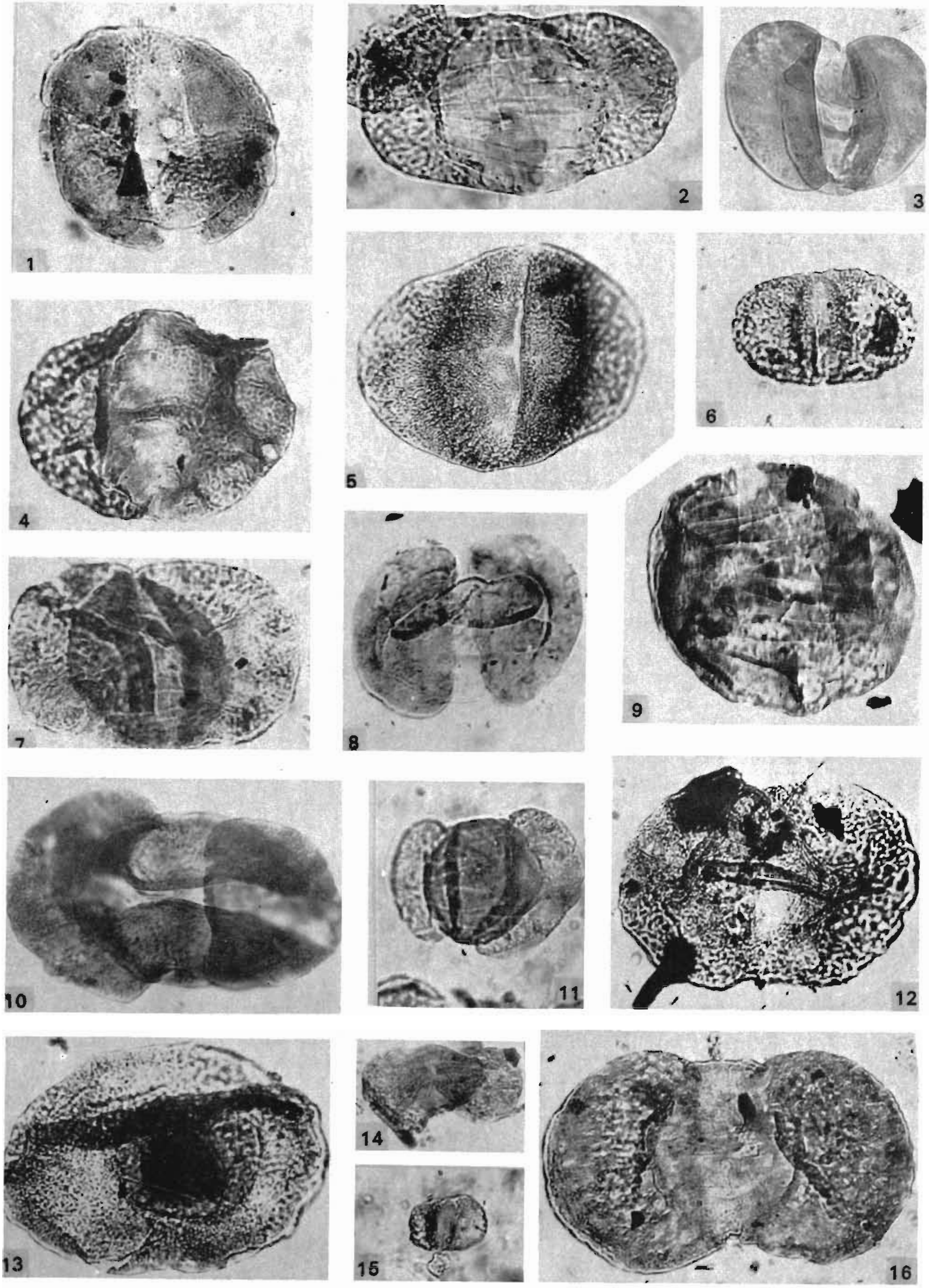


PLATE 1

Bore-hole GGK-27—The samples of bore-hole GGK-27 lithologically belong to Kamthi Formation. The boundary between the Lower and Upper members of the Kamthi Formation has been marked at 776.70 m in bore-hole GGK-27. But Lower Kamthi palynoflora has been observed up to 792 m. The actual upper limits of the palynoflora is not known but could well have extended to 776.70 m level as lithologically stipulated. Thus, the palynodata corresponds with the lithodata. Assemblages II and III represent palynoflora of Middle Member of the Kamthi Formation. Assemblage II represents lower part while Assemblage III represents upper part of Middle Member in bore-hole GGK-27.

DISCUSSION

The Kamthi Formation of Wardha-Godavari Valley coalfields has been correlated with the Raniganj Formation of Damodar Basin on the basis of plant fossils. Hughes (1877) considered them to represent a time equivalent of the upper part of Damuda Series and a part of Panchet Formation of Damodar Basin. This contention has been corroborated by the present palynological investigation.

The palynological investigations carried out in the bebehhhhhhhRamagundam area show a close resemblance with the palynoflora of the Raniganj Formation of Damodar Valley. The entire sequence shows the dominance of striate-disaccate pollen grains. The Lower Member of the Kamthi Formation which contains a workable coal seam, has been lithologically identified between 851.15 to 776.70 m in the bore-hole GGK-27 and between 87.90 to 200.15 m from the surface in the bore-hole GGK-20. With the beginning of the Middle Member of the Kamthi Formation the carbonaceous sediments disappear and an uninterrupted sequence of alternating medium to coarse-grained grey-white sandstone, shales and clays predominates. Palynologically, the lower part of Middle Member (between 776.70-366.70 m in bore-hole GGK-27) is characterised by association of high *Striasulcites* + striate-disaccates + low *Densipollenites*. In the overlying sequence *Striasulcites* vanishes and *Densipollenites* attains dominance. This youngest assemblage is known to occur between 54-334 m and palynologically corresponds with the upper part of Raniganj Formation in the Damodar basin.

At specific level it has been found that the palynoflora of Middle Member of the Kamthi Formation is much more diversified than that of Lower Member. Few species of *Densipollenites* are present only in Middle Member, viz., *D. magnicorpus*, *D. brevis*, *D. kamthiensis* and *D. marginalis* (Srivastava & Jha, MS). Besides, *Striasulcites ovatus*, *S. tectus* and *Strotersporites crasseletus* (Srivastava & Jha, MS) are restricted to Middle Member of the Kamthi Formation only. The distribution of different species is as follows :

SPECIES	LOWER KAMTHI	MIDDLE KAMTHI
Lophotriletes rectus	+	+
Gondisporites sp.		+
Verrucosisporites surangei Maheshwari & Banerji 1970		+
Horriditriletes ramosus (Balme & Hennelly) Bharadwaj & Salujha 1964	+	+
H. rampurensis Tiwari 1968	+	+
Microbaculispora tentula Tiwari 1965	+	+
Brevitriletes communis Bharadwaj & Srivastava emend. Tiwari & Singh 1981	+	+
B. unicus (Tiwari) Bharadwaj & Srivastava emend. Tiwari & Singh 1981	+	+
Osmundacidites senectus Balme 1963		+
O. pilatus Tiwari & Rana 1981		+
Laevigatosporites colliensis (Balme & Hennelly) Venkatachala & Kar 1968	+	+
Polypodiidites perverrucatus Couper 1953		+
Praecolpatites sinuosus (Balme & Hennelly) Bharadwaj & Srivastava 1969		+
Callumispora tenuis Srivastava 1969	+	+
Densipollenites indicus, Bharadwaj 1962		+
D. invisus Bharadwaj & Salujha, 1964		+
D. densus Bharadwaj & Srivastava 1969		+
D. minimus Venkatachala & Kar 1968		+
D. brevis Lele & Srivastava 1977		+
D. sp. cf. *D. brevis* Lele & Srivastava 1977		+
D. magnicorpus Tiwari & Rana 1981		+
D. sp. cf. *D. magnicorpus* Tiwari & Rana 1981		+
D. kamthiensis Srivastava & Jha (MS)		+
D. marginalis Srivastava & Jha (MS)		+
Densipollenites sp.		+
Tiwarisporis novus Bharadwaj & Dwivedi 1981		+
Weylandites minutus Bharadwaj & Srivastava 1969	+	+
W. circularis Bharadwaj & Srivastava 1969	+	+
W. obscurus (Tiwari) Bharadwaj & Dwivedi 1981	+	+
Vesicaspora luteus Salujha 1965		+
Parasaccites korbaensis Bharadwaj & Tiwari 1964	+	+
P. obscurus Tiwari 1965	+	+
P. distinctus Tiwari 1965	+	+
P. diffusus Tiwari 1965	+	+
P. bilateralis Tiwari 1965	+	+
P. densus Maheshwari 1967	+	+
P. talchirensis Lele & Makada 1972	+	+
Virkkipollenites orientalis Tiwari 1968		+
Lueckisporites sp.		+
Guttulapollenites hannonicus Goubin 1965		+
Lunatisporites diffusus Bharadwaj & Tiwari 1977		+
Lunatisporites sp.		+
Corisaccites alutus Venkatachala & Kar, 1966	+	+
C. distinctus Venkatachala & Kar 1968	+	+
Hamiapollenites sp.		+
Striatites communis Bharadwaj & Salujha 1964	+	+
S. solitus Bharadwaj & Salujha 1964	+	+
S. tentulus Tiwari 1965	+	+
Striatites sp.	+	+

Labirites rarus Bharadwaj & Salujha 1964	+	+
L. singularis Bharadwaj & Dwivedi 1981	+	+
L. karanpuraensis Bharadwaj & Dwivedi 1981	+	+
L. levicorpus Tiwari 1968		+
L. rhombicus Maithy 1965		+
Verticipollenites gibbosus Bharadwaj 1962	+	+
V. debilis Venkatachala & Kar 1968		+
V. finitimus Bharadwaj & Salujha 1964		+
V. crassus Bharadwaj & Salujha 1964	+	+
Verticipollenites sp.		+
Hindipollenites indicus Bharadwaj 1962		+
H. globosus Kar 1968a		+
H. sp. cf. *H. rajmahalensis*		+
Striatopodocarpites tiwari Bharadwaj & Dwivedi 1981	+	+
S. globosus (Maheshwari) Bharadwaj & Dwivedi 1981	+	+
S. brevis Sinha 1972	+	
S. diffusus Bharadwaj & Salujha 1964	+	+
S. rotundus (Maheshwari) Bharadwaj & Dwivedi 1981	+	+
S. decorus Bharadwaj & Salujha 1964	+	+
S. labrus Tiwari 1965	+	+
S. subcircularis Sinha 1972	+	+
Striatopodocarpites sp.	+	+
Faunipollenites parvus Tiwari 1965	+	+
F. goraiensis (Potonié) Lele & Maithy 1965	+	+
F. copiosus Bharadwaj & Salujha 1965	+	+
F. varius Bharadwaj, 1962	+	+
F. bharadwajii Maheshwari 1967	+	+
F. singrauliensis Sinha 1972	+	+
F. gopadensis Bharadwaj & Srivastava 1969	+	
Faunipollenites sp.		+
Strotersporites crassiletus sp. nov. Srivastava & Jha (MS)		+
Strotersporites sp.		+
Striapollenites monosaccoides Tiwari & Rana 1981		+
Distriatites insolitus Bharadwaj & Salujha 1964	+	+
D. distinctus Sinha 1972	+	+
Distriatites sp.		+
Rhizomaspora indica Tiwari 1965		+
R. monosulcata Tiwari 1968	+	
Primuspollenites levis Tiwari 1964	+	+
Schizopollis extremus Venkatachala & Kar 1964		+
Striasulcites tectus Venkatachala & Kar 1968		+
S. ovatus Venkatachala & Kar 1968		+
Distriamonocolpites circularis Sinha 1972		+
Crescentipollenites barakarensis (Sinha) comb. nov.		+
C. fusus (Bharadwaj) Bharadwaj, Tiwari & Kar 1974	+	+
C. gondwanensis (Maheshwari) Bharadwaj, Tiwari & Kar 1974	+	+
C. talchirensis (Lele) comb. nov.		+
C. densus Srivastava & Jha (MS)		+
Circumstriatites ovatus Lele & Makada 1972	+	
C. obscurus Lele & Makada 1972	+	
Marsupipollenites fasciolatus Balme & Hennelly 1956		+
Pretricolpipollenites bharadwajii Balme 1970		+
Potonieisporites neglectus Potonié & Lele 1961		+
Scheuringipollenites maximus (Hart) Tiwari 1973	+	+
S. minutus (Sinha) Bharadwaj & Dwivedi 1981		+
S. barakarensis (Tiwari) 1973	+	+
S. tentulus (Tiwari) Tiwari 1973	+	+
Ibisporites jhingurdahiensis Sinha 1972	+	+
Alisporites indarraensis Segroves 1969	+	+
A. landianus Balme 1970	+	+
Chordasporites australiensis de Jersey 1962	+	+
Cuneatisporites royaliensis Saxena 1971		+
Falcisporites nuthallensis (Clark) Balme 1970	+	+
Paravesicaspora ovata (Balme & Hennelly) Bharadwaj & Dwivedi 1981	+	+
P. brevis (Sinha) Bharadwaj & Dwivedi 1981		+
Aurangapollenites gurturiensis Srivastava 1977		+
Vitreisporites pallidus (Reissinger) Balme 1970	+	+
Pilasporites sp.	+	+
Inaperturopollenites nebulosus Balme 1970	+	+
Singraulipollenites indicus Sinha 1972	+	+
S. finitimus Sinha 1969	+	+

Lithologically, both the sequences are devoid of coal-bearing sediments and present a monotonous sequence of sandstone, shale and clay. However, the sandstones of the Middle Member of the Kamthi Formation show a greenish tint more frequently in the upper part of the sequence. It is also interesting to note that the upper part of the Middle Member in GGK-27 shows a declining trend in the genus *Densipollenites.* Further, the presence of *Verrucosisporites, Osmundacidites, Polypodiidites, Vitreisporites* and *Falcisporites* becomes more frequent in this zone and thus heralds the incoming of the younger, the Panchet, elements. It is probable that the Permian Period comes to a close somewhere not much above this palynozone of the Middle Member of the Kamthi Formation. If this presumption holds good the equivalent of Panchet Formation may be expected close to the present level of Assemblage III in Middle Member studied from the bore-hole GGK-27 in Ramagundam-Mantheni area of Godavari Graben.

CONCLUSION

The palynological investigations of the Kamthi Formation in Ramagundam-Mantheni area brought to light for the first time that the Lower and Middle members are characterised by three palynological assemblages with two breaks separating one assemblage restricted to Lower Member, one to older part of Middle Member and the third in the upper part of latter. Palynostratigraphically, these assemblages indicate a close resemblance with the Raniganj Formation of Damodar Basin except certain variations which are restricted to Godavari Graben. Further, it is reasonable to presume that the younger part of Middle Member and Upper Member of Kamthi Formation is homotaxial with the Panchet Formation of Damodar Basin in part or whole.

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Palynology of the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road Section, Jaintia Hills (Meghalaya) and Cachar (Assam). Part-VII. Discussion

H. P. Singh, M. R. Rao & R. K. Saxena

Singh, H. P., Rao, M. R. & Saxena, R. K. (1987). Palynology of the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road Section, Jaintia Hills (Meghalaya) and Cachar (Assam). Part-VII. Discussion. *Palaeobotanist* **35**(3) : 331-341.

The palynofloral assemblages from the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road Section, Meghalaya and Assam have been discussed and interpreted. The total assemblage consists of 68 genera and 113 species. Qualitative analysis of the assemblage reveals that Lycopodiaceae, Polypodiaceae, Matoniaceae, Hymenophyllaceae, Ophioglossaceae, Schizaeaceae, Cyatheaceae, Osmundaceae, Gleicheniaceae, Parkeriaceae, Podocarpaceae, Pinaceae, Palmae, Potamogetonaceae, Araceae, Oleaceae, Bombacaceae, Labiatae, Mimosaceae and Malvaceae are represented in the assemblage. The present day distribution of these families indicates the prevalence of mainly tropical-subtropical climate during the deposition of Barail-Surma sediments. The environment of deposition has been interpreted as coastal marine. Quantitatively, the pteridophytic spores constitute a major part (62%) of the assemblage followed by gymnospermous pollen grains (23%), angiospermous pollen grains (5.5%), dinoflagellate cysts (5%) and fungal remains (4.5%). A comparison of this assemblage with similar Oligocene-Lower Miocene assemblages of India has been made. The age of the sediments has also been discussed.

Key-words—Palaeopalynology, Tropical-subtropical climate, Barail-Surma Groups, Oligocene-Lower Miocene (India).

