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Palaeocene-Eocene marker pollen from India and tropical Africa

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The Palaeocene-Eocene epochs have witnessed a great floral diversification in tropical areas, which is also reflected in the pollen spectra. The important Indian stratigraphical marker taxa have been examined and a comparative study with extant material has provided botanical affinities to some of the taxa. Their comparison with those recorded in Africa leads to reflection on their palaeogeographical distribution. The stratigraphic ranges have been shown in the range chart. Some of the taxa common to India and Africa are: *Retistephanocolpites williamsi, Spinizonocolpites* spp., *Tricolpites reticulatus, Proxapertites* spp., *Anacolosidites luteoides* and *Marginipollis* spp. A number of Indian as well as African taxa are not recorded beyond the terminal Eocene; some of them could have migrated from India to other countries such as *Gonystylus* (*Cryptopolyporites*) to Malaysia and *Gunnera* (*Tricolpites reticulatus*) to Australia. The relative location and motion of India during these epochs could explain the singularity of the Early Tertiary Indian palynoflora.

Key-words—Palynology, Palaeogeography, Continental Drift, Palaeocene-Eocene, India, Africa.

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सारौंश

भारत एवं उष्णकटिबन्धीय अफ्रीका से पुरानूतन-आदिनूतन सूचक परागकण

बेंगलूर श्रीनिवासा वेंकटाचाला, सी. करातिनी, सी. तिसत् एवं रंजीत कुमार कर

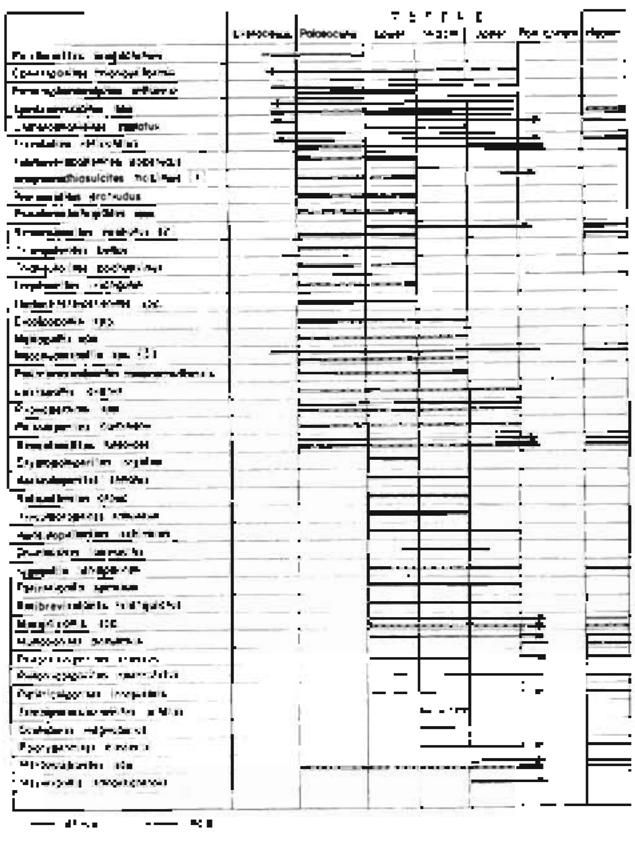
पुरानूतन-आदिनूतन कल्पों से उष्णकटिबन्धीय क्षेत्रों में अत्याधिक वनस्पतिजातीय विविधता के प्रमाण मिलते हैं। यह विविधता परागकण-स्पेक्ट्रमों से भी व्यक्त होती है। इस शोध पत्र में महत्वपूर्ण भारतीय स्तरिकीय-सूचक वर्गकों का अध्ययन किया गया है तथा वर्तमान वर्गकों से तुलनात्मक अध्ययन करने पर कुछ वर्गकों की वनस्पतिक सजातीयता भी प्रेक्षित की गई है। इन वर्गकों की अफ्रीकी वर्गकों से तुलना करने पर इनके पुराभौगोलिक वितरण पर प्रकाश पड़ता है। विस्तृति-तालिका में स्तरिकीय प्रसार दर्शाये गये हैं। **रेटिस्टीफ़ेनोकॉल्पाइटिस विलियमसाई, स्पाइनीजोनोकॉल्पाइटिस** जातियाँ, **ट्राइकॉल्पाइटिस रेटिकुलेटस, प्रोक्सापर्टाइटिस** जातियाँ, **ऐनाकोलोसिडाइटिस ल्यूटिऑयडिस** एवं **मार्जिनीपॉलिस** जातियों के कुछ वर्गक भारत एवं अफ्रीका दोनों में ही सामान्य हैं। अनंतिम आदिनूतन के बाद अनेक भारतीय एवं अफ्रीकी वर्गक नहीं मिलते; इनमें से कुछ भारत से अन्य देशों में स्थानान्तरित हो गये हैं जैसे **गोनीस्टाइलस (क्रिप्टोपोलीपोराइटिस)** मलेशिया में तथा **गुन्नेरा (ट्राइकॉल्प्पाइटिस रेटिकुलेटस)** ऑस्ट्रेलिया में। इन कल्पों में भारत की आपेक्षिक स्थिति तथा स्थानान्तरण से प्रारम्भिक तृतीयक कल्प में भारतीय परागाणुवनस्पतिजात की यथार्थता अन्वेषित की जा सकती है।

THANIKAIMONI *et al.* (1984) made an attempt to establish the relationship between Indian and African Tertiary pollen. This paper concerns with the same theme but restricts its investigation to the Lower Tertiary, viz., Palaeocene and Eocene. These two periods witnessed maximum development and subsequent diversification and spread of angiosperms in many directions. They registered a gradual decline in Upper Eocene and later in Lower Oligocene at a time when many global changes are recorded (Pomerol & Premoli-Silva, 1986). New groups of plants appeared while some faced extinction. Stratigraphic markers of India and western Africa (from Senegal to Gabon) are discussed. Reflections on floristic provinces in relation to the continental drift have been made.

COMPARATIVE STRATGRAPHIC RANGES IN INDIA AND AFRICA

The enclosed distribution chart (Text-fig. 1) is a result of detailed study of Palaeogene stratigraphic markers used in India and Africa. Certain difficulties were encountered in making this comparison as the taxonomic treatment is different in the two regions. With the publication of the atlas of Tertiary pollen by Thanikaimoni *et al.* (1984) some of the differences have been narrowed down. It is hoped that with the publication of this comparative account this would further be narrowed down. For example, African palynologists are familiar with the generic name *Echimonocolpites* which is known as *Neocouperipollis* in India while *Longapertites brackenensis* is known as *Dandotiaspollis*. We have not attempted any nomenclatural change till detailed comparative studies are accomplished.

Significant Indian marker pollen have been described either in Thanikaimoni *et al.* (1984) or in this paper. The geological background and the location of the sedimentary basins are detailed in Thanikaimoni *et al.* (1984).



Text-figure 1—Range chart of Palaeocene-Eocene stratigraphic markers in India and Africa. (1) = *Longapertites brasiliensis*, (2) = *Spinizonocolpites baculatus*, (3) = *Echimonocolpites* spp.

The morphological complex of polycolpate pollen despite its high value for Eocene stratigraphy has not been considered here since a great taxonomic confusion does exist in this group which needs serious investigations (Caratini, 1983).

In Africa, the main features of the phytogeographical divisions in the Early Tertiary have been tentatively reconstructed by Raven (1978) and Simon *et al.* (1981). More recently, Bonnefille (1987) has insisted on the distinction between western and eastern parts of Africa because of the differences in the formation of the sedimentary basins. For this reason and because of only a few investigations carried out in the east compared to a large number of studies available on the western continental margin, only the west part is considered here. The African palynological data have been compiled mainly by Germeraad *et al.* (1968) and later in the papers published by numerous authors cited in the references.

RELATIONSHIP BETWEEN INDIAN AND AFRICAN PALYNOFLORA

There is only some similarity between the Early Palaeogene pollen flora of Africa and India since most of the taxa have been recorded only in either of the two countries. It is striking that the common taxa are mainly pantropical such as *Retistephanocolpites williamsi*, *Spinizonocolpites* spp., *Tricolpites reticulatus*, *Proxapertites* spp., *Matanomadhiasulcites lacunosus* and *Margocolporites* spp. which exhibit almost the same stratigraphic range in both the countries. Nevertheless, certain species considered as pantropical by Germeraad *et al.* (1968), *Echitriporites trianguliformis*, for example, have not been recorded in India.

Other taxa occurring in both regions correspond to large morphological groups of extant genera, hence these have no definite botanical significance. *Margocolporites* as well as *Retitricolporites* *sensu lato* may have several living generic counterparts within Caesalpiniaceae. *Ctenolophonidites costatus* appears as a characteristic taxon since it occurs both in India and Africa but has not been recorded either in South America or in South-East Asia. No major phytogeographic conclusions can be drawn on this basis alone.

The dissimilarities of Palaeocene-Eocene floras of India and Africa could be explained due to continental position during this period (Text-fig. 2). India and Africa were distinctly apart as early as Late Cretaceous, and the gap between them did not favour the continuity and exchange of vegetation. A perusal of the chart eloquently exhibits an important feature in the pattern of extinction of many species in the terminal Eocene both in India and Africa. This also corroborates with the distributional pattern in other tropical areas (Germeraad *et al.*, 1968). Significant global events must have influenced such an extinction. Nevertheless, it will be demonstrated further that in India local causes have also contributed to such an extinction.

EVOLUTION OF THE PALAEOCENE-EOCENE PALYNOFLORA IN INDIA

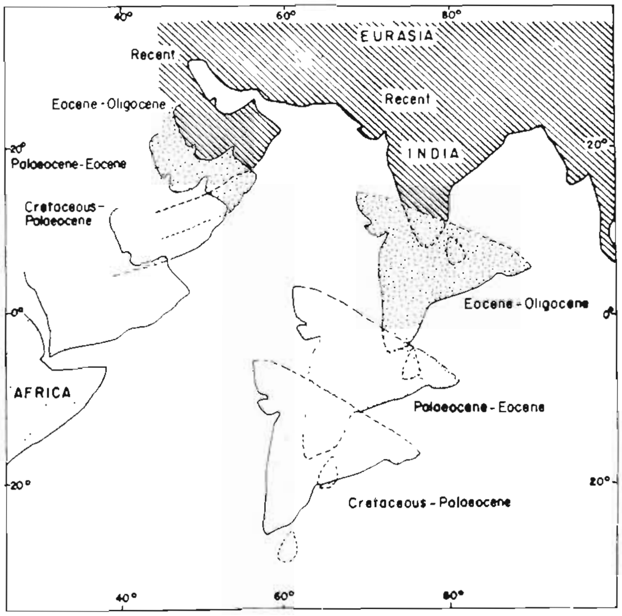
A careful analysis of the chart exhibits that during the Early Palaeogene the flora of India has been subjected to numerous changes. Many genera which are recorded in India during Palaeocene-Eocene either migrated or faced extinction. The extant genus *Durio* (Bombacaceae) may be cited here as an example. This modern genus represented by the pollen genus *Lakiapollis* is found in Palaeocene-Eocene sediments in several regions: Kutch, Kerala, Meghalaya and Assam. Post Eocene records of this pollen in India are absent till to-day. Nevertheless, pollen comparable to *Durio* have been recorded in Miocene and Post-Miocene sediments of Malaysia where the genus is now well established (Anderson & Muller, 1975; Barré de Cruz, 1982).

Similar examples of taxa which habitated in India during Eocene, became extinct in the Post-Eocene period, but are found in other continents even today, for example *Cryptopolyporites* (= *Gonystylus*, Gonystylaceae) now restricted to Malaysia, *Ctenolophonidites costatus* (= *Ctenolophon englerianus*, Ctenolophonaceae) presently in Africa or *C. philippinensis* in South-East Asia, *Retistephanocolpites* (= *Ctenolophon parvifolius*) now in South-East Asia. *Tricolpites reticulatus* (= *Gunnera*, Gunneraceae) and *Proteacidites* (= Proteaceae) now in Australia constitute examples of taxa that disappeared from India and established in disjointed areas: Malaysia, Africa, South America for the former; Australia and South Africa for the later.

Kielmeyerapollenites eocenicus Sah & Kar 1974 from the Palaeocene-Eocene appears closely comparable to extant pollen of the South American *Kielmeyera* (Clusiaceae). Other records of disjointed distribution between fossil and corresponding extant taxa are also known such as *Regnellidium* (Salviniaceae). This fresh water fern which was a common fossil of the Upper Cretaceous-Eocene Deccan Intertrappean flora (Sahni & Rao, 1943) is now restricted to South America. The extinction pattern in India may be related to two main causes:

1. Continental drift

India has been migrating northwards after Cretaceous-Palaeocene (Text-fig. 2). The changes in the latitudinal position and the resulting variations in climate may have been responsible for such extinction in India but these genera continued to live in other regions. While India was drifting and moving away from the equator, Malaysia attained more or less the same position during Oligocene-Miocene and this placement of Malaysia perhaps favoured the migration and subsequent settlement of genera such as *Durio* or *Gonystylus*. The relative position of Malaysia and India may have enabled intercontinental migration as advocated by Axelrod (1979).



Text-figure 2—Location and relative motion of Africa and India from the Cretaceous-Tertiary boundary to Recent (after Olivet *et al.*, 1987).

2. Palaeogeographical condition of sedimentation

The Palaeocene-Eocene Indian palynoflora is recorded mainly from coal and lignite deposits of Meghalaya, Assam, Kutch, Cambay, Rajasthan and other basins. This palynoflora is fairly characterised by certain swamp dwellers such as the fossil pollen corresponding to *Barringtonia (Marginipollis), Durio (Lakiapollis), Gonystylus (Cryptopolyporites), Nypa (Spinizonocolpites)* as well as associated floral elements including evergreen forest representatives related to Ctenolophonaceae (*Ctenolophonidites* and *Retistephanocolpites*), Olacaceae (*Anacolosidites*), Caesalpiniaceae (*Margocolporites* and *Striacolporites*). This swampy ecological condition did not dominate in these basins after Oligocene. The Neogene sediments of India are predominantly riverine deposits and the change in edaphic condition could have also led to the temporary disappearance of the swampy vegetation which occurred during the Palaeogene sequence. This is likely the explanation for the absence of *Spinizonocolpites-Nypa* during the Upper Palaeogene and the Lower Neogene. It occurs again in the Quaternary sediments of India (Thanikaimoni, 1987), and *Nypa* is still growing now-a-days in some parts of the Indian coastal areas such as Sunderbans and Andaman Islands. This riverine depositional process might also explain the occurrence of Permian, Early Cretaceous and Palaeogene reworked pollen in the Neogene basins. These reworked pollen have been the reason for apparent extension of some of Palaeogene taxa into Neogene.

SYSTEMATIC PALYNOLOGY

Inaperturate

Genus—*Retipollenites* González Guzmán 1967
Pl. 1, figs 1-6; Pl. 2, figs 1-6

Original diagnosis—"Pollen grains with a heavy reticulum that is apparently not placed on a basal layer. Apparently there are no apertures. There seems to be no clear similarities with other genera."

Species studied—*Retipollenites confusus* González Guzmán 1967 and *R. confusus* Rawat *et al.* 1977 (*Cheilanthoidspora monoleta* Sah & Kar 1974, illustrated in Kar, 1985, pl. 22, fig. 1 and *C. enigmata* Sah & Kar 1974, illustrated in Kar, 1985, pl. 22, fig. 2 are here attributed to *Retipollenites* sp.).

Description :

Symmetry and form: Subsphaeroidal to oval.

Dimension :	50-85 μm.
Aperture :	Inaperturate.
Exine :	Tectate
Sexine :	Broadly reticulate, meshes 8-15 μm broad, forming subcircular-rhomboidal-various shaped meshes, muri 2-4 μm thick displaying prominent attachment to the nexine, lumina 4-15 μm wide.
Nexine :	± 1 μm thick, continuous.
Variability :	Quite variable in shape and size; the reticulate pattern is loose to strictly adhered to the body.

Occurrence—Very common in Middle Eocene sediments in western India.

Remarks—*Spirosyncolpites* González Guzman 1967, *Retipollenites* González Guzmán 1967, *Praedapollis* (Boltenhagen & Salard) Legoux 1978, *Periretitricolpites* Jan du Chêne *et al.* 1978 and *Cambonaepollenites* Kedves 1986 share in common the overall organization consisting of a subsphaeroidal body enmeshed in a broad reticulum. *Spirosyncolpites* according to González Guzmán (1967) is "syncolpate", the furrow forming a helix which is often not clearly visible.

Praedapollis is triporate as exemplified by Salard-Cheboldaeff, 1977 (pl. 19, fig. 10) but Legoux (1978) in her emendment of the genus *Praedapollis* opines that the pollen is triaperturate with sometimes reduced colpi or apertures not discernible. *Periretitricolpites* Jan du Chêne *et al.* 1978 is tricolpate.

In a large number of specimens of *Retipollenites* studied, the authors have not been able to recognize any aperture. Some specimens of *Cheilanthoidspora monoleta* and *C. enigmata* described by Kar (1985) exemplify a clear disposition of the body bearing the columellae structure supporting the reticulum; the body is never seen detached or free of reticulum. These specimens not showing germinal apertures are now attributed to *Retipollenites*. However, *Cheilanthoidspora monoleta* (Sah & Kar, 1974: pl. 1, figs 11-14) and *C. enigmata* (Sah & Kar, 1974: pl. 1, figs 7-10) show distinct monolete and trilete apertures. It is possible that some of the *Cheilanthoidspora* could also show alete disposition. The attribution of individuals either to *Cheilanthoidspora* or *Retipollenites* rests on the nature of exine stratification.

Fossil Records :

India :

Kutch

Lower Eocene, Middle Eocene to ? Upper Eocene, *C. enigmata* Kar 1985, pl. 22, fig. 2.

Middle Eocene to ? Upper Eocene, *Cheilanthoidspora enigmata* Kar & Saxena 1981, pl. 2, figs 22, 23.

Cambay

Lower-Middle Eocene, *Retipollenites confusus* Rawat *et al.* 1977, pl. 3, figs 108, 109.

Affinity—Unknown.

Monosulcate

Genus—*Matanomadhiasulcites* Kar 1985
Pl. 3, figs 1-4; Pl. 4, figs 1-13

Original diagnosis—"Pollen grains oval-elliptical in shape. Monosulcate, sulcus distinct to indistinct, almost extending end to end. Exine retipilate-retibaculate".

Species studied—*Matanomadhiasulcites maximus* (Saxena) Kar 1985, *Matanomadhiasulcites kutchensis* (Saxena) Kar 1985, and *Matanomadhiasulcites* sp., Pl. 3, figs 1-4.

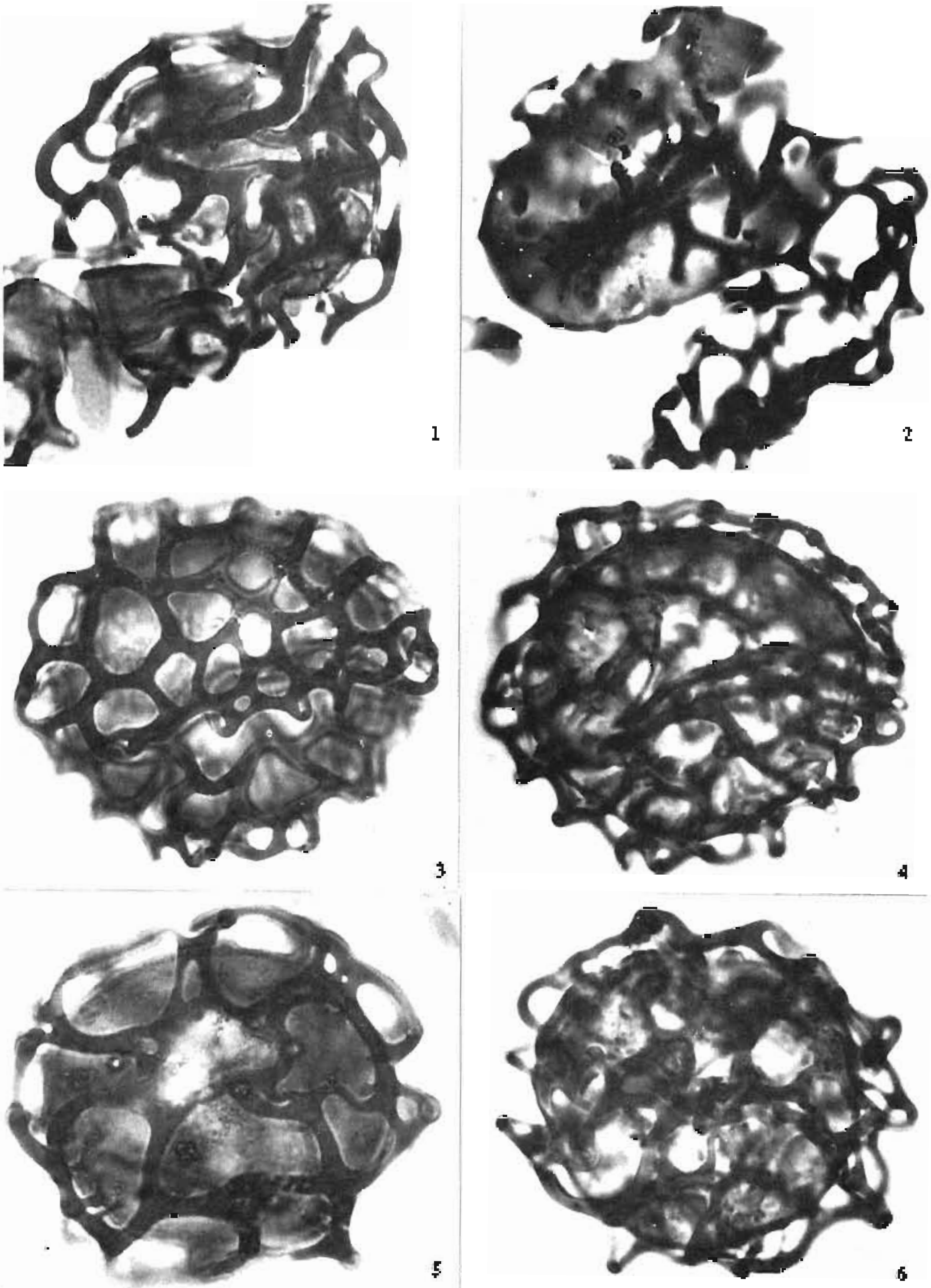


PLATE I

(All photomicrographs magnified × 1000)

1-6. *Retipollenites confusus*. Lower to Middle Eocene, Kutch.

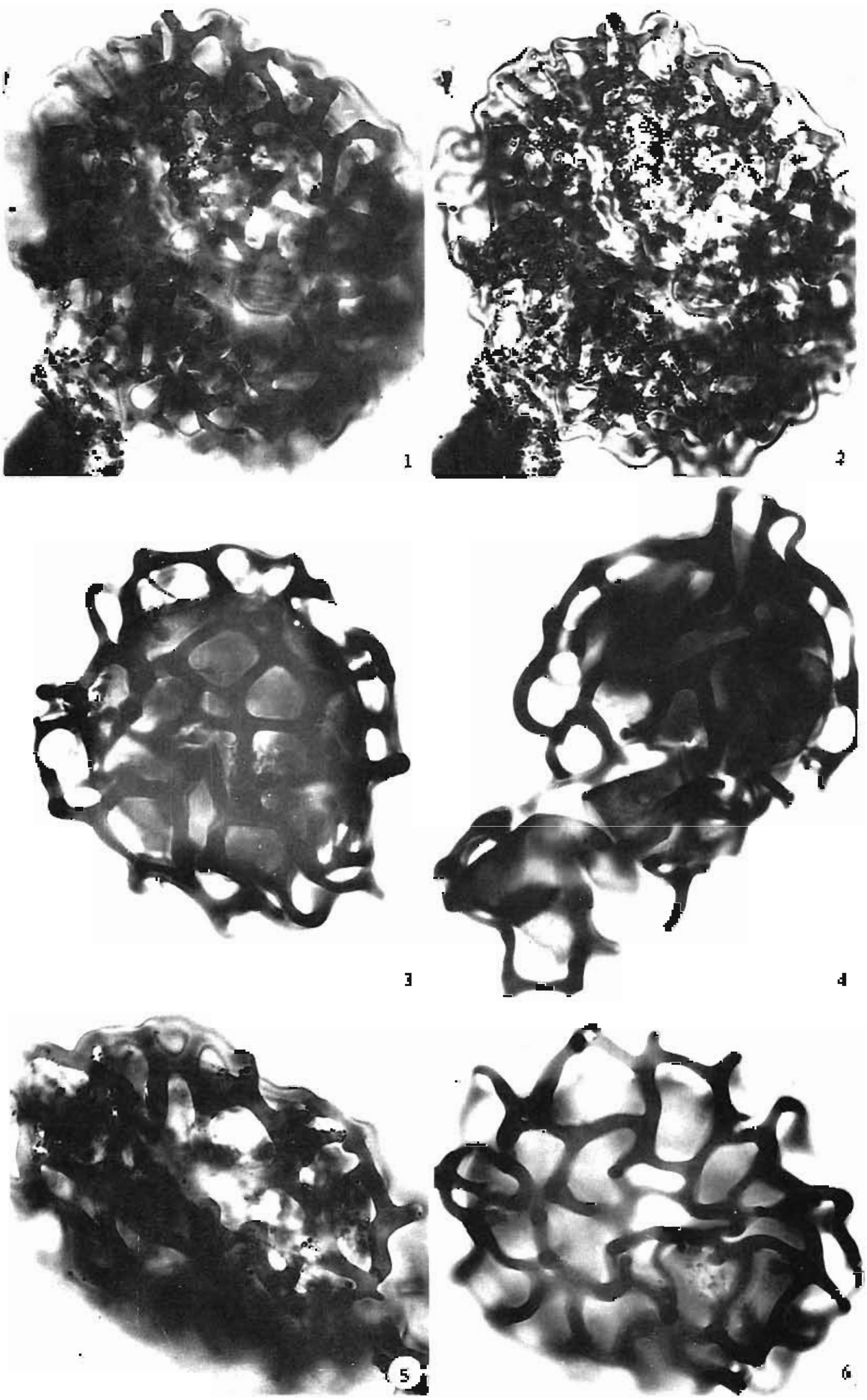


PLATE 2

(All photomicrographs magnified, × 1000)

1, 2. *Retipollenites confusus*, Lower to Middle Eocene, Cutch. 3-6. *R. confusus*, Lower to Middle Eocene, Kutch

Description :

Symmetry and form: Heteropolar, oval to elliptical in shape, rarely observed in tetrad.

Dimension : 60-205 × 35-145 μm.

Aperture : Single, in shape of furrow, often simulating a sulcus, or ill-defined as it may occur in isolated monads showing scar from the original tetrad.

Exine : Tectate.

Sexine : Tectum 2-4 μm thick, perforate, size of perforations variable; infratectum columellar; columella 3-8 μm thick, 1-2, 5 μm broad, closely placed.

Nexine : Discontinuous.

Variability : Quite variable in size and shape; the texture of the sexine is more or less constant in individual specimens though variations are observable between two individuals.

Occurrence—Matanomadhiasulcites is common (up to 5%) in the Palaeocene of India. It is rare in Africa and America.

Remarks—The genus *Matanomadhiasulcites* has not been accommodated in *Longapertites* since the type species *L. marginatus* defined by van Hoeken-Klinkenberg (1964) has two types of reticulation pattern on the exine, coarser on the distal area opposite the aperture and thinner on the rest of the area and on the proximal side. Moreover the diagnosis of the genus *Longapertites* is broad enough to accommodate all the fossil pollen with "one aperture longer than half the greatest circumference of the grain". It is necessary to closely circumscribe genera and hence *Matanomadhiasulcites* has been maintained.

Tetrads have rarely been found in India; González Guzmán (1967) mentions tetrads as common in *Longapertites brasiliensis*.

Fossil Records :

India :

Kutch

Palaeocene, Liliacidites kutchensis Saxena 1979, pl. 1, figs 9, 10.

Matanomadhiasulcites maximus Kar 1985, pl. 3, figs 1, 2.

Lower Eocene, *Liliacidites baculatus* Venkatachala & Kar 1969, pl. 1, fig. 17.

cf. *Liliacidites* Sah & Kar 1970, pl. 1, fig. 21.

Matanomadhiasulcites maximus Kar 1985, pl. 10, fig. 3.

Meghalaya

Palaeocene, *Matanomadhiasulcites maximus* Kar & Kumar 1986, pl. 5, fig. 5 and pl. 6, fig. 1

Liliacidites microreticulatus Dutta & Sah 1970 from Palaeocene of Meghalaya does not show a reticulate exine with smaller meshes near the ends, as stated in the original diagnosis of *Liliacidites* (Couper, 1953) and is regarded belonging to the genus *Matanomadhiasulcites*.

Africa :

Niger (Sougheera)

Upper Eocene, *Matanomadhiasulcites* sp., Pl. 3, figs 1-4; Pl. 5, figs 5-13 (Thanikaimoni *et al.*, in press).

The illustrations given by the following authors can be considered as corresponding to pollen belonging to this same morphological group.

Eocene, *Liliacidites* cf. *L. vaneendenburgi* Boudouresque, 1980, pl. 5, fig. 14a.

Longapertites brasiliensis Boudouresque 1980, pl. 6, figs 1a, 1b.

Cameroun

Eocene and Oligocene, *Longapertites brasiliensis*, Salard-Cheboldaeff, 1977, pl. 7, fig. 6, p. 156.

South America :

Venezuela

Palaeocene, *Proxapertites maracaiboensis*, Muller *et al.*, 1987, pl. 2, fig. 1.

Eocene, cf. *Liliacidites* sp. B Muller *et al.* 1987, pl. 1, fig. 7.

Columbia

Middle Eocene, *Longapertites brasiliensis* González Guzmán 1967, pl. 25, figs 1-1a.

North America :

Texas

Palaeocene, *Schizosporis palaeocenicus* Elsik 1968, pp. 284-285, pl. 5, fig. 3, named in Elsik 1970 as *Annona ?paleocenicus* (p. 99) after the fossil recorded by Warter (1965) in the Lower Eocene from Mississipi.

Affinity—González Guzmán attributes affinity with Annonaceae for *Longapertites brasiliensis.* Some specimens of *Matanomadhiasulcites* studied and illustrated here (Pl. 3, figs 1-4; Pl. 4, figs 5-13) are comparable to some genera of Annonaceae, particularly *Annona* (Pl. 3, figs 5-7) because of the general structure of the exine and the shape of the aperture (A. Le Thomas, in *litt.*), but for most of them, a monocotyledonous affinity (*i.e.* Liliaceae, Agavaceae, etc.) may be stated. Muller (1981) has rejected the affinity with *Annona* given by Warter (1965) and Elsik (1970) for the Palaeocene fossils from Mississipi and Texas.

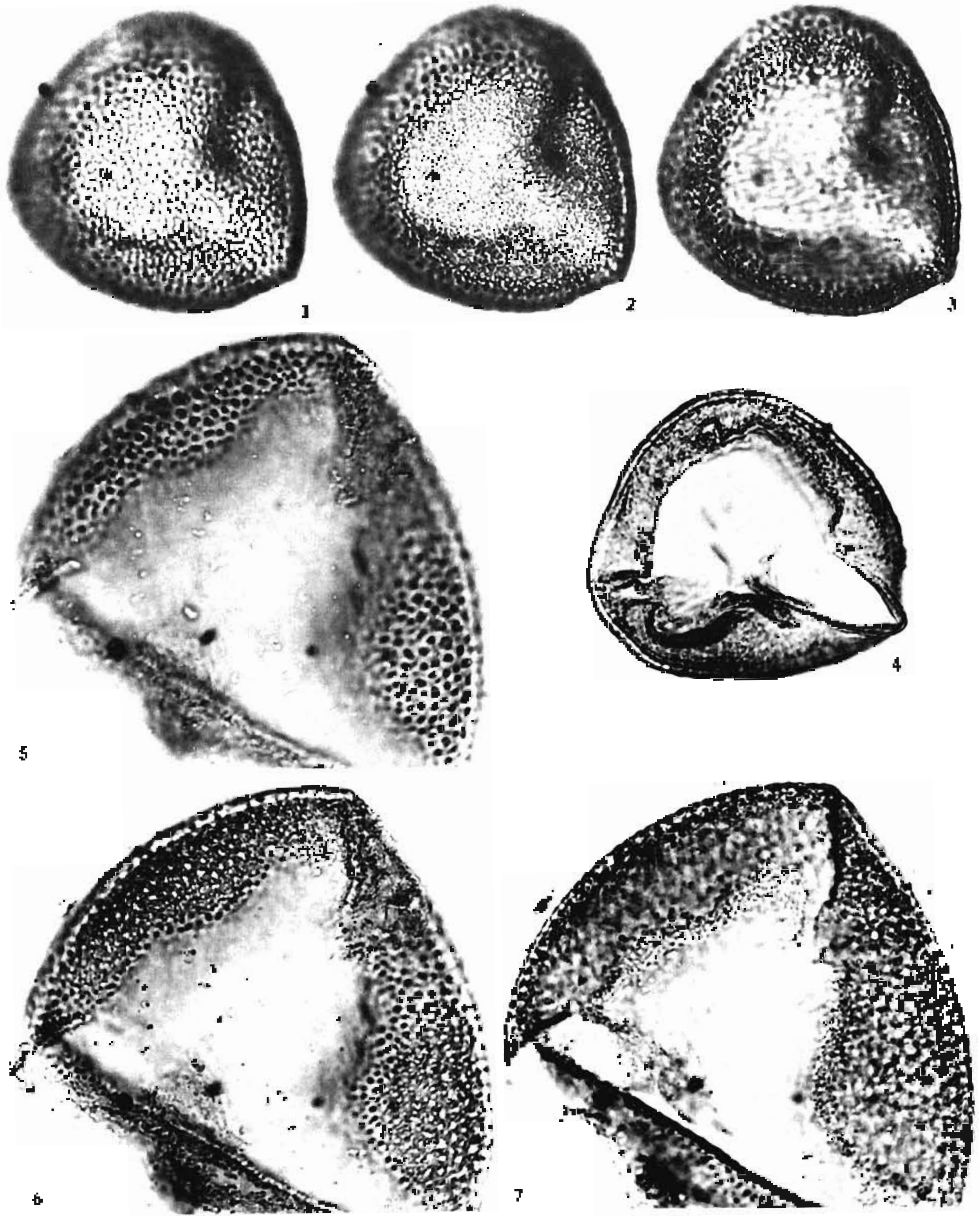


PLATE 3

(All photomicrographs magnified × 1000)

1-4. *Matanomadhiasulcites* sp., Upper Eocene, Saugheera, Niger. 1-3. distal side, 4. proximal side. 5-7. *Arenga longiflora* S. Wats (slide BSIP 20232)

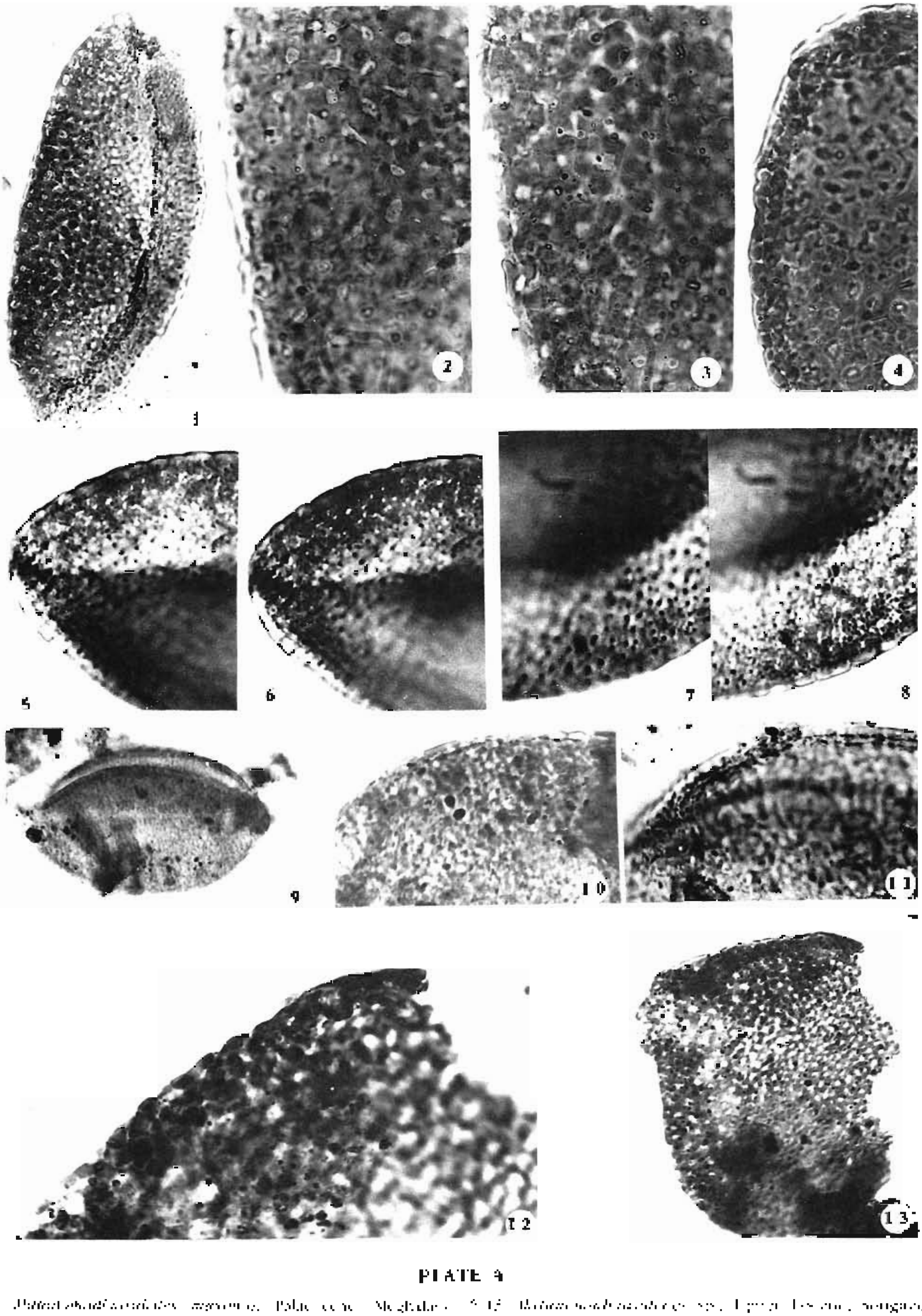


PLATE 4

1-4. [illegible], Palaeocene, Meghalaya, India (1 × 500; 2-4 × 1000).

5-13. [illegible], Upper Eocene, [illegible] Naga [illegible] (5-8, 10-12 × 1000; 9, 13 × 500).

Tricolpate

Genus—*Tricolpites* Cookson (1947) ex Couper (1953) emend. Potonié 1960

Pl. 5, figs 1-11

Species studied—Tricolpites reticulatus Cookson 1947.

Description :

Symmetry and form : Subprolate to oblate, circular in polar view, often trilobate.
Dimension : 17-30 μm.
Aperture : Tricolpate, colpi long forming a small polar triangle.
Exine : ± 1.5 μm; reticulate, reticulum fine.
Sexine : ± 1 μm, reticulate; infratectum columellate.
Nexine : Continuous, as thick as sexine and thicker near the colpi.
Variability : Not much neither in shape, size nor ornamentation.

Occurrence—Common in India.

Fossil records—T. reticulatus is a very well known morphological taxon, pantropical, ranging from Turonian to Recent (for further details see Kemp & Harris, 1977 or Muller 1981, besides other authors).

In India, *T reticulatus* is a fairly good stratigraphic marker of Palaeocene and Eocene, named differently by various authors (listed below). Well documented pollen having the general organization and reticulate ornamentation of *Gunnera* type as exemplified in the type species is considered here.

India :

Kutch

Palaeocene-Eocene, *Intrareticulites (Tricolpites) brevis* Kar 1985, pl. 14, figs 1, 2.

Lower Eocene, *Tricolpites* sp. Venkatachala & Kar 1969, pl. 2, fig. 50.

T. brevis Sah & Kar 1970, pl. 1, fig. 6.

Cauvery

Palaeocene-Miocene, *Retitricolpites peroblatus* Venkatachala & Rawat 1972, pl. 2, figs 20, 21.

Tricolpites longicolpatus Venkatachala & Rawat 1972, pl. 2, figs 16-19.

Ladakh

Eocene-Miocene, *Tricolpites* sp. Bhandari *et al.* 1977, pl. 2, figs 1-5, 10.

T reticulatus Mathur & Jain 1980, pl. 1, fig. 17

Meghalaya

Palaeocene, *Tricolpites reticulatus* Kar & Kumar 1986, p. 179 (not illustrated).

Affinity—Gunnera (Gunneraceae); see Praglowski (1970) and Muller (1981), besides other authors, for a detailed discussion.

Ecology and present distribution—Palkovic (1974) and Jarzen (1980) provided data on *Gunnera* ecology (herbs of tropical and south temperate super humid environment) and present distribution (Kenya, Tanzania, South Africa, Malagasy Republic, Malaysia, Solomon Islands, Tasmania, New Zealand, Hawaii, Mexico southward to Chile and Argentina); for distribution map, see Good, 1953, p. 116.

Triporate

Genus—*Proteacidites* (Cookson, 1950) ex Couper 1953

Pl. 6, figs 1-3

Species studied—Proteacidites protrudus Sah & Kar 1970.

Original diagnosis—"Pollen grains triangular, 50-60 × 48-55 μm, 3 porate, pore distinct. Exine finely scrobiculate".
Holotype illustrated in Sah and Kar, 1970, pl. 2, fig. 61.

Description :

Symmetry and form : Isopolar, triangular in polar view.
Dimension : 50-60 μm.
Aperture : Triorate, ora situated at the extremities of the triangle, 6-8 μm large.
Exine : Tectate, reticulate
Sexine : 1 μm thick, finely reticulate, meshes < 1 μm; simplicolumellate, columellae long.
Nexine : Continuous, 1 μm thick, becoming thinner near the apertures.
Variability : Not much.

Occurrence—Commonly observed in Palaeocene-Lower Eocene sediments, rare in Middle Eocene.

Fossil records :

India :

Kutch

Palaeocene, *Proteacidites protrudus* Saxena 1979, pl. 3, fig. 55.

Lower Eocene, *P protrudus* Sah & Kar 1970, pl. 2, fig. 61.

Affinity—Proteaceae. Martin and Harris (1974, p. 109) included this species in the genus *Proteacidites* Cookson & Couper 1953 (emend. Martin & Harris, 1974) and compared it with the extant species of the tribes Proteae and Personieae. *Proteacidites dehaani* Germeraad *et al.* 1968, marker

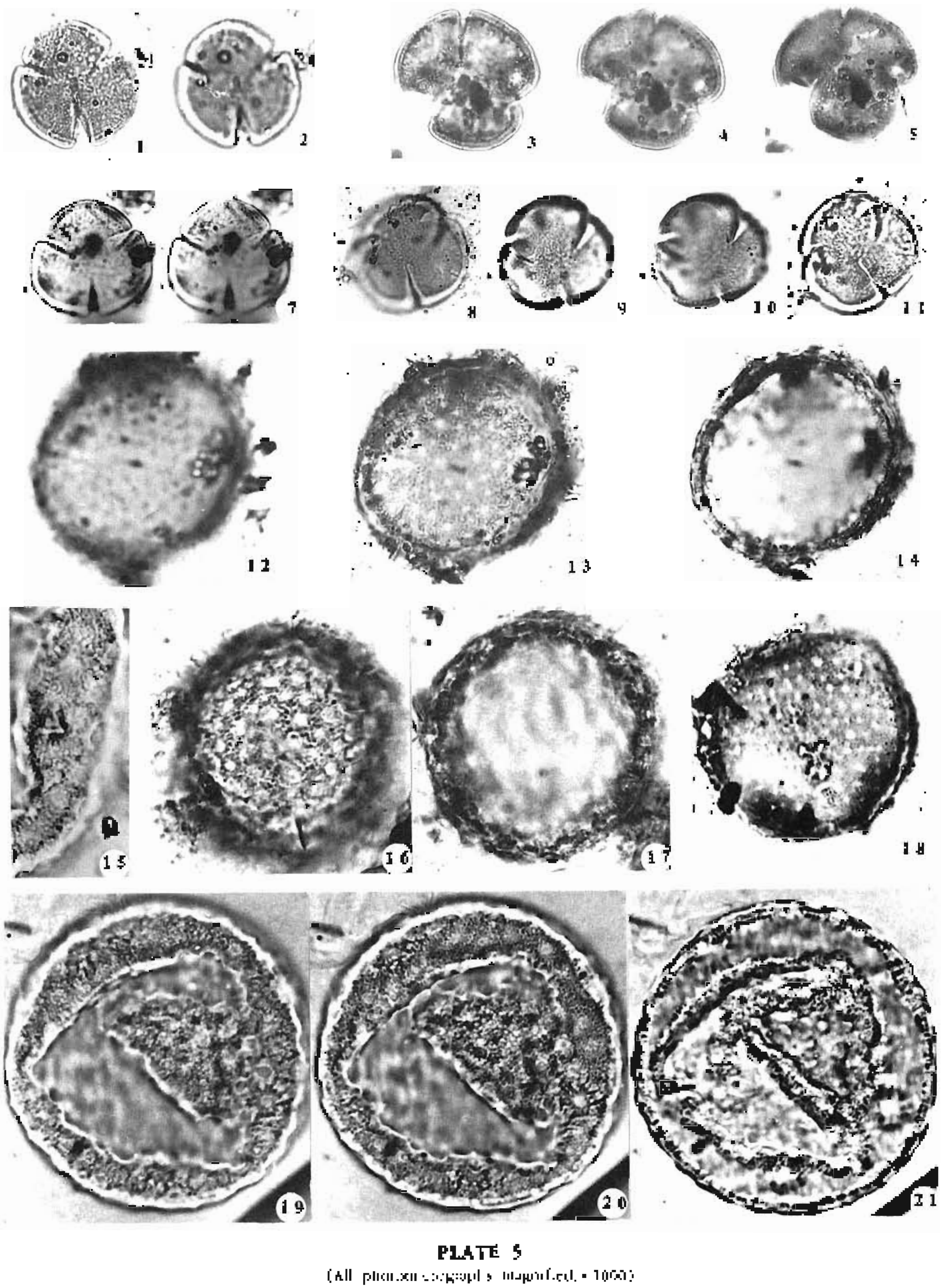


PLATE 5

(All photomicrographs magnified × 1000)

1-11. *Tricolpites reticulatus*, Lower Eocene, Kutch.

12-14. *Cryptopolyporites cryptus*, holotype, Lower Eocene, Kutch.

16-18. *C. cryptus*, Lower Eocene, Kutch.

15, 19-21. *Convolvulus marginatus* Hook. f., Recent.

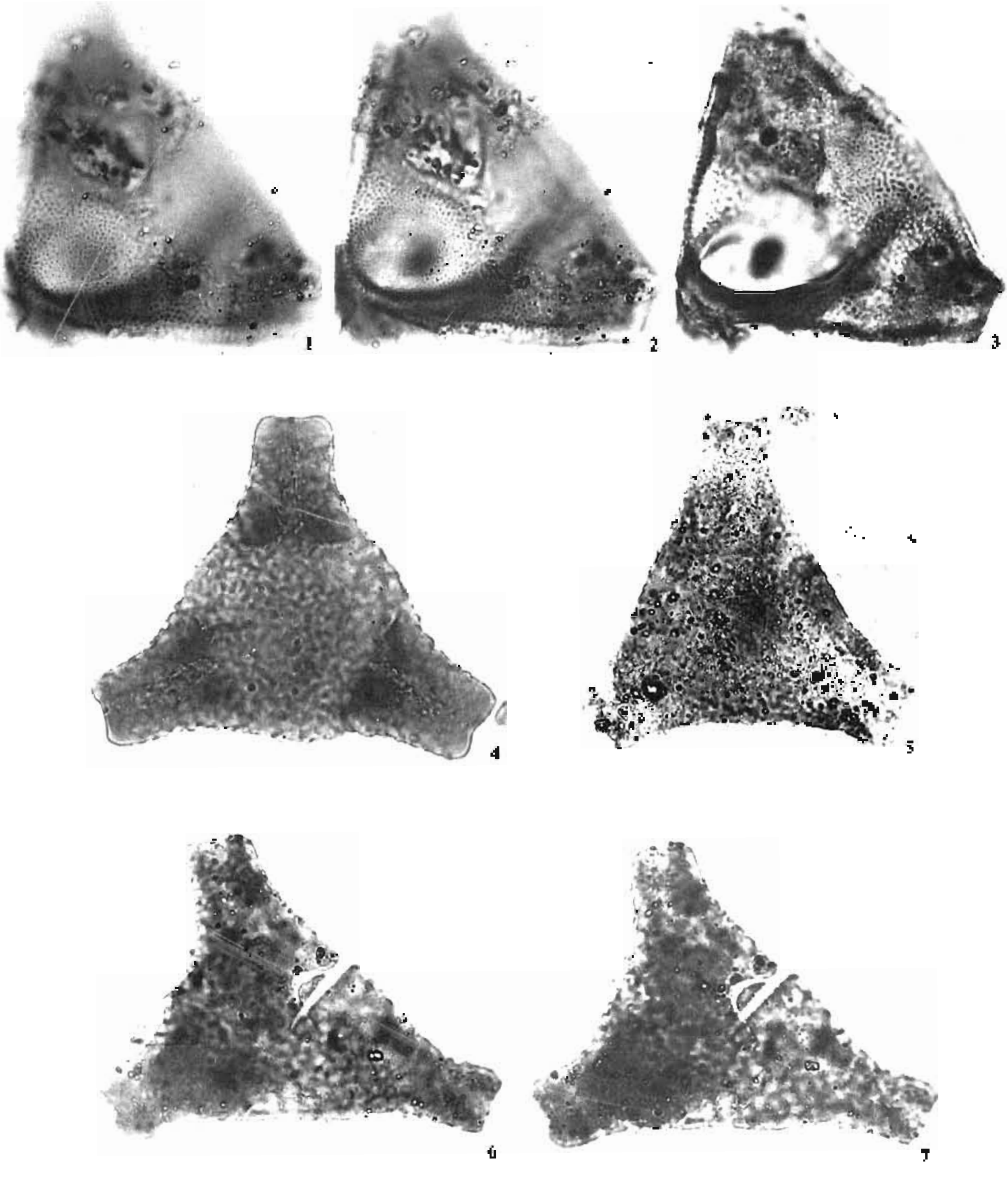


PLATE 6

(All photomicrographs magnified × 1000)

1-3. *Proteacidites protrudus*, Lower Eocene, Kutch.
4. *Triangulorites ambiverruca*, holotype, Palaeocene, Meghalaya.
5-7. *T. ambiverruca*, Palaeocene, Meghalaya.

of Maastrichtian in Africa, is different since it is duplicolumellate, with smaller pores.

Genus—*Triangulorites* Kar 1985
Pl. 7, figs 1-8

Original diagnosis—"Pollen grains triangular-subtriangular in polar view, tri- to tetraorate, ora distinct, present on each extended arm. Exine granulose-conied, forming negative reticulum in surface view".

Species studied—*Triangulorites bellus* (Sah & Kar) Kar 1985; Holotype is illustrated in Sah & Kar, 1970, pl. 2, fig. 70; Kar, 1985, pl. 19, figs 7, 8 and in this paper, Pl. 7, figs 1-4.

Description :

Symmetry and form : Generally isopolar, triangular-subtriangular in polar view with a circular central body and three projecting arms.

Dimension : Pollen body without apertures, 35 × 60 μm; arms 10-35 μm long and 10-18 μm broad.

Aperture : Generally triorate, may be rudimentarily tetraorate; ora situated on atrium-extended tubular processes. Os ends mostly opening in the form of a bowl.

Exine :

Sexine : ± 1 μm thick, granular, forming negative reticulum, more pronounced and specially concentrated at the base of the arms.

Nexine : ± 1 μm thick on the pollen body and 2-3 μm thick at the base of the arm in the form of arcuate angular thickenings in sectional view.

Variability : Variable in size, number and length of extended arms.

Occurrence—Common in Palaeocene-Lower Eocene pollen assemblages of India.

Remarks—*Hakeidites martinii* Khan 1976 (fig. 22), is described from the Pliocene of Papua and New Guinea. This is a grossly comparable pollen with *Guettarda* and *Timonius*. *Hakeidites* is tectate, columellate with concentration of structure on the body region. The apertural arm is also distinctly different. *Propylipollis* Martin & Harris 1974 (fig. 2G), from Lower Tertiary, Australia, has an atrium not protruding as in *T. bellus* and the reticulum is simplior pluricolumellate.

Fossil records :

India :

Cambay

Lower Eocene, *Triorites* cf. *T. inferius* (Dutta & Sah) Rawat *et al.* 1977, pl. 2, fig. 81.

Kutch

Palaeocene, *Triorites bellus* Saxena 1979, pl. 3, fig. 53.

Palaeocene-Lower Eocene, *Triangulorites bellus* Kar 1985, pl. 4, fig. 7 and pl. 19, figs 6-8.

Lower Eocene, *Triorites bellus* Sah & Kar 1970, pl. 2, fig. 70.

Meghalaya

Palaeocene, *Triorites communis* Sah & Dutta 1966, pl. 2, figs 34, 36-38; this taxon seems to belong to the same species but could not be confirmed as the type slide is missing).

Proteacidites excertus Dutta & Sah 1970, pl. 9, figs 25, 26; this taxon also seems to belong to the same species but could not be confirmed as the type slide is missing.

Triangulorites bellus Kar & Kumar 1986, pl. 10, figs 13, 14, 16.

Kerala

Lower Eocene, *T. bellus* Raha *et al.* 1986a, pl. 1, fig. 14.

Rajasthan

Lower Eocene, *Triorites hirsutus* Sah & Kar 1974, pl. 2, fig. 53.

Bengal

Palaeocene-Lower Eocene, *Proteacidites* sp. Baksi 1972, text-fig. 2.

Affinity—Unknown. Some proteaceous types, more particularly within Grevilleae tribe, show a grossly comparable general aspect, but in *Triorites bellus*, the structure of the apertures, with long and strong extended arms, is distinct; besides, the exine ornamentation is granulose-conied instead of reticulate.

Polyporate

Genus—*Cryptopolyporites* Venkatachala & Kar 1969
Pl. 5, figs 12-14, 16-18

Original diagnosis—"Pollen grains circular in polar view. Panporate. Pores hidden, not easily recognisable, covered with baculate processes as in non-porate region".

Species studied—*Cryptopolyporites cryptus* Venkatachala & Kar 1969.

Description :

Symmetry and form : Sphaeroidal.

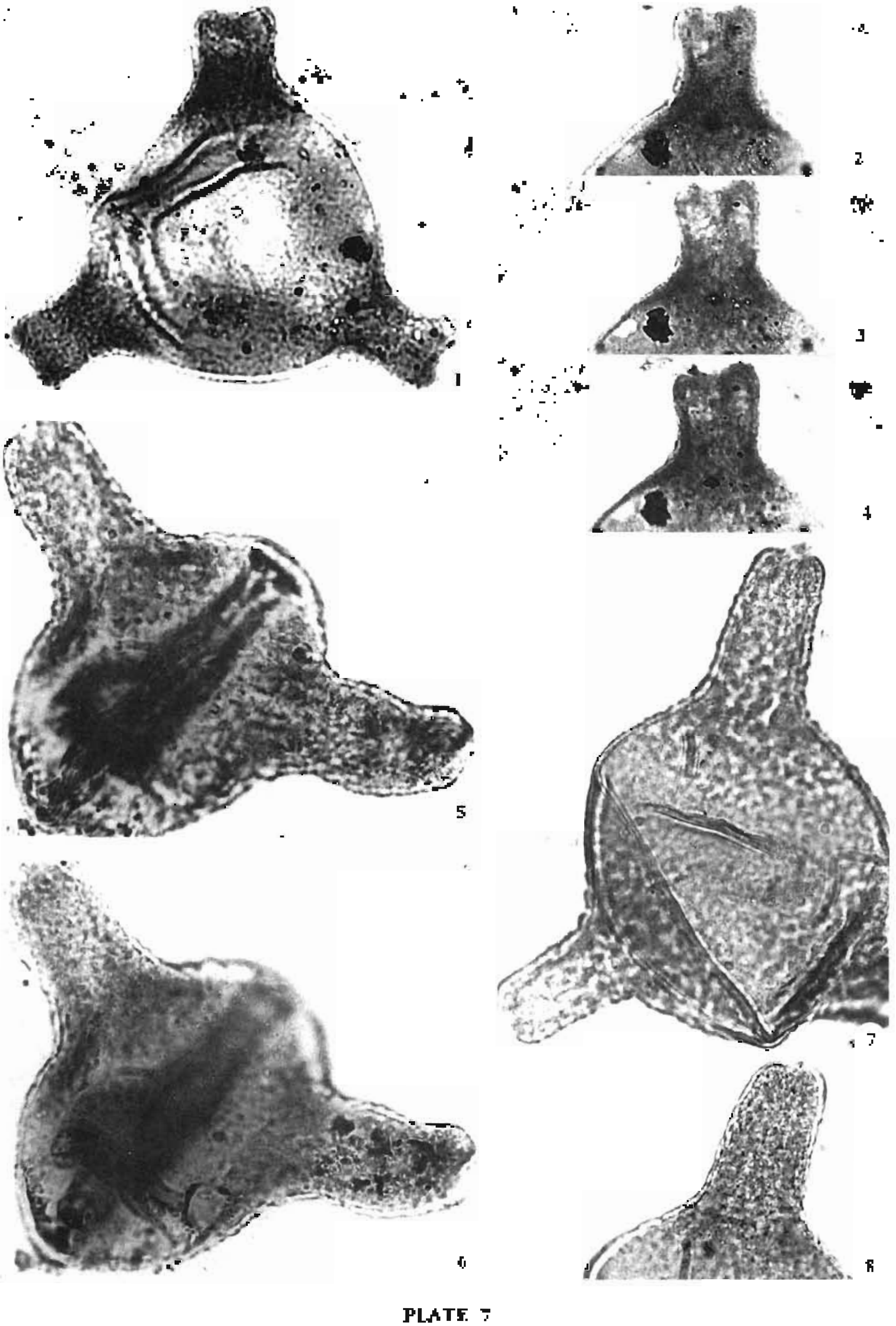


PLATE 7

(All photomicrographs magnified × 1000)

1-4. *Triangulorites bellus*, holotype, lower Eocene, Kutch. 5-8. *T. bellus* reworked in Miocene, Tripura.

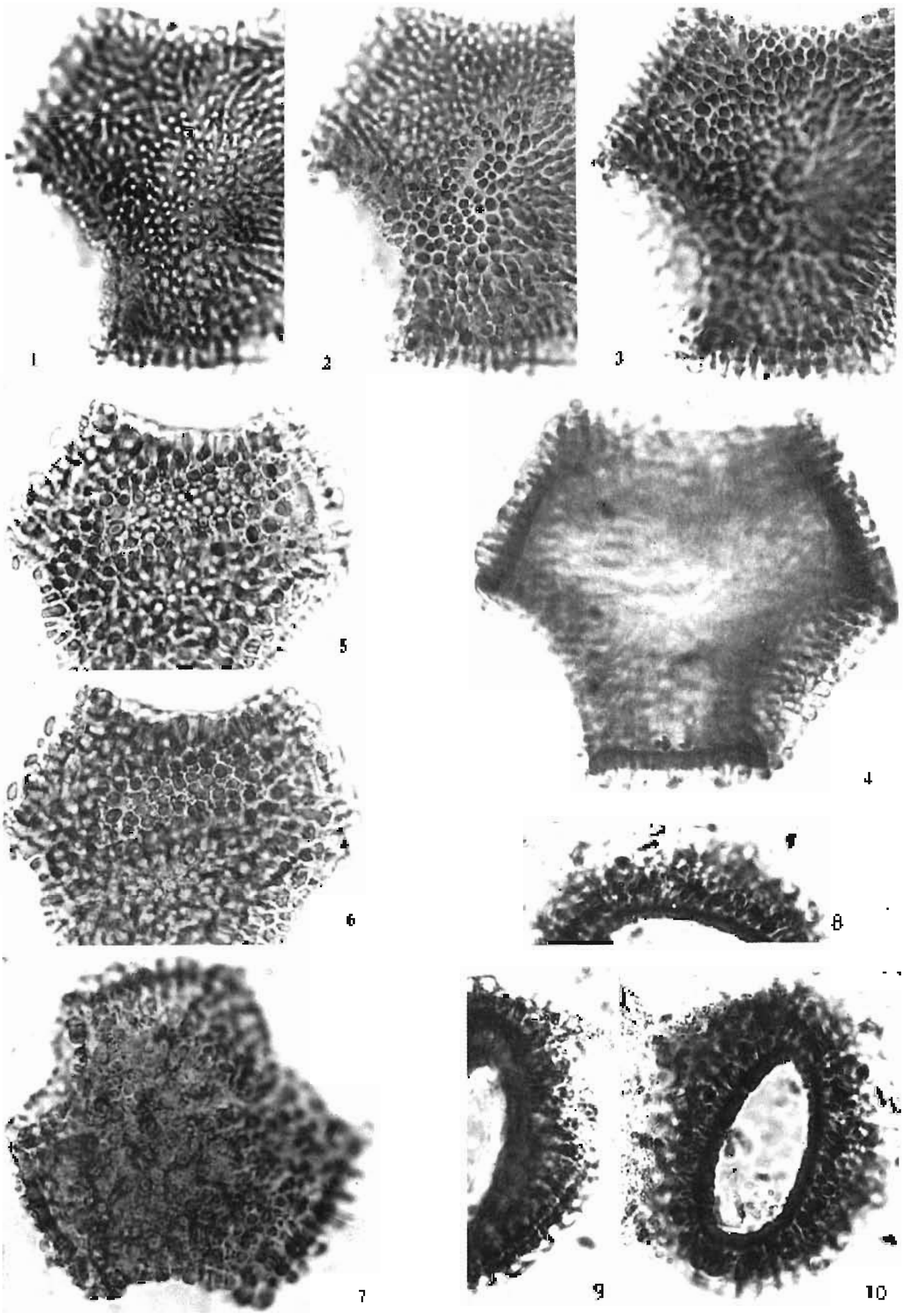


PLATE 8

(All photomicrographs magnified, × 1000)

1-10. *[illegible]* Miocene (reworked), Tripura. 8-10. Showing details of the exine.

Dimension : 40-50 μm
Aperture : Periporate, it is difficult to discern the number of pores, not uniformly distributed, pores 1-2 μm, sub-circular-circular, obscured in the structure
Exine : 2-3 μm, tectate
Sexine : Foveolate, tectum undulating, infra-tectum columellar
Nexine : Not as thick as sexine, seems to be discontinuous
Variability : Negligible

Occurrence—Rare.

Fossil records :

India

Kutch
Lower Eocene—*Cryptopolyporites cryptus* Venkatachala & Kar 1969, pl. 2, fig. 28.

Affinity—Gonystylaceae (Pl. 5, figs 18, 19-21). According to Nowicke *et al.* (1985) this family has a uniform type of pollen. The oldest occurrence of fossil pollen is from Oligocene of Borneo (Muller 1981).

Ecology and distribution of modern genera—Fresh water peat swamp forests from Malaysia to Solomon and Fiji. Now-a-days, this family is no more represented in India.

Genus—*Triangulorites* Kar & Kumar 1986
Pl. 5, figs 4-7

Holotype—Illustrated in Kar & Kumar, 1986, pl. 10, fig. 18.

Species studied—*Triangulorites pachyexinus* Kar & Kumar 1986.

Description :
Symmetry and form : Isopolar, triangular-subtriangular in polar view with three projecting arms
Dimension : Pollen body without aperture 30-40 μm, arms 20-25 μm long and ± 15 μm broad at basal part
Aperture : Generally triorate, ora situated on extended tubular atrial processes, os-ends opening slightly broadening
Exine
Sexine : 2-3.5 μm thick, reticulate, reticulum not uniform, muri sinuous, larger at the base with a more or less dome-shaped section about 1 μm wide, narrower than lumina
Nexine : In central body 1.5 μm thick and up to 10 μm thick at the base of the arm, thickening restricted and uniform in arm
Variability : Not much

Occurrence—Common in Palaeocene of Meghalaya.

Fossil records :

India :

Meghalaya
Palaeocene—*Triangulorites pachyexinus* Kar & Kumar 1986, pl. 10, figs 11, 17, 18.
Triorites sp. Sah & Dutta 1966, pl. 2, fig. 45.

Kutch
Palaeocene-Lower Eocene, *Triorites tubiferus* Venkatachala & Rawat 1972, pl. 3, fig. 55.

Affinity—Unknown.

Genus—*Tripilaorites* Kar 1985
Pl. 6, figs 1-10

Holotype—Illustrated in Sah & Kar, 1970, pl. 2, fig. 54.

Original diagnosis—"Pollen grains triangular in polar and oval in equatorial view. Triorate, ora very large, distinct. Exine pilate-baculate."

Species studied—*Tripilaorites triangulus* (Sah & Kar) Kar 1985.

Description :
Symmetry and form : Hexagonal in polar and oval in equatorial view
Dimension : 29-55 μm
Aperture : Triorate, ora elliptical occupying the entire concave side of the hexagon
Exine : 5-7 μm, pilate
Sexine : 1.5-3 μm, pilate, pila 3-5 μm long with broad heads, 2-4 μm apart, interpilar space granulate
Nexine : 1-3 μm, continuous
Variability : In size but not in shape and ornamentation

Occurrence—Common in some Lower Eocene sediments.

Fossil records :

India

Kutch
Palaeocene-Lower Eocene, *Tripilaorites triangulus* Kar 1985, pl. 19, figs 1, 2.

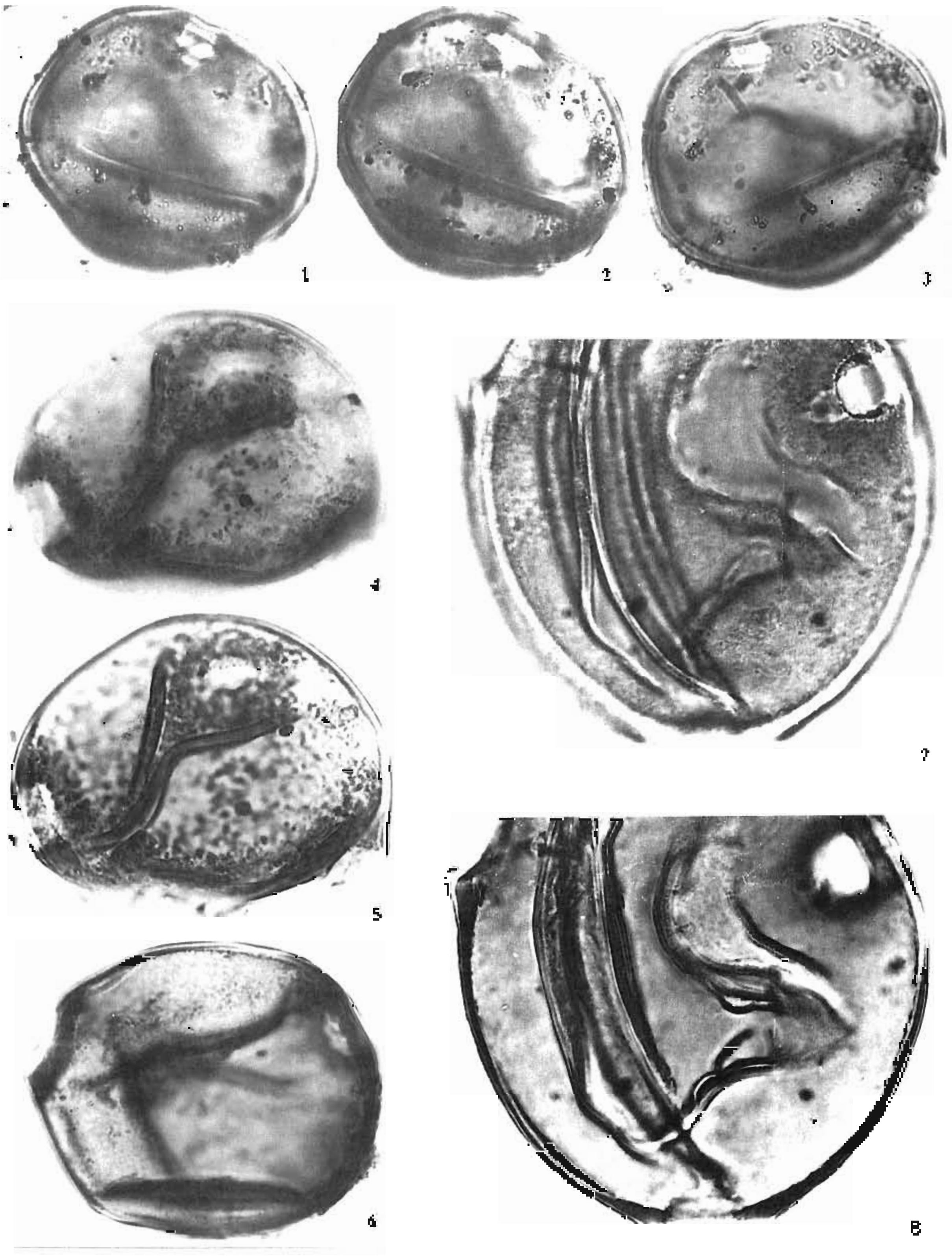


PLATE 9

(All photomicrographs magnified × 1000)

1-6. *Lakiapollis ovatus*, Lower Eocene, Kutch

7-8. *Durio* [illegible], Recent

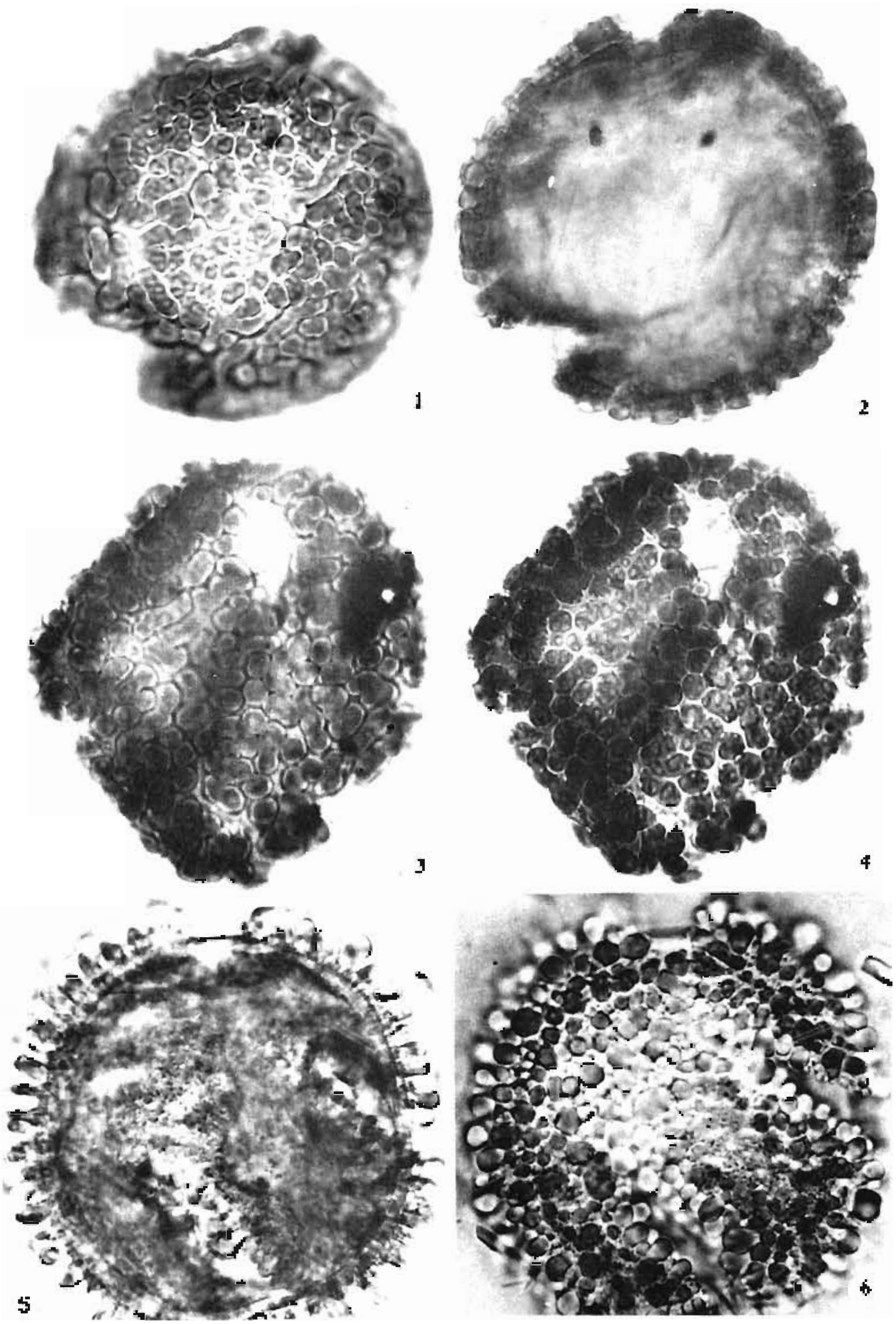


PLATE 10

(All photomicrographs magnified × 1000)

1-4. [illegible]

5, 6. [illegible]

Lower Eocene, *Tripilaorites triangulus* Sah & Kar 1970, pl. 2, fig. 55.

Tripura

Miocene (as reworked) (Kar, unpublished report).

Remarks—*Cranwellipollis* [illegible] Martin & Harris 1974 is comparable but is distinguished by its ± sphaeroid shape and smaller oral area while *Tripilaorites* is hexagonal with ora occupying the entire breadth of a side of a hexagon. The differences with *Triorites magnificus* Cookson 1950 have been discussed in Kar, 1985 (p. 88). Pocknall and Crosbie (1988) published (pl. 12, fig. 5) a pollen grain attributed to *Beaupreaidites verrucosus* Cookson 1950 which shows a general resemblance to *Tripilaorites triangulus* in overall shape but the former is distinguished by its main features and particularly by consistent microreticulation and tricolporoid aperture.

Affinity—Unknown.

Tricolporate

Genus—*Lakiapollis* Venkatachala & Kar 1969

Pl. 9, figs 1-6

Original diagnosis—"Pollen grains subcircular-circular in polar view. Tricolporate, brevicolpate, colpi narrow. Pores well developed, oval-elliptical in shape, broader than the colpus. Exine laevigate and infrastructured". For description and ecology, see Thanikaimoni *et al.*, 1984, p. 59. The type species *L. ovatus* Venkatachala & Kar 1969, pl. 5, fig. 77 is reillustrated here.

Species studied—*L. ovatus* Venkatachala & Kar 1969.

Occurrence—Common in India.

Remarks—Venkatachala and Kar (1969) included pollen grains with both smooth as well as ornamented pattern under *Lakiapollis*. *Lakiapollis* is now restricted to psilate-scabrate pollen as stated in the original diagnosis. *L. matanomadhensis* earlier accommodated under this genus has been transferred to *Retitribrevicolporites* Kar 1985, since *L. matanomadhensis* has a reticulate exine while *L. ovatus* has a psilate exine.

Fossil records:

India:

Kutch

Palaeocene, *Lakiapollis matanomadhensis* Saxena 1979, pl. 2, fig. 37 and pl. 3, fig. 39.

Palaeocene-Lower Eocene, *L. ovatus* Venkatachala & Kar 1969, pl. 5, figs 77-78.

Palaeocene-Lower Eocene, *L. ovatus* Kar 1985, pl. 17, figs 7-9.

Eocene, *L. ovatus*, in Thanikaimoni *et al.*, 1984, pl. 20, figs 301-305 and pl. 21, figs 306-309.

Lower Eocene-Middle Eocene, *L. ovatus* Kar 1978, p. 1-3 (not illustrated).

Middle Eocene-Upper Eocene, *L. ovatus* Kar & Saxena 1981, pl. 4, fig. 67.

Assam

Eocene, *L. ovatus* Kar (unpublished report).

Meghalaya

Palaeocene, *L. ovatus* Kar & Kumar 1986, pl. 4, fig. 5.

Upper Eocene, *L. ovatus* Trivedi (unpublished).

Kerala

Lower Eocene, *L. ovatus* Rao *et al.*, 1986a, pl. 1, figs 17-19 and 1986b, pl. 1, figs 7, 8.

Miocene (reworked), *L. ovatus* Kar & Jain 1981, pl. 3, fig. 11 and pl. 6, fig. 125.

Borneo

Oligocene, *Durio* type, Muller 1972 (not illustrated).

Miocene, *Durio* type, Anderson & Muller 1975, pl. 5, fig. 1.

Miocene, *Durio* type, Barré de Cruz 1982, pl. 12, fig. 12.

Affinity—Muller (1981) remarks that "*Lakiapollis ovatus* by Venkatachala & Kar (1969) from the undifferentiated Eocene of Kutch (India) appears closely similar to the *Durio* (Bombacaceae) type. If confirmed, this would extend the record at least into the Upper Eocene". Naredi Formation in Kutch from where this species was first recorded is now dated as Early Eocene (Biswas & Raju, 1971). Subsequently, *L. ovatus* was recorded from the Matanomadh Formation of Palaeocene age by Kar (1985). This pollen was also recorded from the Lakadong Formation, Meghalaya (Kar & Kumar, 1986) also dated as Palaeocene by Biswas (1962). A study of pollen of *Durio carinatus* Becc. (Pl. 9, figs 7, 8) confirms the contention of Muller (1981).

Genus—*Tricolporopollites* Kar 1985

Pl. 10, figs 1-4

Holotype—Illustrated in Kar 1985, pl. 25, fig. 1.