H. P. Singh, M. R. Rao & R. K. Saxena, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

जयन्तिया पहाड़ियों (मेघालय) एवं कछार (असम) में सोनपुर-बदरपुर मार्ग खंड के संग-संग विगोपित बैरेल (पश्चनूतन) एवं सूरमा (अधरि मध्यनूतन) अवसादों का परागाणविक अध्ययन. भाग 7–विवेचन

हरिपाल सिंह, मलागलापल्ली रामचन्द्र राव एवं रमेश कुमार सक्सेना

मेघालय एवं असम में सोनपुर-बदरपुर मार्ग खंड के संग-संग विगोपित बैरेल (पश्चनूतन) एवं सूरमा (अधरि मध्यनूतन) अवसादों से उपलब्ध परागाणुवनस्पतिजात की व्याख्या एवं विवेचन किया गया है। सम्पूर्ण समुच्चय में 68 प्रजातियाँ एवं 113 जातियाँ विद्यमान हैं। समुच्चय के गुणात्मक विश्लेषण से व्यक्त होता है कि इसमें लाइकोपोडिएसी, पोलिपोडिएसी, मेटोनिएसी, हाइमेनोफ़िल्लेसी, ओफ़िओग्लोसेसी, शाइजिएसी, स्याथिएसी, ओस्मुन्डेसी, ग्लाइकीनिएसी, पार्केरिएसी, पोडोकार्पेसी, पाइनेसी, पाल्मी, पोटेमोजिटोनेसी, अॅरेसी, ओलिएसी, बोम्बेकेसी, लेबिएटी, माइमोसेसी एवं माल्वेसी नामक कुल विद्यमान हैं। इन कुलों के वर्तमान वितरण से बैरेल-सूरमा अवसादों के निक्षेपण के समय मुख्यतया उष्णकटिबन्धीय-उपोष्णकटिबन्धीय जलवायु का होना इंगित होता है। निक्षेपण का वातावरण तटीय-समुद्री के रूप में प्रस्तावित किया गया है। टेरीडोफ़ाइटी बीजाणु भारात्मक दृष्टि से समुच्चय का प्रमुख भाग (62 प्रतिशत) हैं जिनके पश्चात् अनावृतबीजी परागकण (23 प्रतिशत), आवृतबीजी परागकण (5.5 प्रतिशत), घूर्णीकशाभ पुटीयाँ (5 प्रतिशत) तथा कवकीय अवशेष (4.5 प्रतिशत) क्रम में आते हैं। इस समुच्चय की तुलना भारत के सदृश पश्चनूतन-अधरि मध्यनूतन युगीन समुच्चयों से की गई है। इसके अतिरिक्त इन अवसादों की आयु भी विवेचित की गई है।

THE area under present study, i.e. Sonapur-Badarpur Road Section, is located in the southeast of Shillong, in Jaintia Hills (Meghalaya) and Cachar (Assam) districts and constitutes a part of the Shillong-Badarpur Highway (National Highway-44). Excellent sections of Barail (Oligocene) and Surma (Lower

Miocene) groups of geosynclinal facies are exposed along this section. The Barail Group of this area is divided into Laisong, Jenam and Renji formations. The Laisong Formation (1750 m thick) represents mainly arenaceous facies consisting of grey, very hard, thinly bedded, very fine to medium grained sandstones alternating with subordinate, hard, sandy shales. The Jenam Formation (850 m thick) is mainly argillaceous and consists of shales and sandy shales with fine to medium grained sandstones. The Renji Formation (800 m thick) is again arenaceous and is made up of thickly bedded or massive, fine to medium grained, hard, ferruginous sandstones alternated by thin shales. The Renji Formation is unconformably overlain by the Surma Group. This group is divided into Bhuban and Bokabil formations. The Bhuban Formation (1850 m thick) is further divided into Lubha, Umkiang and Dona members. The lower and upper members are mainly arenaceous whereas the middle member is argillaceous. The Bokabil Formation (150 m thick) is made up of thick sandy shales with alternations of very fine grained laminated sandstone. The lithostratigraphy of the section has been published by Saxena and Tripathi (1982).

Palynological study of the Barail and Surma sediments of this section has been carried out by Sein and Sah (1974), Rao (1983), Singh and Rao (1984), Saxena and Rao (1984), Rao *et al.* (1985), Singh *et al.* (1986), Rao (1986), Saxena *et al.* (1987) and Rao and Singh (1987). Based on the above work, the present paper deals with the qualitative and quantitative analyses of Barail-Surma palynoflora, its comparison with other similar palynoassemblages from India and interpretations regarding palaeoclimate, environment of deposition and age.

PALYNOFLORAL ASSEMBLAGE

Dinoflagellate Cysts

Polysphaeridium subtile Davey & Williams *in* Davey *et al.*, *Polysphaeridium* sp., *Impletosphaeridium insolitum* Eaton, *Adnatosphaeridium vittatum* Williams & Downie *in* Davey *et al.*, *Membranilarnacia donaensis* Saxena & Rao, *Cordosphaeridium inodes* (Klumpp) Eisenack emend. Morgenroth, *C. multispinosum* Davey & Williams in *Davey et al.*, *C. fibrospinosum* Davey & Williams in Davey *et al.*, *C. gracilis* (Eisenack) Davey & Williams in Davey *et al.*, *Operculodinium* sp. cf. *O. major* Jain & Dutta in Dutta & Jain, *Achomosphaera ramulifera* (Deflandre) Evitt, *A. sagena* Davey & Williams in Davey *et al.*, *Homotryblium floripes* (Deflandre & Cookson) Stover, *Homotryblium meghalayaensis* Saxena & Rao, *Tuberculodinium vancampoae* Rossignol) Wall emend. Wall & Dale, Dinocyst types 1, 2, 3, *Heliospermopsis* sp. (acritarch).

Fungal Remains

Phragmothyrites eocaenica Edwards emend. Kar & Saxena, *Phragmothyrites* sp., *Paramicrothallites menonii* Jain & Gupta, *Notothyrites setiferus* Cookson, *N. amorphus* Kar & Saxena, *N. padappakarensis* Jain & Gupta, *Parmathyrites ramanujamii* Singh *et al.*, *Kutchiathyrites* sp., *Lirasporis intergranifer* Potonié & Sah emend. Jain & Kar, *Inapertisporites ovalis* Sheffy & Dilcher, *I. miocenicus* Singh *et al.*, *Inapertisporites* sp., *Inapertisporites* sp. cf. *I. kedvesii* Elsik, *Dicellaesporites fusiformis* Sheffy & Dilcher, *Dicellaesporites* spp. A, B, *Multicellaesporites* spp. A, B, C, D, *Lacrimasporonites* sp., *Monoporisporites* sp., *Dyadosporonites grandiporus* Singh *et al.*, *Dyadosporonites* sp., *Diporisporites* sp., *Pluricellaesporites verrucatus* Singh *et al.*, *Pluricellaesporites* spp. A, B, *Pluricellaesporites* sp. cf. *P. alleppeyensis,* Ramanujum & Rao, *Diporicellaesporites verrucatus* Singh *et al.*, *Diporicellaesporites* spp. A, B, *Fusiformisporites* sp., *Frasnacritetrus* sp.

Pteridophytic Spores

Cyathidites australis Couper, *C. minor* Couper, *Lygodiumsporites lakiensis* Sah & Kar emend. Rao & Singh, *L. eocenicus* Dutta & Sah, *L. donaensis* Rao & Singh, *Todisporites major* Couper, *T. minor* Couper, *Biretisporites meghalayaensis* Rao & Singh, *B. oligocenicus* Rao & Singh, *Surmaspora sinuosa* Singh & Rao, *Gleicheniidites senonicus* Ross, *Dictyophyllidites indicus* Rao & Singh, Garotriletes sp., *Corrugatisporites* sp., *Foveotriletes* spp. A, B, *Foveosporites triangulus* Dutta & Sah, *F. miocenicus* Ramanujam, *Foveosporites* sp., *Lycopodiumsporites abundans* Salujha *et al.*, *Striatriletes susannae* van der Hammen emend. Kar, *S. sinuosus* Rao & Singh, *S. pachyexinus* Rao & Singh, *Malayaeaspora costata* Trivedi *et al.*, *Cingutriletes* sp., *Polypodiaceaesporites tertiarus* Sah & Dutta, *P. chatterjii* Kar, *Monolites major* (Cookson) Potonié, *Polypodiisporites favus* Potonié, *P. speciosus* Sah, *P. formosus* Salujha *et al.*, *P. tuberculensis* (Baksi) Rao & Singh.

Gymnospermous Pollen

Laricoidites punctatus Saxena, *Podocarpidites classicus* Salujha *et al.*, *Podocarpidites meghalayaensis* Rao, *Podocarpidites* sp., *Pinuspollenites foveolatus* Rao, *Piceapollenites* sp., *Abiespollenites surmaensis* Rao.

Angiospermous Pollen

Retipilonapites delicatissimus Ramanujam, *Verrualetes assamicus* Singh & Saxena, *Verrualetes* sp., *Assamiapollenites* sp., *Spinainaperturites* spp. A, B, *Palmidites maximus* Couper, *Couperipollis robustus* Saxena, *C. donaensis* Rao *et al.*, *C. ramanujamii* Rao *et al.*, *Couperipollis* sp. cf. *C. wodehousei* (Biswas) Venkatachala & Kar, *Proxapertites* sp., *Tricolpites* sp., *Verrutricolpites* sp., *Retitrescolpites* sp., *Trifossapollenites constatus* Dutta & Sah, *Bombacacidites inausus* Venkatachala & Rawat, *Echistephanocolpites meghalayaensis* Rao *et al.*, *Echistephanocolpites* sp. cf. *E. echinatus*, Wijmstra, *Gemmastephanocolpites* sp., *Triporopollenites* sp., *Stephanoporopollenites* sp., *Malvacearumpollis* sp., *Polyadopollenites sahii* Rao *et al.*

DISCUSSION

Pteridophytic spores and gymnospermous pollen are the dominant constituents of the Barail-Surma Assemblage while angiospermous pollen are comparatively poorly represented. Algal and fungal remains are also present. The qualitative and quantitative analyses of the palynofloral assemblage and its comparison with other known equivalent assemblages from India have been discussed.

Qualitative Analysis

THALLOPHYTA

The thallophytic remains are represented in the assemblage by dinoflagellate cysts (9 genera & 15 species), epiphyllous fungi and fungal spores (17 genera & 34 species).

PTERIDOPHYTA

Pteridophytic spores are richly represented in the Barail-Surma sediments of Sonapur-Badarpur Road Section. Their comparison with the extant flora indicates the presence of the following families :

Lycopodiaceae—Lycopodiumsporites abundans, *Foveotriletes* spp. A, B and *Foveosporites triangulus* are comparable to the spores found in some members of the family Lycopodiaceae. This family is represented in tropical to temperate regions and inhabits moist and shady places.

Polypodiaceae—This family is represented by *Monolites major, Polypodiaceaesporites tertiarus, P. chatterjii, Polypodiisporites favus, P. formosus, P. tuberculensis* and *P. speciosus.* The present day distribution of Polypodiaceae is cosmopolitan.

Matoniaceae—Dictyophyllidites indicus may be related to the fern family Matoniaceae.

Hymenophyllaceae—Biretisporites oligocenicus and *B. meghalayaensis* are doubtfully related to the family Hymenophyllaceae.

Ophioglossaceae—Foveosporites miocenicus is similar to the spores of some species of *Ophioglossum* of the family Ophioglossaceae.

Schizaeaceae—Lygodiumsporites lakiensis, L. eocenicus and *L. donaensis* compare with the spores of the family Schizaeaceae. It is chiefly distributed in tropical and subtropical regions.

Cyatheaceae—Cyathidites australis and *C. minor* are referable to this family. Plants of this family are mainly found in tropical and subtropical area.

Osmundaceae—Todisporites major and *T. minor* are referable to this family. Members of this family are found both in tropical and temperate regions, generally inhabiting damp woods and thickets.

Gleicheniaceae—Morphologically *Gleicheniidites senonicus* is comparable to the spores produced by some members of the family Gleicheniaceae. The members of this family chiefly grow in tropics.

Parkeriaceae—All the three species of *Striatriletes*, viz., *S. susannae, S. sinuosus* and *S. pachyexinus* seem to be related to *Ceratopteris* (Parkeriaceae). The genus *Ceratopteris* is a water fern of the tropical and subtropical regions.

GYMNOSPERMAE

Gymnospermous pollen grains are comparatively less represented in the assemblage than pteridophytic spores. These are referable to the following families :

Podocarpaceae—Podocarpidites classicus, P. meghalayaensis, and *Podocarpidites* sp. have close affinity with this family. The family is distributed in subtropical as well as temperate regions.

Pinaceae—Pinuspollenites foveolatus, Abiespollenites surmaensis, Piceapollenites sp. and *Laricoidites punctatus* are referable to the members of Pinaceae which is a temperate taxon.

ANGIOSPERMAE

The angiospermous pollen are not richly represented in the Barail-Surma assemblage, however, they form a significant group at certain levels. These are represented by the following families :

Palmae—Palmidites maximus, Couperipollis robustus, C. donaensis and *C. ramanujamii* are comparable to the pollen of Palmae. The distribution of this family is restricted to tropical and subtropical regions.

Potamogetonaceae—Retipilonapites delicatissimus is comparable to the pollen grains of Potamogetonaceae. This aquatic family is cosmopolitan.

Araceae—Proxapertites sp. resembles the pollen of Araceae. The family is chiefly tropical.

Oleaceae—This family appears to be represented by the pollen of *Retitrescolpites*. The family is restricted to tropical and warm temperate regions of the world.

Bombacaceae—Bombacacidites inausus is comparable to the pollen of Bombacaceae.

Labiatae—Trifossapollenites constatus, Echistephanocolpites meghalayaensis and *Gemmastephanocolpites* sp. are probably related to family Labiatae. The present day distribution of this family is ubiquitous.

Mimosaceae—The pollen grains of *Polyadopollenites sahii* show definite affinity with this family. At present, the members of this family are found mainly in tropical-subtropical regions of the world.

Malvaceae—Malvacearumpollis sp. resembles the pollen grains of Malvaceae. The family is mainly tropical in distribution.

Quantitative Analysis

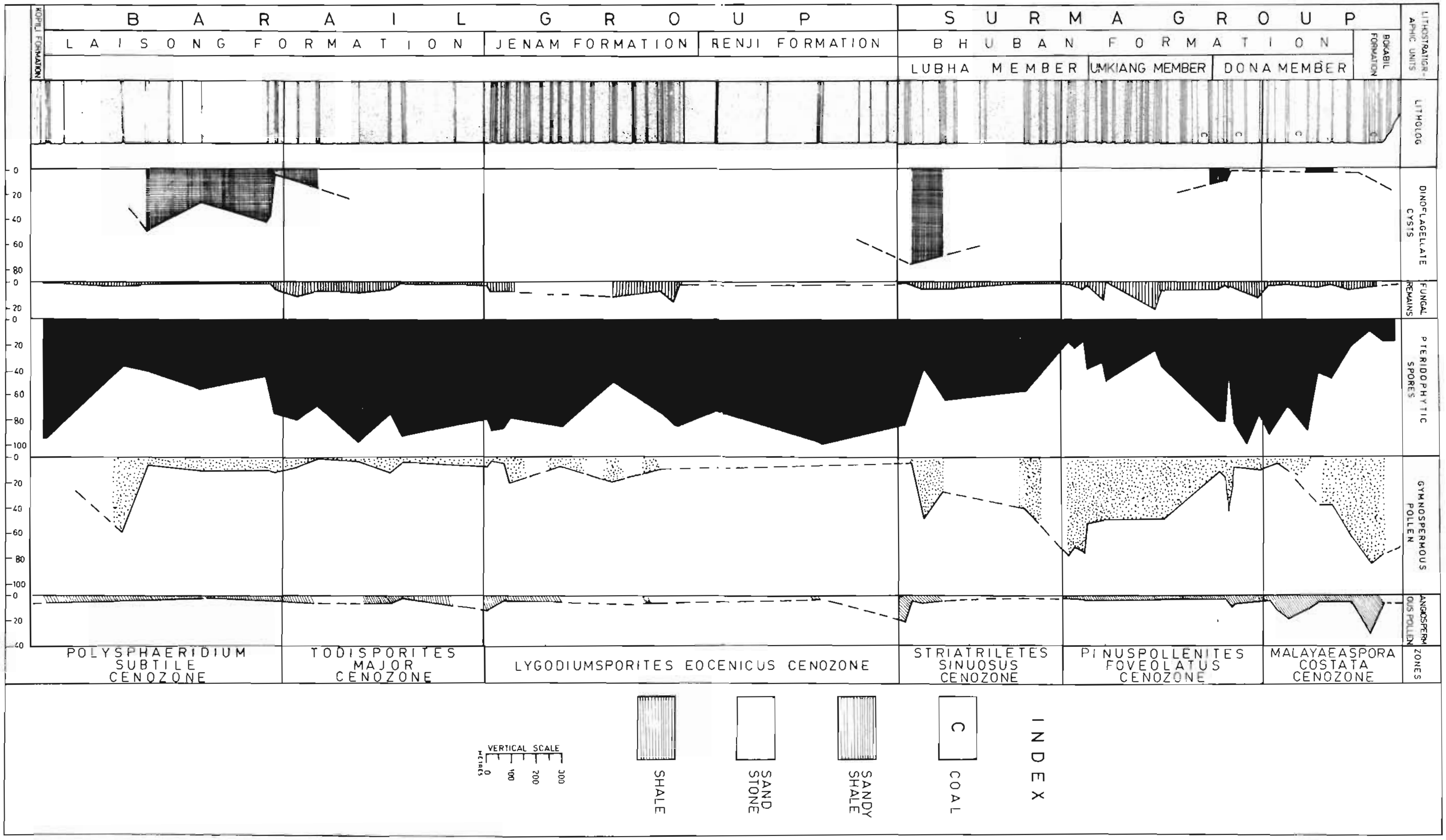
The present palynoassemblage is populated by 68 genera and 112 species of dinoflagellate cysts, fungal remains, pteridophytic spores and gymnospermous and angiospermous pollen grains. Quantitatively, the pteridophytic spores constitute a major part (62%) of the assemblage, followed by gymnospermous pollen grains (23%), angiospermous pollen grains (5.5%), dinoflagellate cysts (5%) and fungal remains (4.5%). The botanical allocation of the various genera and species is given below: dinoflagellate cysts-9 genera and 15 species; fungal remains 17 genera and 33 species; pteridophytic spores 18 genera and 32 species; gymnospermous pollen grains 5 genera and 7 species; angiospermous pollen grains 18 genera and 24 species; *incertae sedis* 1 genus and 1 species. The quantitative analysis of the assemblage has been done on the basis of the frequency of various species in a count of 200 specimens per sample but in some cases where the yield was poor only 100 to 150 palyno-fossils were counted. The percentage of each group in each sample has been calculated and plotted to show its distribution in the Barail-Surma Sequence of the Sonapur-Badarpur Section (Text-fig. 1).

The quantitative analysis of the palynoflora recorded from each formation is discussed below :

Laisong Formation—The palynotaxa of the Laisong assemblage (Lower Oligocene) are represented by the following percentages : dinoflagellate cysts (14.3%), fungal remains (4.5%); pteridophytic spores (62.5%), gymnospermous pollen grains (16%) and angiospermous pollen grains (2.7%). The dinoflagellate cysts are dominant in the lower part of the Laisong Formation (*Polysphaeridium subtile* Cenozone) but they decrease in frequency in the upper part (*Todisporites major* Cenozone). *Polysphaeridium subtile* constitutes 30 per cent of the dinoflagellate cysts in the lower part of the formation. In some samples its frequency reaches up to 45 per cent. *Adnatosphaeridium vittatum* is restricted to this formation only. *Cordosphaeridium inodes, C. fibrospinosum, C. multispinosum* and *Homotryblium floripes* are among the other species of dinoflagellate cysts recorded from this formation. The fungal remains are better represented in the upper part (up to 12%) than in the lower part (1-4%) and consist of *Notothyrites setiferus* and *Phragmothyrites eocaenica.* Among the pteridophytic spores, trilete spores form the dominant element while the monolete spores remain insignificant. *Striatriletes* is the most dominant genus throughout the formation and in some samples its frequency reaches up to 60%. Other pteridophytic genera in the order of their relative abundance are *Todisporites* and *Lygodiumsporites.* Gymnospermous pollen, mainly represented by *Pinuspollenites foveolatus* are insignificant in the lower part of the formation while in the upper part their frequency is comparatively low. *Podocarpidites* is another important gymnospermous pollen genus in this formation. The angiospermous pollen grains constitute 2.7 per cent of the assemblage, being represented by *Polyadopollenites sahii* and *Echistephanocolpites meghalayaensis.*

Jenam Formation—The Jenam Formation consists of fungal remains (12.2%), pteridophytic spores (77%), gymnospermous pollen grains (7.5%) and angiospermous pollen grains (3.3%) while dinoflagellate cysts are completely absent. The frequency of the fungal remains increases (12%) in this formation. The species recorded are : *Notothyrites setiferus, Phragmothyrites eocaenica* and *Paramicrothallites menonii.* Like Laisong Formation, this formation too is rich in trilete spores while the monolete spores occur in lesser frequency. The monolete spores recovered from this formation are represented by *Polypodiaceaesporites tertiarus* only. Among the trilete spores, *Striatriletes* spp. occur at all levels of this formation. *Striatriletes pachyexinus* (49%) has been recovered only from one sample and is restricted to this formation. The frequency of *Striatriletes susannae* is 60 per cent and at some levels it increases even up to 78 per cent. *Lygodiumsporites* spp. and *Todisporites major* are among the other significant forms. The gymnospermous pollen grains are poorly represented in this formation, being only 7.5 per cent. *Polyadopollenites sahii* and *Malvacearumpollis* sp. are among the important species of angiospermous pollen grains. Angiospermous pollen are not represented in the upper part of this formation.

Renji Formation—In this formation the yield of palynomorphs was comparatively poor. The pteridophytic spores (99.4%) form the most dominant element in this formation while angiospermous pollen grains are rare (0.6%). Algal and fungal



Text-figure 1—Group-wise distribution of palynofossils in Barail-Surma Sequence of Sonapur-Badarpur Road Section, Jaintia Hills (Meghalaya) and Cachar (Assam).

remains and gymnospermous pollen grains are absent. *Dictyophyllidites indicus* (46%), a trilete pteridophytic spore, is restricted to this formation. *Striatriletes susannae* (40%), *Lygodiumsporites lakiensis* (7%) and *Todisporites major* (6%) are the other important taxa. The angiospermous pollen grains are represented by *Malvacearumpollis* sp. only.

Bhuban Formation—The palynoflora recovered from this formation is represented by dinoflagellate cysts (4.3%), fungal remains (5%), pteridophytic spores (50%), gymnospermous pollen grains (37%) and angiospermous pollen grains (3.7%). The dinoflagellate cysts reappear in the lower part of the Bhuban Formation. *Cordosphaeridium inodes* and *Homotryblium floripes* are the important species. The fungal remains consist of *Notothyrites setiferus, N. padappakarensis, Parmathyrites ramanujamii, Phragmothyrites eocaenica, Inapertisporites miocenicus, Dicellaesporites* spp., *Dyadosporonites grandiporus, Pluricellaesporites* spp. and *Multicellaesporites* spp. The pteridophytic spores are dominant in the lower (57%) and upper (66%) members of this formation whereas in the middle member their frequency is comparatively less (29%). The genus *Striatriletes* occurs in all the samples. *Striatriletes sinuosus* is restricted to the lower part (Lubha Member) only whereas the *Surmaspora sinuosa, Malayaeaspora costata, Biretisporites meghalayaensis* and *Lygodiumsporites donaensis* are restricted to the upper part (Dona Member). In addition, the frequency of *Lygodiumsporites eocenicus* decreases in the lower part, being completely absent in the middle and finally reappearing in the upper part. *Cyathidites australis, C. minor, Foveosporites triangulus, Todisporites major, T. minor, Polypodiaceaesporites tertiarus, P. chatterjii, Polypodiisporites speciosus* and *P. formosus* are some of the other important species of pteridophytic spores. The gymnospermous pollen are comparatively better represented (64%) in the middle levels than in the lower (23%) and upper (20%) levels of this formation. *Pinuspollenites foveolatus* constitutes the major part (60%) of gymnospermous pollen grains in the middle levels (Umkiang Member). *Abiespollenites surmaensis* is an important taxon in the Lower Bhuban Formation but its frequency decreases in the middle and upper parts of the Bhuban Formation. *Podocarpidites meghalayaensis, Piceapollenites* sp. and *Laricoidites punctatus* are the other important forms. The angiospermous pollen grains show comparatively higher frequency in the Upper Bhuban Formation than those in the lower and middle levels. *Couperipollis* spp. constitute the major part of the assemblage. The frequencies of *Malva-cearumpollis* sp. and *Echistephanocolpites megha-layaensis* increase in this formation. The other important taxa are: *Verrualetes assamicus, Retipilonapites delicatissimus* and *Polyadopollenites sahii.*

Bokabil Formation—The Bokabil palynoflora consists of fungal remains (3%), pteridophytic spores (15.8%), gymnospermous pollen grains (60%) and angiospermous pollen grains (21.2%). Dinoflagellate cysts are completely absent. *Monoporisporites* sp. is the only fungal species recorded from this formation. The pteridophytic spores are represented by *Striatriletes susannae, Lygodiumsporites lakiensis* and *Polypodiaceaesporites tertiarus.* Among the gymnospermous pollen grains, *Pinuspollenites foveolatus* is an important taxon being represented by (50%). Other gymnospermous pollen species present are: *Abiespollenites surmaensis* (8%) and *Piceapollenites* sp. (3%). *Assamiapollenites* sp., *Couperipollis* spp., and *Malvacearumpollis* sp. are the angiospermous pollen genera recorded from this formation.

Palynofloral Comparison

During the last twentyfive years significant contributions to the Tertiary palynostratigraphy of Kutch, Meghalaya, Assam, Bengal, Himachal Pradesh and South India have been made. A comparison of the present assemblages with those known from the above areas has been attempted below.

KUTCH

Kar (1979) reported a rich palynoflora consisting of 39 genera and 33 identifiable species, from the Maniyara Fort Formation (Oligocene) of Kutch, Gujarat. The palynotaxa common to the Maniyara Fort assemblage and present Barail assemblage are: *Cyathidites, Lygodiumsporites lakiensis, Todisporites, Biretisporites, Striatriletes susannae, Polypodiaceaesporites chatterjii, Polypodiisporites, Podocarpidites, Couperipollis, Tricolpites, Triporopollenites, Stephanoporopollenites, Malvacearumpollis, Phragmothyrites eocaenica, Notothyrites, Kutchiathyrites, Inapertisporites, Dyadosporonites, Polysphaeridium* and *Homotryblium.* The palynotaxa present in the Maniyara Fort assemblage but absent from the present assemblage are: *Punctatisporites, Intrapunctisporis, Toroisporis, Leptolepidites, Laevigatosporites, Cheilanthoidspora, Retitricolpites, Trisyncolpites, Araliaceoipollenites, Retibrevitricolpites, Paleosantalaceaepites, Monoporopollenites, Cleistosphaeridium, Spiniferites, Membranilarnacia, Fromea* and *Aplanosporites.* The palynotaxa present in the Barail assemblage but absent from the Maniyara Fort assemblage are: *Garotriletes, Gleicheniidites, Corrugatisporites, Foveotriletes, Pinuspollenites, Piceapollenites, Abiespollenites, Laricoidites, Verrutricolpites, Bombacacidites inausus, Echistephanocolpites meghalayaensis, Polyado-*

pollenites sahii, Dicellaesporites, Multicellaesporites, Fusiformisporites, Adnatosphaeridium, Cordosphaeridium, Impletosphaeridium and *Frasnacritetrus*. A comparative study reveals that the Maniyara Fort Assemblage of Kutch and the present Barail Assemblage are mostly comparable qualitatively.

MEGHALAYA—ASSAM

The palynological studies on the Tertiary sediments of Meghalaya and Assam have been carried out by Biswas (1962), Baksi (1962, 1965), Sah and Dutta (1966, 1968, 1974), Dutta and Sah (1970), Sah *et al.* (1970), Salujha *et al.* (1972, 1973, 1974), Singh (1977a, 1977b), Singh and Singh (1978), Mehrotra (1981, 1983) and Dutta and Jain (1982). There are few reports from Upper Assam by Banerjee *et al.* (1973), Srivastava *et al.* (1974), Singh and Tewari (1979), Sah *et al.* (1980) and Singh and Saxena (1984). The palynofloras reported by the above mentioned authors are largely from the Palaeocene-Eocene sediments whereas the reports from the Oligocene-Miocene sediments are very scanty. A comparative study of the distributional patterns of the known Oligocene-Miocene palynofloras from the Assam Basin is given below:

Banerjee (1964) published some palynotaxa from the Surma sediments (Miocene) of Garo Hills, Meghalaya. To make a comparative study of this palynoflora with the present one, it was thought essential to transcribe various genera described therein to the equivalent forms in the present assemblage. To accomplish this objective, the names of the genera used by Banerjee are given in parentheses. The palynotaxa in common with the Surma Group of Garo Hills and that of the present section are: *Polypodiaceaesporites* = (*Psilamonoletes*, in Banerjee, pl. 1, fig. 3), *Lygodiumsporites* = (*Retitriletes*, in Banerjee, pl. 1, fig. 4), *Todisporites* = (*Scabratriletes*, in Banerjee, pl 1, figs 8, 10), *Pinuspollenites* and *Podocarpidites* = (*Saccites*, in Banerjee, pl. 2, figs 1-6), *Palmidites maximus* (=*Monocolpites*, in Banerjee, pl. 2, fig. 7), *Echistephanocolpites* =(*Stephanocolpites*, in Banerjee, pl. 2, fig. 29), *Striatriletes* and *Tricolpites*. A comparative study reveals that the present Surma assemblage is closely comparable with that of Garo Hills.

Baksi (1962) described palynomorphs from the Simsang River Section, South Shillong Front, Meghalaya and recognized four palynozones. Of these, the third and fourth palynozones were assigned to Oligocene and Miocene ages respectively. The present assemblage and the assemblage of third and fourth zones of Simsang River Section have the following genera in common: *Striatriletes, Malayaeaspora* ± = *Schizaeaceaesporites, Parkeriaceaesporites*, in Baksi, pl. 3, fig. 41; pl. 5, fig. 54), *Cyathidites/Lygodiumsporites/Todisporites* ± = (smooth trilete spores of *Leiotriletes garoensis*, in Baksi pl. 3, fig. 36), *Polypodiisporites tuberculensis* = (*Polypodiaceaesporites tuberculensis*, in Baksi, pl. 3, fig. 40), *Couperipollis* ± = (spinose monocolpate pollen in Baksi, pl. 2, fig. 18) and *Triporopollenites* ± = (triporate pollen, in Baksi, pl. 3, fig. 33). Besides, conifer pollen grains and dinoflagellate cysts are also common to the two assemblages. The palynotaxa present in the Simsang River Section but absent from the present assemblage are: gemmate syncolpate pollen, *Meyeripollis, Bauhinia burdwanensis, Tetradopites, Tricolpopites, Polygonaceaepites* and *Densexinosporites*. The palynotaxa present in the present assemblage but absent from the third and fourth zones of Simsang River Section are: *Biretisporites, Surmaspora, Gleichenii-dites, Dictyophyllidites, Garotriletes, Foveosporites, Foveotriletes, Corrugatisporites, Lycopodiumsporites, Monolites, Laricoidites, Retipilonapites, Verrualetes, Palmidites, Proxapertites, Bombacacidites, Verrutri-colpites, Retitrescolpites, Trifossapollenites, Echistephanocolpites, Gemmastephanocolpites, Malvacearumpollis* and *Polyadopollenites*. The present authors have established 3 palynozones in the Barail Group (Oligocene), viz., (i) *Polysphaeridium subtile* Cenozone, (ii) *Todisporites major* Cenozone, and (iii) *Lygo-diumsporites eocenicus* Cenozone which are broadly comparable to the third palynozone of Baksi (1962) from the Simsang River Section.

Likewise, the Surma Group (Miocene) strata of the present investigation is also divided into three palynozones, viz., (i) *Striatriletes sinuosus* Cenozone, (ii) *Pinuspollenites foveolatus* Cenozone, and (iii) *Malayaeaspora costata* Cenozone. In the fourth zone of Simsang River Section, the abundant occurrence of two-winged coniferous pollen grains and the frequent occurrence of ribbed spores (*Ceratopteris* type) have been recorded by Baksi (1962). A comparative study reveals that the *Pinuspollenites* = (coniferous pollen, Baksi, pl. 4, fig. 49; pl. 5, fig. 60) and *Striatriletes* = (*Ceratopteris* Baksi, pl. 4, fig. 53) are present in both the assemblages. So the fourth zone of Simsang River Section is comparable to the fourth, fifth and sixth cenozones of the Surma Group of Sonapur-Badarpur Road Section.

Besides the above, the present assemblage was also compared with those recorded by Salujha *et al.* (1972, 1974 Palaeogene assemblage from Garo Hills and Jaintia Hills respectively), Salujha *et al.* (1973, Surma assemblage from the southern edge of Shillong Plateau), Sein and Sah (1974, Eocene-Oligocene assemblage from Jaintia Hills), Banerjee *et al.* (1973, Oligocene-Miocene assemblage from the subcrops of Upper Assam) and Singh and Saxena (1984, Neogene assemblage from Jorajan Well-3, Upper Assam) but none of them was found to be closely comparable.

BENGAL BASIN

Deb (1970) studied the palynology of the Cenozoic sediments of Bengal Basin, south of Calcutta. She instituted three palynozones for the Miocene, Pliocene and Quaternary sediments respectively. The palynozone III (Miocene) contains *Striatriletes* =(*Ceratopteris*, in Deb, pl. 2, fig. 9) and pollen grains of Coniferae and Palmae which are also present in the present assemblage.

Baksi (1972) made a detailed palynostratigraphic study of the Upper Mesozoic and Tertiary succession of Bengal Basin, subdividing it into 7 palynological zones. Of these, zones IV and V are of Oligocene and Miocene ages respectively. These zones possess some palynomorphs which also occur in the present assemblage, viz., *Cyathidites/Lygodiumsporites/Todisporites* ±=(*Leiotriletes garoensis/Cyathidites minor*), *Polypodiisporites tuberculensis* ±=(*Polypodiaceaesporites tuberculensis/Polypodiisporites speciosus/P. oligocenicus*), *Malayaeaspora/Striatriletes* ±=(*Schizaeaceaesporites*), *Couperipollis* =(spinose monocolpate pollen) and *Tricolpites*. In addition to these, some dinoflagellate cysts, fungal spores/discs and conifer pollen are also shared by the two assemblages. The association of some important elements like *Meyeripollis*, abundant occurrence of small tricolpate pollen and first appearance of *Bauhinia burdwanensis* and *Barringtonia* in the Zone IV and V of Bengal Basin have not been detected in the Oligocene and Miocene sediments of the present study. Other palynotaxa like *Biretisporites, Dictyophyllidites, Polyadopollenites, Echistephanocolpites* and *Malvacearumpollis* which are present in Barail and Surma groups of the present section are absent from the zones IV and V of the Bengal Basin. Thus, the two assemblages are broadly comparable.

The present assemblage was also compared with Lower Siwalik assemblages from Himachal Pradesh, Uttar Pradesh and Nepal recorded by Banerjee (1968), Mathur (1973), Nandi (1975, 1980) and Saxena *et al.* (1984); Port Blair Formation (Palaeogene) of Andaman Islands recorded by Banerjee (1966); and Neogene assemblages of Tamil Nadu and Kerala recorded by Ramanujam (1960, 1966), Navale (1962), Jain and Gupta (1970), Deb (1972), Ramanujam and Rao (1973, 1977), Venkatachala and Rawat (1973), Rao and Ramanujam (1978, 1982), Navale and Misra (1979), Jain and Kar (1979), Kar and Saxena (1981), Ambwani *et al.* (1981) and Srisailam *et al.* (1981). It has been observed that these assemblages are not comparable with the present ones, hence their detailed account has not been given.

Palaeoclimate and Environment of Deposition

The Barail-Surma palynoflora from the Sonapur-Badarpur Road Section, Meghalaya and Assam consists of dinoflagellate cysts, fungal remains, pteridophytic spores, gymnospermous and angiospermous pollen grains. Based on the palynofloral evidence, an attempt is made here to interpret the palaeoclimate and environment of deposition prevalent during the sedimentation of this sequence.