Original diagnosis—"Pollen grains triangular-subcircular in polar and subcircular-oval in equatorial views. Tricolporate, colpi short-long, pore well developed, margin generally thickened. Exine heavily pilate, pila robustly built, interpilar space granulate, sculptural elements furnish negative reticulum in surface view". The specimens have

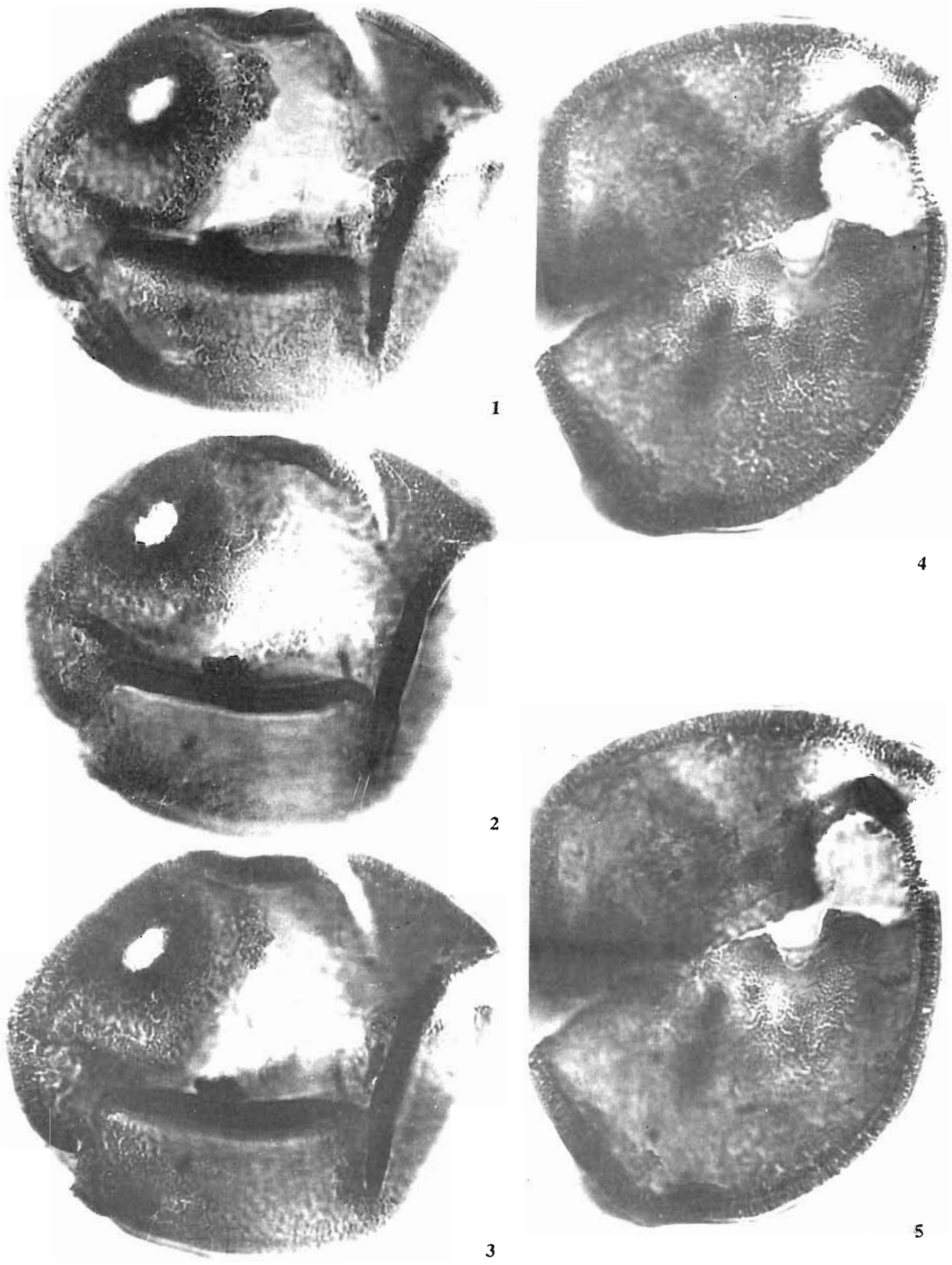


PLATE 11

(All photomicrographs magnified, × 1000)

1-5. *Tricolporocolumellites pilatus*, Eocene, Kutch.

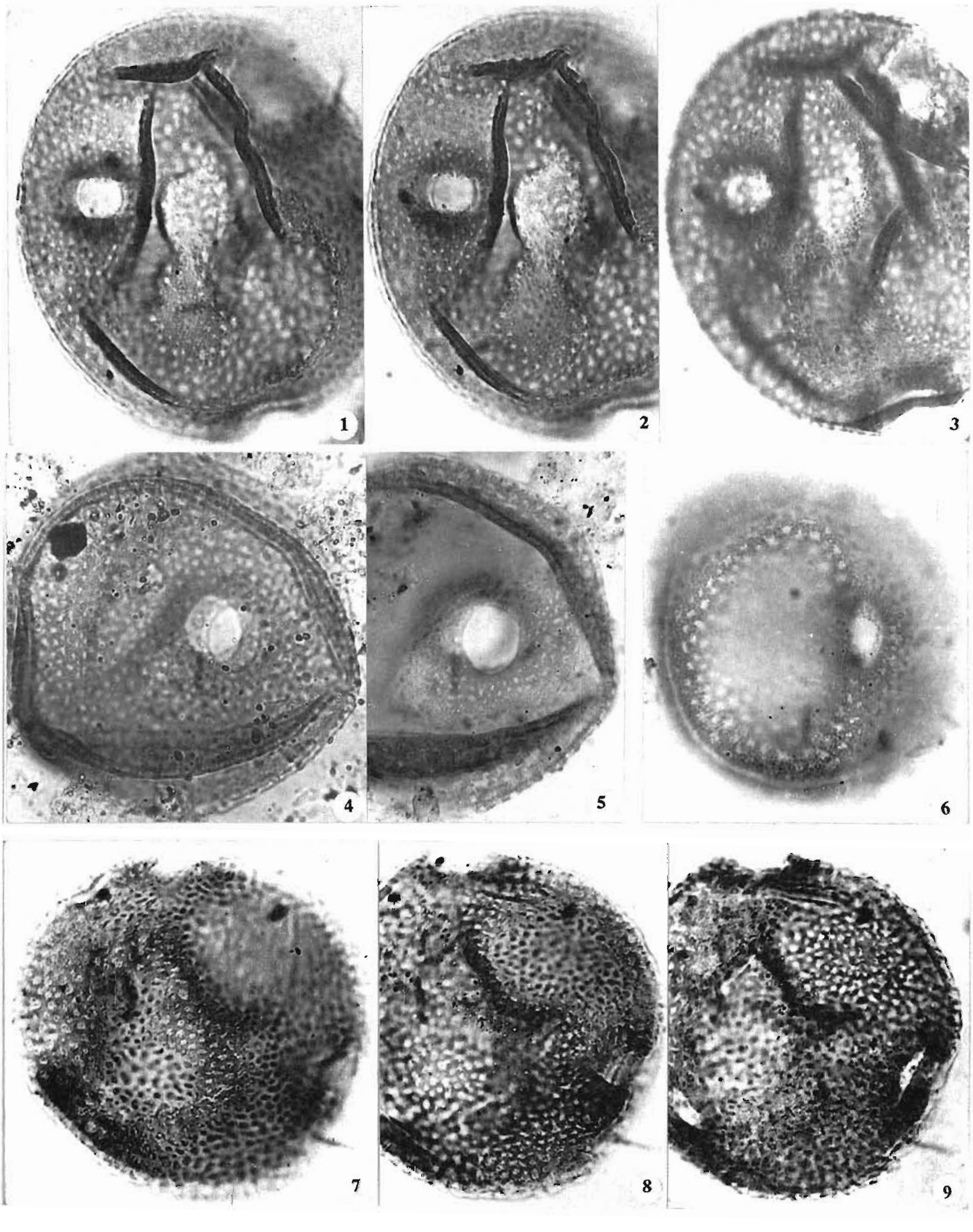


PLATE 12

(All photomicrographs magnified, × 1000)

1-9. *Retitribrevicolporites matanamadhensis*, Lower Eocene, Kutch.

been restudied here and they are distinctly tricolporate (Jansonius & Hills, 1987).

Species studied—Tricolporopilites robustus (Kar & Saxena) Kar 1985.

Description :

Symmetry and form : Subsphaeroidal, triangular-subcircular in polar and subcircular-oval in equatorial view.
Dimension : 55-96 × 50-85 μm.
Aperture : Tricolporate (Pl. 10, fig. 2).
Ectoaperture : Elliptic, short, ends pointed.
Endoaperture : ± rounded, costate.
Exine : 3-6 μm thick.
Sexine : Much thicker than nexine, gemmate, gemmae often coalescing to form irregular mounds, 4-7 μm long, 2-5 μm broad at top, supported by 2 or more columellae.
Nexine : Continuous, thick.
Variability : In size, but not much variable in ornamentation pattern.

Occurrence—Common in India.

Fossil records :

India :

Kutch

Middle Eocene-?Upper Eocene, *Retitrescolpites robustus* Kar & Saxena 1981, pl. 3, figs 59, 60.
Middle Eocene-? Upper Eocene, *Tricolporopilites robustus* Kar 1985, pl. 23, figs 1, 2

Kerala

Lower Eocene-Middle Eocene, *Tricolporopilites pseudoreticulatus* Raha *et al.* 1986b, pl. 1, figs 1-6.

Incertae sedis, in Thanikaimoni *et al.*, 1984 (figs 653-661), from the Miocene of Assam are referred to this genus, however, these pollen grains are interpreted to be reworked, as Eocene pollen in the Miocene of Assam Basin are common.

Affinity—Unknown. Comparisons can be made with certain species of *Alangium*, particularly *A. villosum* (Bl.) Wang (Pl. 10, figs 5, 6). Affinity with Bombacaceae is not ruled out because of the closely comparable apertural features.

Genus—*Tricolporocolumellites* Kar 1985
Pl. 11, figs 1-5

Holotype—Illustrated in Kar, 1985, pl. 23, fig. 4.

Original diagnosis—"Pollen grains subcircular-oval, tricolporate, brevicolpate, pore margin thickened. Exine columellate, pila forming negative reticulum in surface view"

Species studied—Tricolporocolumellites pilatus Kar 1985.

Description :

Symmetry and form : Subspheroidal to oval, generally not observed in polar view.
Dimension : 70-94 × 70-88 μm.
Aperture : Tricolporate, occupies subequatorial position.
Ectoaperture : Short, elliptical, 10-18 × 6-14 μm.
Endoaperture : Distinct, circular-oval, more or less of same size as those of ecto-aperture, costate.
Exine : Tectate, ± 4 μm thick.
Sexine : Thicker than nexine, columellate, columella closely placed.
Nexine : Continuous, cracked.
Variability : In size but not in ornamentation pattern.

Occurrence—Common in Middle Eocene of Kutch.

Fossil records :

India :

Kutch

Middle Eocene-?Upper Eocene, *Lakiapollis matanamadhensis* Kar & Saxena, 1981, pl. 4, fig. 68.
Tricolporocolumellites pilatus Kar 1985, pl. 23, figs 4, 5.

Affinity—Extant equivalents have not been encountered by the authors, however, on analogy, a Bombacaceous affinity is suggested.

Genus—*Retitribrevicolporites* Kar 1985
Pl. 12, figs 1-9

Original diagnosis—"Pollen subcircular, tribrevicolporate, colpi and pore more or less of same size, pore margin thickened. Exine reticulate".

Species studied—R. matanamadhensis (Venkatachala & Kar) Kar 1985 (illustrated in Thanikaimoni *et al.*, 1984, pl. 20, figs 295-300 under the name of *Lakiapollis matanamadhensis*). The holotype could not be located, so a lectotype has been selected from the same material in the slide no. 3353/2.

Description :

Symmetry and form : Sphaeroidal-subsphaeroidal.
Dimension : 30-58 × 35-56 μm.

Aperture : Tribrevicolporate, apertures mostly found in subequatorial position.
Ectoaperture : ± 10 µm large, round to elliptical in shape.
Endoaperture : Round, ± 10 µm large. Costae pronounced.
Exine : Tectate, ± 4 µm thick, sexine thicker than nexine.
Sexine : Reticulate, pluricolumellate, pronounced.
Nexine : Continuous.
Variability : Not much variation.

Occurrence — Common in India.

Remarks — *Retitribrevicolporites* is distinguished from *Lakiapollis* by its reticulate texture and by the pluricolumellate structure of the sexine. The aperture consisting of exo- and endoaperture is closely comparable to that of *Lakiapollis*.

Fossil records

India :

Kutch

Palaeocene, *L. matanomadhensis* Saxena 1979, pl. 3, fig. 39.

Palaeocene-Eocene, *Retitribrevicolporites matanamadhensis* Kar 1985, pl. 3, fig. 5; pl. 9, fig. 7; pl. 13, figs 1, 2.

Lower Eocene, *Lakiapollis matanamadhensis* Venkatachala & Kar 1969, pl. 3, figs 79, 80.

Meghalaya

Palaeocene, *Tricolporopollis decoris* Dutta & Sah 1970, pl. 9, figs 10, 11.

T. rubra Dutta & Sah 1970, pl. 9, figs 13, 14.

Retitribrevicolporites decoris Kar & Kumar 1986, pl. 8, fig. 19.

R. matanamadhensis Kar & Kumar 1986, pl. 8, fig. 17.

Assam

Palaeocene-Lower Eocene, *Retitribrevicolporites matanamadhensis* Kar (unpublished).

Affinity — Unknown.

Conclusion on the morphological group Tribrevicolporate pollen

Lakiapollis, *Tricolporopilites*, *Tricolporocolumellites* and *Retitribrevicolporites* share in common the apertural feature consisting of a pronounced costate pore and a short colpi which is mostly distinct. The ornamentation is variable from smooth to variously ornamented.

—*Lakiapollis ovatus* exemplifies psilate to scabrate exine,

—*Tricolporopilites* is gemmate,

—*Tricolporocolumellites* has distinctly columellate exine structure with cracked nexine,

—*Retitribrevicolporites* is reticulate, pluricolumellate.

The columella in *Tricolporocolumellites* and *Retitribrevicolporites* are distinct and also shows varied diversification ranging from obscured to well-pronounced. Some of these tribrevicolporate pollen show clear relationship with Bombacaceous genera, i.e. *Lakiapollis* with *Durio* and *Cullenia*, while *Tricolporopilites* seems closer to some Alangiaceae such as *Alangium villosum*. This group appears to show a trend of diversification from psilate to distinct structured exine. But, in the recent pollen, these corresponding morphological types are manifested in different families.

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Venation pattern in the sphenophyll *Trizygia speciosa* Royle from the Raniganj Formation

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There has been a running controversy about the independent taxonomic status of the genus *Trizygia* vis-a-vis *Sphenophyllum*. The basic organisation of the foliage shoot in both the genera is apparently similar, except for the trizygoid leaf whorls in the former. The trizygoid leaf whorls are, however, not unknown in *Sphenophyllum*. The two genera can not be compared at the level of anatomy of the axes or the organisation of the fertile shoot as this information is not available for *Trizygia*. The venation pattern in leaves of *Trizygia* has been analysed in detail with a view to compare it with that of *Sphenophyllum*, when that information is forthcoming. The parameters chosen for analysis include length, width and area-index of leaves and number of dichotomies, ultimates and dichotomy levels.

Key-words—Sphenopsida, *Trizygia*, Venation pattern, *Sphenophyllum*, Raniganj Formation.

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साराँश

रानीगंज शैल-समूह से स्फ़ीनोफ़िल ट्राइज़ीजिया स्पेसिओसा रॉयल में शिराविन्यास का स्वरूप

हरिकृष्ण माहेश्वरी, विनय कुमार सिंह एवं ऊषा बाजपेयी

स्फ़ीनोफ़िल्लम् की तुलना में **ट्राइज़ीजिया** प्रजाति की निरपेक्ष वर्गीकरणिक स्थिति विवादात्मक रही है। **ट्राइज़ीजिया** में केवल ट्राइज़ॉइगॉयडी पर्ण-चक्रों के अलावा उक्त दोनों प्रजातियों में पर्ण-समूह प्ररोह का विन्यास स्पष्टतः एक ही जैसा है। तथापि, **स्फ़ीनोफ़िल्लम्** ट्राइज़ाइगॉयडी पर्ण-चक्र अविदित नहीं है। अक्ष के शारीरीय लक्षणों अथवा अबन्ध्य प्ररोह के अंग-विन्यास के आधार पर इन दोनों प्रजातियों की तुलना नहीं की जा सकती क्योंकि **ट्राइज़ीजिया** के विषय में अभी तक यह जानकारी उपलब्ध नहीं है। **स्फ़ीनोफ़िल्लम्** से तुलना करने के लिए **ट्राइज़ीजिया** की पत्तियों के शिराविन्यास का विस्तृत विश्लेषण किया गया है। **स्फ़ीनोफ़िल्लम्** के विषय में अभी इस प्रकार की जानकारी नहीं है। प्रस्तुत विश्लेषण हेतु पत्तियों की लम्बाई, चौड़ाई एवं क्षेत्र-सूचक तथा द्विभाजनों की संख्या, अविभाज्य एवं द्विभाजन स्तरों का उपयोग किया गया है।

THE sphenophylls, important constituents of the Northern Hemisphere Upper Carboniferous floras, have a very distinctive foliage comprising a number of leaves, generally in multiples of 3, arranged in radially symmetrical whorls at each node of an articulate axis. The foliage shoots are referred to the genus *Sphenophyllum* Koenig 1825 (International Code of Botanical Nomenclature, 1982, p. 255, ascribes the genus to Brongniart, 1828). The sphenophyllalean foliage is also represented in the Permian sediments of Gondwana, but only as a minor component. The foliage shoots named as *Trizygia speciosa* Royle are different in having characteristic radially asymmetrical (trizygoid) whorls of 6 leaves at each node.

Trizygoid forms, however, do occur in the Northern Hemisphere coal floras and some of the species, e.g., *Sphenophyllum oblongifolium* (Germar & Kaulfuss 1831) Unger 1850 and *S. sinocoreanum* Yabe 1922 have been considered to be closely related to the Gondwana *Trizygia speciosa* (Asama, 1966). This fact coupled with apparent similarity in epidermal features of *Sphenophyllum* and *Trizygia* species led some authors to merge the two genera (McClelland, 1850; Pant & Mehra, 1963). However, Asama (1970) not only maintained separate identity of the two genera but established two more genera, viz., *Parasphenophyllum* and *Paratrizygia*. He feels that the straight or curved course of the veins has significance for generic delimitation.

In view of the apparent confusion about the taxonomic status of sphenophyll foliage genera we decided to investigate the venation pattern. The present study deals with the venation pattern in *Trizygia speciosa* Royle 1839.

The foliage shoots of *T. speciosa* have slender articulate axes. Three pairs of leaves, different in size, arise at each node in zygomorphic but bilaterally symmetrical whorls. The maturation of foliage shoots is acropetal, that is, the larger or older whorls are towards the base and smaller or younger whorls are towards the apex. However, a definite basal or apical leaf whorl has not been reported so far. The longer diameter of the leaf whorls greatly varies and if the leaf size was taken to be a criterion for establishing species, more than a species will have to be chalked up.

MATERIAL AND METHODS

The specimens of *T. speciosa* selected for analysis of the venation pattern were collected from the roof shale and intercalated shale of Nega Seam, Raniganj Formation, Raniganj Coalfield. After preliminary examination of several hundred specimens in field and laboratory, 99 better preserved leaf whorls were selected for study. The leaves were probably very delicate because more often than not the carbonified crust is found in oxidized state. Only those specimens were selected in which leaves were complete and veins were traceable from base to apex of the lamina.

The length, width and area-index of leaves, number of dichotomies, ultimates and dichotomy levels, nodal distances and angle of leaves were observed by wetting the specimens with liquid paraffin or xylol or with a mixture of both.

OBSERVATIONS

The leaves of the first or uppermost pair are inserted at an angle of 55°-85° to the node. The point of insertion is usually concealed and could be ascertained only after removing the overlying axis. The leaves of second or middle pair are inserted more or less at right angles, one each on either side of the axis whereas the leaves of the third or lowermost pair are pendulous and inserted on the exposed surface of the axis at an angle of 135°-155°.

The first pair leaves are larger and are 0.7 to 2.9 cm long and 0.3 to 0.9 cm wide at the broadest point. The second or middle pair leaves are more or less similar and are 0.7 to 2.5 cm long and 0.3 to 1 cm wide.

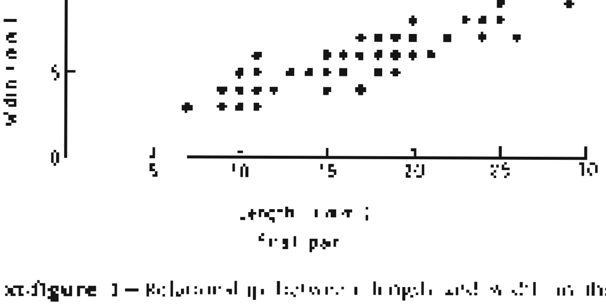
The third pair leaves are comparatively small, 0.4 to 2 cm long and 0.2 to 1 cm wide. The relationship between leaf length and width is plotted in Text-figures 1-3. It is apparent from the figures that the relationship between the two is quite consistent. The relationships between area-index (length × width) and length and between area-index (length × width) and width are also approximately the same (Text-figure 4) in leaves of all pairs. The lamina of leaves are entire and simple with rounded apices. The length of internodes increases basipetally in successive whorls and ranges from 0.5 to 2.5 cm in observed specimens.

Table 1 summarizes observations on 230 normal leaves (68 of first pairs, 77 of second pairs and 85 of third pairs) from 99 whorls. In 53 whorls, leaves of all the 3 pairs are satisfactorily preserved while in 46 whorls leaves of only one or the other pair are suitable for observation. Five abnormal leaves (3 leaves of first pair and 1 each of the second and third pair) were also studied.

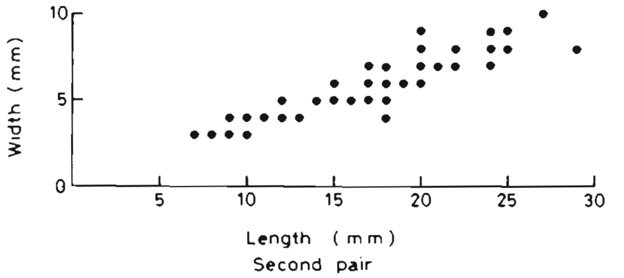
The minimum total number of vein dichotomies is seven, which has been observed in smallest leaves of all the 3 pairs (Text-figure 5.1). In this case the dichotomy category is 1 of I order, 2 of II order and 4 of III order resulting 7 dichotomies. The minimum number of ultimate veins (ultimates) is 8, all being III order ultimates.

Leaves in which veins reach the fourth level dichotomy normally should have a total of 15 dichotomies including 8 dichotomies of the IV order. However, hardly any leaf has more than 6 dichotomies of the IV order and hence the highest total number of dichotomies in such leaves is only 13. Rather some leaves have only 1 dichotomy of IV order. In all cases, the two peripheral ultimates of III order, one on each side, do not dichotomize, thus the maximum number of ultimates is fourteen (Text-figures 5.2-5.7).

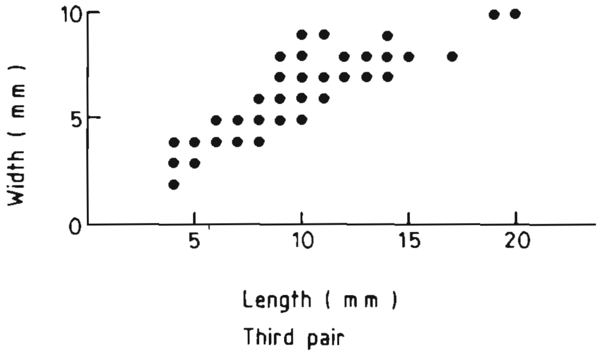
The V order dichotomy level is reached only when all the 6 IV order dichotomies are present. Of



Text-figure 1 — Relationship between length and width in the first pair leaves; each dot represents at least one leaf in this and other subsequent figures.



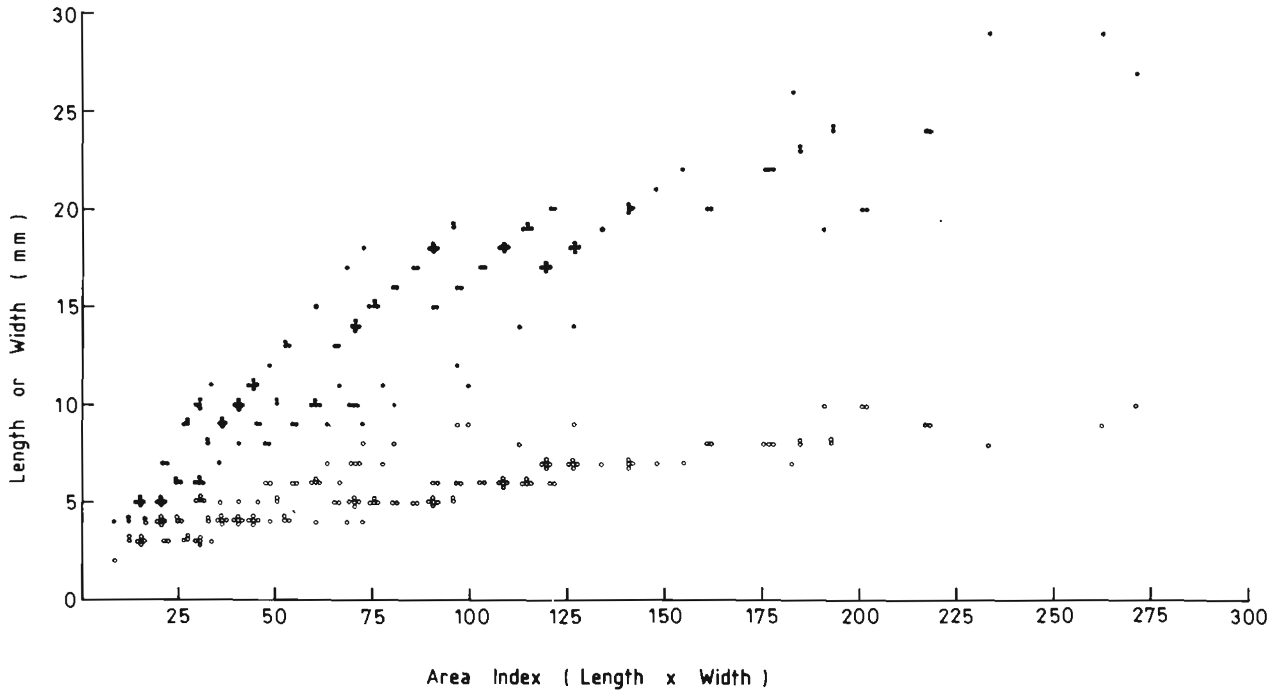
Text-figure 2—Relationship between length and width in the second pair leaves.



Text-figure 3—Relationship between length and width in the third pair leaves.

the 12 IV-order veins resulting from these dichotomies, only 1-10 vein further dichotomies and thus a maximum of 24 ultimates can be present in a leaf. Although the fifth-level dichotomy usually takes place in the central veins, it may occur in any of 12 IV-order veins (Text-figures 5.8-5.17).

A few leaves show slight variation in venation pattern. Three first pairs leaves, with maximum fifth-level dichotomy have unusual venation. One leaf with 14 dichotomies though has only 5, against the usual 6, IV-order dichotomies, yet it reaches the V-order dichotomy level. In this leaf 2 out of the 10, IV-order veins have entered the fifth level of dichotomy without satisfying the condition that all the 6 potential III-order veins be present (Text-fig. 5.20). The second leaf has got all the possible 8, IV-order dichotomies, instead of the normal 6, and 6, V-order dichotomies. Here all the 8, III-order veins, including the 2 peripheral ones dichotomize (Text-fig. 5.22). The third leaf has 7, IV-order dichotomies, one more than the usual 6, and 8 V-order dichotomies. Here only one peripheral III-order vein has not dichotomized (Text-fig. 5.21). A second pair leaf with 12 dichotomies has 5, IV-order dichotomies, 4 in one half and only one in the other half of the lamina. Here all the 4, III-order veins including peripheral one in one half, have dichotomized (Text-fig. 5.18). A third pair leaf also shows fifth level dichotomy though only 5, IV-order dichotomies are present. Here one out of 10 IV-order veins has dichotomized (Text-fig. 5.19).



Text-figure 4—Relationship between area-index (length × width) and length (solid dots) or width (hollow dots) of leaves.

Table 1—Observed first, second and third pair leaves with maximum dichotomy levels, length × width-range, number of dichotomies and ultimates and their orders

Maximum dichotomy level	Number of leaves	Length × width (mm)	Number of dichotomies and their order	Number of ultimates and their order
		FIRST PAIR		
third	4	7-9 × 3-4	7 1 (I), 2 (II), 4 (III)	8 8 (III)
fourth	46	9-25 × 3-8	8-13 1 (I), 2 (II), 4 (III), 1-6 (IV)	9-14 7 (III), 2 (IV) to 2 (III), 12 (IV)
fifth	18	14-29 × 5-9	14-23 1 (I), 2 (II), 4 (III), 6 (IV), 1-10 (V)	15-24 2 (III), 11 (IV), 2 (V) to 2 (III) 2 (IV), 20 (V)
		SECOND PAIR		
third	4	7-9 × 3-4	7 1 (I), 2 (II), 4 (III)	8 8 (III)
fourth	44	9-25 × 3-9	9-14 1 (I), 2 (II), 4 (III), 2-6 (IV)	10-14 6 (III), 4 (IV) to 2 (III), 12 (IV)
fifth	29	13-29 × 4-10	14-22 1 (I), 2 (II), 4 (III), 6 (IV), 1-9 (V)	15-23 2 (III), 11 (IV), 2 (V) to 2 (III), 3 (IV), 18 (V)
		THIRD PAIR		
third	5	4-5 × 2-3	7 1 (I), 2 (II), 4 (III)	8 8 (III)
fourth	60	4-20 × 3-10	9-13 1 (I), 2 (II), 4 (III), 2-6 (IV)	10-14 6 (III), 4 (IV) to 2 (III), 12 (IV)
fifth	20	7-20 × 5-10	14-20 1 (I), 2 (II), 4 (III), 6 (IV), 1-7 (V)	15-21 2 (III), 11 (IV), 2 (V) to 2 (III), 5 (IV), 14 (V)

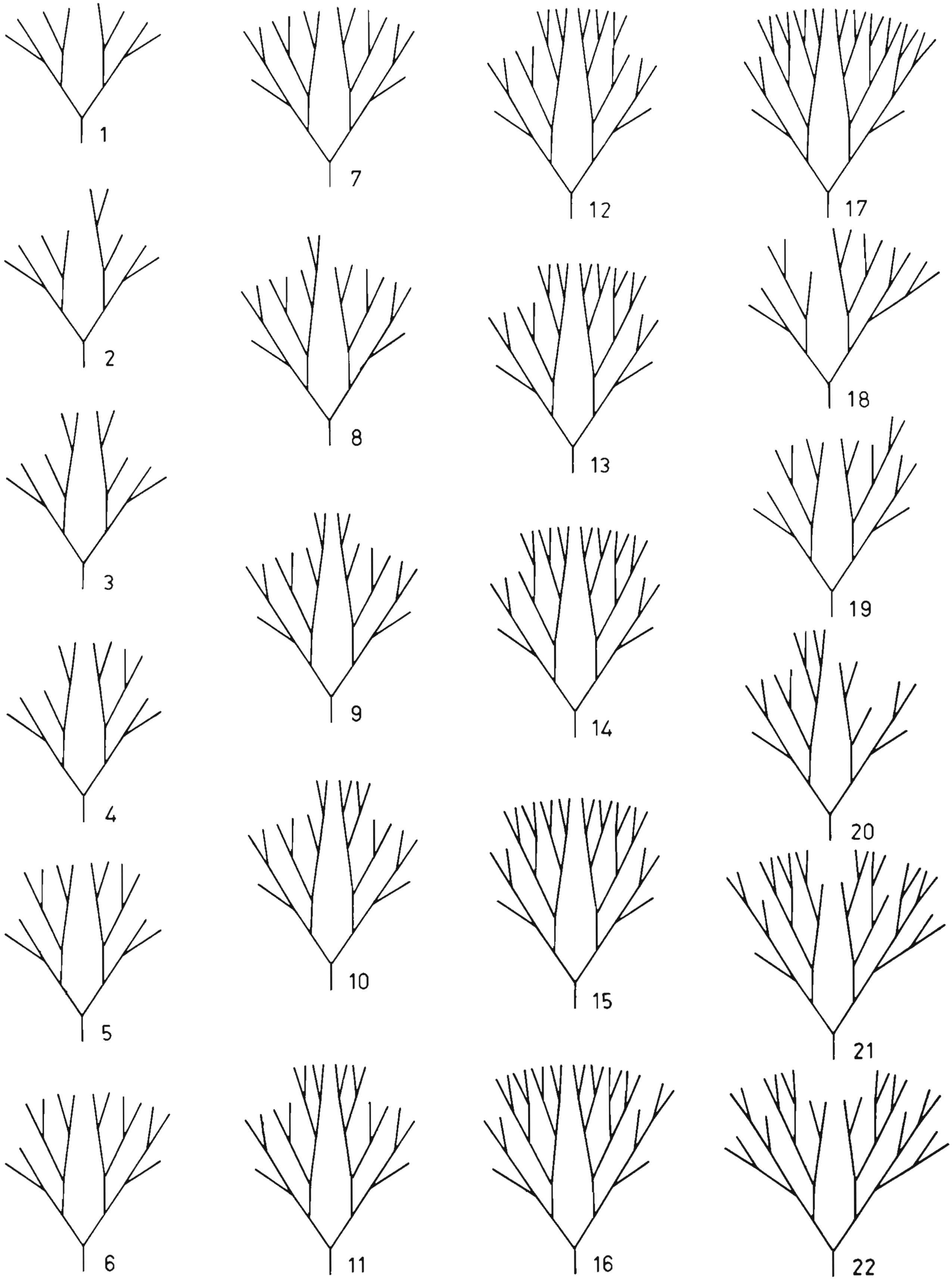
Numbers outside the parentheses indicate dichotomy or ultimate orders, respectively, mentioned in Roman numerals within the parentheses.

The relationships of total dichotomies to the length (Text-figs 6-8), to the width (Text-figs 9-11) and to the area-index (length × width, text-figures 12-14) in the leaves of all the pairs are more or less parallel. In Text-figures 6-11, the variation in dimensions of individual leaves having equal number of dichotomies is shown by the vertical lines. For example, the leaves having 13 dichotomies are 10 to 20 mm long in first pair (Text-fig. 6), 10 to 20 mm long in second pair (Text-fig. 7) and 5 to 14 mm long in the third pair (Text-fig. 8). For less than 10 or more than 15 dichotomies, the deviation in length range is small except in the third pairs where leaves having 17 dichotomies may be 10 to 19 mm in length. That is to say the greatest length variation is usually among the leaves having 11 to 15 dichotomies.

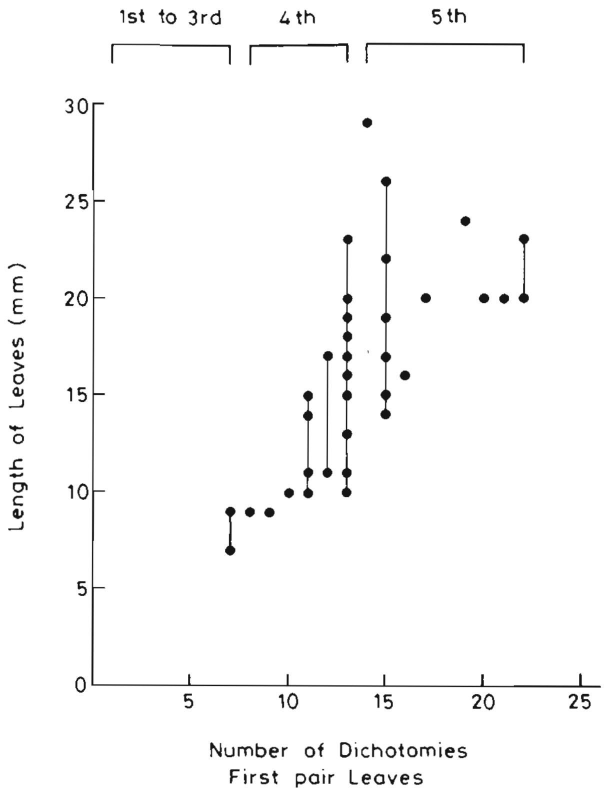
The greatest width variation, like that of length occurs among the leaves having 11 to 15 dichotomies in all the pairs (Text-figs 9-11). For example, leaves with 13 dichotomies vary from 3 to 8 mm in width. The variation in width is very small in leaves with less than 11 or more than 17 dichotomies.

In terms of length, the maximum variation in dichotomy numbers occurs at 10 and 23 mm in the first pairs, 22 and 24 mm in the second pairs and 9 mm in the third pair leaves. In terms of width the maximum variation in number of dichotomies occurs at 8 mm in the first pairs, 4 mm in the second pairs and 3 mm in the third pair leaves.

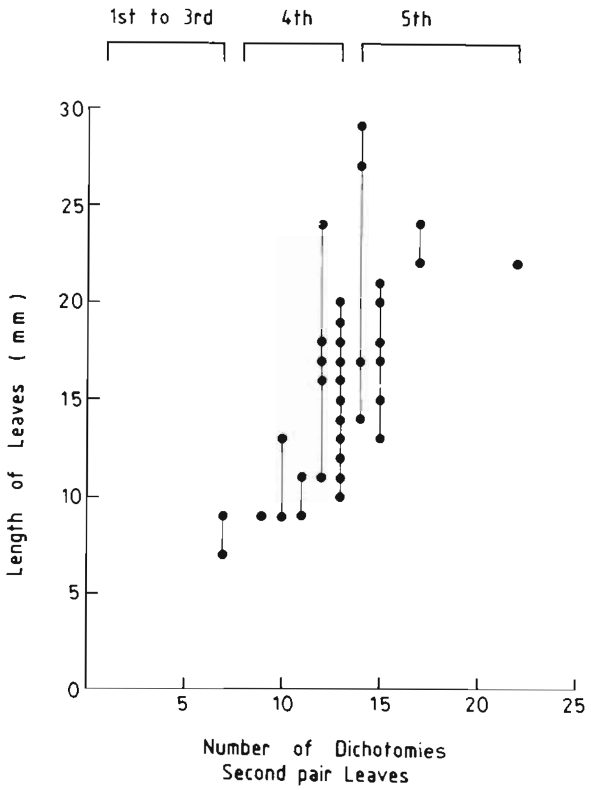
The relationship between area-index (length × width) and number of dichotomies is shown in Text-figures 12 to 14. The greatest area-index variation, like that for length and width, occurs among the leaves having 11 to 15 dichotomies. The leaves having 13 dichotomies vary in area-index from 30 to 185 in first, 30 to 126 in



Text-figure 5—Diagramatic representation of variation in leaf venation. Text-figure 5.1 represents the basic skeleton of venation in leaves of all pairs. Text-figures 5.2 to 5.17 illustrate the increasing number of dichotomies and dichotomy levels. Text-figures 5.18 to 5.22 represent unusual venation.



Text-figure 6—Relationship between length and number of dichotomies in leaves of first pair Vertical lines show length variation found in leaves having same number of dichotomies. Brackets indicate dichotomy levels in this and subsequent diagrams.



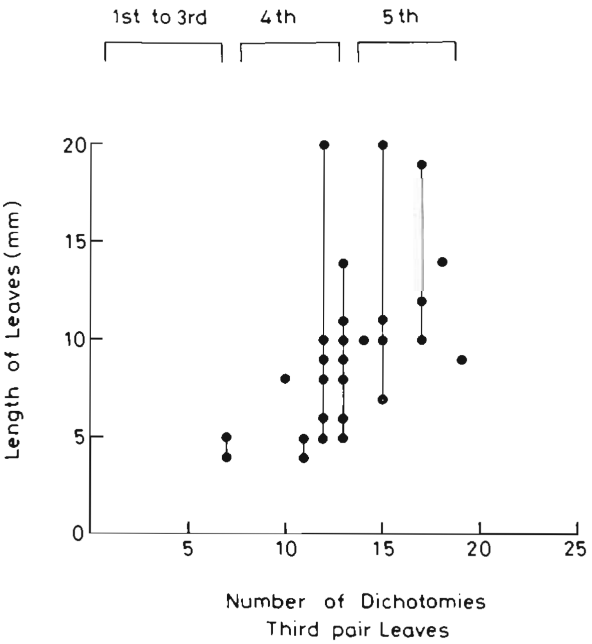
Text-figure 7—Relationship between length and number of dichotomies in leaves of second pair. Vertical lines show length variation found in leaves having same number of dichotomies.

second, and 15 to 112 in the third pair leaves.

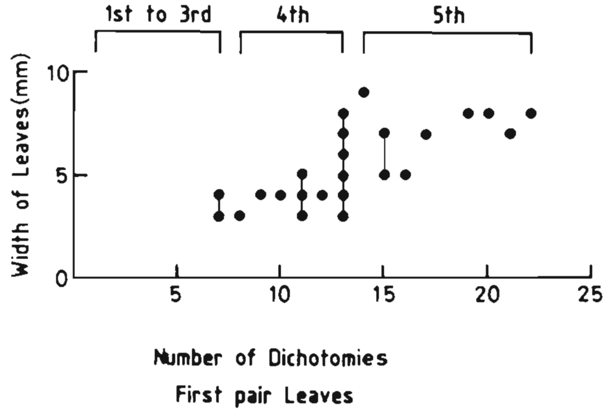
The frequency of leaves with different dichotomy numbers and dichotomy levels is shown in Text-figure 15. The data is plotted from leaves of 53 complete whorls. The majority of leaves in all the 3 pairs have 13 dichotomies. The frequency of leaves with 7 dichotomies increases from first to third pairs and frequency of leaves with higher number of dichotomies decreases from first to third pairs. The analysis of data indicates that although the leaves of the 3 pairs are dissimilar in dimensions yet have similar venation pattern.

Fifteen dichotomies are possible after the completion of fourth level dichotomy and 31 dichotomies after the fifth level dichotomy, i.e., 1 dichotomy of the I-order, 2 dichotomies of the II-order, 4 of the III-order, 8 of the IV-order and 16 of the V-order.

Of the five dichotomy levels, first to third (with total 7 dichotomies) are present in all the leaves, from smallest to largest. Except for a couple of leaves, only 6 out of the possible 8 dichotomies could be observed after the fourth dichotomy level (with 13 total dichotomies). Two outermost veins,



Text-figure 8—Relationship between length and number of dichotomies in leaves of third pair. Vertical lines show length variation found in leaves having same number of dichotomies.

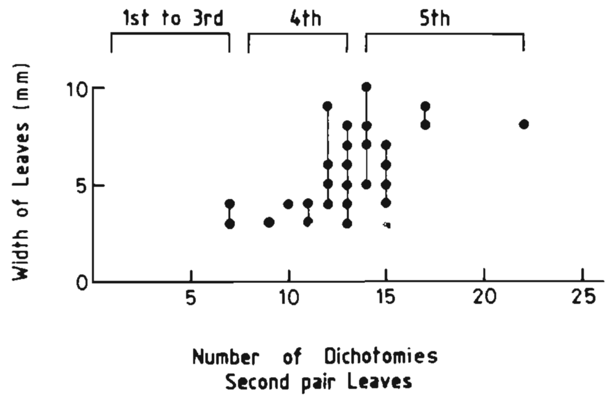


Text-figure 9—Relationship between width and number of dichotomies in leaves of first pair Vertical lines show width variation found in leaves having the same number of dichotomies.

one on either side, do not enter into fourth level dichotomy.

The highest number of dichotomies observed is 23 (with 10 dichotomies of fifth level dichotomy) and the lowest number of dichotomies observed is 7 (with third level dichotomy).

The number of dichotomies may either be equal in all the leaves of a whorl or may vary slightly. Out of the fiftythree complete whorls studied, all the leaves in twentytwo whorls have equal number of dichotomies (Table 2). For example, one of the smallest and youngest whorls in our study has only 7 dichotomies (8 ultimates) in all the leaves; none of the dichotomies entering the fourth level dichotomy. In another smaller whorl the second and third pair leaves have 7 dichotomies each (8 ultimates) whereas the first pair leaves have 9 dichotomies (10 ultimates). In the latter pair, 2 out of the 8 III-order veins, have entered the fourth level



Text-figure 10—Relationship between width and number of dichotomies in leaves of second pair. Vertical lines show width variation found in leaves having the same number of dichotomies.

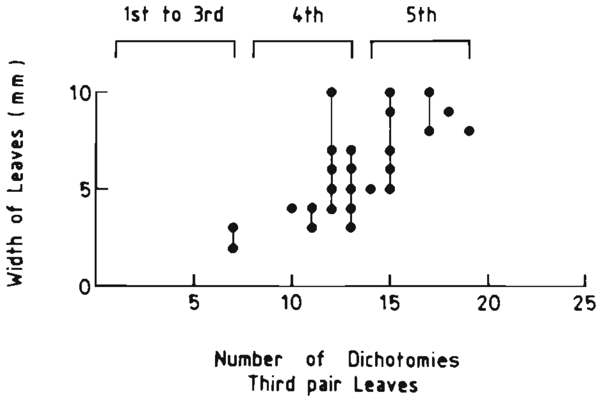
Table 2—**Observed complete whorls (identical or unidentical) with number of dichotomies in leaves of all the 3 pairs**

Number of whorls	Number of dichotomies in first pair leaves	Number of dichotomies in second pair leaves	Number of dichotomies in third pair leaves
1	7	7	7
1	9	7	7
1	8	9	7
1	10	10	7
1	10	11	7
1	12	13	10
1	7	7	11
3	11	11	11
1	12	12	12
6	13	12	12
2	13	13	12
1	15	15	12
1	11	10	13
1	11	13	13
15	13	13	13
1	13	14	13
1	15	13	13
1	15	14	13
2	15	15	13
1	15	15	14
1	15	14	15
1	15	15	15
1	16	15	15
1	21	15	15
1	19	17	15
1	14	14	17
1	17	17	17
1	20	22	17
1	22	17	18
1	22	22	19

Total whorls studied = 53

dichotomy resulting into 2 dichotomies and 4 ultimates of the IV-order; 6 III-order ultimates have remained unbranched further.

There are three whorls that show third pair leaves with 7 dichotomies (8 ultimates) but their first and second pair leaves have entered the fourth level dichotomy resulting in 8 to 11 dichotomies (9 to 12 ultimates, respectively). One to 4, III-order veins enter the fourth level dichotomy to produce 1 to 4 dichotomies (2 to 8 ultimates respectively) leaving 7 to 4 III-order ultimates respectively, unforked. In a rather rare condition, the third pair leaves have more dichotomies than those of the other two pairs. One such unusual whorl shows its first and second pair leaves with 7 dichotomies (of up to third level dichotomy) but its third pair leaves have unusually entered the fourth level dichotomy to produce 4 dichotomies resulting 8, IV-order ultimates, leaving 4 III-order ultimates, 2 each on either side on the periphery.



Text-figure 11—Relationship between width and number of dichotomies in leaves of third pair Vertical lines show width variation found in leaves having the same number of dichotomies.

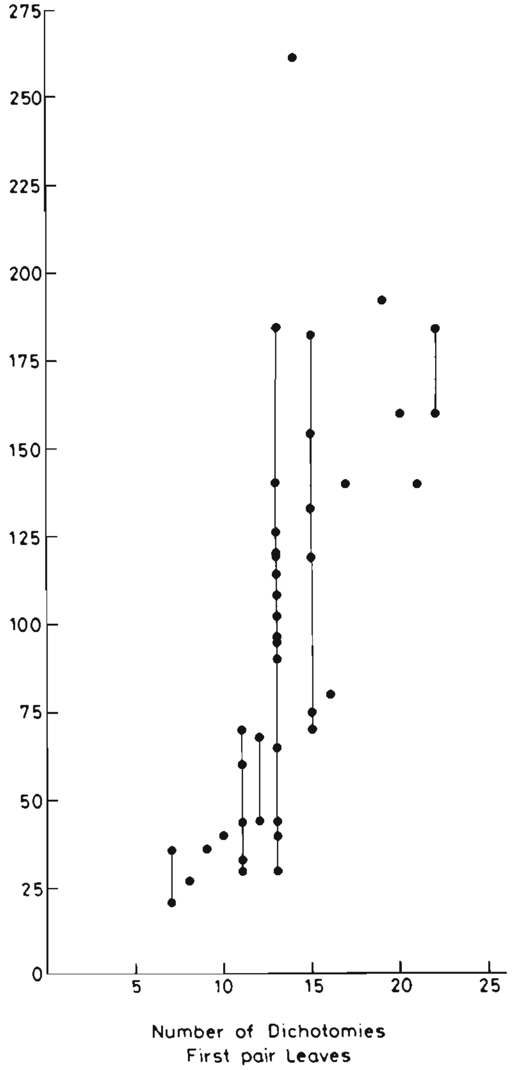
In leaves with total 11 dichotomies, 4 out of 8, III-order veins, two in either half of lamina, enter the fourth level dichotomy. Thus the leaves have 4, III-order and 8, IV-order ultimates. If the total number of dichotomies is 12, then 5, III-order veins enter the fourth level dichotomy, thus producing 3, III-order and 10, IV-order ultimates. In leaves with 13 dichotomies, all III-order veins, except 2, one on either side, divide to produce 12, IV-order ultimates, remaining two being of III-order.

All the leaves that have a total of 14 or more dichotomies, one or more veins enter the fifth level dichotomy. There is no definite trend as to leaves of which pair will first enter the higher level dichotomy.

A total of 17 complete whorls, show fifth level dichotomy. All the leaves in 11 whorls show V-order dichotomy but one such whorl has first pair leaves with 7, IV-order dichotomies, one more than the usual 6. In 4 whorls the third pair leaves do not attain fifth level dichotomy. One whorl has only first pair leaves with V-order dichotomy while still another whorl has only second pair leaves with fifth level dichotomy. Another group of 20 whorls also shows V-order dichotomies but in these whorls one or the other leaf pair is not well-preserved.

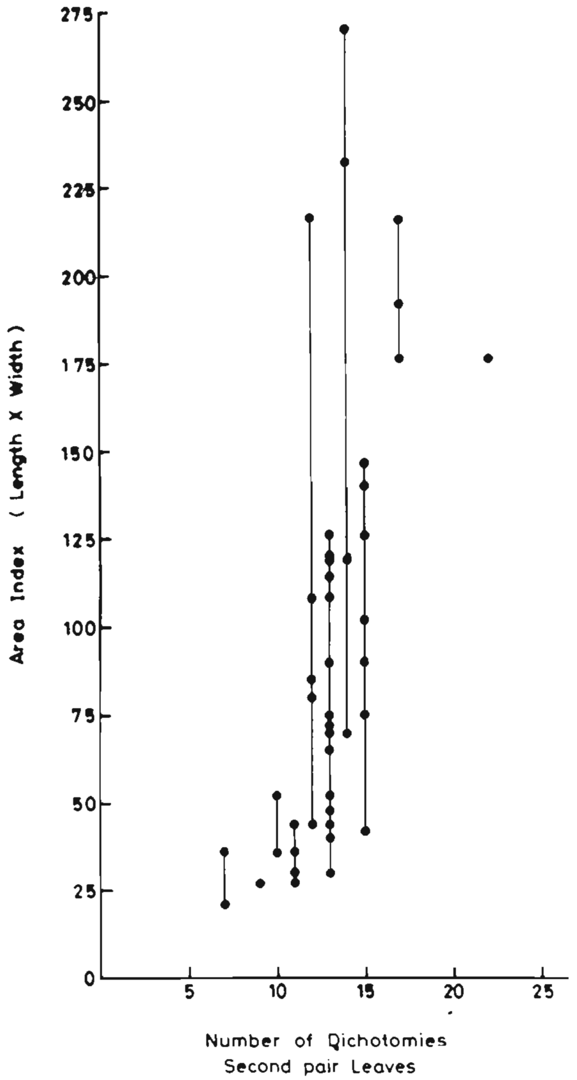
DISCUSSION

Although more than one vein may usually be seen entering the base of the leaf yet the fact is that the venation in all the leaves of *Trizygia speciosa* results from a single vein (frequently distinct in younger and smaller leaves) which arises from a single trace at the point of leaf attachment. The initial vein after the first dichotomy results into two basic I-order veins, one for the left and other for the right half of the lamina. These two costae (veins) form the basis of venation. Each dichotomizes two to four times and produces usually similar venation pattern in its respective half.

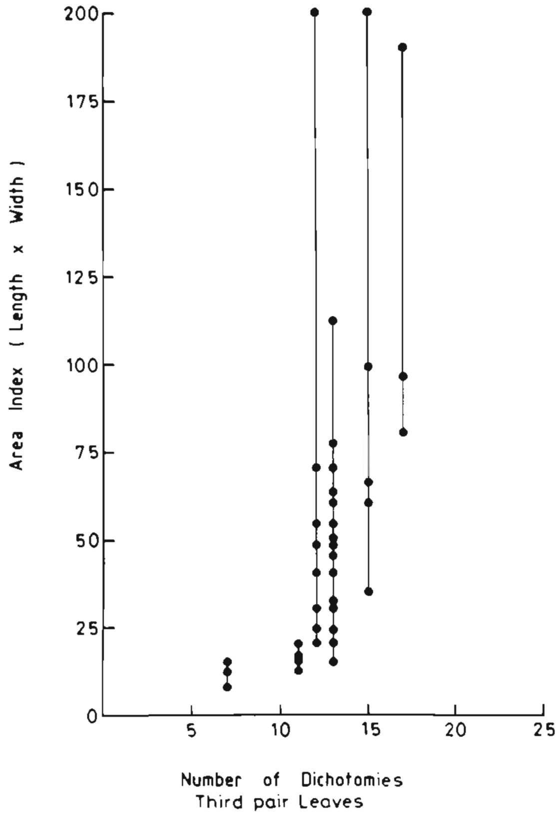


Text-figure 12—Relationship between area-index (length × width) and number of dichotomies in leaves of first pair Vertical lines show variation in area-index in leaves having the same number of dichotomies.

Further dichotomy of two basic I-order veins results into 4, II-order veins. The two successive dichotomies, first and second, occur so close to the point of attachment that 2-4 veins are apparently seen entering the lamina base. The 4, II-order veins further dichotomize. Thus a total of 7 dichotomies results into 8 ultimates, the minimum for a leaf. These 8, III-order veins may terminate as ultimates in younger and smaller leaves or a maximum of 6 may further divide. The two III-order peripheral veins, one in either half, normally do not dichotomize.



Text-figure 13—Relationship between area-index (length × width) and number of dichotomies in leaves of second pair. Vertical lines show area-index variation in leaves having the same number of dichotomies.



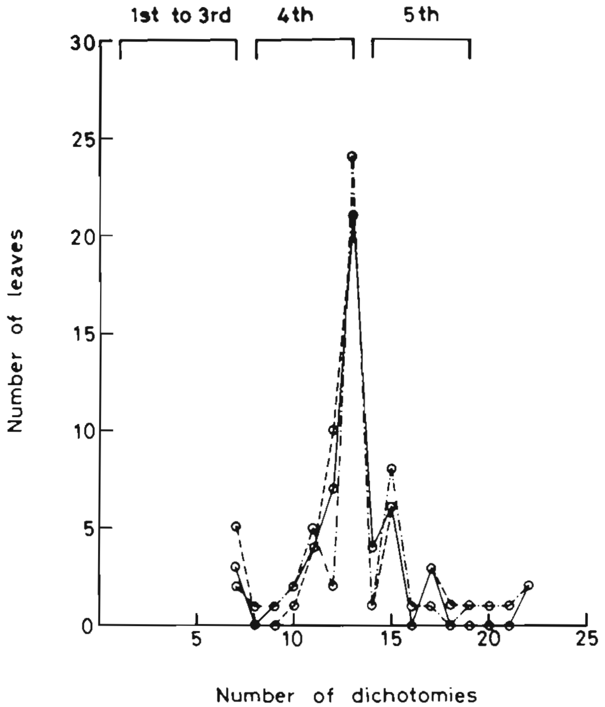
Text-figure 14—Relationship between area-index (length × width) and number of dichotomies in leaves of third pair. Vertical lines show variation in area-index in leaves having the same number of dichotomies.

The maximum dichotomy level found in leaves of all pairs is 3 to 5 and that of dichotomies is 7 to 23 (8 to 24 ultimates, respectively). No leaf of any pair has been observed possessing less than 7 dichotomies (8 ultimates) with the maximum third dichotomy level or more than 23 dichotomies (24 ultimates) with the maximum third dichotomy level or more than 23 dichotomies (24 ultimates) with the maximum fifth dichotomy level.

The leaves advance into the fourth dichotomy level mostly in larger and older leaves. The first leaves of a whorl are usually the first to enter the next higher dichotomy level. The leaves with fourth dichotomy level may have 8 to 13 dichotomies and 9 to 14 ultimates, respectively. At this level all the 6, III-order potential veins are satisfied by the IV-order dichotomies, except in a few cases where the leaf has produced one V-order dichotomy after satisfying all but one potential III-order vein by the IV-order dichotomies.

The leaves advance into fifth dichotomy level, generally after filling all the 6, IV-order dichotomies. The leaves possessing fifth level of maximum dichotomy, the highest level in the present study and found in leaves of all the pairs, may have 14 to 23 dichotomies (15 to 24 ultimates, respectively). The highest number of dichotomies in first pair leaves is 23 (10, V-order dichotomies) observed in a single leaf, in second pair leaves 22 (9, V-order dichotomies) observed in two leaves and in third pair leaves 20 (7, V-order dichotomies) observed in a single leaf.

Asama (1966) proposed two types of evolutionary series in *Sphenophyllum*, (1) *Sphenophyllum oblongifolium* series, changing in order of *S. oblongifolium* → *S. speciosum* → *S. sincoreanum* and (2) *Sphenophyllum thonii* series, changing in order of *S. shansiense* → *S. Thonii* → *S. thonii* var. *minor*. According to him in the former, trizygoid series represented in Cathaysian and Gondwana floras, the size of the leaf segment



Text-figure 15—Comparative frequency of leaves with different number of dichotomies. Broken line with dot, solid line and broken line represent leaves of first, second and third pairs respectively.

increases with the lapse of time whereas it decreases in the latter, non-trizygoid series. For establishing the *T. oblongifolia* series, Asama (1966) selected 3 specimens of *T. speciosa* from the Barakar Formation and 10 specimens from the Raniganj Formation all figured by Feistmantel (1880). The specimens selected from Barakar were smaller than those of Raniganj. However, it does not necessarily mean that there were apparent size differences between Barakar and Raniganj forms. Feistmantel had also pointed that the differences in size between Barakar and Raniganj specimens can not be taken as distinguishing and constant characters.

It is noteworthy that, so far, branching or apical or basal regions have not been observed in *T. speciosa* from the Gondwana. The specimens from the Raniganj Formation show small as well as large leaf whorls, obviously belonging to apical and basal parts respectively, of different specimens.

Although a very simple open dichotomous venation is present in sphenophyllalean leaves, a detailed analysis of venation pattern was not attempted so far. We were encouraged to undertake this investigation following interesting results from similar investigation on venation pattern in petals of certain dicotyledonous flowers. Our study shows significant and strong correlation between leaf length and number of dichotomies, leaf width and number of dichotomies, area-index of leaves and frequency of dichotomies. Sphenophyllales is a large group comprising a number of species distributed in southern and northern palaeofloristic zones from Lower Carboniferous to Upper Permian or Lower Triassic and hence one may expect a considerable variation in venation pattern. Detailed analyses of venation pattern in other species of the group may indicate affinities between northern and southern members of the group. The botanical affinities of *Trizygia speciosa* are certainly with the Arthrophyta, notwithstanding the alleged connection between *Trizygia speciosa* Royle foliage shoot and *Vertebraria indica* Royle, a gymnospermic root axis (Maithy, 1976). It is just one of the million examples of overlap of a fossil by another. This fact was overlooked in the excitement of a new discovery and to justify his observation Maithy (1976, p. 273, 274) even found morphographical and anatomical differences between *Vertebraria* and the axis reported by him (1976, pl. 1, figs 2, 4, 5, 6; pl. 2, fig. 9), where none existed.

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Fossil algae from the Cretaceous of Varagur, Tiruchirapalli District, Tamil Nadu

P. K. Misra* & Pramod Kumar

Misra, P. K. & Kumar, Pramod (1989). Fossil algae from the Cretaceous of Varagur, Tiruchirapalli District, Tamil Nadu. *Palaeobotanist* **37**(1) : 36-51.

Algal remains from the limestone deposits at Varagur area, pertaining to Trichinopolly Group in Tiruchirapalli District, Tamil Nadu have been described. The assemblage comprises 31 species of 17 genera belonging to Cyanophyceae, Chlorophyceae and Rhodophyceae, of which, *Palaeomastigocladus indicus* gen. et sp. nov. and *Amphiroa varagurense* sp. nov. are newly proposed taxa. *Cayeuxia* sp. cf. *C. kurdistanensis* Elliott, *Pycnoporidium lobatum* Yabe & Toyama, *Cylindroporella* sp. cf. *C. sugdeni* Elliott, *Thaumatoporella incrustata* (Elliott) Johnson & Kaska, *Ethelia alba* (Pfender) Massieux & Denizot, *Ethelia* sp., *Archaeolithothamnium parisiense* (Grumbel) Lémoine, *A rude* Lémoine, *Mesophyllum varians* Lémoine, *Archaeolithophyllum* sp., *Amphiroa* sp., *A. elliotti* Johnson and *Amphiroa* sp. cf. *A. guatemalense* Johnson & Kaska are new records for India. The Varagur algal assemblage mostly contains the forms which are known from the Upper Cretaceous. The palaeoecological interpretations of the Varagur deposits have been made and it is visualised that during Upper Cretaceous there was a shallow warm sea at the site of deposition.

Key-words—Fossil algae, Cyanophyceae, Chlorophyceae, Rhodophyceae, Palaeoecology, Upper Cretaceous (India)

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सारॉंश

तिरुचिरापल्ली जनपद (तमिल नाड्डु) में वरागुर के क्रीटेशी कल्प से अश्मित शैवाल

प्रदीप कुमार मिश्रा एवं प्रमोद कुमार

तिरुचिरापल्ली जनपद (तमिल नाड्डु) में त्रिचनापल्ली समूह से सम्बद्ध वरागुर क्षेत्र के चूनापत्थर निक्षेपों से प्राप्त शैवालीय अवशेषों का वर्णन किया गया है। इस समुच्चय में सियॅनोफ़ाइसी, क्लोरोफ़ाइसी एवं रोडोफ़ाइसी नामक कुलों की 17 प्रजातियाँ एवं 31 जातियाँ विद्यमान हैं जिनमें से पेलियोमेस्टीगोक्लेडस इंडिकस नव प्रजाति व जाति एवं ऍम्फ़ीरोआ वरागुरेन्से नव जाति नये प्रस्तावित वर्गक हैं। **कैयूक्सिआ** जाति सजातीय **कै० कुर्डिस्टानेन्सिस** इलियट, **पिक्नोपोरीडियम लोबेटम** याबे व तोयामा, **सिलिन्ड्रोपोरेल्ला** जाति सजातीय **सि० सुगडेनाइ** इलियट, **थोमेटोपोरेल्ला इनक्रस्टेटा** (इलियट) जॉन्सन व कास्का, **एथेलिआ ऍल्बा** (फेन्डर) मेसीयूक्स व डेनिजॉत, **एथेलिआ** जाति, **आर्कियोलिथोथैम्नियम् पेरिसीयेन्से** (ग्रम्बॅल) लैमॉय, **आ० रुडे** लैमॉय, **मीसोफ़िल्लम् बेरियेन्स** लैमॉय, **आर्कियोलिथोफ़िल्लम्** जाति, **ऍम्फ़ीरोआ** जाति, **ए० इलियटाई** जॉन्सन एवं **एम्फ़ीरोआ** जाति सजातीय **ए० ग्वाटामालेन्से** जॉन्सन व कास्का नामक वर्गक भारत से पहली बार अभिलिखित किये गये हैं। वरागुर शैवालीय समुच्चय में प्रायः वही प्ररूप मिले हैं जो कि उपरि क्रीटेशी कल्प से विदित हैं। वरागुर निक्षेपों की पुरापारिस्थितिकीय व्याख्या की गई है तथा ऐसा अनुमान है कि उपरि क्रीटेशी कल्प में इस स्थान पर छिछला गर्म समुद्र विद्यमान था।

VERY little information is available on the fossil algae of Tiruchirapalli District in the Cauvery Basin of South India. Rama Rao (1956), Pascoe (1959) and Sastry *et al.* (1972) have divided the Cretaceous rocks of Tiruchirapalli District into four divisions (Groups), viz., Utatur, Trichinopolly, Ariyalur and Niniyur. Fossil algae from the Utatur Group were reported for the first time by Rama Rao and Prasannakumar (1932) who described *Lithothamnium* from Cullygody limestone mines. Later, from these beds Narayana Rao (1944, 1946)

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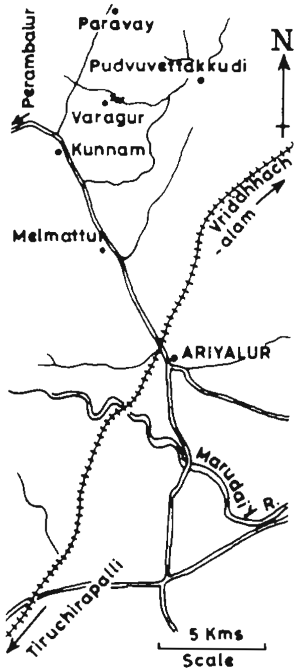
reported two new species, namely *Solenopora coromandelensis*, *S. jurassica*, and Rama Rao and Gowda (1954) described *Solenopora sahnii* and *Archaeolithothamnium lugeonii*. The earlier phycological records from Ariyalur Group are scanty. So far, Mamgain *et al.* (1968) have reported *Archaeolithothamnium* sp., *Lithothamnium* sp. and *Mesophyllum* sp. from South west of Ariyalur town. Most of the contributions on the fossil algae of Tiruchirapalli District have been made from the youngest Niniyur Group. Rama Rao (1931) recorded *Archaeolithothamnium torulosum* from Niniyur beds. Rama Rao and Pia (1936) studied fossil algae from these beds and described 11 taxa belonging to Dasycladaceae, Chaetophoraceae, Solenoporaceae and Corallinaceae. Rama Rao (1938, 1950, 1956, 1958) reported some dasycladaceous algae and reviewed the earlier work done on fossil algae of Niniyur Group. Varma (1952, 1954) described three dasycladaceous algae, viz., *Clypeina*, *Neomeris* and *Acicularia* from the Niniyur beds. Gowda (1953, 1954, 1959, 1978) further added *Holosporella*, *Piania niniyurensis*, fossil Holothuroids, *Solenopora* and *Amphiroa* to the algal flora of this group. Pal (1971a) reported *Archaeolithothamnium pondicherriensis*, *A. zonatum* and *Distichoplax raoi* from Palaeocene of Niniyur Group. Recently, Sastry and Gururaja (1980), in their catalogue of Indian fossil algae, have given a list of taxa known from South India.

Pascoe (1959) has divided the Trichinopolly Stage into lower and upper sub-stages and placed Varagur under the latter indicating Early Senonian age. Rama Rao (1956), Varadarajan and Jagtap (1968), Sastry *et al.* (1972) and Sundaram and Rao (1979) also considered that the beds exposed near Varagur Village belong to Trichinopolly Group of Late Cretaceous age. Ramanathan (1968) suggested Turonian to Senonian age for Trichinopolly Group. Sastry *et al.* (1968), Sastry and Mamgain (1971) and Chiplonkar and Tapaswi (1975) have mentioned Santonian age for the Upper part of Trichinopolly Group.

Rama Rao (1956) and Sundaram and Rao (1979) described the lithology of the Trichinopolly Group which comprises conglomerates, grits, shell limestones, hard calcareous sandstones, shales, arenaceous limestones, silt, soft sandstone and numerous pebbles of the adjacent Archaean gneisses-charnockites. At Varagur the sandstone is overlain by the beds of arenaceous limestone, which is dark brown in colour with a pinkish tinge.

Present investigation on the limestones of Varagur has revealed 31 species of fossil algae belonging to following 17 genera of Cyanophyceae, Chlorophyceae and Rhodophyceae. All slides and negatives are preserved at the Birbal Sahni Institute



Map 1—Location map of Varagur showing exposures of algal limestone.

of Palaeobotany Museum and each specimen has been indicated by a mark number.

CYANOPHYCEAE

Cayeuxia Frollo (1 sp.), *Palaeomastigocladus* gen. nov. (1 sp.).

CHLOROPHYCEAE

Pycnoporidium Yabe & Toyama (1 sp.), *Cylindroporella* Elliott (1 sp.), *Indopolia* Pia (1 sp.), *Larvaria* Defrance (1 sp.), *Neomeris* Lamouroux (1 sp.).

RHODOPHYCEAE

Solenopora Dybowski (4 spp.), *Parachaetetes* Daninger (2 spp.), *Thaumatoporella* Pia (1 sp.), *Ethelia* Weber van Bosse (2 spp.), *Archaeolithothamnium* Rothpletz (5 spp.), *Mesophyllum* Lémoine (2 spp.), *Archaeolithophyllum* Johnson (1 sp.), *Lithophyllum* Philippi (3 spp.), *Distichoplax* Pia (1 sp.), and *Amphiroa* Lamouroux (3 spp.).

Palaeomastigocladus indicus gen. et sp. nov and *Amphiroa varagurense* sp. nov. are being proposed as new taxa and *Cayeuxia* sp. cf. *C. kurdistanensis* Elliott, *Pycnoporidium lobatum* Yabe & Toyama, *Cylindroporella* sp. cf. *C. sugdeni* Elliott, *Thaumatoporella incrustata* (Elliott) Johnson & Kaska, *Archaeolithothamnium parisiense* (Grümbel) Lémoine, *A. rude* Lémoine, *Mesophyllum varians*

Lemoine, cf. *Archaeolithophyllum* sp., *Amphiroa elliotti* Johnson and *A. guatemalense* Johnson & Kaska are new records for the Indian fossil algae.

The source of material, for the present algal studies, is from the beds exposed near Varagur Village, situated about 12-14 km north-north-west of Ariyalur town in Tiruchirapalli District, Tamil Nadu (Map 1). An outcrop of 4-5 limestone bands is exposed at 79°3′ longitude and 11°5′ latitude in a nala cutting at about 150-200 m north-east of the village.

All the specimens have been studied in thin sections made from the limestones by using conventional methods.

DESCRIPTION

The genera have been arranged after Wray (1977). Species under each genus are in alphabetic sequence.

Cyanophyceae

Genus—*Cayeuxia* Frollo 1938

Cayeuxia sp. cf. *C. kurdistanensis* Elliott
Pl. 1, figs 2, 3

Description—Thallus obovoid crustaceous tuft, 0.9 mm long, 0.7 mm broad; tuft composed of several loosely packed and radially arranged tubes; tubes branched, 9-12.5 μm in diameter, branches forming an angle for some distance then abruptly turning and running more or less parallel to main tube.

Specimen—Slide no. B.S.I.P. 8513-mark 4.

Remarks—In general arrangement of tubes the present thallus resembles *C. kurdistanensis* Elliott (1956a), but the tubes of the former are slightly narrower than those of the latter.

Elliott (1956a) has described *C. kurdistanensis* from Palaeocene of Iraq. Johnson (1969) has mentioned the occurrence of this species from Middle Jurassic to Upper Cretaceous. Frollo (1938), Elliott (1956) and Pal (1968) have treated the genus *Cayeuxia* Frollo under family Codiaceae in Siphonales of the class Chlorophyceae. But Maslov (1956) assigned this alga to the calcareous blue-green algae. This treatment was later followed by Wray (1977) and Schäfer and Senowbari-Daryan (1983). However, they did not mention the order and family of this taxon.

Genus—*Palaeomastigocladus* gen. nov.

Diagnosis—Filaments heterotrichous, long, interwoven, confluent, with true branching; branches usually arising on one side in the form of inverted-V; sheath firm and thin.

Type species—*P. indicus* sp. nov.

Comparison—The present specimen differs from the known fossil stigonematallean algae, viz., *Langiella* Croft & George (1959) and *Kidstoniella* Croft & George 1959, *Westiellopsis mahabalei* Biradar 1977 and *Ghoshia* Mandal & Maithy (in Mandal *et al.*, 1984) in having loose interwoven habit and unilateral inverted V-shaped branching pattern of filaments. These characters bring the present fossil close to recent *Mastigocladus* Cohn and nearest to its species *M. lamellosum* Cohn (Desikachary, 1959). Reproductive bodies have not been observed in the present fossil. These are also not known in modern *Mastigocladus* Cohn. However, heterocysts are reported in living algae, but they are absent in the present specimen.

PLATE 1 →

1, 6, 17. *Ethelia alba* (Pfender) Massieux & Denizot: 1. *Ethelia alba* magnified to show filaments. × 100, Slide no. BSIP 8520-mark 1; 6. Showing diverging filaments. × 100, Slide no. BSIP 8519-mark 1; 17. Thallus. × 30.

2, 3. *Cayeuxia* sp. cf. *C. kurdistanensis* Elliott: 2. Thallus. × 50; 3. An enlarged portion of thallus showing branching pattern of tubes. × 100, Slide no. BSIP 8515-mark 4.

4. *Ethelia* sp. thallus. × 100, Slide no. BSIP 8519-mark 2.

5. *Distichoplax biserialis* (Dietrich) Pia: Section of a fragment. × 30, Slide no. BSIP 8511-mark 1.

7, 11. *Parachaetetes asvapatii* Pia: 7. An oblique section showing cross section of filaments in the centre. × 30, Slide no. BSIP 8514-mark 2; 11. Longitudinal section. × 30, Slide no. BSIP 8506-mark 8.

8. *Solenopora tiruchiensis* Rama Rao & Sambe Gowda: Thallus. × 30, Slide no. BSIP 8514-mark 1.

9, 14, 15. *Pycnoporidium lobatum* Yabe & Toyama: 9, 14. Cross section of thallus. × 30, Slide no. BSIP 8509-mark 1; 15. Longitudinal section of thallus. × 30; 9. An enlarged portion of longitudinal section showing branched filaments, Slide no. BSIP 8506-mark 10.

10. *Archaeolithophyllum* sp. : Section of a part of thallus. × 100, Slide no. BSIP 8507-mark 1.

12, 13. *Parachaetetes* sp. : 12. A magnified portion showing cells. × 50, Slide no. BSIP 8513-mark 5; 13. Shape of thallus. × 30.

16. *Neomeris cretaceae* Steinmann : Cross section of vegetative thallus. × 20, Slide no. BSIP 8506-mark 11.

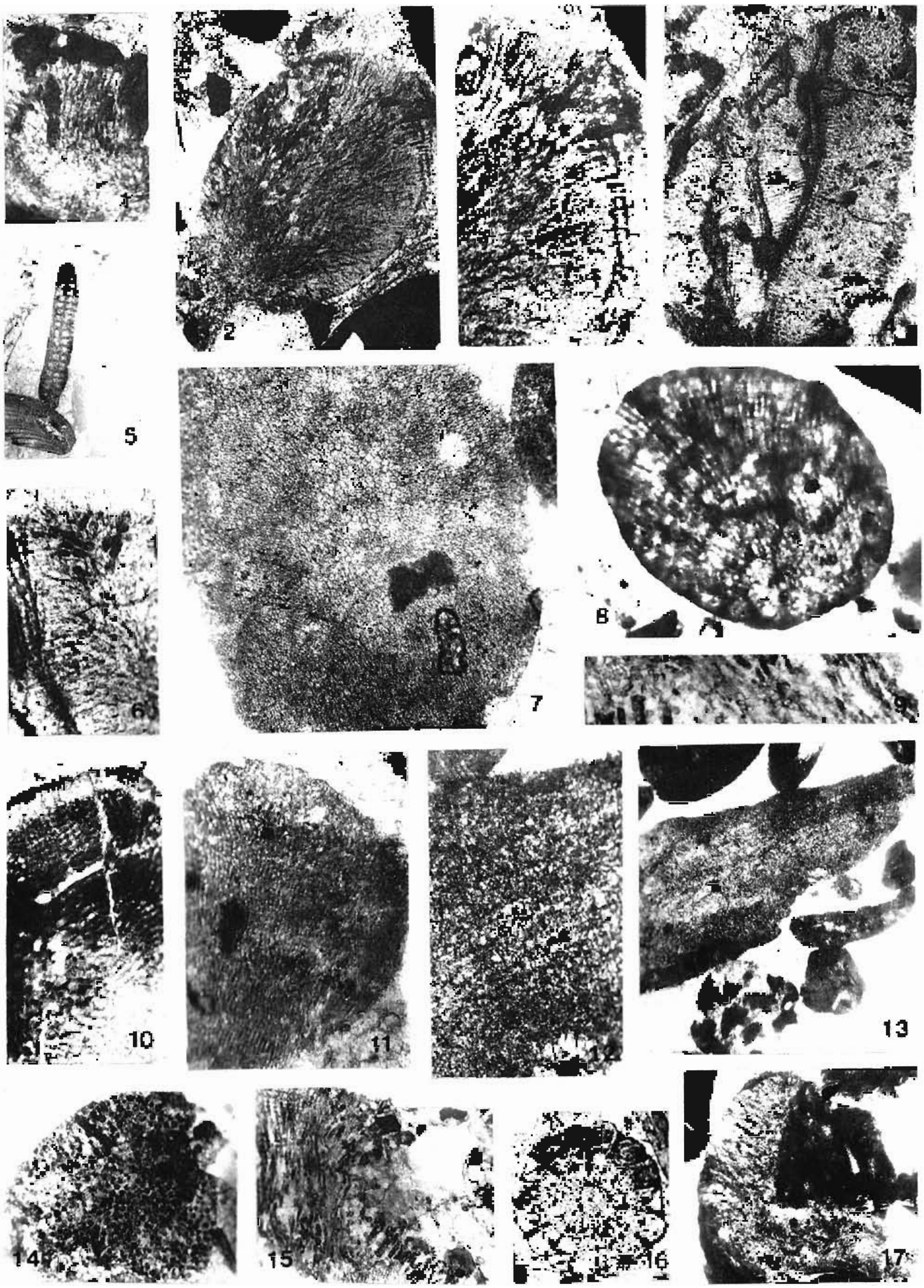


PLATE 1

Palaeomastigocladus indicus sp. nov.
Pl. 3, figs 2, 6

Diagnosis—Filaments heterotrichous, long, interwoven, confluent with true branching, branches usually arising on one side in the form of inverted-V; sheath firm and thin; filaments slightly constricted at septa; cells barrel-shaped to short cylindrical, 3.5-4.5 μm broad, 6-10.5 μm long; heterocysts not seen.

Holotype—Slide no. B.S.I.P. 8506-mark 4.

Locality—Varagur Village, Tiruchirapalli District, Tamil Nadu.

Horizon—Trichinopolly Group (Upper Cretaceous).

Genus—*Pycnoporidium* Yabe & Toyama 1928

Pycnoporidium lobatum Yabe & Toyama
Pl. 1, figs 9, 14, 15

Description—Thallus more or less rounded with irregular mass of loosely packed tubular filaments, radiating from centre to outwards and showing dichotomous branching at few places; outline of filaments circular to polyhedral in cross section, transverse partitions prominent, cells 31.0-43.5 μm broad, 37-82 μm long, cell wall 1.5-2.0 μm thick.

Specimen—Slide nos. B.S.I.P. 8506-mark 10, B.S.I.P., 8509-mark 1.

Remarks—This is the first record of this genus from India. The genus is known from Jurassic to Palaeocene (Johnson, 1969), but the species *P. lobatum* Yabe & Toyama has been recorded from Lower Cretaceous to Middle Cretaceous (Johnson & Kaska, 1965). However, the present report extends the geologic range of this species up to Upper Cretaceous.

Johnson (1964, 1969) and Johnson and Kaska (1965) have described this genus under the family Solenoporaceae of Class Rhodophyceae while Johnson and Konishi (1960) assigned it to the order Siphonocladales of Chlorophyceae. Wray (1977) commented that this alga may belong to green algae.