PALAEOCLIMATE

The present day distribution of the various families represented in the Barail-Surma palynoflora is as follows :

Tropical	Tropical-subtropical	Temperate	Cosmopolitan
Matoniaceae	—	—	—
Gleicheniaceae	—	—	—
—	Ophioglossaceae	—	—
—	Cyatheaceae	—	—
—	Schizaeaceae	—	—
—	Parkeriaceae	—	—
—	Palmae	—	—
—	Mimosaceae	—	—
—	—	Pinaceae	—
—	—	—	Polypodiaceae
—	—	—	Osmundaceae
—	—	—	Podocarpaceae
—	—	—	Labiatae
—	—	—	Potamogetonaceae
—	—	—	Lycopodiaceae
—	—	—	Malvaceae
—	Oleaceae (Tropical-warm temperate)	—	—
—	Araceae	—	—
—	Bombacaceae	—	—

Parkeriaceae, Schizaeaceae, Ophioglossaceae, Cyatheaceae, Matoniaceae, Gleicheniaceae, Palmae and Mimosaceae are tropical to subtropical in distribution. The family Gleicheniaceae has been recorded only from the Barail Group while other families, viz., Cyatheaceae, Schizaeaceae, Osmundaceae, Matoniaceae and Mimosaceae are better represented in the Barail Group than in the Surma Group. The spores of Parkeriaceae occur predominantly throughout the Barail-Surma Sequence. Oleaceae which is subtropical to warm temperate in distribution, is poorly represented in and restricted to the lower Bhuban Formation. The tropical-subtropical elements are thus well represented throughout the Barail-Surma Sequence. The only temperate family, viz., Pinaceae, which is represented by *Pinuspollenites, Piceapollenites* and *Abiespollenites*, occurs sporadically in the Barail Group (Oligocene) and attains predominance throughout the Surma Group.

Lakhanpal (1970), on the basis of palaeobotanical evidences, envisaged that the Palaeogene and Neogene floras in the Indian subcontinent were predominantly tropical. The occurrence of *Pinus* pollen grains (a temperate genus) in the latter may be interpreted as coming in from higher altitudes of temperate climate. The above observation is amply supported by the present palynofloral data too.

The present assemblage, as a whole, is dominated by pteridophytic spores (62%) indicating warm humid condition. This is also supported by the occurrence of epiphyllous microthyriaceous fungi, viz., *Phragmothyrites, Notothyrites* and *Parmathyrites.*

It may, therefore, be concluded that the area of present study enjoyed a mainly tropical-subtropical climate during the Oligocene-Lower Miocene time. The rich representation of pinaceous pollen grains in the Surma Group may be due to their derivation from the nearby upland region. A gradual cooling of the climate in the Miocene epoch may also be partly responsible for their occurrence. It appears likely that the Himalayan chain in the north of present area would have been sufficiently high during the Miocene to support the pinaceous elements.

ENVIRONMENT OF DEPOSITION

The oldest sediments of the present sequence, i.e. lower Laisong Formation (*Polysphaeridium subtile* Cenozone) consist of pteridophytic spores, gymnospermous pollen and dinoflagellate cysts. The dinoflagellate cysts are dominant in the lower part of the Barail Group, decrease in its middle and upper parts and again become important in the lower Bhuban Formation. The pteridophytic spores, mainly represented by *Striatriletes* are dominant throughout the sequence. The gymnospermous pollen exhibit low frequency in Barail Group while in the younger sediments, viz., Bhuban and Bokabil formations, they are encountered in very high frequency.

The dinoflagellate cysts are dominant in the lower part of the Barail Group and continue to be represented in the present sequence up to Lower Bhuban Formation indicating the prevalence of coastal marine environment of deposition. *Palmidites maximus, Couperipollis ramanujamii* and *C. donaensis* show proximity to the shore line. These as well as the fresh water elements, viz., *Retipilonapites* (Potamogetonaceae), *Proxapertites* and *Assamiapollenites* appear to have been transported to the site of deposition.

Age of the sediments

Limited efforts have so far been made on the palynological studies of the Barail and Surma groups (Baksi, 1962, 1965; Banerjee, 1964; Salujha, Kindra & Rehman, 1972, 1974; Salujha, Rehman & Kindra, 1973; Singh & Tewari, 1979). These papers have mainly concentrated on the systematic description of the palynoflora and its stratigraphic and palaeoecological significance. The interpretation regarding age of these sediments, on the basis of palynofossils has not so far been attempted. An attempt is therefore made here to assess the age of these sediments on palynological evidence.

Barail Group—The palynoflora recorded here from the Barail Group is characterized by *Adnatosphaeridium vittatum, Polysphaeridium subtile, Biretisporites oligocenicus, Dictyophyllidites indicus* and *Striatriletes pachyexinus.* These forms do not extend to the Surma Group. The present assemblage has been compared with the Oligocene assemblages described from Kutch (Kar, 1979) and Bengal Basin (Baksi, 1972). Out of 39 palynomorph genera recorded from the Maniyara Fort Formation (Oligocene) of Kutch, 19 genera are also found in the present assemblage. Similarly, most of the important taxa from the palynological zone IV (Oligocene) of Bengal Basin (Baksi, 1972) are also encountered herein. Thus, the present Barail assemblage is also assignable to Oligocene age.

Surma Group—The palynoassemblage recorded from the Surma Group of the present section is characterized by *Lygodiumsporites donaensis, Surmaspora sinuosa, Biretisporites meghalayaensis, Striatriletes sinuosus, Malayaeaspora costata, Polypodiaceaesporites chatterjii, Polypodiisporites formosus, Couperipollis donaensis, C. ramanujamii, Assamiapollenites* sp. and *Malvacearumpollis* sp. The Surma Assemblage also shows the predominance of *Pinuspollenites, Abiespollenites* and *Piceapollenites.*

Among the other known Miocene palynofloras from Bengal (Deb, 1970; Baksi, 1972), Meghalaya (Banerjee, 1964; Salujha *et al.*, 1973), Tamil Nadu (Navale, 1962; Ramanujam, 1966; Venkatachala & Rawat, 1973; Navale & Misra, 1979) and Kerala (Ramanujam, 1960; Jain & Gupta, 1970; Ramanujam & Rao, 1973, 1977, 1978; Rao & Ramanujam, 1976, 1978, 1982; Jain & Kar, 1979; Kar & Jain, 1981; Ramanujam *et al.*, 1981), the palynofloras from Meghalaya are favourably comparable with the present Surma mioflora. The rich representation of the bisaccate pinaceous pollen in these floras is particularly significant in this connection. Hence the present Surma mioflora is assignable to Miocene age.

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Palynology of Kamthi Formation from Chelpur Area, Godavari Graben, Andhra Pradesh, India

Suresh C. Srivastava & Neerja Jha

Srivastava, Suresh C. & Jha, Neerja (1987). Palynology of Kamthi Formation from Chelpur Area, Godavari Graben, Andhra Pradesh, India. *Palaeobotanist* **35**(3) : 342-346.

Palynofossil assemblages recovered from the subsurface sediments of Chelpur area in the Godavari Graben of Kamthi Formation have been studied. It is deduced that the palynoflora is characterised by the dominance of striate-disaccate pollen. *Densipollenites* is nearly absent. The palynoflora has been compared with the known Lower Kamthi palynoflora in Ramagundam area of Godavari Graben and also with Raniganj palynoflora of Damodar Valley coalfields. The recovered palynoflora indicates Late Permian age.

Key-words—Palynology, Striate-disaccate pollen, Kamthi Formation, Late Permian (India).

Suresh C. Srivastava & Neerja Jha, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

आँध्र प्रदेश (भारत) में गोदावरी द्रोणिका के चेलपुर क्षेत्र से कामथी शैल-समूह का परागाणविक अध्ययन

सुरेश चन्द्र श्रीवास्तव एवं नीरजा झा

कामथी शैल-समूह की गोदावरी द्रोणिका में स्थित चेलपुर क्षेत्र के उपसतही अवसादों से उपलब्ध परागाणविक समुच्चयों का अध्ययन किया गया है। यह निष्कर्ष निकाला गया है कि परागाणुवनस्पतिजात रेखीय-द्विकोष्ठीय परागकणों से प्रभावी है। डेन्सीपोलिनाइटिस करीब-करीब अनुपस्थित है। उपलब्ध परागाणुवनस्पतिजात की तुलना गोदावरी द्रोणिका में रामागुँडम् क्षेत्र से ज्ञात अधरि कामथी वनस्पतिजात तथा दामोदर घाटी के कोयला-क्षेत्रों से उपलब्ध रानीगंज परागाणुवनस्पतिजात से की गई है। उपलब्ध परागाणुवनस्पतिजात अर्नोतिम परमी आयु इंगित करता है।

KAMTHI Formation was named by Blanford (1868) after the military station Kamthi (20° 10′ : 79° 15′) close to Nagpur. These rocks are exposed extensively in Wardha-Godavari Valley in Maharashtra and Andhra Pradesh. In Godavari Graben these sediments are present in subsurface in Chelpur, Ramagundam, Mantheni, Indaram, Kundaram, Jaipuram, Ramkrishnapuram, Manuguru and near Siripuram areas.

A brief report of the presence of pteridophytic spores and striate-disaccate pollen was made by Ramanamurty (1979). Thereafter, the palynofloras of Kamthi Formation have been studied in detail from Ramagundam area (Bharadwaj *et al.*, 1984; Bharadwaj *et al.*, in press). In the same pursuit, the present investigation has been extended to Chelpur area of Godavari Graben.

LITHOLOGY OF KAMTHI FORMATION

On the basis of lithological attributes the Kamthi Formation has been divided into three members—Lower, Middle and Upper. The Lower Member consists of medium-grained greyish white, calcareous sandstone and a few coal seams. The Middle Member consists of alternating sequence of medium-grained grey white sandstone and shales/variegated clays. The sandstone and shales exhibit greenish tint at places. This member is devoid of coal seams. The Upper Member comprises coarse-grained sandstone and bands of ferruginous sandstones and brick-red siltstone. The sandstone is characterised by bands of pebble or conglomerates. In Chelpur area (bore-hole GJ-3) the Lower Member (±231.93 m) consists of medium to coarse-grained white sandstone including black shale, grey shales and a number of coaly horizons at various levels. The overlying Middle Member is developed to a limited extent (36.65 m) and includes greenish coarse-grained ferruginous sandstone. The underlying Barren Measures Formation shows a gradational contact.

MATERIAL AND METHOD

The material (bore-hole no. GJ-3) for the present study was supplied by Geological Survey of India from Chelpur area of Godavari Graben. The bore-hole penetrates the Kamthi Formation and closes at 417.60 m in Barren Measures Formation. In all, 14 samples were macerated and heavy liquid solution was used to remove silica wherever needed. The details of samples are given in Histogram 1.

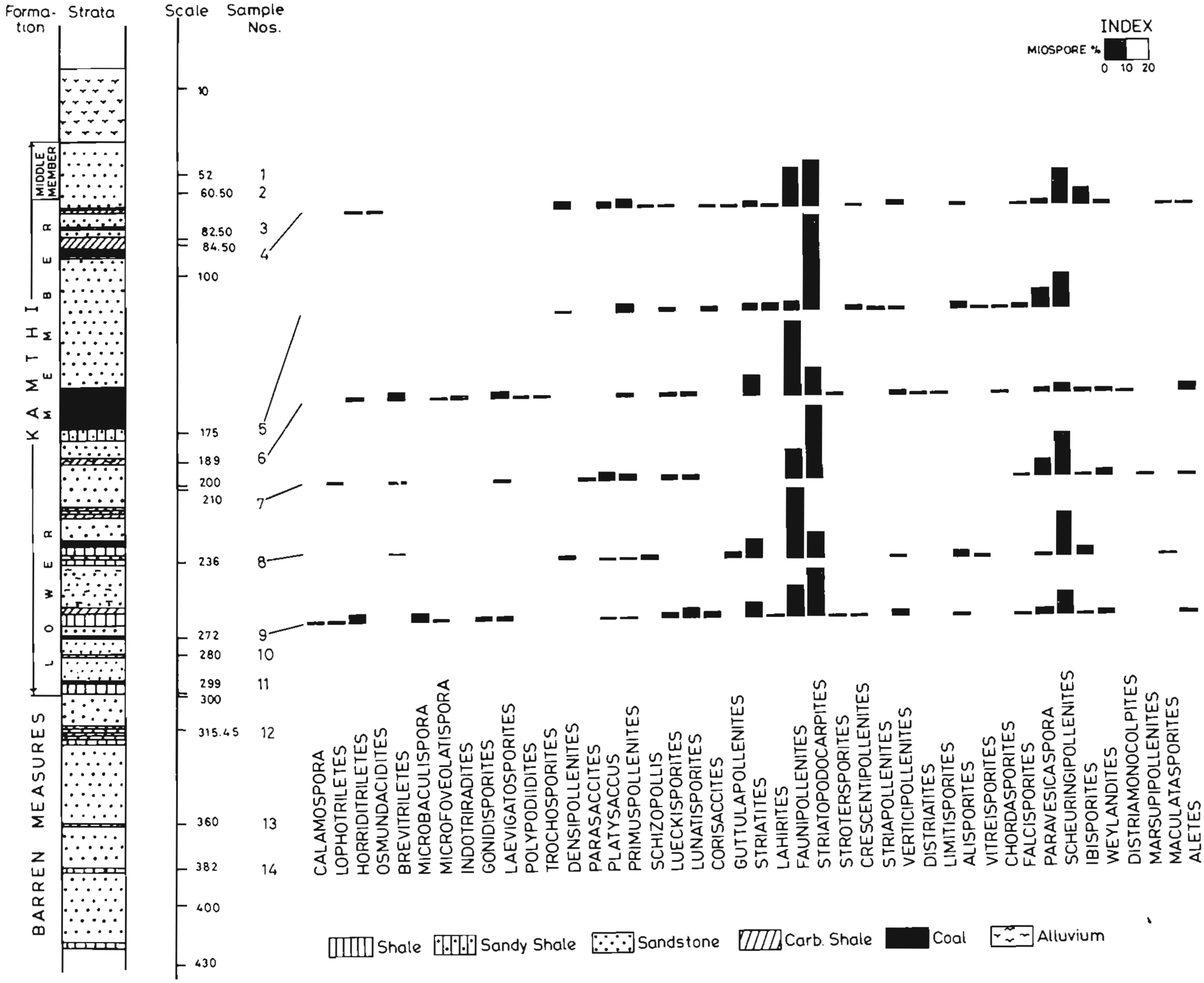
PALYNOFOSSIL ASSEMBLAGES

The quantitative and qualitative distribution of miospore genera shows following assemblage in the bore-hole GJ-3.

Assemblage-A

Only one assemblage is present in bore-hole GJ-3 between 272.00 to 84.50 m (sample nos. 4-9). The assemblage is characterised by the dominance of striate-disaccates like *Faunipollenites* and *Striatopodocarpites* while *Scheuringipollenites* marks the subdominance. Appearance of *Lunatisporites, Corisaccites, Guttulapollenites, Crescentipollenites, Verticipollenites, Alisporites, Falcisporites, Vitreisporites, Chordasporites, Gondisporites, Osmundacidites* and *Polypodiidites* is the characteristic feature of this assemblage. *Densipollenites* is very rare. In some samples *Striatopodocarpites* is dominant while in others *Faunipollenites* is the dominant element, but as a whole striate-disaccate forms the dominant component of the assemblage. Few triletes like *Brevitriletes, Microbaculispora, Calamospora, Lophotriletes, Osmundacidites, Microfoveolatispora, Indotriradites, Gondisporites, Verrucosisporites* are present but their percentage gradually decreases upwards. Taeniate genera vary from 1-5 per cent. Monosaccates are very rare in occurrence. A detailed list of species present in this assemblage is as follows:

Indotriradites sparsus Tiwari 1965
  I. korbaensis Tiwari 1964
Gondisporites sp.
Lophotriletes rectus Bharadwaj & Salujha 1964
Horriditriletes ramosus (Balme & Hennelly) Bharadwaj, & Salujha 1964
  H. rampurensis Tiwari 1968
  H. concavus Maheshwari 1969
Brevitriletes unicus (Tiwari) Bharadwaj & Srivastava emend. Tiwari & Singh 1981
  B. communis (Tiwari) Bharadwaj & Srivastava emend. Tiwari & Singh 1981
Microbaculispora tentula Tiwari 1965
Microfoveolatispora foveolata Tiwari emend. Tiwari & Singh 1981
Calamospora exila Bharadwaj & Salujha 1964
Osmundacidites indicus (Singh, Srivastava & Roy) Srivastava & Jha (MS)
Verrucosisporites surangei Maheshwari & Benerji 1974
Laevigatosporites colliensis (Balme & Hennelly) Venkatachala & Kar 1968
Polypodiidites perverrucatus Couper 1953
Densipollenites indicus Bharadwaj 1962
  D. densus Bharadwaj & Srivastava 1969
  D. invisus Bharadwaj & Salujha 1964
Weylandites circularis Bharadwaj & Srivastava 1969
  W. minutus Bharadwaj & Srivastava 1969
  W. obscurus Bharadwaj & Srivastava 1969
Caheniasaccites distinctus (Lele & Makada) Srivastava & Jha (Ms)
Parasaccites diffusus Tiwari 1965
Virkkipollenites orientalis Tiwari 1968
Trochosporites sp.
Lueckisporites crassus Sinha 1972
  L. microgranulatus Klaus 1963
  Lueckisporites sp.
Guttulapollenites hannonicus Goubin 1967
Lunatisporites diffusus Bharadwaj & Tiwari 1977
  L. pellucidus (Goubin) Maheshwari & Banerji 1974
  L. ovatus (Goubin) Maheshwari & Banerji 1974
Corisaccites alutus Venkatachala & Kar 1966
Striatites rhombicus Bharadwaj & Salujha 1964
  S. solitus Bharadwaj & Salujha 1964
  S. communis Bharadwaj & Salujha 1964
  S. tentulus Tiwari 1965
  S. obliquus Srivastava 1979
Lahirites levicorpus Tiwari 1968
  L. rarus Bharadwaj & Salujha 1964
Faunipollenites varius Bharadwaj 1962
  F. singrauliensis Sinha 1972
  F. parvus Tiwari 1965
  F. bharadwajii Maheshwari 1967
  F. copiosus Bharadwaj & Salujha 1965
Striatopodocarpidites diffusus Bharadwaj & Salujha 1964
  S. rotundus (Maheshwari) Bharadwaj & Dwivedi 1981.
  S. decorus Bharadwaj & Salujha 1964
  S. labrus Tiwari 1965
  S. subcircularis Sinha 1972
  S. tiwarii Bharadwaj & Dwivedi 1981
  S. globosus (Maheshwari) Bharadwaj & Dwivedi 1981
Strotersporites sp.



Histogram 1—Showing percentage frequency of various miospore genera in bore-hole GJ-3, Chelpur Area, Godavari Graben.

Crescentipollenites gondwanensis (Maheshwari) Bharadwaj, Tiwari & Kar 1974
- *C. fuscus* (Bharadwaj) Bharadwaj, Tiwari & Kar 1974
- *C. implicatus* (Bose & Maheshwari) Tiwari & Rana 1980

Schizopollis extremus Venkatachala & Kar 1964
Striapollenites saccatus Bharadwaj 1962
Verticipollenites crassus Bharadwaj & Salujha 1964
- *V. secretus* Bharadwaj 1962
- *V. gibbosus* Bharadwaj 1962

Distriatites insolitus Bharadwaj & Salujha 1964
Marsupipollenites fasciolatus Balme & Hennelly 1956
Limitisporites rectus Leschik 1956
Scheuringipollenites maximus (Hart) Tiwari 1973
- *S. minutus* (Sinha) Bharadwaj & Dwivedi 1981
- *S. tentulus* (Tiwari) Tiwari 1973

Ibisporites diplosaccus Tiwari 1968
- *I. jhingurdahiensis* Sinha 1972

Platysaccus plicatus Bharadwaj & Dwivedi 1981
- *P. papilionis* Potonié & Klaus 1954

Primuspollenites levis Tiwari 1964
- *P. distinctus* Sinha 1972
- *P. obscurus* Tiwari 1965

Paravesicaspora brevis (Sinha) Bharadwaj & Dwivedi 1981
- *P. ovata* (Balme & Hennelly) Bharadwaj & Dwivedi 1981

Falcisporites nuthallensis (Clark) Balme 1970
- *F. stabilis* Balme 1970

Chordasporites australiensis de Jersey 1962
Vitreisporites pellidus (Reissinger) Balme 1970
Alisporites indarraensis Segroves 1969
Maculatasporites gondwanensis Tiwari 1965
Leiosphaeridia talchirensis Lele & Karim 1971
Pilasporites sp.

COMPARISON

The present assemblage compares well with Assemblage 1 of bore-holes GGK-20 and GGK-27 in Ramagundam area within the basin (Bharadwaj, Srivastava, Ramanamurty & Jha, in press) in almost all respect, i.e. in the dominance of striate-disaccate pollen, subdominance of *Scheuringipollenites* and presence of some younger forms like *Falcisporites, Vitreisporites, Lunatisporites, Alisporites, Chordasporites* and *Crescentipollenites.*

Assemblage-A compares with the palynoflora of Jhingurdah seam in Singrauli Coalfield (Tiwari & Srivastava, 1984) in the occurrence of younger elements like *Falcisporites, Gondisporites, Lunatisporites* and *Corisaccites* besides the dominant striate disaccates. *Densipollenites* is characteristically sporadic in both the assemblages. Assemblage-A of bore hole GJ-3 can also be compared with the Raniganj palynoflora of Auranga Coalfield (Lele & Srivastava, 1979), Assemblage 1 of bore-hole RAD-2 (Singh & Tiwari, 1982), Assemblage 2 of bore-hole RNM-3 (Rana & Tiwari, 1980) and Assemblage II of bore hole RNM-2 (Tiwari & Rana, 1984) from East Raniganj Coalfield in having dominant striate-disaccates. However, some younger forms which appear in Lower Kamthi Member of Godavari Graben are absent in Raniganj palynoflora of Raniganj and Auranga coalfields. Also *Densipollenites* is better represented in Assemblage 2 of RNM-3 and Assemblage II of RNM-2 in East Raniganj Coalfield.

The presence of *Scheuringipollenites* in higher percentages in association with striate-disaccates simulates a Barakar-like affinity but such occurrence has also been observed in bore-hole GGK-27 in Ramagundam Area. However, the presence of *Lunatisporites* (1 5%), *Guttulapollenites* (1-3%), *Falcisporites* (1-2%), *Vitreisporites* (1%), *Chordasporites* (1%), *Osmundacidites* (1%), *Gondisporites* (2%) suggests a younger aspect to the present assemblage. *Verrucosisporites surangei, Lunatisporites pellucidus* and *L. ovatus* present in Maitur Formation of Damodar Valley (Maheshwari & Banerji, 1974) are also present in the Assemblage A of Chelpur.

COMPARISON OF PALYNODATA WITH LITHODATA

The older samples of the bore-hole GJ-3, i.e. at the level of 382-298.90 m, are lithologically of Barren Measure Formation. These have not yielded miospores in countable percentage. Lower Kamthi Member has been marked lithologically at the levels of 280.33-67.45 m, while Middle Kamthi Member above the level of 67.45 m. But the palynoflora found in the samples supposed to be from Middle Kamthi Member is the same as in Lower Kamthi Member. Thus, only one palynological assemblage of Lower Kamthi Member has been found in the bore-hole. Hence, the palynodata do not correspond with the lithodata. The non-correspondence between the two parameters may be due to the well recog-nised fact that lithologically the transition between succeeding formations are often not clearly demar-cated, being mostly gradational.

DISCUSSION

The samples from the bore-hole GJ-3 have yielded good results. There are a number of miospore genera in high percentage which would apparently suggest a Barakar affinity, but the presence of striate-disaccate grains alongwith younger forms allienates the present samples more closer to the Kamthi palynoflora as has been found in bore-hole GGK-20 and GGK-27 by Bharadwaj, Srivastava, Ramanamurty and Jha (in press).

Thus, the palynoflora characterised by the dominance of striate-disaccate (*Faunipollenites* & *Striatopodocarpites*), subdominance of *Scheuringipollenites* and appearance of younger forms like *Guttulapollenites, Falcisporites, Alisporites, Vitreisporites, Chordasporites, Lunatisporites, Crescentipollenites, Verticipollenites, Gondisporites, Osmundacidites* and *Polypodiidites* is dated to be equivalent to Lower Kamthi Member. The palynoflora of Middle Kamthi Member has not been obtained in this bore-hole. When compared with the known Kamthi mioflora in Ramagundam area of Godavari Graben and also with the Raniganj palynofloras of Damodar Valley coalfields, a Late Permian age is suggested for the levels under study.

CONCLUSION

The existence of Lower Kamthi palynoflora in Chelpur area of Godavari Graben has been established on the basis of dominance of striate-disaccates and subdominance of nonstriate-disaccates. Late Permian age has been suggested for Lower Kamthi Member on the basis of palynological studies.

ACKNOWLEDGEMENT

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Late Precambrian microfossils from Deoban Limestone Formation, Lesser Himalaya, India

Manoj Shukla, V. C. Tewari* & V. K. Yadav

Shukla, Manoj, Tewari, V. C. & Yadav, V. K. (1987). Late Precambrian microfossils from Deoban Limestone Formation, Lesser Himalaya, India. *Palaeobotanist* **35**(3) : 347-356.

A well-preserved microbiota consisting of filamentous Cyanobacteria, viz., *Oscillatoriopsis, Cyanonema, Siphonophycus, Eomycetopsis, Gunflintia* and *Animikiea*; spheroidal unicells, viz., *Glenobotrydion, Globophycus, Sphaerophycus* and *Myxococcoides*; Eubacteria, viz., *Archaeotrichion, Biocatenoides*; and acritarch (?plankton) *Kildinosphaera*, is described from petrographic thin sections of cherts from the Deoban Formation, Garhwal Lesser Himalaya. The assemblage has been compared with other authentic Proterozoic records. The palaeomicrobial community is interpreted to have inhabited protected shallow intertidal environment.

Key-words—Palaeoecology, Cyanobacteria, Spheroidal unicells, Eubacteria, Lesser Himalaya, Precambrian (India).

Manoj Shukla & V. K. Yadav, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India

**V. C. Tewari, Wadia Institute of Himalayan Geology, General Mahadeo Singh Road, Dehradun, India*

साराँश

लेसर हिमालय (भारत) में देवबन चूनाश्म शैल-समूह से अनंतिम कॅम्ब्रिय-पूर्व सूक्ष्मजीवाश्म

मनोज शुक्ला, वी॰ सी॰ तिवारी एवं विनोद कुमार यादव

गढ़वाल लेसर हिमालय में देवबन शैल-समूह से एकत्रित सममैकाश्मों की शैलिकीय पतली काटों में सूत्रवत् सियनोजीवाणु अर्थात् ऑसिलेटोरिऑप्सिस, सियनोनीमा, साइफोनोफ़ाइकस, इओमाइसिटॉप्सिस, गनफ़्लिंशिआ एवं एनिमीकिआ; गोलाभ एककोशायें अर्थात् ग्लीनोबॉट्रीडायन, ग्लोबोफ़ाइकस, स्फेयरोफ़ाइकस एवं मिक्सोकोकॉयड्स; यूबैक्टीरिआ अर्थात् आर्कियोट्राइकिऑन, बायोकेटिनॉयडिस तथा एक ऐक्रीटार्क (प्लवक) किल्डिनोस्फेयरा से युक्त एक सुपरिरक्षित सूक्ष्मजीविता का वर्णन किया गया है। इस समुच्चय की तुलना अन्य प्रामाणिक आद्यजीवी अभिलेखों से की गई है। उक्त पुरासूक्ष्मजैविक समुदाय संरक्षित छिछले अन्तराज्वारीय वातावरण में विद्यमान था।

LATE Proterozoic microbiota is known from over 150 localities establishing considerable biological diversity and ecological variability. Fossiliferous Proterozoic formations are known from Australia, Canada, Africa, Greenland, India, USA, USSR and China, which contain authentic biota both as carbonised remains from shales and permineralised from cherts. The chert biotas are three dimensionally preserved in fine grained chert matrix permitting an indepth study of the morphology and complexities achieved by the organism. The synsedimentary nature is established by evaluation of the relationship between mineral matrix and microbiota in petrographic thin sections while the acid resistant biotic remains known from shales do not have any direct evidence of their being synsedimentary in nature, however, the relationships is only implied.

The present paper deals with three dimensionally preserved carbonaceous remains from stratified and lensoid black chert in Deoban Limestone near Chakrata area. This sedimentary sequence exposed in the inner sedimentary belt of Lesser Himalaya is characterised by siliciclastic-carbonate sequence with profuse development of columnar stromatolites.

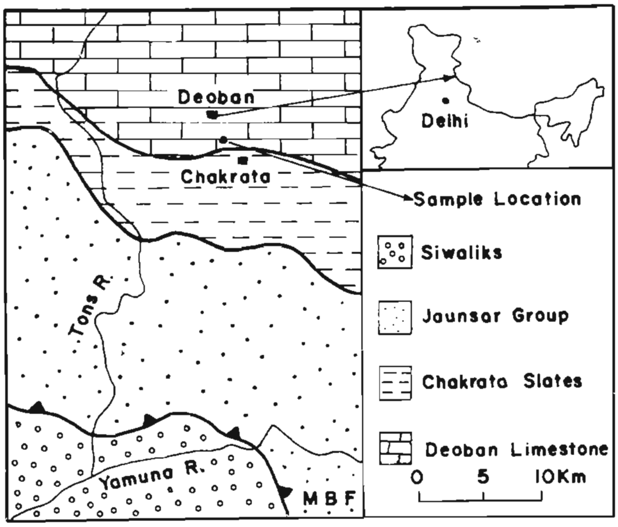
Kumar and Singh (1979a) recorded microbiota from this area in petrographic thin sections. They have reported three forms namely *Glenobotrydion majorinum* Schopf & Blacic, *Huronispora* sp. Awramik & Barghoorn and *Eomycetopsis filiformis* Schopf. However, detailed descriptions of these forms are lacking. A detailed systematic analysis of morphological types present in these cherts, their affinities and comparison with other microbiota and palaeoecological analysis have been attempted in this paper.

GEOLOGICAL SETTING AND AGE

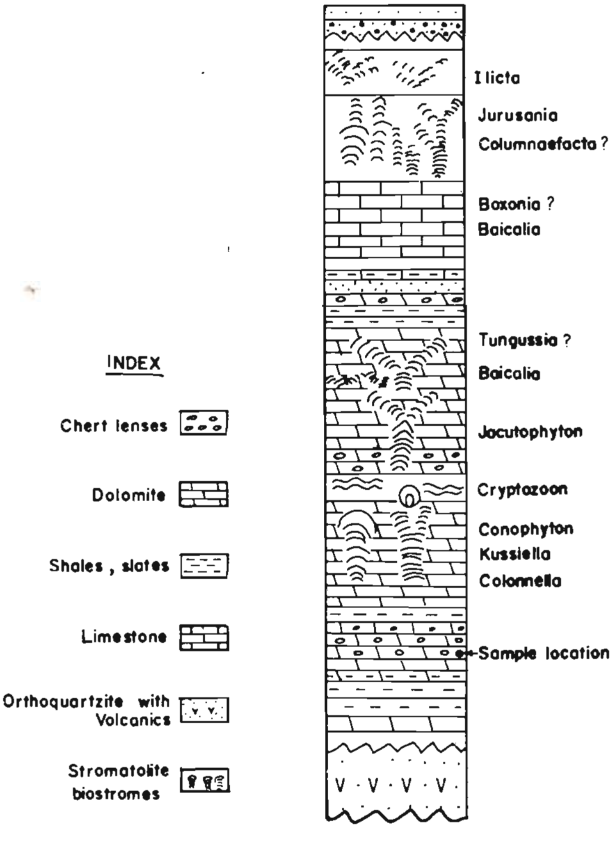
Deoban Limestone Formation is extensively developed in Deoban mountain (30°45′ : 77°54′), north of Chakrata (Text-fig. 1) in Garhwal Lesser Himalaya. It was first designated by Oldham (1883) for a sequence of pale-grey dolomitic limestone with cherty concretions occuring north of Chakrata. It comprises thick succession of stromatolitic dolomite, dolomitic limestone, cherty limestone, oolitic intraclastic limestone and slates (Text-fig. 2). The Deoban Limestone overlies the Atal Quartzite in Tons Valley and is overlain by Mandhali Slate and Limestone and the contact is normal gradational. However, Prashra (1977) marked a thrust contact in Tons area where the Subathus (nummulites) and Simla Slate are found along the thrust plane. The Deoban Group in the area, north of Deoban belt, is unconformably succeeded by the Mandhali Formation of Jaunsar Group.

Thin layers and lenses of black chert, which have yielded microfossils, occur in the limestone bed showing development of stromatolites (Text-fig. 2). The thickness of the chert layers varies from 1 mm to 10 cm. The limestone show prolific development of columnar stromatolites. The extension of Deoban Limestone in south-eastern Kumaon was designated as the Gangolihat Dolomite by Valdiya (1969). Detail geology of the area is discussed by Prashra (1977), Valdiya (1980) and Srikantia and Bhargava (1982). Valdiya (1969) on the basis of specific forms of stromatolites and lithological similarities correlated Deoban Limestone with Gangolihat Dolomite, Shali Formation of Satluj Valley, Dharamkot Limestone of Dharamsala area and Jammu Limestone of Riasi area in the Lesser Himalaya.

No direct radiometric date is available for Deoban Limestone Formation. However, Valdiya (1986) assigned approximately 1,000 Ma age to these beds on the basis of correlation with Jammu Limestone. Raha *et al.* (1978) gave Pb/U dates based on Galena of 967 Ma for the Jammu Limestone. Late Precambrian columnar stromatolites in Deoban Limestone have been recorded by Valdiya (1969), Prashra (1977) and Kumar and Singh (1979b). However, Sinha and Raaben (1981) recorded Lower Cambrian stromatolites from this area. Tewari (1983, 1984) in a detailed systematic study of stromatolites from Kumaon Himalaya has assigned Lower-Middle Riphean age to Deoban Limestone Formation based on *Kussiella-Conophyton-Baicalia* Assemblage (Text-fig. 2).



Text-figure 1—Geological map of Deoban area showing the locality.



Text-figure 2—Simplified litholog of Deoban Limestone showing distribution of stromatolites and sample location of chert lenses yielding microbiota (after Tewari, 1983).

SYSTEMATICS

The fossil taxa described here have been recorded through the study of petrographic thin sections of black cherts under transmitted light. Morphologically they can be classified into filaments, coccoids, tubular sheaths and fine thread-like forms. The forms are grouped here under the existing fossil taxa to facilitate comparison with other known Proterozoic microbiota. The affinity of these forms have been discussed separately. The type and figured specimens are deposited in the repository of Birbal Sahni Institute of Palaeobotany, Lucknow.

Genus—*Eomycetopsis* Schopf 1968

Eomycetopsis robusta Schopf 1968 emend. Knoll & Golubic 1979

Pl. 1, figs 10, 11, 17, 20

Description—Nonseptate, unbranched, partially flattened tubular sheaths with circular to elliptical cross section, 2.5-5 μm in diameter and 120 μm in length. Surface texture coarsely granular.

Genus—*Siphonophycus* Schopf 1968

Siphonophycus kestron Schopf 1968

Pl. 1, figs 8, 14

Description—Nonseptate, unbranched, tubular or cylindrical sheaths, 8-18 μm wide and up to 140 μm long (incomplete specimen). Straight to slightly bent, surface texture rugose.

Genus—*Oscillatoriopsis* Schopf 1968

Oscillatoriopsis media Mendelson & Schopf 1982

Pl. 1, figs 1, 22

Description—Multicellular, uniseriate, unbranched trichomes 8-12 μm wide slightly tapering towards apices, generally not constricted at septa, cross walls distinct, somewhat granular, disc-shaped, cells more closely spaced near apices than in medial portion 3-4 μm in diameter. Sheath absent. Poorly preserved with smaller cells in apical part.

Genus—*Cyanonema* Schopf 1965

Cyanonema sp.