Genus—*Cylindroporella* Johnson 1954

Cylindroporella sp. cf. *C. sugdeni* Elliott
Pl. 2, fig. 12

Description—Thallus large, cylindrical, 0.89-0.91 mm broad and 2.45 mm long; branches absent; sporangia large, subspherical, 185-210 μm in diameter.

Specimen—Slide no. B.S.I.P. 8510-mark 1.

Remarks—General morphology and dimensions show its close resemblance with *C. sugdeni* Elliott (Elliott, 1957; Johnson, 1968). This species was, so far, unknown from India (Sastry & Gururaja, 1980). Elliott (1957) described it from the Lower Cretaceous of Fahud, Oman. Johnson (1969) has suggested an Aptian-Albian age for this dasycladaceous alga.

Genus—*Indopolia* Pia 1936

Indopolia sp. cf. *I. satyavanti* Pia
Pl. 2, figs 2, 3

Description—Thallus broadly cylindrical, 1.7 mm long, 0.95 mm broad, central axis large, 0.4 mm in diameter; primary branches fairly regular, more or

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PLATE 2 →

1, 14. *Mesophyllum* sp. cf. *M. daviesi* Narayana Rao: 1. Thallus showing biconvex conceptacle (c) in perithallus. × 50, 14. A magnified portion of the same exhibiting reduction in the gap between the bands (marked by arrow). × 100, Slide no. BSIP 8506-mark 1.

2, 3. *Indopolia* sp. cf. *I. satyavanti* Pia: 2. Longitudinal section of thallus. × 30, Slide no. BSIP 8517-mark 1; 3. Cross section of thallus. × 30, Slide no. BSIP 8518-mark 1

4. *Solenopora* sp.: Section through vertical axis. × 100, Slide no. BSIP 8506-mark 9.

5, 9, 15. *Archaeolithothamnium* ? sp.: 9. An oblique section through a branch. × 50, Slide no. BSIP 8510-mark 2; 5. Thallus. × 50; 15. A magnified portion of same thallus showing rings (R). × 100, Slide no. BSIP 8506-mark 7.

6. *Thaumatoporella incrustata* (Elliott) Johnson & Kaska, section of a fragment. × 30, Slide no. BSIP 8510-mark 4.

7 *Lithophyllum* sp. A: Section of wide and platy branch segment. × 50, Slide no. BSIP 8510-mark 1.

8. cf. *Solenopora* sp.: Cross section of filaments. × 50, Slide no. BSIP 8508-mark 1.

10. cf. *Larvaria* sp.: Vertical section of thallus. × 30, Slide no. BSIP 8517-mark 1.

11 *Amphiroa elliottii* Johnson: Section through long and slender vegetative segment. × 50, Slide no. BSIP 8510-mark 3.

12. *Cylindroporella* sp. cf. *C. sugdeni* Elliott: Oblique longitudinal section of thallus showing sporangia. × 30, Slide no. BSIP 8510-mark 1

13. *Neomeris cretaceae* Steinmann: Cross section of fertile thallus showing sporangia. × 30, Slide no. BSIP 8510-mark 1

16, 18. *Lithophyllum* sp. B: 16. Section of vegetative thallus. × 50; 18. A part of thallus magnified to show hypothallus. × 70, Slide no. BSIP 8510-mark 4.

17. *Mesophyllum varians* Lemoine: Vegetative thallus showing coaxial hypothallus. × 50, Slide no. BSIP 8511-mark 2.

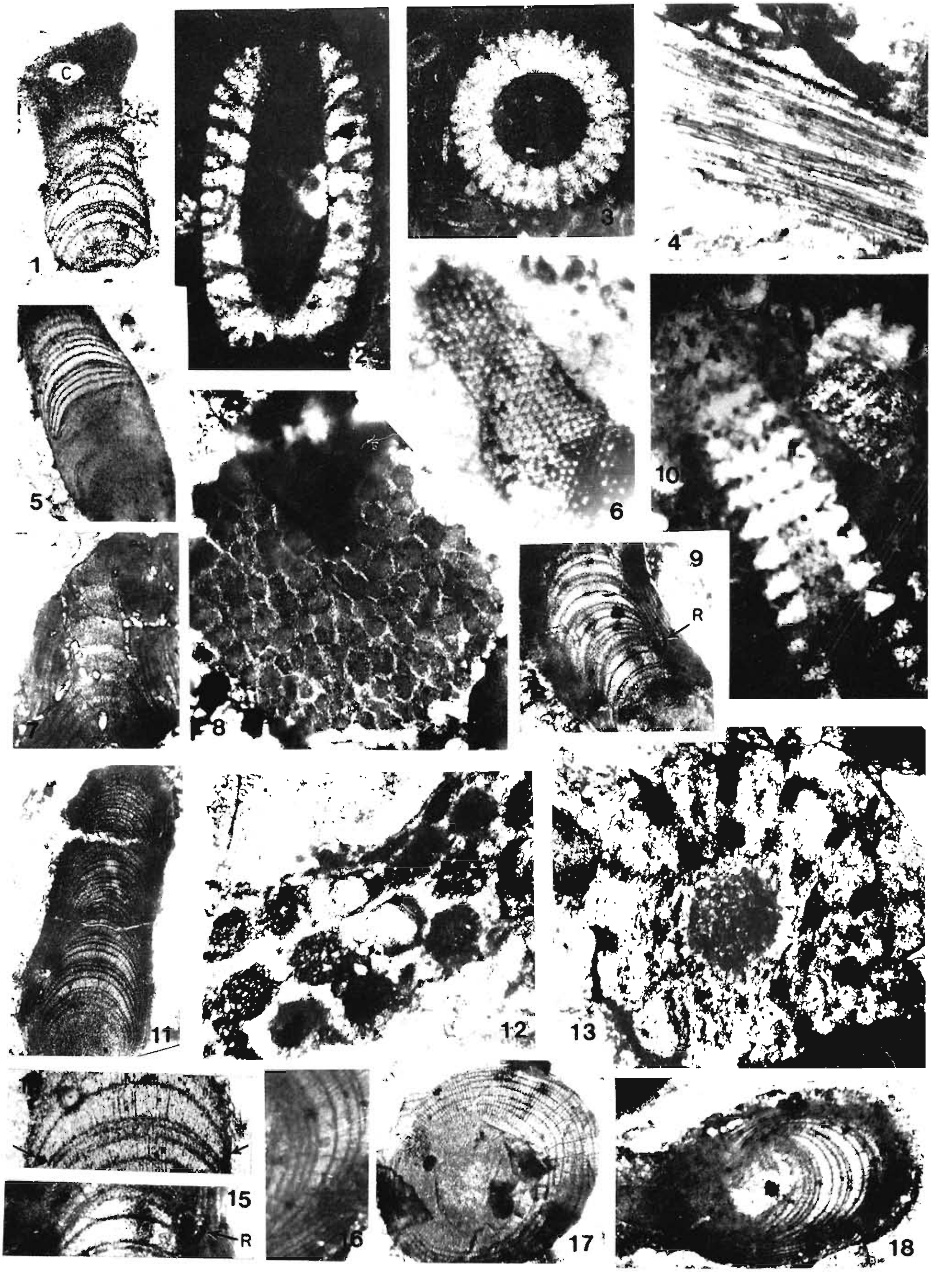

PLATE 2

less oppositely arranged (22 in a whorl); secondary branches slightly inclining and diverging with swollen ends, primary branches equal to secondary branches meeting with external surface at right angle, sporangia not seen.

Specimen—Slide nos. B.S.I.P. 8517-mark 1; B.S.I.P. 8518-mark 1.

Remarks—Vegetative morphology of the studied specimen agrees with *Indopolia* Pia, but due to absence of fertile structures it is regarded as *Indopolia* sp. cf. *I. satyavanti* Pia. The genus *Indopolia* Pia has been described from the uppermost Cretaceous of Niniyur, South India.

Genus—*Larvaria* Defrance 1822

cf. *Larvaria* sp.
Pl. 2, fig. 10

Description—Thallus fragmentary, cylindrical with acuminating end, 2.83 mm long, 0.65 mm broad in the middle; primary branches in regular whorls, short and straight, each dividing into V-shaped secondary branches; sporangia not seen.

Specimen—Slide no. B.S.I.P. 8517-mark 2.

Remarks—Only one longitudinal section of the vegetative fragment is available, hence, the number of primary branches in a whorl and arrangement of sporangia could not be observed. However, this segment resembles *Larvaria* Defrance (Johnson & Kaska, 1965) in vegetative characters. According to Johnson and Kaska (1965), the occurrence of this genus is recorded in Middle to Upper Cretaceous. Sastry and Gururaja (1980) have mentioned that Morellet (1916) has recorded *Larvaria* from Cretaceous of central Tibet. No record of this genus has been made from India.

Genus—*Neomeris* Lamouroux 1816

Neomeris cretaceae Steinmann
Pl. 1, fig. 16; Pl. 2, fig. 13

Description—Cross sections circular, 1.7-2.2 mm in diameter, central axis 0.8-0.95 mm broad bearing a whorl of considerably elongated primary branches; primary branches divided into short secondary branches near the outer surface, secondary branches overlap or lie close to each other; sporangia apparently stalked, usually present at junction of primary and secondary branches, oblong or subspherical, 110-145 μm long, 95-120 μm broad.

Specimen—Slide no. B.S.I.P. 8506-mark 10, 11.

Remarks—The specimens resemble illustrations given by Johnson (1969, pl. 50, figs 3-5) in having similar outline of cross sections, branching pattern and shape, size and position of sporangia. This is the first report of this species from India. According to Johnson (1969) the stratigraphic distribution of this species is from the Lower Cretaceous only.

Rhodophyceae

Genus—*Solenopora* Dybowski 1877

Solenopora filiformis Nicholson
Pl. 3, fig. 7

Description—Thallus obovoid, nodular mass of radiating filaments, filaments branched at few places, cross partitions inconspicuous, filaments rounded to polygonal in cross section, 35-37 μm in diameter.

Specimen—Slide no. B.S.I.P. 8513-mark 3.

Remarks—This specimen agrees well with the forms described as *Solenopora filiformis* Nicholson by Rothpletz (1913) and Johnson *et al.* (1959). Occurrence of this species in the Upper Cretaceous of Varagur appears to be interesting because its known stratigraphic range is from Silurian to Ordovician (Johnson, 1960).

Solenopora tiruchiensis Rama Rao & Sambe Gowda
Pl. 1, fig. 8

Description—Thallus broad, fan-like, filaments unbranched, closely placed and diverging from centre to periphery; cross partitions indistinct, cells 33-36 μm broad and 62-132 μm long.

Specimen—Slide no. B.S.I.P. 8514-mark 1.

cf. *Solenopora* sp. A
Pl. 2, fig. 8

Description—Cross section of thallus showing filaments in the form of nodular mass of closely packed polyhedral cells with undulating margin and 60-85 μm diameter.

Specimen—Slide no. B.S.I.P. 8508-mark 1.

Remarks—The present specimen compares well with *Solenopora compacta* Rothpletz (1908) in outline, compactness and width of filaments. Since the longitudinal section of this specimen was not observed, the nature of septation and the arrangement of filaments could not be studied.

Solenopora sp.
Pl. 2, fig. 4

Description—Thallus flat, ribbon-shaped with loosely arranged narrow filaments ranging 5-6.5 μm in width; cross partitions indistinct and irregularly placed.

Specimen—Slide no. B.S.I.P. 8506-mark 9.

Remarks—Few ill-preserved thalli were observed. Morphologically these longitudinal sections are assignable to the genus *Solenopora* Dybowski, but due to lack of good preservation of

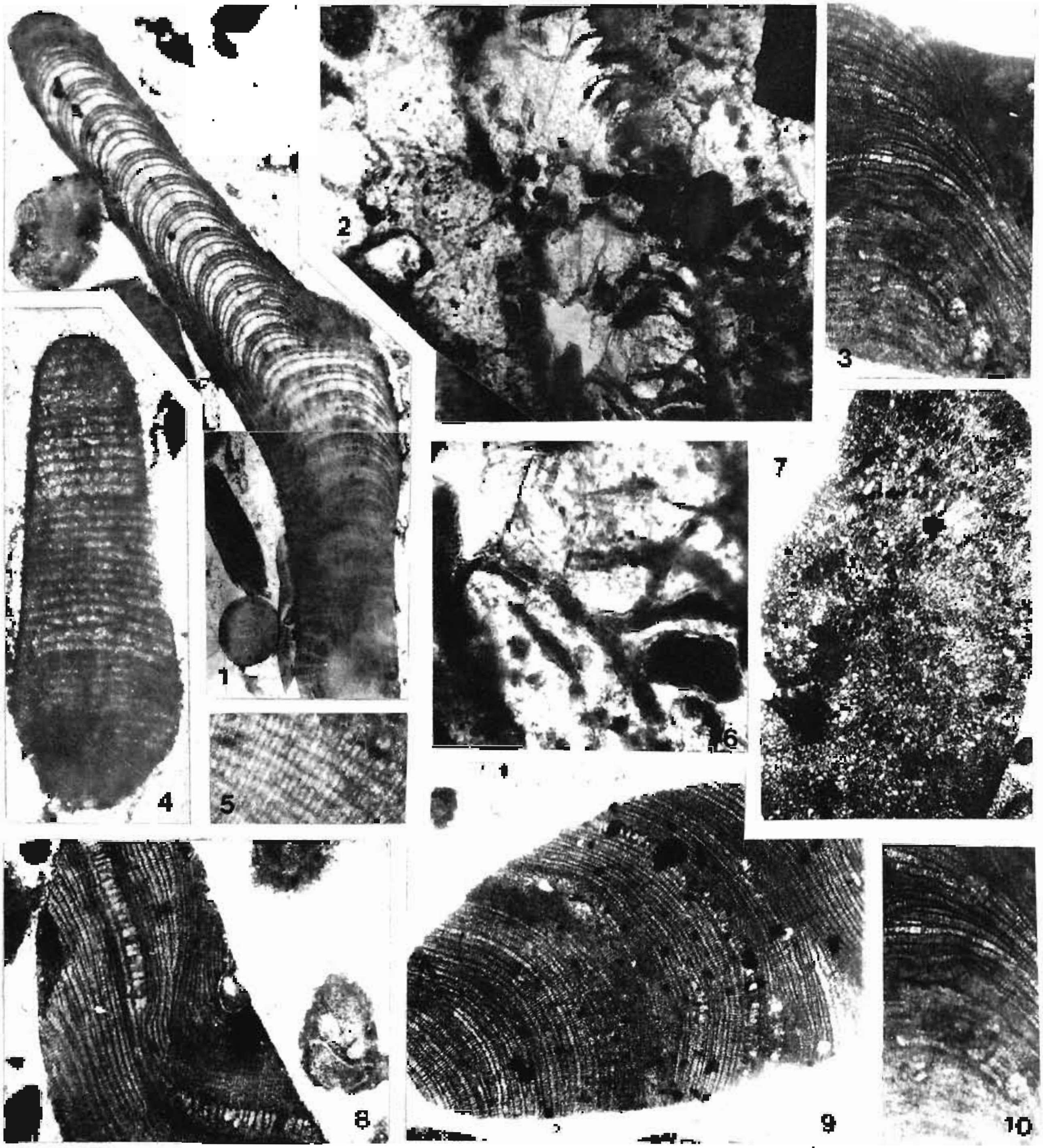

PLATE 3

1. *Amphiroa varagurense* sp. nov. Section of branch segment showing alternation of 2 rows of short cells with 2 rows of long cells in medullary hypothallus × 30. Slide no. BSIP 8506 mark 3.

2, 6. *Palaeomastigocladus indicus* gen. et sp. nov. 2. Habit × 30, 6. Branching of the filaments × 100, Slide no. BSIP 8506 mark 4.

4. cf. *Lithophyllum* sp. Section through cylindrical segment × 100, Slide no. BSIP 8506 mark 5.

5, 9, 10. *Archaeolithothamnium tiruchirapalliensis* Sripada Rao. A part of same thallus enlarged to show rectangular cells × 300. Slide no. BSIP 8512 mark 5. 9. Section of fertile thallus × 50, Slide no. BSIP 8512 mark 1. 10. A fragment showing arrangement of sporangia × 50.

7. *Solenopora filiformis* Nicholson. Oblique longitudinal section × 50, Slide no. BSIP 8513 mark 3.

8, 10. *Archaeolithothamnium parisiense* (Gümbel) Lemoine. Thallus with scattered sporangia × 50. 10. A portion of thallus showing morphology of tetrasporangia × 75, Slide no. BSIP 8511 mark 1.

septa and cross section of filaments, their specific identification is not possible.

Genus — *Parachaetetes* Deninger 1906

Parachaetetes asvapatii Pia
Pl. 1, figs 7, 8

Description — Thallus oblong to hemispherical, cushion-like with shallow marginal fissures, 5-15 mm long and 2.5-4 mm broad; perithallus and hypothallus indistinguishable; cellular filaments regular, compactly arranged, radiating towards periphery; vertical walls of cells thicker than cross walls; cells 31-37 µm broad, 62-114 µm long.

Specimen — Slide no. B.S.I.P. 8506 mark 8; B.S.I.P. 8514 mark 2.

Remarks — *Parachaetetes asvapatii* Pia (Rama Rao & Pia, 1936) was described from the Uppermost Cretaceous beds of Niniyur. Elliott (1956b) and Johnson (1964a) recorded this species from Palaeocene of Iraq. Johnson and Kaska (1965) reported this taxon from uppermost Cretaceous as well as Palaeocene of Guatemala.

Parachaetetes sp.
Pl. 1, figs 12, 13

Description — Thallus broad with a gradually narrowing end; filaments ill-preserved, apparently closely packed; cells more or less rectangular, 11-15 µm broad and 15-30 µm long.

Specimen — Slide no. B.S.I.P. 8513 mark 5.

Remarks — In the arrangement of filaments and shape and size of cells the present species compares well with *Parachaetetes* sp. of Johnson (1964a) reported from the Palaeocene of Iraq. However, the latter has a circular outline while the present specimen possesses an acuminating thallus.

Genus — *Thaumatoporella* Pia 1927

Thaumatoporella incrustata (Elliott) Johnson & Kaska
Pl. 2, fig. 6

Description — Thallus thin monostromatic crust containing more or less polygonal prismatic cells measuring 45-70 µm in diameter.

Specimen — Slide no. B.S.I.P. 8510 mark 4.

Remarks — The cells of the present specimen are slightly narrower than those of the holotype (65 to 104 µm in diameter). Johnson and Kaska (1965) and Johnson (1969) included the genus *Polygonella* Elliott (1957) in the synonymy of *Thaumatoporella* Pia (1927) on the basis of similar morphology and the priority. Elliott (1957) has recorded it from the Upper Jurassic of Middle East. Johnson (1965) has given the stratigraphic range of this taxon from Upper Jurassic to Lower Palaeocene. This is the first record of the genus from the Upper Cretaceous of Varagur.

Genus — *Ethelia* Weber van Bosse 1913

Ethelia alba (Pfender) Massieux & Denizot
Pl. 1, figs 1, 6, 17

Description — Thallus small, ribbon-shaped, more or less curved, 350-530 µm broad; hypothallus with closely packed cellular filaments lying parallel to axis in the centre and curved outwards to meet the edges perpendicularly; filaments 9-11.5 µm broad; cells of the filaments gradually becoming smaller from center towards the margin of thallus and forming indistinct and thin layer of perithallus.

Specimen — Slide nos. B.S.I.P. 8519 mark 1; B.S.I.P. 8530 mark 1.

PLATE 4

1, 2. *Archaeolithothamnium* sp. 1. Section through branched segments × 50. Slide no. BSIP 8510 mark 2; Slide no. BSIP 8506 mark 6.

3, 4. *Mesophyllum vaughani* Lemoine. 3. Enlarged portion of coaxial hypothallus × 50. Slide no. BSIP 8506 mark 10. 4. Thallus showing conceptacle (c) and initiation of branch (b) × 30. Slide no. BSIP 8510 mark 5.

5, 10, 12. *Amphiroa guatemalense* Johnson & Kaska. 5. Thallus × 50. 10. Same magnified to show alternation of one row of short cells with 2 rows of long cells in hypothallus × 100. 12. Enlarged view of hypothallus and perithallus × 100. Slide no. BSIP 8510 mark 3.

6, 8, 16. *Archaeolithothamnium rude* Lemoine. 6. A thallus containing flattened pear-shaped sexual conceptacles × 100. Slide no. BSIP 8515 mark 1. 8. Section of fertile thallus × 30. 16. A portion of same magnified to show serrate outline of tetrasporangia × 100. Slide no. BSIP 8513 mark 2.

7, 9, 11, 14, 17. *Archaeolithothamnium lugeoni* Pfender. 7. Section of thallus under low magnification × 50. 9. An enlarged portion of thallus exhibiting sporangia in series × 50. 11. Oval shape of sporangia — some with an acuminating end × 100. 14. Magnified view of thallus showing hypothallus, perithallus and sporangia arranged in clusters × 50. 17. Serial sporangia in oblique section × 50. Slide no. BSIP 8512 mark 2.

15. *Archaeolithothamnium mangalacharensis* Sripada Rao. Magnified view of rectangular/oval sporangia × 100. Slide no. BSIP 8513 mark 1.

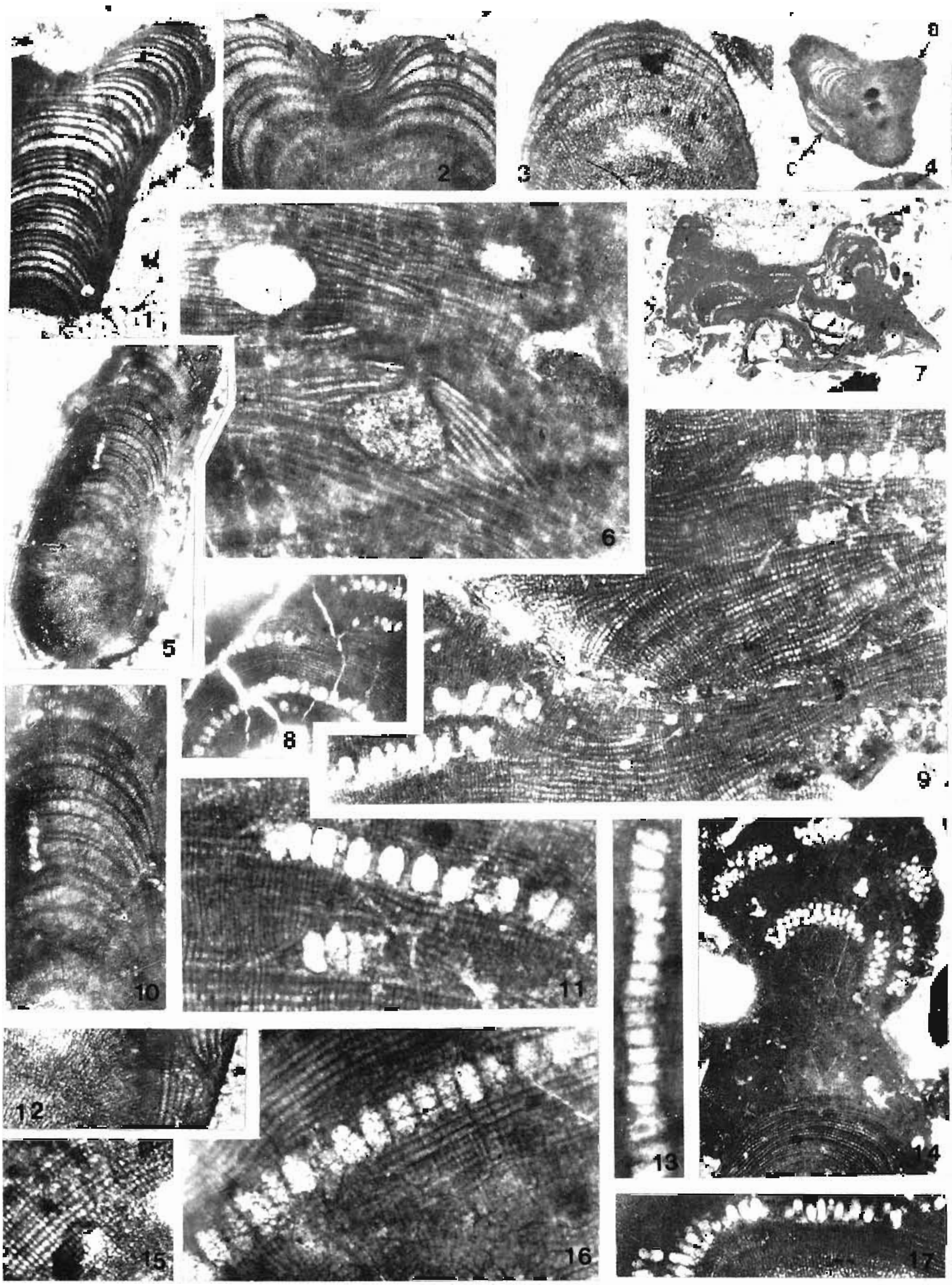

PLATE 4

Remarks—Morphologically, the fossils closely resemble the specimens reported by Johnson and Kaska (1965) and Orszag-Sperber *et al.* (1977) from the Upper Cretaceous-Palaeocene of Guatemala and Miocene beds of Turkey. Johnson and Kaska (1965) have discussed the taxonomy of this species and treated *Pseudolithothamnium album* Pfender as a synonym of the former. Orszag-Sperber *et al.* (1977) retained the specific name given by Pfender without any proper reasons. However, the views of Johnson and Kaska (1965) have been followed here.

Ethelia sp.
Pl. 1, fig. 4

Description—Thallus bladded, crustose, 450 μm broad, 700 μm long; central hypothallial area possessing indistinct straight filaments meeting the edge perpendicularly; filaments 12-14 μm broad.

Specimen—Slide no. B.S.I.P. 8519-mark 2.

Genus—*Archaeolithothamnium* Rothpletz 1891

Archaeolithothamnium lugeoni Pfender
Pl. 4, figs 7, 9, 11, 14, 17

Description—Thallus crustose and lobate, 8 mm long, 4.5 mm broad; hypothallus with regular superimposed layers of cells, hypothallial cells 15-24 μm long, 10-12 μm broad, medullary hypothallus absent in protuberances of thallus; perithallus compact, consisting of fairly uniform lattice of polygonal cells; sporangia loosely arranged in linear rows, oval, some of them exhibiting accuminate ends, 60-75 μm long, 30-40 μm broad, in tangential section appearing in groups of various clusters.

Specimen—Slide no. B.S.I.P. 8512-mark 2.

Remarks—Johansen (1969) points "the name *Archaeolithothamnium* was used only provisionally by Rothpletz (1891) and therefore Heydrich's (1897) generic epithet *Sporolithon* should be applied. Thus Littler (1972), Dixon (1973) and Johansen (1976) have followed the same treatment and described the recent species of this extant genus under the generic name *Sporolithon* Heydrich. However, Orszag-Sperber *et al.* (1977), Wray (1977) and Bosence (1983) have retained the name *Archaeolithothamnium* Rothpletz for the fossil specimens, and the same has been adopted here.

Rao and Pia (1936) have mentioned that in this species the appearance of sporangia in the form of cluster is because of the tangential cutting of thallus. However, in one of the thin sections of presently studied specimens, sporangia were seen to be arranged in series as well as in clusters. Beak-like projection of sporangial-end has been illustrated by Lémoine (1928). This is also perceptible in Varagur specimen. Johnson (1963) has enlisted *A. lugeoni* Pfender with Upper Jurassic species of this genus. However, Rao and Pia (1936) recorded this alga from the Upper Cretaceous of Niniyur in Tiruchirapalli District.

Archaeolithothamnium nongsteinensis Sripada-Rao
Pl. 3, figs 5, 9, 10; Pl. 4, fig. 13

Description—Thallus encrusted and mamillated, perithallus compact with curved layers of cells; cell-wall generally even but at places cross walls slightly thicker than vertical walls; cells 15-21 μm long, 7-9.5 μm broad; sporangia rectangulo-ovoid, arranged in concentric rows, 40-58 μm long and 15-22 μm broad.

Specimen—Slide nos. B.S.I.P. 8509-mark 2; B.S.I.P. 8512-marks 1, 3; B.S.I.P. 8513-mark 1.

Remarks—Johnson (1963) recorded the occurrence of this species from Palaeocene to Eocene.

Archaeolithothamnium parisiense (Grümbel) Lémoine
Pl. 3, figs 3, 10

Description—Thallus fragmentary and crustose, somewhat mammilated; hypothallus not preserved; perithallus composed of irregular layers of 17-32 μm long and 8-10.5 μm broad cells; sporangia ovoid to obovoid, irregularly distributed; 0.86-1.2 mm long, 0.8-0.92 mm broad.

Specimen—Slide no. B.S.I.P. 8516-mark 1.

Remarks—Some sporangia of the present specimen are slightly longer, otherwise it agrees well with *A. parisiense* (Grümbel) Lémoine (in Johnson & Ferris, 1948). Johnson (1963) has mentioned the occurrence of this species from Palaeocene to Eocene. This is the first record of *A. parisiense* (Grümbel) Lemoine from the Upper Cretaceous. This species is a new record from India.

Archaeolithothamnium rude Lemoine
Pl. 4, figs 6, 8, 16

Description—Thallus crustose with apparently short protuberances; hypothallus poorly developed, consisting of few layers of ill-preserved cells; perithallus with compactly-arranged irregular layers of cells, whose wall being evenly thickened; perithallial cells 12-23 μm long, 11-14 μm broad; asexual tetrasporic sporangia arranged in curved rows, oblong to sub-spherical with faintly serrate margin, 63-98 μm long, 40-75 μm broad; sexual conceptacles of cystocarps irregularly scattered in the tissue, slightly flattened pear-shaped with a large apical pore, 240-310 μm in diameter, 150-180 μm in length.

Specimen—Slide nos. B.S.I.P. 8513-mark 2; B.S.I.P. 8515-mark 1.

Remarks—Flat, conical and large conceptacles, similar to the present fossil have also been reported in leafy-plate like crustose thallus of *Lithophyllum indicum* Sastry *et al.* (1963), but the latter shows coaxial hypothallus and lacks apical pore in the conceptacles. Moreover, these conceptacles are asexual while those of *A. rude* Lémoine are sexual. This species has been earlier recorded from Upper Jurassic to Lower Cretaceous of France, Spain and Algeria by Pfender (1926), Lémoine (1939) and Johnson (1969), respectively. The present record extends its stratigraphic distribution up to Upper Cretaceous. However, this species is being reported for the first time from India.

cf. *Archaeolithothamnium* sp.
Pl. 2, figs 5, 9, 15; Pl. 4, figs 1, 2

Description—Thalli represented by short, stubby branches with rounded ends; hypothallus coaxial and medullary, hypothallial cells 20-42 μm long, 6-8.5 μm broad; marginal perithallus thin or thick, perithallial cells 11-13.5 μm long, 9 μm broad, junction of hypothallus and perithallus in one specimen exhibiting ring-like structure on either side in the form of 'inverted-P', reproductive bodies not seen.

Specimen—Slide nos. B.S.I.P. 8506-mark 6, 7; B.S.I.P. 8510-mark 2.

Remarks—In the genus *Archaeolithothamnium* Rothpletz, the hypothallus is generally non-coaxial (Wray, 1977). Johnson (1963) has mentioned that in certain branched forms of this genus, particularly those from Cretaceous, the medullary hypothallus is coaxial. Rama Rao and Pia (1936) have reported a vegetative thallus as *Archaeolithothamnium* sp. from uppermost Cretaceous of Niniyur, district Tiruchirapalli. Their specimen also shows coaxial hypothallus. However, the ring-like structures seen in one specimen are hitherto unknown in this genus. Because of the absence of reproductive organs the final specific placement of the thalli is questionable.

Genus—*Mesophyllum* Lémoine 1928

Mesophyllum varians Lémoine
Pl. 2, fig. 17; Pl. 4, figs 3, 4

Description—Thalli crustose, 1.3 mm long, 0.7-1.03 mm broad, some of them showing branched habits, hypothallus coaxial, growth zones generally irregular, cells of the same layer vary in length; cells 18-34 μm long, 16-19 μm broad; conceptacle oblong, poorly preserved, 335 μm long, 100 μm broad.

Specimen—Slide nos. B.S.I.P. 8506-mark 10; B.S.I.P. 8510-mark 5; B.S.I.P. 8511-mark 2.

Remarks—Lémoine (1934) reported this species from the Lower Cretaceous of France while Johnson (1965a) recorded this taxon from Palaeocene of Greece. This is the first record of this species from the Upper Cretaceous of India.

Mesophyllum sp. cf. *M. daviesi* Narayana Rao
Pl. 2, figs 1, 14

Description—Thallus crustose with coaxial hypothallus showing concentric bands at different intervals, hypothallial cells 14-30 μm long, 10-13.5 μm broad; perithallus homogeneous with more or less polygonal cells, perithallial cells 14-17 μm in diameter; conceptacle biconvex 150 μm long, 75 μm broad.

Specimen—Slide no. B.S.I.P. 8506-mark 1.

Remarks—The hypothallial cells of the present specimen are larger in dimensions as compared to those of the species described by Narayana Rao (which measure 18.6 × 7.7 μm). The hypothallus of the latter also shows zig-zag growth zones which are not prominent in the Varagur fossil. However, the biconvex conceptacle of the present studied specimen resembles the conceptacle of *M. daviesi* Narayana Rao. This species has been originally described from Palaeocene of Upper Ranikot Series of the Samana range (N.W. India).

Genus—*Archaeolithophyllum* Johnson 1956

cf. *Archaeolithophyllum* sp.
Pl. 1, fig. 10

Description—Thallus fragmentary, crustaceous and rectangular, measuring 0.47 mm in length and 0.35 mm in breadth; hypothallus composed of arcuate rows of large polygonal cells showing thick walls, hypothallial cells 18.5-37 μm long, 9-14 μm broad; perithallus poorly preserved, consisting of regular rows of small, rectangular, thin-walled 6-8.5 μm long, 4-5 μm broad cells; conceptacles not seen.

Specimen—Slide no. B.S.I.P. 8507-mark 1.

Remarks—The present vegetative thallus is comparable to *Archaeolithophyllum* Johnson (Johnson, 1960; Wray, 1979) but in the absence of conceptacle, the present specimen can not finally be assigned to it. Wray (1977) has given the stratigraphic range of this genus from Lower Carboniferous to Upper Permian.

Genus—*Lithophyllum* Philippi 1837

Lithophyllum sp. A
Pl. 2, fig. 7

Description—Branch encrustated, coaxial medullary hypothallus showing faint growth zones, hypothallus gently tapering upwards and consisting of alternate layers of short, dark cells and long, light-coloured cells; hypothallial cells 25-50 μm long, 12 μm broad; perithallus equally broad, width gradually increasing upwards, perithallus separated from hypothallus by a row of wide cells, ranging 20-40 μm in length and 12-28 μm in breadth, perithallial cells 11-23 μm long, 10 μm broad; reproductive structures not seen.

Specimen—Slide no. B.S.I.P. 8510-mark 8.

Remarks—The coaxial medullary hypothallus does not show strong growth-zones and comprises alternate layers of dark and light-coloured cells, hence it is suggested that this specimen belongs to *Lithophyllum* Philippi (Johnson, 1965b). Since the present fragment is wide and platy, it has not been considered as a remain of *Amphiroa* Lamouroux.

Lithophyllum sp. B
Pl. 2, figs 16, 18

Description—Thallus fragmentary, short, rounded plate-like branch; hypothallus coaxial with irregular alternate layers of short and long cells; hypothallial cells 10.5-29 μm long, 11 μm broad; perithallus less than half of the width of hypothallus, perithallial cells 8 μm broad, 12-16 μm long.

Specimen—Slide no. B.S.I.P. 8510-mark 4.

Remarks—The reasons for assigning the present specimen to the genus *Lithophyllum* Philippi, are based on the observations made by Johnson (1965b).

cf. *Lithophyllum* sp.
Pl. 3, fig. 4

Description—Segment crustose, cylindrical with a rounded end, medullary hypothallus quite regular with rectangular cells arranged in horizontal rows, transverse walls of cells more prominent than vertical, cells 12.5-18 μm long, 11-14.5 μm broad; perithallus and conceptacles not present.

Specimen—Slide no. B.S.I.P. 8506-mark 5.

Remarks—Because of the lack of perithallus and conceptacle, the placement of fossil in the genus *Lithophyllum* is doubtful. However, the general construction of the hypothallus and the rounded tip of the thallus are very similar to a sterile branch specimen of *Lithophyllum* Lemoine, reported from the Miocene of Iraq by Johnson (1964b).

Genus—*Distichoplax* Pia 1934

Distichoplax biserialis (Dietrich) Pia
Pl. 1, fig. 5

Description—Thallus showing two rows of cells in section, cells oppositely arranged and disposed at right angle to central axis, rectangular to slightly polygonal, 58-67 μm long, 27-29.5 μm broad.

Specimen—Slide no. B.S.I.P. 8511-mark 1.

Remarks—The specimen exhibits relatively thicker cell walls, otherwise it agrees well with *Distichoplax biserialis* (Dietrich) Pia (in Elliott, 1956b; Johnson, 1966). According to Johnson (1966) this is a very widespread fossil taxon which was more developed during the Palaeocene and Lower Eocene. This species has been recorded in India from Palaeocene of Andaman Islands, Nerinia beds and Vridhachalam areas of Tamil Nadu and Middle to Upper Eocene of Assam (Sastry & Gururaja, 1980). Pal (1968a) has reported this taxon from the Upper Cretaceous of Bagh beds in Madhya Pradesh. Pal and Dutta (1979) have reported it from the uppermost Palaeocene (Landenian) of Lakadong Member in Jaintia Hills, Assam. Johnson (1966) believed that *Distichoplax biserialis* is an index fossil of Palaeocene to Early Eocene age but Pal (1968b) has described it from Late Cretaceous of Bagh beds. The present finding is also from the Upper Cretaceous deposits; this discourages the use of this taxon as an Index Fossil of Palaeocene-Early Eocene age.

Genus—*Amphiroa* Lamouroux 1812

Amphiroa elliottii Johnson
Pl. 2, fig. 11

Description—Segment long, slender, more or less cylindrical, 1.9 mm long and 0.4 mm broad; medullary hypothallus surrounded by thin marginal perithallus; hypothallus showing irregular alternate layers of long and short cells, marginal cells diverged outward, hypothallial cells 30-40 μm long, 9-11 μm broad; marginal perithallus consisting of 3-4 rows of cells, measuring 15-18 μm in length, 11-12.5 μm in breadth.

Specimen—Slide no. B.S.I.P. 8510-mark 3.

Remarks—The present specimen is slightly shorter and narrower than the *Amphiroa elliottii* Johnson (1964a, 1965a) but it shows close resemblance with Johnson's specimen in having similar outline of thallus, shape, size and arrangement of cells.

Johnson (1964a, 1965a) described this species from the Palaeocene deposits of Rayat in Iraq and Akros in Greece. Sastry *et al.* (1963) have described *Amphiroa* sp. from Upper Cretaceous of Nerinia beds of Pondicherry. Their specimen lacks perithallus and conceptacles and shows hypothallus having alternation of five long cells with one short cells. Johnson (1965a) mentioned that the specimens from Iraq and Greece were fragmentary and possibly they were the remains of those *Lithophyllum* Philippi which usually possessed long spine-like branches.

Amphiroa guatemalense Johnson & Kaska
Pl. 4, figs 5, 10, 12

Description—Segment broadly cylindrical, 1.08 mm long and up to 0.5 mm broad, medullary hypothallus shows two rows of long cells alternating with one row of short cells, long cells 20-35 μm long, 7-8.5 μm broad, short cells 11-19 μm long, 7-8 μm broad; perithallus consisting of 6-8 rows of cells measuring 7 μm in length and 6 μm in breadth.

Specimen—Slide no. B.S.I.P. 8510-mark 3.

Remarks—This species was described from the Upper Palaeocene and the Lower Eocene of Guatemala by Johnson and Kaska (1965). It is a new record for India.

Amphiroa varagurense sp. nov.
Pl. 3, fig. 1

Diagnosis—Branch segment long and slender, measuring 3.1 mm in length, 0.5-0.6 mm in breadth; medullary hypothallus coaxial with deep curved rows of cells, two rows of short cells alternating with two rows of long cells; long cells 36-66 μm long, 12-14 μm broad, short cells 23-30 μm long, 11-16 μm broad; perithallus thin, comprising 2-3 layers of cells and measuring 95 μm in breadth; perithallial cells poorly preserved, distinct cells 17-25 μm long, 15 μm broad; conceptacle not seen.

Holotype—Slide no. B.S.I.P. 8506-mark 3.

Locality—Varagur Village, Tiruchirapalli District, Tamil Nadu.

Horizon—Trichinopolly Group (Upper Cretaceous).

Remarks—The studied specimen differs from all the other known fossil species of *Amphiroa* Lamouroux in having extremely long cylindrical thallus, which shows alternation of two long and two short cells in the medullary hypothallus.

DISCUSSION AND CONCLUSION

A review of the previous data on the stratigraphic distribution of various taxa, similar to or closely comparable with those encountered in the Varagur limestones, reveals that the majority of the taxa is known from Upper Cretaceous. Some of them have been reported either from the sediments of Palaeocene to Miocene age or from the Jurassic to Middle Cretaceous, or even older deposits.

The presence of certain species, viz., *Indopolia satyavanti* Pia, *Larvaria* sp., *Ethelia alba* (Pfender) Massieux & Denizot, *Solenopora tiruchiensis* Rama Rao & Sambe Gowda, *Parachaetetes asvapatii* Pia, *Archaeolithothamnium lugeoni* Pfender and a vegetative thallus of *Archaeolithothamnium* Rothpletz similar to one described by Rama Rao and Pia (1936) suggests Late Cretaceous age for Varagur beds. It is further supported by the occurrence of three species of the genus *Lithophyllum* Philippi, because Johnson (1965b) mentioned that such algae had a greater development during Maestrichtian.

Distichoplax biserialis (Dietrich) Pia is known from Palaeocene to Eocene (Johnson, 1966). The report of this alga from Upper Cretaceous of Bagh beds by Pal (1971) and present findings from Varagur beds indicates that this taxon might have evolved in Late Cretaceous but could flourish only during Palaeocene to Eocene.

Specimens denoting Palaeocene-Eocene age to Varagur beds are *Archaeolithothamnium nongsteinensis* Sripada Rao, *A. parisiense* (Grümbel) Lémoine, *Amphiroa elliotii* Johnson and *A. guatemalense* Johnson & Kaska.

While discussing stratigraphic implication of Niniyur algae, Pia (in Rama Rao & Pia, 1936) pointed out a transitional position of that flora between Cretaceous and Tertiary periods and suggested that these algae could not be employed to make any stratigraphic conclusions for South India, particularly when many of them were new.

The diverging recommendations of the present algal assemblage regarding the age reveal that most of the taxa suggest a Late Cretaceous age for the beds exposed near Varagur Village. All the specimens of older age, except *Solenopora filiformis* Nicholson, have been found to occur up to Lower or Middle Cretaceous and now it appears that these algae have extended up to Upper Cretaceous. The fossils suggesting Palaeocene-Eocene age might have originated in Late Cretaceous but they bloomed up during favourable conditions of Early Tertiary period.

According to Rama Rao (1956) the rocks of Trichinopolly Group, to which Varagur beds belong, are essentially littoral deposits. Palaeoecological interpretations of Varagur area with respect to fossil algae are based on information on growth habit and ecological conditions of modern representatives of these taxa.

Dasycladaceous algae, represented by *Cylindroporella* Johnson, *Larvaria* Defrance, *Indopolia* Pia and *Neomeris* Lamouroux, are tropical or subtropical plants inhibiting shallow marine warm waters (Wray, 1977). Species of *Ethelia* Weber van Bosse occur at shallow depth, from just-below tide level in tropical or subtropical marine waters (Wray, 1977). The same habitat is preferred by *Archaeolithothamnium* Rothpletz, which is generally found at 12-60 m depth (Johnson, 1963). Chiplonkar and Borkar (1972) have suggested shallow marine conditions in the Middle-Upper Cretaceous of Wadhwan Formation in Gujarat on the basis of the presence of three species of *Archaeolithothamnium* Rothpletz. Greater development of the taxa belonging to genus *Lithophyllum* Philippi is also in the tropical seas, where they inhibit tidal or intertidal pools in depth ranging from 10 to 33 m.

According to Phansalkar and Kumar (1984) the shell limestone of Trichinopoly Group as well as the fauna contained in it is suggestive of infraneritic depths; the wood logs, most of them arranged parallel to each other, indicate a near shore possibly littoral conditions.

The present interpretations, as also supported by other studies, help us in visualising that during the Upper Cretaceous, a shallow warm sea was prevailing at the depositional site of Varagur beds. Presently the coastal line has shifted about 150 km towards east from this place.

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Some more fossil woods from the Lower Siwalik sediments of Kalagarh, Uttar Pradesh and Nalagarh, Himachal Pradesh

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Yadav, R. R. (1989). Some more fossil woods from the Lower Siwalik sediments of Kalagarh, Uttar Pradesh and Nalagarh, Himachal Pradesh. *Palaeobotanist* **37**(1) : 52-62.

Seven fossil woods comparable with the woods of *Anisoptera oblonga* and *Dipterocarpus obtusifolius* of Dipterocarpaceae, *Aglaia edulis* of Meliaceae, *Acrocarpus fraxinifolius, Ormosia robusta, Koompassia malaccensis* and *Adenanthera pavonina* of Fabaceae are described from the Lower Siwaliks of Kalagarh, Uttar Pradesh and Nalagarh, Himachal Pradesh. Occurrence of these taxa is indicative of a warm and humid climate around Kalagarh and Nalagarh during the Lower Siwalik period.

Key-words—Fossil woods, Xylotomy, Dipterocarpaceae, Meliaceae, Fabaceae, Lower Siwaliks, Middle Miocene (India).

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सारॉंश

उत्तर प्रदेश में कालागढ़ तथा हिमाचल प्रदेश में नालागढ़ के अधरि शिवालिक अवसादों से प्राप्त कुछ और अश्मित काष्ठ

राम रतन यादव

उत्तर प्रदेश में कालागढ़ एवं हिमाचल प्रदेश में नालागढ़ के अधरि शिवालिक अवसादों से उपलब्ध अश्मित काष्ठों का वर्णन किया गया है। ये काष्ठ डिप्टेरोकार्पेसी कुल के **ऐंनाइसॉप्टेरा ओबलोंगा** एवं **डिप्टेरोकार्पस ऑबट्यूसीफ़ोलिया**, मिलियेसी के **ऐंग्लेआ ऐंड्यूलिस** तथा फैबेसी के **ऐंक्रोकार्पस फ्रेक्सिनिफ़ोलियस, ओर्मोसिआ रोबस्टा, कूम्पासिआ मलक्केन्सिस** एवं **एडिनेन्थीरा पवोनिया** की काष्ठों से तुलनीय हैं। इन वर्गकों की उपस्थिति से अधरि शिवालिक के समय कालागढ़ एवं नालागढ़ के आस-पास उष्ण एवं आर्द्र जलवायु का होना इंगित होता है।

THE Lower Siwalik sediments exposed in the foothills of Himalaya near Kalagarh, Uttar Pradesh and Nalagarh, Himachal Pradesh are rich in petrified woods. Earlier, Prakash (1978, 1981), Trivedi and Ahuja (1978a, b, 1979a, b, 1980), Trivedi and Misra (1978, 1979, 1980), and Prakash and Prasad (1984) described the fossil woods from Kalagarh. Some more fossil woods were also reported from the Lower Siwalik of Nalagarh, Himachal Pradesh (Prakash, 1975, 1979a, b). Further investigation of the petrified woods from the above localities has shown the presence of some new forms resembling species of *Anisoptera, Dipterocarpus, Aglaia, Acrocarpus, Ormosia, Koompassia* and *Adenanthera*.

SYSTEMATIC DESCRIPTION

Family—Dipterocarpaceae

Genus—*Anisopteroxylon* Ghosh & Kazmi 1958

Anisopteroxylon oblongoides sp. nov.
Pl. 1, figs 1, 3, 5

The fossil wood described here is a small piece of secondary xylem. *Wood* diffuse-porous. *Growth rings* absent. *Vessels* medium to large, mostly solitary, rarely in pairs, thick-walled, usually round to oval, 4-5 per sq mm, t.d 120-230 μm, r.d. 180-330 μm; vessel-members 180-375 μm long with truncate ends; perforations simple; inter-vessel pits not seen, tyloses present. *Vasicentric trachieds* sparse, oval to peripherally flattened, intermingled with paratracheal parenchyma; 30-40 μm in diameter, vessel-tracheid pits numerous, bordered. *Parenchyma* both paratracheal as well as apotracheal; paratracheal parenchyma vasicentric, apotracheal parenchyma diffuse to diffuse-in-aggregate, often forming irregular lines, several rows of parenchyma cells usually surround the gum canals; cells thin-walled, 32-40 μm in diameter and 64-132 μm in length. *Xylem rays* usually broad, spindle-shaped, 1-9 (11) seriate, mostly 7-9 seriate and 20-180 μm wide, about 5-56 cells and 150-1080 μm high, 4-8 per mm; ray tissue heterogeneous with rays composed of both upright and procumbent cells; upright cells forming 1-2 or more marginal rows at one or both the ends and also present as sheath cells along the flanks of multiseriate rays, quite often forming a continuous sheath; procumbent cells 12-20 μm in vertical height and 60-80 μm in radial length; upright cells 40-52 μm in vertical height and 20-28 μm in radial length. *Fibres* polygonal in cross-section, 20-28 μm in diameter, thick-walled. *Gum canals* vertical, scanty, large, round to oval, encircled by parenchyma cells, usually in continuous tangential rows, occasionally solitary, 120-150 μm in diameter.

Affinities—The characters of the fossil wood indicate its affinity with the woods of *Anisoptera* Korth. A detailed comparative study of fossil with thin sections of modern woods of *Anisoptera* shows that the fossil wood resembles closely the wood of extant *Anisoptera oblonga* Dyer in all important characters, such as the size and distribution pattern of vessels and parenchyma, ray structure and in the type and distribution of vertical gum canals (F.R.I. slide no. 6887).

So far only six species of *Anisopteroxylon* are known from the Tertiary of India and Southeast Asia (Ghosh & Kazmi, 1958; Ghosh & Ghosh, 1958; Navale, 1963; Prakash & Tripathi, 1970; Prakash, 1978; Ghosh & Roy, 1980). All these species markedly differ from the present fossil wood especially in the absence of concentric rows of gum canals. Besides, the xylem rays are very broad and fusiform in the present fossil as compared to all the known species in which the xylem rays are narrower.

The genus *Anisoptera* consisting of about 30 species is widely distributed from Chittagong in Bangla Desh to New Guinea in the Pacific. The largest number of species, however, occur in the Malay Peninsula, Sumatra and Borneo. The nearest comparable species of the present fossil wood, *A. oblonga*, occurs in semi-evergreen and deciduous forests from Arakan to Mergui Victoria Point in Burma at low altitudes and also in Malay Peninsula (Chowdhury & Ghosh, 1958).

Specific Diagnosis

Anisopteroxylon oblongoides sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* large to medium, t.d. 120-230 μm, r.d. 180-330 μm, mostly solitary, 4-5 per sq mm, usually tylosed; vessel-tracheid pits bordered, numerous. *Vasicentric tracheids* sparse, 30-40 μm in diameter. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric; apotracheal parenchyma diffuse to diffuse-in-aggregate forming uniseriate tangential lines; several rows of cells also surround the gum canals. *Xylem rays* 1-9 (11) seriate, mostly 7-9 seriate, 5-56 cells in height, 4-8 per mm; ray tissue heterogeneous, rays heterocellular; multiseriate rays with continuous row of sheath cells on the flanks. *Fibres* libriform, 20-28 μm in diameter, nonseptate. *Gum canals* vertical, scanty, usually in long tangential rows, occasionally solitary, 120-150 μm in diameter.

Holotype—Museum specimen no. BSIP 35754.

Locality—Kalagarh, Tehri Garhwal District, Uttar Pradesh.

Genus—*Dipterocarpoxylon* Holden emend. Den Berger 1927

Dipterocarpoxylon kalagarhensis sp. nov.
Pl. 1, figs 6, 8, 10

The description of the fossil wood is based on a small piece of secondary xylem. *Wood* diffuse-porous. *Growth rings* absent. *Vessels* visible to the naked eye, medium to large, mostly solitary, rarely in pairs, round to oval or elliptical, 4-6 per sq mm, heavily tylosed, thin-walled, t.d. 116-224 μm, r.d. 184-320 μm; vessel-members 240-480 μm long with truncate ends; perforations simple, vessel tracheid pits bordered. *Vasicentric tracheids* sparse, associated with the vessels, tracheidal cells oval to peripherally flattened, 25-40 μm in diameter, bordered pits present in rows. *Parenchyma* mostly apotracheal, the paratracheal being scanty, present around some of the vessels, apotracheal parenchyma diffuse to diffuse-in-aggregate forming uniseriate lines and surrounding the gum canals and forming 2-4 seriate sheath, t.d. 18-24 μm, length 68-240 μm. *Xylem rays* fine to broad, 1-6 seriate, usually 4-5 seriate, 20-112 μm wide and 5-40 cells or about 120-1540 μm high, closely spaced, 5-8 per mm, ray tissue heterogeneous, rays heterocellular, uniseriate rays composed of upright and procumbent cells while the broad rays with upright or square cells at one or both the ends and procumbent cells in the middle, sometimes with sheath cells on the flanks, procumbent cells with vertical height 12-20 μm, radial length 28-68 μm; upright cells with vertical height 36-60 μm, radial length 24-35 μm. *Fibres* polygonal in cross section, 12-20 μm in diameter, moderately thick-walled, inter-fibre pits bordered. *Gum canals* vertical, moderately small to medium, abundant, single or usually in pairs, sometimes in tangential rows of 3-4 and occasionally in continuous trangential rows, 88-180 μm in diameter, round to oval, encircled by parenchyma.

Affinities—In having solitary vessels, vasicentric tracheids, heterogeneous xylem rays with some sheath cells on the flanks and axial gum canals which are mostly in tangential pairs some times in tangential rows of 3-4 or even more and occasionally in continuous rows the fossil wood is very similar to that of *Dipterocarpus*. A detailed comparison of the fossil with available thin sections of wood of several species of *Dipterocarpus* as well as descriptions and photographs of about 26 species of *Dipterocarpus* (Moll & Janssonius, 1906; Kanehira, 1924 a, b; Pearson & Brown, 1932; Desch, 1957; Chowdhury & Ghosh, 1958; Kribs, 1959; Miles, 1978) shows its close resemblance with that of *Dipterocarpus obtusifolius* (F.R.I. Slide no. A 5964) except that the parenchyma is not so profuse in the latter.

A large number of fossil woods resembling to *Dipterocarpus* are known from India and abroad, most of which were earlier listed by Prakash (1973) and Awasthi (1974) and subsequently few more species of *Dipterocarpoxylon* were described (Awasthi, 1974, 1980; Prakash, 1975, 1978, 1979b, 1980; Ghosh & Roy, 1979; Trivedi & Ahuja, 1980). *Dipterocarpoxylon kalaicharparense* Eyde shows some similarity with the present fossil wood but differs in having abundant apotracheal parenchyma forming patches in the ground tissue and comparatively narrower xylem rays as compared to the present fossil. As the present fossil wood is different from all the known species of *Dipterocarpoxylon*, it is described as a new species, *Dipterocarpoxylon kalagarhensis*.

The genus *Dipterocarpus* includes about 80 species which grow mainly in the Indo-Malayan region having maximum development in Borneo, Malay Peninsula and Sumatra. *Dipterocarpus obtusifolius* with which the fossil is comparable, grows in Burma up to 900 m above sea level and also in Cochin-China, Thailand and Malay Peninsula (Chowdhury & Ghosh, 1958).

Specific Diagnosis

Dipterocarpoxylon kalagarhensis sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* medium-sized to large, t.d. 116-224 μm, r.d. 184-320 μm, 4-6 per sq mm and tylosed; vessel members 240-480 μm. *Vasicentric tracheids* sparse, 25-40 μm in diameter. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma scanty, often partly encircling the vessels; apotracheal parenchyma associated with gum canals and diffuse to diffuse-in-aggregate forming uniseriate lines. *Xylem rays* 1-6 (mostly 4-5) seriate, 5-8 per mm; rays heterocellular; sheath cells quite common. *Fibres* thick-walled, non-septate, 12-20 μm in diameter. *Gum canals* vertical, abundant, solitary or usually in pairs, sometimes in tangential rows of 3-4 and occasionally in continuous tangential rows, 88-180 μm in diameter, round to oval in shape.

Holotype—Museum specimen no. BSIP 35755.

Locality—Kalagarh, Tehri Garhwal District, Uttar Pradesh.

PLATE 1 →

1. *Anisopteroxylon oblongoides* sp. nov.—Cross section showing type and distribution of the vessels and parenchyma. × 35; Slide no. BSIP 35754-1.
2. *Anisoptera oblonga*—Cross section showing similar type and distribution of vessels and parenchyma. × 35.
3. *Anisopteroxylon oblongoides* sp. nov.—Tangential longitudinal section showing type and distribution of the xylem rays. × 50; Slide no. BSIP 35754-2.
4. *Anisoptera oblonga*—Tangential longitudinal section showing similar type and distribution of xylem rays. × 50.
5. *Anisopteroxylon oblongoides* sp. nov.—Cross section under low power showing the distribution of vessels and gum canals. × 15; Slide no. BSIP 35754-1
6. *Dipterocarpoxylon kalagarhensis* sp. nov.—Cross section showing distribution of vessels, parenchyma and gum canals. × 30; Slide no. BSIP 35755-1.
7. *Dipterocarpus obtusifolius*—Cross section showing similar type and distribution of vessels, parenchyma and gum canals. × 30.
8. *Dipterocarpoxylon kalagarhensis* sp. nov.—Tangential longitudinal section showing type and distribution of the xylem rays. × 50; Slide no. BSIP 35755-2.
9. *Dipterocarpus obtusifolius*—Tangential longitudinal section showing similar type of xylem rays. × 50.
10. *Dipterocarpoxylon kalagarhensis* sp. nov.—Cross section under low power showing the distribution of vessels and gum canals. × 15; Slide no. BSIP 35755-1

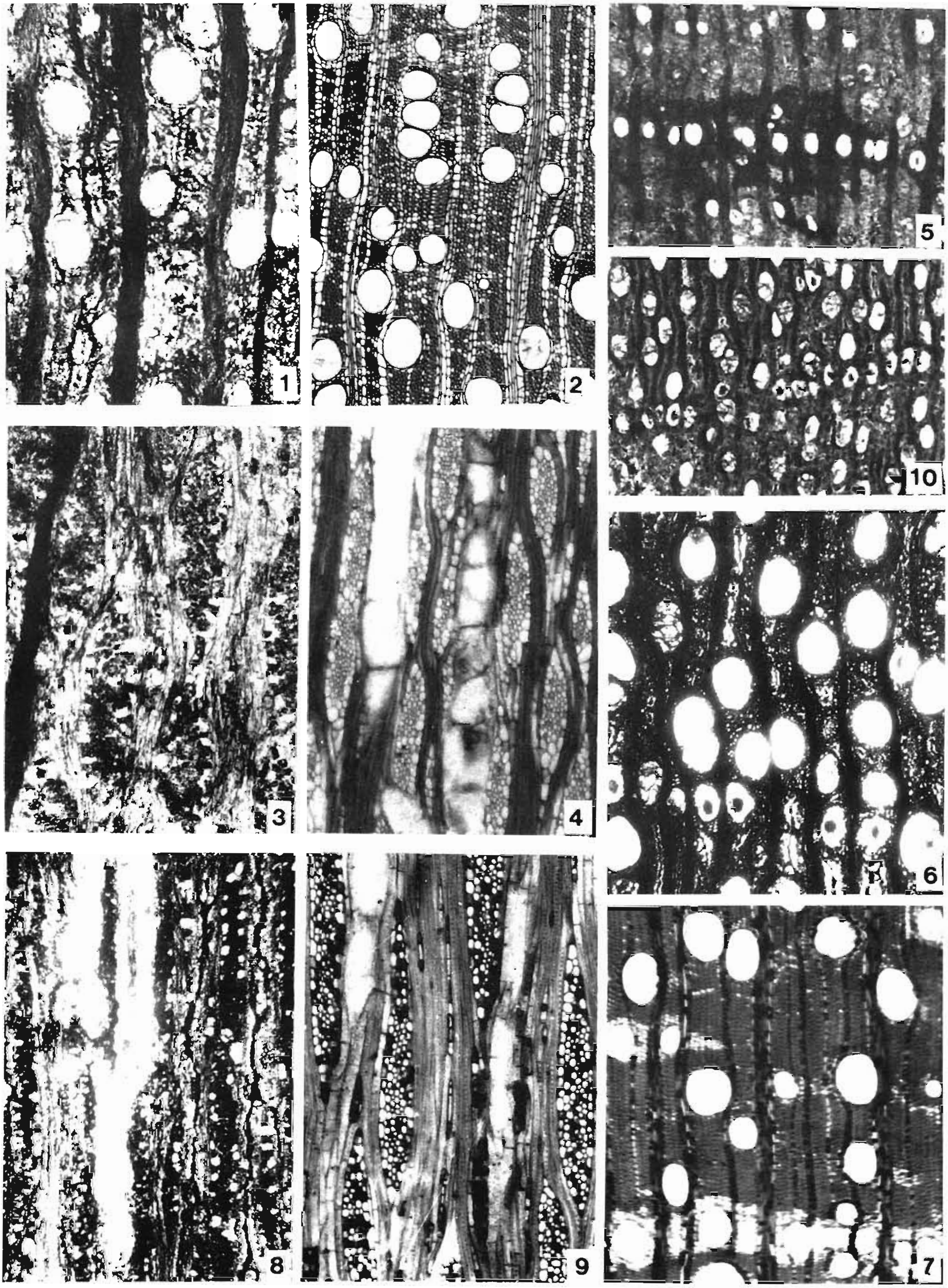

PLATE 1

Family—Meliaceae

Genus—*Aglaia* Laour.

Aglaia nahanensis (Prakash) comb. nov.
Pl. 2, figs 1, 3, 4

1975 *Dryoxylon nahanai* Prakash, pp. 206, 208, pl. 5, figs 23, 24.

Prakash (1975) described the wood as *Dryoxylon nahanai* since its affinity with any extant taxon could not be ascertained. The present description is based on the critical re-examination of type slides as well as thin sections prepared from the type specimen.

Revised description—Wood diffuse porous. *Growth rings* indistinct. *Vessels* small to medium, solitary and in radial multiples of 2-3, mostly 2, oval to irregular in shape owing to pressure during fossilization, 6-9 per sq mm, sometimes plugged with gummy deposits, thin-walled, t.d. 50-150 μm, r.d. 75-190 μm, vessel members 400-500 μm long with truncate ends, perforations simple, intervessel pits minute, 3-4 μm in diameter with linear to lenticular apertures. *Parenchyma* paratracheal, vasicentric to aliform confluent, usually forming short, irregular, undulating bands, cells thin-walled with t.d. 8-10 μm and 40-80 μm in length. *Xylem rays* 1-4 (mostly 3) seriate, 15-70 μm wide and 5-34 cells or 120-600 μm high, 8-15 per mm, ray tissue heterogeneous with rays composed either of procumbent cells only or sometimes with single marginal row of square or upright cells, ray cells thin-walled, procumbent cells 15-18 μm in tangential height and 25-70 μm in radial length, upright cells 20-24 μm in radial length and 28-30 μm in tangential height. *Fibres* irregularly arranged in between the consecutive xylem rays, thick-walled, polygonal in cross section, septate, 5-12 μm in diameter and 600-1100 μm in length; interfibre pits not seen.

Affinities—Small to medium sized, solitary vessels and in radial multiples of 2-3 (mostly 2), with gum plugs and minute inter-vessel pits; 1-4 seriate and weakly heterocellular xylem rays; vasicentric to aliform-confluent parenchyma, usually forming short, undulating bands and septate fibres indicate a close affinity with the *Aglaia edulis* A. Gray of Meliaceae (Slide no. BSIP 7535).

The fossil woods of Meliaceae, so far known, are many though no definite record of *Aglaia* as known. *Aglaioxylon mandlaense* from the Deccan Intertrappean beds of Mandla District (Trivedi & Srivastava, 1982) does not appear to show any affinity with the genus *Aglaia* as the xylem rays described as homocellular, are always heterocellular in *Aglaia*. However, to ascertain the indentification of *A. mandlaense* Trivedi & Srivastava, the original specimens need to be restudied. In view of the doubtful affinity of *Aglaioxylon mandlaense*, the present fossil wood is described as *Aglaia nahanensis* (Prakash) comb. nov.

Aglaia is a large genus consisting of small to moderate sized tree distributed in the Indo-Malayan region and southern China. About 20 species are reported to occur in India and Burma. *Aglaia edulis* with which the present fossil resembles grows in Sibsagar, Mikir Hills, North Cachar Hills and Khasi Hills in Assam up to 600 m elevation (Anonymous, 1963, p. 89).

Holotype—Museum specimen no. BSIP 7/1014.

Locality—Nalagarh, Solan District, Himachal Pradesh.

PLATE 2 →

1. *Aglaia nahanensis* (Prakash) comb. nov.—Cross section showing the vessel and parenchyma distribution × 40; Slide no. BSIP 4739.
2. *Aglaia edulis*—Cross section showing similar type of vessels and parenchyma. × 40.
3. *Aglaia nahanensis* (Prakash) comb. nov.—Tangential longitudinal section showing type and distribution of xylem rays and septate fibres. × 100; Slide no. BSIP 4740.
4. *Aglaia nahanensis* (Prakash) comb. nov.—Magnified intervessel pit-pairs. × 500; Slide no. BSIP 4740.
5. *Aglaia edulis*—Tangential longitudinal section showing similar type of xylem rays and fibres. × 100.
6. *Acrocarpus siwalicus* sp. nov.—Cross section showing type and distribution of the vessels and parenchyma. × 30.
7. *Acrocarpus fraxinifolius*—Cross section showing similar type of vessels and parenchyma. × 30.
8. *Acrocarpus siwalicus* sp. nov.—Tangential longitudinal section showing type and distribution of xylem rays. × 50; Slide no. BSIP 35756-2.
9. *Acrocarpus fraxinifolius*—Tangential longitudinal section showing similar type and distribution of xylem rays. × 50.
10. *Acrocarpus siwalicus* sp. nov.—Radial longitudinal section showing heterocellular xylem rays. × 120; Slide no. BSIP 35756-3.
11. *Acrocarpus siwalicus* sp. nov.—Magnified intervessel pit-pairs. × 400; Slide no. BSIP 35756-2.

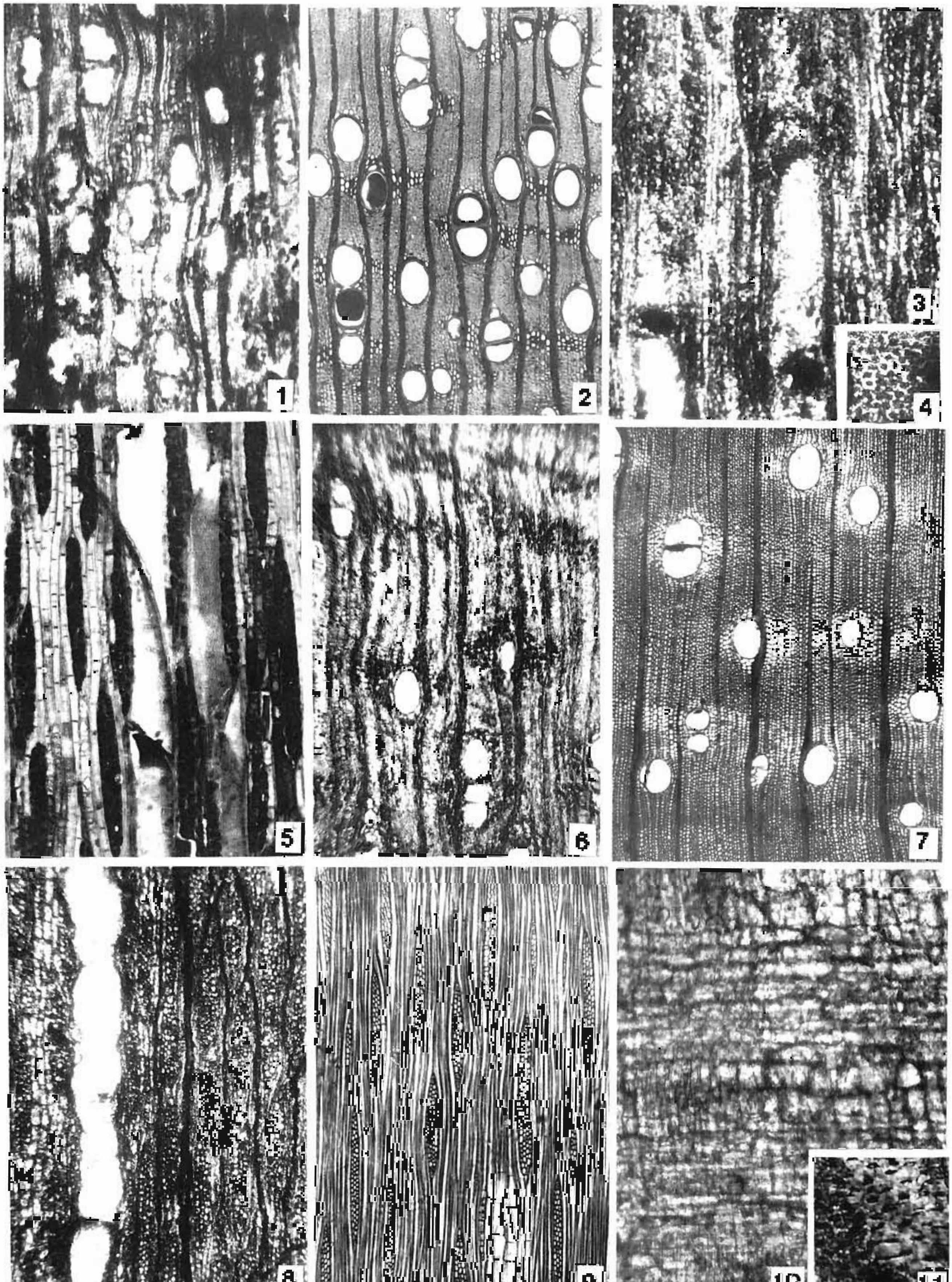

PLATE 2

Family—Fabaceae

Genus—*Acrocarpus* Wight ex Arn.

Acrocarpus siwalicus sp. nov.
Pl. 2, figs 5, 8, 10, 11

The present species is based on a piece of secondary wood measuring about 12 cm in length and 8 cm in diameter.

Wood diffuse-porous. *Growth rings* present, delimited by thin lines of parenchyma. *Vessels* medium to large, solitary and in radial multiples of 2-5, circular to oval when solitary and with flat contact walls when in groups, evenly distributed, 12-14 per sq mm; tyloses absent; thin walled, t.d. 100-250 µm, r.d. 110-250 µm; perforations simple; vessel members 100-600 µm long with truncate ends; intervessel pits alternate, vestured, small, 5-7 µm in diameter with linear to lenticular apertures. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma aliform to aliform-confluent; apotracheal parenchyma terminal and forming short 8-10 seriate tangential bands in the ground tissue; parenchyma cells 30-40 µm in diameter, 80-100 µm in length; crystals present in parenchyma strands. *Xylem rays* 1-5 seriate or 12-100 µm wide and 5-35 cells or 90-560 µm high, 4-6 per mm; ray tissue heterogeneous with rays either composed of procumbent cells only or with 1-2 marginal rows of upright cells; ray cells thick walled; procumbent cells 20-30 µm in tangential height and 25-75 µm in radial length; upright cells 30-35 µm in tangential height and 30-40 µm in radial length; crystals usually present in upright cells. *Fibres* aligned in radial rows in between the xylem rays, thick-walled, polygonal in cross section, septate, 12-18 µm in diameter and 480-1200 µm in length; interfibre pits not seen.

Affinities—The important anatomical diagnostic features of the present fossil wood such as typically aliform to aliform-confluent parenchyma along with apotracheal bands separating the growth zones, vestured intervessel pits, crystalliferous parenchyma strands, weakly heterogeneous xylem rays and septate fibres indicate that it belongs to the family Fabaceae. Predominance of aliform parenchyma and heterogeneous xylem rays are characteristic of *Acrocarpus fraxinifolius* Wight and *Saraca indica* L. But *Saraca indica* L. differs in having very fine (1-2 seriate) xylem rays as against 1-5 seriate in the fossil. The fossil shows its close resemblance with the wood of *Acrocarpus fraxinifolius* in having aliform to aliform-confluent and terminal parenchyma separating the growth zones, 1-5 seriate weakly heterocellular xylem rays with crystals in the marginal upright cells, crystalliferous parenchyma strands, vestured pits, and thick-walled, septate fibres.

In view of its close resemblance with the woods of *Acrocarpus*, the fossil wood is assigned to *Acrocarpus* and is named as *A. siwalicus* sp. nov.

The genus *Acrocarpus* consists of three species confined to Southeast Asia and India. In India it is represented by *Acrocarpus fraxinifolius* only in the evergreen forests of Western Ghats from south Kanara southwards up to an elevation of 1 200 m and in the eastern Himalaya in Sikkim and hills of Assam, Chittagong, and Burma (Ramesh Rao & Purkayastha, 1972, p. 61).

Specific Diagnosis

Acrocarpus siwalicus sp. nov.

Wood diffuse-porous. *Growth rings* present, demarcated by bands of terminal parenchyma. *Vessels* medium to large, t.d. 100-250 µm, r.d. 110-260 µm, solitary and in radial multiples of 2-5, 12-14 per sq mm; vessel members 100-560 µm long with truncate ends; perforations simple; intervessel pits bordered, vestured, alternate, 5-7 µm in diameter

PLATE 3

1. *Dracontomelon bengalensis* Awasthi & Prakash—Cross section showing type and distribution of vessels and parenchyma × 50. Slide no. BSIP 35757-I.
2. *Dracontomelon dao*—Cross section showing similar type of vessels and parenchyma × 50.
3. *Dracontomelon bengalensis* Awasthi & Prakash—Tangential longitudinal section showing type and distribution of xylem rays × 50. Slide no. BSIP 35757-II.
4. *Dracontomelon dao*—Tangential longitudinal section showing similar type of xylem rays × 50.
5. *Kingiodendroxylon siwalicus* Prakash—Cross section showing type and distribution of vessels and parenchyma × 40. Slide no. BSIP 35758-I.
6. *Kingiodendron pinnatum*—Cross section showing similar type and distribution of vessels and parenchyma × 30.
7. *Kingiodendroxylon siwalicus* Prakash—Tangential longitudinal section showing storied xylem rays × 50. Slide no. BSIP 35758-II.
8. *Kingiodendron pinnatum*—Tangential longitudinal section showing similar type and arrangement of xylem rays × 50.
9. *Adenantheroxylon pavoninium* Prakash & Tripathi—Cross section showing type and distribution of vessels and parenchyma × 40. Slide no. BSIP 35759.
10. *Adenantheroxylon pavoninium* Prakash & Tripathi—Tangential longitudinal section showing type and distribution of xylem rays × 100. Slide no. BSIP 35759-II.

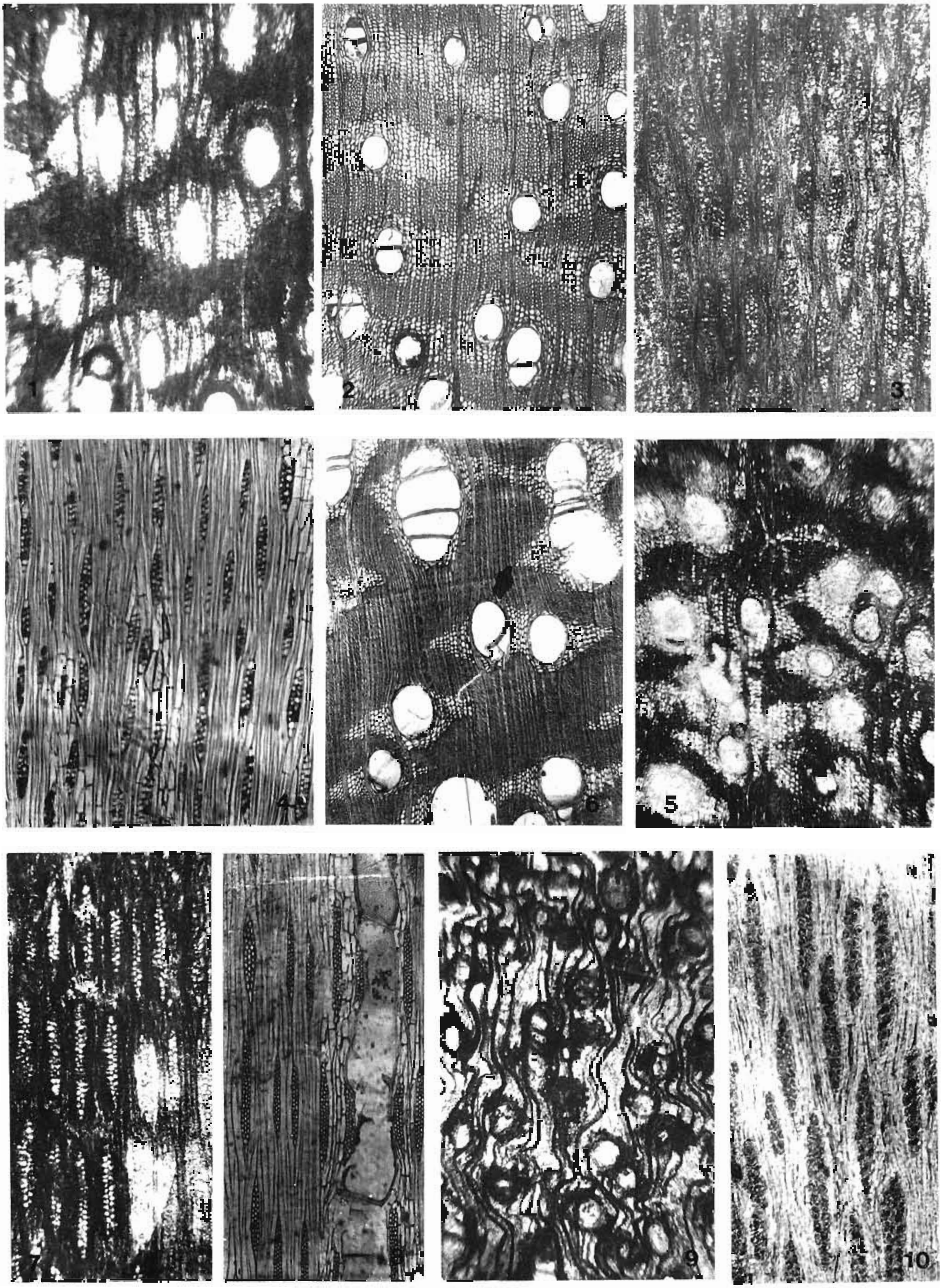

PLATE 3

with linear to lenticular apertures. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma aliform to aliform confluent; apotracheal parenchyma demarcating the growth rings as well as forming short, 4-10 seriate bands in the ground tissue. *Xylem rays* 1-5 seriate or 12-100 μm wide and 5-35 cells or 90-560 μm high, ray tissue weakly heterogeneous, composed either of procumbent cells only or with one to two rows of marginal upright cells. *Fibres* thick-walled, septate, 12-18 μm in diameter and 480-1200 μm in length, inter-fibre pits not seen.