Pl. 1, fig. 18

Description—Sharply curved, up to 120 μm long (inocomplete specimen) multicellular, uniseriate, unbranched, trichomes not at all constricted at septa, cross walls distinct, sheath absent. Trichome not capitate, solitary, or in mesh-like mass. Cells commonly as long as wide (2.8-3.5 μm). Apical cells are considerably smaller than medial cells. Reproductive structures unknown.

Genus—*Gunflintia* Barghoorn 1965

Gunflintia minuta Barghoorn 1965

Pl. 1, figs 2, 3, 4, 5, 6, 9, 12, 13, 15

Description—Unbranched, uniseriate, straight or curved filaments up to 350 μm long and 1 to 4 μm in diameter. Transverse septa and reproductive structures are not recognisable.

Genus—*Animikiea* Barghoorn 1965

Animikiea septata Barghoorn 1965

Pl. 1, fig. 21

Description—Multicellular unbranched filaments up to 120 μm long and 8-12 μm wide, straight or curved, with closely spaced transverse septae. Individual cells much wider than long. Enclosing sheath distinct, surface texture granular.

Genus—*Myxococcoides* Schopf 1968

Myxococcoides minor Schopf 1968

Pl. 2, fig. 8

Description—Spheroidal or ellipsoidal cells 8 to 12 μm in diameter, occasionally distorted and flattened due to mutual compression, solitary or clumped in globular colonies. Number of cells differ in colonies. Surface texture varies from psilate to reticulate. Cell wall distinct and about 0.5 μm thick.

Genus—*Sphaerophycus* Schopf 1968

Sphaerophycus parvum Schopf 1968

Pl. 2, figs 11-18

Description—Spheroidal or ellipsoidal cells with 2-4.2 μm in diameter, commonly solitary or sometime in groups of three, four, eight or more, surface texture commonly psilate, occasionally granular. Sheaths encompassing cells occasionally present. Reproduction apparently by fission, followed by separation of resulting daughter cells.

Genus—*Melasmatosphaera* Hofmann 1976

Melasmatosphaera media Hofmann 1976

Pl. 2, figs 2, 3

Description—Cells spheroidal, solitary, occasionally double-walled, diameter 15-20 μm, containing numerous scattered or clustered submicron to micron sized granules.

Genus—*Glenobotrydion* Schopf 1968

Glenobotrydion aenigmatis Schopf 1968

Pl. 2, figs 1, 19, 20

Description—Spheroidal or ellipsoidal cells, in losely associated groups, distorted by mutual compression. Ranging from 8-10 μm in diameter. A small circular organic structure eccentrically placed on inner surface of cell wall; amber to black coloured intracellular body, 0.5 to 2.0 μm in diameter.

Glenobotrydion majorinum Schopf 1971
Pl. 2, figs 6, 7

Description—Solitary spheroidal, undistorted cells, 20-35 μm in diameter, sheath not present, circular organic body with 3-4 μm diameter present on inner surface of cell wall, or near centre.

Genus—*Globophycus* Schopf 1968

Globophycus sp.
Pl. 2, figs 4, 9, 10, 21

Description—Large, spheroidal, solitary, light coloured, thin-walled cells ranging in diameter from 18-20 μm, encapsulating darker, thick-walled spheroids with 5-7 μm in diameter. Inner spheroids detached from the outer spheroid and has more irregular configuration. Reproductive structure unknown.

Genus—*Archaeotrichion* Schopf 1968

Archaeotrichion sp.
Pl. 1, fig. 7

Description—Solitary or irregularly entangled, narrow, sinuous, nonseptate, unbranched, flexed, twisted and compressed tubes, up to 150 μm long, 2-4 μm wide and about 1/2 μm thick.

Genus—*Biocatenoides* Schopf 1968

Biocatenoides sp.
Pl. 1, figs 16, 19

Description—Slender, chain-like, unbranched filamentous colonies, composed of rod-shaped or coccoid cells, uniseriate, less than 0.5-2 μm broad, colonies thread-like, often sinuous or recurved, up to 150 μm long. Reproductive structures unknown.

Genus—*Kildinosphaera* Shepeleva & Timofeev 1963 emend. Vidal 1963

Kildinosphaera sp.
Pl. 2, fig. 5

Description—Spheroidal vesicles up to 260 μm in diameter, thick-walled, wall psilate and characteristically folded and wrinkled.

MICROBIOTA—COMPARISON AND AFFINITIES

Comparison

The microbiota comprises multicellular septate trichomes, tubular remnants, spheroidal coccoids with or without eccentrically placed intracellular dark bodies; narrow thread-like filaments and ?plankton associated with dark brown to black organic residue disseminated in the rock matrix. Spheroidal structures are dominantly present in bedded cherts while filaments dominate the chert lenses. Table 1 gives a comparative account of the Deoban microbiota with other records.

Microbiota of Deoban cherts and Bitter Springs Formation (Barghoorn & Schopf, 1965; Schopf 1968; Schopf & Blacic, 1971) of Central Australia are remarkably similar. Both deposits contain well preserved filamentous and spheroidal unicells. Ten Deoban taxa are morphologically comparable to the ones recorded from the Bitter Springs Formation. Four of these genera are filamentous cyanobacteria, viz., *Oscillatoriopsis, Cyanonema, Siphonophycus* and *Eomycetopsis* and four genera of spheroidal unicells, viz., *Glenobotrydion, Globophycus, Sphaerophycus* and *Myxococcoides*. Two genera of Eubacteria, viz., *Archaeotrichion* and *Biocatenoides* are common to both. However, the Bitter Springs microbiota is dominated by septate filamentous trichomes, which in Deoban is represented only by *Oscillatoriopsis media* and *Cyanonema* sp. The Deoban microbiota is dominated by coccoid and nonseptate filamentous forms.

Eomycetopsis, an abundant and cosmopolitan component of the Proterozoic microbiota, is recorded from most of the Proterozoic deposits of the world (see Mendelson & Schopf, 1982). In India, this genus is recorded from Kheinjua Formation (Kumar, 1978; McMenamin *et al.*, 1983), Suket Shale (Maithy & Shukla, 1977) of Lower Vindhyan and

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PLATE 1 →

Filamentous microfossils from thin sections of Deoban cherts.

1, 22.	*Oscillatoriopsis media*, Slide no. BSIP 9628. × 500.
21	*Animikiea septata*,. Slide no. BSIP 9629 × 1000.
18.	*Cyanonema sp.*, Slide no. BSIP 9629 × 1000.
10, 11, 17, 20.	*Eomycetopsis robusta*, filamentous colony of *E. robusta*, note three dimensionally preserved tubular filament (fig. 10) having circular opening, Slide nos. BSIP 9628, 9629, 9630; fig. 10 × 1000; figs 11, 17, 20. × 500.
2-6, 9, 12, 13, 15.	*Gunflintia minuta*, Slide nos. BSIP 9628, 9629, figs 2, 3, 4, 13, 15. × 500, figs 5, 6, 9, 12. × 1000.
8, 14.	*Siphonophycus kestron*, possible empty sheath of *Oscillatoriopsis media*, Slide no. BSIP 9628. × 500.
7.	*Archaeotrichion contortum*, possible bacteria or flattened "*Eomycetopsis filiformis*", Slide no. BSIP 9628. × 1000.
16, 19.	*Biocatenoides* sp., Slide nos. BSIP 9628, 9629. × 1000.

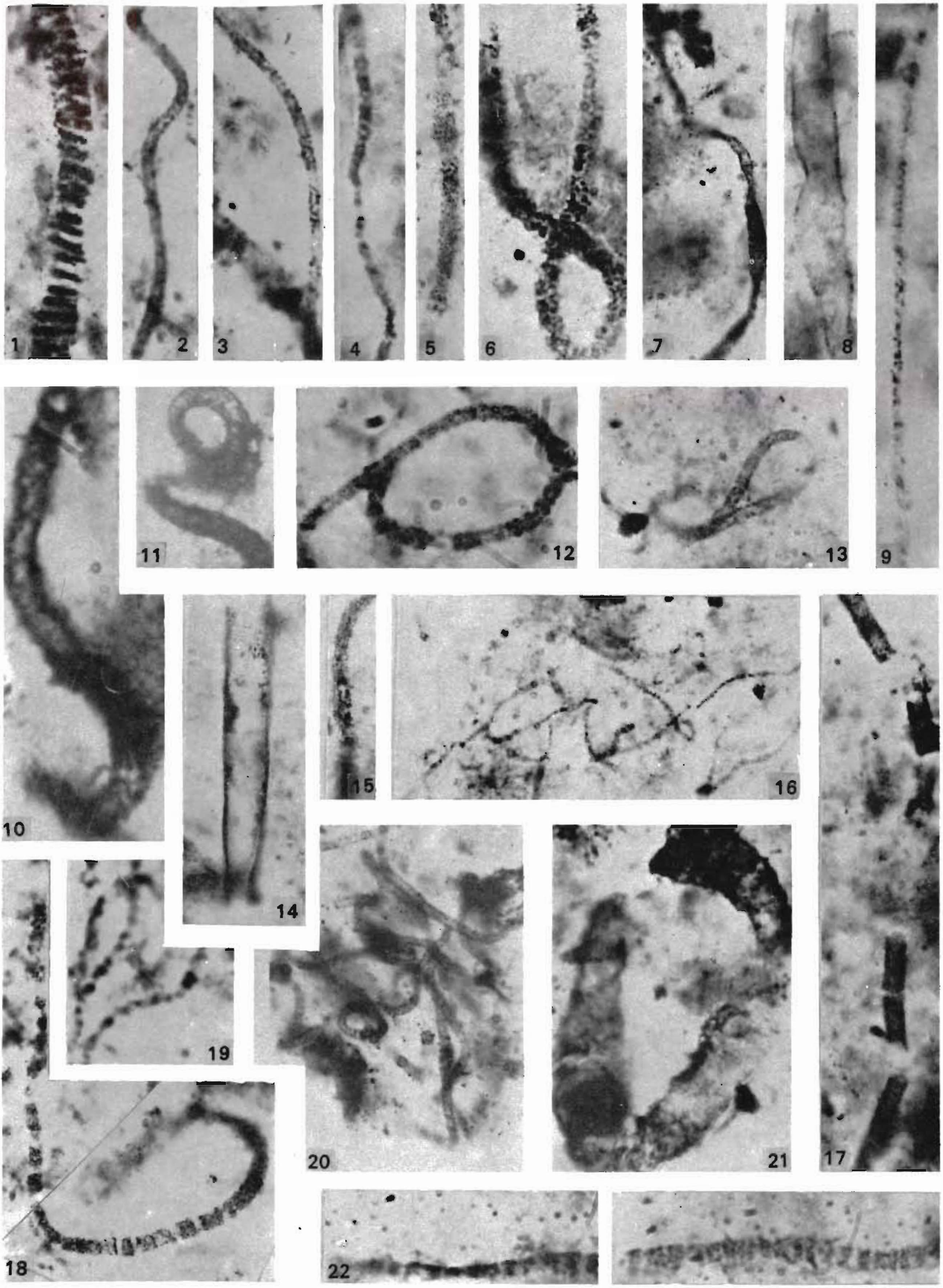

PLATE 1

Gangolihat Dolomites (Nautiyal, 1978 a, b, c, 1980). The authenticity of *Eomycetopsis* from Gangolihat Dolomite has been questioned by Mendelson and Schopf (1982). Banerjee (1973) recorded a single specimen of *Eomycetopsis* (20-25 μm across) from Aravalli Supergroup. This specimen does not fall within the size range of *E. robusta* described from the Deoban Limestone.

Gunflintia minuta and *Animikea septata*, first described from 2,000 Ma old Gunflint Iron Formation (Barghoorn & Tyler, 1965), are also recorded from the Deoban cherts. Probably due to post depositional diagenesis of organic matter septae are not clearly visible. Morphotype similar to *Gunflintia minuta* have also been recorded from Kheinjua Formation of Lower Vindhyan (McMenamin *et al.*, 1983). Chroococcacean spheroidal unicells, *Myxococcoides* and *Sphaerophycus* without intracellular organelles-like bodies are present in Bitter Springs (Schopf, 1968; Schopf & Blacic, 1971), Balbirni Dolomite (Muir, 1974, 1976), HYC Pyrite Member (Oehler, 1977), Amelia Dolomite, Australia (Oehler, 1978) and Belcher Supergroup (Hofmann, 1976), Canada. Narrow thread-like filamentous *Biocatenoides* are comparable to similar forms recorded from Bitter Springs (Schopf, 1968; Schopf & Blacic, 1971) and Belcher Supergroup (Hofmann, 1976). *Biocatenoides* and *Archaeotrichion* recorded from HYC Pyrite Member of McArthur Group; Sukhaya Tunguska, Shorikha and Yudoma Formation of Siberian Platform, forms significant components of the Deoban biota (for detailed comparison see Table 1).

Table 1

Deoban cherts	Bitter Springs Formation 1	Siberian platform 2	Balbirni Dolomite McArthur Group 3	HYC— Pyritic Shale Member 4	Amelia Dolomite 5	Belcher Super Group 6	Gunflint Iron Formation 7
Archaeotrichion contortum	S	G				G	
Biocatenoides sp.	G			G		G	
Myxococcoides minor	S		G	G	G	S	
Sphaerophycus parvum	S		S	S	S	S	G
Melasmatosphaera media						S	
Glenobotrydion aenigmatis	S					G	S
G. majorinum	S					S	
Globophycus sp.	G			G		G	
Oscillatoriopsis media	G	S		G			
Siphonophycus kestron	S		G				
Cyanonema sp.	G			G	G		
Eomycetopsis robusta	S	S	G	G		G	
Gunflintia minuta					S		S
Animikiea septata							S

G = Genus present; S = Species present

PLATE 2

→

Spheroidal microfossils from thin sections of Deoban cherts.

11-18. *Sphaerophycus parvum*, showing probably cell division. Note cells in pair (fig. 11 and in tetrad fig. 16), Slide no. BSIP 9628. × 1000.

1, 19, 20. *Glenobotrydion aenigmatis*, Note eccentrically placed, black pyrenoid-like intracellular bodies at the bottom of fig. 1 ellipsoidal cell has larger dimension of pyrenoid-like intracellular body. Slide no. BSIP 9628. × 1000.

4, 9, 10, 21. *Globophycus*. arrow in fig. 9 points possible thread-like bacteria, Slide nos. BSIP 9628, 9629; figs 9, 10, 21. × fig. 4. × 500.

2, 3. *Melasmatosphaera media*, Note double-walled cell (fig. 2), Slide no. BSIP 9628. × 1000.

5. *Kildinosphaera*, a planktonic body. Note the robust and folded cell wall, Slide no. BSIP 9628. × 250.

6, 7 *Glenobotrydion majorinum*, Slide no. BSIP 9628. × 1000.

8. *Myxococcoides minor*, Slide no. BSIP 9628. × 1000.

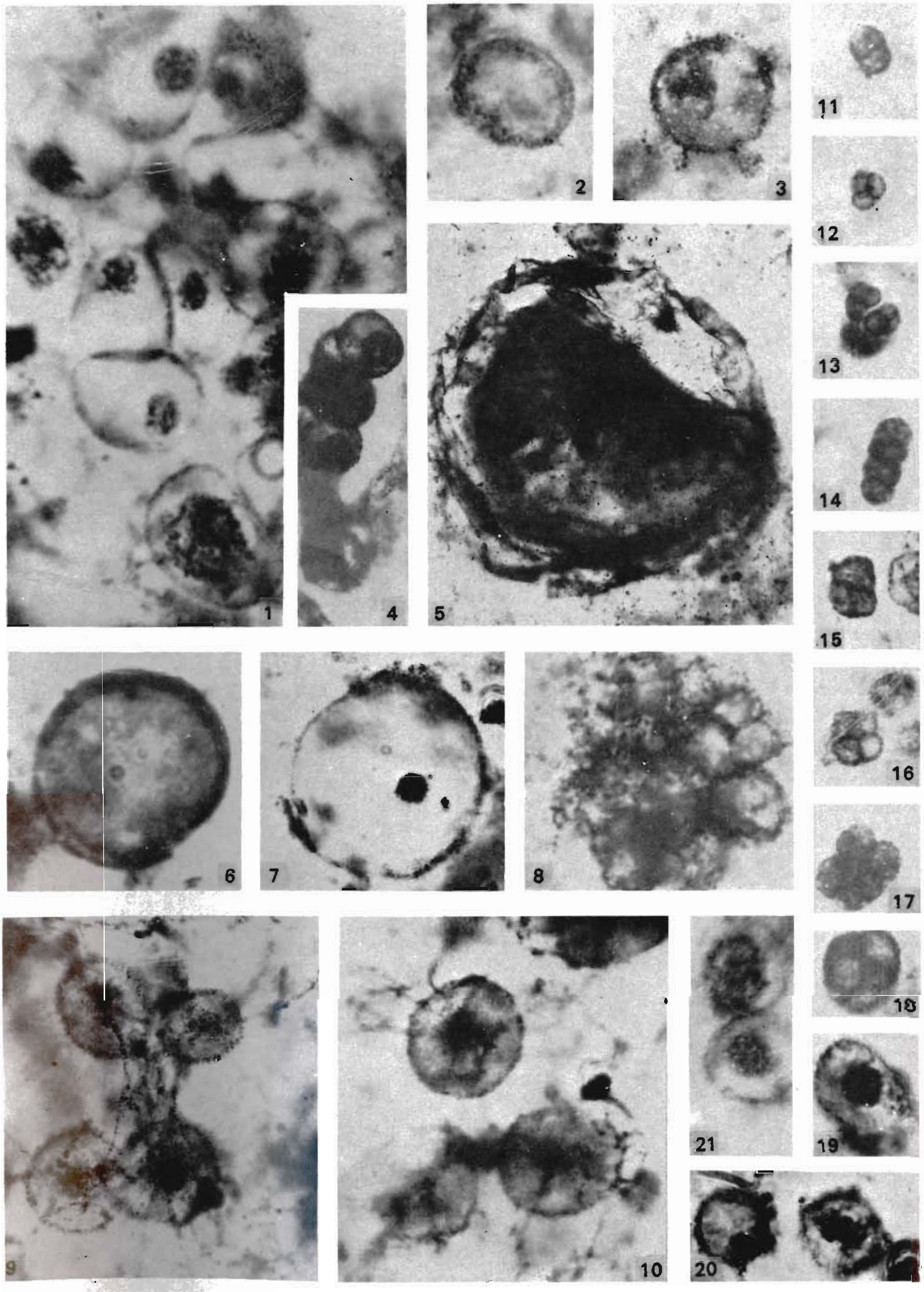

PLATE 2

Affinities

Septate filamentous forms in Deoban Limestone are represented by *Oscillatoriopsis media, Cyanonema, Animikea septata* and *Gunflintia minuta.* These taxa are morphologically comparable with modern Cyanobacteria belonging to Oscillatoriaceae.