Holotype—Museum specimen no. BSIP 35756.

Locality—Nalagarh, Solan District, Himachal Pradesh.

Genus—*Ormosioxylon* Bande & Prakash 1980

Ormosioxylon bengalensis Bande & Prakash 1980
Pl. 3, figs 1, 3

The description of the present fossil wood is based on a well-preserved small piece of secondary xylem.

Wood diffuse porous. *Growth-rings* indistinct. *Vessels* small to moderately large, mostly solitary, sometimes in radial multiples of 2-5, evenly distributed, round to oval when solitary, with flat contact walls when in groups, 8-12 per sq mm, tyloses absent, thin-walled, t.d. 105-210 μm, r.d. 150-270 μm; vessel members 96-420 μm long with truncate ends; perforations simple, inter-vessel pit pairs vestured, alternate, 6-10 μm in size, with linear to lenticular apertures. *Parenchyma* paratracheal, aliform with blunt ends to aliform-confluent; cells thin-walled, 13-24 μm in diameter and 30-70 μm in length, parenchyma strands 2-4 celled, sometimes crystalliferous. *Xylem rays* 1-4 (mostly 3) seriate, 6-40 μm wide and 4-45 cells or 30-500 μm high, closely spaced, 5-8 per mm, ray tissue weakly heterogeneous, rays composed either of procumbent cells only or with 1-2 rows of upright cells at one or both the ends, ray cells thin-walled, procumbent cells 16-24 μm in tangential height and 70-95 μm in radial length, upright cells 60-72 μm in tangential height and 25-37 μm in radial length; rays with storied tendency. *Fibres* non-septate, 8-12 μm in diameter and 450-800 μm in length, interfibre pits not preserved.

Affinities—The present wood specimen is quite similar to *Ormosioxylon bengalensis* Bande & Prakash 1980 and therefore is assigned to the same species.

Specimen—Museum specimen no. BSIP 35757.

Locality—Nalagarh, Solan District, Himachal Pradesh.

Genus—*Koompassioxylon* Kramer 1974

Koompassioxylon elegans Kramer 1974
Pl. 3, figs 5, 7

The description of the present fossil wood is based on a single piece of petrified secondary xylem. *Wood* diffuse-porous. *Growth-rings* distinct, delimited by thin lines of terminal parenchyma and smaller vessels. Vessels medium-sized to moderately large, mostly solitary, sometimes in radial multiples of 2-4 or more, rarely in tangential pairs, 2-4 per sq mm, mostly open, thin-walled, solitary vessels round to oval in shape, t.d. 112-320 μm, r.d. 120-326 μm, vessel members 160-592 μm long with truncate ends, storied, perforations simple, intervessel pits alternate, 5-8 μm in diameter, vestured with linear to lenticular apertures. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma aliform, usually with pointed wings on both the sides, sometimes confluent, apotracheal parenchyma terminal, forming 2-3 seriate lines delimiting the growth rings, parenchyma cells thin-walled, 24-42 μm in diameter and 40-50 μm in height, showing storied tendency, parenchyma strands 7-8 celled and crystalliferous. *Xylem rays* fine to very fine and low, 1-3 (mostly 2) seriate, 7-13 per mm and storied, 12-60 μm wide and 8-25 cells or 80-450 μm high; ray tissue heterogeneous, rays weakly heterocellular consisting of 1-2 rows of marginal upright cells at one or both the ends, ray cells thin-walled, procumbent cells 18-25 μm in tangential height and 42-72 μm in radial length; upright cells 40-55 μm in tangential height and 30-40 μm in radial length. *Fibres* polygonal in cross section, libriform, nonseptate, 14-17 μm in diameter and 650-800 μm in length, interfibre pits not seen. *Ripple marks* present due to storied arrangement of vessel members and xylem rays.

Affinities—The fossil wood shows close resemblance with the wood of *Koompassia* especially to *K. malaccensis* Maing. ex Benth. of Fabaceae in having aliform sometimes confluent parenchyma with crystalliferous and storied parenchyma strands, vestured intervessel pits, 1-3 seriate, weekly heterogeneous and storied xylem rays, similar vessel distribution with storied vessel elements and in the nature of fibres. Fossil wood resembling *Koompassia malaccensis* Maing. ex Benth. is described as *Koompassioxylon elegans* (Kramer, 1974; Bande & Prakash, 1980). The present fossil wood too is identical to this species except some minor differences.

Specimen—Museum specimen no. BSIP 35758.

Locality—Nalagarh, Solan District, Himachal Pradesh.

Genus—*Adenantheroxylon* Prakash & Tripathi 1968

Adenantheroxylon pavoninium
Prakash & Tripathi 1968
Pl. 3, figs 9, 10

The material consists of a single piece of decorticated secondary xylem measuring 8 cm in length and 5 cm in diameter.

Wood diffuse porous. *Growth-rings* present, demarcated by smaller vessels. *Vessels* small to medium sized, solitary and in radial multiples of 2-5, numerous, 9-13 per sq mm, open, sometimes filled with dark contents, thin-walled, t.d. 80-176 μm, r.d 85-190 μm; vessel members 64-320 μm in length with truncate or slightly tapered ends, perforations simple, intervessel pits very small, alternate, vestured, measuring 3-4 μm in diameter with linear to lenticular apertures. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric to aliform, sometimes joining adjacent vessels, apotracheal parenchyma present as diffuse cells, parenchyma cells filled with dark contents, cells thin-walled, 12-15 μm in diameter and 20-30 μm in length; crystalliferous strands present. *Xylem rays* narrow, 1-2 (3) mostly 2 seriate, 12-25 per mm, ray tissue homogeneous, rays homocellular; composed entirely of procumbent cells, measuring 8-15 μm in tangential height and 20-30 μm in radial length. *Fibres* libriform, non-septate, 12-16 μm in diameter, 520-900 μm in length; inter-fibre pits not seen.

Affinities—The fossil wood resembles the modern wood of the genus *Adenanthera* in general and *A. pavonina* in particular (F.R.I. Slide no. 3657). Prakash and Tripathi (1968, 1969) described a fossil wood of *Adenanthera pavonina* L. from the Tertiary of Assam as *Adenantheroxylon pavoninium.* The present fossil wood is quite similar to it except the frequency of vessels.

Specimen—Museum specimen no. BSIP 35759.

Locality—Nalagarh, Solan District, Himachal Pradesh.

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The Palaeobotanist **37**(1) : 63-76, 1988.

Algal and fungal remains from Jowai-Sonapur Road Section (Palaeocene-Eocene), Meghalaya

S. K. M. Tripathi

Tripathi, S. K. M. (1989). Algal and fungal remains from Jowai-Sonapur Road Section (Palaeocene-Eocene), Meghalaya. *Palaeobotanist* **37**(1) : 63-76.

This paper deals with the systematic description of dinoflagellate cysts and fungal remains recovered from the Jowai-Sonapur Road Section (Palaeocene-Eocene), Meghalaya. The dinoflagellate cysts are represented by 12 genera and 21 species. The fungal remains comprise fruiting bodies and spores assignable to 10 genera and 12 species

Key-words—Palynology, Dinoflagellate cysts, Fungal remains, Palaeocene-Eocene (India).

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साराँश

मेघालय में जोवई-सोनपुर मार्ग खंड (पुरानूतन-आदिनूतन) से शैवालीय एवं कवकीय अवशेष

सूर्यकान्तमणि त्रिपाठी

इस शोध-पत्र में जोवई-सोनपुर मार्ग खड (पुरानूतन-आदिनूतन) से उपलब्ध घूर्णीकशाभ पुटीयों एवं कवकीय अवशेषो का वर्गीकृत वर्णन किया गया है। घूर्णीकशाभ पुटीयाँ 12 प्रजातियो तथा 21 जातियों से निरूपित हैं जबकि कवकीय अवशेषों में फलन कायो एव बीजाणुओं की 10 प्रजातियाँ एव 12 जातियाँ हैं।

THE Jowai-Sonapur Road Section is located in the south-east of Shillong and encompasses strata ranging in age from Palaeocene to Eocene. The sediments belong to the shelf facies and are represented by Therria, Sylhet Limestone and Kopili Formation. Exposures of these formations are observed along the National Highway 44 connecting Shillong and Badarpur. The area of investigation is situated between latitudes 25°0′ and 25°30′ and Longitudes 92°0′ and 92°30′.

The basement for the deposition of the Tertiary sediments of Jowai-Sonapur Road Section is provided by the Precambrian Shillong Group. At Jowai the Shillong Group is unconformably overlain by the Therria Formation. Further southward the Therria Formation is overlain by the Sylhet Limestone which in turn is succeeded by the Kopili Formation. A detailed geological information with a geological map of the area has been published by Saxena and Tripathi (1982). Lithological characters of these formations have been discussed ahead in the paper in brief.

The Therria Formation is constituted by monotonous, white-brown and pale-red, medium to very coarse grained, often gritty, cross-bedded, ferruginous sandstone alternated by subordinate shale and fine grained carbonaceous sandstone. The shale is mostly bentonitic, sulphurous, occasionally pyritous and generally carbonaceous without megafossils. The carbonaceous sandstones are generally associated with thin coal seams. The Sylhet Limestone is made up mainly of limestone with thin alternations of sandstone. Lithologically this formation is divisible into 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 alternated with shales which represent ellipsoidal structures showing laminae-like successive layers of onion.

Sein and Sah (1974) studied the palynology of Jowai-Sonapur area and on its basis demarcated the Eocene and Oligocene sediments exposed along the road between Lumshnong and Sonapur. In this paper the morphology of the referred taxa has not been discussed and most of the forms are designated up to generic level only. Later, Dutta and Jain (1980) described acritarch and dinoflagellate assemblages from the Sylhet Limestone and Kopili Formation in the Lumshnong area near this road section and pointed out their biostratigraphic potential.

The palynostratigraphical informations presented in the above mentioned two papers are meagre and these studies are based on limited number of samples. Thus, there exists a scope for detailed morphological and palynostratigraphical work in this area.

MATERIAL AND METHOD

Stratigraphically located rock samples were collected from well-measured sections of the Therria, Sylhet Limestone and Kopili formations. Measurement of the sections was done following the standard Brunton tape method. In order to obtain fresh samples, the weathered rocks were removed. Precautions were also taken to avoid surface contamination.

The rock samples were first treated with dilute hydrochloric acid (10%) in order to remove the carbonates. The carbonate free rock samples were treated with hydrofluoric acid (40%) to remove silicates. The carbonaceous shales or coaly samples were treated with warm solution of sodium carbonate (10%) for 2-4 minutes and washed repeatedly with distilled water to remove alkali. The residue was finally washed through 400 mesh sieve. Some samples showed better results when the macerated residue was acetolysed. For acetolysis Erdtman's (1952) method was followed. The slides were prepared in polyvenyl alcohol and mounted in the DPX mountant. The slides prepared have been preserved in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

SYSTEMATIC DESCRIPTION

Dinoflagellate cysts

Family—Gonyaulacystaceae (Sarjeant & Downie) Sarjeant & Downie 1974

Genus—*Gonyaulacysta* Deflandre emend. Stover & Evitt 1978

Type species—*Gonyaulacysta jurassica* (Deflandre) Norris & Sarjeant 1965

Gonyaulacysta sp.
Pl. 3, fig. 5

Description—Cysts proximate, endocyst subspherical to ovoidal in shape, apical horn present, epipericoel and hypopericoel very ill-developed, parasutural septa with denticulate to spinulate crest. Periphragm between septa finely granulose, sometimes small spines also present, endophragm smooth. Paratabulation indicated by parasutural features, formula 0-1a, 6″, 6C, 5-6‴/, Ip, 1⁗, 0-lS. Archaeopyle precingular, type P (3″ only), operculum free. Paracingulum distinct, indicated by sub-rectangular paraplates (6c), cingulum helicoid, parasulcus distinct, extending up to the epitract.

Dimensions :
Cyst body—100—100 × 90 μm
Apical horn—Up to 20 μm long

Occurrence—Upper part of Kopili Formation (Upper Eocene), Meghalaya.

Family—Apteodiniaceae Eisenack emend. Sarjeant & Downie 1974

Genus—*Apteodinium* Eisenack 1958

Type species—*Apteodinium granulatum* Eisenack 1958

Apteodinium sp.
Pl. 2, fig. 5

Description—Cysts proximate, body subspheroidal in shape, apical horn present, parasutural features absent or represented by faint markings of low ridges. Autophragm granulose. Paratabulation not indicated. Archaeopyle precingular, type P (3″ only), operculum free. Paracingulum indistinct and represented by shallow transverse groove, sometimes also bordered by low ridges, parasulcus not indicated.

Dimensions :
Cyst body—95—108 × 90-92 μm
Apical horn—Up to 18 μm long

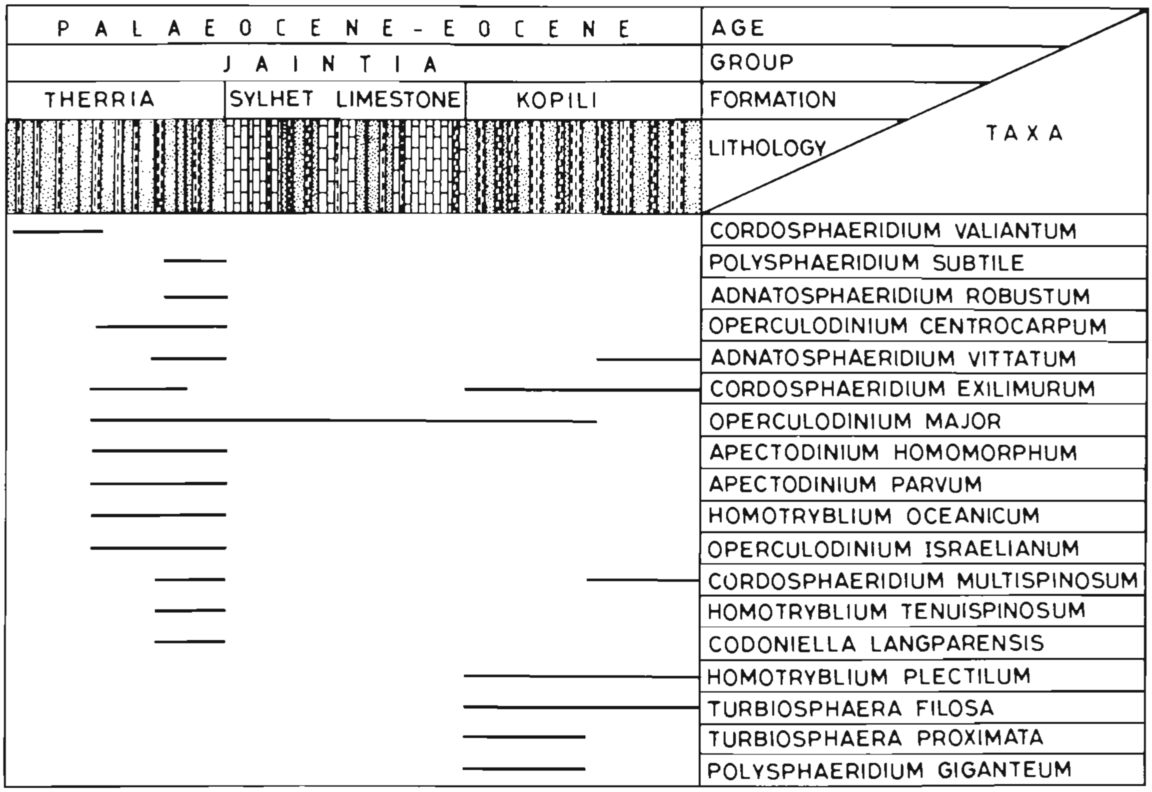
Occurrence—Middle-Upper part of Kopili Formation (Upper Eocene), Meghalaya.

Family—Spiniferitaceae Sarjeant emend. Sarjeant & Downie 1974

Genus—*Turbiospbaera* Archangelsky 1969

Type species—*Turbiosphaera filosa* (Wilson) Archangelsky, 1969

Turbiosphaera proximata sp. nov.
Pl. 1, figs 9, 12; Pl. 2, figs 6, 10; Pl. 3, fig. 6



Text-figure 1—Distribution of dinoflagellate species in Jaintia Group sediments (Palaeocene-Eocene) exposed along Jowai-Sonapur Road, Meghalaya.

Holotype—Pl. 1, fig. 9; Slide no. 9623.

Type horizon—Kopili Formation.

Type locality—At 131.25 km from Shillong on Shillong-Badarpur Road, Meghalaya.

Diagnosis—Cysts chorate; body ovoidal-ellipsoidal; processes intratabular, varying in shape and size, fibrous, two adjacent processes proximally connected by fibrous membrane, processes expanded distally; periphragm fibrous; endophragm smooth; archaeopyle precingular; paratabulation 1-4′, 6″, 5-6″, 1p, 1‴; paracingular processes not indicated.

Comparison—*T. filosa* (Wilson) Archangelsky (1969) exhibits small sulcul processes which are absent in the present form. *T. magnifica* Eaton (1976) and *T. gelatea* Eaton (1976) possess an apical and triangular horn or process which is expanded proximally. *T. proximata* sp. nov. is distinguished from other species in having proximally connected processes.

Dimensions :

Size range	*Holotype*
Cyst body-66-95 × 53-68 μm	66 × 60 μm
Processes-12-30 μm long	24-27 μm long
10-12 μm wide	20-22 μm wide

Occurrence—Lower part of Kopili Formation (Upper Eocene), Meghalaya.

Turbiosphaera filosa (Wilson) Archangelsky, 1969
Pl. 1, figs 2, 8; Pl. 2, fig. 11

Previous records—Eocene of Antarctica (Wilson, 1967); Eocene of Argentina (Archangelsky, 1969).

Occurrence—Lower part of Kopili Formation (Upper Eocene), Meghalaya.

Family—Deflandreaceae Eisenack emend. Sarjeant & Downie 1974

Genus—*Apectodinium* (Costa & Downie) Lentin & Williams 1977

Type species—*Apectodinium homomorphum* (Deflandre & Cookson) Lentin & Williams, 1977

Apectodinium homomorphum (Deflandre & Cookson) Lentin & Williams 1977

Pl. 1, figs 10, 14; Pl. 2, figs 15, 16

Previous records—Palaeocene of New Zealand (Wilson, 1967); Tasmania (Cookson & Eisenack, 1967); northern France (Chateauneuf & Grusas-Cavagnetto, 1968); northern Spain (Caro, 1973) and of India (Dutta & Jain, 1980); Lower Eocene of

Belgium (Pastiels, 1948—as *Hystrichosphaeridium geometricum*; De Coninck, 1965, 1967, 1968, 1972; Morgenroth, 1966 & Graus-Cavagnetto, 1968); the Hampshire and London basins in southern England (Williams & Downie, 1966; Downie, Hussain & Williams, 1971) and Victoria, Australia (Deflandre & Cookson, 1955); Middle Eocene of northern France (Graus-Cavagnetto, 1971); Upper Eocene and Lower and Middle Oligocene of northern France (Chateauneuf & Gruas-Cavagnetto, 1968).

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

Apectodinium parvum (Alberti) Lentin & Williams emend. Harland 1979
Pl. 1, figs 6, 13

Previous records—Upper Palaeocene and Lower Eocene of Germany (Alberti, 1961); Palaeocene of New Zealand (Wilson, 1967); Lower Eocene of Germany (Gocht, 1969); Sparnacian of Paris Basin (Gruas-Cavagnetto, 1968); Palaeocene and Lower Eocene of Germany and England; Landenian of Belgium (Costa & Downie, 1976) and Upper Palaeocene of North sea Basin (Harland, 1979) and India (Dutta & Jain, 1980).

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

Apectodinium sp. cf. *A. hyperacanthum* (Cookson & Eisenack) Lentin & Williams 1977
Pl. 1, fig. 15

Description—Cyst proximochorate, cornucavate, body ovoidal in shape (antapical part of the cyst compressed), apical horn not observed, antapical horn single but compressed, two lateral horns conspicuous and well-developed. Processes numerous, nontabular, short, tubular, slender, distally open, rarely bifurcated distally. Periphragm smooth, forming the horns, endophragm smooth, giving an ovoidal shape to the body. Archaeopyle quadra style, intercalary, operculum free. Paracingulum and parasulcus not observed.

Dimensions :
Cyst body—90 × 50 μm (including horns)
Processes—5-10 μm long

Remarks—Only a single specimen of this type was recovered. It is noted that the apical horn is not developed, the antapical horn which ends into a single long blunt tip in *A. hyperacanthum* is also not very distinct here due to the compression of the antapical part of the cyst. However, the two lateral horns are more conspicuously developed. Due to these reasons and nonavailability of more similar specimens, the present form has only been compared with *A. hyperacanthum*.

Occurrence—Upper part of Therria Formation (Palaeocene), Meghalaya.

Family—Homotrybliaceae Sarjeant & Downie emend. Sarjeant & Downie 1974

Genus—*Homotryblium* Davey & Williams in Davey *et al.* 1966

Type species—*Homotryblium tenuispinosum* Davey & Williams in Davey *et al.* 1966

Homotryblium tenuispinosum Davey & Williams in Davey *et al.* 1966
Pl. 2, fig. 17

Previous records—Lower Eocene of northern Spain (Caro, 1973); of London Basin in southern England (Davey & Williams in Davey *et al.*, 1966; Downie, Hussain & Williams, 1971) and Lower, Middle and Upper Eocene of the Isle of Wight, southern England (Eaton, 1976).

PLATE 1 →

(All photomicrographs are enlarged Ca. × 500)

1 *Cordosphaeridium exilimurum* Davey & Williams; Slide no. BSIP 8340; coordinate: 116.6 × 14.8
2, 8. *Turbiosphaera filosa* (Wilson) Archangelsky; Slide nos. BSIP 8353 & 8352; coordinates: 114.2 × 15.3 and 117.8 × 26.7 respectively.
3. *Homotryblium oceanicum* Eaton; Slide no. BSIP 8347; coordinate: 80.9 × 14.8
4, 5. *Homotryblium plectilum* Drugg & Loeblich; Slide nos. BSIP 8341 and 8342; coordinates: 81.7 × 9.5 and 89.8 × 20.8 respectively
6, 13. *Apectodinium parvum* Lentin & Williams; Slide nos. BSIP 8351 and 9622; coordinates: 95.8 × 22.9 and 104.2 × 17.1 respectively
7. *Dicellaesporites popovii* Elsik; Slide no. BSIP 7034; coordinate: 98.5 × 11.5
9. *Turbiosphaera proximata* sp. nov. (Holotype); Slide no. BSIP 9623; coordinate: 89.6 × 20.8
10, 14. *Apectodinium homomorphum* Lentin & Williams; Slide nos. BSIP 9624 and 8365; coordinates: 86.1 × 14.4 and 96.7 × 18.8 respectively.
11. *Cordosphaeridium valiantum* (Sah, Kar & Singh) Stover & Evitt; Slide no. BSIP 8360; coordinate : 72.3 × 6.1
12. *Turbiosphaera proximata* sp. nov.; Slide no. BSIP 9625; coordinate: 101.10 × 15.2
15. *Apectodinium* sp. cf. *A. hyperacanthum* Lentin & Williams; Slide no. BSIP 8343; coordinate: 114.7 × 12.00

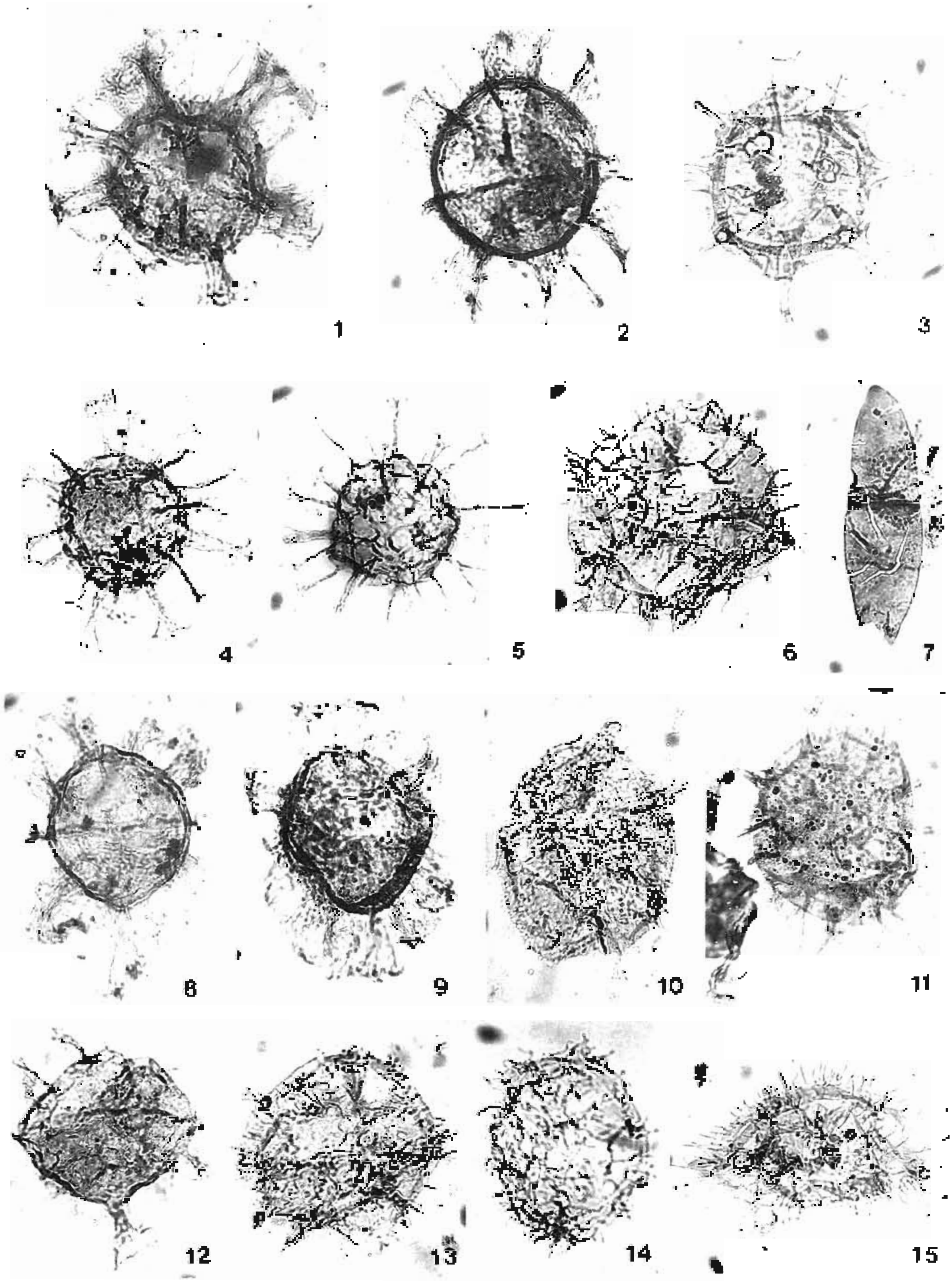


PLATE 1

Occurrence—Upper part of Therria Formation (Palaeocene), Meghalaya.

Homotryblium oceanicum Eaton 1976
Pl. 1, fig. 3

Previous record—Middle-Upper Eocene of Isle of Wight, southern England (Eaton, 1976).

Occurrence—Middle and Upper part of Therria Formation (Palaeocene), Meghalaya.

Homotryblium plectilum Drugg & Loeblich 1967
Pl. 1, figs 4, 5

Previous records—Middle-Upper Eocene of Isle of Wight, southern England (Eaton, 1976); Upper Eocene of north Germany (Agelopoulos, 1964, 1967) and India (Dutta & Jain, 1980); Oligocene of U.S.A. (Drugg & Loeblich, 1967).

Occurrence—Kopili Formation (Upper Eocene), Meghalaya.

Family—Cordosphaeridiaceae Sarjeant & Downie 1974

Genus—*Cordosphaeridium* Eisenack emend. Davey 1969

Type species—*Cordosphaeridium inodes* (Klumpp) Eisenack 1963

Cordosphaeridium exilimurum Davey & Williams 1966
Pl. 1, fig. 1

Previous records—Lower Eocene of Hampshire and London Basin, southern England (Davey & Williams in Davey *et al.*, 1966; Downie, Hussain & Williams, 1971); Lower-Middle and Upper Eocene of Isle of Wight, southern England (Eaton, 1976) and Middle Eocene of India (Dutta & Jain, 1980).

Occurrence—Therria Formation (Palaeocene) and Kopili Formation (Upper Eocene), Meghalaya.

Cordosphaeridium valiantum (Sah, Kar & Singh) Stover & Evitt 1978
Pl. 1, fig. 11

Previous record—Langpar Formation (Lower Palaeocene) of Therriaghat, South Shillong Plateau, Assam, India (Sah, Kar & Singh, 1970).

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

Family—Systematophoraceae Sarjeant & Downie 1974

Genus—*Prolixosphaeridium* Davey *et al.* emend. Davey 1969

Type species—*Prolixosphaeridium parvispinosum* (Cookson & Eisenack) Davey *et al.* in Davey *et al.* 1966

Prolixosphaeridium conulum Davey 1969
Pl. 3, fig. 14

Remarks—The present form is very similar to *P. conulum* in shape and size of the cyst, but here the archaeopyle is very indistinct. Additionally, very few specimens representing this genus have been recovered.

Previous record—Upper Cenomanian of Fetcham Mill, Comptom Bay, Escalles (Davey, 1969).

Occurrence—Upper part of Therria Formation (Palaeocene), Meghalaya.

PLATE 2 →

1. *Adnatosphaeridium vittatum* Williams & Downie in Davey *et al.*; Slide no. BSIP 8359; coordinate: 77.6 × 15.7
2, 9. *Codoniella langparensis* Jain, Sah & Singh; Slide nos. BSIP 8346 and 9626; coordinates: 111.4 × 13.1 and 99.10 × 21.1 respectively
3. *Callimothallus pertusus* Dilcher; Slide no. BSIP 8363; coordinate: 91.6 × 21.6
4. *Diporicellaesporites* sp.; Slide no. BSIP 7030; coordinate: 96.1 × 21.0
5. *Apteodinium* sp.; Slide no. BSIP 8348; coordinate: 92.9 × 5.2
6, 10. *Turbiosphaera proximata* sp. nov.; Slide nos. BSIP 8353 and 8793; coordinates: 97.2 × 9.7 and 83.2 × 8.7 respectively.
7. *Inapertisporites kedvesii* Elsik; Slide no. BSIP 7036; coordinate: 86.4 × 15.5
8. *Cucurbitariacites bellus* Kar, Singh & Sah; Slide no. 8364; coordinate: 101.3 × 11.5
11. *Turbiosphaera filosa* (Wilson) Archangelsky; Slide no. BSIP 8793; coordinate: 95.6 × 18.7
12. *Polysphaeridium giganteum* Caro; Slide no. BSIP 8349; coordinate: 95.3 × 4.2
13. *Polysphaeridium subtile* Davey & Williams in Davey *et al.*; Slide no. BSIP 8358; coordinate: 117.5 × 23.8
14. *Phragmothyrites eocaenica* Edwards; Slide no. BSIP 8362; coordinate: 116.9 × 12.2
15, 16. *Apectodinium homomorphum* Lentin & Williams; Slide no. BSIP 8365; coordinate: 96.7 × 18.8 and 110.7 × 16.2 respectively.
17. *Homotryblium tenuispinosum* Davey & Williams in Davey *et al.*; Slide no. BSIP 8350; coordinate: 119.9 × 19.7
18. *Operculodinium israelianum* (Rossignol) Wall; Slide no. BSIP 8356; coordinate: 86.8 × 26.5
19, 20. *Operculodinium centrocarpum* (Deflandre & Cookson) Wall; Slide nos. BSIP 8790 and 8361; coordinate: 110.8 × 16.3 and 99.5 × 13.5 respectively.

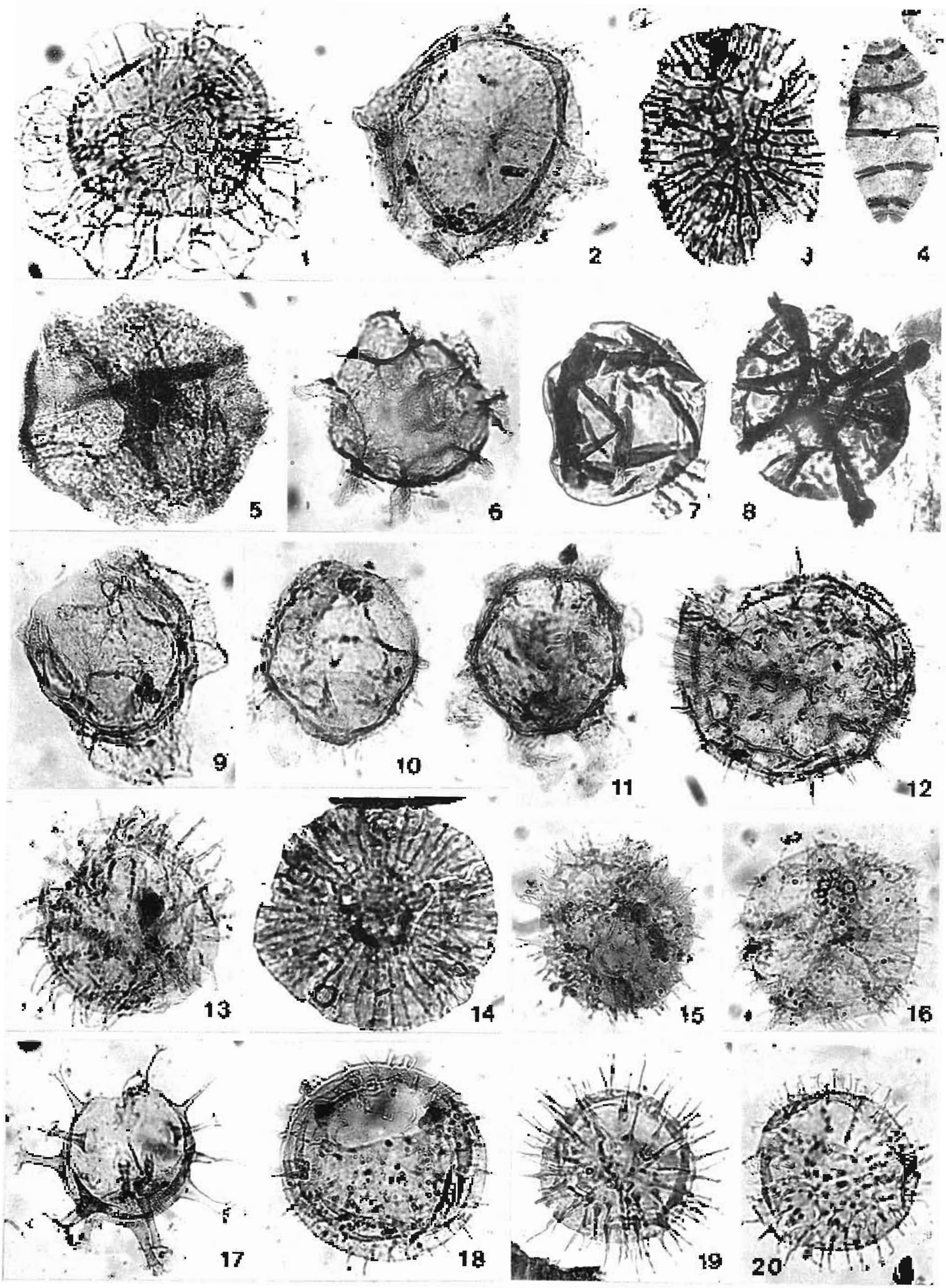


PLATE 2

Family—Cleistosphaeridiaceae Sarjeant & Downie 1974

Genus—*Polysphaeridium* Davey & Williams in Davey *et al.* 1966

Type species—*Polysphaeridium subtile* Davey & Williams in Davey *et al.* 1986

Polysphaeridium subtile Davey & Williams in Davey *et al.* 1966
Pl. 2, fig. 13

Remarks—Davey *et al.* (1966) recorded the cyst body of *P. subtile* up to 50 μm but the specimens from this assemblage range from 68-74 μm in size.

Previous records—Palaeocene and Lower Eocene of northern Spain (Caro, 1973); Lower Eocene of London Basin in southern England (Davey & Williams in Davey *et al.*, 1966, Gruas-Cavagnetto, 1970) and Lower, Middle and Upper Eocene of Isle of Wight, southern England (Eaton, 1976).

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

Polysphaeridium giganteum Caro 1973
Pl. 2, fig. 12

Previous record—Palaeocene of northern Spain (Caro, 1973).

Occurrence—Lower part of Kopili Formation (Upper Eocene), Meghalaya.

Polysphaeridium ornamentum Jain & Tandon 1981
Pl. 3, fig. 4

Previous record—Middle Eocene of Kachchh, India (Jain & Tandon, 1981).

Occurrence—Middle part of Kopili Formation (Upper Eocene), Meghalaya.

Family—Lingulodiniaceae Sarjeant & Downie 1974

Genus—*Operculodinium* Wall 1967

Type species—*Operculodinium centrocarpum* (Deflandre & Cookson) Wall 1967

Operculodinium centrocarpum (Deflandre & Cookson) Wall 1967
Pl. 2, figs 19, 20

Previous records—Ypresian of Belgium (De Coninck, 1965); Oligocene of Kachchh (Dutta & Jain, 1980); Miocene of Australia (Deflandre & Cookson, 1955); Middle Oligocene to Middle Miocene of Germany (Gerlach, 1961); Pleistocene and Recent (Wall & Dale, 1968); Late Palaeocene to Pleistocene, offshore Florida and Scotian shelf (Williams & Bujak, 1977).

Occurrence—Therria Formation (Palaeocene) and Lower part of Kopili Formation (Upper Eocene), Meghalaya.

Operculodinium israelianum (Rossignol) Wall 1967
Pl. 2, fig. 18

Previous records—Pleistocene of Israel (Rossignol, 1962); deep sea cores from Carribbean Sea (Wall, 1967).

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

Operculodinium major Jain & Dutta in Dutta & Jain 1980
Pl. 3, fig. 9

Previous record—Upper Palaeocene of Lakadong member of Sylhet Formation, Meghalaya, India (Dutta & Jain, 1980).

Occurrence—Upper part of Therria Formation (Palaeocene), Meghalaya.

Family—Adnatosphaeridiaceae Sarjeant & Downie 1966

PLATE 3 →

1. *Microthallites* sp.; Slide no. BSIP 8362; coordinate: 110.10 × 10.8
2. *Phragmothyrites* sp.; Slide no. BSIP 8342; coordinate: 99.4 × 14.5
3. *Pluricellaesporites psilatus* Clarke; Slide no. BSIP 7036; coordinate: 101.5 × 15.8
4. *Polysphaeridium ornamentum* Jain & Tandon; Slide no. 8354; coordinate: 83.1 × 16.5
5. *Gonyaulacysta* sp.; Slide no. BSIP 8357; coordinate: 85.5 × 27.6
6. *Turbiosphaera proximata* sp. nov.; Slide no. BSIP 9627; coordinate: 114.8 × 14.2
7. *Paramicrothallites* sp.; Slide no. BSIP 8342; coordinate: 110.7 × 16.2
8. *Callimothallus pertusus* Dilcher; Slide no. BSIP 8363; coordinate: 110.3 × 12.2
9. *Operculodinium major* Jain & Dutta in Dutta & Jain; Slide no. BSIP 8345; coordinate: 117.9 × 17.10
10. *Eocladopyxis* sp.; Slide no. BSIP 8355; coordinate: 116.7 × 9.3
11. *Diporisporites* sp.; Slide no. BSIP 7034; coordinate: 90.10 × 20.0
12. *Dicellaesporites minutus* Kar & Saxena; Slide no. BSIP 7036; coordinate: 94.1 × 5.5
13. *Phragmothyrites eocaenica* Edwards; Slide no. BSIP 7034; coordinate: 118.7 × 16.9
14. *Prolixosphaeridium conulum* Davey; Slide no. BSIP 8347; coordinate: 90.2 × 16.2

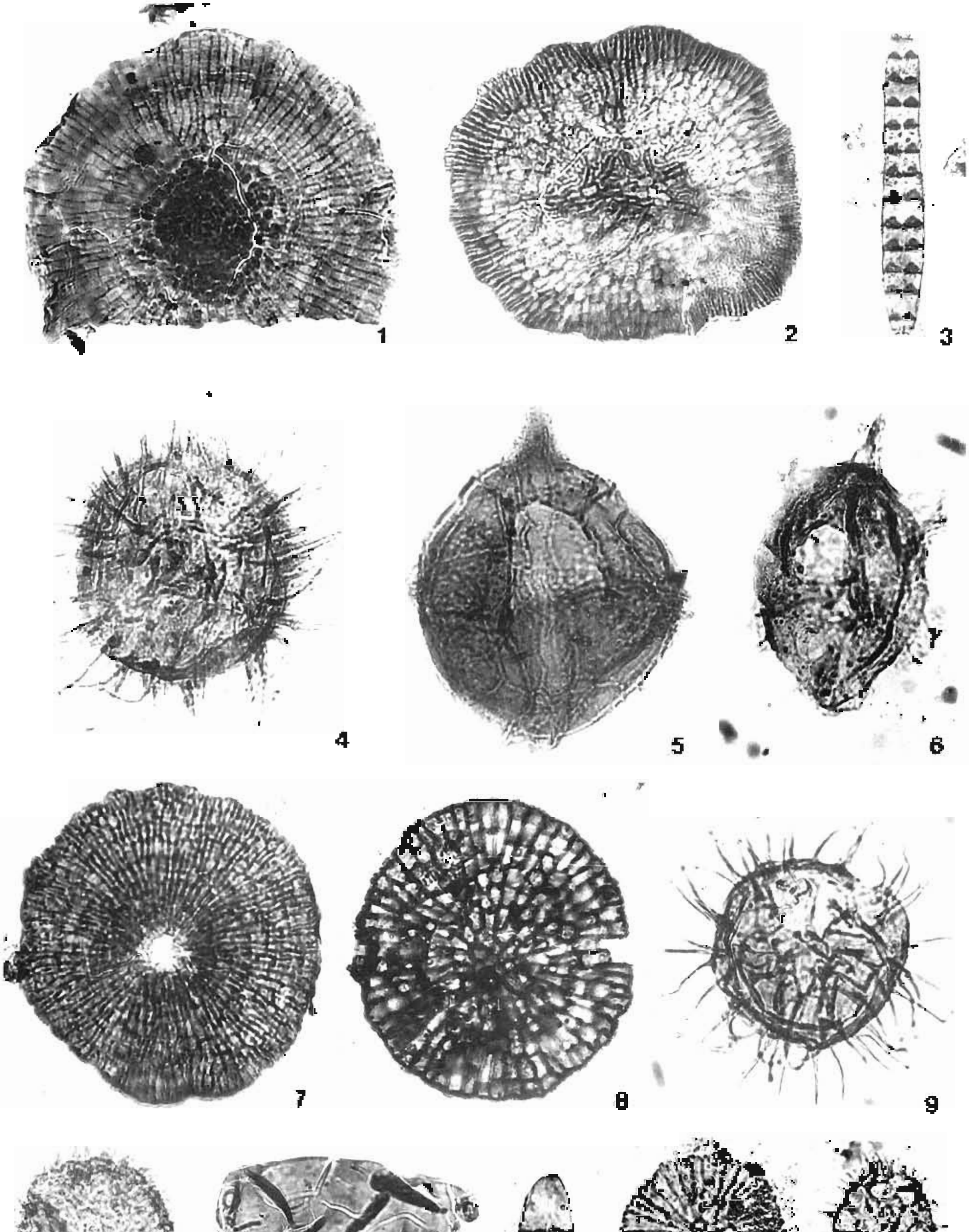


PLATE 3

Genus—*Adnatosphaeridium* Williams & Downie in Davey *et al.* 1966

Type species—*Adnatosphaeridium vittatum* Williams & Downie in Davey *et al.* 1966

Adnatosphaeridium vittatum Williams & Downie in Davey *et al.* 1966
Pl. 2, fig. 1

Previous records—Lower Eocene of southern England (Williams & Downie in Davey *et al.*, 1966); Palaeocene of northern Spain (Caro, 1973) and Lower to Upper Eocene of southern England (Eaton, 1976).

Occurrence—Therria and Kopili formations (Palaeocene-Eocene), Meghalaya.

Family—Uncertain.

Genus—*Codoniella* Cookson & Eisenack 1961

Type species—*Codoniella companulata* (Cookson & Eisenack) Downie & Sarjeant, 1965

Codoniella langparensis Jain, Sah & Singh, 1975
Pl. 2, figs 2, 9

Previous record—Lower Palaeocene of Lower Assam, India (Jain, Sah & Singh, 1975).

Occurrence—Upper part of Therria Formation (Palaeocene), Meghalaya.

Genus—*Eocladopyxis* Morgenroth emend. Stover & Evitt, 1978

Type species—*Eocladopyxis peniculata* Morgenroth, 1966

Eocladopyxis sp.
Pl. 3, fig. 10

Description—Cyst proximochorate, body ovoidal in shape, parasutural features very indistinct. Processes numerous nontabular, closely placed, having bulbous base and pointed tips, distally closed. Periphragm granulose, endophragm smooth. Paratabulation indistinct, many processes per plate area, archaeopyle combination type, formed by apical and precingular plates, operculum free. Paracingulum and parasulcus not indicated.

Dimensions:
Cyst body—60 × 54 μm
Processes—4·9 μm long

Remarks—*Eocladopyxis* sp. is represented by only a single specimen. It is distinct from *E. peniculata* in not exhibiting the paratabulation distinctly. *Eocladopyxis* sp. described by Dutta and Jain (1980) from the Upper Palaeocene sediments of Meghalaya possesses reticulate periphragm.

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

Fungal Remains

Genus—*Callimothallus* Dilcher 1965

Type species—*Callimothallus pertusus* Dilcher 1965

Remarks—The genus *Callimothallus* was proposed by Dilcher (1965) with the following diagnosis: "No free hyphae. Stroma round, radiate, ascomate, no central dehiscence, individual cells may possess single pore. Spores undetermined". Subsequently, Kar and Saxena (1976) merged *Callimothallus* with *Phragmothyrites* after emending the diagnosis of the latter. Their main contention was that there exists uncertainty regarding the presence or absence of pores in individual cells of the ascomata in either of the genus. Elsik (1981) classified the fungal bodies on the basis of presence or absence of pores in the individual cells, and treated it as the main diagnostic characteristic. Personally I also subscribe to the same thought and concur with Elsik (1981) in maintaining the original taxonomic status of *Callimothallus*.

Callimothallus pertusus Dilcher 1965
Pl. 2, fig. 3; Pl. 3, fig. 8

Previous record—Eocene of western Tennesse, U.S.A. (Dilcher, 1965).

Occurrence—Lower part of Therria Formation (Palaeocene) and Lower part of Kopili Formation (Upper Eocene), Meghalaya.

Genus—*Phragmothyrites* Edwards 1922

Type species—*Phragmothyrites eocaenica* Edwards, 1922

Phragmothyrites eocaenica Edwards 1922
Pl. 2, fig. 14; Pl. 3, fig. 13

Previous records—Palaeocene of Kachchh (Kar & Saxena, 1976); and Lower Eocene of Kachchh (Venkatachala & Kar, 1969).

Occurrence—Lower part of Therria Formation (Palaeocene) and Lower part of Kopili Formation (Upper Eocene), Meghalaya.

Phragmothyrites sp.
Pl. 3, fig. 2

Description—Ascomata ovoidal in shape, 130 × 110 μm in diameter, non-ostiolate, lacking free hyphae, hyphae radially arranged, connected with each other forming pseudoparenchymatous cells, margin of ascomata uneven. Central cells comparatively thick-walled, slightly elongated, arranged ± parallel to longer axis of the ascomata. Cells in the middle part isodiametric, thin-walled. Marginal cells radially elongated, narrow, thick-walled.

Remarks—*Phragmothyrites* sp. is represented by a single specimen only hence, no specific designation has been given to it. The present form is unique morphologically as it exhibits three distinct layers of pseudoparenchymatous hyphae.

Occurrence—Lower part of Kopili Formation (Upper Eocene), Meghalaya.

Genus—*Paramicrothallites* Jain & Gupta 1970

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

Paramicrothallites sp.
Pl. 3, fig. 7

Description—Ascomata ± circular in shape, ostiolate, 95-115 μm in diameter, lacking free hyphae, hyphae radially arranged, connected with each other forming pseudoparenchymatous cells, margin of ascomata smooth to uneven, all the cells isodiametric to slightly elongated. Ostiole not very well-defined, 13-15 μm across, cells around the ostiole slightly thickened, the ostiole appearing to be the result of the dissolution of central cells of the ascomata.

Occurrence—Lower part of Kopili Formation (Upper Eocene), Meghalaya.

Genus—*Microthallites* Dilcher 1965

Type species—*Microthallites lutosus* Dilcher 1965

Remarks—The genus *Microthallites* was proposed by Dilcher (1965) to accommodate ostiolate and non-ostiolate microthyriaceous forms having radiate parenchymatous hyphae. Later, Jain and Gupta (1970) transferred *Microthallites spinulatus* Dilcher (1965), an ostiolate form, to a new genus, viz., *Paramicrothallites*, proposing the former as Type Species. However, the genus *Microthallites* was retained for the reception of non-ostiolate forms having the central cells modified into a dense knob. During the present study a fungal thyrothecium having radiate, pseudoparenchymatous hyphae and numerous central dense knobs was examined. In my opinion this form should be kept under the genus *Microthallites*. Unfortunately, only a single specimen of this type has been observed. Thus it seems difficult to assign any specific designation to it.

Microthallites sp.
Pl. 3, fig. 1

Description—Ascomata ± circular in shape (partly broken), non-ostiolate, 140 μm in diameter, lacking free hyphae, hyphae radially arranged and connected with each other forming pseudoparenchymatous cells, margin of ascomata uneven. Central cells represented by dense knobs of 2-3 μm in diameter and gradually assuming isodiametric shape. Marginal cells thin-walled, elongated and narrow.

Occurrence—Lower part of Kopili Formation (Upper Eocene), Meghalaya.

Family—Cucurbitariaceae

Genus—*Cucurbitariaceites* Kar, Singh & Sah 1972

Type species—*Cucurbitariaceites bellus* Kar, Singh & Sah 1972

Cucurbitariaceites bellus Kar, Singh & Sah 1972
Pl. 2, fig. 8

Previous record—Palaeocene of Garo Hills, Meghalaya (Kar, Singh & Sah 1972).

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

Family—Sporae Multicellae Elsik 1976

Genus—*Pluricellaesporites* (van der Hammen) Elsik 1968

Type species—*Pluricellaesporites typicus* van der Hammen 1954

Pluricellaesporites psilatus Clarke 1965
Pl. 3, fig. 3

Previous records—Upper Cretaceous of Central Colorado (Clarke, 1965); Eocene and Oligocene of Washington (Hopkins, 1969).

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

Family—Sporae Dicellae Elsik 1976

Genus—*Dicellaesporites* Elsik 1968

Type species—*Dicellaesporites popovii* Elsik 1968

Dicellaesporites popovii Elsik 1968
Pl. 1, fig. 7

Previous records—Palaeocene of Texas (Elsik, 1968) and Kutch, India (Kar & Saxena, 1976).

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

Dicellaesporites minutus Kar & Saxena 1976
Pl. 3, fig. 12

Previous record—Palaeocene of Kachchh (Kar & Saxena, 1976).

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

Genus—*Diporisporites* (van der Hammen) Elsik 1968

Type species—*Diporisporites elongatus* van der Hammen 1954

Diporisporites sp.
Pl. 3, fig. 11

Description—Spores unicellular, diporate, elliptical in shape, 95-102 × 52-60 μm in size, lateral ends rounded. Pores 3-4 μm across, situated at the extreme of the lateral ends, pore margin thickened. Spore wall ± 1 μm thick, dark in colour, associated with a few irregular folds.

Remarks—*Diporisporites* sp. is comparable to the fungal spore described by Hopkins (1969, pl. 12, fig. 174) as *Diporate* A, but in the latter pores are situated slightly away from the lateral ends.

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

Genus—*Diporicellaesporites* Elsik 1968

Type species—*Diporicellaesporites stacyi* Elsik 1968

Diporicellaesporites sp.
Pl. 2, fig. 4

Spore 6-celled, oval in shape, 70 × 35 μm in size, diporate. Pores present at the lateral ends, sunken. Septa thick, spore wall very thin, granulose, granules sparsely placed.

Remarks—*Diporicellaesporites* sp. is different from the other species of the genus in having sunken pores, thin and granulose spore wall.

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

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

Type species—*Inapertisporites typicus* van der Hammen 1954

Inapertisporites kedvesii Elsik 1968
Pl. 2, fig. 7

Previous records—Palaeocene of Milam county, Texas (Elsik, 1968) and Palaeocene of Kachchh, India (Kar & Saxena, 1976).

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

DISCUSSION

Composite lithosection representing the Jowai-Sonapur Road Section (Palaeocene-Eocene), Meghalaya along with sample position is published by Tripathi and Singh (1984) while establishing palynostratigraphic zones in this geological section hence, is not being given here. Litholog (not to the scale) and distribution of recovered dinoflagellate species have been given in Text-figure 1. Dinoflagellates register a low frequency in the lower part of Therria Formation but share 78 per cent of the total assemblage in upper part of this formation which has been identified as *Apectodinium homomorphum* Cenozone (Tripathi & Singh, 1984). This cenozone is characterised by the dominance of the genus *Apectodinium* (23%) being represented by *A. homomorphum* (14%) and *A. parvum* (9%). The Sylhet Formation is devoid of dinoflagellates except the recovery of a few forms of *Operculodinium major*. Lower part of the Kopili Formation shows a high frequency of dinoflagellate cysts in comparison to the upper part.

Occurrence of *Apectodinium parvum* in the Upper Palaeocene-Lower Eocene sediments has been reported from Europe, New Zealand and North sea (Alberti, 1961; Wilson 1967; De Coninck, 1969; Gocht, 1969; Gruas-Cavagnetto, 1968; Costa & Downie, 1976). Chateauneuf and Gruas-Cavagnetto (1978) discussed Palaeogene zones based on *Apectodinium* in Paris Basin and correlated them with other north-west European zones. They found that the lower most C-1, *Apectodinium homomorphum* Zone extends from top of Thanetian to the base of Sparnacean. They also observed that at the base of Sparnacean *Apectodinium homomorphum* is represented by 80-90 per cent of palynological assemblage, thus, being characterised by monospecific microplankton assemblage.

Dutta and Jain (1980) recovered three species of the genus *Apectodinium*, viz., *A. homomorphum, A. parvum* and *A. hyperacanthum* from Lakadong Sandstone Member of Sylhet Formation. Keeping in view the geological distribution of *A. parvum* they dated the lower part of Sylhet Formation as Palaeocene and placed Palaeocene-Eocene boundary at the upper part of Lakadong Sandstone member of Sylhet Formation. But present studies indicate that *A. parvum* marks its first appearance in the upper part of Therria Formation. Therefore, top of the Therria Formation has been dated as Upper Palaeocene.

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Chitinozoa-like remains from Vindhyan Supergroup of Son Valley

P. K. Maithy & Rupendra Babu

Maithy, P. K. & Babu, Rupendra (1989). Chitinozoa-like remains from Vindhyan Supergroup of Son Valley. *Palaeobotanist* **37**(1) : 77-80.

Chitinozoa-like remains have been recorded from the Arangi Formation and Markundi Quartzite of Vindhyan Supergroup exposed near Dala and Agori villages in Son Valley, Mirzapur District. These remains closely resemble *Melanocyrillium fimbriatum* Bloeser, *M. hexodiadema* Bloeser, *M. horodyskii* Bloeser and *Melanocyrillium* sp. A preliminary analysis of their distribution in the strata shows that they may be morphologically diversified in the younger horizons.

Key-words—Chitinozoa-like remains, *Melanocyrillium*, Vindhyan Supergroup, Proterozoic, Son Valley (India).

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साराँश

सोन घाटी के विन्ध्य महासमूह से काइटीनीजीवी-सदृश अवशेष

प्रभात कुमार माइती एवं रूपेन्द्र बाबू

मिर्जापुर जनपद मे सोन घाटी में डाला एव अगोरी नामक गाँवो के समीप विगोपित विन्ध्य महासमूह के आरंगी शैल-समूह एवं मरकुन्डी स्फटिक में काइटीनीजीवी-सदृश अवशेष अभिलिखित किये गये हैं। ये अवशेष **मिलेनोसाइरिलियम् फिम्ब्रिएटम्** ब्लॉयसर, **मि० हेक्सोडियाडीमा** ब्लॉयसर, **मि० होरोडिस्काई** ब्लॉयसर एव **मिलेनोसाइरिलियम्** जाति से घनिष्ठ समानता प्रदर्शित करते हैं। इन स्तरों में इनके वितरण के प्रारम्भिक विश्लेषण मे व्यक्त होता है कि अल्पायु के सस्तरो में आकारिकीय दृष्टि से ये भिन्न प्रकार के हो सकते हैं।

OCCURRENCE of chitinozoa-like or vase-shaped remains is quite common in the Precambrian rocks. Ewetz (1933) first described vase-shaped microremains in the phosphatic nodules from the Visingo beds of southern Sweden. Further populations of distinctively Chitinozoa or vase-or flask-shaped fossils were described from the shales of Chuar Group, Grand Canyon, Arizona (Bloeser *et al.*, 1977); limestone pebbles from the Jacadigo Group, south-western Brazil (Fairchild *et al.*, 1978); dolomites from the Murdama Group, Saudi Arabia (Binda & Bokhari, 1980); limestone, silicified dolomites and silicified pyritic shales of the correlative Akademikerbreen and Roaldtoppen groups of Ny Friesland and western Nordaustlandet, Svalbard (Knoll, 1982); phosphate nodules from near shore marine shales and siltstones of the Visingo beds, Sweden (Knoll & Vidal, 1980); and Sinian System of China (Jichneg *et al.*, 1980). Recently, Bloeser (1985) put them under a new genus *Melanocyrillium* from Chuar Group, Grand Canyon.

In India, early doubtful forms of chitinozoans or chitinozoa-like microremains have been observed in the Precambrian rocks of Vindhyan Supergroup and Himalayan areas (Salujha *et al.*, 1971a, 1971b, 1972; Salujha, 1973; Nautiyal, 1982). *Incertae sedis* Type 3, resembling *?Desmochitina* Eisenack, was first reported by Salujha *et al.* (1971a, p. 32, pl. III, fig. 31) from the Vindhyan rocks of Son Valley. In contrary, *Incertae sedis* Type 1, resembling more or less chitinozoan genus *Hoegisphaera* Staplin was recorded from the Upper Vindhyan rocks (Late Cambrian to Ordovician) of Rajasthan (Salujha *et al.*, 1971b, pp. 70-79, pl. 1, fig. 35). Later Salujha (1973) described this doubtful chitinozoan as *Hoegisphaera* sp. (pl. 1, fig. 18, pp. 64-67) from the Upper Vindhyan deposits of Rajasthan.

Other forms of chitinozoa, vaguely resembling *Desmochitina* Eisenack (Salujha *et al.*, 1972, p. 129, pl. 1, figs 32-34), were reported as *Incertae sedis* Type 2 from the Kurnool rocks (Late Precambrian to Cambrian) of Andhra Pradesh. A few chitinozoa-like tests (Nautiyal, 1982, fig. 13, pp. 273, 274) were also recorded from the Late Precambrian medium dark grey flute casted silty shale of the Lower Sanjauli Formation in Himachal Pradesh. Nautiyal (1978, figs 18-23, pp. 222-226) described definitive and distinctive forms of chitinozoans showing affinities with desmochitinids (*Desmochitina minor, D. ovulum, D. bohemica*) from the Late Precambrian Simla Slates (= Upper Simla Group) of the Satpuli area in Garhwal Himalaya. Subsequently, their stratigraphic occurrence was demonstrated in a section of Simla Slate Group (Nautiyal, 1979, pp. 29, 30; Nautiyal, 1981, p. 50).

The present paper deals with the occurrence of some non-colonial vesicle-shaped organic-walled chitinozoa-like remains from the Arangi Formation (Semri Group) and Markundi Quartzite (Kaimur Group) of the Vindhyan Supergroup in Son Valley.

GENERAL GEOLOGY

Auden (1933) gave a generalized stratigraphic succession of the Semri and Kaimur groups around Chopan in Son Valley. Later, Ahmad (1971), Mathur (1981) and Prakash and Dalela (1982) revised the geological succession of the area as follows:

Group	*Formation*
Kaimur	Dhandraul Quartzite Bijaigarh Shale Markundi Quartzite Ghurma Shale Ghaghar Quartzite
Semri	Rohtas Limestone Basuhari Sandstone Bargawan Limestone Kheinjua Shale Chopan Porcellanite Kajrahat Limestone Arangi Formation

The rock samples for the present study were collected from the areas as detailed below:

Formation	*Location*	*Lithology*
A. Arangi Formation	1. 1-½ km NW of Dala (near barrier of Kajrahat Quarry)	Dirty grey to horn-blende green, very fine grained shales
	2. Parsoi (exposed in Arangi Nala)	
B. Markundi Quartzite	3. 3-½ km NW of Agori Khas railway station (along the railway cutting near the contact of Markundi Quartzite with overlying Bijaigarh Shale)	Ash grey cherts

ISOLATION OF BIOTA

To isolate chitinozoa-like microfossils, the silicified rocks were treated with hydrochloric and hydrofluoric acids, and the carbonaceous rocks with nitric acid. Subsequently, extracted organic residue was washed repeatedly in distilled water and after clearing it was mounted on the slides with Canada Balsam or D.P.X. mountant. The organic remains are dark black and opaque forms which were studied under transmitted light. All the slides have been deposited in the Birbal Sahni Institute of Palaeobotany, Museum.

DESCRIPTION

Four types of Chitinozoa-like microremains have been recorded.

Melanocyrillium fimbriatum Bloeser
Pl 1, fig. 1

Ovoid chamber (or body), 160-200 μm long (overall size), aboral end rounded; chamber gradually reducing in size towards oral end. Oral end and collar not preserved; margin entire, surface laevigate. In general morphology, the specimen closely resembles *Melanocyrillium fimbriatum* Bloeser 1985.

Melanocyrillium hexodiadema Bloeser
Pl. 1, figs 2, 3

Ellipsoidal to ovoid chamber or body, 25-50 μm long (overall size); aboral end rounded, chamber gradually reducing towards oral end into narrow neck; margin entire, surface laevigate. Morphologically the specimens, although fairly small-sized,

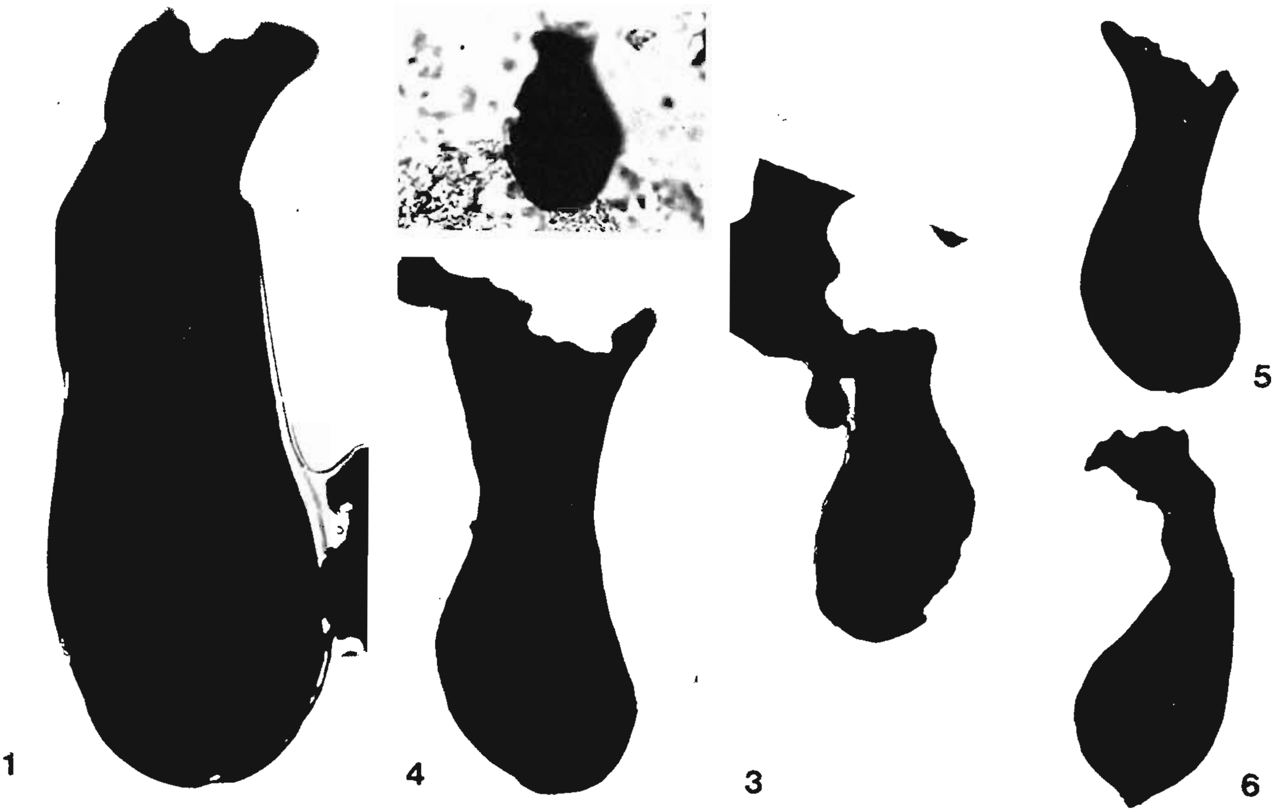

PLATE 1

1. *Melanocyrillium fimbriatum* Bloeser; Slide no. BSIP 8018 at X 61/1. × 500.
2. *Melanocyrillium hexodiadema* Bloeser; Slide no. BSIP 8017 at E 48/2. × 1000.
3. *Melanocyrillium hexodiadema* Bloeser; Slide no. BSIP 8018 at X 47/3. × 500.
4. *Melanocyrillium horodyskii* Bloeser; Slide no. BSIP 8018 at X 38/3. × 500.
5. *Melanocyrillium horodyskii* Bloeser; Slide no. BSIP 8018 at T 31/1. × 500.
6. *Melanocyrillium* sp.; Slide no. BSIP 8019 at V 28/4. × 500.

show close resemblance with *Melanocyrillium hexodiadema* Bloeser 1985.

Melanocyrillium horodyskii Bloeser
Pl. 1, figs 4, 5

Ovoid chamber or body, 35-70 μm long (overall size); aboral end rounded, abruptly reducing to a narrow neck and subsequently expanding towards oral end into a wide collar; margin entire, surface laevigate. The specimens, although small-sized, closely resemble *Melanocyrillium horodyskii* Bloeser 1985.

Melanocyrillium sp.
Pl. 1, fig. 6

Pear-shaped chamber or body, 40-60 μm long (overall size); aboral margin rounded with a conical projection; neck narrow, curved, becomes broad at oral end; margin entire, exine laevigate. This specimen also shows affinity to some forms of *Melanocyrillium* Bloeser 1985. The collars are not preserved in the specimens due to which their detailed comparison is not possible. Thus they have been referred to *Melanocyrillium* sp.

CONCLUSIONS

Chitinozoans, in recent years, are being considered to be remains of animals rather than of plant origin. They are also considered to be marine and predominantly planktonic in habit. Fairchild *et al.* (1978) considered these Precambrian vase-like fossils comparable to cilliate protistan tintinids. This opinion also received the support from Knoll and Vidal (1980). However, recently Bloeser (1985) interpreted them as encystment of unidentified alga.

In the present study, chitinozoa like remains have been recorded from the dirty green to hornblende green shales of Arangi Formation and ash grey chert of Markundi Quartzite belonging to Semri and Kaimur groups respectively of Son Valley. Knoll and Vidal (1980) also recorded similar micro-remains from the Proterozoic rocks of contrasting lithofacies, i.e., ripple-marked argillites, off-shore shale deposit, marine carbonates and organic chert beds interbedded with carbonaceous, pyritic shales. Thus their occurrences in varying lithofacies are suggestive of their planktonic habitat. Nevertheless, the presence of chitinozoa like microfossils or vase-shaped microremains in the Precambrian Son Valley sediments may prove stratigraphically significant and obviously their further detailed study is needed to reach at a definitive conclusion.

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Palynology of the Talchir Formation from Betul Coalfield, Satpura Basin, India

Suresh C. Srivastava, Anand-Prakash & O. S. Sarate

Srivastava, Suresh C., Anand-Prakash & Sarate, O. S. (1989). Palynology of the Talchir Formation from Betul Coalfield, Satpura Basin, India. *Palaeobotanist* **37**(1) : 81-84.

The palynoflora recovered from the sediments of Talchir Formation of Mura-Kuppa area in Betul Coalfield, Satpura Basin is rich in *Plicatipollenites*, followed by *Parasaccites* and *Virkkipollenites*. *Potonieisporites* and *Rugasaccites* occur consistently but in low percentages. This palynoflora is closely comparable with the known older palynofloras of the Talchir Formation of India.

Key-words—Palynology, Betul Coalfield, Talchir Formation, Satpura Basin (India).

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सारॉंश

सतपुड़ा द्रोणी (भारत) में बेतुल कोयला-क्षेत्र के तलचीर शैल-समूह का परागाणविक अध्ययन

सुरेश चन्द्र श्रीवास्तव, आनन्द प्रकाश एवं ओमप्रकाश शिवदास सराटे

सतपुड़ा द्रोणी के बेतुल कोयला-क्षेत्र में स्थित मुरा-कुप्पा क्षेत्र के तलचीर अवसादों से उपलब्ध परागाणुवनस्पतिजात में **प्लिकेटिपोलिनाइटिस** की बाहुल्यता है, इसके पश्चात **पेरासेक्काइटिस** तथा **विर्किपोलिनाइटिस** की बाहुल्यता आती है। **पोतोनियेस्पोराइटसि** एवं **रुगासेक्काइटिस** हालाँकि निरन्तर मिलते हैं परन्तु इनकी प्रतिशत मात्रा कम है। इस संमुच्चय से उपलब्ध यह परागाणुवनस्पतिजात तलचीर शैल-समूह से ज्ञात अन्य प्राचीनतर परागाणुवनस्पतिजातों से घनिष्ठ तुलनीय है।

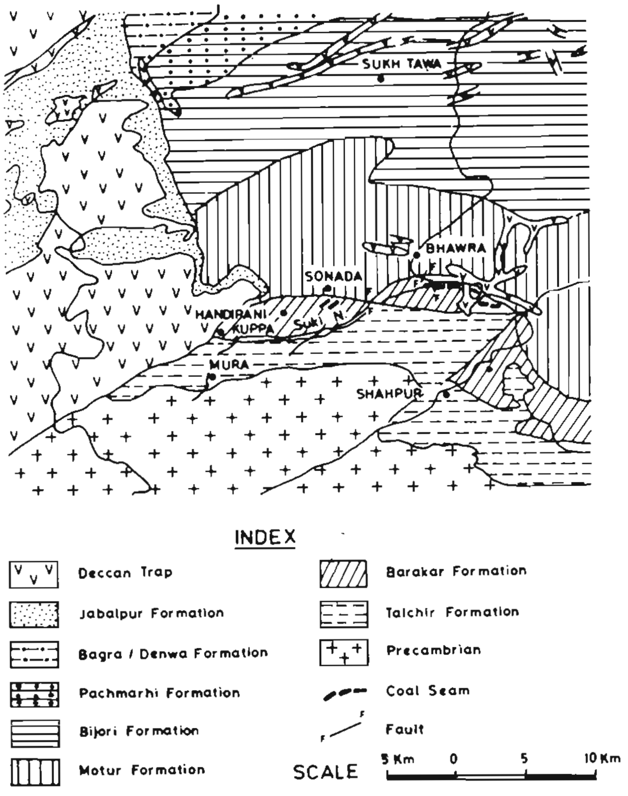
TALCHIR Formation occurs in the southern part of the Satpura Basin as a continuous stretch from Junardeo in the east to Mura Village in the west. They also occur in patches on the northern fringes of the basin, south of Piparia, east of Gotitoria (Mohpani Coalfield) and at the confluence of Anjan and Pathapani streams. The general palynology and the succession of palynofloras within the Talchir sediments from northern part of Satpura Basin have been studied by Bharadwaj and Anand-Prakash (1972) from Mohpani Coalfield. Bharadwaj, Navale and Anand-Prakash (1974) studied palynoflora from Talchir sediments exposed on Kanhan River Section in Pench-Kanhan Coalfield in the southern part of the basin. Bharadwaj, Tiwari and Anand-Prakash (1978) described another palynoflora from the Talchir sediments exposed at the confluence of Anjan-Pathapani streams in northern part of the Satpura Basin. So far, no information is available about the palynology of Talchir sediments from south-western part of the basin where these sediments occupy a large area and comprise a significant part of the Lower Gondwana Sequence. In the present investigation Talchir sediments from Mura-Kuppa area (Table 1) have been analysed for palynofossils to fill the gap in the knowledge of Talchir palynostratigraphy of the Satpura Basin.

In Betul Coalfield (Shahpur Coalfield) almost all the lithological units of Lower Gondwana Sequence (Talchir, Barakar, Motur and Bijori formations) are exposed around Shahpur Village. The metamorphic rocks form the basement for the Gondwana sediments in the Betul Coalfield and are well exposed south of Mura Village forming a chain

Table 1—Showing details of samples collected from Mura-Kuppa area of Betul Coalfield, Satpura Basin

Sample no.	Lithology	Palynofossils Present (+) Absent (-)
T-1	Basal boulder bed (Bottom)	-
T-2	Sandstone	-
T-3	Shaly green sandstone	-
T-4	Sandstone	-
T-5	Greenish needle shale	-
T-6	Needle shale	-
T-7	Needle shale	-
T-8	Needle shale	-
T-9	Khaki green shaly sandstone	-
T-10	Fine laminated sandstone	-
T-11	Greenish mudstone	-
T-12	Greenish needle shale	-
T-13	Mudstone	-
T-14	Khaki green shale (Top)	+

of small hillocks. The sediments of the Talchir Formation overlie the basement metamorphic rocks and extend as a continuous patch from Mura Village in the west to Shahpur in the east (Map 1). The basal unit (boulder bed) of the Talchir Formation comprises dispersed clasts of various kinds exposed



Map 1—Geological map of western part of the Satpura Basin, Madhya Pradesh.

in a small stream near Mura Village. This is overlain by greenish, fine-grained sandstones. Succeeding this member is a thick succession of turbidite facies forming small mounds north of Mura Village, a feature unique of Talchir Formation seen in this coalfield. The Talchir sediments are also affected by a N-S trending dyke near Kuppa Village. At one place ripple marks have been observed in the Talchir sandstones near Handipani Village.

PALYNOLOGY

The following genera and species have been recorded from the Talchir Formation exposed around Mura-Kuppa area :

Callumispora tenuis Bharadwaj & Srivastava 1969
Leiotriletes conspicuous Saksena 1971
Parasaccites diffusus Tiwari 1965
Parasaccites densicorpus Lele 1975
Parasaccites talchirensis Lele & Makada 1972
Plicatipollenites indicus Lele 1964
Plicatipollenites densus Srivastava 1970
Plicatipollenites trigonalis Lele 1964
Plicatipollenites gondwanensis (Balme & Hennelly) Lele 1964
Caheniasaccites elongatus Bose & Kar 1966
Caheniasaccites densus Lele & Karim 1971
Potonieisporites crassus Lele & Chandra 1973
Rugasaccites orbiculatus Lele & Maithy 1969
Virkkipollenites sp.
Faunipollenites sp.
Crescentipollenites amplus (Balme & Hennelly) Tiwari & Rana 1980
Crescentipollenites globosus Maithy 1965
Leiosphaeridia sp.
Foveofusa sp.

The palynoflora is rich in radial monosaccate pollen grains (86.5%), chiefly *Plicatipollenites* (43.0%) and *Parasaccites* (30.5%). *Virkkipollenites, Potonieisporites* and *Rugasaccites* follows next in the order of dominance (Histogram 1). Trilete spores and disaccate pollen grains are poorly represented.

DISCUSSION

The palynoflora from Talchir Formation of Mohpani Coalfield (Bharadwaj & Anand-Prakash, 1972) is characterised by the dominance of radial monosaccate pollen genus *Parasaccites* followed by *Virkkipollenites* and *Plicatipollenites* and thus differs from the present assemblage. *Rugasaccites, Crescentipollenites, Leiosphaeridia, Foveofusa* recorded in the present investigation are absent in Mohpani assemblage.

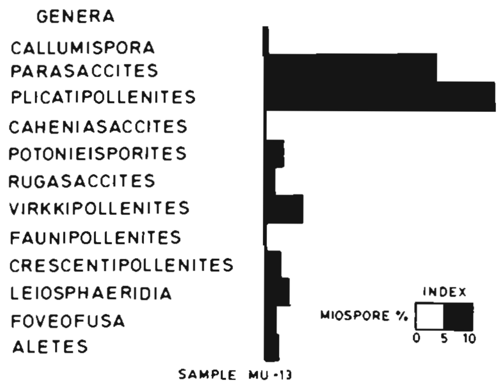
The palynoflora of Talchir Formation from Kanhan River Section (Bharadwaj, Navale & Anand-Prakash, 1974) is also dominated by *Parasaccites*. Here the subdominance is attained by *Plicatipollenites* followed by *Virkkipollenites* and *Pilasporites*. The palynological resemblance between these assemblages and Mura-Kuppa assemblage is only superficial since the nature of overall dominance is almost inverse. Moreover, *Rugasaccites, Crescentipollenites* and *Leiosphaeridia* are absent in the assemblage of Kanhan River Section.

Bharadwaj, Tiwari and Anand-Prakash (1978) described an assemblage from the Talchir sediments exposed in the northern part of Satpura Basin (6 km south of Fatehpur at the confluence of Anjan-Pathapani streams). In this assemblage the radial monosaccates are in very small amounts and the bulk of percentage is shared by *Foveofusa* and *Leiosphaeridia* and thus differs from the Mura-Kuppa assemblage.

Thus the Talchir sediments of Mura-Kuppa Village of Betul Coalfield show older aspects in the Talchir sequence. Amongst the Talchir palynofloras described so far from the Satpura Basin, the assemblage recorded from Anjan-Pathapani River Section appears to be stratigraphically older to the present assemblage while those described from Mohpani Coalfield and Kanhan River Section are younger than the Mura-Kuppa assemblage.

Tiwari (1975) made a comparative study of the known Talchir palynofloras and concluded that *Plicatipollenites* dominance has an older tendency, while *Parasaccites* dominance has a younger tendency. The palynoflora in the present investigation is dominated by *Plicatipollenites* associated with *Parasaccites* and is thus comparable with the *Plicatipollenites* dominant T-1 and T-2 palynozones of Tiwari (1975).

Lele (1975) also observed the possibility of occurrence of two palynofloras in the Talchirs. Chandra and Lele (1979) studied the Talchir palynoflora from South Rewa Gondwana Basin and concluded that *Plicatipollenites* dominance is associated with older sediments while *Parasaccites* is dominant in the younger Talchir sediments. A similar conclusion was also drawn simultaneously by Bharadwaj, Srivastava and Anand-Prakash (1979) in a sequential study of a measured section from Hasia Nala of Manendragarh area. Almost a similar association is observed in the present investigation of Mura-Kuppa Talchir sediments. However, *Jayantisporites* and *Divarisaccus* recorded from Hasia Nala Section of Manendragarh are absent in the present assemblage. *Leiosphaeridia, Crescentipollenites* and *Foveofusa* which are present



Histogram 1—Percentage distribution of pollen and spores from Talchir Formation of Mura-Kuppa Area, Betul Coalfield, Satpura Basin.

in Betul Coalfield assemblage are absent in the palynofloral assemblage of Hasia Nala section of Manendragarh.

The palynoflora recorded from Jayanti Coalfield (Lele & Karim, 1971) is also dominated by *Plicatipollenites* (sample nos. D14-B & D10-B) and is much closer to the present palynofloral assemblage. In sample nos. D10-D and D10-E (Jayanti Coalfield), though *Plicatipollenites* is a dominant genus, the subdominance is marked by *Virkkipollenites*. The palynoflora of Jayanti Coalfield also contains pollen grains like *Tuberisaccus, Divarisaccus, Vestigisporites, Limitisporites* which are absent in the present assemblage. *Leiosphaeridia, Rugasaccites, Crescentipollenites* and *Foveofusa* which are recorded in the present assemblage are absent in the palynological assemblage recovered from Jayanti Coalfield.

Lele and Shukla (1980) have recently described a palynoflora from Talchir Formation of Hutar Coalfield which shows the dominance of *Parasaccites* over *Plicatipollenites* and thus differs from the present assemblage. The Talchir assemblage described from Jharia Coalfield (Tiwari *et al.*, 1981) also contains a palynoflora similar to that of Hutar Coalfield and thus does not compare with the present assemblage of Betul Coalfield.

The palynoassemblage recovered from Korba Coalfield by Bharadwaj and Srivastava (1973, histogram 1, p. 146; bore-hole NCKB-19; sample no. 140, depth 684.63-681.51 m) closely compares with the present findings. The assemblage here is dominated by *Plicatipollenites* and subdominant *Parasaccites*. The other associated forms are *Callumispora, Platysaccus, Caheniasaccites, Scheuringipollenites* and *Faunipollenites* (1 to 2%).

The palynological study shows that the sediments investigated here represent the older

Talchir sediments in the Satpura Basin. The field studies also indicate a similar possibility, as in other areas of the Satpura Basin. The Talchir sediments have not been found resting directly on the basement metamorphics except in the Anjan-Pathapani Section. In Anjan-Pathapani Section the basal Talchir sediments are highly crushed and metamorphosed due to the intense faulting along the northern margins of the basin and do not yield palynofossils. Therefore, the palynoflora represents a comparatively younger part in the Talchir sequence. In Mohpani area the basement rocks are not exposed, thus it is believed that the basal part of the Talchir sediments is also not exposed and whatever palynoflora is known represents a younger part of the Talchir sequence. Similarly, in Kanhan River Section the palynoflora does not represent the base of the Talchir Formation. In the light of these facts it becomes clear that the sediments of Mura-Kuppa area represent the basal part of the Talchir sequence in Satpura Basin. The palynological investigation further substantiates that the younger sediments of the Talchir Formation are probably missing due to the faulted contact of the Talchir and Barakar formations.

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The Palaeobotanist **37**(1) : 85-89, 1988.

A fossil gymnospermous wood from the Miocene of Yunnan, China

Nai-Zheng Du & Uttam Prakash

Du, Nai-Zheng & Prakash, Uttam (1989). A fossil gymnospermous wood from the Miocene of Yunnan, China. *Palaeobotanist* **37**(1) : 85-89.

A fossil gymnospermous wood *Taxodioxylon chinense* sp. nov. is described from the Miocene beds of South Yunnan Province, China. This is for the first time that a fossil wood of *Taxodium-Sequoia* type has been found in the Neogene of China.

Key-words—Fossil wood, Gymnosperm, Xylotomy, Miocene (China).

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साराँश

चीन में यूनान के मध्यनूतन कल्प से एक अश्मित अनावृतबीजी काष्ठ

नाइ-यंग दु एवं उत्तम प्रकाश

चीन में दक्षिण यूनान प्राँत के मध्यनूतन सस्तरों से **टेक्सोडिऑक्सीलॉन चाइनेन्से** नव जाति के नाम से एक अश्मित अनावृतबीजी काष्ठ का वर्णन किया गया है। यह पहला अवसर है कि चीन के पश्चनूतन कल्प में **टेक्सोडियम-सिकोया** सदृश अश्मित काष्ठ प्राप्त हुई है।

THIS detailed anatomical study is based on a fossil wood sent to one of us (N.Z.D.) by Mr Dung-min Liu who collected it from the Miocene Coal Mine of Jingdung County in Yunnan Province of China. Although many palaeobotanical studies have been carried out on the Tertiary flora of Yunnan, this forms the first record of a fossil wood in this flora. Besides, a number of dicotyledonous leaf-impressions and a few gymnospermous fossil leaves comprising *Pinus yunnanensis* Fr. and *Calocedrus lantenoisii* (*Laurent*) comb. nov. are also known from this flora (Anonymous, 1978, pp. 10, 15).

The fossils of Taxodiaceae are known from the Eocene and Palaeocene of China consisting of *Glyptostrobus europaeus* (Brongniart) Heer, *Taxodium tinajorum* Heer, *Metasequoia disticha* (Heer) Miki, *Sequoia chinensis* Endlicher emend. Wang et Li, from the Eocene of Fushun and *Taxodioxylon cryptomerioides* Schönfeld, *Sequoioxylon sequoianum* (Schmal.) Du, *Taiwanioxylon Krasheninnikovii* (Jam.) Khudaiberdyev and *Taxodioxylon* sp. from the Palaeocene of Fushun, although they were reported from North America, Europe and Siberia of USSR from the Late Cretaceous to the Pliocene (Anonymous, 1978, pp. 10-14, Du, 1982). Therefore, the present study records the presence of plants comparable to *Taxodium-Sequoia* in China during the Miocene period.

SYSTEMATIC DESCRIPTION

Family—Taxodiaceae

Genus—*Taxodioxylon* Hartig 1848 emend. Gothan 1905

Taxodioxylon chinense sp. nov.
Pl. 1, figs 1, 3; Pl. 2, figs 5-9

Material—This species is based on a single piece of petrified secondary wood measuring about 10 cm in length and 7 cm in diameter.

Description—*Growth rings* distinct, demarcated by radially compressed tracheids of the late wood, 840-1260 μm in width, transition from early to late wood more or less abrupt. *Late wood* zones narrow to wide, about 7-18 cells, usually more than 10 cells or 180 µm wide, narrower than early wood (Pl. 1, fig. 1), tracheids thick-walled, walls about 6 µm thick, flattened, squarish to rectangular in cross-section with small lumina, t.d. 24-25 µm, r.d. 18-45 µm. *Early wood* zones about 10-20 cells thick, tracheids thin-walled, walls about 3 µm thick, squarish or rectangular in shape in cross-section with wide lumina, t.d. 36-45 µm, r.d. 45-90 µm (Pl. 2, fig. 5). *Pits* on radial walls of tracheids bordered, 1-3 seriate, usually 2-3 seriate in the early wood tracheids, round, opposite and separate to contiguous, often paired, 27 µm in diameter, pit apertures round, about 9 µm in diameter (Pl. 2, figs 6, 7); tangential walls of tracheids usually smooth, sometimes pitted, pits bordered, round, separated and smaller than on radial walls, about 15 µm in diameter with round apertures. *Bars of Sanio* present (Pl. 2, figs 6, 7). *Xylem rays* uniseriate, 1-16 cells or 30-390 µm high, usually 4-9 cells or 182-266 µm high (Pl. 1, fig. 3), ray cells round, squarish, rectangular or barrel-shaped in tangential section, usually 27 µm in width, 30 µm in vertical height and up to 150 µm in radial length, some of them with dark gummy deposits (Pl. 1, fig. 3); the horizontal and tangential walls of ray cells thin and smooth. *Cross field* pits taxodioid, 2-5, usually 3 per cross-field, rather large oval in shape, about 14 µm in diameter and commonly in 1-2 horizontal rows, aperture quite big, oval in shape, 12 µm in diameter and arranged horizontally or diagonally (Pl. 2, figs 8, 9). *Axial parenchyma* abundant, diffuse or sometimes in tangential rows (Pl. 2, fig. 5), mainly distributed in early wood, cells squarish or rectangular in cross-section, about 30 µm in diameter and 155 µm in vertical height, often with dark gummy deposits.

Affinities—The important anatomical characters of the fossil wood are—distinct growth rings, 1-3 seriate bordered pits, uniseriate xylem rays, taxodioid cross-field pits and abundant axial parenchyma. All these features indicate that the present fossil belongs to conifers. Among the conifers it can easily be separated from the families Araucariaceae, Taxaceae and Cephalotaxaceae in the absence of alternate, hexagonal pits and the spiral thickenings on the walls of the tracheids. The absence of resin ducts and the pinoid or abietinean pitting excludes Pinaceae or Abietineae. In Podocarpaceae, the cross-field pits are large, simple or slightly bordered and the growth rings are generally not sharp. Besides, the cross-field pits are also vertically oblique in Podocarpaceae. Cupressaceae and Taxodiaceae show very close xylotomical features with the present fossil wood. However, Cupressaceae can be distinguished by the presence of cupressoid cross-field pits, almost exclusively uniseriate, rarely biseriate pits in the radial walls of the tracheids and generally short xylem rays (Greguss, 1955; Phillips, 1941). Thus it is only with the family Taxodiaceae that the fossil wood shows a close similarity specially with *Taxodium* and *Sequoia* (Greguss, 1955; Jane, 1956).

As neither traumatic resin canals nor partly biseriate xylem rays are seen in the present fossil wood, it can not belong to the genus *Sequoia*. However, the present fossil wood shows close similarity with *Taxodium distichum* in most of anatomical features, except the shape of the cross-field pits which somewhat approximates that of *Sequoia sempervirens* (Brown & Panshin, 1940, p. 347, fig. 105). Probably, the fossil is an intermediate between these two genera.

PLATE 1

1. *Taxodioxylon chinense* sp. nov.—Cross section showing distinct growth rings and early and late wood zones × 50. Slide no. XJ-1-1.
2. *Taxodium distichum* (L.) Rich.—Cross section of the modern wood showing similar growth rings and the tracheids as in the fossil wood × 50. Slide no. BSIP W190.
3. *Taxodioxylon chinense* sp. nov.—Tangential longitudinal section showing distribution of xylem rays × 130. Slide no. XJ-1-3.
4. *Taxodium distichum* (L.) Rich.—Tangential longitudinal section of the modern wood showing similar structure of xylem rays as in the fossil wood × 130. Slide no. BSIP W190.
5. *Taxodioxylon chinense* sp. nov.—Another cross section showing the tracheids and axial parenchyma × 50. Slide no. XJ-1-1.
6. *Taxodioxylon chinense* sp. nov.—Radial longitudinal section showing 1-3 seriate bordered pits on radial walls of tracheids × 210. Slide no. XJ-1-2.
7. *Taxodioxylon chinense* sp. nov.—Radial longitudinal section magnified to show the details of 2-3 seriate bordered pits on tracheids and the Bars of Sanio × 1225. Slide no. XJ-1-2.
8. *Taxodioxylon chinense* sp. nov.—Radial longitudinal section magnified to show the cross-field pitting × 1225. Slide no. XJ-1-2.
9. *Taxodioxylon chinense* sp. nov.—Another radial longitudinal section magnified to show the cross-field pitting × 1225. Slide no. XJ-1-3.

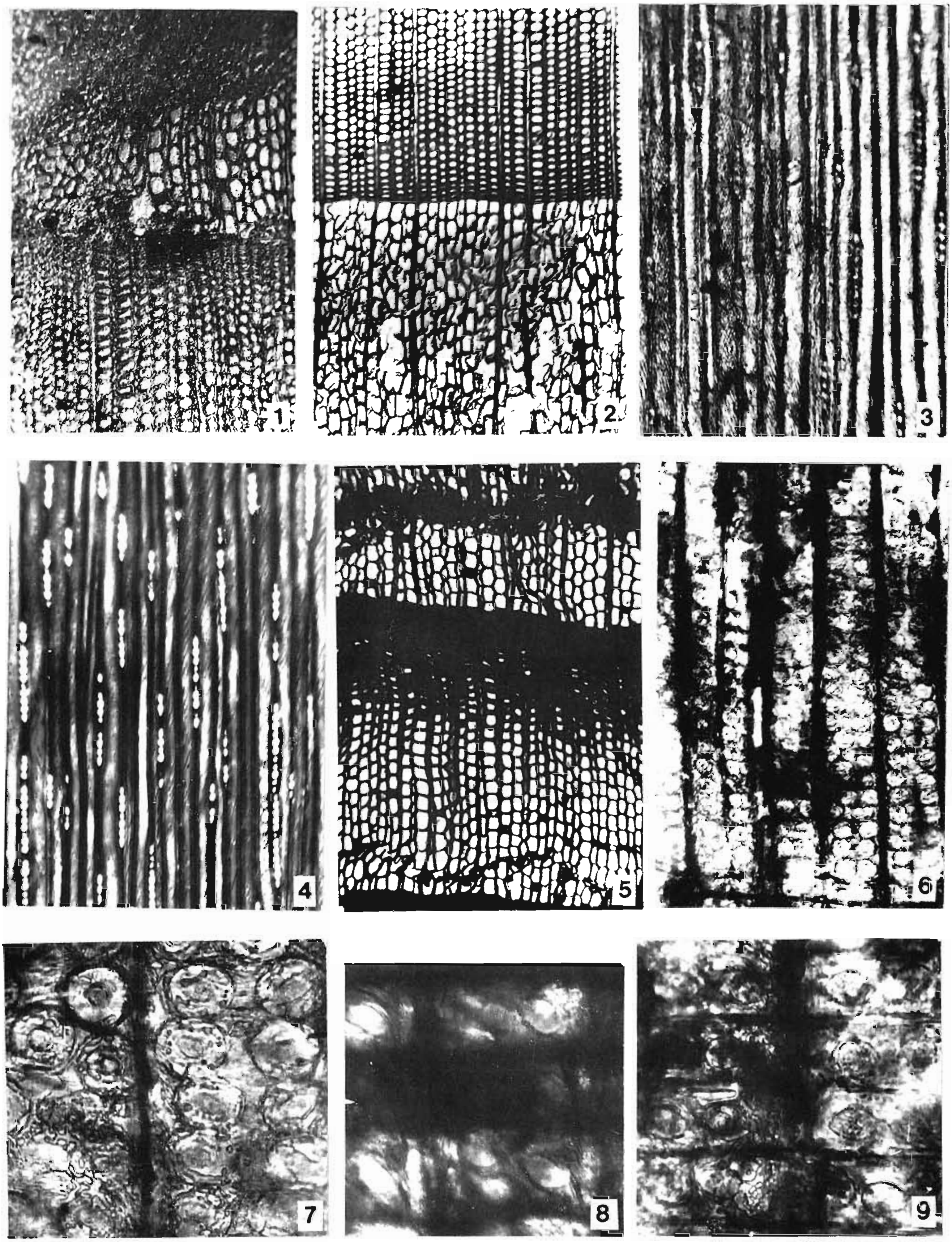

PLATE 1

The genus *Taxodioxylon* was established by Hartig in 1848 for describing the fossil woods of Taxodiaceae (Seward, 1919). A large number of species of *Taxodioxylon* have so far been described from the Cretaceous and Tertiary formations throughout the world. These have been enumerated and classified by Kräusel (1919, 1949) and Prakash (1968, 1972). Since then, a number of species have been added to *Taxodioxylon*. Besides, some other taxodiaceous fossil woods have also been recorded, viz., *Glyptostroboxylon tenerum* (Kraus) Conwentz (Kostyniuk, 1967) from the Tertiary of Turow, south-west Poland, *Metasequoioxylon hungaricum* Greguss 1967, *Sequoioxylon* cf. *S. germanicum* Greguss 1967, *Sequoioxylon medullare* Greguss 1967, and *Sequoioxylon podocarpoides* Greguss 1967—all from the Tertiary of Hungary and *Sequoioxylon sequoianum* (Schmal.) Du 1982 as well as *Taiwanioxylon krasheninnikovii* (Jam.) Khudaiberdyev (Du, 1982) from the Palaeocene of Fushun, China. Amongst those reported from China are: *Taxodioxylon cryptomerioides* (Schonfeld) Du 1982, *Sequoioxylon sequoianum* (Schmal.) Du 1982 and *Taiwanioxylon krasheninnikovii* (Jam.) Khudaiberdyev (Du, 1982) which apparently bear affinities with the woods of *Cryptomeria, Sequoia* and *Taiwania* respectively and differ from the present fossil in having 1-2 seriate usually uniseriate bordered pits in radial walls of the tracheids and 1-4, usually 2 cross-field pits in *Taxodioxylon cryptomerioides*, very narrow late wood zones (usually 1-2 cells thick) and very high xylem rays (1-40 cells high) in *Sequoioxylon sequoianum*, and cupressoid cross-field pits in *Taiwanioxylon krasheninnikovii*.

A detailed comparison with other fossil woods of *Taxodioxylon* indicates that the present fossil is also different from all of them in some features such as number, shape and size of cross-field pits on the radial wall, height of xylem rays, etc. Hence, it is being named here as a new species *Taxodioxylon chinense* sp. nov., the specific name indicates its occurrence in the Miocene sediments of China.

Although a number of fossil species which may belong to the genus *Taxodium* have been reported from all over the world, there are only three living representatives in this genus, i.e., *Taxodium ascendens* Brongniart, *T. distichum* (L.) Rich. and *T. mucronatum* Ten., while the genus *Sequoia* is represented only by one species, *Sequoia sempervirens* Endlicher (Willis, 1973, pp. 1060, 1132). *Taxodium distichum* and *Sequoia sempervirens* are both very large trees and now-a-days they grow in North America only. But during the Cretaceous and Tertiary times they were widely distributed throughout the Northern Hemisphere (Florin, 1963, pp. 209-212). According to Florin's study on the distribution of conifer genera in time and space, the genera *Sequoia* and *Taxodium* probably disappeared from the Europe-Asian continent by the end of the Pliocene period (Florin, 1963, p. 210). However, so far no fossils showing affinities with these genera are known from the Neogene deposits of China, although a few fossil leaf and woods resembling *Taxodium* and *Sequoia* were found from the Eocene and Palaeocene formations of this region (Anonymous, 1978, pp. 11, 13; Du, 1982). So the present finding adds some more evidence about the occurrence and distribution of the genera *Taxodium* and *Sequoia* in China during the Neogene.

SPECIFIC DIAGNOSIS

Taxodioxylon chinense sp. nov.

Growth rings distinct. *Late wood* about 7-18(10) cells thick; tracheids thick-walled, walls about 6 μm thick, flattened, squarish to rectangular in shape with small lumina, t.d. 24-25 μm, r.d. 18-45 μm. *Early wood* usually several times wider than the late wood; *tracheids* squarish or rectangular in shape with wide lumina, t.d. 36-45 μm, r.d. 45-90 μm. *Pits* on the radial walls of tracheids 1-3 seriate, bordered usually 2-3 in the early wood, round, opposite and separate to contiguous, often paired, 27 μm in diameter; apertures round, about 9 μm in diameter; tangential walls usually smooth, pits round, separated and smaller than in radial walls, about 15 μm in diameter with round apertures. *Bars of Sanio* present. *Xylem rays* uniseriate, 1-16 cells or 39-390 μm high; ray cells round, squarish, rectangular or barrel-shaped in tangential section, usually 27 μm in width and 30 μm in vertical height, up to 150 μm in radial length; the horizontal and tangential walls of ray cells thin and smooth. *Cross-field pits* taxodioid, 2-5 usually 3 per cross-field, rather large, oval in shape, about 14 μm in diameter and commonly in 1-2 horizontal rows; pit apertures quite big, oval in shape, 12 μm in diameter and arranged diagonally. *Axial parenchyma* abundant, diffuse and in tangential rows, mainly distributed in the early wood and resiniferous; parenchyma cells squarish or rectangular in cross-section, about 50 μm in diameter. *Resin canals* absent.

Holotype—Palaeobotany Department Herbarium Specimen no. YJ-1, Botanical Institute, Academia Sinica, China.

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A new interpretation on the structure of *Sahnia nipaniensis* Mittre from the Rajmahal Hills

O. P. Suthar & B. D. Sharma

Suthar, O. P. & Sharma, B. D. (1989). A new interpretation on the structure of *Sahnia nipaniensis* Mittre from the Rajmahal Hills. *Palaeobotanist* **37**(1) : 90-93.

Description of five, serial, longitudinal sections cut through a male flower *Sahnia nipaniensis* of the Pentoxyleae, collected from the Rajmahal Hills, Bihar has been given. The flower was borne terminally on a dwarf shoot. Sporophylls are spirally arranged around a cylindrical receptacle. Sporangia are produced in opposite rows. A restoration of the flower is also given.

Key-words—Megafossil, Pentoxyleae, Gymnosperm, *Sahnia*, Rajmahal Hills (India).

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सारॉंश

राजमहल पहाड़ियों से साहनिआ निपनियेन्सिस की संरचना पर एक नवीन व्याख्या

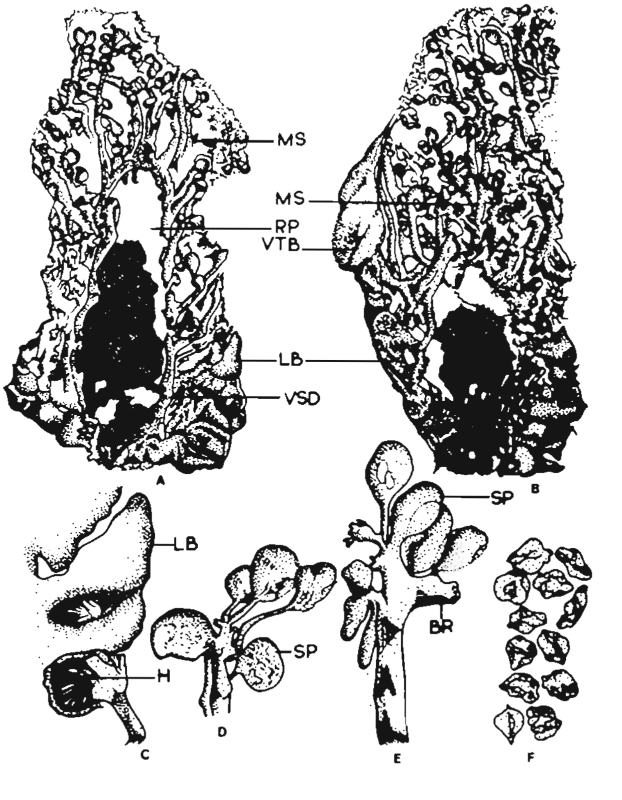
ओ० पी० सुथार एवं बी० डी० शर्मा

बिहार में राजमहल पहाड़ियो से एकत्रित पेन्टॉक्सीली समूह के **साहनिआ निपनियेन्सिस** नामक नर पुष्प की पाँच क्रमिक लम्बवत् काटों का वर्णन किया गया है। यह पुष्प एक बौने प्ररोह के अन्तिम सिरे पर लगा हुआ था। इस पुष्प में बीजाणुपर्ण बेलनाकार धानी के चारों ओर चक्र के रूप में विन्यस्त हैं तथा बीजाणुधानीयाँ विपरीत पंक्तियों में विद्यमान हैं। इस पुष्प का पुनः स्थापित चित्र भी इस शोध-पत्र में प्रस्तुत किया गया है।

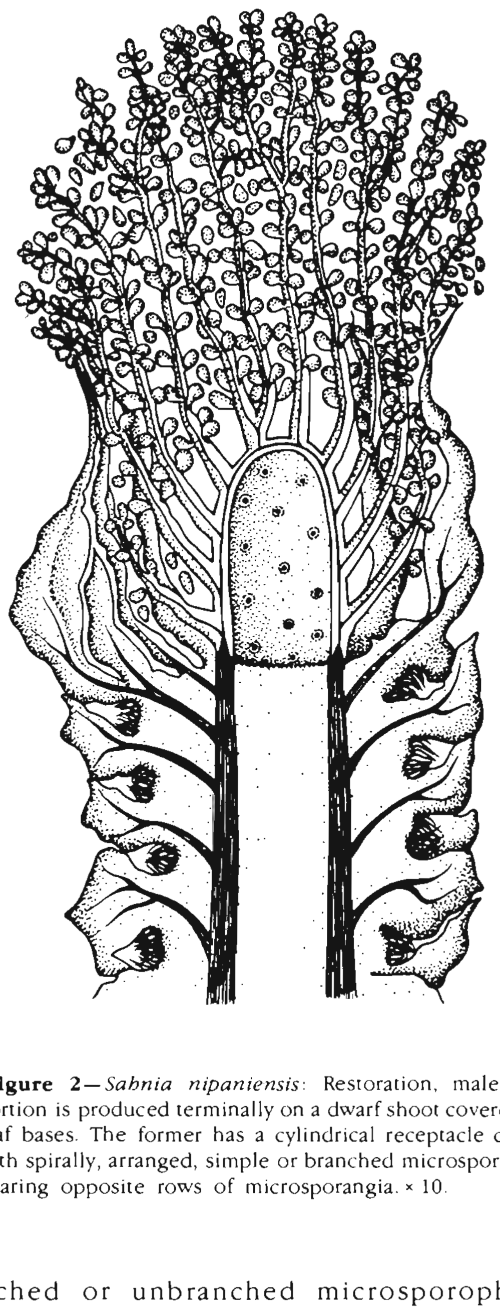
THE genus *Sahnia* was established by Vishnu-Mittre (1953) for a male flower of the Pentoxyleae, borne terminally on a dwarf shoot and consisting of about 24 simple or branched microsporophylls with spirally arranged pear-shaped sporangia. Each sporangium produced a large number of boat-shaped, monocolpate pollen. For the present study 5 serial longitudinal sections were cut through a male flower collected from Nipania, Rajmahal Hills by late Professor K. M. Gupta in 1956 and very kindly spared for the present study. It is a hard silicified chert.

DESCRIPTION

The dwarf shoot is covered with spirally arranged, rhomboid or laterally elliptical leaf bases, the abaxial surfaces of which are provided with dense growth of hairs (Text-fig. 3). Each leaf base has a hypodermal layer and the ground tissue is made up of parenchyma. A number of vascular bundles are arranged in a straight line on the upper half of each leaf base; however, details of the bundles are not clear. In the terminal portion of the dwarf shoot is a long, cylindrical receptacle measuring 10 × 4 cm (Pl. 1, fig. 1; Text-fig. 1A) from the entire surface of which arise simple or branched, 2.7-4.2 mm long, microsporophylls in close spirals. Each microsporophyll has a number of balloon-or pear-shaped, sub-sessile or stalked, sporangia in two lateral rows (Pl. 1, figs 3, 4; Text-figs 1D, E). The sporangia originate little above the point of attachment of sporophylls to the receptacle. Each sporangium is 162 × 129 μm in size and encloses boat-shaped, elliptical or circular monocolpate pollen ranging 7 × 17-10 × 22 μm in size (Pl. 1, figs 5-7; Text-fig. 1F). Young sporangium has 3-4 cells thick wall which remains only one cell thick in the



Text-figure 1—A, *Sahnia nipaniensis*: L. S. showing central receptacle and sporophylls originating from its entire surface. Sporophylls possess sporangia. × 8; **B**, Tangential longitudinal section showing fertile portion and the dwarf shoot. × 8; **C**, Leaf bases on dwarf shoot bearing hairs on abaxial surfaces. × 24; **D**, Portions of microsporophylls producing opposite rows of balloon-shaped microsporangia. × 24; **E**, Spores of various shapes and sizes with irregular exine. × 120. (**MS**—Microsporophyll, **SP**—Sporangium,. **DS**—Dwarf shoot, **LB**—Leaf bases, **H**—Hair, **R**—receptacle).



Text-figure 2—*Sahnia nipaniensis*: Restoration, male fertile portion is produced terminally on a dwarf shoot covered with leaf bases. The former has a cylindrical receptacle covered with spirally, arranged, simple or branched microsporophylls bearing opposite rows of microsporangia. × 10.

mature sporangium. The cells of inner layers are different from that of the outermost layer, i.e., epidermis. The former are large, rectangular and probably acted as tapetum. The basal portion of receptacle with its microsporophylls is protected by the vertically oriented bracts (Pl. 1, fig. 2; Text-fig. 1B). These are modified leaves, 4 to 6 mm in length.

RECONSTRUCTION

Vishnu-Mittre (1953) in his reconstruction of *Sahnia nipaniensis* suggested the occurrence of 24 unbranched sporophylls united at their bases, around a dome-shaped receptacle at the apex of the dwarf shoot. Bose *et al.* (1985) believe that the sporangiophores were stiff, straight and branched and bore simple pollen-sacs. In the re-construction suggested here (Text-fig. 2), the apical long, cylindrical receptacle bears spirally arranged, branched or unbranched microsporophylls. Branching is dichotomous or monopodial. Two lateral, opposite rows of balloon-shaped sporangia are produced on the sporophylls. Each sporangium encloses a large number of monocolpate pollen with reticulate exine. The dwarf shoot possesses spirally arranged leaf bases with dense growth of hairs on abaxial surface. In the upper portion of the shoot there are vertical bracts which surround the receptacle and basal portions of the sporophylls.

DISCUSSION

The male reproductive organ of the Pentoxyleae is rare in occurrence. It was earlier believed to be partly identical to the male bennettitalean flower

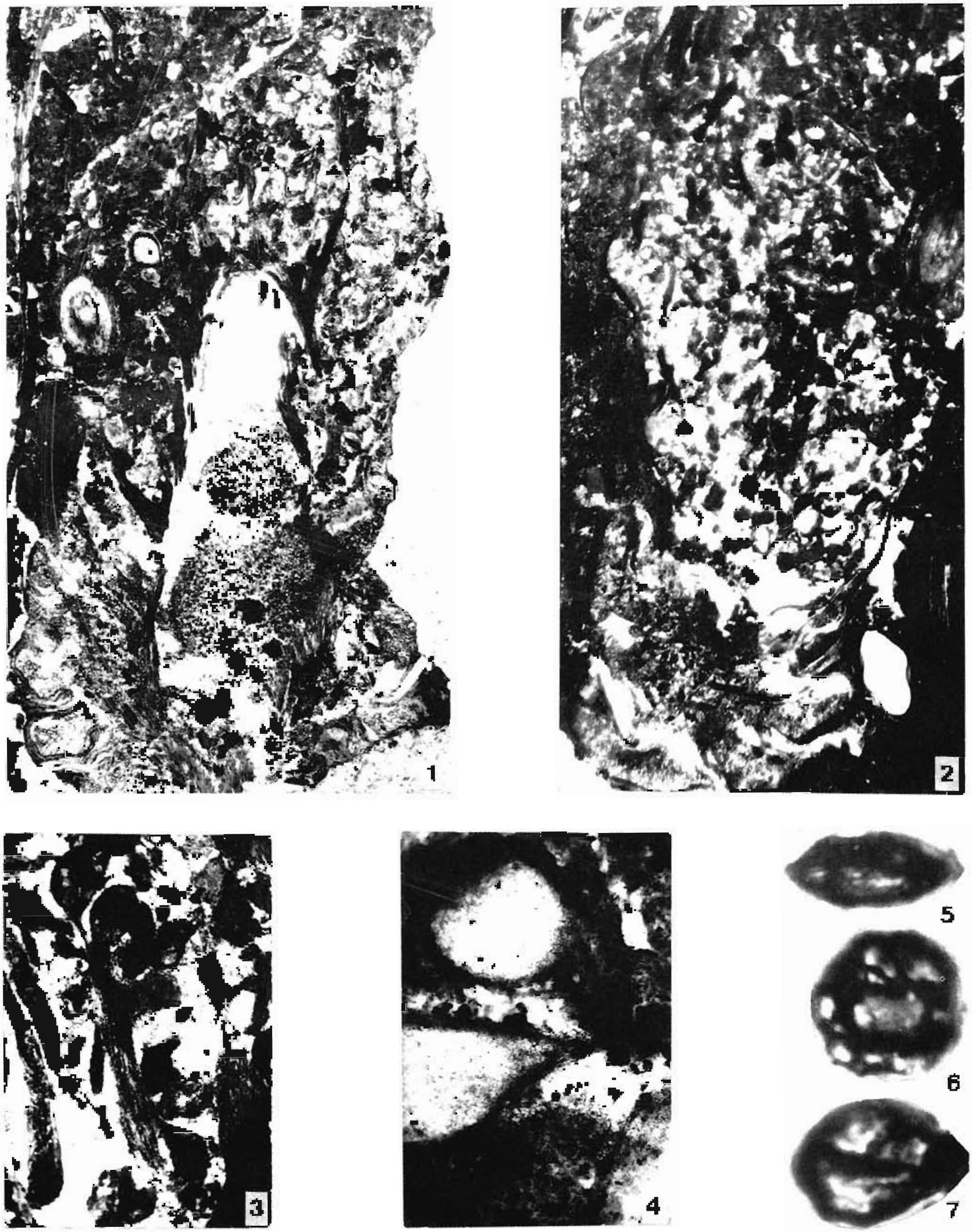


PLATE 1

Weltrichia santalensis Sitholey & Bose 1971 (Mittre, 1953, 1957; Rao, 1974, 1981). Twenty to 24 microsporophylls originated in a whorl surrounding a small dome-shaped receptacle. The bases of microsporophylls were fused and formed a cup like structure. However, on the basis of the study of a well-preserved *Sahnia* fructification it is suggested that *Sahnia* is not identical to *Weltrichia santalensis*. It has spirally arranged, radial, branched sporophylls similar to some of the pteridospermous plants, e.g., Caytoniales and Corystospermales. Bose *et al.* (1985) also suggested that *Sahnia* was built on a different plan than *Weltrichia*.

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PLATE I

Sahnia nipaniensis

1. L.S. of fructification showing a long, cylindrical receptacle with microsporophylls originating from it. On dwarf shoot portion leaf bases are seen. × 30.
2. Tangential longitudinal section through the fructification. Basal portion with dwarf shoot bearing leaf bases and the upper portion with microsporophylls. × 20.
3. A microsporophyll with opposite, balloon shaped sporangia. × 18.
4. Balloon shaped sporangia. × 25.

5-7. Monocolpate pollen of various shapes and sizes. (Note irregular) × 500.

The Palaeobotanist **37**(1) : 94-114, 1988.

Sporae-dispersae and correlation of Gondwana sediments in Johilla Coalfield, Son Valley Graben, Madhya Pradesh

R. S. Tiwari & Ram-Awatar

Tiwari, R. S. & Ram-Awatar (1989). Sporae dispersae and correlation of Gondwana sediments in Johilla Coalfield, Son Valley Graben, Madhya Pradesh. *Palaeobotanist* **37**(1) : 94-114.

The dispersed spores and pollen grains preserved in the sediments exposed along Johilla River Section, Ganjra Nala Section and in three bore-cores, viz., JHL-23, JHL-24, JHL-25, in Johilla Coalfield have been described. The rich miofloral assemblage consists of 58 genera and 126 species, out of which seven species are new on the basis of their morphological characters. These are—*Callumispora paliensis, C. saksenae, Osmundacidites baculatus, Dentatispora mammoida, D. reticulata, Gondisporites reticulatus* and *Lunatisporites paliensis*.

On the basis of composition of spores and pollen grains, it has been concluded that the South Rewa Gondwana Basin shows broader relationship with equivalent strata in other basins of India. In general, the monosaccate pollen have a better representation in the Talchir as well as Barakar sediments which is suggestive of relatively cooler conditions than those in Damodar Valley. Six palynological zones have been identified on the basis of quantitative analysis.

Key-words—Palynostratigraphy, Correlation, Gondwana, Son Valley Graben (India).

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सारॉश

मध्य प्रदेश में सोन घाटी द्रोणिका के जोहिल्ला कोयला-क्षेत्र में गोंडवाना अवसादों से विकीरित बीजाणु-परागकण तथा इनके सहसम्बन्ध

राम शंकर तिवारी एव राम अवतार

जोहिल्ला नदी खंड, गजरा नाला खड के संग-संग विगोपित अवसादों तथा जोहिल्ला कोयला-क्षेत्र के जे-एँच-एँल० 23, जे-एँच-एँल० 24 एवं जे-एँच-एँल० 25 नामक तीन वेध-क्रोड़ों में सुपरिरक्षित बीजाणुओं एवं परागकणों का वर्णन किया गया है। उपलब्ध भरपूर समुच्चय में 58 प्रजातियाँ एवं 126 जातियाँ विद्यमान है जिनमें से आकारिकीय लक्षणो के आधार पर सात जातियाँ नई हैं। ये **केलूमिस्पोरा पालीयेन्सिस, के० सक्सेनी, ओस्मुन्डेसीडाइटिस बेक्युलेटस, डेन्टाटिस्पोरा मेमोइडा**, **डे० रेटिकुलाटा**, **गोन्डिस्पोराइटिस रेटिकुलेटस** एवं **ल्यूनाटिस्पोराइटिस पालीयेन्सिस** नामक वर्गक हैं।

बीजाणुओं एवं परागकणों की संरचना के आधार पर यह निष्कर्ष निकाला गया है कि दक्षिण रीवा गोंडवाना का भारत की अन्य द्रोणियों में स्थित समतुल्य स्तरों से विस्तृत सम्बन्ध है। सामान्यतया तलचीर एवं बराकार अवसादों में एक-कोष्ठीय परागकणों का अपेक्षाकृत अच्छा निरूपण है जिससे यहां दामोदर घाटी की अपेक्षा ठंडी परिस्थितियों का होना इंगित होता है। परिमाणात्मक विश्लेषण के आधार पर छः परागाणविक मडल अभिनिर्धारित किये गये हैं।

JOHILLA Coalfield is situated (23°16′ : 23°23′ latitude and 80°57′ : 81°05′ longitude) at about 33 km south-east of Umaria Railway station on Katni-Bilaspur line of the Central Railway in district Shahdol, Madhya Pradesh. In this area, the age of Pali and Parsora formations and the strata of Middle Gondwana have been controversial since long.

During the last two decades, considerable palynological work has been carried out on the sediments of Son Valley Graben (South Rewa Gondwana Basin). Mehta (1944), for the first time, reported the presence of spores and pollen grains from this area and identified them as—*Pityosporites gondwanensis, Hymenozonotriletes,* etc. Saksena

(1947, 1949) reported a number of megaspores and seed-like bodies from Ganjra Nala bed from this region. Later on, Tripathi (1952) recorded the presence of megaspores from coal horizons of Umaria Coalfield and Saksena and Krishnamurti (1960) also reported a miofloral assemblage from Rangta Coal mine in South Rewa Gondwana Basin. Potonié and Lele (1961) were the first to report the *Sporae dispersae* from the Talchir Formation exposed at Goraia in Johilla Coalfield and recorded 13 genera of palynofossils from this bed; in this assemblage two species, i.e., *Lunatisporites goraiaensis* and *Potonieisporites neglectus* were proposed to be new. Maithy (1968) also recorded some miospores from Umaria and Johilla coalfields. Lele and Chandra (1969, 1972) reported Talchir assemblages including acritarch-like microfossils from this area. In 1971, Saksena described the dispersed palynofossils from the Ganjra Nala Section, while Lele and Chandra (1973) gave detailed account of palynological assemblages from this area. Thereafter, Chandra and Lele (1979) recovered palynofloras from Talchir Formation of Birsinghpur Pali, Anuppur, Chirimiri, Manendragarh and Umaria areas and established two major palynological zones—*Plicatipollenites-Parasaccites* miofloral Zone and *Parasaccites-Plicatipollenites* Zone within the Talchir. Jhingran (1979) also recorded palynofossils from Johilla Coalfield and commented upon the age of Parsora Formation. Srivastava and Anand-Prakash (1984) and Anand-Prakash and Srivastava (1984) have given an account of palynozones in Umaria and Johilla coalfields, respectively. Recently, Tiwari and Ram-Awatar, (1986, 1987) and Ram-Awatar (1988) recorded two palynological assemblages from Pali Formation and dated them Permian and Permian/Triassic in age, respectively.

Recently, Chandra and Srivastava (1986) have reported palynological assemblages from four areas, viz., Umaria, Birsinghpur Pali, Anuppur and Chirimiri with their biostratigraphical significance and assigned Karharbari age to these beds.

Presently, the results of palynological investigations have been given for the material representing Talchir to Pali formations (i.e. Early Permian to Early Triassic) from Birsinghpur Pali (Johilla Coalfield) in Son Valley, Madhya Pradesh. Palynological assemblages have been determined after quantitative analysis; sequential successions have also been built up. New taxa have been described in detail and compared morphographically. The six recognized palynozones have been dated, correlated and compared for general relationship. These results have thrown light on the variability of palynoassemblages in Lower Gondwana of this basin in comparison to Damodar Basin.

GEOLOGY

The area was surveyed by Medlicott in 1860; later, Hughes in the year 1881, systematically mapped the area. In 1928, Gee proved the presence of workable coalseams in Umaria Coalfield. Fox (1934) gave a brief geological account of the Johilla Coalfield describing the presence of Talchir, Karharbari, Barakar and Supra-Barakar formations in the area; he also suggested the presence of Karharbari horizon at about 0.92 km South of Mangthar Village. The oldest rocks found in the Johilla Coalfield are metamorphic which are exposed mainly in the southern region of Birsinghpur Pali. The Archean rocks are unconformably overlain by Gondwana sediments the base of which is Talchir, overlain by Barakar and Supra-Barakar sediments; still younger sequences consist of Lameta and trap covered by soil. According to Jhingran (1979), the lithostratigraphic sequence is as given below (Map 1):

Traps
Lametas
..................................Unconformity..............................
Supra-Barakar
Barakar
Talchir
..................................Unconformity..............................
Metamorphic

The characteristic sedimentological features and other details of the lithological succession are as follows.

Metamorphic—These rocks cover an area of about 20.72 sq km lying in the southern part of the coalfield; towards their north, the basement rocks are covered by Talchir and partly by alluvium. The south-west portion is bordered by Lametas.

Talchir—Talchir Formation overlies the metamorphics; they are characterised by boulder bed, needle shales, siltstone and green sandstone. In Johilla Coalfield, Talchir exposures occupy an area about 10.84 km long and 0.9 km wide between the villages Kudri and Kumurdu; it is also exposed as a small band to the north of Mangthar. A good section of Talchir exposures can be seen near Barachada (23°21′ : 81°1′) where laminated greenish sandstone and needle shales are exposed at the base. Talchir boulder bed is exposed near Ponri

Village, where contact of Archean and Talchir can be traced.

Barakar—In Johilla Coalfield, Barakar sediments are exposed in south and south-west of Birsinghpur Pali township. Good sections of Barakar are exposed at about 3.6 km north-east of Mangthar Village, in a nala which is a tributary of Johilla River (Chandra & Lele, 1979) and at the junction of Ganjra Nala with Johilla River, 4.5 km south-west of Pali The Barakar sediments consist of yellowish to greyish feldspathic, silicious sandstone, shale, carbonaceous shale and coal.

The important seam in the northern area is Johilla seam which is exposed in Ganjra Nala in the east and Marjada Nala on the west splitting into three distinct bands.

Supra-Barakar—The Supra-Barakar encompasses all the Gondwana beds that are younger to the typical coal-bearing Barakars and differ in its lithology. Supra-Barakar sediments include Pali and Parsora formations which are homotaxial with Raniganj, Panchet and Supra-Panchet formations, in sequential position.

The Supra-Barakar are highly ferruginous in composition characterized by varuiys tints of red, yellow and whitish colour. The texture is graded and sandstones are with low iron content. The rocks near Parsora Village are fine-grained, dark red, ferruginous and reddish-brown sandstone, with thin bands (1-2 cm) of various shades of clay.

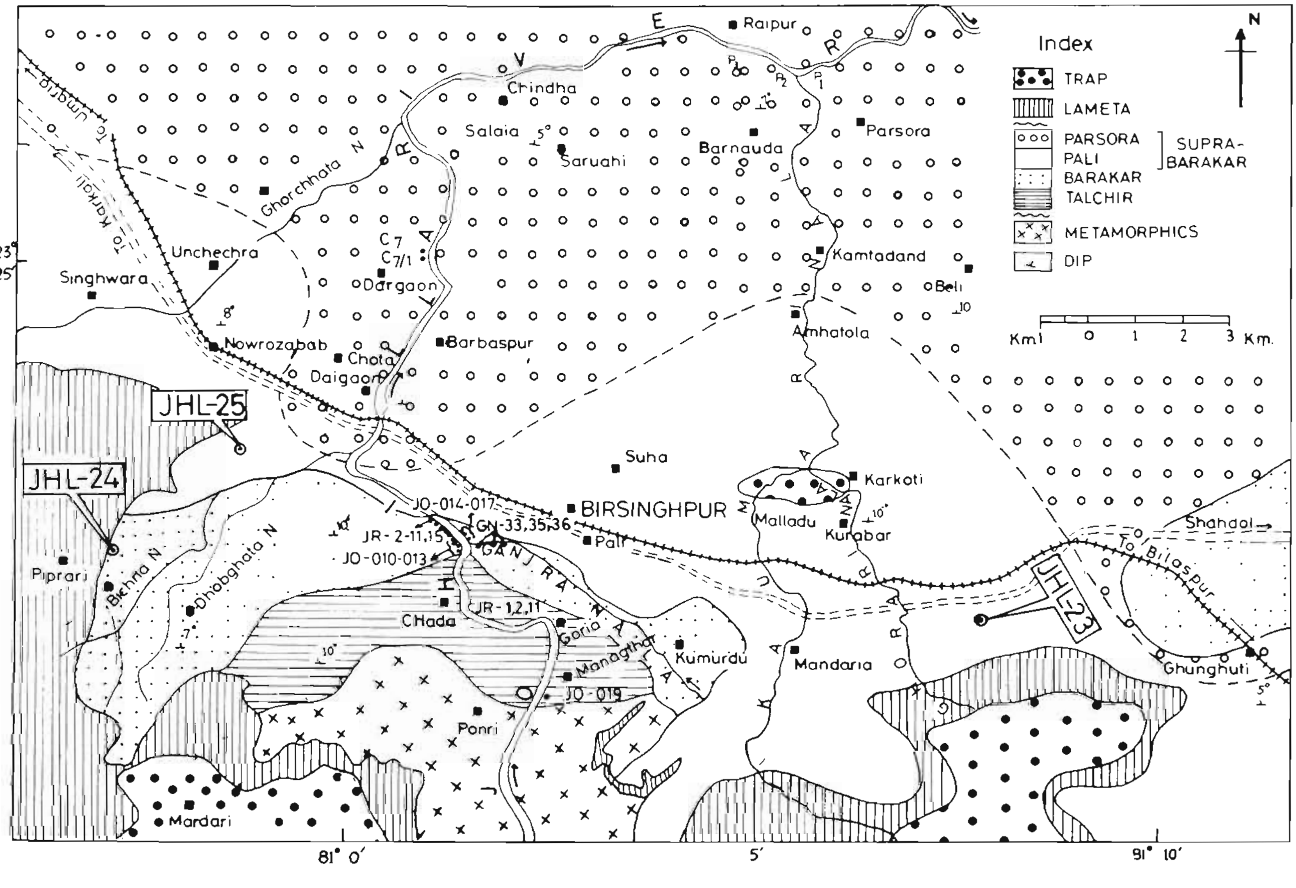
Lameta—The Lameta unconformably overlies Supra-Barakar which are exposed at the fringes, at about 1.8 km south of Maliagura and 3.7 km east of Ponri Village; there is an outlier of Lameta rock overlying the metamorphics. The rock type of Lametas are limestone, mostly gritty, but sometimes crysalline also.

Trap—The trap-flows exposed in the area are probably the continuation of Deccan trap (Hughes, 1884).

Soil—It covers different formations in different parts of the area. The blackish colour of the soil suggests that it is derived from trap rocks.

MATERIAL AND METHODS

For the present investigation 374 samples were collected, out of which 118 samples were found to



Map 1—Geological map of the part of Johilla Valley showing location of bore-holes and outcrop samples studied.

be productive. The samples were procured from three bore-holes (JHL-23, JHL-24 and JHL-25) and three river nala sections, viz., Johilla River, Gampa Nala and Kamun Nala (locally known as Ghorari Nala). A list of productive samples alongwith their locations are given in the following Tables (1-5). In maceration the usual method of acid and alkali treatment was followed and all the slides and negatives have been deposited at the Birbal Sahni Institute of Palaeobotany Museum.

Table 1 — Eastern part of Johilla Coalfield—bore-hole no. JHL-23

Sample nos	Lithology	Depth in meters
JHL 23/59	Coarse grained greenish sandstone	153.00-150.00
JHL 23/58	Sandy shale in sandstone	157.00-156.20
JHL 23/57	Carbonaceous streak in sandstone	173.50
JHL 23/56	Shale and coal in sandstone	175.50
JHL 23/55	Sandy shale	182.80-180.00
JHL 23/54	Sandy shale	193.00-192.80
JHL 23/53	Shale and sandy shale	185.00-183.00
JHL 23/52	Black shale	165.00
JHL 23/51	Fine laminated shale	166.50-165.50
JHL 23/50	Siltstone with dark shale streaks	187.50-186.50
JHL 23/49	Coaly shale	188.20-187.50
JHL 23/47	Shale	190.50-191.00
JHL 23/46	Shale	203.00-202.50
JHL 23/45	Carbonaceous shale	201.00-205.00
JHL 23/44	Shaly coal	205.00-204.00
JHL 23/43	Shale	206.00-205.00
JHL 23/42	Shale	206.00
JHL 23/41	Coal streaks in sandstone	206.80
JHL 23/40	Shale in sandstone	207.00-206.40
JHL 23/38	Shale	213.70-212.70
JHL 23/37	Carbonaceous shale	218.00-217.00
JHL 23/36	Carbonaceous shale	219.00-218.00
JHL 23/35	Coal with shale	220.80-219.00
JHL 23/34	Grey shale	222.80-220.80
JHL 23/33	Coaly shale	240.00-239.70
JHL 23/27	Shale	242.70-242.00
JHL 23/26	Micaceous greenish sandstone	245.70
JHL 23/21	Shale in sandstone	277.00
JHL 23/20	Shale	280.80-280.00
JHL 23/19	Shale	283.00
JHL 23/17	Carbonaceous shale in sandstone	285.50-286.00
JHL 23/16	Coarse grained sandstone	299.00-298.00
JHL 23/15	Shale streak in sandstone	305.00-304.00
JHL 23/13	Coaly shale	317.00
JHL 23/12	Grey shale	329.23-327.00
JHL 23/11	Grey shale	331.70-330.00
JHL 23/9	Shale	334.00-333.50
JHL 23/8	Shale	335.00
JHL 23/7	Shale	336.20-335.45
JHL 23/6	Shale	339.20-337.20
JHL 23/5	Grey shale	339.00
JHL 23/4	Shale	340.00
JHL 23/3	Shale	344.00
JHL 23/2	Shale	347.80
JHL 23/1	Shale	348.00

Table 2 — Western part of Johilla Coalfield—bore-hole no. JHL-24

Sample nos	Lithology	Depth in meters
JHL 24/9	Carbonaceous shale	72.30-72.00
JHL 24/10	Shale	73.50-74.00
JHL 24/11	Shale	80.50
JHL 24/13	Coarse grained sandstone	81.00-82.50
JHL 24/14	Shale	82.50-82.80
JHL 24/15	Shale with fossils	82.80-83.00
JHL 24/16	Carbonaceous streak in sandstone	83.00-85.00
JHL 24/17	Carbonaceous shale	85.00-85.30
JHL 24/18	Coal	85.30-85.60
JHL 24/19	Shale and coal	85.60-86.00
JHL 24/20	Sandstone and shale	87.00-88.00
JHL 24/21	Shale and sandstone	88.00-88.10
JHL 24/23	Shale and sandstone	90.00-91.00
JHL 24/24	Carbonaceous shale	91.00-91.20
JHL 24/25	Sandstone with shale streak	91.00-92.10
JHL 24/27	Sandstone with shale streak	93.00-95.00
JHL 24/29	Shale	105.80-107.20
JHL 24/30	Shale	112.00-113.00
JHL 24/33	Shale	150.00-150.25
JHL 24/34	Sandstone with compact shale	153.25-155.00
JHL 24/35	Sandstone with coal streak	161.00
JHL 24/36	Shale	174.00-175.00
JHL 24/37	Shale	180.00-185.00
JHL 24/39	Compact shale	181.00-187.00
JHL 24/40	Grey shale	192.00-193.00
JHL 24/41	Black shale	193.00-194.00
JHL 24/42	Sandstone	194.00-200.00
JHL 24/43	Shale with fossils	200.00-207.70
JHL 24/44	Sandstone with shale	209.00-210.00
JHL 24/45	Sandstone with shale	211.00-210.00
JHL 24/45A	Sandstone with shale	210.00-211.00
JHL 24/46	Sandstone with shale	212.00-212.50
JHL 24/47	Sandstone with shale	212.50-213.00
JHL 24/48	Sandstone with shale	213.00-213.50
JHL 24/49	Sandstone with shale	213.50-215.00
JHL 24/50	Sandstone with coal	215.00-215.50
JHL 24/51	Sandstone with shale	231.00-234.00

Table 3 — Western part of Johilla Coalfield—Bore hole no. JHL 25

Sample nos	Lithology	Depth in meters
JHL 25/12	Shale	39.50-37.00
JHL 25/13	Carbonaceous shale and coal	40.00-39.50
JHL 25/11	Carbonaceous shale	40.00
JHL 25/10	Shale	65.00
JHL 25/8	Coal	108.20-106.40
JHL 25/7	Shale	133.13
JHL 25/5	Coaly shale	135.75
JHL 25/1	Shale	180.00
JHL 25/31	Shale	190.00

Table 4 — Johilla River Section from Pali to Dargaon villages

Sample nos	Lithology	Remarks
C-7	Black micaceous shale	
C-7/1	Black micaceous shale	Rich

Jo-13	Coal	Barakar
Jo-14	Shale	
Jo-015	Coal	
Jr-10	Coal	Karharbari
Jr-15	Coal	
Jr + 3	Carbonaceous shale	
Jr + 4	Fine grained sandstone	
Jr + 5	Coal	
Jr + 6	Carbonaceous shale	
Jr + 7	Carbonaceous shale	
Jr + 8	Coarse grained sandstone	
Jr + 9	Carbonaceous shale	
Jr + 11	Carbonaceous shale	
Jr - 2	Mudstone	Talchir
Jo - 09	Khaki shale	

Table 5—Ganjra Nala Section

Sample nos.	*Lithology*	*Remarks*
GN-33	Carbonaceous shale	Karharbari/Barakar
GN-35	Carbonaceous shale	
GN-36	Carbonaceous shale	

SYSTEMATIC PALYNOLOGY

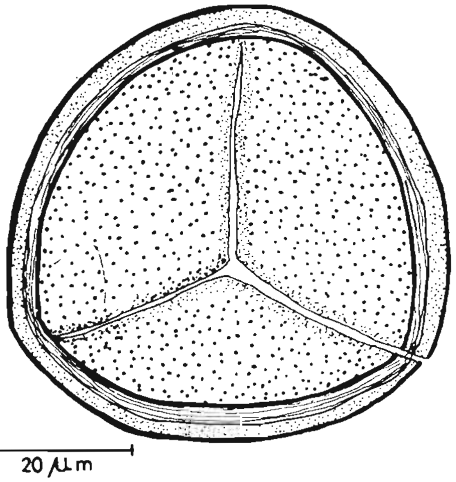
Genus—*Callumispora* Bharadwaj & Srivastava 1969

Type species—*Callumispora barakarensis* Bharadwaj & Srivastava 1969

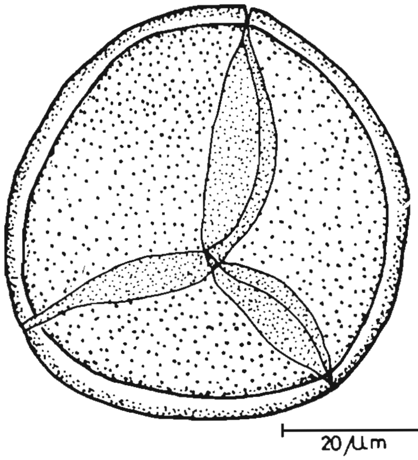
Callumispora paliensis sp. nov.
Pl. 1, figs 5-8; Text-fig. 1

Holotype—Pl. 1, fig. 5, size 58 μm; slide no. BSIP 9308.

Locus typicus—Bore-hole no. JHL-25, depth 180-190 m, about 8 km west from Birsinghpur-Pali, Johilla Coalfield, Lower Karharbari Formation, Early Permian.



Text-figure 1—*Callumispora paliensis* sp. nov. showing the nature of trilete mark, rays extending up to the equatorial margin; distribution of intrapunctate structure throughout the surface, and the thickened exine.



Text-figure 2—*Callumispora saksenae* sp. nov. showing the nature of folded trilete rays extending up to the equatorial margin.

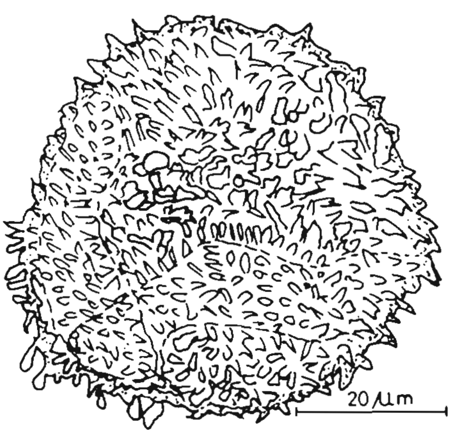
Diagnosis—Triangular to subtriangular with prominent trilete mark, rays reaching up to equatorial margin. Exine finely inframicropunctate in structure, with uniformly distributed pits all over body surface, exine 3-4 μm thick, a sharp line of thickness demarcation being distinct in optical section. *Extrema lineamenta* smooth.

Description—Miospores triangular to subtriangular with convex sides and rounded corners. Size range 58-70 μm. Trilete rays distinctive in being extended up to the equator and in having uniformly thick lips. Exine thickness sharply defined in optical section, puncta not restricted to the contact area, on the contrary uniformly distributed all over the body surface.

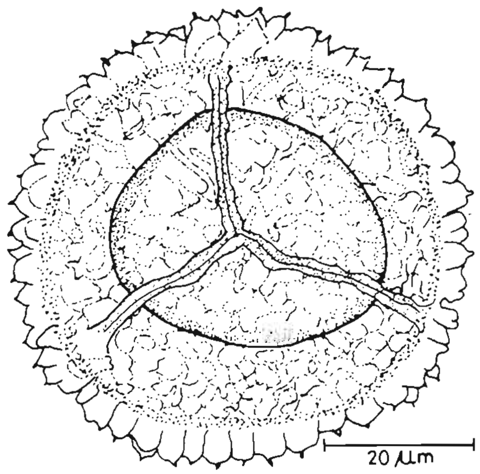
Comparison—*Callumispora paliensis* sp. nov. *differs from all the known species of the genus—C. barakarensis, C. tenuis* (Bharadwaj & Srivastava 1969) and *C. fungosa* (Balme) Bharadwaj & Srivastava emend. Bharadwaj & Tiwari 1977, in having well-defined trilete mark whose rays reach up to the equator and also in the nature of uniformly structured exine.

The scanning electron micrograph (Pl. 1, fig. 8) of a slightly opened specimen reveals the presence of structure within the surface on inner side (top left region) and also the nature of surface where few sparse low elevations are seen (top right region), suggesting thereby that the exine is not 'polished' smooth but has some specks or pimple-like low elevations which could be revealed only in SEM.

Derivation of name—The name has been derived after Pali Village, the type area.



Text-figure 3—*Osmundacidites baculatus* sp. nov. exhibiting the nature of ornamentation including bacula and coni on the equator as well as on surface.



Text-figure 4—*Dentatispora mammoida* sp. nov. showing the nipple-like sculptural elements and folded, thick-lipped trilete mark beside the cingulum, inner body and general pattern of sculpture.

Callumispora saksenae sp. nov.
Pl. 1, figs 3, 4; Text-fig. 2

Holotype—Pl. 1, fig. 3, size 66 µm; slide no. BSIP 9309.

Locus typicus—Bore-hole no. JHL-25, depth 182-190 m; about 8 km west from Birsinghpur-Pali, Johilla Coalfield, Lower Karharbari Formation, Early Permian.

Diagnosis—Subcircular to circulotriangular. Trilete mark distinct, rays reaching up to equator, accompanied with prominent folds. Exine 2-3 µm thick, distinctly and uniformly inframicropunctate; *extrema lineamenta* smooth.

Description—Size range 52-82 µm. Trilete mark prominent, rays associated with flapy folds which are broader at their centres (10-20 µm) and narrower at their tips. Exine coarsely infrapunctate, puncta distributed all over the body surface.

Comparison—Among the known species, only *Callumispora fungosa* (Balme) Bharadwaj & Srivastava 1969 emend. Bharadwaj & Tiwari 1977 compares due to its uniformly punctate nature of exine structure, but *C. saksenae* sp. nov. differs in having distinct folds which accompany the trilete rays.

Derivation of name—The name has been derived after Prof. S. D. Saksena.

Genus—*Osmundacidites* Couper 1953

Type species—*Osmundacidites wellmanii* Couper 1953

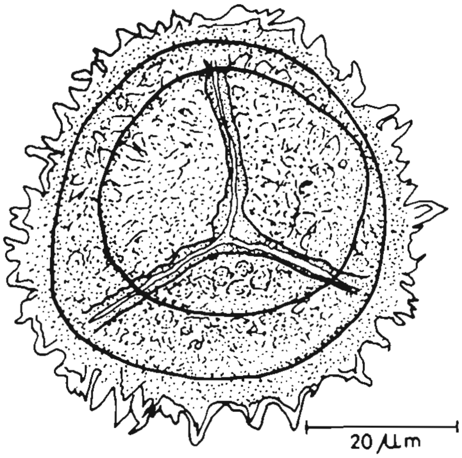
Osmundacidites baculatus sp. nov.
Pl. 1, figs 12-13; Text-fig. 3

Holotype—Pl. 1, fig. 12; size-53 µm; Slide no. BSIP 9052.

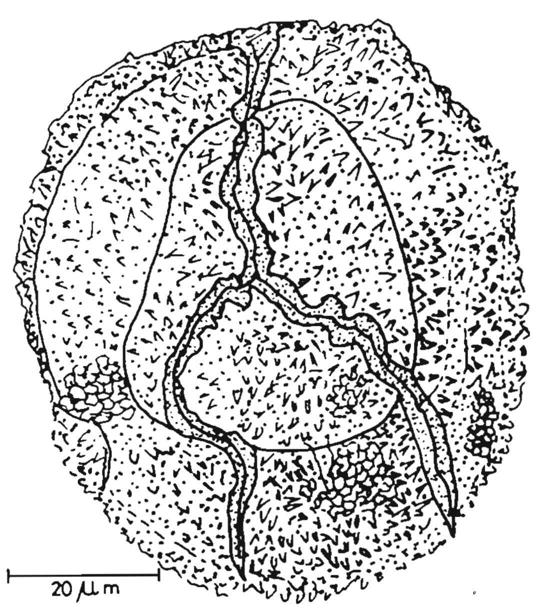
Locus typicus—Near Dargaon Village; Johilla River Section, Johilla Coalfield, Pali Formation, Late Permian/Early Triassic.

Diagnosis—Circular to subcircular; trilete mark distinct, rays reaching ± ¾ of spore radius; exine ± 1 µm thick, sculpture consisting of densely placed, 3-5 µm long and 1-1.5 µm broad, round-headed as well as finger-shaped bacula of varying shapes and sizes, intermixed with rare short coni and spines.

Description—Normally circular to subcircular, 50-60 µm, may be subtriangular due to folding and orientation of compressions. Trilete mark distinct, rays straight, simple with thin lips and low vertex. Ornamentation predominantly consisting of broad



Text-figure 5—*Dentatispora reticulata* sp. nov. showing reticulate exine, characteristic cingulum and the trilete mark.



Text-figure 6—*Gondisporites reticulatus* sp. nov. specimen showing the reticulate nature of exine at places.

cylindrical, round-headed, bacula or finger-shaped processes; short coni or spines are rarely found; sculptural elements found all over the surface of spore.

Comparison—*O. wellmanii* Couper 1953, *O. senectus* Balme 1963 and *O. pilatus* Tiwari & Rana 1981 are different from this species because of the nature of sculptural elements. The genus *Osmundacidites* is based on the type species which possesses small coni intermixed with a few spines. The present species possesses bacula, thus basically it is different, but now the circumscription of the genus being enlarged by inclusion of other types of ornamentation in this group, the present species has also been assigned to this genus. The mixed type of elements, however, remains the basic character of this genus.

Genus—*Dentatispora* Tiwari 1964

Type species—*Dentatispora indica* Tiwari 1964

Dentatispora mammoida sp. nov.
Pl. 1, figs 9-11; Text-fig. 4

Holotype—Pl. 1, fig. 9; size 60 × 62 µm; Slide no. BSIP 9307.

Locus typicus—Bore-hole no. JHL-24, depth 212.0-213.50 m; 10 km west from Birsinghpur-Pali, Johilla Coalfield, Barakar Formation, Permian.

Diagnosis—Subcircular to roundly triangular. Trilete mark distinct, rays thick-lipped extending up to inner margin of cingulum. Proximally exine intramicropunctate, on distal face ornamented with mostly nipple-like, rarely coni-type sculptural elements measuring 4-5 µm high and 3-4 µm broad at their bases. Cingulum distinct, 5-10 µm wide, bearing 4-8 µm high mammoidal sculpture. Inner body distinct.

Description—Roundly triangular in general shape, 60-72 µm, Y-mark distinct, rays thick-lipped, folded, reaching up to the cingulum; sculptural elements nipple-like, rarely coni, sometimes two or more than two elements being fused with each other; sparsely to densely distributed all over the distal surface as well as on the cingulum. A triangular, thin inner body generally seen.

Comparison—*D. mammoida* sp. nov. differs from all the other known species of this genus in having nipple-like sculptural elements.

Dentatispora reticulata sp. nov.
Pl. 1, figs 1-2; Text-fig. 5

Holotype—Pl. 1. fig. 1; size 70 µm; Slide no. BSIP 9304.

Locus typicus—Bore-hole no. JHL-24, depth 213.0-213.50 m; 10 km east from Birsinghpur-Pali, Johilla Coalfield, Barakar Formation, Permian.

Diagnosis—Subtriangular with dentate cingulum. Trilete mark distinct, rays thick-lipped, reaching up to cingulum. Body exine prominently intramicroreticulate, distally ornamented with 5-7 µm long, pointed or round-tipped coni which sometimes fused with each other. Inner body distinct.

Description—Trilete, rays thick-lipped and occasionally folded, reaching up to the cingulum, 65-70 µm. Body exine distinctly structured as intramicroreticulate (Pl. 1, fig. 1) distally ornamented with 5-7 µm high and 4-5 µm broad at base, conical sculptural elements which being closely placed and sometimes fused with each other at their bases. Cingulum 5-10 µm, unevenly broad, bearing longer processes. A subtriangular, thin inner body present.

Comparison—The specimens studied here are comparable to *D. gondwanensis* Tiwari 1965 in the nature of ornamentation but differs in having reticulate structure of exine.

Genus—*Gondisporites* Bharadwaj 1962

Type species—*Gondisporites raniganjensis* Bharadwaj 1962

Gondisporites reticulatus sp. nov.
Pl. 1, figs 16, 17; Text-fig. 6

Holotype—Pl. 1, fig. 16, size 90 × 95 μm; Slide no. BSIP 9055.

Locus typicus—Near Dargaon Village, Johilla River Section, Johilla Coalfield, Pali Formation, Late Permian/Early Triassic.

Diagnosis—Subcircular to roundly subtriangular. Exine thin, uniformly inframicroreticulate; trilete mark distinct, rays reaching beyond the equatorial ridge and entering into zona. Body surface showing coarse reticulate sculpture at places with fine muri and wide meshes, also sparsely spinulate to baculate ornaments present. Inner body distinct.

Description—Generally subcircular but sometimes aquiring subtriangular shape 90-95 μm in size; a well-defined inner body present. Y-mark prominent, rays extending up to the outer margin of zona; thick-lipped, slightly folded. Exine coarsely intrareticulate sculptured, at places, muri ± 1 μm thick, meshes 2-4 μm in diameter. Zona thin, transparent, consisting of irregular denticulate edge, densely covered with spinules, rarely less than 1 μm coni. Inner body distinct in being darker in appearance than the central body.

Comparison—Amongst the known species of *Gondisporites*, the present species compares with *G. raniganjensis* Bharadwaj 1962 in having densely covered spinules all over the surface as well as the zona. However, the specimens studied here are entirely different due to the presence of coarse reticulate sculpture at places on the exine.

Genus—*Lunatisporites* Leschik 1955 emend. Scheuring 1970

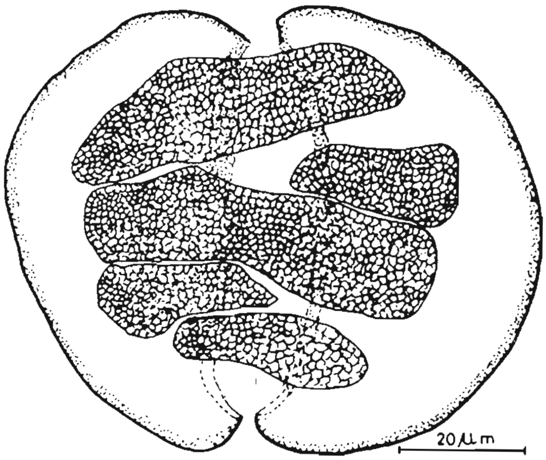
Type species—*Lunatisporites acutus* Leschik 1955

Lunatisporites paliensis sp. nov.
Pl. 1, figs 14, 15; Text-fig. 7

Holotype—Pl. 1, fig. 14; size 110-40 μm; Slide no. BSIP 9305.

Locus typicus—Bore-hole no. JHL-23, depth 203.0-204.0 m; about 9 km east from Birsinghpur-Pali, Johilla Coalfield, Barakar Formation, Permian.

Diagnosis—Central body indistinct, apparently subcircular to horizontally oval, indicated by taeniae-ends, bearing 3-5 big and massive taeniae having intramicroreticulate structure; rest of exine unstructured. Sacci proximally equatorially attached, distally inclined leaving a 10-20 μm broad free area, no typical lunar folds present, only narrow sometimes indistinct folding of saccus seen at the distal attachment zones. Sacci less than hemispherical, intramicroreticulate, meshes fine to medium-sized, muri thin.



Text-figure 7—*Lunatisporites paliensis* sp. nov. showing complete to incomplete, broad, thick, band-like massive taeniae and coarse reticulation on them.

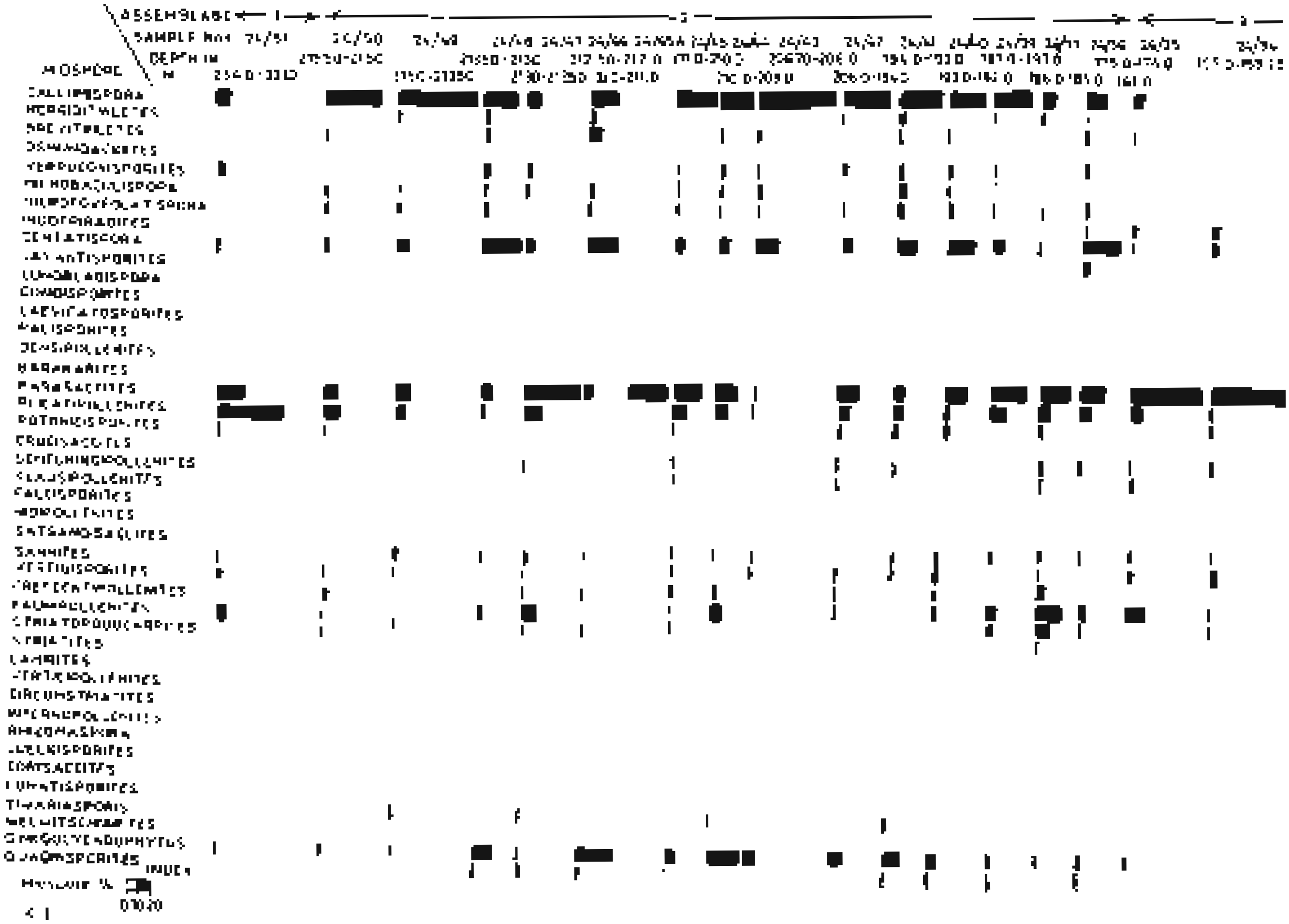
Description—Sacci hemispherical or less than hemispherical imparting a subcircular to oval outline to the grains. Taeniae massive, thick, strip-like and incomplete to complete with relation to the body width. Intrareticulation of sacci and that of the taeniae giving more or less similar pattern of structure indicating the comparable development as sexinal layers. Body outline very thin or ill-defined. Sacci structure exhibiting fine intrareticulate structure.

Comparison—Among the known species of this genus, *L. diffusus* and *L. rhombicus* (Bharadwaj & Tiwari 1977) have diffused and rhomboidal central body, respectively; *L. asansoliensis* Tiwari & Rana 1981 differs from the present species in having ± vertically elongated body with a thick equatorial rim around it. *L. asulcus* described by Bose and Kar (1966) possesses a distinct central body with prominent lunar folds along the distal attachment of saccus in the body. The present species differs from all the known species in having almost indistinct central body, thick, massive, complete to incomplete taeniae and the absence of typical lunar folds along the zones of saccus attachment.

Derivation of name—After Pali Village, the type area from where the present species has been described.

PALYNOSTRATIGRAPHY

In all, three bore-cores have been quantitatively studied for their palynological succession. The details are given below:



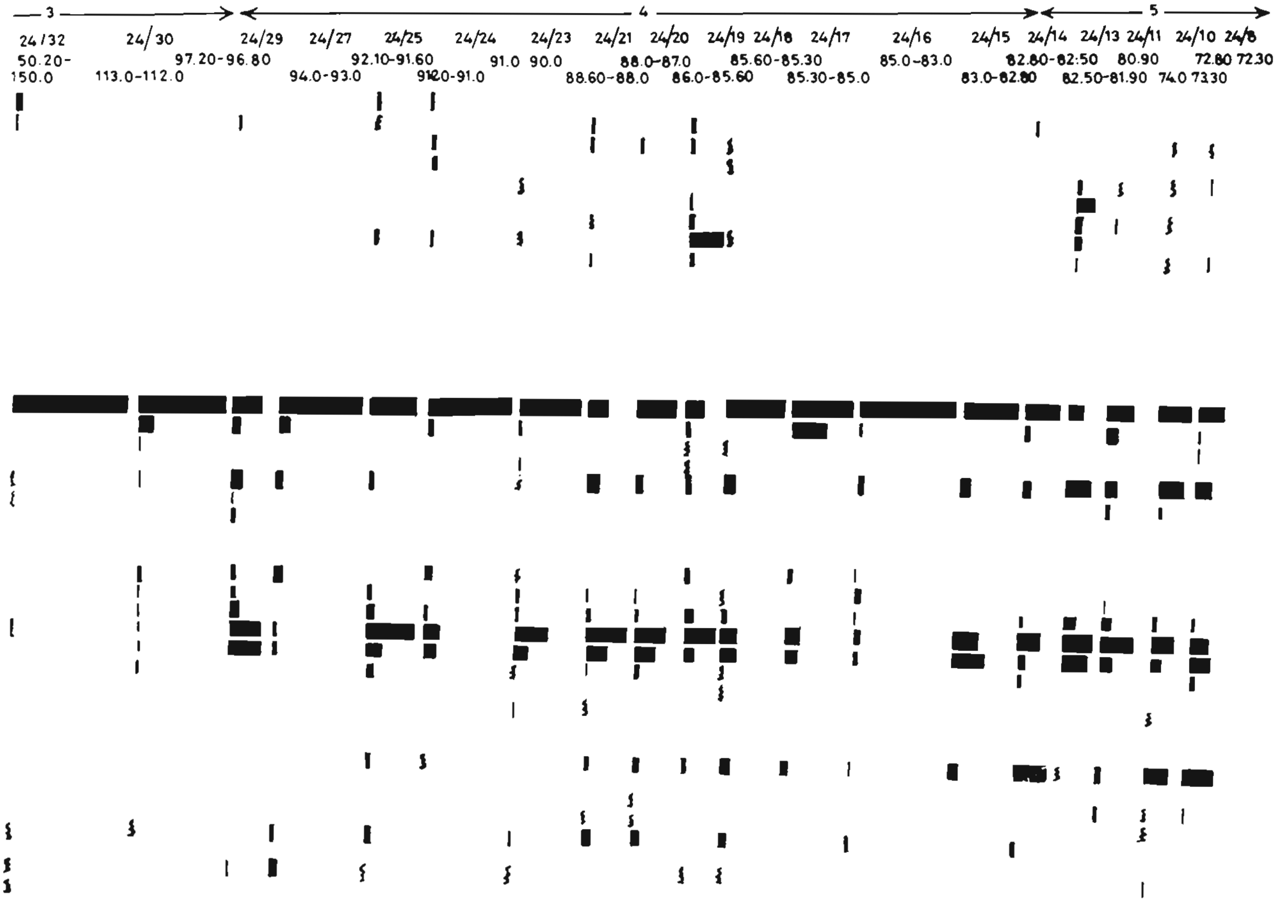
Histogram 3 — Percentage frequency of important miospore genera through bore-hole JHL-24.