Schopf (1968) interpreted tubular remanants of *Eomycetopsis robusta* as possibly belonging to fungi (*Eumycophyta*). Hofmann (1976) and Knoll and Golubic (1979) re-examined the type material and suggested that the tubules responding to *Eomyceptopsis* are sheaths of either *Phormidium* type of Cyanobacteria or *Leptothrix* type of filamentous bacteria. *Siphonophycus kestron* Schopf (1968) apparently represents empty mucilaginous sheath of *Oscillatoria-Lyngbya*-like Cyanobacteria (Schopf, 1968).

Coccoid microfossils are of mainly two types, i.e. one with eccentrically placed, intracellular, dark, pyrenoid-like bodies and the other lacking in these dark bodies. Spheroidal unicells without pyrenoid-like dark bodies are represented by *Myxococcoides* and *Sphaerophycus.*

Myxococcoides minor Schopf shows colonial habit and is comparable to *Anacystis* a genus of the family Chroococcaceae. *Sphaerophycus parvum* Schopf is apparently a product of asexual reproduction. Cells are not only present in pairs but in group of three, four and more cells (Pl. 2, figs 11-18). These cells probably represent cell division by fission.

Coccoid microfossils with amber to black coloured, eccentrically placed intracellular pyrenoid or organelles-like bodies are represented by *Glenobotrydion aenigmatis, G. majorinum* and *Globophycus* sp. These dark intracellular bodies in *Glenobotrydion* and other similar Proterozoic fossil taxa have been considered the product of cytoplasmic degradation (Awramik *et al.*, 1972; Knoll & Barghoorn, 1975; Hofmann, 1976; Golubic & Hofmann, 1976; Peat *et al.*, 1978; Knoll & Golubic 1979; Zhang, 1980). However, others (Schopf, 1968, 1974; Schopf & Blacic, 1971; Schopf & Oehler, 1976; Oehler, 1976, 1977a, b; Licari, 1978) consider them to be remanants of delicate cell organelles-like pyrenoid and nucleus. They opined that consistency in size, shape and distribution among members of each species establishes that they are original intracellular organelles rather than shrunk or coalesced cytoplasm. Oehler (1977a) studied these structures in *Glenobotrydion aenigmatis* and suggested that they are similar to pyrenoids and nuclei. Some species of *G. aenigmatis* probably represent coccoid green algae. Thus *Glenobotrydion aenigmatis* and *Glenobotrydion majorinum* in Deoban cherts apparently represent eukaryotic green algae.

Thin sections of Deoban cherts have also yielded large (260 μm across), characteristically folded, thin-walled acritarchs. These acritarchs of uncertain origin could be a cyst, or comparatively sturdy outer membrane formed by a unicellular plankton during resting stage in its life cycle.

Long narrow thread-like filaments referred to *Archaeotrichion contortum* and *Biocatenoides* are abundant in Deoban cherts. Schopf (1968) considered them ?Eubacteria. Hofmann (1976) compared *Archaeotrichion* sp. with *Leptothrix* and *Spirophyllum*-like Iron Bacteria. He further opined that they could be collapsed or deflated nonseptate filaments of *Eomycetopsis filiformis.* However, it is difficult to precisely assign taxonomic position to these forms.

PALAEOECOLOGY

Sedimentological studies indicate that the Deoban Limestone is a product of deposition in carbonate tidal flats. The primary sedimentary structure like parallel laminations, wavy laminations and ripple bedding are well preserved in the limestone containing bedded black cherts and the chert lenses yielding microbiota. The presence of oolites and intraclasts in the Deoban Limestone indicates high energy condition in intertidal zone.

The microbiota assemblage present in Deoban cherts represent not only benthic cyanobacterial communities but also plankton. Shallow benthic communities were represented by both motile and nonmotile prokaryotic micro-organisms. The mat building filaments belong to the family Oscillatoriaceae of Cyanobacteria and are much like the modern mat forming Cyanobacteria *Phormidium-Lyngbya-Oscillatoria plexus.* These microfossils indicate restricted coastal intertidal environment. However, according to Knoll (1985) filamentous microfossils corresponding to the extant genera *Oscillatoria, Lyngbya, Phormidium* and *Microcoleus* occur as mat builders in a wide variety of environments and also as nonmat forming microbenthos and allochthonous (transported) elements in shelf sediments. The presence of plankton indicates open sea environment. It is interpreted that these were transported and preserved in shallow marine locales. Extensive development of columnar stromatolites in Deoban Limestone indicates that they were formed in shallow water environment protected from stronger current activity where flat laminated mats form columnar stromatolites.

Presence of *Siphonophycus kestron* representing the original mucilaginous, empty sheath of

Oscillatoria-Lyngbya-like Cyanobacteria and unsheathed trichomes recorded here are indicators of gliding motility of these micro-organisms. Trichomes are well known to glide towards light source leaving behind empty sheaths. Thus, this population of filamentous Cyanobacteria were phototactic and mat builders as are extant *Oscillatoriaceae.*

CONCLUSION

Palaeomicrobial community found in Deoban Limestone Formation consists of *Oscillatoria*-like Cyanobacteria, eukaryotic green algae and *Leptothrix/Spirophyllum*-like filamentous Eubacteria. Phytoplanktons are rare.

Forms like *Glenobotrydion aenigmatis* and *G. majorinum* present in Deoban cherts are similar to forms described from Bitter Springs Formation and apparently represent eukaryotic green algae.

The Deoban biota (1,000 Ma) consists of mostly spheroid and nonseptate filaments while the Bitter Springs is distinguished by septate filamentous biota. This perhaps reflects that the Bitter Springs biota shows distinctive advancement over the Deoban biota. The microbiota shows evidence of development in shallow restricted coastal intertidal environment.

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Diatom analysis of Hirpur Locality III (Lower Karewa), Kashmir Valley

H. P. Gupta & Asha Khandelwal

Gupta, H. P. & Khandelwal, Asha (1987). Diatom analysis of Hirpur Locality III (Lower Karewa), Kashmir Valley. *Palaeobotanist* **35**(3) : 357-362.

This paper embodies the results of diatom analysis of 54 samples covering all the lithofacies in Hirpur Locality III, Kashmir Valley. Out of 54 samples, only 16 samples have yielded diatoms whereas rest of the samples proved barren. Diatom analysis has enabled to present two-fold comments: (i) the sediments are poor in diatoms and most of the frustules are ground, and (ii) these sediments are rich in Pennales. Furthermore, the frequency and nature of diatoms in the samples have revealed that the depositional environments were not wholly ponding rather there might have been violent floodings of the lake which perhaps hampered the growth of diatoms and their preservation too.

Key-words—Diatoms, Palaeoclimate, Lower Karewa, Upper Pliocene (India).

H. P. Gupta & Asha Khandelwal, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

काश्मीर घाटी में हिरपुर संस्थिति-तृतीय (अधरि करेवा) का डायटम विश्लेषण

हरीपाल गुप्ता एवं आशा खण्डेलवाल

इस शोध-पत्र में काश्मीर घाटी की हिरपुर संस्थिति-तृतीय में सभी शैल-संलक्ष्णीयों से एकत्रित 54 नमूनों के डायटम विश्लेषण के परिणाम प्रस्तुत किये गये हैं। एकत्रित 54 नमूनों में से 16 नमूनों से डायटम उपलब्ध हुए हैं तथा शेष सभी नमूने अधारक पाये गये हैं। डायटम विश्लेषण से दो प्रकार की टिप्पणियाँ की गई हैं : (अ) डायटमों की अवसादों में अल्प मात्रा है तथा अधिकतर फ्रस्ट्यूल भौमिक हैं, तथा (आ) ये अवसाद पिन्नेल्स से प्रभावी हैं। इसके अतिरिक्त नमूनों से उपलब्ध डायटमों की प्रकृति एवं बारम्बारता से व्यक्त होता है कि निक्षेपणीय वातावरण पूर्णतया सरोवरी नहीं थे बल्कि झील भीषण बाढ़ से सम्भवतया प्रभावित थी जिसके कारण शायद डायटमों की वृद्धि तथा इनका परिरक्षण रुक गये थे।

THE Hirpur Locality III (33°41′N, 75°41′E) exposed along the Rimbiara River, southwest of Srinagar in Anantnag District, forms a part of Hirpur Formation and marks the basal part of Lower Karewa in Kashmir Valley. These sediments are subjected to diatom analysis. However, there are reports on diatom floristics from Karewa sediments exposed elsewhere in the valley. The information available on the occurrence of diatoms in Kashmir Valley is meagre and largely deals with the enumeration of diatom taxa.

The diatom study of Karewas dates back to the early twentieth century when Conger (in de Terra & Paterson, 1939) could enumerate about 70 species of diatoms from lignite bearing beds at Handawor and in Shaliganga Valley. The information of diatom study by Lundquist (1936) was briefly summarized by de Terra and Paterson (1939). Iyengar and Subrahmanyan (1943) analysed Karewa shale exposed at about 9,000 ft at Gulmarg for diatom recovery and recognised 10 genera, 13 species, two varieties, one new variety and one new form. Thereafter, Karewas did not receive any attention from scientists of this discipline and after a lapse of about two decades, the Karewa sediments from clayey blocks at Laredura in Kashmir Valley were investigated by Rao and Awasthi (1962) who made a short report of centric diatoms belonging to *Melosira, Cyclotella* and *Stephanodiscus* and they also noted the occurrence of pennate diatoms. Puri

(1948) has also made a passing reference of diatoms so far worked out by the earlier workers. Nevertheless, Roy (1974, 1980) collected about 1,000 samples from 32 measured sections between Nichahom and Kurigam for biozonation of Karewas in Kashmir Valley. He also emphasized that the Lower Karewa is quite rich in fossil diatoms while the Upper Karewa is devoid of them. It is further observed that there is an uniformity in the trend of distribution and assemblage of fossil diatoms in the Lower Karewa beds. Based on these studies, Roy (1974, 1980) divided Lower Karewa into: (i) the lower Centrales assemblage zone, and (ii) the upper Pennales assemblage zone and assigned Miocene and Pliocene age respectively. Earlier, Roy (1971) recorded 72 species of diatoms belonging to 29 genera from the Lower Karewa in Kashmir Valley. Gandhi and Mohan (1983) and Gandhi *et al.* (1985, 1986) while studying Bal Tal and other samples in Kashmir Valley have noted a rich assemblage of diatoms.

The object of undertaking diatom study of Hirpur (Lower Karewa) was firstly to work out the depositional environments as an ancillary to the pollen and spore analysis and secondarily to confirm the observations of Roy (1974, 1980) as regards the age of Karewas which has been a matter of discussion amongst Cenozoic geologists, sedimentologists, palynologists, palaeobotanists and magnetostratigraphers.

MATERIAL AND METHOD

The samples were procured from scarpment exposed along the Rimbiara River and have been recognised as Hirpur Locality III. About 10 gm of material from each sample was first gently ground and boiled in concentrated HCL for about an hour in order to remove the carbonates present in the matrix. Then the material was kept in distilled water for 4-5 hours to settle down. Later the fluid was decanted out and the residue was boiled in concentrated HNO_3 with a few crystals of $K_2Cr_2O_7$ to remove organic material. Thereafter, the samples were washed repeatedly with distilled water and allowed the residue to settle down. The permanent slides were prepared in canada balsam and traverses were counted under 40× objective of microscope. The slides have been deposited in the repository of Birbal Sahni Institute of Palaeobotany, Lucknow.

In all, 54 samples were studied for diatoms in varying frequencies. The frequency of the various components was assessed on four point scale (abundant, frequent, occasional and rare) as given below:

DIATOM COMPOSITION

The samples have been analysed from all the three lithounits, viz., laminated muds, lignitic muds and sands which yielded diatoms. However, most of the samples from laminated muds have not shown the positive results. On the whole, the diatom assemblage from Hirpur Locality III is poor. The diatom assemblage depicts the preponderance of Pennales as compared to Centrales.

MORPHOLOGICAL DESCRIPTION

Genus—*Cocconeis* Ehrenberg

Cocconeis placentula Ehrenberg

Text-fig. 8

Valve broad, elliptical, length 27.0 μm, breadth 18.0 μm. Striae punctate, linear and in longitudinal series, 18-20 in 10 μm.

Nature—Fresh and brackish water.

Sample no.	33	36	38	72	80	95	109	111	123	141	164	202	212	225	230	247
Nature of sediments	Lignite	Lignite	Lignite	Mud	Sand	Lignite	Clay	Sand	Sand	Lignite	Lignite	Muddy sand	Muddy sand	Lignite	Lignitic Mud	Clay
Taxa																
Cocconeis	—	R	O	—	—	R	—	—	R	O	—	—	—	—	—	—
Cyclotella	—	—	O	—	—	O	—	O	F	R	R	—	—	—	—	R
Fragilaria	—	O	O	—	—	—	O	—	O	R	—	R	—	—	O	O
Gomphonema	—	R	R	—	—	—	O	—	F	F	F	F	—	F	R	O
Melosira	F	F	A	F	—	—	—	—	R	R	R	—	—	R	O	—
Navicula	A	F	A	F	—	—	F	—	F	O	A	R	—	F	F	A
Nitzschia	A	A	A	—	F	—	A	R	—	A	F	F	—	F	R	O
Pleurosigma	—	—	—	—	—	—	—	R	R	R	—	—	—	—	—	—
Surirella	—	—	—	—	—	—	—	—	—	—	—	—	—	—	R	—
Synedra	A	—	—	F	F	A	—	—	O	A	O	—	R	—	O	O
Unidentified	—	R	R	R	R	—	—	—	—	—	R	—	R	—	—	—

A = Abundant; F = Frequent; O = Occasional; R = Rare.

Genus—*Cyclotella* Kutzing

Cyclotella meneghiniana Kutz.
Text-fig. 17

Valve discoidal, diameter 23.5 μm, valve margin striated. Striae wedge-shaped, short, 9-11 in 10 μm.

Nature—Fresh to marine water.

Cyclotella sp. 1
Text-fig. 20

Valve discoidal, diameter 30.0 μm, valve margin striated. Striae long, 8-9 in 10 μm.

Cyclotella sp. 2
Text-fig. 24

Valve discoidal (pressed rectangularly in permanent slide), diameter 25.0 μm, valve margin striated. Striae short, 9-10 in 10 μm.

Genus—*Fragilaria* Lyngbye

Fragilaria construens (Ehrenberg) Grun.
Text-fig. 29

Valve lanceolate with apices rostrate, inflated in median portion, length 10-20 μm, breadth 5-7 μm. Striae very delicate.

Nature—Fresh water.

Fragilaria sp.
Text-fig. 14

Five valves in chain, length of valve 19.5 μm.

Genus—*Gomphonema* Agardh

Gomphonema augur Ehrenberg
Text-fig. 13

Valve cordate-cuneate, with upper apex obtuse-apiculate, lower apex attenuate, slightly subrostrate, length 30 μm, breadth 13.0 μm. Striae distinct, 10-14 in 10 μm.

Nature—Fresh water.

Gomphonema olivaceum (Lyngb.) Kutz.
Text-fig. 19

Valve clavate, with broadly rounded apex and attenuated base, length 27.5 μm, breadth 13.0 μm. Striae indistinct.

Nature—Fresh water.

Genus—*Melosira* Agardh

Melosira ambigua (Grun.) O. Muller
Text-fig. 6

Valve cylindrical, in chains, height of one semicell 11.0 μm, diameter 9.0 μm. Punctae and sulcus indistinct.

Nature—Fresh water.

Genus—*Navicula* Bory

Navicula sp. 1
Text-fig. 4

Valve linear-lanceolate with capitate ends, length 64.5 μm, breadth 23.5 μm. Striae and nodules faint.

Nature—Fresh Water.

Navicula sp. cf. *N. exiqua* (Gregory) O. Muller
Text-fig. 5

Valve elliptic-lanceolate, with capitate-rostrate ends, length 63.0 μm, breadth 13.5 μm; central area distinct with more or less radial striae.

Nature—Fresh water.

Navicula sp. 2
Text-fig. 11

Valve attenuate, rounded at the ends, length 25.0 μm, breadth 10.0 μm. Striae indistinct.

Nature—Fresh water.

Navicula sp. 3
Text-fig. 25

Valve broadly lanceolate with feeble constriction and capitate ends, length 38.0 μm, breadth 12.0 μm. Raphe thin and straight. Striae 8-13 in 10 μm.

Nature—Fresh water.

Navicula sp. 4
Text-fig. 26

Valve elliptical-lanceolate with slight constriction and broadly produced rounded ends, length 46.0 μm, breadth 15.0 μm. Striae indistinct.

Nature—Fresh water.

Navicula sp. 5
Text-fig. 28

Valve linear-lanceolate with pointed ends, length 26.0 μm, breadth 6.0 μm at the broadest. Striae indistinct.

Nature—Fresh water.

Genus—*Nitzschia* Hassall

Nitzschia obtusa W. Smith
Text-fig. 1

Valve linear, slightly constricted towards the centre and tapering towards the truncate ends, length 105.0 μm, breadth 10.5 μm. Keel punctae 9-10 in 10 μm. Striae indistinct.

Nature—Fresh and brackish water.