Bore-hole JHL-23 — From this bore-hole, 79 samples were macerated (depth from surface 150.00-348.00 m), out of which 45 samples were found to be productive. On the basis of qualitatively as well as quantitatively significant genera five palynological assemblages have been identified (Histogram 2). In the following tables, palynological assemblages have been delimited and details, like depth of the samples, quantitatively dominating as well as important genera and rare but qualitatively significant genera, are given.

Assemblage	Depth in metre	Quantitatively dominant genera	Rare but qualitatively significant genera	Horizon
5	[illegible]	*Parasaccites, Faunipollenites, Striatopodocarpites*	*Crescentipollenites, Verticipollenites, Marsupipollenites*	Raniganj
4	220.50 [illegible]	*Callumispora, Scheuringipollenites, Parasaccites*	*Scheuringipollenites, Crescentipollenites, Striatites, [illegible]*	Barakar
3	240.0 [illegible]	*Callumispora, Plicatipollenites*	*[illegible], Microbaculispora*	Upper Karharbari
2	317.80 [illegible]	*Parasaccites, Plicatipollenites, Callumispora*	*Crescentipollenites, Ginkgocycadophytus, Potonieisporites, Scheuringipollenites, Microbaculispora*	Lower Karharbari
1	[illegible]-348.00	*Callumispora, Parasaccites*	*[illegible], Verrucosisporites, [illegible], Potonieisporites*	Talchir

Bore-hole JHL-24 — In this bore-hole, out of 51 samples 37 samples yielded pollen and spores (depth 72.30-234.0 m from the surface, Histogram 3). The palynological assemblages have been grouped into five zones as under:

Assemblage	Depth in metre	Quantitatively dominant genera	Rare but qualitatively significant genera	Horizon
5	[illegible] 72.30	*Striatopodocarpites, Faunipollenites, [illegible]*	*Scheuringipollenites*	Raniganj
4	[illegible]	*Parasaccites, Faunipollenites*	*[illegible], Scheuringipollenites*	Barakar



Histogram 1—*Contd*

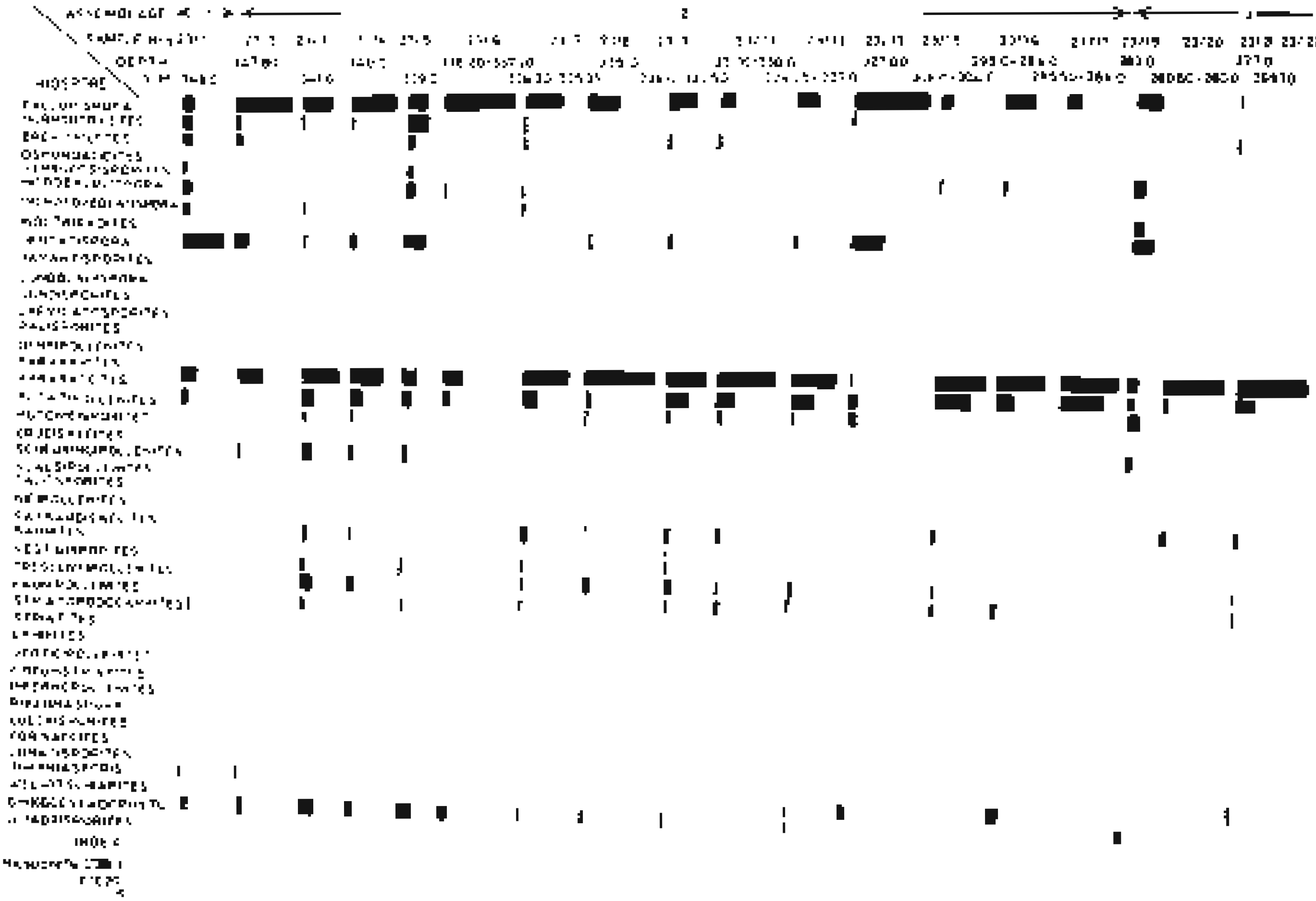
		Striatopodocarpites		
3	213.0-161.0	*Parasaccites, Callumispora*	*Callumispora, Microfoveolatispora, Faunipollenites, Horriditriletes, Brevitriletes, Striatopodocarpites, Faunipollenites*	Upper Karharbari
2	215.50-213.0	*Callumispora, Plicatipollenites, Parasaccites*	*Microbaculispora, Scheuringipollenites, Brevitriletes*	Lower Karharbari
1	234.0-231.0	*Plicatipollenites, Parasaccites*	*Callumispora, Verrucosisporites, Ginkgocycadophytus*	Talchir

Bore-hole JHL-25—From this bore-hole, 15 samples have been macerated out of which nine samples yielded (depth from surface 190.0-37.0 m). After a critical study of palynological contents they have been grouped into three aseemblages, as given below (Histogram 3).

Assemblage nos.	*Depth in meter*	*Quantitatively important genera*	*Rare but qualitatively significant genera*	*Horizon*
3	65.0-37.0	*Parasaccites, Faunipollenites, Crescentipollenites*	*Callumispora, Verrucosisporites, Dentatispora*	Barakar
2	135.75-65.0	*Parasaccites, Plicatipollenites*	*Verrucosisporites, Indotriradites, Scheuringipollenites, Faunipollenites*	Upper Karharbari
1	190.0-180.0	*Callumispora*	*Dentatispora, Parasaccites, Plicatipollenites*	Lower Karharbari

Beside the above bore-cores, about 175 outcrop samples were also macerated from Johilla River Section, Ganjra Nala Section and Kamari Nala (locally known as Ghorari Nala) Section. The palynological details of each section and their palynozonations are given below

Johilla River Section—Sixty samples have been macerated out of which only 17 samples yielded the miospores. On the basis of this analysis following six palynological assemblages have been delimited (Histogram 5).



Histogram 2—Percentage frequency of important miospore genera through bore hole JHL-25

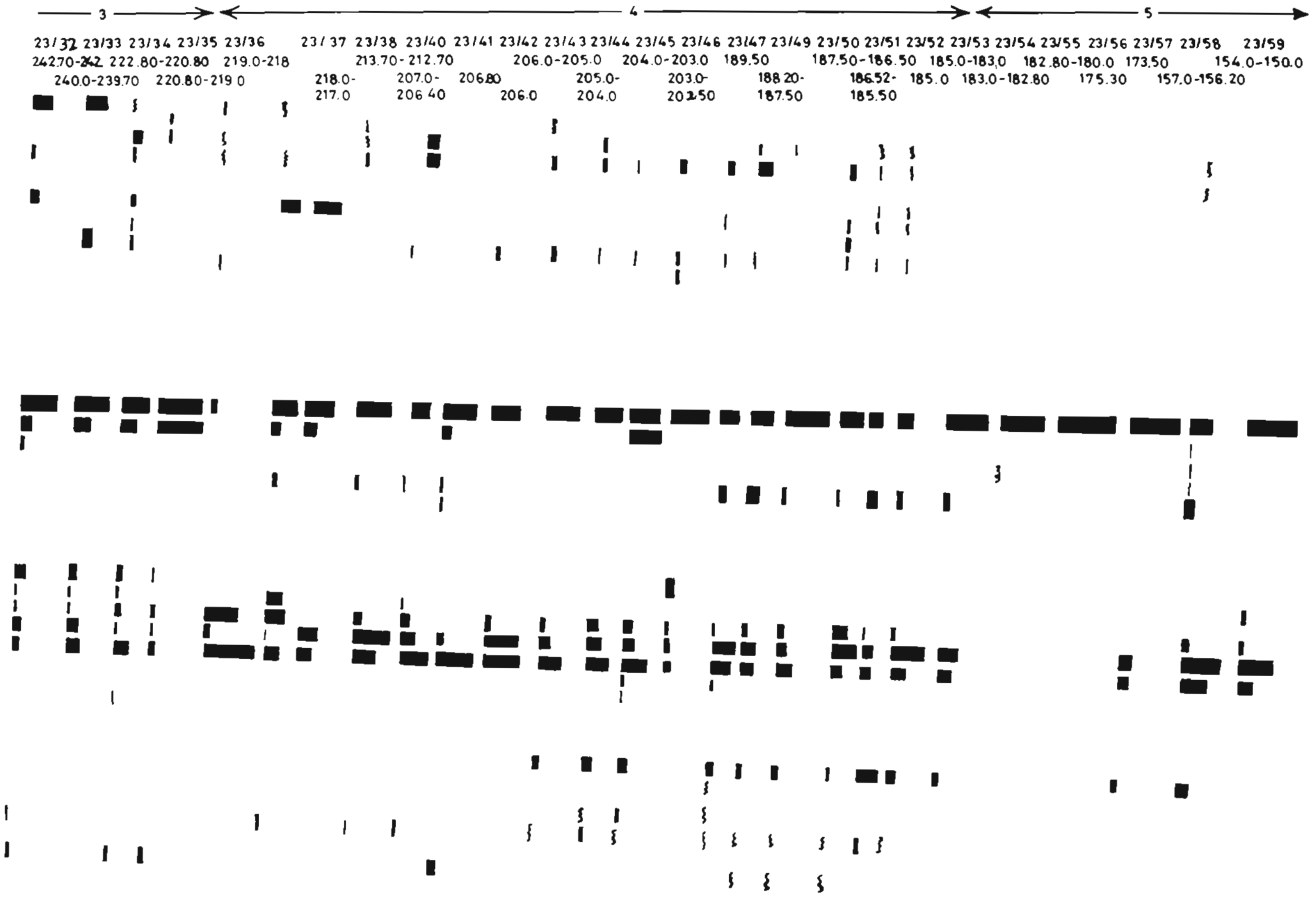
Assemblage no.	Sample nos	Quantitatively important genera	Rare but qualitatively significant genera	Horizon
JVI	[illegible]	Scheuringipollenites, Striatopodocarpites	Lundbladispora, Densoisporites, Scheuringipollenites, Falcisporites	Permian/Triassic
JV	JH 15, JH 24, JH 25	Parasaccites, Faunipollenites	Vertebrisporites, Densipollenites	Upper Barakar
JIV	JH 30, JH 35	Callumispora, Cordaitina, Plicatipollenites	Brevitriletes, Florinites, Crucisaccites, Potonieisporites	Upper Karharbari
JIII	JH 2, 3, 4, 5, 6, 7, 8, 9, 11	Parasaccites, Plicatipollenites, Caheniasaccites, Striatopodocarpites	Callumispora, Scheuringipollenites, Florinites, Vestigisporites	Talchir
JII	JH 2	Parasaccites	Plicatipollenites, Caheniasaccites, Crucisaccites, Striatopodocarpites	Talchir
JI	JH 1	Parasaccites, Plicatipollenites	Sulcatisporites, Striatopodocarpites	Talchir

Ganjra Nala Section—Forty samples were macerated out of which only 3 samples yielded spores and pollen. The single palynological assemblage identified here is dominated by the genus *Parasaccites* and *Striatopodocarpites*.

Assemblage no.	Sample nos	Quantitatively important genera	Rare but qualitatively significant genera	Horizon
I	GN 35, 36	Parasaccites, Striatopodocarpites, Faunipollenites	Plicatipollenites, Scheuringipollenites, Rhizomaspora, Crescentipollenites	Upper Barakar

CORRELATION

After delimiting various assemblages in the three bore holes and two out-crop sections as well as Bore hole JHL 27A and UKD 8 (Tiwari & Ram-Awatar, 1986, 1987b) a relationship amongst these assemblages have been established which is mainly based on the dominance and subdominance of various taxa. Six successive palynological zones (A to F) have been recognised.



Histogram 2—*Contd.*

Palynological Zone-A

It includes Assemblage-1 of Bore-hole no. JHL-24 and Assemblages J-I, J-II, J-III of Johilla River Section. Quantitatively important taxa are: *Parasaccites* and *Faunipollenites*, while qualitatively *Callumispora* is an important taxon.

Diagnostic features—This assemblage is poor in overall diversification. The monosaccates are in dominance; triletes and striate-disaccates are rare. The genus *Callumispora* is present but not so effective in its incidence.

Palynological Zone-B

It incorporates the following assemblages:

(i) Assemblage-1, 2 of Bore-hole no. JHL-23
(ii) Assemblage-2, 3 of Bore-hole no. JHL-24
(iii) Assemblage-1 of Bore-hole no. JHL-23
(iv) Assemblage-J-IV of Johilla River Section (Pars.)

The quantitatively important taxa are: *Dentatispora, Parasaccites, Ginkgocycadophytus, Callumispora, Plicatipollenites,* while qualitatively important taxa are: *Microbaculispora, Faunipollenites, Quadrisporites, Dentatispora* and *Ginkgocycadophytus.*

Diagnostic features—This assemblage is characterized by the dominance of smooth and zonate triletes and subdominance of girdling monosaccates. A few striate-disaccate and non-striate disaccate are also common.

Palynological Zone-C

Two assemblages, as given below, are included in this zone:

(i) Assemblage-3 of Bore-hole no. JHL-23
(ii) Assemblage-2 of Bore-hole no. JHL-25

Quantitatively, the taxa *Callumispora, Brevitriletes, Verrucosisporites, Faunipollenites, Sahnites and Vestigisporites* are important for this level.

Diagnostic features—In this palynological zone, the girdling monosaccates are in dominance, while

Callumispora is relatively less represented; non-striate-disaccates with monolete mark are also significant.

Palynological Zone-D

This zone includes the following assemblages:
(i) Assemblage-4 of Bore-hole no. JHL-23
(ii) Assemblage-4 of Bore-hole no. JHL-24
(iii) Assemblage-3 of Bore-hole no. JHL-25
(iv) Assemblage-J-V of Johilla River Section
(v) Assemblage-1 of Ganjra Nala Section

Quantitatively the important identified taxa in this zone are: *Faunipollenites, Striatopodocarpites, Crescentipollenites, Parasaccites, Plicatipollenites,* while qualitatively important taxa are *Scheuringipollenites* and *Faunipollenites.*

Diagnostic features—In this palynological zone, the striate-disaccates are in dominance and taeniate-disaccates are in common occurrence. The monosaccates are rare but varied.

Palynological Zone-E

This zone includes the following assemblages:
(i) Assemblage-5 of Bore-hole no. JHL-23
(ii) Assemblage-5 of Bore-hole no. JHL-24
(iii) Assemblage-1 of Bore-hole no. UKD-8 (Tiwari & Ram-Awatar, 1987b)
(iv) Assemblage-1 of Bore-hole no. JHL-27A (Tiwari & Ram-Awatar, 1986)

Here the quantitatively important taxa are represented by *Faunipollenites, Striatopodocarpites, Barakarites, Scheuringipollenites* and *Parasaccites* while qualitatively important taxa are *Ibisporites, Rhizomaspora, Infernopollenites, Densipollenites, Gondisporites* and *Microfoveolatispora.*

Diagnostic features—This zone is dominated by striate-disaccates, while monosaccates are less significant, in general, the trilete spores exhibit a declined percentage.

Palynological Zone-F

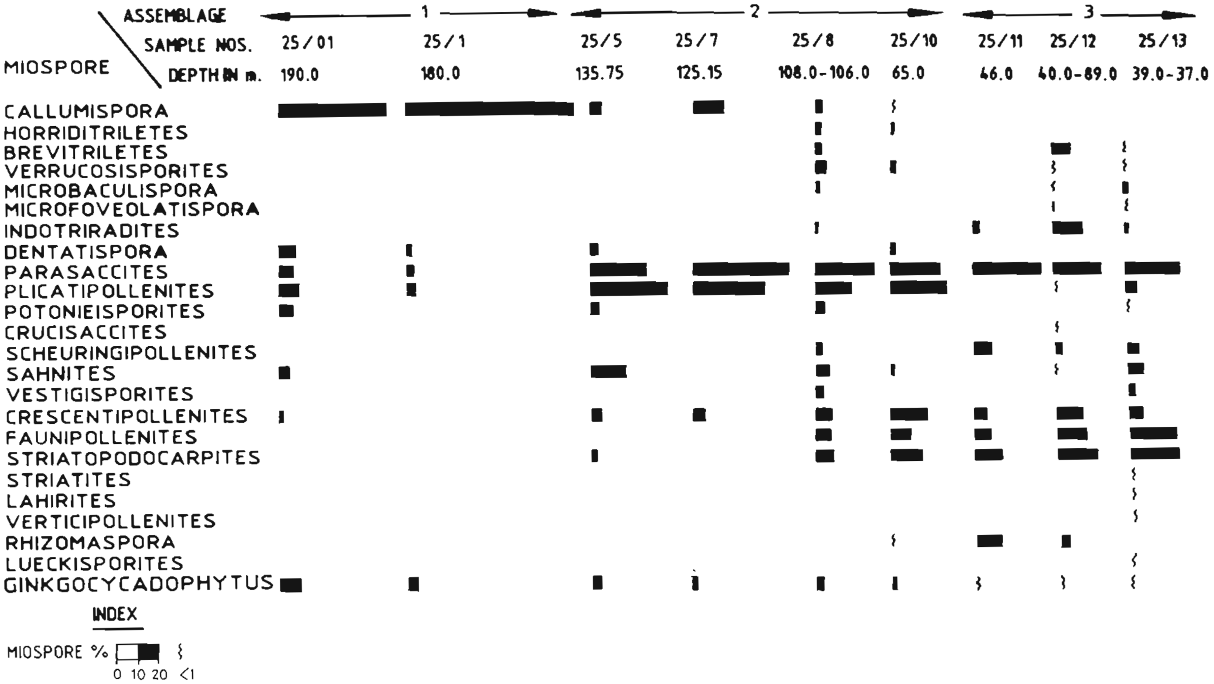
This zone is composed of two assemblages:
(i) Assemblage J-VI of Johilla River Section
(ii) Assemblage-2 of Bore-hole no. UKD-8 (Tiwari & Ram-Awatar, 1987b)

The taxa such as *Faunipollenites, Crescentipollenites, Striatopodocarpites, Parasaccites, Callumispora, Densipollenites, Satsangisaccites* are quantitatively prominent while *Klausipollenites* is significant.

Diagnostic features—In this zone striate-disaccates are in dominance. The apiculate, zonate triletes are also present but the monosaccates are poor in frequency.

DISCUSSION

The identification of 58 genera and 126 species of pollen and spores in the palynological



Histogram 3—Percentage frequency of important miospore genera through bore-hole JHL-25.

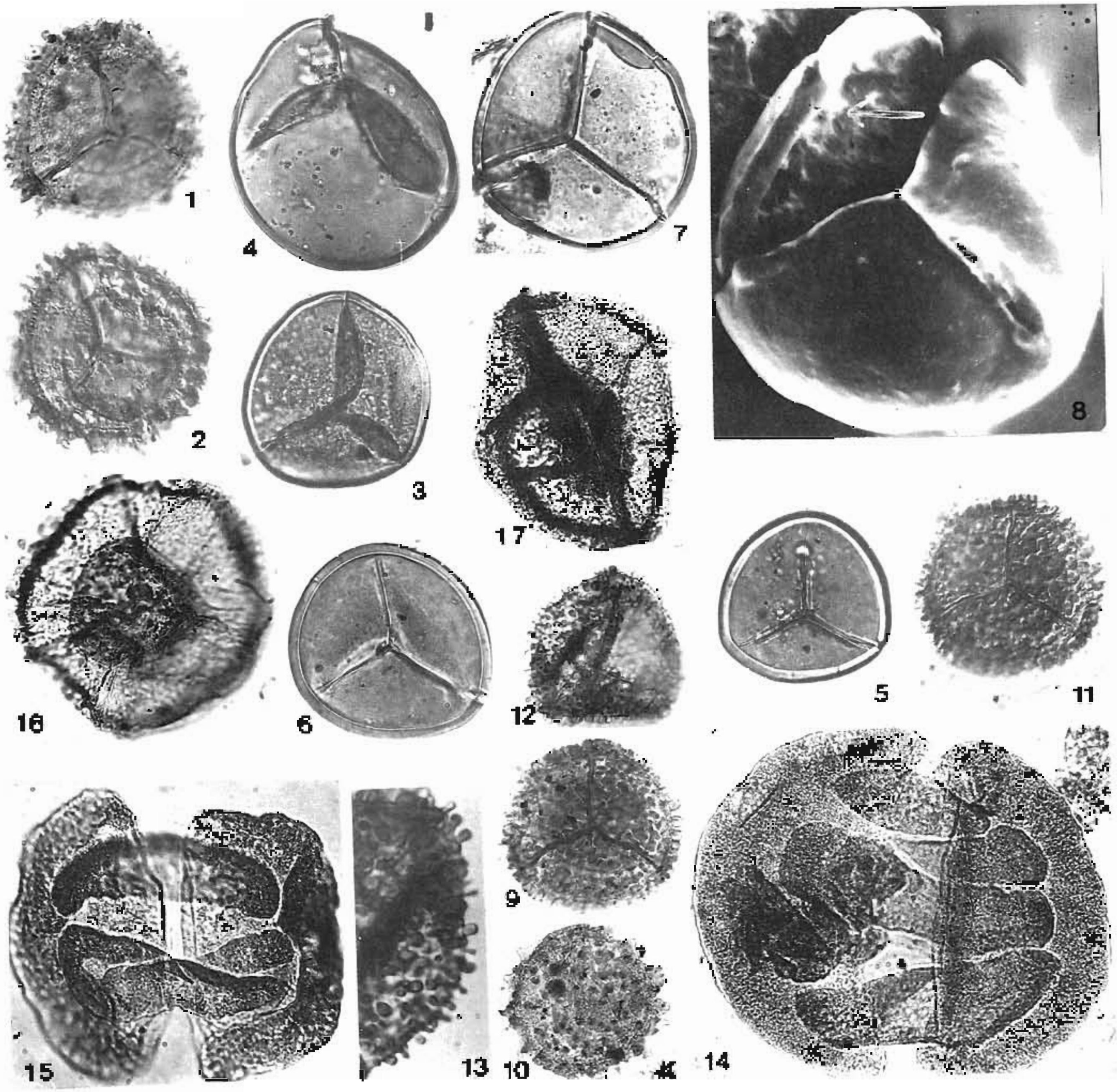


PLATE 1

(All photomicrographs are enlarged ca × 500)

1, 2. *Dentatispora reticulata* sp. nov.—1. Holotype, slide no. BSIP 9304. 2. Same specimen under differential interference phase contrast showing the distinct intrareticulate structure on the surface.

3, 4. *Callumispora sakariae* sp. nov.—3. Holotype, slide no. BSIP 9309. 4. Specimen under normal light, slide no. BSIP 9311.

5-8. *Callumispora pahariensis* sp. nov.—5. Holotype, slide no. BSIP 9308. 6, 7. Specimens under normal light, slide no. BSIP 9309. 8. Scanning electron micrograph of a specimen showing the nature of parts and smooth nature of exine with few specks, also a partly open portion (arrow) shows the internal structure of the exine within the spore cavity × 1500, slide no. BSIP 9309.

9-11. *Dentatispora mammillata* sp. nov.—9. Holotype, slide no. BSIP 9307. 11. Same specimen under differential interference phase contrast showing the nipple-like sculptural elements. 10. Specimen under normal light, slide no. BSIP 9310.

12, 13. *Osmundacidites baculatus* sp. nov.—12. Holotype, slide no. BSIP 9052. 13. An enlarged portion of fig. 12, showing the finger shaped baculi × 750, slide no. BSIP 9052.

14, 15. *Lunatisporites pahariensis* sp. nov.—14. Holotype, slide no. BSIP 9305. 15. A specimen under normal light, slide no. BSIP 9306.

16, 17. *Granulatisporites reticulatus* sp. nov.—16. Holotype, slide no. BSIP 9055. 17. Specimen showing the reticulate pattern on the surface, slide no. BSIP 9053.

Table 6 — Distribution chart of different species in palynological zones A-E

PALYNOTAXA	Zone A TALCHIR (Early Permian)	Zone B LOWER KARHARBARI (Early Permian)	Zone C UPPER KARHARBARI (Early Permian)	Zone D UPPER BARAKAR (Late Permian)	Zone E MIDDLE PALI (Late Permian)
Plicatipollenites trigonalis	•				
Plicatipollenites [illegible]	•				
[illegible]	•				
Potonieisporites [illegible]	•				
[illegible]	•				
[illegible]	•				
[illegible]	•				
[illegible]	•				
[illegible]	•	•			
Callumispora barakarensis	•	•			
Callumispora tenuis	•	•			
[illegible]	•	•			
[illegible]	•	•			
Parasaccites diffusus	•	•			
Parasaccites bilateralis	•	•			
[illegible]	•	•			
[illegible]	•	•			
[illegible]	•	•			
[illegible]	•	•			
[illegible]	•	•			
Callumispora [illegible]	•	•	•		
Callumispora [illegible]	•	•	•		
Callumispora [illegible]	•	•	•		
Callumispora [illegible]	•	•	•		
[illegible]		•	•		
[illegible]		•	•		
[illegible]		•	•		
[illegible]		•	•		
[illegible]		•	•		
[illegible]		•	•		
[illegible]	•	•	•		
[illegible]		•	•		
[illegible] *barakarensis*		•	•		
[illegible]			•		
[illegible]			•		
[illegible]			•		
[illegible]			•		
[illegible] *foveolata*			•		
[illegible]			•		
[illegible]			•	•	
[illegible]			•	•	
[illegible]			•	•	
[illegible]			•	•	
[illegible]			•	•	
[illegible]		•		•	
[illegible]			•	•	
[illegible]			•	•	
Parasaccites [illegible]			•	•	
Parasaccites [illegible]			•	•	
Parasaccites [illegible]			•	•	
Plicatipollenites [illegible]			•	•	
Plicatipollenites [illegible]			•	•	
Plicatipollenites [illegible]			•	•	
Potonieisporites [illegible]			•	•	
Potonieisporites [illegible]			•	•	
[illegible]			•	•	
Sahnites [illegible]				•	
Sahnites [illegible]				•	
[illegible]				•	
Scheuringipollenites barakarensis				•	
Scheuringipollenites [illegible]				•	
Scheuringipollenites [illegible]				•	
[illegible]				•	•

Table 6—Contd.

			Stage I MIDDLE [illegible] UPPER [illegible] (Permian Triassic)
[illegible]	•	•	
[illegible]	•	•	
[illegible]	•	•	
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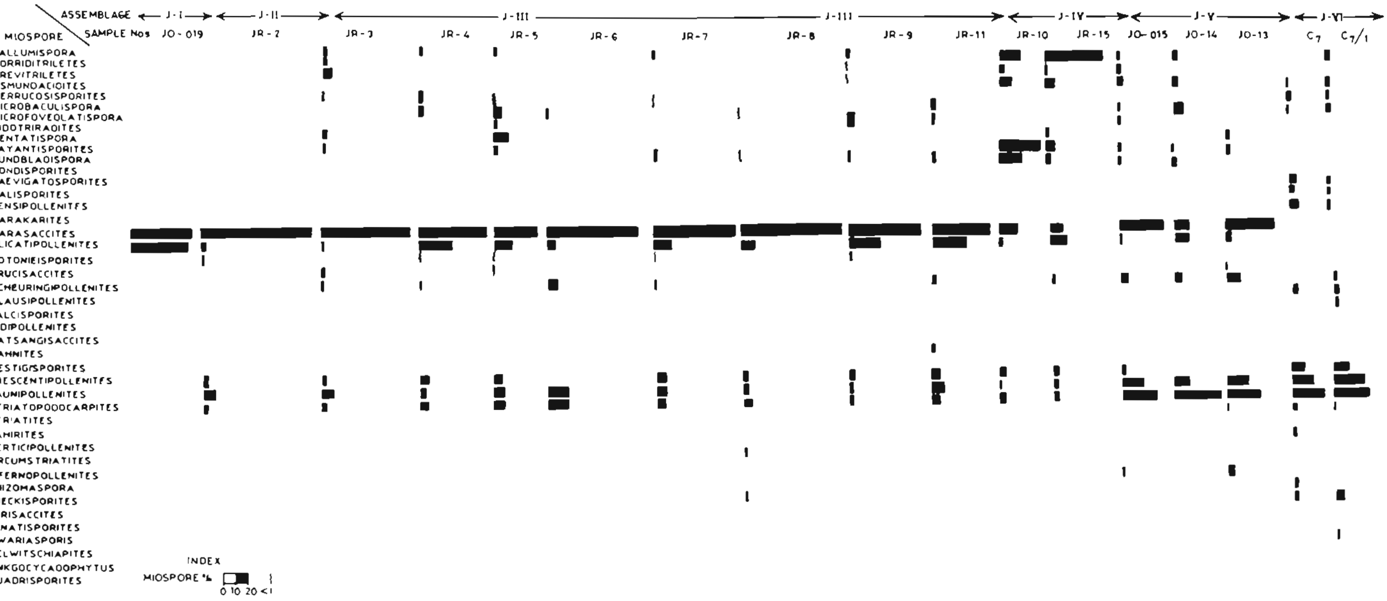

Histogram 4—Percentage frequency of important miospore genera in Johilla River Section.

assemblages described above indicates their diversified nature. The presence of several new taxa indicates the characteristic feature of vegetational components in Johilla Valley.

The palynological dating of Pali beds in the Supra-Barakar Formation has been a significant outcome of this study. The palynological assemblage found in the coal beds of Pali (in subsurface samples) has been dated to be Late Permian, while beds exposed in between Dargaon and Salaia villages contain a Permian/Triassic transitional palynoflora (Tiwari & Ram-Awatar, 1986, 1987a; Ram-Awatar, 1988). The assemblages described here (Assemblage A to F) represent Talchir, Lower and Upper Karharbari, Upper Barakar, middle Middle Pali Member and uppermost Middle Pali Member respectively.

Relationship between Umaria, Korar and Johilla coalfields—A comparison of palynoassemblages from Johilla, Umaria and Korar coalfields of Son Valley shows a close correlation in composition. In Lower Permian the monosaccate pollen are dominating, while few striate-disaccates are also present. In view of this data, the presently designated Palynological Zone-A is dated to be of Early Permian age because this assemblage is dominated by monosaccate genera, viz., *Parasaccites, Plicatipollenites* and the trilete genus *Callumispora*. The Assemblage-A described in this paper, thus, corresponds the mioflora described by Potonié and Lele (1961) from the locality of Goraia, and Assemblage Zone-A of Chandra and Lele (1979) in the Johilla Coalfield; so also the assemblage reported by Lele and Chandra (1969, 1972) from Umaria Coalfield had a closer affinity.

Palynological Zone-B, equated to the Lower Karharbari mioflora, contains *Callumispora* as a dominating taxon followed by *Parasaccites* and *Plicatipollenites*, zonate, non-striate and striate-disaccate forms. The Zone-B, thus, resembles the mioflora described by Lele and Maithy (1969) and Saksena (1971) from Ganjra Nala Section and Anand-Prakash and Srivastava (1984) from Pali coalmine; palynoflora described by Chandra and Srivastava (1986) from this area also compares closely. It also resembles the flora described by Maithy (1966), and Zone-1 of Srivastava and Anand-Prakash (1984) in Umrar River near Jawalamukhi Temple, except that *Dentatispora* is replaced by *Jayantisporites*.

Palynological Zone-C, as designated here, is equated with Upper Karharbari which resembles the palynoflora described by Lele and Maithy (1969), Saksena (1971), and Zone-2 proposed by Anand-Prakash and Srivastava (1984) from this region.

Palynological Zone-D, consisting of *Striatopodocarpites, Faunipollenites, Scheuringipollenites*, etc., has been dated as Upper Barakar and compared with miofloral assemblage of Jhingran, (1979). So also, palynological Zone-4 of Anand-Prakash and Srivastava (1984) from Johilla Coalfield has a correspondence with Zone-D of present paper.

The palynoflora yielded from Pali Formation (Late Raniganj) contains mainly striate forms (more than 80%) with rare occurrence of zonate and triletes grains; this zone closely resembles Assemblage-1 of Tiwari and Ram-Awatar (1986) from Bore-hole no.

JHL-27A, Johilla Coalfield (Palynological Zone-E). It is also comparable with Assemblage-1 of Tiwari and Ram-Awatar (1987b) from Korar Coalfield (Bore-hole no. UKD-8).

Palynological Zone-F, dominated by *Faunipollenites, Striatopodocarpites* and some younger elements like—*Nidipollenites* and *Klausipollenites*, has been dated to be Permian/Triassic. It shows resemblance with Assemblage J-VI of Tiwari and Ram-Awatar (1987a). To some extent, the Assemblage-2 of Tiwari and Ram-Awatar (1987b) from Bore-hole no. UKD-8, Korar Coalfield, also shows similarity with Zone-F.

Comparison with other basins

As such, this area of Son Valley has similar palynological history in its older horizons (i.e., Talchir and Karharbari) when compared with Damodar Basin, while in the upper horizons, i.e., Barakar and Supra-Barakar (Pali), the constituents of the assemblage show considerable differences. The Talchir mioflora is dominated by monosaccates, as in the case of Damodar Valley, Satpura Gondwana and Mahanadi basins (Lele, 1975; Lele & Karim, 1971; Lele & Makada, 1972; Bharadwaj & Srivastava, 1973; Srivastava, 1973; Bharadwaj & Anand-Prakash, 1972).

In case of Talchir palynoflora, in the Johilla Coalfield (Assemblage J-I, J-II, J-III in Histogram-IV and Assemblage-1 of Bore-hole no. JHL-24) it is evident that the genus *Parasaccites* is outstanding in percentage. It is also interesting to note that the disaccates, on the whole, are meagre in this assemblage.

As in other basins, the general trends of the monosaccate decline in the Lower Karharbari (where *Callumispora* increases), and their rise in the Upper Karharbari have been recorded in Johilla Coalfield also (cf. Bharadwaj & Srivastava, 1973; Tiwari, 1973; Srivastava, 1973; Srivastava, 1980). However, certain trends of variation have been observed here, viz., unlike other basins, the genus *Ginkgocycadophytus* (and to a certain extent *Quadrisporites*) shows a well-marked presence in Lower Karharbari. The genus *Dentatispora* has a very good representation in these beds, while it is not so in other basins where this group of spores occurs in the younger horizon. In the Upper Karharbari (Assemblage-4 of Bore-hole no. JHL-24) of the presently studied succession, the assemblage is totally dominated by *Parasaccites* while most of the triletes and striate-disaccate grains have declined. This is a major difference when compared to the other areas where normally the complexity of pollen contents increases in the Upper Karharbari.

The Barakar palynoflora is diversified, both quantitatively as well as qualitatively, in all the basins of India, and broadly speaking the assemblages of Johilla Coalfield at this level also have a closer resemblance with them (Tiwari, 1973; Srivastava, 1973; Kar, 1973, Bharadwaj & Tripathi, 1978; Bharadwaj, Navale & Anand-Prakash, 1974; Srivastava & Anand-Prakash, 1984). However, there are certain changes in the behaviour of some palynofossils which qualify the present assemblage. The presence of taeniate forms like—*Lunatisporites paliensis* sp. nov., shows a peculiar condition for Johilla River Section, because in other basins taeniate forms are found only in the Late Permian and Triassic horizons. Similarly, the zonate cingulate trilete spores are relatively less represented in the presently studied Barakar samples. The monosaccate genus *Parasaccites* continues to be quite significant even in Barakar Formation of Johilla Coalfield, while it is not the case in other basins. This indicates a lingering on of the cooler effect of the older condition even into the Barakar Formation in this basin.

The palynoflora from Pali, designated here to be of Raniganj equivalent, resembles those of Upper Permian from other basins (Bharadwaj 1962; Bharadwaj & Tiwari, 1977; Kumaran & Maheshwari, 1980; Tiwari & Rana, 1980) in the prominence of striate-disaccate pollen grains. However, the genus *Infernopollenites* makes the Pali Assemblage a peculiar palynoflora, as no where else such a combination has been found so far. The absence of *Indospora, Thymospora* and *Gondisporites* and the presence of *Brachysaccus, Densipollenites, Lunatisporites*, etc. further make the present assemblage different from other comparable assemblages.

The assemblage from upper part of Pali Formation contains a variety of miospores. The dominating elements are mainly striate-disaccate in which it resembles Late Raniganj assemblage (Bharadwaj, 1962; Bharadwaj & Salujha, 1964; Bharadwaj, Tiwari & Anand-Prakash, 1979). Besides, some younger elements like—*Lundbladispora, Guttulapollenites, Nidipollenites, Satsangisaccites* are also present in this assemblage which are definite indicators of younger aspect. Therefore, the Palynological Zone-F is correlatable with the Permian-Triassic transitionary phase (see Bharadwaj & Tiwari, 1977; Maheshwari & Banerji, 1975; Rana & Tiwari, 1980; Tiwari & Singh, 1983).

The distribution of various species in Palynological Zones-A to F has been plotted (Table 6). The picture thus obtained clearly depicts a systematic and synchronised mode of qualitative occurrence. This corroborates with the quantitative results obtained in the present analysis. Identity of each zone, characteristic for each level of formation, is thus established through specific distributional determination.

PALAEOGEOGRAPHY AND PALAEOCLIMATE

During Permian and Triassic times, India was still a part of Gondwanaland, including Africa, Antarctica, South Africa and Australia (Dietz & Holden, 1970). The initial rifting of continents probably occurred in Jurassic and Lower Cretaceous time (Smith & Hallam, 1970).

As we are concerned mainly with the Permian and Early Triassic times, it is significant to note that the peninsular India laid between 50° and 70° south latitude during the Permo-Carboniferous times; in Late Permian times most of it remained in this belt except for its north-western portion which extended up to 40° south of equator. It is also envisaged that during the Triassic time, the present eastern part of India was situated between 60°-55° latitude and rest between 52°-30° south. The shifting has apparently taken place due to rotation of continents as well as the polar wandering (McElhinny, 1973; Bharadwaj, 1976). It is presumed from this situation that most of the peninsular India must have had a cold climate during the Permian time, but a little less cold or even warm during the Triassic time. The South Rewa Gondwana Basin occupies a position at an angle formed by the chain of Damodar Valley coalfields as one arm and the Son-Mahanadi Valley coalfields as the other arm. These two valleys were separated by a highland, named as "Fox-ridge". On the northern as well as southern side of these valleys also two highlands existed (Ahmad, 1961). Such physical barriers and the latitudinal difference were responsible for the variance in the palynoflora of Damodar and Son Valley basins. The South Rewa Basin lays in the lowland along with other basins and these low lying areas were partly connected with sea, as it has been evidenced in the Umaria, Manendragarh, Daltonganj and other places of the Peninsular India.

The sedimentation in Johilla Coalfield also started with the deposition of Tillite of the Talchir Formation. As in other coal-basins, here also the miospore assemblage from the Talchir is dominated by monosaccates suggesting a resemblance of climate with other similar areas having mainly glacial and fluvio-glacial environmental conditions (Lele & Chandra, 1972; Srivastava, 1973; Kar, 1976).

The dominance of the genus *Callumispora* in the assemblage comparable to Lower Karharbari suggests that influence of cold climate was decreasing. However, in the Upper Karharbari the *Parasaccites* again came into prominence suggesting a cooler climate once again (Bharadwaj, 1975). These cycles have also been supported by the present study. The coal-bearing Barakar Formation records the upsurge of trilete forms but the monosaccates continue to be relatively abundant; moreover, the diversity in kinds has also increased tremendously in this phase of deposition. This observation is in accordance with rest of the records known from Damodar Basin and other areas (Tiwari, 1973). Thus, in Barakar the intensive cold climate was replaced by the relatively warmer climate. The massive coal deposits point out that the climate must have been humid and palynological study indicates a diversity and richness of vegetation.

In the Supra-Barakar (Pali-Parsora), normally the coal is absent and the rocks consist of clay, red, white, yellow, grey shales and ferruginous sandstone. On the basis of this type of lithology it is generally interpreted that the climate must have been dry, warm or even semi-arid during these phases. However, the present palynological findings do not support this contention. The Supra-Barakar includes equivalents of Barren Measures, Raniganj, Panchet and younger horizons of Supra-Panchet. In Johilla Coalfield Barren Measures appear to be subdued; the palynological assemblages of Pali Formation are highly diversified having striate and non-striate disaccates, laevigate as well as ornamented triletes, cavates, monosaccates and alete miospore genera. This naturally reflects that the vegetation was quite luxuriant which gave rise to qualitatively complex spore and pollen assemblages, consequently the climate must have been humid to have produced such a plant population. The presence of coal beds in Middle Pali supports this view. However, the absence of coal in rest of the Pali, inspite of rich vegetation, may be due to the tectonic behaviour of the basin and absence of suitable conditions in the area leading to the peat deposition. The continuous energy flow and supply of oxygen in shallow swamps did not create the aseptic conditions, hence no coals.

CONCLUSION

The present analysis of the Gondwana sediments in Johilla Coalfield evidences that new groups of spores and pollen grains existed in this region, when compared to the miofloras of other basins of India. Besides, it has also come to light that the radial monosaccate pollen genera continue to occur for quite some extent in the Lower Gondwana succession, including the Barakar Formation. The significant constituents of this group in the Upper Permian does not coincide with the situation in other basins. Generally, the monosaccate pollen are indicators of cooler climate, and hence cold and humid type of climate is envisaged for the Barakar in this region. This conclusion is also supported by the fact that during Permian times the position of South Rewa Gondwana Basin was relatively nearer to the South Pole than that of the Damodar Basin.

On the basis of the complexity of spores and pollen in kind and number from Pali Formation it has been concluded that the vegetation was very rich, and not poor as generally considered although there is no major coal horizon in these formations; the reason for the later situation is attributed to the local tectonic conditions and energy distribution. The basin has its own individuality in the components of vegetation, palaeoecology and climatic condition. The climate during the deposition of Pali Formation was not arid because it sustained a luxuriant vegetation. On the basis of palynomorphs, Talchir, Lower Karharbari, Upper Karharbari and Barakar assemblages have been identified. It has been concluded that Pali Formation is of Upper Permian age in its middle part; it transgresses into Triassic in the upper part. The Parsora Formation represents still younger sequence.

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Late Maastrichtian-Danian nannoplankton from basal Subathu of Dharampur, Simla Himalaya, India—Palaeogeographic implications

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The discovery of Danian calcareous nannoplankton of combined NP3-NP4: *Chiasmolithus danicus/Ellipsolithus macellus* zones from apparently unproductive Subathu of Dharampur, offers new scope for high resolution dating; reworked nannofloral elements of Late Maastrichtian (*Micula mura* Zone of low-mid latitudes) demand the fixing of lower age limit of Subathu Formation straddling K/T boundary. This may signify an event permitting the entry of Assam-Arakan sea along lesser Himalayan rift via Arunachal during Late Maastrichtian.

Key-words—Calcareous nannoplankton, Palaeogeography, Cretaceous, Simla Hills (India).

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सारांश

शिमला हिमालय (भारत) में धरमपुर के आधारी सुबाथु से अनंतिम मास्ट्रिक्शियन-डेनियन परासूक्ष्मप्लवक–पुराभौगोलिक महत्व

सैय्यद अब्बास जाफ़र एवं पुष्कर नाथ कपूर

धरमपुर के स्पष्टतया अधारक सुबाथु से सयोजित एन-पी० 3- एन-पी० 4–**चिआसमोलिथस डेनिकस/ऐलिप्सोलिथस मेसिलस** नामक मंडलों के डेनियन युगीन चूनामय परासूक्ष्मप्लवकों के अन्वेषण से इनके पुनः कालनिर्धारण के नये अवसर बढ़ गये हैं। अनंतिम मास्ट्रिक्शियन (निम्न-मध्य अक्षांसों का मिकुला मुरा मंडल) के पुनरीक्षित परासूक्ष्मवनस्पतिजातीय अवयवों के कारण सुबाथु की अभी तक अनिश्चित क्रीटेशी/तृतीयक सीमा की अधरि आयु को सुनिश्चित करने की आवश्यकता है। इससे अनंतिम मास्ट्रिक्शियन काल में अरूणाचल से होकर लघु हिमालय भ्रंश के संग-संग असम-अराकन समुद्र के प्रवेश की घटना व्यक्त हो सकती है।

WELL-KNOWN Subathu-Dagshai-Kasauli sequence of rocks (Map 1A-C), established over a century ago (Medlicott, 1864), represents the last waning phase of marine sedimentation in lesser Himalaya, bearing the imprint of tectonic history prior to collision of Indian-Asiatic plates (Powell, 1979; Ray & Acharyya, 1976; Acharyya & Ray, 1982). Open tidal sea of Subathu changing to estuarine and complete withdrawl of sea during Kasauli sedimentation (Singh, 1978) is characterised by intermittent influx of terrestrial elements, viz., bone beds, shell layers, etc. These mostly contain broadly datable elements, like larger foraminifera, dinoflagellates, spores and pollen. Planktonic foraminifera and nannoplankton permitting high resolution dating are rather scarce and concentrated in thin horizons that often lack any other fossil. The present discovery of late Maastrichtian-Danian nannoplankton is extremely important from the viewpoint of palaeogeography, as no authentic and documented reports of coeval age are known from western Indian sections, Pakistan (Haq, 1971) and western Himalaya (Mathur, 1983). In contrast, the eastern sector of India contains datable plankton of nearly complete Cretaceous succession including rich suite of *Globotruncana* matching *A. mayaroensis* Zone of Late Maastrichtian in Assam-Arakan Basin (Rangarao, 1983).

MATERIAL AND METHODS

Collections were made from two profiles, about 1 km apart on Dharampur-Dagshai road (Map 1B). Finely laminated grey to olive-green claystone-siltstone interbedded with a few centimeter thick Oyster shell-beds, failed to yield any other mega- or micro-fossil for age determination. Basement was concealed in both the profiles and the entire sequence matches olive-green shale facies recognised within Subathu (Singh, 1978). Samples were drilled with sharp needle to release powder from partially recrystallised fine matrix of calcareous shales; conventional smear slides were prepared with Caedax mounts. Out of 10 samples, two proved productive (Map 1B; samples DD1, DD4), while DD1 revealing better preservation yielded most of the forms documented here. Abundant fine carbonate grains acted as background noise in recognition and identification of rather ill-preserved and scarce but datable nannoplankton under the light microscope (Pl. 1, figs 1-41).

RECORDED NANNOPLANKTON TAXA

Reworked Late Maastrichtian (*Micula mura* Zone) Assemblage

Watznaueria barnesae (Black) Perch-Nielsen 1968
Micula mura (Martini) Bukry 1973
Micula decussata Vekshina 1959
Micula sp.
Tetralithus? sp.
Cretarhabdus crenulatus Bramlette & Martini 1964
Cretarhabdus? sp.
Glaukolithus compactus (Bukry) Perch-Nielsen 1984
Lithraphidites quadratus Bramlette & Martini 1964
Lithraphidites helicoideus (Deflandre) Deflandre 1963
Eiffellithus gorkae Reinhardt 1965
Octolithus? spp.
Zygodiscus spiralis Bramlette & Martini 1964

Early Palaeocene = Late Danian-combined NP3-NP4 (*Cb. danicus-E. macellus* zone) Assemblage

Sphenolithus sp.
Pontosphaera plana (Bramlette & Sullivan) Haq 1971
Micrantholithus sp.
Braarudosphaera bigelowii (Gran & Braarud) Deflandre 1947
Braarudosphaera sp.
Thoracosphaera operculata Bramlette & Martini 1964
Thoracosphaera saxea Stradner 1961
Markalius inversus (Deflandre) Bramlette & Martini 1964
Biantholithus sparsus Bramlette & Martini 1964
Prinsius bisulcus (Stradner) Hay & Mohler 1967
Ericsonia cava (Hay & Mohler) Perch-Nielsen 1969
Ericsonia subpertusa Hay & Mohler 1967
Cruciplacolithus tenuis (Stradner) Hay & Mohler 1967
Neochiastozygus concinnus (Martini) Perch Nielsen 1971
Neochiastozygus modestus Perch-Nielsen 1971
Neochiastozygus imbrei Haq & Lohmann 1976
Placozygus sigmoides (Bramlette & Sullivan) Romein 1979
Hornibrookina? spp.

DISCUSSION

The checklist of taxa and the interpretation of the data have been slightly modified than published earlier as abstract on the same set of samples (Jafar & Kapoor, 1984). The assemblage suggests precise Late Danian age corresponding to combined NP3-NP4: *Chiasmolithus danicus-Ellipsolithus macellus* zones, despite the absence of both these markers (Martini, 1971). Tiny species of *Neochiastozygus* and large *Biscutum*-like elements identified as *Hornibrookina?* spp. acted as substitute markers (Perch-Nielsen, 1979, 1981). The absence of species belonging to typical Late Palaeocene genera: *Bomolithus, Fasciculithus, Heliolithus* and *Discoaster*, lends further support to this dating. However, outcropping sections in Pondicherry (Cauvery Basin) yielded typical nannoplankton assemblage of NP4: *E. macellus* Zone, including the marker (authors unpublished data). *Hornibrookina?* sp. with peculiar rhomboidal outline (Pl. 1, figs 3a-c) and oval outlines (Pl. 1, figs 6a, b; 7a, b) displays extinction pattern quite unlike large *Biscutum* (Perch-Nielsen, 1985) but shows affinity with *H. edwardsii* and *H. teuriensis* typically known from Early Palaeocene of middle to high latitudes, e.g., New Zealand, Atlantic and Mediterranean belt. Dharampur forms, except for their large size, closely resemble primitive and small *Biscutum? romeini* (Perch-Nielsen, 1981).

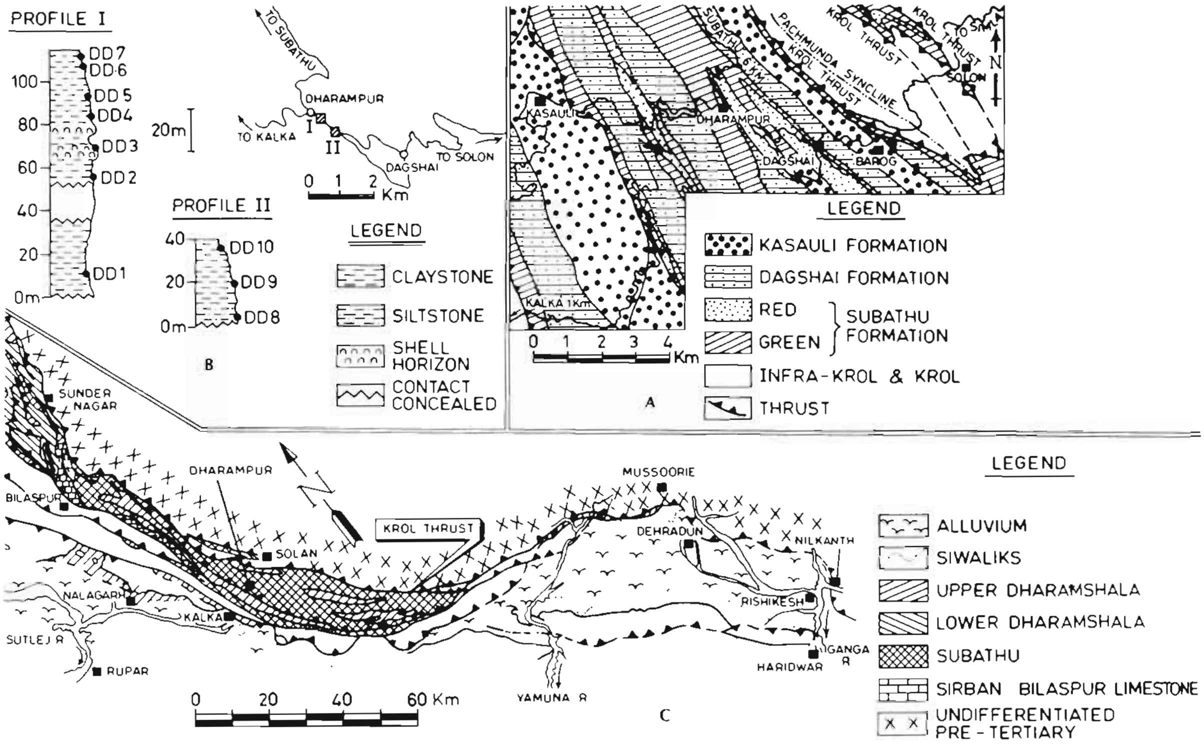
Careful empirical observations backed by Iridium and stable isotope data on some rare hiatus and bioturbated free K/T boundary pelagic sediments both on land and deep sea suggest that unlike several communities suffering "Catastrophic" extinction, the terminal Cretaceous nannoflora did survive for a while in basal Danian (Perch-Nielsen, McKenzie & He, 1982). However, for practical purposes these survivors vanished before the dawn of NP3 and occur in a few centimeters of basal Danian sediments. As such the Cretaceous nannoplankton of Dharampur associated with younger sediments (NP3-NP4) must be interpreted as reworked and can be assigned to low-middle latitude *Micula mura* Zone of Late Maastrichtian age. Further, this implies widespread existence of calcareous shales of comparable age below the conventional Subathu.

Out of the two earlier reports of nannoplankton from the so-called "Krol" of lesser Himalaya, that of Tewari (1969) deserves rejection owing to poor documentation, while that of Sinha (1975) assumes renewed significance in view of the present discovery of Dharampur nannoplankton. A critical assessment of this paper, however, revealed inorganic crystals besides two determinable species indicating broad Late Cretaceous age (Jafar, 1980; Singh, 1981). About 15 meters of calcareous shales yielding these species, as would normally be expected, appear to be sandwitched between different Krol units as tectonic slices. Due to general paucity of megafossils it may readily be confused with various Precambrian shales (Acharyya, 1983). Detailed mapping would reveal more frequent occurrence of such shales as tectonic wedge between Precambrian rocks and may prove to be of Late Maastrichtian age.

From palaeoceanographic viewpoint, the Dharampur succession reflects low energy, rather shallow embayment with access to open sea current system, permitting flourishing of nannoplankton crop of low but normal diversity, distinctly controlled by subdued salinities. In view of facies and tectonics, one should never expect a high frequency and excellent preservation of nannoflora as observed elsewhere in pericratonic basins of India. The shell beds (Map 1B) were formed by reworking, sorting and concentration of only low salinity tolerant and sturdy Oyster communities inhabiting coastal margins by periodic storms (Singh, 1978).

The most likely high energy equivalent of Late Maastrichtian coccolith bearing shales are the so-called Shell Limestone or Upper Tal Limestone known from widespread localities of lesser Himalaya (Bhatia, 1980). Such facies is not expected to yield datable plankton including coccoliths, except from diagenesis-free marly intercalations. As such this important lithounit after generating heated controversies in lesser Himalayan biostratigraphy, is nevertheless enjoying by widespread consensus a broad Maastrichtian-Danian dating based on rich invertebrate fossils (Bhatia, 1980; Singh, 1981). Several workers have attempted to date this unit on the basis of "planktonic foraminifera" recognizable only in thin sections. Unless one is dealing with hard indurated pelagic limestone containing common plankton, extreme caution is needed to date the unit alone on the basis of a few sporadic and fragmentary specimens (Singh, 1980). A detailed work on invertebrate fossils, excluding planktonic elements, is likely to furnish more precise date for Shell Limestone than now available, and some sections may contain Late Maastrichtian or Danian exclusively or encompass K/T boundary. Singh and Rai (1983), upon the strength of facies and other evidences, suggested Precambrian to Early Cambrian age for the Blaini-Infra Krol-Krol-Tal sequence of rocks with explicit exclusion of this Shell Limestone unit from classic concept of Tal Formation (Bhatia, 1980; Singh, 1979). While lower contact of Shell Limestone has been recognised as unconformable with varying lithounits, the upper contact, if at all seen, is considered transitional with Subathu, such as in Garhwal area. Considering this, the concept of marine cycle and limited thickness of Shell Limestone observed all over, it would be reasonable to include it in Subathu Formation with distinct and mappable member rank splitting (Rupke, 1974). This concept would have added advantage of recognising Late Maastrichtian transgressive event, with entire Triassic, Jurassic and Cretaceous except terminal Late Maastrichtian part, signifying a period of non-deposition of marine sediments in lesser Himalaya.

Marine sediments of Danian age were hitherto unknown in lesser Himalaya, whereas, definite Late Palaeocene corresponding to Kakra Series (Srikantia & Bhargava, 1967) is firmly established, largely on the basis of index larger foraminifera (Datta & Banerji, 1966; Tewari & Singh, 1976) and palynofossils (Singh, Khanna & Sah, 1978; Mathur & Venkatachala, 1979). None of the data published so far is convincing enough for the presence of Middle to Late Eocene marine sediments in Subathu, being supported by long ranging species of foraminifera, ostracode and palynofossils. This needs to be more critically evaluated to determine the last phases of marine influences in the Himalaya subsequent to collision of India-Eurasia land masses. In fact, marine Subathu-Dagshai with exclusion of fluviatile Kasauli, most probably encompass Late Maastrichtian-Early Eocene time slice. These signify a single marine cycle starting with Late Maastrichtian transgressive event along lesser Himalayan rift, probably triggered due to widespread Deccan Trap



Map 1—A, Simplified geological map displaying structure and outcrop pattern around Dharampur (after Raiverman, 1976); **B,** Two profiles showing sampling points on Dharampur-Dagshai Road Section; and **C,** Simplified geological map showing structural units and outcrops in Simla Himalaya and adjoining regions (after Karunakaran & Rao, 1976).

activity on the Indian craton. Besides, extensive terrestrial outpouring of lava, both east and west coast bear evidence of extrusion in coastal marine milieu, being characteristically interbedded with *Globotruncana* bearing sediments of Late Maastrichtian age (Mehrotra & Biswas, 1986; Govindan, 1981). This, coupled with significant findings of Courtillot *et al.* (1986), strongly suggests the initiation of Trap activity in Late Maastrichtian throughout Indian craton and continuing up to basal Danian, thereby containing K/T boundary. Disputed, however, is cessation time of trap activity, which may have lasted a little longer than suggested by Courtillot *et al.* (1986). An event of such a magnitude can not span several million years as presumed earlier, mainly due to the fact, that a wealth of flora and fauna published from the Intertrappean beds display monotonous assemblage of similar age. Moreover, plate stratigraphers can not reconcile with the assumption that during rapid northward flight India can contain hot spot for several million years.

REMARKS ON CRETACEOUS PALAEOCEANOGRAPHY AND ENTRY OF SUBATHU SEA

In order to grasp the geotectonic evolution of India, it is instructive to briefly review a few critical models proposed for Cretaceous time slice. Such models proposed within recent years, despite their shortcomings, are based on a wealth of data generated by Deep Sea Drilling Project alone, data based on Indian basins alone or a combination of both (McGowran, 1978; Powell, 1979; Barron & Harrison, 1980; Biswas, 1982; Datta *et al.*, 1983, Sahni, 1984). The earliest Mesozoic marine sediments on Indian craton are curiously confined to northwestern basins of Kutch and Jaisalmer and signify a typical epicontinental Tethyan facies developed in response to a Middle Jurassic (Bajocian) transgressive event followed by Early Cretaceous regressive event. The latter characterized by paucity of marine mega- and micro-fossils and preponderance of terrestrial plant fossils and

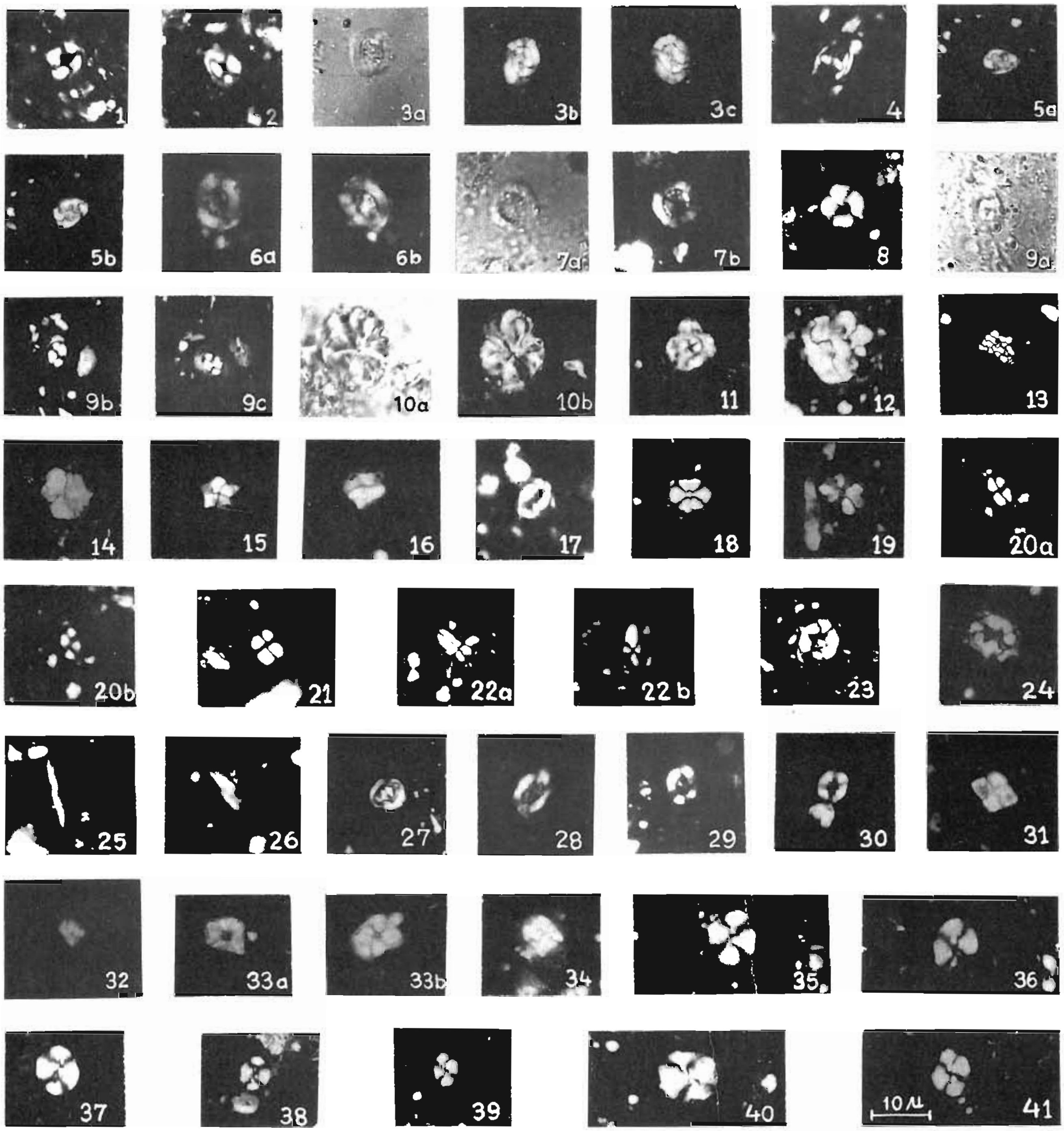


PLATE 1

(Figures 3a, 9a and 10a were photographed under single Polarizer, the rest were taken under crossed polarized illumination. Scale bar in Figure 41)

1, 2. *Ericsonia cava*
3a-c. *Hornibrookina* ? sp. 1
4. *Placozygus sigmoides*
5a, b. *Neochiastozygus modestus*
6a, b. *Hornibrookina* ? sp. 2
7a, b. *Hornibrookina* ? sp. 3
8. *Ericsonia subpertusa*
9a-c. *Prinsius bisulcus*
10a, b. *Biantholithus sparsus*
11. *Markalius inversus*
12. *Thoracosphaera saxea*
13. *Thoracosphaera operculata*
14. *Braarudosphaera bigelowii*
15. *Braarudosphaera* sp.
16. *Micrantholithus* sp.
17. *Zygodiscus spiralis*
18, 19. *Octolithus* ? spp.
20a, b, 21. *Pontosphaera plana*
22a, b. *Sphenolithus* sp.
23, 24. *Eiffellithus gorkae*
25. *Lithraphidites helicoideus*
26. *Lithraphidites quadratus*
27 *Glaukolithus compactus*
28. *Cretarhabdus* ? sp.
29, 30. *Cretarhabdus crenulatus*
31. *Tetralithus* ? sp.
32. *Micula* sp.
33a, b. *Micula decussata*
34. *Micula mura*
35-41. *Watznaueria barnesae*

palynoflora and tempted classic workers to brand them as "non-marine coastal Gondwanas." In view of recent findings these must now be considered fully marine, with intermittent condensation horizons, intraformational conglomerates and increasing deltaic influence during Neocomian to Albian. The concomitant change in the coastal geometry restricted the entry of organic-walled plankton and calcareous nannoplankton (Jaikrishna *et al.*, 1983; Jaikrishna, 1983). The onset of Early Cretaceous regressive phase in epicontinental Tethyan domain of Kutch and Jaisalmer appears to be intimately connected with the growth of juvenile Indian Ocean (see 120 Ma and 100 Ma reconstructions of Barron & Harrison, 1980). Madagascar-Seychelles-India landmass was separated from East Africa by a narrow spreading channel, which became dormant and later shifted to a position between madagascar and Seychelles-India, finally between Seychelles and India to impart independent status to Indian craton during terminal Cretaceous. With regressive phase operating in Tethyan area and the shores of juvenile Indian Ocean lying too far, the possibility of an Early Cretaceous transgressive event must be ruled out in the western sector of Indian craton, specially along intracratonic set up of Cambay and Narmada and Son grabens, containing Dhrangadhara-Wadhwan and Nimar Sandstone formations, respectively, and erroneously interpreted as fluvio-deltaic sediments of Early Cretaceous transgression (Biswas, 1982, 1983).

It must be emphasized that during the Early Cretaceous time slice and even later the growing Indian Ocean failed to establish any connection with retreating shores of Tethyan Ocean, either via northwestern or northeastern sectors of Indian craton, therefore left blank or connection questionably depicted in several published reconstructions including those of Dietz and Holden (1970) and Barron and Harrison (1980). The juvenile Indian Ocean was fed by current system operating via channels between South America and Antarctica landmasses and as recently demonstrated by Veévers (1986), also via channel between Antarctica and Australian landmasses during Aptian-Albian. Lack of connection between juvenile Indian Ocean and Tethyan Ocean would explain widespread stagnant bottom conditions prevailing in juvenile Indian Ocean-South Atlantic sector and the entire North Atlantic sector, resulting in spectacular development of Black shale facies of extraordinary magnitude during middle-Cretaceous (Roth, 1979).

In contrast to Early Cretaceous marine sediments of northwestern part of Indian craton representing regressive facies and genetically related to middle Jurassic epicontinental Tethys, another set of Early Cretaceous marine sediments developed along east coast of India in response to rifting, vulcanism and possibly eastward reversal of drainage of Indian craton for regions lying south of Narmada-Son lineament (Datta *et al.*, 1983). This significant reversal of drainage which had maintained westerly course during Gondwana sedimentation, is supported by paralic sediment packages developed in Mahanadi, Krishna-Godavari, Palar and southernmost Cauvery basins. Coarse clastics with preponderance of plant megafossils and palynofossils and scarcity of marine mega- and microfossils including plankton, prompted earlier workers to brand them as "non-marine coastal Gondwana" of Late Jurassic to Early Cretaceous age. Recent work has, however, demonstrated (Jaikrishna *et al.*, 1983; Venkatachala & Rajanikanth, 1988) that these sediment packages were formed during Neocomian with gradual increase of pelagic sedimentation toward southern basins, thereby permitting finer resolution in dating by phytoplankton. Rapid fluctuations in shoreline and offshore enrichment of plankton make them attractive from viewpoint of hydrocarbon exploration. Black shale facies, though developed in restricted way in southernmost Cauvery Basin (Dalmiapuram Formation), should display wider development farther offshore as per stagnant bottom water model cited for Middle Cretaceous of juvenile Indian Ocean (Roth, 1979).

The palaeogeography of India during Early Cretaceous, as backed by deep sea data and cratonic basins of India, permits recognition of two distinct regions, viz., northwest regressive epicontinental Tethys of Kutch and Jaisalmer and transgressive Neocomian epicontinental sea stretching from Mahanadi to Cauvery basins on the east coast of India. The entire cratonic region including Cambay and Narmada grabens on the west coast, northeastern regions of Meghalaya, Bengal and Assam including lesser Himalayan belt must be shown as positive area. Palaeocurrent data of coeval fresh water sediments developed in Rewa, Satpura and Godavari basins (Datta *et al.*, 1983) is needed to understand the nature of drainage reversal caused due to significant Neocomian rifting and Rajmahal-Sylhet vulcanism on the eastern sector of India.

Late Cretaceous palaeogeography of India was controlled by rapid growth of plates leading to fast growth of juvenile Indian Ocean coupled with activation of pre-existing rifts on Indian craton (see 80 Ma and 60 Ma reconstructions of Barron & Harrison, 1980). Most significant was establishment of north-south Atlantic connection, thereby shortest entry to Tethyan current system into juvenile Indian Ocean, as more direct connections to Tethys via northwest and northeast sectors of the Indian craton are not confidently known. Activation of prominent rift grabens of Cambay and Narmada, which had maintained N-S and E-W palaeodrainage, respectively, despite eastward reversal of drainage during Neocomian rifting on the east coast, attracted a solitary and shortlived marine transgression during Turonian (Jafar, 1982). Failure to achieve at least stage level dating, had resulted in broad "Late Cretaceous" dating of Narmada Valley sediments and their correlation with lesser Himalayan Cretaceous based on a few long ranging invertebrate species common to both, resulting in erroneous palaeogeographic reconstructions (Singh, 1979, 1981; Singh, 1980). It must be emphasized that Turonian dating of Narmada Valley Cretaceous was not only based upon recovery of datable nannoplankton assemblage from Nimar Sandstone, but also took critical note of a wealth of data published on vertebrates, invertebrates and microfossils coupled with facies succession Sandstone-Nodular Limestone-Coralline Limestone of reduced thickness, without evidence of this sedimentary package being of condensed nature. Therefore, a shortlived marine transgression emanating from westward lying juvenile Indian Ocean must be envisaged. Further work on largely concealed pretrappean sediments of Saurashtra (Wadhwan-Dhrangadhara formations) is likely to yield Turonian age for Wadhwan against Early Cretaceous age suggested by Biswas (1982, 1983), especially inview of close faunal similarity with Narmada Cretaceous (Chiplonkar & Borkar, 1975) and geometry of the basins.

Two important events characterize rapid growth of juvenile Indian Ocean on the eastern sector of India. Firstly, the paralic sedimentation ceased on the coastal basins of Mahanadi to Cauvery with dominance of pelagic sedimentation in offshore areas. The southernmost Cauvery Basin displays nearly complete succession of Cretaceous sediments with minor hiatuses and evidence of significant coastal upwelling during Late Albian basal Uttatur sediments that contain phosphate influx with bloom of plankton including appearance of radiolaria (Garg & Jain, 1979). The oldest oceanic crust, close to the passive eastern margin of India has not been encountered and dated, though deep sea data suggest Early Campanian age for large areas in Bay of Bengal, including oceanic Islands of Andamans, which have yielded Campanian age for the oldest sediments associated with ophiolites (Jafar, 1985). Thus, the birth of proto-Bay of Bengal must remain speculative, which may have come into existence anytime between Aptian to Campanian. Secondly, renewed spreading events during Campanian-Maastrichtian resulted in inundation of cratonic areas with epicontinental sea emanating from growing Indian Ocean, with no sign whatsoever of Tethyan connection. Thus the areas which remained positive during Early Cretaceous, viz., Meghalaya, Bengal, Assam and lesser Himalaya were successively invaded by "northward" shifting marine pulses during Campanian-Maastrichtian time slice.

Despite structural complexities induced by tectonics of collision between north-east segment of the Indian and Asiatic plates, one should not loose sight of the fact that intensive exploration activities during recent years support existence of broad Late Cretaceous sediments and penetration of marine influences deep into the vicinity of Arunachal area (Rangarao, 1983; Datta *et al.*, 1983) via Assam-Arakan Basin. The oldest marine sediments overlying Precambrian crystallines in Meghalaya, and Sylhet traps and partially oceanic crust in Bengal Basin, suggest Campanian age. Lower Disang and Dergaon formations, including ophiolites of Manipur and Nagaland, suggest Maastrichtian or Late Maastrichtian age, basically backed by species of critical *Globotruncana* found in association with long ranging benthonics (Rangarao, 1983).

Terminal part of Cretaceous encompassing Late Maastrichtian-Danian was probably the most significant phase in the northward drift of the Indian craton when Seychelles separated from India in response to rifting and pronounced Deccan trap activity affecting western to eastern sectors of India. New data generated on timings and duration of Deccan traps, based on widely separated areas and filtering out erroneous dates, suggest Late Maastrichtian-Danian outpouring around K/T boundary (Courtillot *et al.*, 1986). This is further strengthened by the findings of *Globotruncana*-bearing Intertrappeans both on the western (Mehrotra & Biswas, 1986) and eastern offshore regions (Govindan, 1981). These suggest a possible correlation with Deccan Trap vulcanism of extraordinary magnitude (McLean, 1985) and Maastrichtian transgressions affecting north-east sector of India. It must be emphasized that western sector of India under the influence of rifting, vulcanism and uplift would not permit the entry of sea along Narmada-Son Graben, as suggested in "Trans Deccan Strait" model of Sahni (1984). This model based on broad "Late Cretaceous" time slice largely backed by dating of marine benthonics and terrestrial vertebrates, is no more tenable. Curiously enough, the entire western sector of India shows absence of Late Maastrichtian-Danian marine sediments in Laki, Sulaiman and Salt ranges in Pakistan (Powell, 1979; Haq, 1971) and western Himalayan ranges (Mathur, 1983), which otherwise contain prolific Late Palaeocene plankton including nannoplankton (Haq, 1971). Similarly, lack of convincing Maastrichtian-Danian marine sediments in western Indian sections (Jafar, 1986) suggests a positive area. Irrespective of the fact, as to whether the marine sediments during Late Maastrichtian-Danian were deposited by Tethyan or Indian Ocean, a positive area is suggested in both the regions.

Lesser Himalayan rift or Subathu-Dogadda rift (Singh, 1979) bears striking resemblance to prominent rift zones of the eastern peninsular India in terms of facies, stratigraphic record, which prompted classic workers to brand it as "Peninsular Himalayas", though tectonic slicing has drastically modified its geometry. In several reconstructions, Indian craton is depicted as an Island with Tethys in the "North" and growing Indian Ocean in the "South" (see 60 Ma reconstruction of Barron & Harrison, 1980), with gaps on north-west and north-east sectors showing no confident connections between contracting Tethys and expanding Indian Ocean. Future studies would probably fill these gaps with microcontinents (Powell, 1979). Nevertheless, under this set up and considering the crustal shortening involved due to collision and rise of Himalayas, the prominent rift grabens on the eastern sector, viz., Subathu, Damodar, Mahanadi and Godavari are suited to receive marine incursions during Late Maastrichtian-Danian, probably triggered due to Deccan trap activity. Palaeobotanical evidence tends to suggest marine estuarine complex extending deep into Godavari Graben during trap activity. It could be an event of short duration, but can have no connection with Narmada Valley Cretaceous, which is of Turonian age and emanated from a westerly incursion, thereby challenging the "Trans Deccan Strait" model of Sahni (1984). From Damodar and Mahanadi grabens, no evidence of coeval marine incursion has come to light so far, but the possibility cannot be ruled out.

The classic discovery of marine invertebrates of Cretaceous age, notably Belemnites by Middlemiss (1885) and nannoplankton by Sinha (1975) and the present discovery of Late Maastrichtian-Danian nannoplankton from lesser Himalaya, need more critical assessment, despite the fact that beside this data, no other conclusive evidence of Cretaceous age has come to light. Rich fauna of Shell Limestone has not yet been resolved into distinctly Cretaceous and Danian. Moreover, throughout the belt stretching from Jammu-Murree to Arunachal area, critical Late Maastrichtian or Lower/Upper Palaeocene plankton markers remains undiscovered. Despite severe tectonic slicing, metamorphism and facies affecting ready recovery of microfossils, the recent find of Early Eocene Subathu sediments in Arunachal area, earlier believed to be absent in regions east of Nepal (Tripathi & Mamgain, 1986), offers strong possibility of Late Maastrichtian-Palaeocene marine sediments to be discovered throughout Subathu belt. The absence of marine elements in western sector during Late Maastrichtian-Danian and their presence throughout north-east regions of Meghalaya, Bengal, Assam-Arakan including oceanic Andaman Islands, as discussed earlier, offers compelling reasons to postulate the entry of Assam-Arakan sea via Arunachal during Late Maastrichtian transgressive event. Planktonic foraminifera coupled with high Iridium anomaly, possibly suggesting K/T boundary are recently reported from Meghalaya outcrops (Bhandari *et al.*, 1987), which may also be present in Andamans (Jafar, 1985) and Lower Disang and Dergaon formations. Radiometric-stable isotope and magnetic datings of fossil poor facies and sustained field work is likely to yield K/T boundary throughout lesser Himalayan belt with possibilities of minor local hiatuses.

CONCLUSIONS

1. The discovery of Late Maastrichtian-Danian nannofloral elements in hitherto undatable Subathu shales of Simla Himalaya suggests a Late Maastrichtian transgressive event along lesser Himalayan rift zone, possibly triggered due to widespread and coeval Deccan Trap vulcanism on Indian craton and matching the rapid spreading events recorded in the growth of juvenile Indian Ocean.

2. Since absence of Late Maastrichtian-Danian marine sediments in western India-Pakistan sections suggest positive area, but well-developed in northeastern Assam-Arakan Basin, one might postulate the entry of Late Maastrichtian Assam-Arakan sea via Arunachal and terminating at Jammu-Murree with retreat by the end of Early Eocene, as published Middle to Late Eocene microfossils and palynological records from lesser Himalaya need critical revaluation.

3. Despite constraints of plate tectonics model, well-defined transgressive events are recognised on the eastern and western sectors of Indian craton and Cretaceous palaeogeography is critically reassessed.

4. The lower age limits of Subathu-Dagshai needs to be pushed down to coincide with Late Maastrichtian transgressive event; coeval marine incursions should be expected along other rift

zones of India viz., Damodar and Mahanadi and more vigorous search must be made in Godavari, which already bears fragmentary evidences of such an incursion.

5. Adverse facies and large scale tectonic slicing in Lesser Himalaya pose severe problems, but careful mapping and recovery of plankton from calcareous shales would help in demonstrating the presence of Late Maastrichtian-Early Palaeocene marine sediments in other areas including Arunachal and a link between Subathu and Assam-Arakan sea. Radiometric, stable isotope and magnetic datings would further help in tracing Late Maastrichtian event containing K-T boundary all through the route with minor local hiatuses.

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Palynostratigraphy of the Lower Gondwana sediments from Shobhapur Block, Pathakhera Coalfield, Madhya Pradesh

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Srivastava, Suresh C. & Sarate, O. S. (1989). Palynostratigraphy of the Lower Gondwana sediments from Shobhapur Block, Pathakhera Coalfield, Madhya Pradesh. *Palaeobotanist* **37**(1) : 125-133.

Palynofloral investigations carried out on bore-hole samples from Shobhapur Block, Pathakhera Coalfield in Madhya Pradesh revealed two distinct palynofloral assemblages. Assemblage Zone-1 is rich in radial monosaccates, chiefly *Parasaccites* and includes the lowermost coal seam of the area, the Bagdona Seam. Assemblage Zone-2 is characterised by the dominance of nonstriate-disaccate—*Scheuringipollenites*, distributed in the younger coal seams including lower (Middle) and upper (Top workable). Assemblage Zone-1, corresponding to the known Upper Karharbari palynofloras, establishes the existence of Karharbari sediments in Shobhapur Block of Pathakhera Coalfield, which were hitherto assigned to Barakar Formation. The Barakar palynoflora has continued into the lower part of Motur Formation in bore-hole no. CMPS 43 of Shobhapur Block.

Key-words—Palynostratigraphy, Karharbari Formation, Barakar Formation, Lower Gondwana (India).

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साराँश

मध्य प्रदेश में पथखेड़ा कोयला-क्षेत्र के शोभापुर ब्लॉक से अधरि गोंडवाना अवसादों का परागाणुस्तरविन्यास

सुरेश चन्द्र श्रीवास्तव एवं ओमप्रकाश शिवदास सराटे

मध्य प्रदेश में पथखेडा कोयला-क्षेत्र के शोभापुर ब्लॉक से **वेध-छिद्र** नमूनों के परागाणविक अन्वेषण से दो विभिन्न परागाणुवनस्पतिजातीय समुच्चय उपलब्ध हुई है। समुच्चय मडल-1 अरीय एककोष्ठीयो, मुख्यतया पैरासैक्काइटिस, से भरपूर है तथा इसमें इस क्षेत्र की अधरितम कोयला-सीम—बागडोना सीम, सम्मिलित है। समुच्चय मडल-2 अरेखीय-द्विकोष्ठीयों, **श्यौरिंगीपोलिनाइटिस**, से अभिलक्षणित है जो कि अधर एव उपरि अल्पायु के कोयला-सीमों में वितरित है। उपरि करहरबारी से ज्ञात परागाणुवनस्पतिजातो से सम्बद्ध समुच्चय मडल-1 के आधार पर शोभापुर ब्लॉक में करहरबारी अवसादो की उपस्थिति इंगित हुई है जिनको कि अब तक बराकार शैल-समूह का माना जाता था। बराकार परागाणुवनस्पतिजात शोभापुर ब्लॉक के बेध-छिद्र संख्या सी-एँम-पी-एँम० 43 में स्थित मोतुर शैल-समूह के निचले भाग मे विद्यमान है।

SATPURA Basin is the westernmost Gondwana Basin and includes Mohpani, Pathakhera and Pench-Kanhan coalfields. The former represents the northernmost limb while the latter two represent the southern and south-western limbs of the Satpura Basin. Anand-Prakash (1972) studied the *sporae-dispersae* from Pench-Kanhan and Pathakhera area but the information as such does not throw any light on the age of the coal seams of Pathakhera Coalfield. The present investigation has been undertaken to develop palynological succession in bore-holes CMPS-35, 38 and 43.

GENERAL GEOLOGY

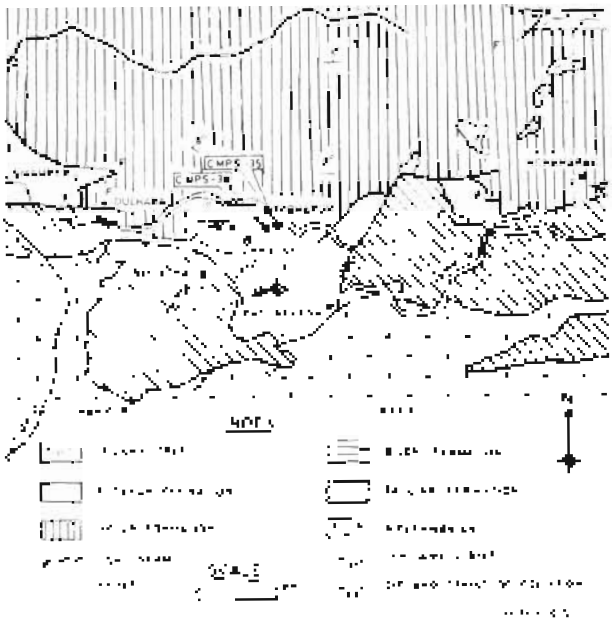
The Pathakhera Coalfield, named after a small village—Pathakhera (22°06′ : 78°10′), lies in the Betul District of Madhya Pradesh. It is 19 km east from Ghodadongri Railway Station. This coalfield is one of the most promising source of coal supply for western India. Shobhapur Block represents the northernmost portion of the Pathakhera Coalfield (Map 1).

The Archaeans here form the basement for the Lower Gondwana sediments which chiefly comprise gneisses, schists and quartz veins. They also form hills of considerable heights on the northern margin. The Talchir sediments overlie the basement metamorphics and include khaki green needle shales, yellowish coarse grained sandstone and the mudstone bands. Boundary in the south-east and west is faulted. The Talchir sediments are overlain by Barakar Formation which is the only coal bearing horizon in Pathakhera Coalfield and includes three coal seams. The Barakar sediments mainly consist of coarse-grained sandstones, rarely fine-grained with occasional shale bands and coal seams. The Motur Formation overlies the Barakar Formation and consists of greenish coarse grained sandstone and red, yellow or green clay. The clays are calcareous in nature with occasional shale bands. The Bijori Formation overlies the Motur Formation and contains fine grained buff coloured sandstones, shales and micaceous flags. These exposures are seen on the banks of Tawa River in the north central part of the Pathakhera Coalfield.

The geological succession (after Sastry *et al.*, 1973) in Pathakhera Coalfield is given below:

Recent to Sub-Recent	Detrital mantle	Soil and newer alluvium, subsoil, older alluvium
Upper Cretaceous Basic intrusives		Dolerite dyke and traps
	Unconformity	
Upper Permian	Bijori Stage (Raniganj)	Green to grey sandstones, shales and micaceous flags
Middle Permian	Motur Stage (Barren Measures)	Greenish grey sandstones with minor shales and coal seams
Lower Permian (Coal-bearing Strata)	Barakar Stage	Grey sandstones with minor shales and coal seams
	Unconformity	
Talchir (Not exposed in the west)	Talchir Series	Greenish fine grained shales and sandstone (boulders are recognised in other adjacent fields to the west)
	Unconformity	
	Archaeans	Gneisses, schists, quartz veins, crystalline limestone
LOWER GONDWANA		

Collection of samples—All the samples are from the bore-holes. Bore-hole no. CMPS-13 is 275.20 m in thickness (Lithology 3?) and is located at about 2.5 km west of Shobhapur coal mine. The clay band at 78.75 m demarcates the overlying Moturs from underlying Barakar sediments. The details are as under:



Map 1—Geological map of Pathakhera Coalfield, Madhya Pradesh.

Sample No.	Depth in Metres	Lithology	Palynofossils Present (+) Absent (—) Rare (*)
1	18.[illegible]	Variegated clay	
2	[illegible]	Variegated clay	—
3	2[illegible]	Fine grained sandstone	—
4	4[illegible]	Green fine grained sandstone	—
5	45.[illegible]	Green fine grained sandstone	—
6	48.5[illegible]	Clay & fine grained sandstone	—
7	4[illegible]	Green fine grained sandstone	—
8	5[illegible]	Sandstone	—
9	57	Micaceous sandstone	—
10	59	Fine green sandstone	—
11	6[illegible]	Fine greenish sandstone	—
12	61.50	Greenish sandstone	+
13	62	Fine greenish sandstone	—
14	63	Gritty sandstone	—
15	63.5	Fine grained sandstone	
16	64	Fine grained sandstone & shale	+
17	6[illegible]	Gritty sandstone & coal	+
18	67.5[illegible]	Variegated clay	
19	[illegible]	Green variegated clay	—
20	7[illegible]	Green fine clay	
21	[illegible]	Green clay	
22	[illegible].75	Greenish sandstone	
23	[illegible]	Fine grained sandstone with carbonaceous streaks	+
24	78	Variegated clay	—
		Motur-Barakar boundary	
25	78.[illegible]	Fine grained sandstone with coal and carbonaceous streaks	—
26	[illegible]	Fine grained sandstone	+
27	[illegible].20	Coarse grained sandstone with clay	+

28	102.50	Fine grained clayey sandstone	—
29	102.90	Fine grained clayey sandstone	—
30	110	Coarse grained sandstone with coal streaks	+
31		Coarse grained sandstone with coal streaks (greenish)	—
32	115	Coarse grained greenish sandstone with shale patches	+
33	124	Fine grained greenish gritty sandstone	+
34	130	Micaceous shale	−
35	130.5	Fine grained sandstone with micaceous streaks	—
36	138.30	Shale	
37	139.25	Fine grained sandstone with shale patch	
38	147.05	Shaly sandstone	+
39	151.00	Sandy shale	+
40	155	Fine grained shaly sandstone	−
41	156	Fine grained shaly sandstone	−
42	156.10	Coal	—
43	[illegible]	Carbonaceous shale	+
44	140	Fine grained shaly sandstone	+
A-1	149.32	Shaly coal	−
A-2	149.54-150.20	Coal	
A-3	189.20-190.82	Shaly coal	+
45	191.20	Shale	+
B-1	211.55-212.25	Coal	—
B-2	212.25-213.42	Carbonaceous shale	—
B-3	213.42-213.85	Coal	—
B-4	213.85-214.85	Coal	+
B-5	214.90-216.12	Shale	+
B-6	216.42-217	Shaly coal	+
B-7	217-217.20	Coaly carb. shale	+
46	217.30	Carbonaceous shale	—
47	218-219	Sandy shale	+
48	224	Shale	+
49	226	Shaly coal	
50	227	Greyish black shale	+
51	228.5-229.5	Carbonaceous shale	+
52	230.60	Shaly sandstone	
53	231.30	Fine grained sandstone with micaceous streaks	
54	242	Fine grained sandstone with micaceous streaks	+
55	243	Shaly coal	—
56	243-243.55	Sandy shale	+
57	244-247.00	Fine grained sandstone with micaceous streaks	+
58	248	Shaly sandstone	−
59	248 to 250	Fine grained sandstone with shale	−
60	250.25	Shaly sandstone	
61	251.70-252	Sandy shale	+
62	252.70-254	Shale	+
63	256-257.75	Shale	+
64	257.25-259.70	Shale	+
65	259.75-260.25	Greyish black shale	−
66	263-264.50	Sandy shale	+
67	265-265.5	Sandy shale	+
BG-1	265-267.20	Coal	+
BG-2	267.20-267.40	Sandy shale	+
BG-3	267.70	Sandstone	−
BG-4	268.35	Coal	+
68	268.5	Shale	−
69	269	Micaceous shale	+
70	270.50	Shale + sandstone	+
71	270.60-271.60	Sandy shale	+
72	272.30	Fine grained sandstone with micaceous bands	+
73	273.10-273.40	Micaceous shale	+

Bore hole closed

The other two bore-holes CMPS 35 and CMPS 38 are located at about 1.2 km north west of Shobhapur mine and the details of samples are as follows.

BORE-HOLE NO. CMPS-35

Depth in meters			*Palyno fossils Present (+) Absent (−) Rare (*)*
164.90-165	Coal	Upper Workable seam	+
165-165.10	Shale	Upper Workable seam	+
165.10-165.60	Shale	Upper Workable seam	+
183.30-184	Shale	Lower Workable seam	+
184-184.30	Coal	Lower Workable seam	+
184.30-185	Shale	Lower Workable seam	+
185-186	Coal	Lower Workable seam	+
186-186.50	Shale	Lower Workable seam	−

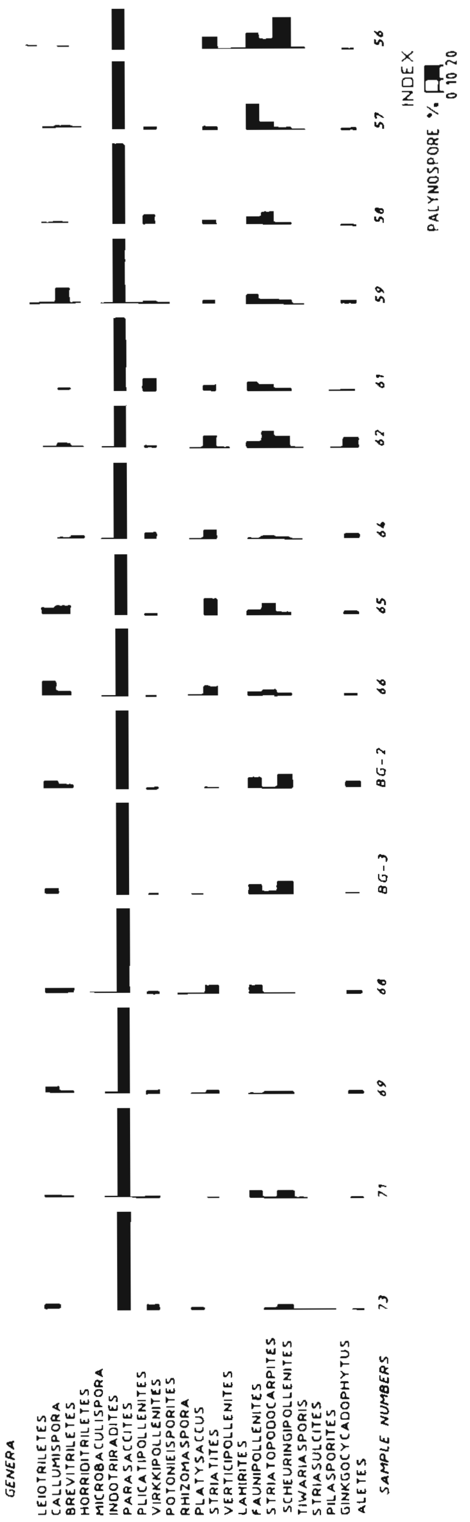
BORE-HOLE NO. CMPS-38

165-165.15	Coal	Upper Workable seam	+
165.15-165.65	Shale	Upper Workable seam	+
165.65-166	Coal	Upper Workable seam	+
166-166.65	Shale	Upper Workable seam	+
185.50-185.90	Coal	Lower Workable seam	
185.90-186	Shale	Lower Workable seam	+
186-186.95	Coal	Lower Workable seam	−
186.95-187	Shale	Lower Workable seam	+
187-187.73	Coal	Lower Workable seam	−

PALYNOFLORA

In the present palynological investigation the following taxa have been recorded.

Indotriradites korbaensis Tiwari 1965
Horriditriletes ramosus Tiwari 1965
Brevitriletes unicus Singh 1972
B. communis Bharadwaj & Srivastava 1969
Playfordiaspora annulata Tiwari & Rana 1980
Pseudoreticulatispora barakarensis Bharadwaj & Srivastava 1969
[illegible] Singh 1964
Callumispora tenuis Bharadwaj & Srivastava 1969



Histogram 1a—Showing palynofloral assemblages in bore-hole no CMPS-43, Shobhapur Block, Pathakhera Coalfield.

C. tenuis var. *minor* Bharadwaj & Srivastava 1969
Weylandites obscurus (Tiwari) Bharadwaj & Dwivedi 1981
W. dubius (Venkatachala & Kar) Bharadwaj & Dwivedi 1981
Parasaccites distinctus Tiwari 1965
P. obscurus Tiwari 1965
P. diffusus Tiwari 1965
P. bilateralis Tiwari 1965
Plicatipollenites indicus Lele 1964
Virkkipollenites corius Bose & Kar 1966
Crucisaccites indicus Srivastava 1970
Lunatisporites sp.
Corisaccites alutus Venkatachala & Kar 1968
C. distinctus Venkatachala & Kar 1968
Corisaccites sp.
Striatites panchetensis Tiwari & Rana 1981
S. tectus Venkatachala & Kar 1968
S. alius Venkatachala & Kar 1968
Lahirites rarus Bharadwaj & Salujha 1964
Verticipollenites gibbosus Bharadwaj 1962
Striatopodocarpites subcircularis Sinha 1972
Faunipollenites goraiensis (Potonié & Lele) Maithy 1965
F. singrauliensis Sinha 1972
F. parvus Tiwari 1965
F varius Bharadwaj 1962
F. enigmatus Maheshwari 1969
Striasulcites tectus Venkatachala & Kar 1968
Distriatites insolitus Bharadwaj & Salujha 1964
Rhizomaspora radiata Wilson 1962
R. indica Tiwari 1965
Crescentipollenites sellingi (Salujha) Tiwari & Rana 1980
Crescentipollenites hirsutus (Kar) Bharadwaj, Tiwari & Kar 1974
Marsupipollenites triradiatus Balme & Hennelly 1965
Ginkgocycadophytus vetus (Balme & Hennelly) Tiwari 1965
Potonieisporites neglectus Potonié & Lele 1961
P. concinus Tiwari 1965
Scheuringipollenites tentulus (Tiwari) Tiwari 1973
S. barakarensis (Tiwari) Tiwari 1973
Ibisporites diplosaccus Tiwari 1968
Platysaccus ovatus Maithy 1965
Falcisporites stabilis Balme 1970
Aurangapollenites gurturiensis Srivastava 1977

PALYNOASSEMBLAGE ZONES

The palynoflora recovered from the three bore-holes is distinctly divisible into two palynozones which are here designated as Assemblage Zone-1 and 2.

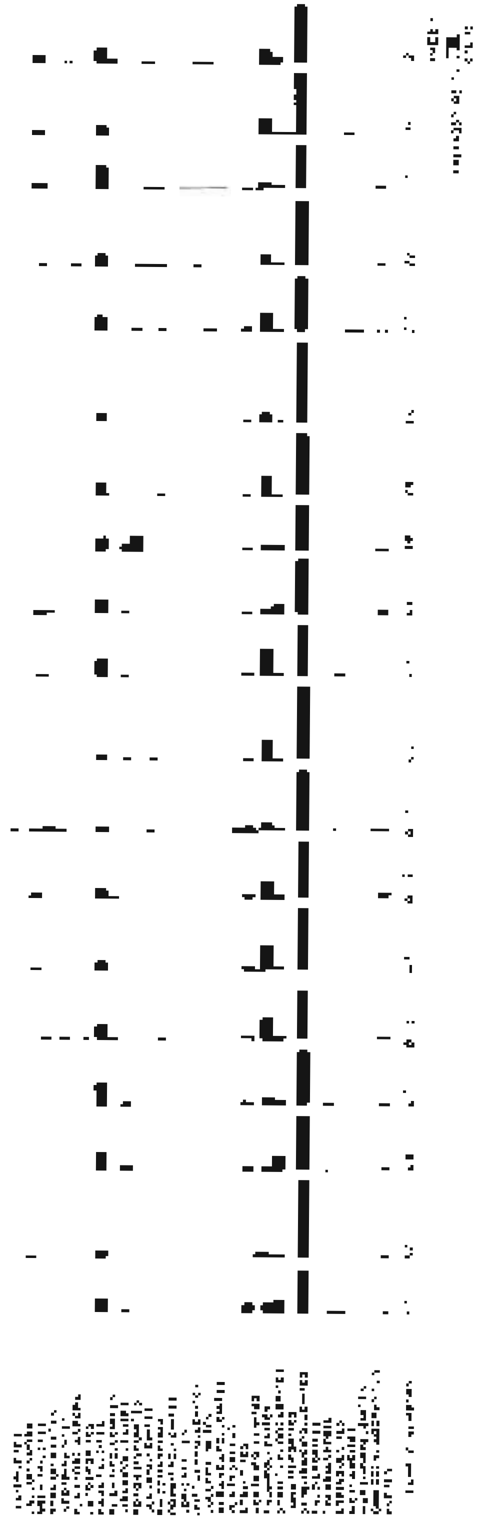
Assemblage Zone 1—The palynofloral Assemblage Zone 1 is distinguished between 278.10 to 243.55 m in bore hole CMPS 43 with an average representation of *Parasaccites* up to 60 per cent (Histogram 1a, Table 1). As we move from older to the younger sediments there is a slow but steady decrease in percentage of *Parasaccites* but it still maintains the dominance up to sample no. 56 (243-243.55 m). The total amount of monosaccates at an average remain 65 per cent, the striate disaccates 17 per cent and non-striate disaccates 6 per cent. Triletes (9%) are comparatively low in percentage distribution. This zone includes the lowermost Bagkata coal seam.

Assemblage Zone 2—The first palynofloral change in bore-hole CMPS 43 is recorded in sample no. 51 (depth 228.5-229.5 m). *Scheuringipollenites* takes over the dominance while *Parasaccites* reduces to considerably low percentage. *Faunipollenites* (average 14%) and *Parasaccites* (average 13%) are next in the order of dominance. *Striatopodocarpites* (average 5%), *Striatites* (average 2%), *Callumispora* (4 to 7%) are in low percentages. *Leschikisporites*, *Marsupipollenites*, *Weylandites*, *Guttulapollenites*, *Corisaccites*, *Rhizomaspora*, *Primuspollenites*, *Densipollenites* and *Potonieisporites* appeared after sample no. 40 (154 m) and are present between 1 to 2 per cent only. Aletes are also recorded to be 1 to 6 per cent (Histogram 1b, Table 2).

Thus, the total representation of the monosaccates have reduced to 15 per cent on an average, while the non-striate disaccates have risen to 50 per cent. The striate disaccates have also increased to 21 per cent. The triletes do not record any significant variation, but the incoming of certain elements, though in rare amount, is characteristic showing younger aspect to the palynoflora. The Upper (Top) and the Lower (Middle) Workable coal seams occur within this palynofloral assemblage zone.

The sample nos. 1 to 24 (depth 16-78 m), lithologically correlatable with the Motur Formation in the present bore hole, however, contained similar palynoflora as has been observed in the underlying samples of Assemblage Zone 2. This shows the continuity of the same palynoflora irrespective of a change in lithology (Histogram 1b, Table 2).

The palynoflora of Lower Workable and Upper Workable coal seams encountered in bore-holes CMPS 35 and CMPS 38 (Histogram 2, Table 3) shows the dominance of *Scheuringipollenites* and thus correlate with Assemblage Zone 2. In bore-hole CMPS 35, the *Parasaccites* and *Faunipollenites* are present in almost similar percentage in lower



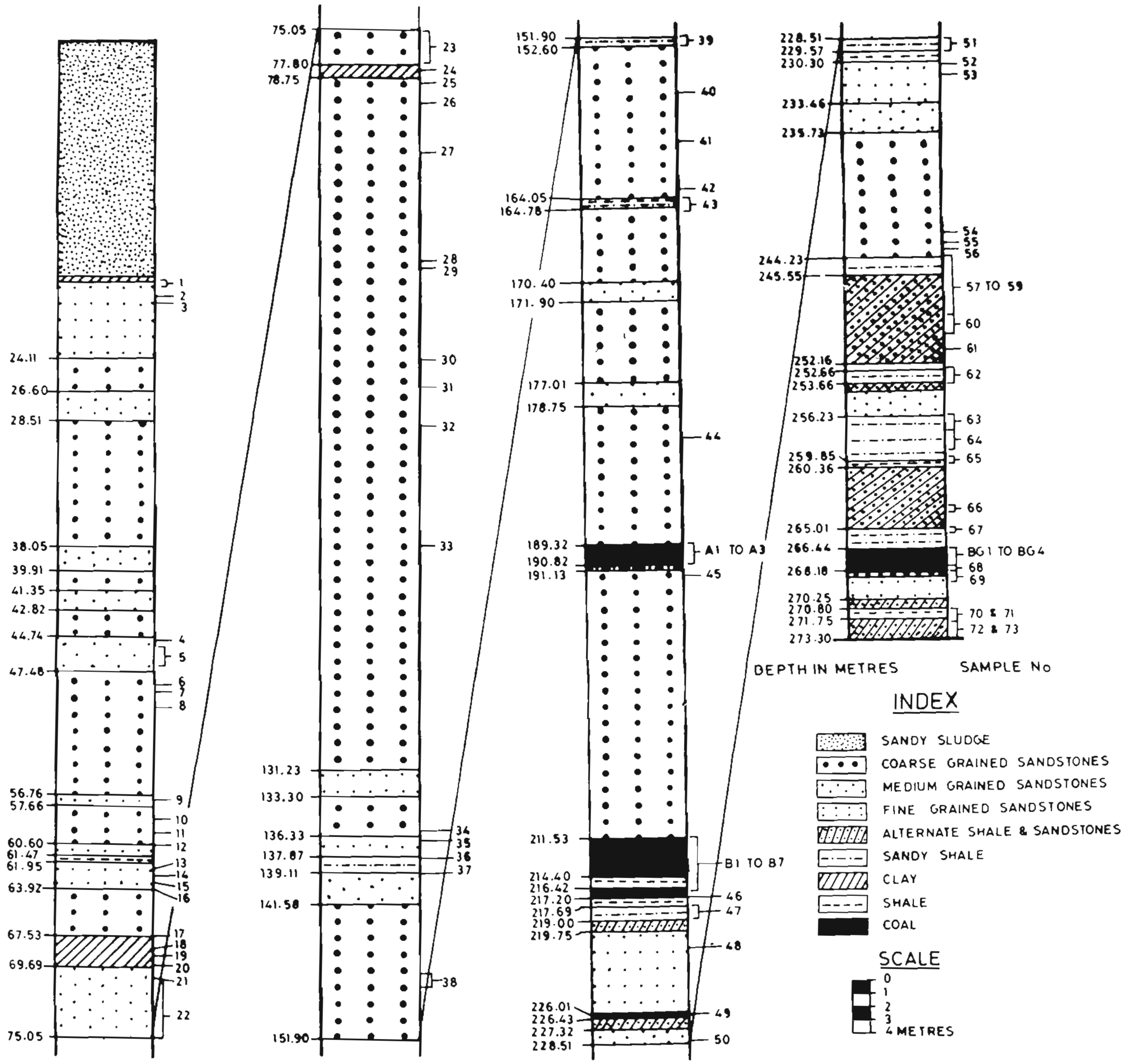
Histogram 1b—Showing palynofloral assemblages in bore-hole no. CMPS 43, Sohagpur Block, Sohagpur Coalfield.

Table 1 — Showing the percentage of various genera in Bore-hole no. CMPS-43

Genera	Sample no. 73	71	67	68	70.3	70.2	66	65	64	62	61	59	58	57	56
	ZONE 1														
Leiotriletes	—			—	—						—	1			1
Cyclogranisporites	4	2	5	4	5	5	15	2	2	2		2	1	1	—
Brevitriletes		2	2	4	—	4	4	1	3	4	5	13	2	1	2
Horriditriletes	—	—		—	—					1		1		1	
Microbaculispora	—	—	—	1	—	—		—			—	—	—	—	—
Indotriradites	1	1	1	1		—	1	—	1	1		1	—	—	—
Parasaccites	78	73	70	69	73	62	54	56	62	55	60	52	55	56	52
Plicatipollenites	—	2		—	—	—	—					1	—	—	—
Virkkipollenites	5	5	5	3	—	1	2	5	7	4	11	4	6	—	5
Potonieisporites		1		—	—						1				
Rhizomaspora	—	—		1	—	—					—	—	—	—	—
Vesicaspora	2		1	1	—	—	2	—	1	1	—	—	—	—	—
Striatites	—	1	3	6	1	1	6	15	4	10	5	5	5	3	10
Verticipollenites	—	—		—	—	—	—	—		1	—	—	—	—	1
Lahirites	—				—	—	—	—	—	—			—	—	1
Faunipollenites		6	1	6	7	9	4	5	5	6	8	9	7	21	15
Striatopodocarpites	2	1	2	—	2	1	5	11	4	14	6	—	11	7	8
Scheuringipollenites	4	5	7	1	10	11	5	8	2	10	8	—	2	5	20
Ibisporites		2	—		1	—	—		1	1		1		1	2
Welwitschiapites	1	—	—	1		—	—	—	—	—	—	—	—		
Pilasporites	1	—	—	—	—	—		—	—			—	—	—	—
Ginkgocycadophytus	—			—	—	—				1	2	—	—	—	—
Alete	1	1	4	5	3	5	3	4	6	5	2	—	1	5	1

Table 2 — Showing the percentage of various genera in Bore-hole no. CMPS-43

Genera	Sample no. 5	39	49	47	16	45	33	31	44	42	41	39	38	34	27	25	17	20	12
	ZONE 2																		
Leiotriletes	—	—		—			—	1			—	—			—	—	—	—	—
Callumispora	1	2				2	6	2	1	1	4	2	1	1	—	1	1	1	1
Brevitriletes		—	—		1		—	5	—	1	4	—					1		
Horriditriletes	1	—	—		—			—		—	—	—	—	—	—	—	—		1
Indotriradites						—	—	—	—	—	1	—	—	—	—	—	—		
Latipulvinospora	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Latosporites	—	—	—	—	—			—	—	—	—	1	—	—	—				
Parasaccites	7	8	9	22	16	8	10	6	6	17	15	5	14	7	5	10	22	10	12
Plicatipollenites	—	—	—	—	1		1		—	—	—	—	—	—			2	1	2
Virkkipollenites	4	—	5	2	—	1			1	1	4	7	—	2	—	—			—
Potonieisporites	—	—	—	—	—						1	4	—	—	1	1			
Primuspollenites	—	—	—	—	—			2	1	—	—	2	—	—		1	1	1	1
Rhizomaspora	—	1	—	—	—				—	—	1	2	1	—	1	2	1		—
Platysaccus	—	—	—	—							1	2	—	—				1	
Sahnites	—	—	—	—	—	—			—	—	—	—	—	—	—		1		—
Lunatisporites	—	—	—	—	—	—			—	—	—	—	—	—	5		1	—	1
Vestigisporites	—	—	—	—										—			2		
Pityosporites	—	3	—	—			—	4	—		—	—							
Striatites	8	2	2	4	5	2	5	5	1	2	2	2	1	2	5	—	2		
Verticipollenites	1	5	—			1		1									1		
Faunipollenites	11	4	4	8	22	24	17	9	26	25	5	7	21	10	16	12	8	7	15
Striatopodocarpites	2	4	15	7	4	5	5	4	1	2	9	6	1	—	1	5	5	4	1
Crescentipollenites	—	—																1	1
Scheuringipollenites	43	71	61	52	[illegible]	57	54	58	60	46	52	42	[illegible]	77	52	62	42	60	55
Ibisporites	—	—	—	—	—		—	—	—	—	—				1				
Vesicaspora	1	—	1	2	—	—	—	1	—	—	—	—					1	—	—
Sulcatisporites	2	—	—	—	—	—	—		—	2	—	—	—	—	—	—	—	—	—
Welwitschiapites	—	—	—	—	—	—	—		—	—	—	—	—	—	1	1	—	2	—
Tiwariasporis	—	—	—	—	—	—	—		—	—	—	—			1			—	
Ginkgocycadophytus	—			—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Alete	5	1	—	4	5	2	5	4	—	—	5	1	1	—	1	2	2	—	—



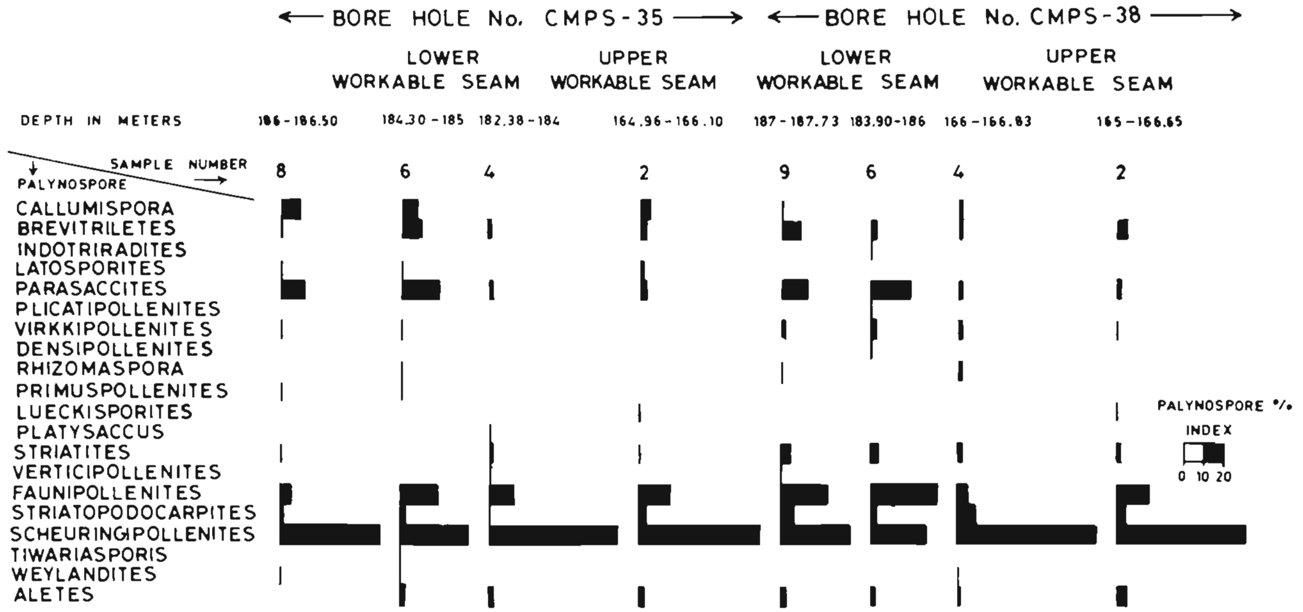
Litholog 1—Succession of Lower Permian sediments in bore-hole no. CMPS-43, Shobhapur Block, Pathakhera Coalfield.

Workable seam while it reduces in Upper Workable seam. The percentage of *Faunipollenites* is considerably higher (28%) in the Lower Workable seam of bore-hole CMPS-38.

DISCUSSION

The Lower Karharbari Seam from Giridih Coalfield (Srivastava, 1973) contained the dominance of *Callumispora* and *Parasaccites*, while the Upper Karharbari Seam contained *Illinites* and other nonstriate-disaccate pollen grains. In subsequent investigation from Korba Coalfield (Bharadwaj & Srivastava, 1973) it was observed that the Lower Karharbari palynoflora is characterised by *Callumispora* and *Parasaccites* while in Upper Karharbari *Parasaccites* attains overall dominance. Both the assemblages were recorded in the subsurface of Korba Coalfield in a continuous and conformable sequence and similar occurrences have also been reported in latter works on Karharbari Formation.

The palynoflora recorded from the Bagdona Seam of Pathakhera Coalfield and lower part of the bore-hole CMPS-43 contains the dominance of *Parasaccites* and in this respect it compares with the lower part of Upper Karharbari palynoflora of the



Histogram 2—Showing palynofloral assemblages in bore-hole nos. CMPS-35 and 38, Shobhapur Block, Pathakhera Coal-field.

Korba Coalfield. In the Barakar type area too, *Parasaccites* dominant assemblage underlying Lower Barakar palynoflora has been recorded from Pusai-Shampur region by Tiwari (1973) which also compares with the present palynoflora. The Upper Karharbari palynoflora recorded from Kauakoh Nala Section from Chirimiri Coalfield (Srivastava, 1980) also shows similar dominance of *Parasaccites* but contains significant percentage of *Ginkgocycadophytus* and *Callumispora*. The palynoflora recorded from Umaria Coalfield (Srivastava & Anand-Prakash, 1984; Zone-2) also contains the dominance of monosaccates but the association of zonate trilete differentiates it from the present assemblage. In the adjoining Johilla Coalfield also, the dominance of monosaccates has been recorded from Johilla Coal

Table 3—Showing the percentage of various genera in Bore-hole nos. CMPS-35 and 38

PALYNOFOSSILS	BORE HOLE NO. CMPS-35				BORE HOLE NO. CMPS-38			
	Lower Workable seam		*Upper Workable seam*		*Lower Workable seam*		*Upper Workable seam*	
Sample no.	8	6	4	2	9	6	4	2
Callumispora	9	8	—	5	1	—	2	—
Brevitriletes	1	10	2	3	9	3	2	5
Indotriradites	—	—	—	—	—	1	—	—
Latosporites	1	1	—	2	—	—	—	—
Parasaccites	12	19	2	4	13	20	2	2
Plicatipollenites	—	—	—	—	—	1	—	—
Virkkipollenites	1	1	—	—	2	3	2	1
Densipollenites	—	—	—	—	—	1	—	—
Rhizomaspora	—	1	—	—	1	—	2	—
Primuspollenites	1	1	—	—	—	—	—	—
Lueckisporites	—	—	—	1	—	—	—	1
Platysaccus	—	—	1	—	—	—	—	—
Striatites	1	—	2	1	3	4	3	2
Verticipollenites	—	—	1	—	2	—	—	—
Faunipollenites	6	19	13	16	23	33	5	16
Striatopodocarpites	2	3	1	4	7	3	9	4
Scheuringipollenites	50	34	75	61	34	28	70	64
Tiwariasporis	—	1	—	—	—	—	—	—
Weylandites	1	—	—	—	—	—	1	—
Aletes	15	2	3	3	3	3	2	5

Mine (Anand-Prakash & Srivastava, 1984; Zone-2) but in the presence of *Scheuringipollenites* and *Vesicaspora* this obviously differs from the present palynoassemblage of the Pathakhera Coalfield (Zone-1).

Anand-Prakash (1972) described the *sporae dispersae* from some bore-hole coal samples of the Pathakhera Coalfield, but he did not provide the quantitative representation of various palynospore genera. The present investigation provides a greater detail of the *sporae dispersae* of the Barakar Formation and the nature of palynological succession in Pathakhera Coalfield and adjoining areas. Bharadwaj, Navale and Anand-Prakash (1974) studied the palynological succession among the coals from Pench-Kanhan Coalfield. Their Assemblage-F is also dominated by *Scheuringipollenites* associated with *Pilasporites* and *Hennellysporites*. In this respect it differs from Assemblage Zone-2 of the present investigation the two genera being absent. Bharadwaj and Anand-Prakash (1972) described *Scheuringipol-lenites* dominant assemblage from the coal-bearing beds of Mohpani Coalfield. The present assemblage of coal-bearing beds and associated sediments from Pathakhera Coalfield compares in the nature of the dominance of various taxa but differs from it in having very small amount of *Brevitriletes* and *Indotriradites* which are associated in subdominance in Mohpani Coalfield. In Korba Coalfield (Bharadwaj & Srivastava, 1973) the *Scheuringipollenites* assemblage (Zone-3) succeeds the underlying Upper Karharbari *Parasaccites* dominant assemblage, but it is associated with *Brevitriletes* and thus differs from the present assemblage. In Giridih Coalfield the palynoflora recorded from Bali and Jatkuti seams shows similar dominance of *Scheuringipol-lenites* and paucity of trilete palynospores.

Thus, in Pathakhera Coalfield (Bore-hole no. CMPS-43) the *Scheuringipollenites* dominant assemblage occurs at the close of *Parasaccites* dominant assemblage. This transition is gradual and continuous either in sedimentation or palynofloral succession. The clay band at the depth of 78.15 m and onwards marks that there is a distinct change in the lithological constituents of the sediments which are designated as Motur Formation. The sandstones in this horizon become coarse-grained and greenish. However, *Scheuringipollenites*-complex continue unabatedly alienating them with Barakar sediments.

The palynoflora representing the Upper Barakar Formation and also Motur Formation (= Barren Measures Formation of the Damodar Valley) are yet to be distinguished in the sediments of Pathakhera Coalfield palynologically. Feistmantel (1879) classified most of the coal seams of Satpura Basin under Karharbari. This contention is applicable only for the lowermost Bagdona coal seam of Pathakhera Coalfield which contains Upper Karharbari palynoflora.

CONCLUSION

The lowermost Bagdona coal seam in bore-hole CMPS-43, contains the dominance of *Parasaccites* representing the Upper Karharbari palynoflora and thus is different from the two younger coal seams, viz., the Lower Workable and Upper Workable coal seams which contain *Scheuringipollenites* dominant Lower Barakar assemblage. The equivalent of Bagdona seam of CMPS-43 has not been studied in bore-holes CMPS-35 and 38. The two coal seams studied in latter two bore-holes correlate closely with the two younger coal seams of bore-hole CMPS 43. Further, Bagdona Seam being the lowermost and associated with the Upper Karharbari palynoflora, contains better quality of coal as compared with the two younger coal seams.

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SEVENTEENTH BIRBAL SAHNI MEMORIAL LECTURE

Why basic science?

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यो ब्रह्माणं विदधाति पूर्वं यो वै वेदांश्च प्रहिणोति तस्मै।
तं ह देवं आत्मबुद्धिप्रकाशं मुमुक्षुर्वै शरणमहं प्रपद्ये।।

Svetasvatara Upanishad—Ch. VI, Sl. 18.

He who at the beginning of creation projected Brahma (universal consciousness), who delivered the Vedas unto him, whose light turns the understanding towards the Atman, desirous of salvation, I resort for refuge.

ॐ असतो मा सद्गमय।
तमसो मा ज्योतिर्गमय।
मृत्योर्मा अमृतं गमय।
ॐ शांतिः शांतिः शांतिः।

Brhadaranyaka Upanishad—1-3-28.

Lead us from untruth to truth, from darkness to light, from death to immortality. Om! Peace... Peace... Peace.

Basic research should be looked upon neither as something which has to be of practical use nor as an ornament to Society. Indeed, it is a pillar on which culture rests. In basic research it is the quality of the work which is more important than the topic of study. Convincing Society of the importance of learning basic sciences in the universities and conducting researches is important in itself. In fact, universities have been patrons of basic researches in all branches of sciences, not only in India, but also in the more advanced countries, and quite rightly so. Therefore, in the control of basic research in mathematics, physical sciences and in the biological sciences, we must recognize the responsibility of Society to Science. There is no such thing as a "scientific society" as, invariably, society appreciates only our gadgets and not profound ideas for further research. Science, if one may say so, is the most successful example of international cooperation. Unlike religion or sport, there is, relatively, less competition except where hi-technology is involved. While we can buy technological know-how, research ideas in the basic sciences have to be generated by individuals working independently or, in small teams in a cloistered and creative atmosphere.

In business, as in science, creativity is known to thrive in unfettered and possibly undisciplined efforts. Nevertheless, it is difficult to convince aid-giving bodies that any investment in basic research should not be measured by the number of patents claimed or the number of industries that have developed round a particular set of experiments. There are many instances of how a basic research finding was found to have relevance to a later discovery, sometimes two or three decades later, and acknowledged as a pioneering effort.

HISTORICAL

A basic question is why did not technology develop in the ancient past. The Greeks did not use technology as a tool to master the world or as labour saving devices. Archimedes and Hero had contributed to mechanical inventions but they hardly made any attempts to employ these gadgets for industrial production. Plutarch's opinion about the many inventions of Archimedes is worthy of our attention: "Archimedes possessed so high a spirit, so profound a soul, and such treasures of scientific knowledge that, though these inventions had now obtained him the renown of more than human sagacity, he yet would not design to leave behind him any commentary or writing on such subjects, but repudiating as sordid and ignoble the whole trade of engineering and every sort of art that leads itself to mere profit, he placed his whole affection and ambition in those purer speculations where there can be no reference to the vulgar needs of life".

Archimedes had constantly apologised for his inventions and looked upon them as mere amusements, as diversions, as useless toys. In such an intellectual climate then obtaining, technology had little chance to develop. The Greeks did not objectify nature sufficiently as they had not developed the experimental method. In fact, they did not concern themselves with the idea of controlling and conquering nature, they were content developing imaginative conjectures of hypotheses about nature.

The discovery of Nature

Later in the middle ages nature became objectified—first, as an object of aesthetic contemplation and second, as an object of exploration and finally as an object of exploitation. It was Francis Bacon (1561-1626) who played the role of a spokesman for the new science introducing the experimental method in science. Bacon announced at the end of the 16th Century *knowledge is power* (that technology is power) and this caught the imagination of the Western intellectual tradition in the centuries to come. Indeed, the ancient Hindu philosophers, and prophets also considered knowledge to be a supreme form of intellectual attainment. One has only to look into our past. We had the Buddha, Adi Sankara, Ramanuja, Madhwa and many others whose creativity made human history in this land of Paramacharyas. They all functioned in an atmosphere of scholarship and high thinking. Bacon argued "the wisdom we have derived principally from the Greeks is but like the boyhood of knowledge and has the characteristic property of boys, it can talk but it cannot generate, for it is fruitful of controversies but barren of works".

The quantification of Nature

The credit for quantification of nature must go to Galileo Galilei (1564-1642). Galileo explored mathematically the empirical world discovered by the Renaissance. But it must be said that mathematics was only an instrument for formulation of results and not a method for acquisition of new knowledge. It was realized that the method of acquiring knowledge was experimental. The basic difference between Bacon's experimental method and Galileo's was that, whereas Bacon urges starting with facts and experiments and induce theories from them, Galileo insisted that we must start with imaginative hypotheses and at the end subject them to empirical tests. Similar eulogies about the value of imagination came from Einstein: "Imagination is more important than knowledge. Knowledge is limited, imagination embraces the world stimulating progress, giving birth to evolution".

The Newtonian Era

In the 17th and 18th Centuries quantification of nature was given by Isaac Newton (1642-1727) as evidenced by the book of nature, Newton's *Philosophiae Naturalis Principia Mathematica* (1687). One century later after Newton's *Principia* appeared, based on Newtonian mechanics, a mechanistic model of the universe appeared. Whatever was not quantifiable was considered either non-existent or unimportant. It was at that point of time that science completed its task for technology and technology prepared itself to start its conquest and subjugation of nature. It is generally assumed that technology is "indifferent" containing no metaphysics. This is not quite correct. Technology, as it grows, is a historical phenomenon born of a certain idea of nature, of a certain idea of progress, of a certain preconception about the deterministic structure of the world, related to specific social ideals and specific vision of the ends of human life. Therefore it has elements of traditional metaphysics.

It is interesting to record here some of the views of Jean Jacques Rousseau (1712-78). He effectively argued that civilization has imposed on us artificial needs. The pursuit of these needs has alienated man and deprived him of his humanity. The tyranny of artificial needs is the greatest malady of mankind because it has fundamentally impoverished the individual life of man. Rousseau advocated individual salvation by defying and opting out from the artificial needs imposed by society and civilization. Man according to him must return to nature, working for liberation from the web of artificial needs and phoney relationships of the technological civilization. Nature for Rousseau was an imaginary matrix, the ideal state where the symbiosis of the individual with the outside and with his inner essence takes place. It is therefore not an object but a subject.

Before we return to a further consideration of technology vis-a-vis science, we could consider some of the revolutionary thinking that has taken place in some areas of Biology in the last three decades. I will choose two areas which have made very significant progress in basic science. This will give us an idea of the dynamism in built in the pursuit of knowledge for knowledge's sake.

GENETIC ENGINEERING

Today man has acquired the basic knowledge to manipulate hereditary material. The discoveries in this area have been breath-taking and man expects much good and bad to come out of this. Application of genetic engineering for commercialization with the many techniques born out of basic research is leading towards spectacular industrialization. To cite just one example, the synthetic production of insulin. Here, therefore, is an enigma of what promise it holds for homo sapiens in the years to come in changing our ecosystems. All these swift developments came from in depth studies on the genetic material, DNA, a simple macro-molecule of universal occurrence in living systems. The currently investigated recombinant DNA technology forms the background of genetic engineering and biotechnology. Genetic engineering itself is the outcome of the vast new fundamental science of molecular biology.

From the observational methods of the 19th century by great biologists like Charles Darwin, Carl Linnaeus and Jean Baptiste Lamarck, it was the celebrated Johann Gregor Mendel who brought in the concept of experimental biology and quantification of his results on the mysteries of inheritance. In fact, Mendel had laid the foundation of modern genetics. In the forties biochemical studies were intensified by frontline biochemists like Oswal T. Avery, C. M. MacLoed and M. McCarty, followed by some classical work on the chemical nature of the substance that could be responsible for the phenomenon of bacterial transformation which resulted in identifying the DNA as the genetic material worthy of all attention. Hot on the heels was the work of Arthur Kornberg, N. D. Zuider, J. Lederberg, A. D. Hershey, M. Chase and H. G. Khorana, that led to the understanding of the genetic macro-molecule DNA and its synthesis. The classical work of George W. Beadle and F. L. Tatum on the bread mould *Neurospora crassa* has also to be mentioned while considering biochemical pathways in protein synthesis.

The Genetic Code

Once established that the DNA molecule was the genetic material, J. W. Watson and F. C. Crick, by their classical experiments proposed a model for the DNA molecule. The Watson-Crick double-helix model gave the first picture of the hereditary substance and how it carried all the information necessary for the determination of the several characteristics of any organism and that it was capable of replicating itself and longitudinally separating itself into two complementary strands of two DNA molecules, quantitatively and qualitatively similar to the parent molecule.

Thus was born the language of genetics, the genetic code, which gave the central role to the DNA which carried coded information and played an important part in the synthesis of polypeptide molecules. The subject of molecular genetics or Molecular Biology had taken root. Studies were initiated on viruses and their manner of reproduction. All DNA viruses, on entry into the host cell, assumed control over the host DNA and made it synthesize viral DNA but in the case of RNA viruses, they entered the cell with the help of an enzyme reverse transcriptase formed one strand of DNA which was complementary to the viral DNA. With this strand of DNA as template and DNA polymerase enzyme, a double-stranded DNA molecule emerged. Today, transfer of DNA from one organism to another has become possible. In plant materials, whole protoplasts have been removed from one cell and transferred to another. The story of introducing the insulin gene from the mouse into the *Escherichia coli* plasmid was the outcome of all these transplantation experiments and recombinant DNA technology, or what is called Genetic Engineering. This applied science has come to be recognized as a first step in tailoring human needs through microbial genetical manipulations.

Revolutionary discoveries

These revolutionary discoveries in science, be it in the physical or biological sciences, will remain as shining examples of creativity. The physicist talks of decay of fundamental particles, they also mention of short to long half-life among isotopes. So too, in technology we see new generation instruments emerging at short intervals, in computers, jet planes, automobiles, and even in soild state TV sets. Indeed, we have these short-lived gadgets only to be superceded by more efficient ones.

Not so, in the breakthrough discoveries. The Raman Effect, the Chandrasekhar Limit, the structure of the DNA molecule by Watson and Crick, the earlier laws of heredity by Mendel, Einstein's relativity, Khorana's contributions to the understanding of the DNA and its synthesis, to mention a few, will remain classics for all time. It has always been a matter of pride to nations when such pacemakers appear on the scientific scene from time to time. It is they that matter, they are the salt of the earth and humanity owes them a deep debt of gratitude.

ULTRAMICROSCOPIC VIRUSES

Turning our attention to some of the exciting ideas that have come after the epoch making discovery by W. M. Stanley in the late thirties, it all started with a study of the tobacco mosaic virus (TMV). He purified and isolated TMV which appeared as long needle-shaped crystals which were infective. Stanley called them liquid crystals or paracrystals. Later work showed that the ultimate TMV particle was a rigid rod-shaped nucleo-protein of the ribose nucleic acid type (RNA) and that the nucleic acid component was the core of the rods and was really the infective part. Several other plant viruses were subsequently isolated and characterised but not all were rod-shaped like TMV, indeed, many were true crystalline forms with a 3-dimensional regularity. Furthermore, the infective nucleic acid could be tagged on to anomalous protein and whole virus molecule was reconstituted and they were infective. Many other discoveries followed, like the unravelling of the ultimate structure of the virus molecule and showing them to be single or double stranded structures. The amino acid sequences, nucleotide composition etc., have all contributed to our understanding of the complexity of the disease producing agents. The TMV has been the most worked upon virus and in it each protein unit is a coiled polypeptide chain containing 158 amino acids, whose sequences have been worked out. The nucleic acid thread contains more than 5000 nucleotides. Therefore, the varying symptoms produced by different strains of a virus must derive directly from either the synthesis of nucleic acid, or, through other proteins than the structural ones, coded for by parts of the nucleic acid other than those producing the structural protein. However, the ability to code for structural protein is not alone enough to confer pathogenicity. This is illustrated by the smallest particle size virus known as the 'satellite' virus. This virus has possibly few nucleotides to spare after coding for its structural protein and it not only fails to cause symptoms but also fails even to multiply unless aided by the large Tobacco necrosis virus with which it is constantly associated in nature.

On the subject of virus multiplication, the main emphasis is on derangement of the mucleic acid metabolism of the host plant. The infecting virus particle may be 'disrobing' and releasing its nucleic acid somewhere in the cell. Then, nucleotides get polymerized to duplicate the virus mucleic acid and it then codes for its structural protein, encloses the nucleic acid in the protein to give the complete virus particles. All these discoveries bring us to the basic question of the origin of viruses. How do plant viruses which appear "inert" nucleoproteins with no signs of "life", as we understand life and living, become aggressively pathogenic once inside the host cell? How do they shed their protein coat outside the cell wall and enter the host cell as a "naked" nucleic acid? Once inside the host cell how do they become dynamic so as to command the host cell to produce more nucleic acid. How do they combine with the host protein to form the entire viral nucleoprotein?

TEACHING OF SCIENCE

F. H. Westheimer (Emeritus Professor of Chemistry, Harvard University, Cambridge, Mass) under the caption: "Are our Universities Rotten at the 'Core' has given much food for thought in dissemination of knowledge in science at various levels. The Harvard University faculty instituted a 'Core-Committee' to give a 'Core' knowledge for all college students before they graduate and join the society of educated men and women". This core curriculum was considered as minimizing science and, therefore, the majority of students graduating from Harvard were, in a sense, uneducated because they knew almost no science. The essential concept that emerged on analysing the problem was that learning in science is primarily vertical or intensive, whereas that in the humanities was primarily horizontal or extensive.

Requirements for teaching Science

Many of the American colleges and universities require the equivalent of only about two half-courses in sciences for graduation and therefore, they watered down courses. In Columbia University science requirement is intended to provide students the opportunity to learn what scientists do, how they think, what kinds of questions they consider, what procedures they develop to evaluate the results of their research, and in what forms they present their knowledge. How scientists think is not talking about science says Westheimer. Their curriculum has no word about atomic energy or metallurgy or medicine or agriculture or chemical synthesis or genetics or immunology or infinite series or any real subject in science or mathematics. In contrast to its modern requirements, Harvard's curriculum in 1849-50 include a course in science or mathematics, or both, in every semester of every year!

Teaching about advances in Science

In the intellectual advances in science in the last 50 years, long after Copernicus, Galileo, Newton, Lavoisier, Darwin, Mendel, Pasteur, there have been many contributions to add to the intellectual heritage of mankind. The great discovery of atomic fission was not published until 1939. Says Westheimer: "But the advances in science in the last half-century have scarcely been confined to nuclear physics. The first practical digital computer was invented during World War II. The discoveries in solid-state physics have revolutionized computers, phonographs, TV sets, etc. The discovery of penicillin and the many antibiotics has benefited modern medicine. Lasers are used in many situations, for eye surgery, for drilling holes in diamond and saffires and in a multitude of ways. For the greatest intellectual revolution for the last 40 years has taken place in biology. 'Can anyone', asks Westheimer, 'be considered educated today who does not understand a little of molecular biology? If we are to teach molecular biology it will be necessary to teach some organic chemistry, and that in turn demands a background of general chemistry'. This sequence of subjects is typical of the 'Vertical Structure' of learning in the Sciences. As mentioned earlier, all these discoveries led to the determination of the structure of proteins and nucleic acids thus leading to the determination of the genetic code and to a methodology of synthesizing genes. Asks Westheimer, 'Should not college students learn something about some of these scientific advances even at a price (and it is a real price—of knowing less literature and history at graduation)? Which will be easier to learn without instruction in later life: more Shakespeare or molecular biology? Graduates from prestigious institutions become legislators, educators, lawyers, judges and business executives. In every situation if they know enough science it would provide them with a background for future learning'.

The Core Curriculum: Intensive and extensive subjects

The reasons for scientists voting for a 'Core' curriculum which ignored the teaching of a minimum quantum of basic science have been attributed by Westheimer, to a general resistance among scientists in teaching anyone who does not want to learn. To this he suggests the remedy lies in selecting those eager to learn science in preference to those that show resistance. He adds that 'If universities demanded some real science from their students, the high schools have to emphasize the importance of working toward better preparation in sciences and mathematics. The result will not be instantaneous, but in a generation we would have much better education. If scientists try to teach non-scientists molecular biology without chemistry, or to teach quantum theory without mathematics, they are unlikely to succeed. If they are deliberately made easy, they are almost devoid of content. If they cover only a specialized field, they necessarily give no sense of the sweep of science'. This is equally true of teaching biology today; you have to have a good background of biochemistry, biophysics and biometrics.

RELEVANCE OF BASIC RESEARCH

In 1945 Vannevar Bush published a book 'Science: The Endless Frontier'. There he concluded: 'On the wisdom with which we bring science to bear against the problems of the coming years depends in large measure our future as a nation'. Bush's famous report to President Truman noted the contributions science had made to winning World War II, and argued that the economic battles that lay ahead in 1945 would also require a major effort in research and development if the United States were to prosper. Erich Bloch has summarised many of the issues under the caption 'Basic Research: The Key to Economic Competitiveness'.

The result of the message of Bush was clear: to restart the continuing of the wartime effort in basic research through the creation of a new agency, the National Science Foundation and this was launched in 1950. The main plank of the Foundation was to support basic research and education in the sciences and engineering. The clarion call was to strengthen American Science and Engineering base by the collection of people, facilities and equipment. It was at once realized that the nation could not prosper without sustained investment in science and engineering education and research in the American universities. Their main goals were as follows:

1. Intrinsic intellectual value
2. To accomplish a specific government mission such as defense or health
3. To make the nation's economy more competitive.

In implementing these laudable objectives, the first goal of intrinsic intellectual value has been given top priority as evidenced by the support given to advances in any field of science and engineering. In other words, they have sought excellence in every one of the scientific activities the nation has undertaken in post-war years. The second goal is important for both the developed and developing nations. The third goal is relevant to both situations because it envisages boosting the economic competitiveness of a nation.

Funding of research

This can only be done by a very balanced funding of basic and applied research. It boils down to this. Those nations that have attained an economically dominant position are most anxious to safeguard their pre-eminent position in science, technology and industrial excellence while maintaining their defense preparedness at as high a level as possible. However, this leadership position resulting in a lion's share of world economy is getting gradually eroded and top three or four nations are being overtaken in this race by newly emerging economic powers in the world. They are steadily progressing not because of any great advantage in natural resources but because of sustained research in both basic and applied sciences. Let there be no ambiguity in understanding this new challenge for a change in world order. It is generally recognized that competitiveness can be improved by automated production systems in industries and judicious combination with meaningful research projects. This has come to be recognized as a far more reliable method of maintaining excellence in national products than trade barriers or protectionist policies. Bloch goes on to say that "any society that wishes to remain competitive in the modern world must do three things:

1. It must support basic research adequately
2. It must educate enough new scientists and engineers
3. It must invest sufficiently in research facilities and equipment

The record in all these areas Bloch says in less than it should be considering their R and D effort

i) The United States has not invested in R and D in recent decades at the rate that sustained growth in a modern society requires. We have slipped from our position of leadership... while our competitors have been pushing ahead... in key technological areas,
ii) The preparation of US federal research support that goes for military purposes is high and rising."

"When military research is eliminated from the comparison, our effort in R and D is significantly less, as a fraction of GNP, than the effort made in Japan and Germany. An encouraging trend, however, has been the increasing fraction of federal support for R and D that is going for basic research. Development expenditures are, quite properly, being left to industry".

Basic research spinoff

Block concluded: "While industry and state governments are deeply involved, basic research and education in science and engineering is a well-established responsibility of the federal government. Basic research produces knowledge that is available to all, not just the organization that pays for the research. Investment in science and engineering has been the source of much of our economic progress over the past four decades. It continues to be the best single way that we can provide the jobs and national wealth that we must have in decades to come. Our science and engineering base, however, needs renewed attention—Science and Technology can provide the means to meet the challenge of international economic competition in the decades ahead, but only if we find the resources to strengthen our effort markedly. The most basic considerations of national welfare demand that we do no less"

THE BIRTH OF TECHNOLOGY

We will now pass on to some general considerations about Technology, its antecedents and precedents. Technology is a part of our intellectual heritage and is an intrinsic component of our society. Technology is power in the modern context and it will be difficult to redirect its course. We can only shift our aim and vision to a model of symbiosis between man and nature based on qualitative and not quantitative criteria. This will need bringing about changes in our economic and social structures.

The Greek ideal of knowledge as enlightenment and source of all progress has been mentioned earlier. The progress of man is concerned here as the progress of his spirituality, and tool making is conceived as a function of this progress. The intellectual conception of technology, rooted in the Aristotelian definition of man conceived as a rational animal, emphasizes the abstract cognitive elements in the make-up and the development of man. The rational and intellectual elements are, then, defining characteristics and the point of departure. Technology in this scheme of things is but contaminated science.

Science vs Technology contrasted

If we contrast the two views, pragmatic and the intellectual, in the pragmatic approach the distinction between science and technology is blurred; the autonomous status of human knowledge is subordinated to a larger scheme of biological survival. In the intellectual approach, on the contrary, the autonomous cognitive status of human knowledge is strongly emphasized. Because of the paramount importance of pure knowledge in man's progress, technology is but a shadow of science, devoid from and congnitively dependent on science. In the pragmatic approach, technology is identified with the tools essential for survival, and is thereby elevated to a sublime height. In the intellectual approach, technology is considered as a cognitive phenomenon, and is thereby deemed trivial, derivative, parasitic. Neither of these two approaches attempts to spell out the distinctive features of technological knowledge as contrasted with other forms of knowledge. Neither seems to grasp the peculiar dialogue which goes on between technology and society. There is probably a third approach, the dialectical approach. In this approach, technology is not a thing-in-itself. It is, and always has been, a continuous dialogue concerning society, its needs and aspirations, and the technical means potentially contained in technology for satisfying those needs and fulfilling those aspirations. The nature of technology cannot be understood without understanding the nature of this dialogue. Indeed, the place of technology in the scope of human knowledge is determined by the nature of dialogue concerning the aspirations of society and the potentials of technology. It is in this sense that we can stress on the dialectical approach to technology.

To analyse these views further, it is a mistake to think of technology as entirely autonomous, although it has secured for itself a great deal of autonomy. It would also be a mistake to think that the technological system is self-justifying in its own terms. The present ecological crisis and fundamental rethinking of technology's role in the society of the future is the *prima facie* illustration of this point. We are going to abandon many technological developments even though the existing technological order justifies their future development. We may have to introduce many new technologies for which there is no need in the existing technological system. Are we going to evolve and invent new forms of technological knowledge which are either unneccessary or simply go against the grain of the existing technological system? We will have to do these things because we are in the process of changing the nature of the dialogue concerning the needs of society and the potentials of technology.

In science we investigate the reality presented to us, the empirical reality, the world around us. In technology, on the other hand, we create a reality according to our designs; this is the man-made reality. Our scientific pursuits are "what there is"; our technological pursuits are based on our ability to construct objects according to our desires. In short, science concerns itself with "what is" whereas technology is concerned with "what is to be". In science we have reality first and then its description; whereas, in technology, we have description or design first, and only afterwards reality.

The process of establishing correspondence between reality and its description in science is known as establishing the truth. Therefore, to establish the correspondence in science is to match description with reality. In technology also a correspondence is established with the only difference that we start with a description with reality, an object. Thus, the classical problem of the quest for truth consists of establishing correspondence between reality and description as in technology. But there is one difference, we do not call the objects satisfying this correspondence as true, but instead call them valid or adequate for the purpose.

Truth and Reality in Science and Technology

In science, reality and truth are assigned an *a priori* position, the process goes from reality to its description. In technology description or blue-print is given first, object or reality is at the end and the process of arriving at the object is called invention, and it is considered as valid. The basic problems of truth in science are centered on reality. By redefining, the basic problem of truth in technology is centered on the notion of the "possible" in the technical sense. Therefore, the validity of technological designs is a function of the scope of the possible, i.e., broadening of the end power of technology is by enlarging the scope of the possible. In other words, the vital characteristic of technology is to attempt to turn the technically possible into the technologically possible.

BASIC DISCOVERIES, TECHNOLOGY AND APPLIED SCIENCE

Technology is thought of as applied science. Scientific theories produce basic explanations about nature, and technology derives practical applications from science. Funding agencies often justify support to fundamental scientific research on the basis of potential technological dividends in the offing. The production of electricity from nuclear energy is one such instance although nuclear material can lead on to destructive and devastating weapons. Yet, technological advance of the late nineteenth and early twentieth centuries developed independently, without scientific research and understanding preceding them. Before fundamental principles of thermodynamics and aerodynamics were understood, the steam engine, the automobile and the aeroplane were developed. Nevertheless, these stray technological landmarks have no validity in the present age as science and technology have very close interaction.

As mentioned earlier, biotechnology and genetic engineering have their base in basic discoveries in unravelling the mysteries of life process and the emergence of the genetic code. Likewise, the simple, yet elegant, experiments conducted by Went on the factors that influenced the coleoptile to bend with unidirectional incident light were a landmark in understanding the phenomenon of growth in plants. The basic discovery of the indole compounds as one of the growth factors in plants brought in its trail a whole host of new growth substances from kinins to gibberellins. Indeed, these basic concepts led on to the recognition of totipotency in isolated plant cells and the new sub-discipline of tissue culture was born. One can go on multiplying these instances in every branch of the basic sciences. For purposes of the present lecture topic, I started with the title "Why Basic Sciences?" This may raise many eyebrows and if, in what I have covered, I have not created convincing evidences justifying the title, I will probably give it a twist to make my intentions more positive and challenging and say "Why not Basic Sciences?". It adds to national pride whenever there is a breakthrough. Fortunately, we have in our country a few centres of basic researches in classical botany. One such is this institute established by my great guru Professor Birbal Sahni. You are the custodians of this legacy. In you rests the onus of keeping its flag flying high. Do not surrender your rights, maintain your status and individuality in the field of Palaeobotany. Never allow incursions into your academic autonomy within limits of motivation and discipline. I place a high premium on loyalty to the cause and the institution, as they are precursors to success. I wish you all a very bright future in your chosen field of specialization. There is enough room for expansion of your research activities within the framework of Palaeobotany without looking for support from other disciplines for, fashion subjects come and go but classics remain as bastions of academic pursuits of excellence.

As all of you are highly motivated academics, I would like to end up by an Upanishadic exhortation addressed to Acharyas and Vidyarthis on the basic concept of sharing knowledge. May you keep this exhortation before you and spread your knowledge, gathered through your researches, to the universities and other centres of learning in Bharat.

श्रद्धया वेयम्। अश्रद्धया: वेयम्। श्रिया वेयम्।
ह्रिया वेयम्। भिया वेयम्। संविदा वेयम्।।

Taittiriya Upanishad

Gifts should be given with faith; it should never be given without faith; it should be given in plenty, with modesty, with sympathy.

HARI OM!

The Palaeobotanist 37(1) : 142, 1988.

Book Review

Origins of Life. Jim Brooks, Lion Publishing Corporation, Herts, England; Lion Publishing Corporation, Beleville, Michigan, U.S.A. and Albatross Books; Sutherland, Australia, 1985; pp. 160, Price £ 9.95.

We have all wondered one time or the other about the Universe and our own place in it. Who made it? When? Why? And how did it all begin? This book tries to answer these inquisitive queries and much more—the wisdom researched and gathered by scientists and philosophised by many. *Origins of Life*, the subject of the book, is a complex one. It requires knowledge of varied disciplines of sciences, like astronomy, biochemistry, geology and biology and even metaphysics. Evidences brought forward from all these varied disciplines of science have been successfully woven into a story told in a lucid style. The excellent illustrations collected from different sources, supported by colourful panoramas and diagrams provide an added attraction to an already lively presentation.

The book presents complex theories, like the Steady State Theory and the Big Bang Theory for the origin of the universe and continues to discuss the origins of stars, solar system including the earth and provides a good background of time scales, radiometric dating, interior of the earth, continental drift, evolution of biosphere, hydrosphere and atmosphere, and the life through ages which are necessary to understand and appreciate the problems of origins of life. With this backdrop, the author defines life, explains theories on chemical evolution including the importance of DNA. Fossil remains of both non-structured organic matter and structured organic micro-organisms are discussed and well illustrated.

The chapter on extinction of dinosaurs is a bit out of place in a book dealing with the theme on Origins of Life. The only relation one can find is the cometary hypothesis on the dinosaur extinction and the study of carbonaceous chondrites.

The author considers the views of pioneers in the field, such as J.D. Bernal, J. B. S. Haldane and A. I. Oparin to have been mainly influenced by Marxist—Leninist doctrine. The present state of our knowledge is due to the efforts of these great men of science who were only motivated by a spirit of enquiry. To consider their efforts as atheistic does not do them justice. The support their views may have given to the Marxist—Leninist theory may just be coincidental.

The author is successful in his approach in presenting latest knowledge in a compact and well-woven form. The Publishers are also worthy of commendations for an excellent publication and a good layout.

B. S. VENKATACHALA

B S I
Acc. No. 19600

Handapaphyllum—a new leaf type from the Upper Permian of Orissa, India

Shaila Chandra & Kamal Jeet Singh

Chandra, Shaila & Singh, K. J. 1989. *Handapaphyllum*—a new leaf type from the Upper Permian of Orissa, India. *Palaeobotanist* **37**(2) : 143-146.

A new genus *Handapaphyllum* is established for fan-shaped, petiolar leaves having symmetrically lobed and dissected lamina with 6-8 dichotomous parallel running veins from the Kamthi Formation of Handapa, Orissa.

Key-words—*Handapaphyllum*, Ginkgoalean leaf, Kamthi Formation, Upper Permian (India).

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साराँश

उड़ीसा (भारत) के उपरि परमी कल्प से एक नई प्रकार की पत्ती—हंडपाफ़िल्लम्

शैला चन्द्रा एवं कमलजीत सिंह

उड़ीसा में हंडपा के कामथी शैल-समूह से प्राप्त सममित पालियों एवं विच्छेदित पत्रफलक से युक्त पंखाकार एवं पर्णवृन्तीय पत्तीयों के लिए **हंडपाफ़िल्लम्** नामक एक नई प्रजाति स्थापित की गई है। इन पत्रफलकों में 6 से 8 तक द्विभाजी समानांतर शिरायें विद्यमान हैं।

GINKGOALEAN type of leaves, although not very common, are known from the Gondwana formations of India as well as from other Gondwana countries. The Permian Gondwana forms are referred to the genus *Ginkgophyllum*. Earlier these forms were placed under the genus *Psygmophyllum* and were recorded from the extra-peninsular region. The ginkgoalean leaves known from the Permian Indian peninsular region are placed under the genera *Platyphyllum* and *Gondwanophyton*.

The order Ginkgoales is represented in the Mesozoic formations of India by leaves assigned to the genera *Ginkgoites* and *Sidhiphyllites*.

MATERIAL AND LOCALITY

The solitary specimen with its counterpart comes from fossiliferous beds of Kamthi Formation exposed in the Hinjrida Ghati Section (20° 58′ : 84° 43′) near Handapa, Dhenkanal District, Orissa and occurs on a compact buff-coloured clayey shale.

SYSTEMATIC DESCRIPTION

Handapaphyllum gen. nov.

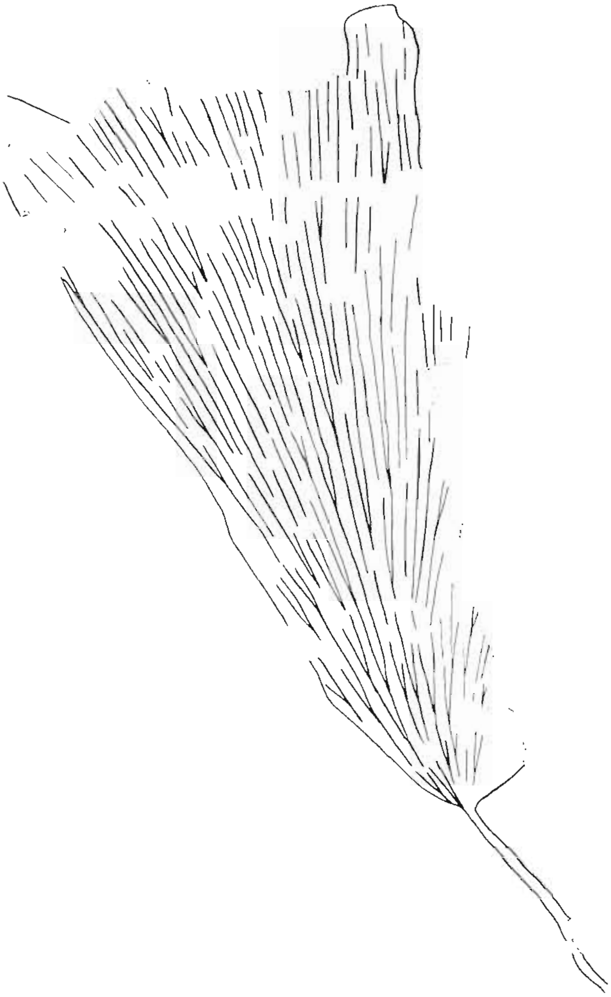
Diagnosis—Fan-shaped, variously lobed, petiolate leaves; oppositely attached to the axis, apex broad, lobed, base cuneate, petiole narrow; veins erect, dichotomous, fanning out in the lamina without interconnections.

Type species—*Handapaphyllum indicum* sp. nov.

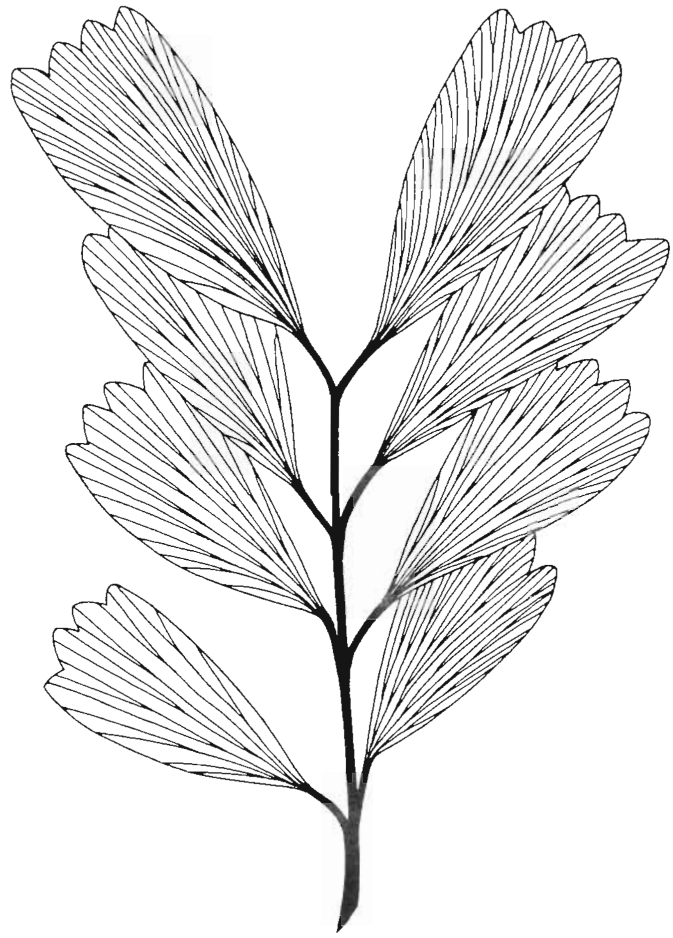
Handapaphyllum indicum sp. nov.
Pl. 1, fig. 1; Text-figs 1, 2

Diagnosis—Fan-shaped lobed petiolate leaves, lobes even, petiole long, slender, veins sparsely placed, erect and dichotomous.

Description—The specimen is 12.1 cm long. Four pairs of petiolate leaves are attached to a slender axis in an opposite manner at the nodes. It is difficult to say whether the leaves are superimposed



Text-figure 1—*Handapaphyllum indicum* gen. et sp. nov : Single leaf drawn to show dichotomously divided erect veins, fanning out in the lamina without interconnections. × 4.



Text-figure 2—Reconstruction of *Handapaphyllum indicum*.

or not, as the exact attachment point is not seen. The leaf is 2.5 cm at the broadest, petiole narrow and 1.2 cm long, apex broad and lobed and the base is cuneate. Nearly 6-8 veins fan out into the lamina of the leaf. Each vein dichotomises several times but never anastomose

Holotype—Specimen no. BSIP 35932.

COMPARISON

Of the three genera of ginkgoalean leaves known from Permian of India, *Ginkgophyllum* is characterised by leaves having lamina gradually passing into a narrow basal portion which is not sharply marked off as a petiole. Moreover, the lamina may have an entire or irregularly cuneate margin or it may be divided by deep sinuses into wedge shaped segments, the divisions between the lobes do not extend to the base of the lamina (Maithy, 1974).

Handapaphyllum is essentially a petiolate leaf and there is no equal lobing of the lamina. Moreover, the leaves in *Ginkgophyllum* are spirally arranged on the axis while in *Handapaphyllum* the leaves are oppositely arranged.