Nitzschia sp. 1
Text-fig. 7

Valve linear, elliptical with rounded ends, length 36.5 μm, breadth 12.5 μm. Keel punctae 10-12 in 10 *μm*.
Nature—Fresh water.

Nitzschia sp. 2
Text-fig. 10

Valve linear, lanceolate, length 24.0 μm, breadth 5.0 μm. Keel punctae 10-12 in 10 μm.
Nature—Fresh water.

Nitzschia sp. 3
Text-fig. 12

Length of the valve 50.0 μm (girdle view), keel punctae distinct.
Nature—Fresh water.

Nitzschia sp. 4
Text-fig. 15

Valve linear, lanceolate, length 60.5 μm, breadth 10.0 μm. Keel punctae generally indistinct.
Nature—Fresh Water.

Nitzschia sp. 5
Text-fig. 16

Valve narrowly lanceolate with tapering ends, length 90.0 μm, breadth 3.0 μm. Keel punctae and striae indistinct.
Nature—Fresh Water.

Nitzschia sp. 6
Text-fig. 18

Valve broadly elliptical-lanceolate, ends somewhat rounded, length 27.0 μm, breadth 15.0 μm. Striae distinct.
Nature—Fresh Water.

Nitzschia sp. 7
Text-fig. 23

Valve linear-lanceolate, slightly inflated in the middle part, length 40.5 μm, breadth 4.0 μm. Keel punctae 10-12 in 10 μm.
Nature—Fresh Water.

Nitzschia sp. 8
Text-fig. 27

Valve broadly linear with slightly concave sides, length 45.0 μm, breadth 10.0 μm. Striae distinct.
Nature—Fresh Water.

Genus—*Pleurosigma* W. Smith

Pleurosigma sp.
Text-fig. 3

Valve elongate-elliptical, sigmoid. Subacutely, rounded at the poles, length 100.0 μm, breadth 13.0 μm. Raphe sigmoid. Striae faint.
Nature—Fresh to brackish water.

Genus—*Surirella* Turpin

Surirella sp.
Text-fig. 21

Valve heteropolar, ovate with broadly rounded apex and acutely cuneate base, length 62.5 μm, breadth 20.0 μm at the broadest point. Flap margins, windows, costae and striae indistinct.
Nature—Fresh to brackish water.

Genus—*Synedra* Ehrenberg

Synedra ulna Nitzsch
Text-fig. 9

Valve linear, apices more or less long-rostrate, generally broken lengthwise, breadth 10.0 μm. Striae distinct.
Nature—Fresh water.

Synedra sp.
Text-fig. 2

Valve linear, apices more or less long-rostrate, length 75.0 μm, breadth 12.0 μm. Striae distinct, leaving a quadrangular hyaline space in median portion.
Nature—Fresh water.

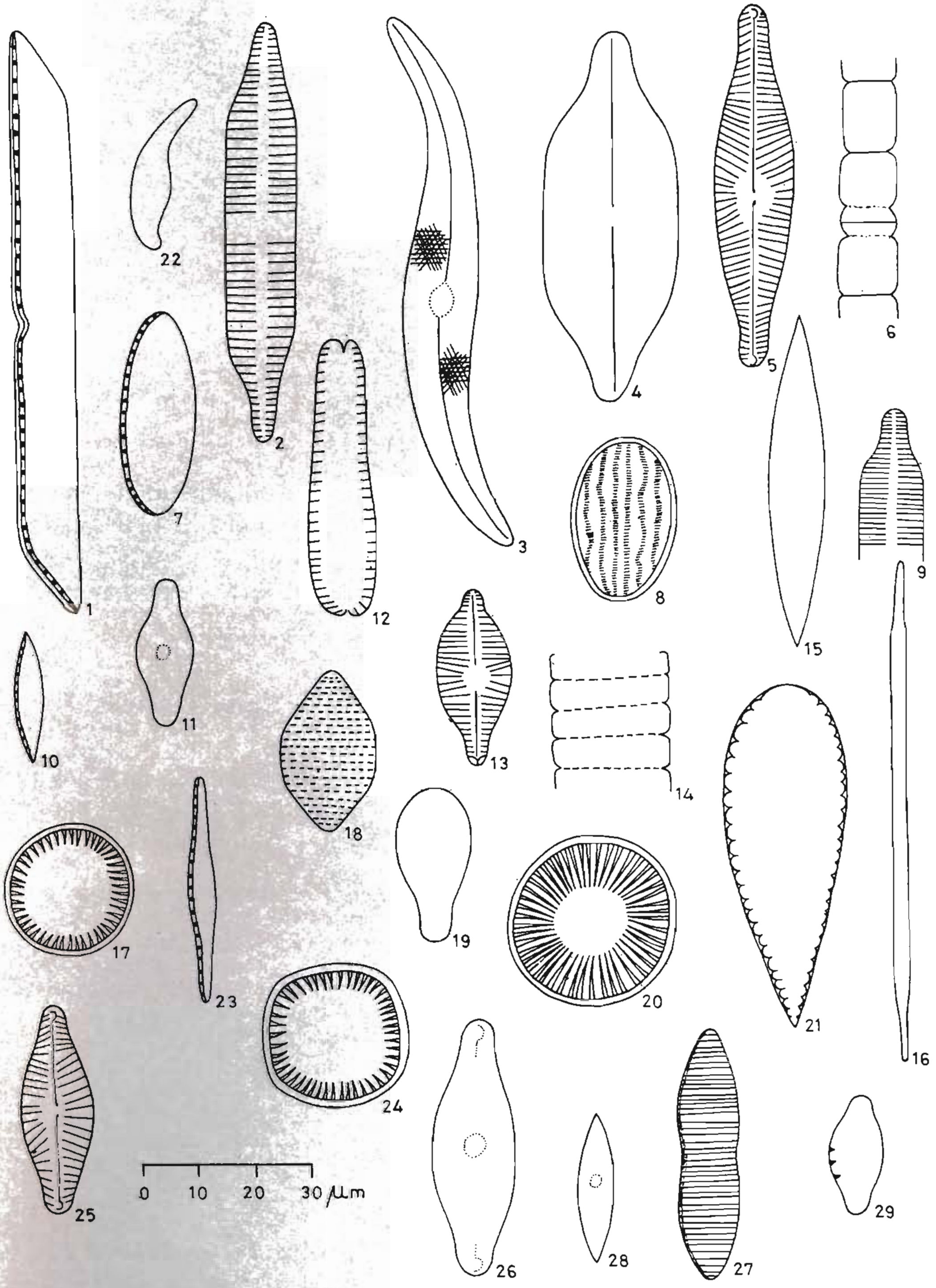
Unidentified form
Text-fig. 22

Valve asymmetrical with indistinct characters.

DISCUSSION AND CONCLUSION

The diatom analysis of Lower Karewa samples from Hirpur Locality III in Kashmir Valley has been assessed in the light of depositional environments as well as the age of Lower Karewa as suggested by earlier workers.

1. The sediments exposed at Hirpur Locality III are all the more poor in diatoms. However, diatoms could be recovered from all the three lithofacies.
2. The diatom assemblage is predominated by Pennales, whereas Centrales are scarce. The stratigraphical distribution of diatoms has revealed that the occurrence of *Nitzschia, Navicula* and *Synedra* is more frequent as compared to other diatom taxa.
3. Most of the diatom frustules are either broken or ground suggesting their allochthonous nature of deposition. Thus, the frequency and nature of diatoms recovered from the sediments portray



Text-fig. 1—1, *Nitzschia obtusa* W. Smith: Slide no. BSIP 36(1); **2**, *Synedra* sp.: Slide no. BSIP 141(4b); **3**, *Pleurosigma* sp.: slide no. BSIP 141(4); **4**, *Navicula* sp. 1: slide no. BSIP 141(2); **5**, *Navicula* sp. cf. *N. exiqua* (Gregory) O. Muller: slide no. BSIP 247(2); **6**, *Melosira ambigua* Muller: slide no. BSIP 38(3); **7**, *Nitzschia* sp. 1: slide no. BSIP 38(3); **8**, *Cocconeis placentula* Ehrenberg: slide no. BSIP 38(2); **9**, *Synedra ulna* Nitzsch: slide no. 95(4); **10**, *Nitzschia* sp. 2: slide no. BSIP 33(1); **11**, *Navicula* sp. 2: slide no. BSIP 33(10); **12**, *Nitzschia* sp. 3: slide no BSIP. 38(2); **13**, *Gomphonema augur* Ehrenberg: slide no. BSIP 141(5); **14**, *Fragilaria* sp.: slide no. BSIP 141(1); **15**, *Nitzschia* sp. 4: slide no. BSIP 141(1a); **16**, *Nitzschia* sp. 5: slide no. 230(4); **17**, *Cyclotella meneghiniana* Kutz.: slide no. BSIP 141(6); **18**, *Nitzchia* sp. 6: slide no. BSIP 141(6); **19**, *Gomphonema olivaceum* (Lyngb.) Kutz: slide no. BSIP 141(2,4); **20**, *Cyclotella* sp. 1: slide no. BSIP 95(7); **21**, *Surirella* sp.: slide no. BSIP 230(4); **22**, Unidentified form: slide no. BSIP 141(4); **23**, *Nitzschia* sp. 7: slide no. BSIP (2); **24**, *Cyclotella* sp. 2: Slide no. BSIP 123(1); **25**, **26**, *Navicula* sp. 3 and 4: slide no. BSIP 38(3); **27**, *Nitzschia* sp. 8: slide no. BSIP 36(3); **28**, *Navicula* sp. 5: slide no. BSIP 38(3); **29**, *Fragilaria construens* (Ehrenberg) Grun.: slide no. BSIP 38(3).

that depositional environments were not wholly ponding/lacustrine. Instead, there might have been periodical violent floodings of the lake which perhaps hampered the growth of diatoms and their preservation too. Another possibility could be that most of the diatoms were drifted from elsewhere along with water streams.

The diatom study could be of paramount importance to work out the palaeo-drainage system with a greater precision provided the finer details of the ecological range of each diatom species are available. Nevertheless, future work on diatoms will also have its impact on determination of palaeo-temperatures. However, the total diatom assemblage indicates fresh water conditions.

4. The age of Lower Karewa had been a matter of controversy since the time of Lydekkar (1883) and there had been practically no unanimity amongst the subsequent workers as regards to the age and thickness of Lower Karewa.

Roy (1974, 1980) based on the concept that the sediments exposed between Nichahom and Kurigam are the sole representatives of the entire Lower Karewa and applied diatom analysis to the sediments for the purpose of biozonation and their age. He formulated two biozones, viz., the lower Centrales Zone and upper Pennales Zone. Considering the monophyletic origin of diatom and in connivance with the general consensus of opinion amongst diatomists that Miocene enjoyed the profusion of centric diatoms, Roy (1974, 1980) envisaged Miocene and Pliocene age respectively.

However, our studies on diatoms from Hirpur Locality III, a part of Hirpur Formation (Bhatt, 1976) and supposed to be the basal part of the Lower Karewa, do not support the hypothesis postulated by Roy (1974, 1980). Our observations, however, reveal the predominance of pennate diatoms which in any case do not suggest Miocene age. We are as a matter of fact afraid to comment on the age on the basis of diatoms alone. Nevertheless, when seen in context with palynostratigraphy and magnetostratigraphy this column of stratigraphy may be put up in Upper Pliocene Age.

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Book Review

FUNDAMENTALS OF PALAEOBOTANY
S. V. Meyen 1987
Chapman and Hall, London & New York, xvi+432, £65.

THIS is probably the third English language text-book of Palaeobotany to be published during the ninety-eighties. This English version of *Osnovy Paleobotaniki* reached Meyen just two hours before his sad demise. Though titled Fundamentals of Palaeobotany, Sergei Viktorovich Meyen's book is much more than a systematic enumeration and description of fossil plant taxa. It is an off-beat book devoting less than half of the volume to systematics and a major part to more contemporary topics. It is a welcome departure from the tradition and thus invites a comparatively wide readership.

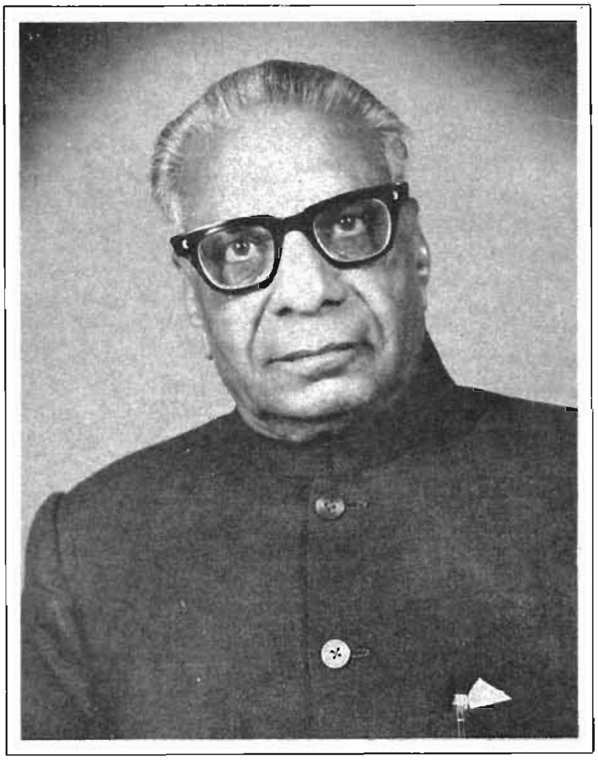
Sergei Viktorovich's comprehension of Palaeobotany includes palaeopalynology, epidermal/cuticular studies, palaeoecology, palaeofloristics, evolutionary patterns and lineages, etc. He has not only reproduced information from published data but has also included his own commentary to guide the reader towards important theoretical aspects, e.g., significance of palaeobotanical data to the concept of punctuated equilibria and cladistic principles in phylogenetics, to the theory of evolution and to the principles of systematics and nomenclature.

The book is organised into eight chapters. Chapter 1 enumerates preservation types and techniques of study, but only very briefly as this information is well covered by earlier text-books. Chapter 2 deals with nomenclatural and typological aspects of Palaeobotany. The concept of 'Parataxa' and 'Eutaxa' as applicable to fossil plant systematics is outlined in detail and the concept of 'Satellite taxa' is introduced. While a typical 'Parataxon' may be based only on a very limited range of characters (e.g., of a detached leaf), an 'Eutaxon' is based on all the possible decipherable characters. Though to an average student the ideas presented in this chapter may at first look to be vague and incomprehensible, yet they are important. Chapter 3 on Fossil Plant Systematics is divided in two parts-I. Prokaryotes and II. Eukaryotes. Part I includes short notes on Bacteria, Cyanobacteria, Calcareous algae, stromatolites and oncolites. Part II commences with an outline of systematics of eurkaryotic algae, leading to those on higher plants. Plants with dominating gametophytes are placed in Bryophyta whereas plants where sporophytes predominate are assigned to Proteridophyta, Pteridophyta, Pinophyta and Magnoliophyta. The latter two divisions relate to Gymnospermae and Angiospermae respectively. Meyen's choice of suprageneric terms in certain cases may not meet the approval of all palaeobotanists. Already, there has been much correspondence on the subject after Meyen's revolutionary ideas appeared in the Botanical Review. For example, he places southern hemisphere Permian glossopterids in the order Arberiales, whereas students of glossopterids would place them in atleast two orders, viz., Ottokariales and Lidgettoniales. Chapter 4 on palaeopalynology is definitely better treatment of the subject than by other contemporary authors. Chapters 5 to 8 deal mostly with applied aspects. The trends in the epidermal-cuticular characters in the geochronological scale are summarised. Practical application value of dispersed cuticles is outlined.

On the whole the book is very well organised and well produced. One thing that strikes the reader is the total lack of photographs. But these are not missed as the line drawings are excellently executed and cover most of the spectrum; a researcher can always go back to original publications for photoillustrations. This book should be well received by graduate students and their teachers, though it would be sometime before number of terms used by Meyen are assimilated in palaeobotanical literature. One also wishes that Meyen should have given more space to southern hemisphere floras. *Fundamentals of Palaeobotany* is a worthy successor to the Krystofovich text and should win laurels.

Hari K. Maheshwari

Professor K. M. Gupta
(1908-1987)



Professor K. M. Gupta was born on October 27, 1908 at Beawar in Rajasthan. He got his early education at Beawar and Agra. He got his Master's Degree in Botany from the Lucknow University in 1932. He was very much impressed with Professor Birbal Sahni, and joined research under his able guidance in the Department of Botany, Lucknow University. In 1932, he accompanied Professor Sahni on an excursion to the Rajmahal Hills, Bihar when the Nipania locality, famous for petrified plant remains particularly those of the Pentoxyleae, was discovered. He worked on "The anatomy and theoretical significance of homoxylous angiosperms" for his Doctoral Thesis. Professor Gupta studied both extant (*Trochodendron, Tetracentron, Drimys* and *Zygogynum*) and extinct plants (Cycadeoideas and Bucklandias) in this connection and came to the conclusion that *Homoxylon rajmahalensis* Sahni was not an angiosperm but a Bennettitalean wood. He was awarded the Ph.D. Degree in Palaeobotany from Lucknow University in the year 1936.

Professor Gupta published a large number of papers on plant fossils, especially from the Rajmahal Hills. He investigated in detail a number of species of the water fern *Marsilea*, especially those found in Rajasthan and wrote a Monograph on the genus.

Professor Gupta started his professional career as a teacher at M.T.B. College, Surat (Maharashtra) in 1936. Later on he taught at Dungar College, Bikaner; Jaswant College, Jodhpur; and Government College, Ajmer. He was appointed Professor and Head of Botany Department, University of Jodhpur in 1967. Professor Gupta did great service to the Indian palaeobotany by introducing palaeobotany in the syllabi of University of Rajasthan and University of Jodhpur.

After superannuation Professor Gupta joined the spiritual mission '*Sahaj Marg*' and devoted his time to it. He passed away on July 20, 1987 at the age of seventynine. He will be long remembered by his many students and fellow palaeobotanists.

B. D. Sharma