Feistmantel (1881, 1886) reported *Rhipidopsis densinervis* Feistmantel and *R ginkgoides* Schmalhausen from the Permian Gondwana of India. The type specimen of *R. ginkgoides* is misplaced or lost from the collection of the G.S.I. According to Maithy (1974) the type specimen of *R. densinervis* is

PLATE 1

1 *Handapaphyllum indicum* gen. et sp. nov.: Specimen showing axis with oppositely attached petiolate leaves having lobed lamina. × 2; Specimen no. BSIP 35932.

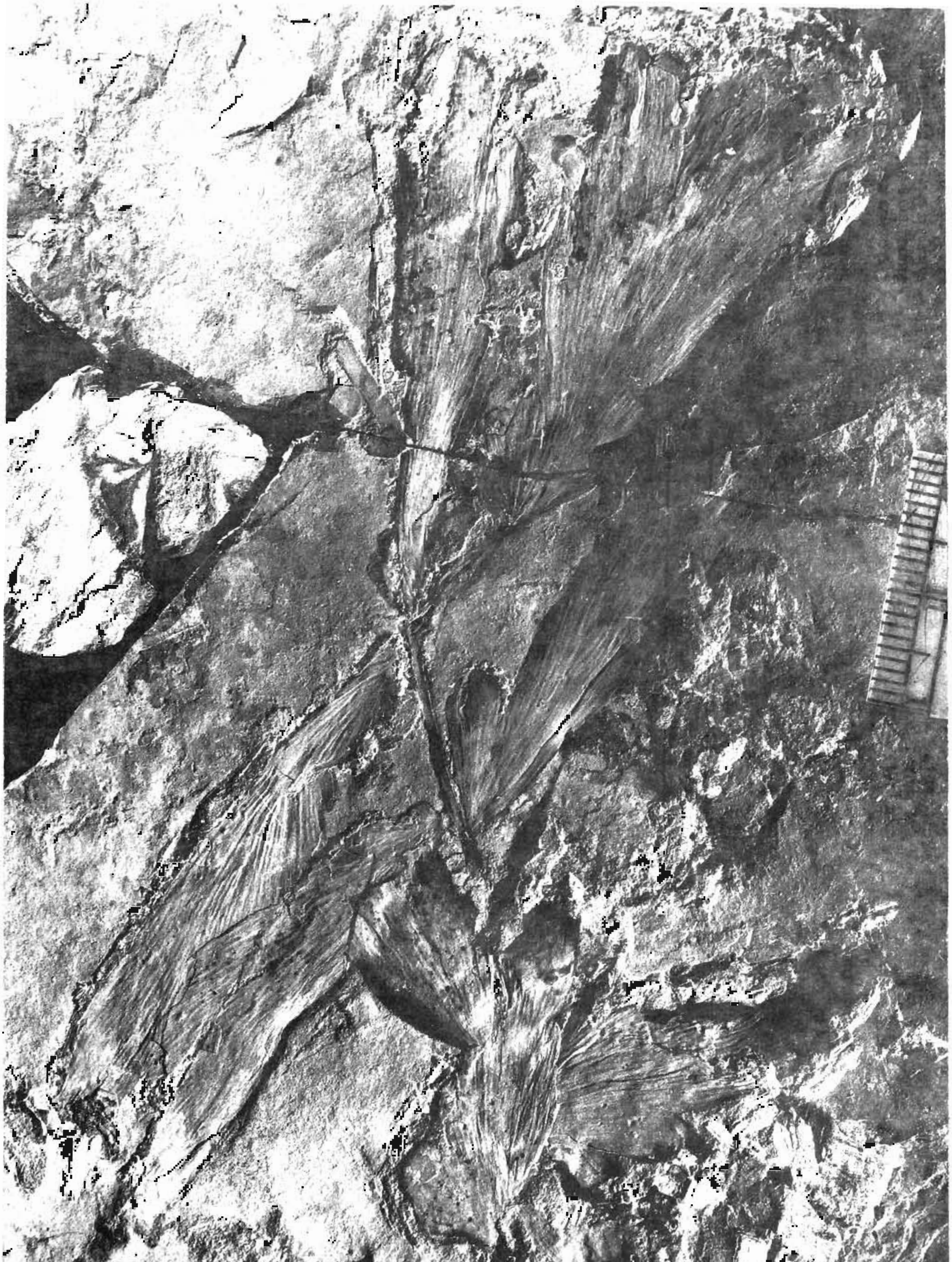


PLATE 1

without any small petiole as reported by Feistmantel (1886) and therefore he transferred this species to the genus *Psygmophyllum*. *Handapaphyllum* is a petiolate genus and therefore distinctly different from *Psygmophyllum*. Maithy (1974) instituted the genus *Gondwanophyton* for certain fan-shaped, entire leaves with broadly rounded apex and truncate base. The leaves are nonpetiolate and alternately attached to the axis. We examined all the specimens kept at BSIP and found that our specimens are quite different from *Gondwanophyton*. Although the description on the basis of which the genus *Gondwanophyton* is instituted is quite different than what is actually seen. The apex is certainly not rounded and the lamina is not continuous, on the contrary one can easily see the definite lobing of the lamina. The Mesozoic ginkgoalean leaves from India are referred to the genera *Ginkgoites* or *Ginkgo* (Sukh-Dev & Bose, 1974). The *Handapaphyllum* leaf differs from these in overall morphography and in the manner of attachment.

The genus *Sidhiphyllites* Srivastava 1984 has a fan-shaped leaf with lamina deeply segmented, almost reaching up to the base. It has obtuse apex and entire margin. Cuticular structures of this genus are also known.

It is evident from the above comparison with the known Gondwana ginkgoalean type of forms that the newly instituted genus *Handapaphyllum* is a distinct and characteristic leaf form.

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Occurrence of *Bischofia* and *Antiaris* in Namsang beds (Miocene-Pliocene) near Deomali, Arunachal Pradesh, with remarks on the identification of fossil woods referred to *Bischofia*

Nilamber Awasthi

Awasthi, Nilamber 1989. Occurrence of *Bischofia* and *Antiaris* in Namsang beds (Miocene-Pliocene) near Deomali, Arunachal Pradesh, with remarks on the identification of fossil woods referred to *Bischofia*. *Palaeobotanist* **37**(2) : 147-151.

Two fossil woods resembling those of *Bischofia* and *Antiaris* belonging to the family Bischofiaceae and Moraceae, respectively, are described from the Namsang beds near Deomali, Arunachal Pradesh. A critical assessment of the structural details of the fossil woods referred earlier to *Bischofia* has revealed that they are quite different from that of *Bischofia*.

Key-words—Xylotomy, *Bischofia, Antiaris,* Namsang beds, Miocene-Pliocene (India).

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साराँश

अरुणाचल प्रदेश में देवमाली के समीपस्थ नामसाँग संस्तरों (मध्यनूतन-अतिनूतन) में बिस्कोफ़िया एवं ऐंन्टीऐरिस की उपस्थिति तथा बिस्कोफ़िया के काष्ठाश्मों के अभिनिर्धारण पर टिप्पणियाँ

नीलाम्बर अवस्थी

अरुणाचल प्रदेश में देवमाली के समीपस्थ नामसाँग संस्तरों से क्रमशः बिस्कोफिएसी एवं मोरेसी कुलों के **बिस्कोफ़िआ** एवं **ऐंन्टीऐरिस** से समानता प्रदर्शित करने वाले दो काष्ठाश्मों का वर्णन किया गया है। पहले से वर्णित **बिस्कोफ़िया** की अश्मित काष्ठों की शारीरीय सरचना के विशिष्ट विश्लेषण से व्यक्त होता है कि ये अश्मित काष्ठें **बिस्कोफ़िया** से बिल्कुल भिन्न हैं।

THE Namsang beds (Miocene-Pliocene) consisting of mottled clays, sandstones, conglomerates and grits resting on the Tipam sandstones are exposed along the Namsang River near Deomali in Arunachal Pradesh. Petrified woods, ranging in size from small pieces to big logs, strewn along with pebbles and boulders in the river beds of Namsang and Buri-Dihing are known to have been derived from these beds. The taxa recovered so far from the Namsang beds belong to the dicotyledonous families, viz., Clusiaceae, Dipterocarpaceae, Sterculiaceae, Burseraceae, Anacardiaceae, Fabaceae, Combretaceae, Lythraceae, Sonneratiaceae, Sapotaceae and Lauraceae (Prakash, 1965, 1966; Prakash & Awasthi, 1970, 1971; Lakhanpal *et al.*, 1981; Awasthi & Prakash, 1987). Further investigation of the petrified woods from the same locality has revealed the presence of *Bischofia* (Bischofiaceae) and *Antiaris* (Moraceae).

SYSTEMATIC DESCRIPTION

Family—Bischofiaceae

Genus—*Bischofia* Bl.

Bischofia palaeojavanica sp. nov.
Pl. 1, figs 1, 3, 4, 5

Material—Three pieces of fairly well-preserved petrified woods.

Description—*Wood* diffuse-porous. *Growth rings* not seen. *Vessels* visible to the naked eye, medium to large (Pl. 1, fig. 1), solitary and mostly in radial multiples of 2-4, sometimes up to 6, tangential diameter of solitary vessels up to 300 μm and radial diameter up to 340 μm, solitary vessels circular to mostly oval (Pl. 1, fig. 1), uniformly distributed, about 12-25 per sq mm; perforations simple; vessel-members with truncate or slightly oblique ends; intervessel pits large, 16-20 μm in diameter,

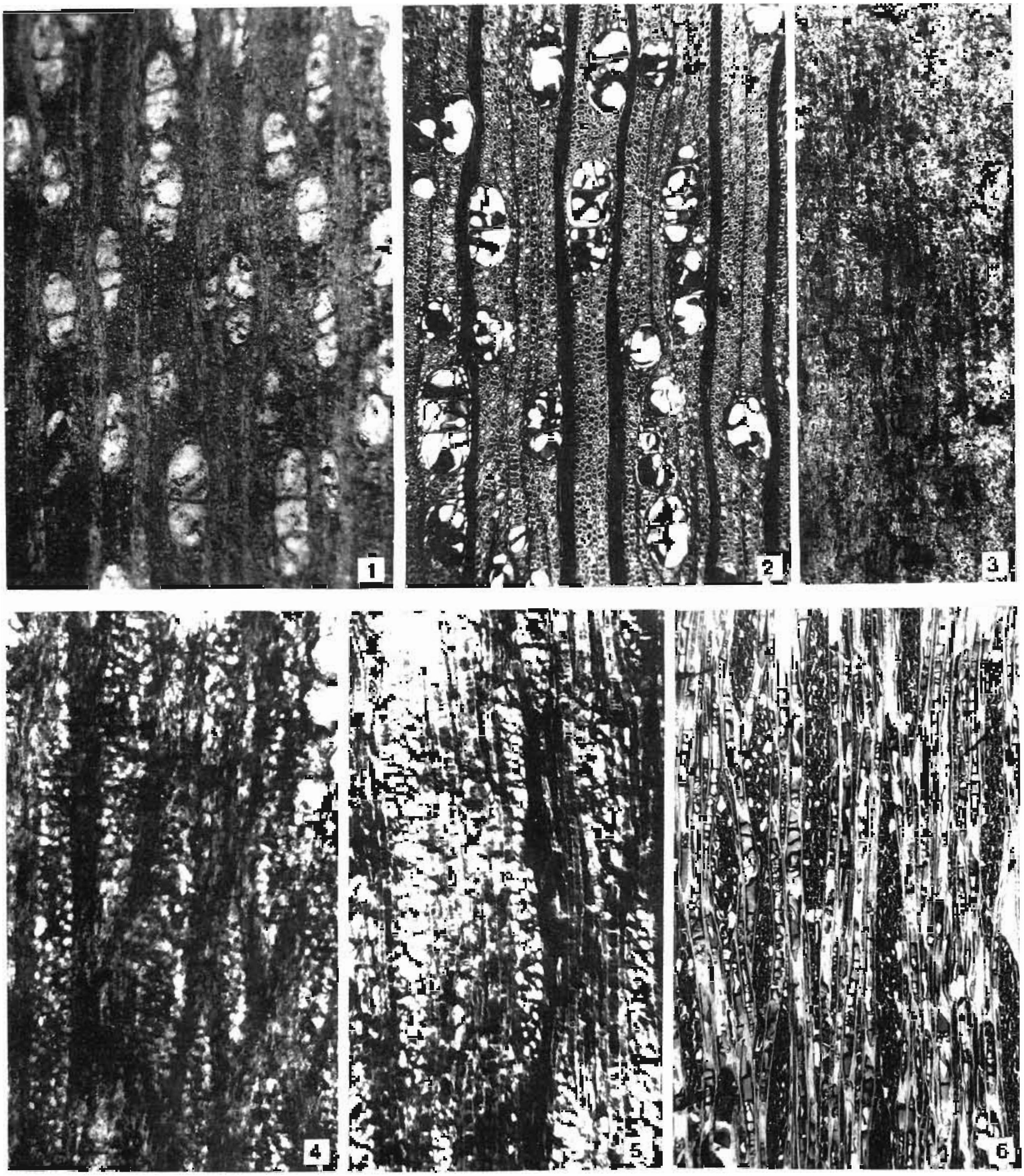

PLATE 1

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]
6. [illegible]

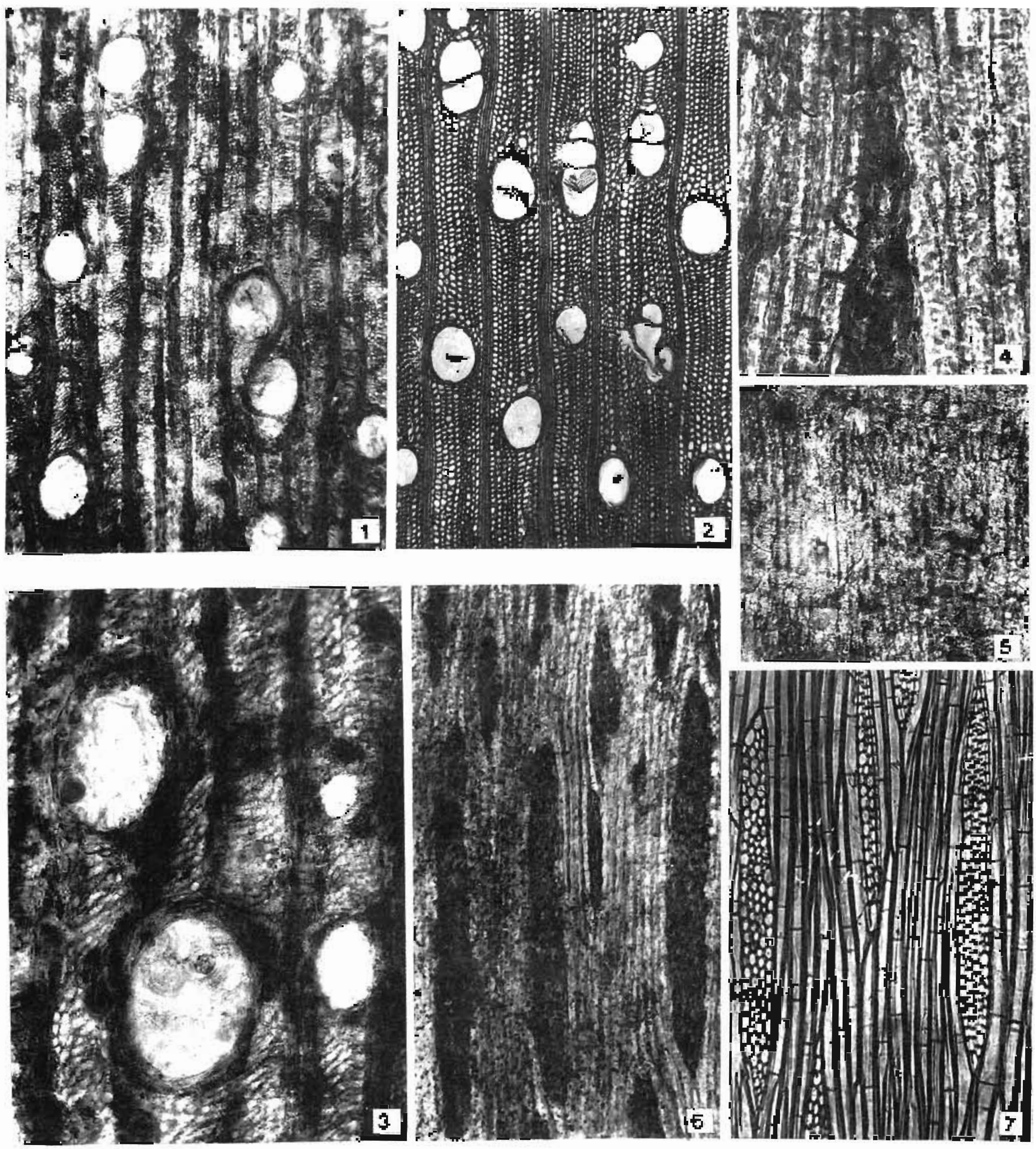

PLATE 2

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]
6. [illegible]
7. [illegible]

alternate, bordered, apertures lenticular; tyloses abundant, often completely occluding the vessels. *Parenchyma* typically absent or 1-2 cells may be rarely present contiguous to the tangential walls of vessels. *Rays* 1-7 seriate, 5-7 per mm, about 70 cells high; ray tissue heterogeneous; uniseriate rays frequent, often moderately low, homocellular to heterocellular; multiseriate rays heterocellular, consisting of 1 to several uniseriate marginal rows of upright cells at one or both the ends (Pl. 1, figs 4, 5) and procumbent cells in the central part; sheath cells often present (Pl. 1, fig. 4); tangential height of upright or square cells about 40-80 μm, radial length 30-50 μm; tangential height of procumbent cells 20-30 μm, radial length 60-130 μm. *Fibres* aligned in radial rows, large, 20-40 μm in diameter, rectangular, thick-walled, walls 6-10 μm in thickness, septate.

Affinities—A combination of the important xylotomical characters of the fossil, such as medium to large vessels, solitary or mostly in radial multiples of up to 6 cells, heavily tylosed; parenchyma typically absent or rarely 1-2 cells present contiguous to tangential walls of the vessels; moderately broad rays up to 70 cells in height, heterocellular with sheath cells and the fibres bigger in size, thick-walled and septate, is met with in the woods of Phyllanthoideae of the family Euphorbiaceae (including Bischofiaceae). However, in all other structural details, e.g., shape, size, frequency of vessels; amount of tyloses; length and width of rays, bigger size of fibres and intervessel pits, the fossil wood shows close similarity with that of *Bischofia javanica* Bl. of Bischofiaceae.

Remarks on fossil woods referred to *Bischofia* Bl.

Ramanujam (1960) instituted the genus *Bischofioxylon* to accommodate a fossil wood from the Cuddalore Sandstone near Pondicherry showing near resemblance with that of *Bischofia*. Mädel (1962) opined that *Bischofioxylon miocenicum* as well as *Euphorbioxylon kraeuselii* Prakash 1957 possess the xylotomical characters of *Bridelia* and not of *Bischofia*. She, therefore, transferred both the species to *Bridelioxylon* Ramanujam 1956. Awasthi (1974) pointed out that *Bridelioxylon miocenicum* and *Bridelioxylon cuddalorense* Ramanujam 1958 are identical, therefore, he merged the former with the latter.

However, on critical re-examination of the type slides of all these fossils it was found that these fossil woods are quite different from those of *Bischofia* and *Bridelia*. One of the important differences is that the vessels in these fossils are mostly in several radial multiples, often reaching up to 25 vessels and appearing as short chains; whereas in *Bridelia* and *Bischofia* they are in radial multiples of mostly 2-5 and occasionally up to 8. Moreover, in *Bischofia* the parenchyma is absent or rarely a few cells may be associated with vessels, and the rays have sheath cells; while in *Bridelia* the apotracheal parenchyma is often present in addition to paratracheal, as widely spaced narrow bands, and the sheath cells in rays are absent. To which extant genus of Euphorbiaceae or other than Euphorbiaceae, these woods belong is yet to be ascertained.

Bande (1974) described a fossil wood from the Deccan Intertrappean beds of Parapani in Mandla District, Madhya Pradesh showing resemblance with that of *Bischofia javanica*. A critical examination of the type slides has revealed that the fossil is quite different from *Bischofia javanica*. In *Bischofia javanica* the parenchyma is typically absent or sometimes one or two cells may be present associated with the vessels that are mostly large. On the contrary, in *Bischofinium deccanii* the parenchyma is paratracheal, vasicentric, completely sheathing the vessels and sometimes aliform and the vessels are mostly medium-sized (Bande, 1974, pl. 2, figs 6, 7). In view of these major anatomical differences, *Bischofinium deccanii* cannot be considered as a fossil wood of *Bischofia javanica*.

Since the present fossil wood shows close similarity with that of *Bischofia*, in accordance with the suggestions of Prakash and Lakhanpal (1980) and Wheeler, Scott and Barghoorn (1977) it is being placed under the same genus and named as *Bischofia palaeojavanica* sp. nov.

Holotype—Specimen no. BSIP 35887; Namsang River beds, Deomali, Arunachal Pradesh; Mio-Pliocene.

Family—Moraceae

Genus—*Antiaris* Lesch.

Antiaris deomaliensis sp. nov.
Pl. 2, figs 1, 3-6

Material—One piece of fairly well-preserved petrified wood.

Description—*Wood* diffuse-porous. *Growth* rings not seen. *Vessels* medium to large, mostly large, sometimes small, solitary and in radial multiples of 2-4 (Pl. 2, fig. 1), sometimes small vessels present in groups associated with bigger vessels, solitary vessels up to 320 μm in tangential diameter and up to 340 μm in radial diameter, thick-walled, common walls up to 16 μm, evenly distributed, about 3-4 vessels per sq mm; perforations simple; vessel-members truncate, very short, about 100-400 μm in length; intervessel pits medium to large, 6-8 µm in diameter, bordered, alternate with lenticular apertures, vestures present. *Parenchyma* paratracheal, vasicentric to aliform, sometimes narrow aliform extension seen meeting with those of adjacent vessels (Pl. 2, fig. 3), cells about 16-24 µm in diameter, filled with dark contents. *Rays* 1-4 seriate (Pl. 2, fig. 6), 7-10 per mm in cross section, about 10-30 cells in height; ray tissue heterogeneous; rays heterocellular, consisting of procumbent cells and 1-2 uniseriate marginal rows of upright or square cells (Pl. 2, fig. 5); crystals present in upright or square cells. *Fibres* aligned in radial rows between two consecutive rays, small, 16-24 µm in diameter, mostly thick walled (Pl. 2, fig. 3), walls about 3-5 µm in thickness, septate (Pl. 2, fig. 4).

Affinities— The above anatomical features of the fossil indicate that it belongs to the family Moraceae and is comparable to the woods of *Artocarpus* and *Antiaris*. In shape, size and distribution of parenchyma, length and width of rays the fossil wood is very similar to *Antiaris* and differs from that of *Artocarpus* in having vessels relatively smaller in size and the rays narrower and shorter. Among the modern woods of *Antiaris*, *A. toxicaria* Lesch. shows closest resemblance with the present fossil wood. As far as the author is aware this is the first record of the fossil wood of *Antiaris* Lesch. It is being described under this genus and assigned to a new species, *A. deomaliensis* indicating its occurrence in the Namsang beds at Deomali.

Holotype— Specimen no. BSIP 35888, Namsang River beds, Deomali, Arunachal Pradesh; Mio-Pliocene.

DISCUSSION

The genus *Bischofia* Bl. is represented by a single species, *B. javanica* Bl. (Willis, 1973, p. 141) which is a large deciduous tree widely distributed in the Indo-Malayan region ranging from the Western Peninsula eastward through Burma and Thailand to Cochin China (South Vietnam), the Philippines, Formosa and Polynesia and southward into Malaya. In India, it occurs in lower Himalaya up to 900 m and sub-Himalayan tract from Jamuna River eastwards, through Uttar Pradesh to Bengal and Assam, southward to Bihar and Orissa, Tirunelveli and Madurai, and on the West Coast from Konkan to the Nilgiris, throughout upper and lower Burma in hills and plains forest, scarce in Andaman Islands (Pearson & Brown, 1932, p. 886). *Antiaris toxicaria* Lesch. which is closely comparable to the fossils, is found in the evergreen forest of Western Ghats, Sri Lanka and Burma (Gamble, 1972, p. 651).

It is important to mention here that out of several taxa recovered from the Namsang sediments near Deomali, *Heligonia* (?), *Gluta*, *Kingiodendron* and *Antiaris* no longer exist in north-east India, though some of their species are known to occur in the evergreen forest of Bangladesh and Burma. Extinction of these elements from this region might have been caused due to considerable change in the environmental conditions in the region since the time of their deposition.

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Ancorisporites venkatachalae sp. nov. from the Lower Permian of Bihar, India

Hari K. Maheshwari & Rajni Tewari

Maheshwari, Hari K. & Tewari, Rajni 1987. *Ancorisporites venkatachalae* sp. nov. from the Lower Permian of Bihar, India. *Palaeobotanist* 35(2): 152-[illegible].

The diagnosis of the genus *Ancorisporites* is emended to include megaspores with [illegible] cushions on their mesosporium. The new species recorded from the [illegible] Formation is diagnosed by anchor-shaped appendages all over the exosporium and [illegible] mesosporium with numerous cushions [illegible] arranged around the [illegible].

Key words—Megaspore, *Ancorisporites*, Lower Permian, [illegible] Formation, [illegible] Coalfield, [illegible].

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सारांश

[illegible]

[illegible]

[illegible]

Pant and Mishra (1986) reported the megaspore *Ancorisporites* from Lower Gondwana of Singrauli Coalfield, Madhya Pradesh. The diagnostic features of the megaspores were circular shape, with indistinct contact areas, absence of arcuate ridges and a mesosporium that either had or did not have cushions. We consider that the presence or absence of arcuate ridges or well-defined contact areas is controlled by preservational factor also to a large extent. According to Pant and Mishra, the

PLATE 1

Ancorisporites venkatachalae sp. nov.

1. A megaspore in dry condition showing a distinct triradiate mark and cushion-like protuberances which are clearly seen along the equator [illegible].
2. The holotype in dry condition; the triradiate mark and the [illegible] areas are clearly seen [illegible].
3. The holotype after [illegible] showing [illegible] with numerous cushions arranged [illegible] the trilete mark. Slide [illegible].
4. [illegible] of the megaspore in Fig. [illegible] showing [illegible] anchor-tipped appendages [illegible] Note the difference in [illegible] of the appendages at [illegible] and at the contact areas [illegible].
5. Appendages on the exosporium [illegible] to show [illegible] [illegible].
6. A portion of megaspore in Fig. [illegible] enlarged to show details of [illegible] and variation in the dimensions of appendages [illegible].
7. A portion enlarged to show [illegible] appendages [illegible].

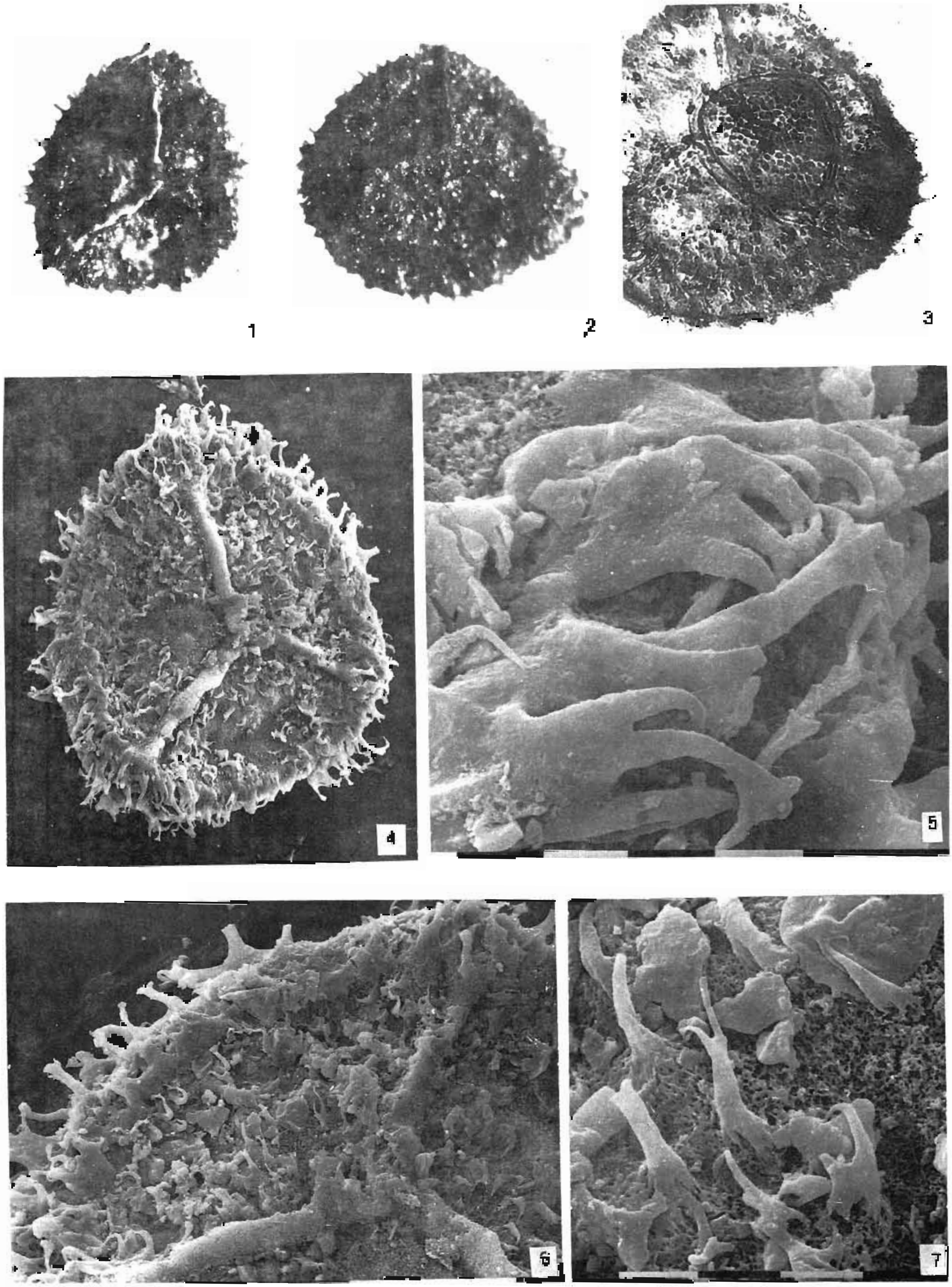

PLATE 1

mesosporium of the genus shows 'pitted' or 'unpitted' nature, i.e., it may either have cushions or may not have cushions. However, presence or absence of cushions in a mesosporium is universally regarded as a distinct generic character, i.e., inner bodies of all the species within a genus either show cushions (which may be numerous or few and arranged biserially, haphazardly or trigonally around the triradiate mark) or do not have cushions. A genus cannot simultaneously show 'pitted' or 'unpitted' mesosporia amongst its various species. If two specimens are morphographically alike, but in one the mesosporium possesses cushions while in the other the mesosporium is devoid of cushions, then both should be placed under separate genera. Since Pant and Mishra have reported only one species, viz., *Ancorisporites [illegible]*, mesosporium of which shows cushions after the dark contents have been removed from it, it is to be followed that the genus shows cushions in the inner body. Hence, the diagnosis of the genus *Ancorisporites* is emended to include only those forms which show exosporium with simple and forked appendages with pointed, tapering and recurved (hook-like) apices, and a mesosporium with cushions.

DESCRIPTION

Genus—*Ancorisporites* Pant & Mishra 1986 emend.

Type species—*Ancorisporites [illegible]* Pant & Mishra 1986.

Emended diagnosis—Megaspores trilete, sub-circular to triangular in proximo-distal orientation; triradiate ridges straight to slightly sinuous, two-thirds of spore radius long, uniformly wide, may or may not reach margin, ending up at arcuate ridges; contact area well defined; sporoderm two-layered; outer exosporium covered with bifurcated or a mixture of simple and bifurcated, evenly distributed appendages; apices of appendages tapering, pointed and recurved; mesosporium thin, hyaline, membraneous, separate from exosporium all over except at proximal pole where attached at inter-radial areas through cushions.

Ancorisporites [illegible] sp. nov.

Pl. 1, figs 1-7

Diagnosis—Megaspores trilete, triangular in outline in proximo-distal orientation; triradiate ridges wavy, ending up at contact ridges; contact area well defined with distinct arcuate ridges; exosporium covered with bifurcated appendages; apices of appendages pointed, tapering and recurved; mesosporium triangular in shape, with numerous cushions arranged trigonally around triradiate mark.

Holotype—Slide no. BSIP 9107/1774; Lower Permian, Basal Barakar (Karharbari?) Formation; Hura Coalfield, Bihar.

Dimensions:

- *Overall size*—516-576 × 522-576 μm (dry condition); 672 × 710 μm (wet condition); 653 μm (after mounting in canada balsam)
- *Thickness of exine*—19 μm (after mounting in canada balsam)
- *Length of triradiate ridges*—194-230 μm (dry condition); 347 μm (wet condition); 288 μm (after mounting in canada balsam)
- *Width of triradiate ridges*—31-56 μm (dry condition); 56 μm (wet condition); 26 μm (after mounting in canada balsam)
- *Width of arcuate ridges*—25 μm (dry condition); 29 μm (wet condition)
- *Length of appendages*—51 μm (dry condition); 51 μm (wet condition)
- *Width of appendages at base*—12 μm (dry condition); 12 μm (wet condition)
- *Width of appendages at apex*—6 μm (dry condition); 6 μm (wet condition)
- *Size of inner body*—305 × 325 μm (wet condition); 213 × 225 μm (after mounting in canada balsam)
- *Size of cushions*—12 × 9 μm (wet condition); 6 × 6 μm (after mounting in canada balsam)

COMPARISON

The only other known species of the genus *A. [illegible]* (Pant & Mishra 1986, pl. 6, figs 39-45; text-figs 11A-G, 12A-C) differs from the new species in showing mixed simple and bifurcate appendages over exosporium, and dark contents in mesosporium which after being removed from the inner body showed few, irregularly distributed cushions. Appendages in the present species, as mentioned earlier, are only of bifurcated type and inner body shows numerous cushions arranged trigonally around triradiate mark.

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Vegetational history and palaeoenvironment of Hirpur Locality-I, Lower Karewa, Kashmir

H. P. Gupta & Chhaya Sharma

Gupta, H. P. & Sharma, Chhaya 1989. Vegetational history and palaeoenvironment of Hirpur Locality-I, Lower Karewa, Kashmir *Palaeobotanist* **37**(2) : 155-158.

The present palynostratigraphical studies carried out on the exposed sediments of Hirpur Locality-I, lying under the earlier worked out Hirpur Locality-III, has revealed continued dominance of arboreal elements in the sequence depicting comparative preponderance of spruce and oak, although showing abrupt change in their values. The palynodata thus obtained has been interpreted to reconstruct the palaeovegetation pattern and to deduce the possible climatic fluctuation witnessed during the course of sedimentation of the 40 m thick lithocolumn. The pollen diagram has been divided into four pollen assemblage zones.

Key-words—Palynostratigraphy, Palaeoenvironment, Palaeovegetation, Lower Karewa (India).

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सारॉंश

काश्मीर में अधरि करेवा की हीरपुर संस्थिति-प्रथम का वनस्पतिकीय इतिहास तथा पुरावातावरण

हरीपाल गुप्ता एवं छाया शर्मा

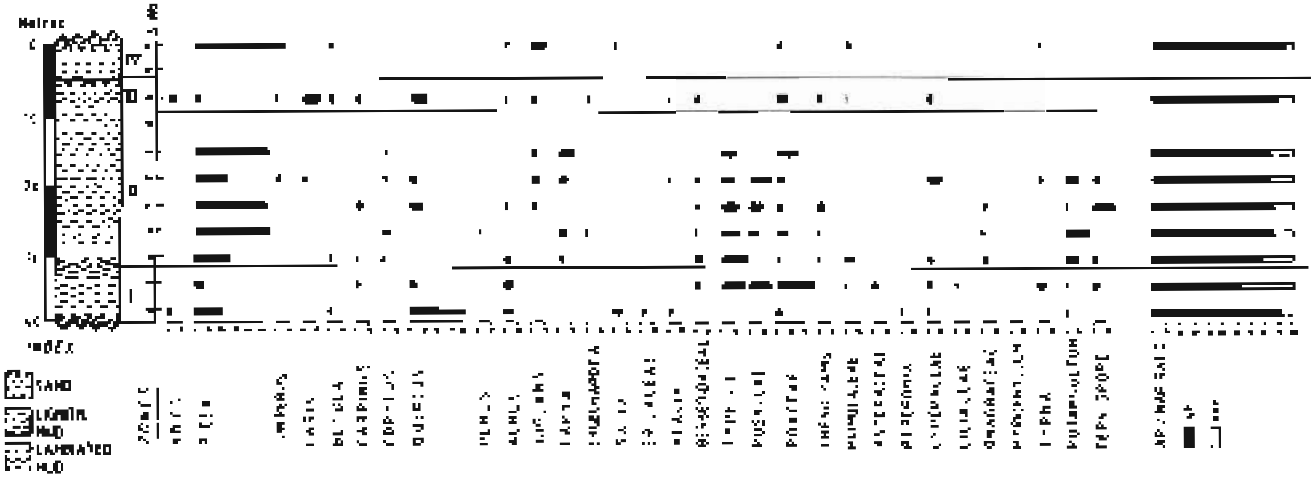
हीरपुर संस्थिति-प्रथम में अनावरित अवसादों के परागाणुस्तरिकीय अध्ययन से इस अनुक्रम में वृक्षीय अवयवों की अविरल प्रचुरता व्यक्त होती है। तुलनात्मक दृष्टि से इन अवयवों में स्प्रूस एवं ओक की बाहुल्यता है हॉलाकि इनकी मात्रा में अनायास परिवर्तन देखा गया है। उपलब्ध परागाणविक आँकड़ों के आधार पर पुरावनस्पतिक स्वरूप तथा इस 40 मीटर मोटे अवसादी स्तम्भ के अवसादन के समय संभव जलवायवी परिवर्तनों की भी व्याख्या की गई है। परागकण-चित्र चार परागकण समुच्चय मंडलों में विभाजित किया गया है।

THE present investigations carried out on the exposed sediments from Hirpur Locality-I (33°42′N-75°41′E) cover the downward extension of earlier worked out Hirpur Locality-III (Gupta *et al.*, 1984a, 1984b) of Lower Karewa in Kashmir Valley. Apparently, the lithofacies in Hirpur Locality-I is very similar to Hirpur Locality-III. The sediments in Hirpur Locality-I consist of laminated as well as lignitic mud with distinct overlying and underlying beds of sand. The former was found palynologically barren whereas, later yielded pollen in appreciable frequency. The techniques employed for the present analysis of soil samples are the same as already discussed in an earlier communication (Gupta *et al.*, 1984a).

POLLEN DIAGRAM AND COMPOSITION

The pollen analysis of nine samples from different horizons of a 40 m thick lithocolumn from Hirpur Locality-I has revealed the predominance of *Picea* and *Quercus*, together with other broad-leaved arboreal elements, which is divisible into four pollen assemblage zones, viz., HLI-I, HLI-II, HLI-III and HLI-IV in ascending order. These zones are primarily aimed to interpret palynological data so as to throw light on the palaeovegetation and if possible to decipher the corresponding climatic changes during the period of sedimentation.

Zone HLI-I—The early phase of this zone is recognized by exceedingly high values of *Quercus*, followed by *Picea, Alnus, Salix, Acacia*, Ericaceae and low frequency of *Abies*. The scarce non-arboreal vegetation is represented by poor values of Poaceae, Asteraceae, Cyperaceae and *Peperomia*. AP/NAP ratio has demonstrated over dominance of arborescent vegetation.



Text-figure 1—[illegible]

The last phase of this zone is marked by steep fall in the values of *Quercus* and *Picea* coupled with the appearance of *Carpinus* and Berberidaceae, and disappearance of *Salix* and Ericaceae. However, *Pinus* remains stable in its values. [illegible] (Gupta *et al.*) NS and Rosaceae also appear in this phase showing fairly high values—maintaining 17 per cent each. The values for Poaceae markedly improve to reach its maximum whereas other non-arboreals such as Asteraceae, Cyperaceae and Liliaceae are sparsely present. Primulaceae in low frequencies and *Typha* in moderately high values appear in this phase. *Potamogeton* maintains almost same low values. The emergence of ferns exhibit low percentage. AP/NAP ratio shows considerable depression in the overall arboreal vegetation as compared to the earlier phase.

Zone HH-II—This zone is identified by the preponderance of *Picea* pollen throughout indicating the existence of spruce forest. The broad-leaved element *Quercus* which was once most dominant declines to moderate values and remains confined only to the middle of the zone. Other associates of *Picea* forest namely *Fraxinus*, *Larix*, *Betula*, *Carpinus* and *Ulmus* are sporadic in this zone. *Corylus* remains confined to this zone only with fluctuating values. *Alnus* continues its high values till the beginning of this zone and then dwindles down in the middle and disappears in the upper half of the zone. However, *Cedrus* too, is restricted to this zone in good frequencies right from the base of the zone showing an upward trend in its values. *Juglans* appears about in the middle of the zone accompanied with *Carya* up to upper half of the zone, the latter with comparatively high values.

Amongst the shrubby taxa, Berberidaceae and Rosaceae are recorded throughout the zone in low and high values respectively but both disappear at the top of the zone. [illegible] (type 1 pollen in pollen diagram) is represented in considerably high values throughout the zone.

The non-arboreal vegetation is depicted distinctly in low frequency. Even Poaceae is poor throughout the zone except for considerable improvement in its values at the top of the zone. The other herbaceous taxa such as Caryophyllaceae, Primulaceae and Onagraceae show fairly high values but are mostly confined to the lower half of the zone. The aquatics are represented by good frequencies of *Potamogeton* throughout the zone except for its intermittent fluctuations. *Typha* is encountered in moderate values but slightly below the top of the zone. Ferns are barely present except their enhanced values at the middle of the zone. AP/NAP ratio indicates dominance of arborescent vegetation except that it is slightly reduced in the upper half of the zone.

Zone HH-III—This is a markedly short spanned zone as compared to the preceding two zones, i.e., HH-I and HH-II and is demarcated by an abrupt fall in the values of *Picea* which has reduced to merely a fraction. The downfall of *Picea* is witnessed by the dominance of *Larix* and *Quercus* in almost equally high values, followed by *Abies*, *Betula* and *Carpinus*. *Alnus* and *Fagus* remain as before whereas *Corylus* is unrepresented and *Engelhardtia* emerges in low values in this zone. Berberidaceae continues with almost the same values. [illegible] is sustainingly present in this zone when compared to its tremendous increase to about 30 per cent of the total values in zone II.

The ground cover is further reduced as compared to what has been witnessed in the previous zone, and is represented by low values of Rubiaceae, Chenopodiaceae, Primulaceae and Caryophyllaceae. Aquatics and ferns remain totally unrepresented in this zone. The AP/NAP ratio again demonstrates the overall continued dominance of arboreal vegetation.

Zone HII-II.—This zone is demarcated by the re-emergence of *Picea*, showing exceptionally high values of *Picea* forest alongwith *Juglans* and less frequent other broad-leaved arboreal elements, namely *Betula*, *Ulmus* and *Salix* showing much reduced values. However, *Juglans* shows fairly high values. No shrubby element is witnessed in these *Picea* woods. *Arecipites hirpurensis* though re-appears in this zone, is in much reduced values.

Herbaceous vegetation too is poorly represented as compared to the preceding zone with scanty values of only Poaceae and Asteraceae. Aquatic elements are totally absent in this zone too, except for *Typha* which is represented in low frequencies. Non-arboreals remain distinctly scanty in contrast to the arboreal taxa present in this zone.

DISCUSSION

The palynostratigraphical studies of the sediments from the Hirpur Locality I demonstrate the existence of a thick *Picea* forest. Nevertheless, *Picea* forest did not remain predominant throughout the pollen sequence but it experienced two major depressions, one at the later phase of zone-I and another showing its very low frequencies during zone III of the pollen diagram. The fluctuations in *Picea*, associated with the replacement or corresponding fluctuations in the broad-leaved elements, especially *Quercus* has lead to the formulation of four pollen zones through which the palaeovegetation pattern is demarcated and the data obtained is interpreted to throw light on the palaeoclimatic changes in time and space in this region of Inner Himalaya.

The well-marked preponderance of *Quercus* followed by *Picea* alongwith associated taxa, viz., *Abies* and *Betula* is suggestive of temperate and humid climate at the beginning of zone I. Later on, at the close of this zone, both *Quercus* as well as *Picea* registered significant depression besides the disappearance of *Abies* and *Betula* indicating amelioration in the temperature or change over to the warm temperate climate.

Similarly in Zone HII-II the restoration of *Picea*, an element of continued dominance, followed by *Arecipites hirpurensis* and Rosaceae in good frequencies alongwith insignificant or sporadic presence of other taxa is indicative of the type of vegetation sustained under cool temperate and humid climate.

Zone HII-III has witnessed a catastrophic degradation of woods where *Picea* reduced to its ever minimum frequencies on one hand but associated with the appearance of *Taxus* as a dominant element restricted to this zone only which is indicative of a cool temperate and still more humid climate comparable to the present subalpine zone in the north-west Himalaya.

Zone HII-IV again reflects a change in the vegetation pattern where *Picea* resumes to its maximum dominant position indicating the advent of cool temperate but dry climate.

However, it may be pointed out that the occurrence of *Arecipites hirpurensis* in high values throughout the Zones HII-I and HII-II in the pollen diagram has led to the inference that the sediments of Hirpur Locality II are in continuation with the underlying sediments of Hirpur Locality I (Gupta *et al.* 1984a, 1984b).

CONCLUSIONS

Pollen analytical investigation of the sediments has led to the following conclusions:

1. Based on the changes witnessed in the palaeovegetation, the pollen diagram has been divided into four pollen assemblage zones, viz., HII-I, HII-II, HII-III and HII-IV in *Picea* dominant forest.
2. Arboreal vegetation remains dominant throughout the pollen diagram as compared to the non-arboreal vegetation.
3. Climatic fluctuations inferred from the worked out palaeovegetational data of different zones are summarized as under:

Zone HII-I	Temperate and humid climate in the beginning and warm temperate at the top.
Zone HII-II	— Cool temperate and humid climate.
Zone HII-III	— Cool temperate and still more humid climate.
Zone HII-IV	— Cool temperate but dry climate.

4. The occurrence of *Arecipites hirpurensis* Gupta, Sharma & Yadav (MS) in Hirpur Locality I demonstrates its continued extension to Hirpur Locality II.

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Some Mesozoic plant remains from Bhuj Formation with remarks on the depositional environment of beds

Jayasri Banerji

Banerji Jayasri [illegible]. Some Mesozoic plant remains from Bhuj Formation with remarks on the depositional environment of beds. *Palaeobotanist* 57(1-2): 159-166.

The paper deals with some plant remains from Pur and Pat River sections exposed near the villages [illegible] and [illegible] in Kachchh District. These are *Trambauthallites spiralis* gen. et sp. nov., *Isoetes* [illegible] sp. nov., [illegible] sp. and [illegible] sp. nov. [illegible]. The presence of *Trambauthallites spiralis* and *Isoetes* indicates the fossiliferous beds are considered to be of fresh water origin.

Key words—Megafossils, Liverworts, Pteridophytes, Bhuj Formation, Middle-Upper Jurassic, India.

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सारांश

भुज शैल समूह से प्राप्त कुछ मध्यजीवी पादप अवशेष तथा संस्तरों के निक्षेपणीय वातावरण पर टिप्पणियाँ

जयश्री बनर्जी

[illegible]

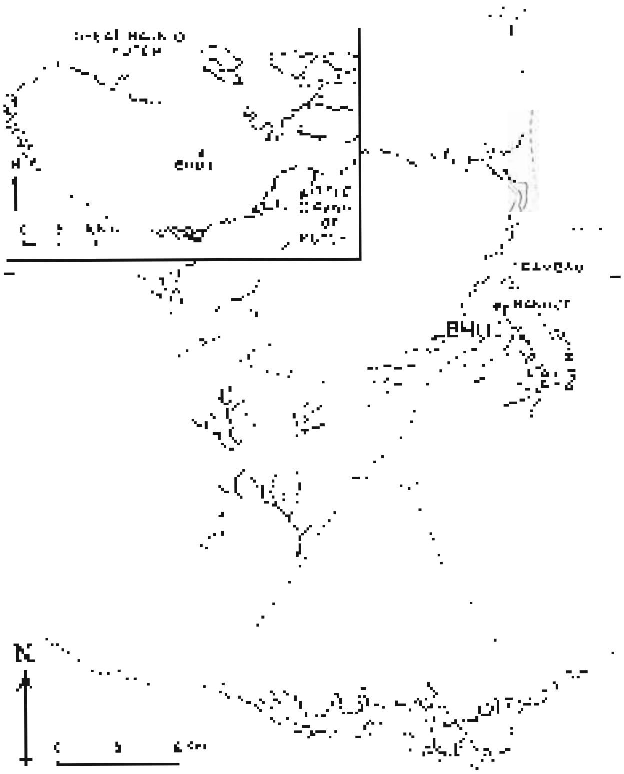
FROM the Pur River Section (Map 1) a large number of megafossils have been described by Bose and Banerji (1984). From the Pat River section only megaspores are so far known (Banerji, Jana & Maheshwari, 1984). The newly discovered fossiliferous bed in Pat River section contains a species of liverwort associated with the filamentous algal remains. This part extends more than 120 m in length though quite thin throughout the outcrop area. About 30 cm beneath is a bed characterized by the presence of only root impressions which are both vertical and horizontal in position, indicating *in situ* deposition. Between the liverwort zone and the zone with root markings another zone is present which is characterized by the presence of fragmentary fern fronds, fragments of *Ptilophyllum* leaves, conifer shoots and *Araucarites*. This assemblage is also present though rare, above the liverwort zone and below the root zones.

In Pat River section, which is about 8-10 km south-east of Pur River, the complexion gets changed. Here one of the lower beds contains fossils of *Isoetes* only, indicating a fresh water environment. The bed overlying the *Isoetes* bed has stray occurrences of fragmentary *Ptilophyllum* leaves and conifer shoots.

DESCRIPTION

Genus—*Trambauthallites* gen. nov.

Diagnosis—Plants thalloid, showing rosette habit, usually 4-6 lobes (rarely 8), radiating from centre, lobes diverging at an angle of 45°-60°, dichotomously branched, linear, further each lobe near apex slightly or deeply notched, sometimes apex obtuse; margin mostly entire, occasionally at places slightly wavy or undulated; substance of thallus extremely thin, but midrib region slightly thicker than rest of lamina, represented by a median groove. Lobes of most of the female thalli at their terminal ends bearing a globular or spheroidal sporogonium on the dorsal surface. Each



Map 1—Showing fossiliferous beds of Trambau and Sukhpur villages, Kutch, Gujarat.

sporogonium bearing more than 20-25 spores. Spores trilete, sub-triangular in shape, with well developed perine; exine showing fairly large irregular reticulations, lumina finely reticulate; trilete distinct, rays almost reaching up to margin.

Type species—*Trambauanthallites* (*Hepaticites*) *sukhpurensis* (Bose & Banerji) comb. nov.

Discussion—Rosettes forming thalli have been described from Sukhpur and Kera as *Hepaticites sukhpurensis* (Bose & Banerji, 1981). Similar thalli have been collected from Trambau. The entire bed is full of sterile as well as fertile thalli which externally resemble *Riccia* [illegible] Lundblad [illegible]. However, in none of the specimens from Kutch ventral scales, rhizoids and pores have been observed. Though the Kutch specimens look very much like the extant species *Riccia* [illegible] yet in the former the position of sporogonium is more like the one met with in most species of the genus *Cyathodium*. The spores in the Kutch species are quite unlike spores met with in various species of *Cyathodium* which are mostly spinulate. In the absence of any rhizoids in Kutch specimens at present, I prefer not to place these specimens under *Hepaticites* Walton which has been referred to the Order Jungermanniales (Jovet-Ast, 1967). The genus *Marchantites* Brongniart as emended by Walton (1925) is characterized by the presence of rhizoids, scales and marchantiaceous air chambers. None of these characters are known in the specimens from Kutch. The characteristic *Riccia*-like thallus, with sporogonium lying dorsal side of near tip of each lobe with reticulate spores separates *Trambauanthallites* from all the existing fossil and living genera belonging to thalloid hepatics (Rodkinde, 195[illegible]).

Trambauanthallites sukhpurensis (Bose & Banerji) comb. nov.

Pl. 1, figs 1-8; Text-fig. [illegible]

1981 *Hepaticites sukhpurensis* Bose & Banerji, [illegible] pl. 1, figs 1-15; text-fig. 2A, B.

Description—More than [illegible] pieces of shale samples with closely packed thalli were collected from Trambau whereas from Sukhpur and Kera only two shale pieces with *Trambauanthallites sukhpurensis* were obtained. Between some of the thalli at places one can also see fine filamentous algal remains (Text-fig. [illegible] A) without showing any definite character. In sterile thalli lobes are more distantly radiating, whereas in fertile thalli lobes are more closer to each other. Overall shape of most of the complete thalli is circular to oval (Pl. 1, figs 3, [illegible]). The substance of thallus is extremely thin, so from them it is difficult to make out whether the sporogonium is lying on dorsal side or on the

PLATE 1

2. Showing a few sterile and fertile thalli of *Trambauanthallites sukhpurensis* (Bose & Banerji) comb. nov. Specimen nos. BSIP [illegible], [illegible].
3. A sterile thallus of *Trambauanthallites sukhpurensis* (Bose & Banerji) comb. nov. Specimen no. BSIP [illegible].
4. A fertile thallus of *Trambauanthallites sukhpurensis* (Bose & Banerji) comb. nov. Specimen no. BSIP [illegible].
5-7. Isolated spores of *Trambauanthallites sukhpurensis* (Bose & Banerji) comb. nov. Slide nos. BSIP [illegible], [illegible] × 200.
8. A specimen of *Trambauanthallites sukhpurensis* (Bose & Banerji) comb. nov. [illegible] The complete [illegible] and the figure on the right hand shows a portion of [illegible] enlarged [illegible] of the [illegible].
9-12. [illegible] specimens showing [illegible] and sporophylls [illegible]. Specimen nos. BSIP [illegible].

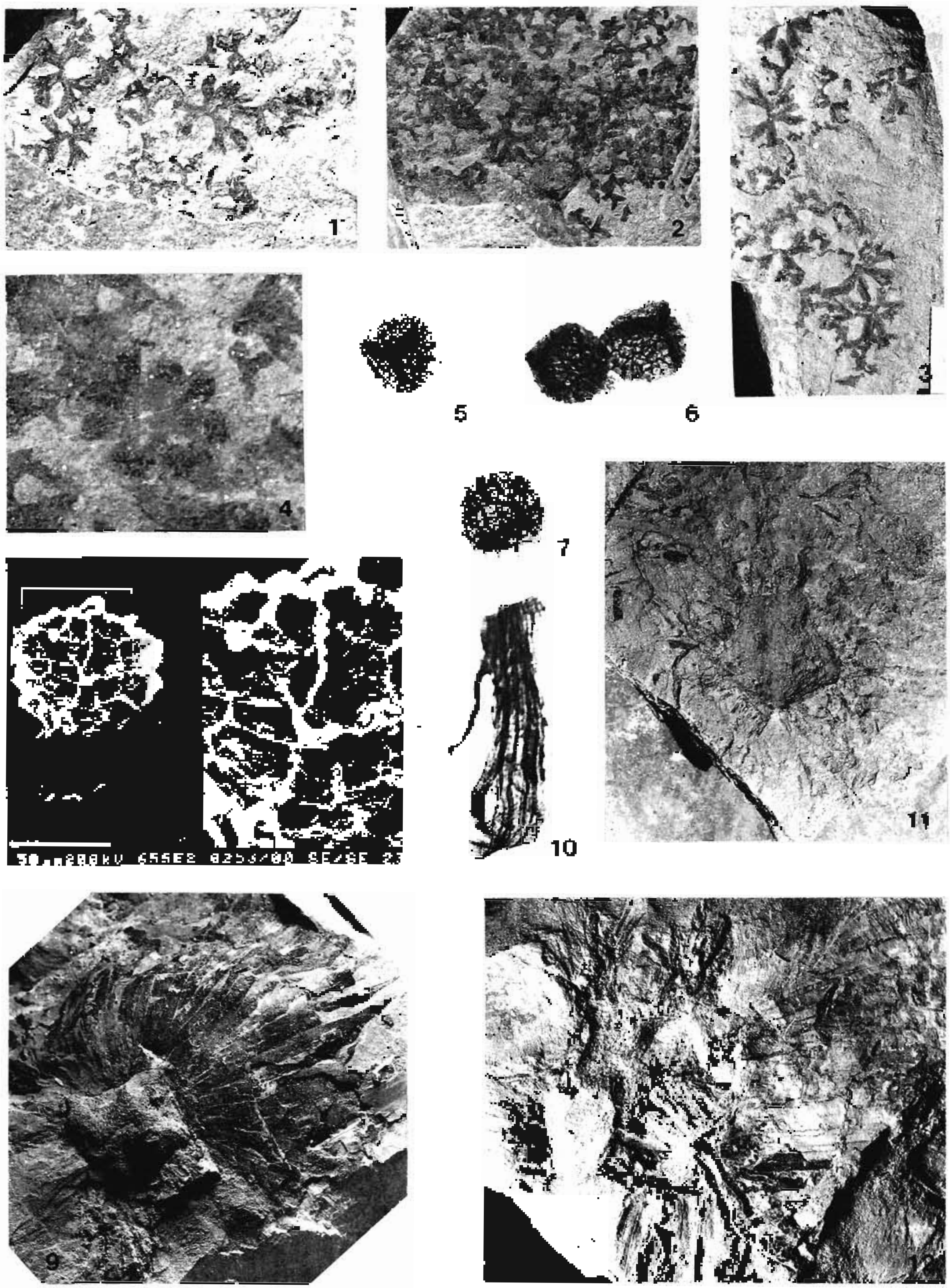
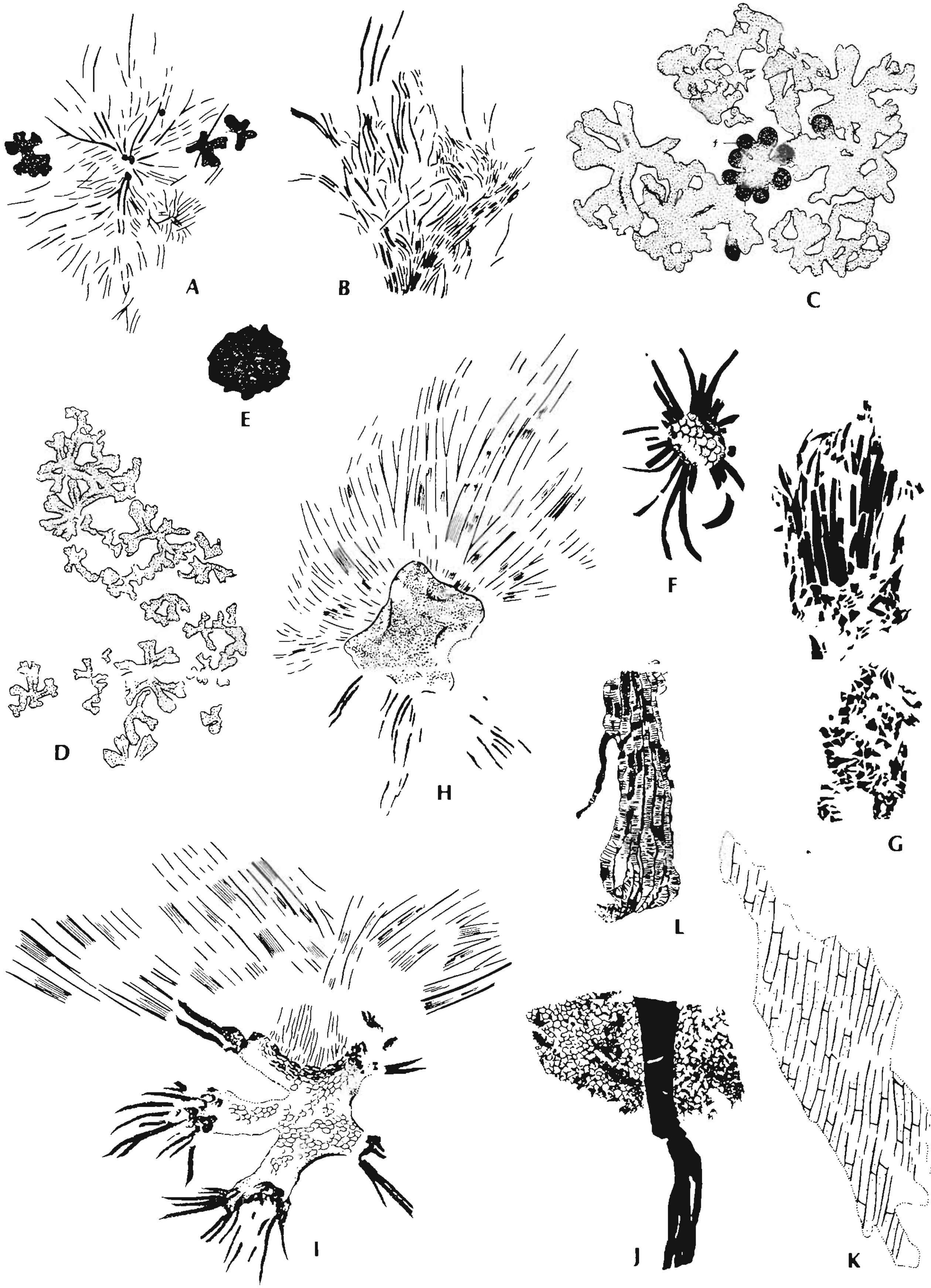


PLATE 1



TEXT-FIGURE 1

ventral side. In some cases, they seem to be lying on dorsal side. Upper SEM lumina of spores show fine perforations (Pl. 1, fig. 8).

Genus—*Isoetes* Linnaeus

Isoetes janaianus sp. nov.

Pl. 1, figs 1-12; Pl. 2, figs 1-6; Text-figs 1F-I, 2A-C

1964 *Isoetites indicus* Bose & Roy, p. 236, pl. 1, figs 6, 7.

1966 *I. indicus* Bose & Roy: Surange, p. 21, fig. 9.

1974 *I. indicus* Bose & Roy: Sukh-Dev, p. 73.

1984 *I. indicus* Bose & Roy: Bose and Banerji, p. 7, pl. 1, figs 9-11; text-fig. 30.

Diagnosis—Plant as a whole elongate-oval in shape, about 14 cm long and 5-7 cm wide at its broadest region. When dorsiventrally or vertically compressed 15 cm in diameter including central portion representing rhizomorph which is about 2-3.5 cm in diameter. Rhizomorph 3-lobed, surface showing irregularly packed polygonal cells. Root scars prominent, roots unbranched or branched, mostly unbranched, at places, showing (?) spiral pittings. Sporophylls numerous, about 80-125 in number, spirally arranged, in dorsiventrally compressed state forming a sort of rosette. Sporophylls about 10-12 cm long, near base about 3-4 mm wide, gradually tapering towards apex, margin entire; surface showing fine striations in longitudinal direction. Sporophyll cuticle showing more or less serially arranged elongated rectangular cells, anticlinal walls straight, periclinal wall smooth. Mega- and microsporophylls externally indistinguishable. Megasporangium oval or oblong in shape, 3.5-6 mm long and 2-4 mm wide; sporangial wall comprising mostly elongate rectangular cells, rarely polygonal but much longer than broad, anticlinal walls undulated, periclinal wall smooth. Megaspores 100-1500 in number, trilete, amb subtriangular, size 390-450 × 360-430 μm, inner body indistinct, equatorial flange 40-50 μm wide, slightly more broader at apical region, membranous; trilete laesurae membranous, more or less of same width as equatorial flange, extending up to equatorial margin. Exine 6-7 μm thick, reticulate, lumina irregularly polygonal, showing intragranulate structure, muri 5-7 μm high. Microsporangium oval or oblong in shape, 4-8.5 mm in length and 3.5-4 mm in width, epidermal cells like cells of megasporangium. Microspores numerous, elliptical or subcircular in shape, usually 20-30 × 16-20 μm in size, alete, exine rough or finely granulose, mostly associated with 1-2 semilunar folds.

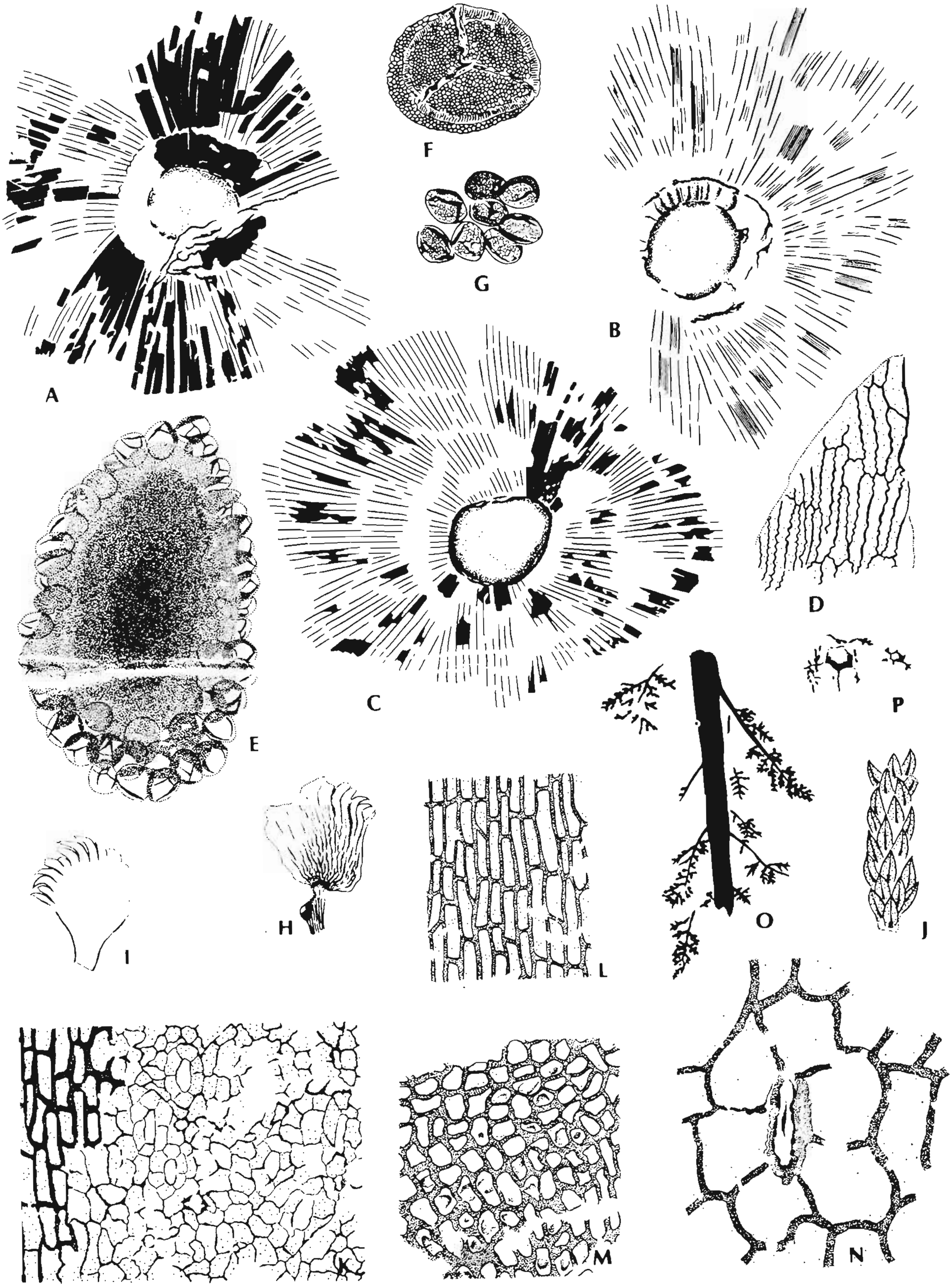
Derivation of name—Earlier fossil specimens resembling *Isoetes* were placed under the genus *Isoetites* Münster. Now when more information is available on roots, rhizomorph, mega- and microsporophylls the generic name *Isoetes* has been accepted here. Bose and Roy (1964) had described one of their species as *Isoetites indicus*. With the transfer of the fossil species to the genus *Isoetes* a change in the name of species is required as an extant species of the genus already bears this species epithet, i.e. *Isoetes indica* Pant & Srivastava 1962. The fossil is therefore renamed as *Isoetes janaianus* after Dr B. N. Jana who first discovered the fossiliferous bed containing *Isoetes* at Pat River.

Holotype—Specimen no. BSIP 35851, Pat and Pur River Section exposed near Nangor and Trambau villages respectively, Bhuj Formation.

Description—From Pat River Section quite a few specimens complete with roots, rhizomorph and sporophylls have been collected. Almost all the specimens from Pur River Section are incomplete; they have only the bases of sporophylls which are arranged in rosettes. But from this locality a young plant with sporophylls attached to rhizomorph has been collected (Text-fig. 1F). This specimen consists of a broadly oval rhizomorph and a few sporophylls. The rhizomorph surface also shows scars of detached sporophylls.

One of the best preserved specimens (Pl. 1, fig. 9; Text-fig. 1H) from Pat River shows 3-lobed nature of the rhizomorph distinctly. Its surface clearly shows the root scars. Another specimen (Text-fig. 1I) from the same locality shows rather deeply lobed rhizomorph. A dorsiventrally compressed specimen with largest diameter has been shown in Text-fig. 2B. The impression of the rhizomorph is somewhat circular and of the sporangial bases are little distinct. Text-figure 2C shows specimen with maximum number of sporophylls. The sporophylls of the specimens from Pat River yielded both mega- and microspores occurring in mega- and

Text-figure 1—A, B, showing [illegible] occurring in association with *[illegible]* (Bose & [illegible]) [illegible] Specimen nos. BSIP 35858 and 35860, × 1. C, D, *[illegible]* (Bose & Banerji) [illegible]; Specimen nos. BSIP 35827, 35828, × 1. D, × [illegible] (enlarged). E, showing a spore under SEM. F-G, *Isoetes janaianus* sp. nov.: F, showing a young plant; Specimen no. BSIP 35861, × 1 and G, laterally compressed plant; Specimen no. BSIP 35862, × 1.5. H, I, showing rhizomorph with roots and sporophylls; Specimen nos. BSIP 35851, 35857, × 1. J, showing surface cells of a microsporangium; Slide no. BSIP 35870, × [illegible]. K, showing epidermal cells of sporophylls; Slide no. BSIP 35869, × 75. L, roots showing [illegible]; Slide no. BSIP 35871, × [illegible].



TEXT-FIGURE 2

microsporophylls belonging to the same plant, whereas, from the Pur River specimens only megaspores could be isolated Megaspores, recovered from the specimens from both the localities are similar in nature. The megaspores were isolated from megasporangium in oval masses (Text-fig. 2E) and the microspores got detached after they were separated from the microsporangium.

Comparison—Among the living species of *Isoetes* from India, *I. janaianus* resembles *I. panchanani* Pant & Srivastava 1962. In both the species the megaspores have reticulate ornamentation. In *I. panchanani* the rhizomorph is bilobed and its microspores have so far not been described. *I. coromandaliana* L. (Pfeiffer, 1922) though resembles *I. janaianus* in gross features, yet differs in having tuberculate megaspores. *I. pantii* Goswami & Arya 1970 differs in having 3-lobed rhizomorph, tuberculate megaspores and trimorphic microspores. *I. sampathkumarani* Rao, *I. dixiti* Shende, *I. sahidri* Mahabale and *I. indica* have 2-3 lobed rhizomorph and dimorphic megaspores (Pant & Srivastava, 1962).

I. janaianus also resembles *I. engelmanni* Brown, *I. foveolata* Eaton and *I. tuckermani* Brown (Pfeiffer, 1922). All the species have reticulate megaspores. All the latter species, however, have bilobed rhizomorphs.

Genus—*Cycadospadix* Schimper

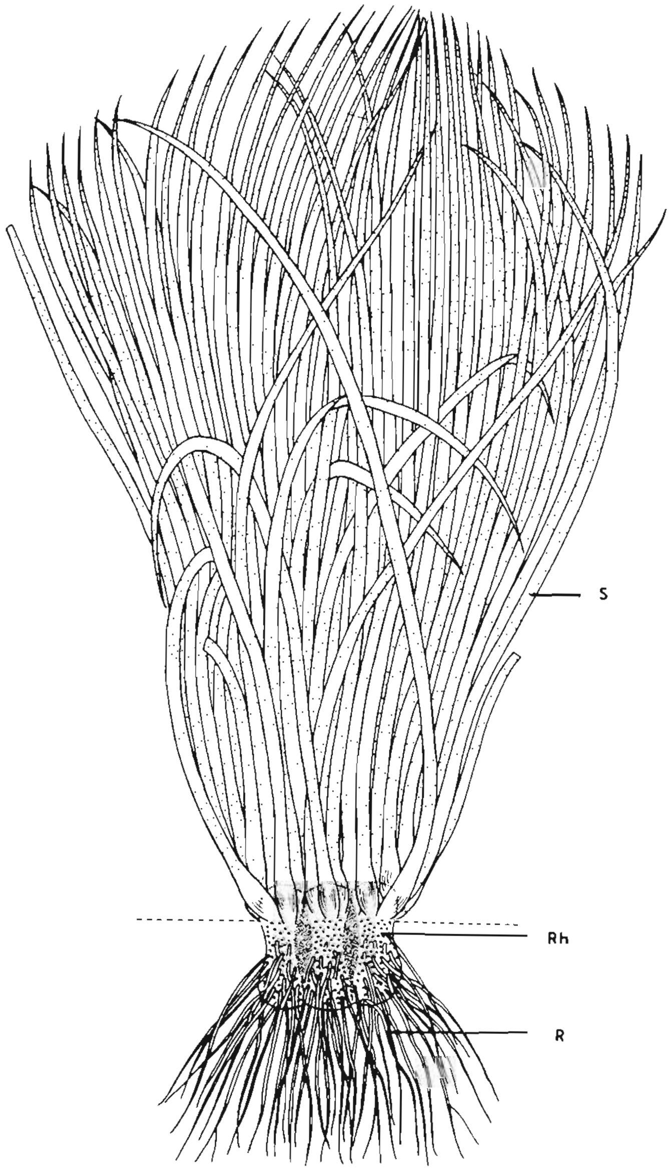
Cycadospadix sp.

Pl. 2, fig. 7; Text-fig. 2H-I

Description—Megasporophylls somewhat wedge-shaped, 2.3-2.8 cm long, 1.8-2 cm wide, narrowing towards base; preserved part of basal region finely striated; surface of megasporophylls pleated, on apical side margin deeply notched, forming finger-like projections, projections 1-1.5 cm long (?). Basal part of one of the specimens (Pl. 2, fig. 19; Text-fig. 2H) shows on one side an oval depression. This may be a scar of a fallen seed base.

Occurrence—Pur River Section near Trambau.

Comparison—*Cycadospadix* sp. may be compared with *Cycadospadix hennoquei* Saporta 1875 and *C. moraeanas* Saporta 1875, but Saporta's species differ from the Kutch specimens in being



Text-figure 3—Reconstruction of *Isoetes janaianus* (**S**—Sporophyll; **Rh**—Rhizomorph; **R**—Root).

larger in size and in having lanceolate shape. The present specimens, in gross features, also match the specimens of *Cycalacis saportae* Barale 1981. Due to lack of epidermal features in Kutch specimens a detailed comparison is not possible. *C. scopulina* Zhou 1983, too looks like *Cycadospadix* sp.

←

Text-figure 2—*Isoetes janaianus* n. sp. **A-C,** Dorsiventrally compressed specimens showing rhizomorphs and sporophylls, Specimen nos. BSIP 35833, 35843 and 35844, × 0.5; **D,** showing cells of sporangial wall, Slide no. BSIP 35835-5, × 75; **E,** showing a mass of megaspores, Slide no. BSIP 35835-5, × 18; **F,** megaspore under SEM showing reticulate exine; **G,** showing a few microspores, Slide no. BSIP 35835-3, × 300; **H, I,** *Cycadospadix* sp., Specimen nos. BSIP 35836 and 35845, × 1; **J-N,** *Allocladus patensis* n. sp., J, showing a fragmentary twig, Specimen no. BSIP 35838, × 1; K, upper surface showing stomatiferous and nonstomatiferous zones, Specimen no. BSIP 35838 1, × 150, L, cells of lower surface, Slide no. BSIP 35838-3, × 150, M, cell of lower surface from basal region of a leaf, Slide no. BSIP 35838 3, × 150, N, a stoma, Slide no. BSIP 35838-3, × 400; **O, P,** showing horizontally and vertically preserved root markings respectively Specimen nos. BSIP 35846 and 35847, × 0.5.

Bracteolepis dactylota (Harris) Florin 1933 resembles *Cycadospadix* sp. in external features.

Genus - *Allocladus* Townrow

Allocladus patensis sp. nov.

Pl. 2, figs 8-11; Text fig. 2I-N

Diagnosis—Coniferous shoot with helically borne leaves, about 2 cm long and 0.5 cm wide. Leaves closely appressed, dorsal side distinctly keeled, rhomboidal in shape, mostly longer than broad, 3-5 mm long, 1.7-3 mm broad at base; apex acute, margin scarious, entire to microscopically fringed towards base, keeled.

Leaf cuticle moderately thick, upper surface comparatively slightly thinner than lower surface, stomata confined to upper surface. On upper surface stomata distributed along middle region flanked on either sides by non-stomatic zones, epidermal cells along non-stomatiferous zones rectangular, mostly 2-4 times longer than broad, anticlinal walls thick and straight, periclinal walls smooth, rarely at places irregularly thickened, cells towards basal region mostly polygonal to squarish in shape with straight and thick anticlinal walls, periclinal wall occasionally thickened towards centre, cells near apex also somewhat similar to basal cells; cells along stomatal region polygonal with straight anticlinal walls, periclinal wall mostly smooth, rarely at places unevenly thickened; cells towards basal region mostly polygonal to squarish in shape with straight and thick anticlinal walls, periclinal wall occasionally thickened towards centre, cells near apex also somewhat similar to basal cells; cells along stomatal region polygonal with straight anticlinal walls, periclinal wall mostly smooth, rarely at places unevenly thickened; trichome bases also present. Stomata longitudinally orientated, at places tending to form short discontinuous files, closely placed. Subsidiary cells mostly 4-6, polygonal in shape, anticlinal walls mostly straight, rarely undulated, periclinal wall smooth; stomatal pit more or less squarish; guard cells sunken, less cutinized than subsidiary and epidermal cells, inner margin slightly more cutinized; stomatal aperture slit-like. Cells on lower surface similar to those of non-stomatiferous zones of the upper surface.

Holotype—Specimen no. BSIP 35838, Pat River Section exposed near Nangor, Bhuj Formation.

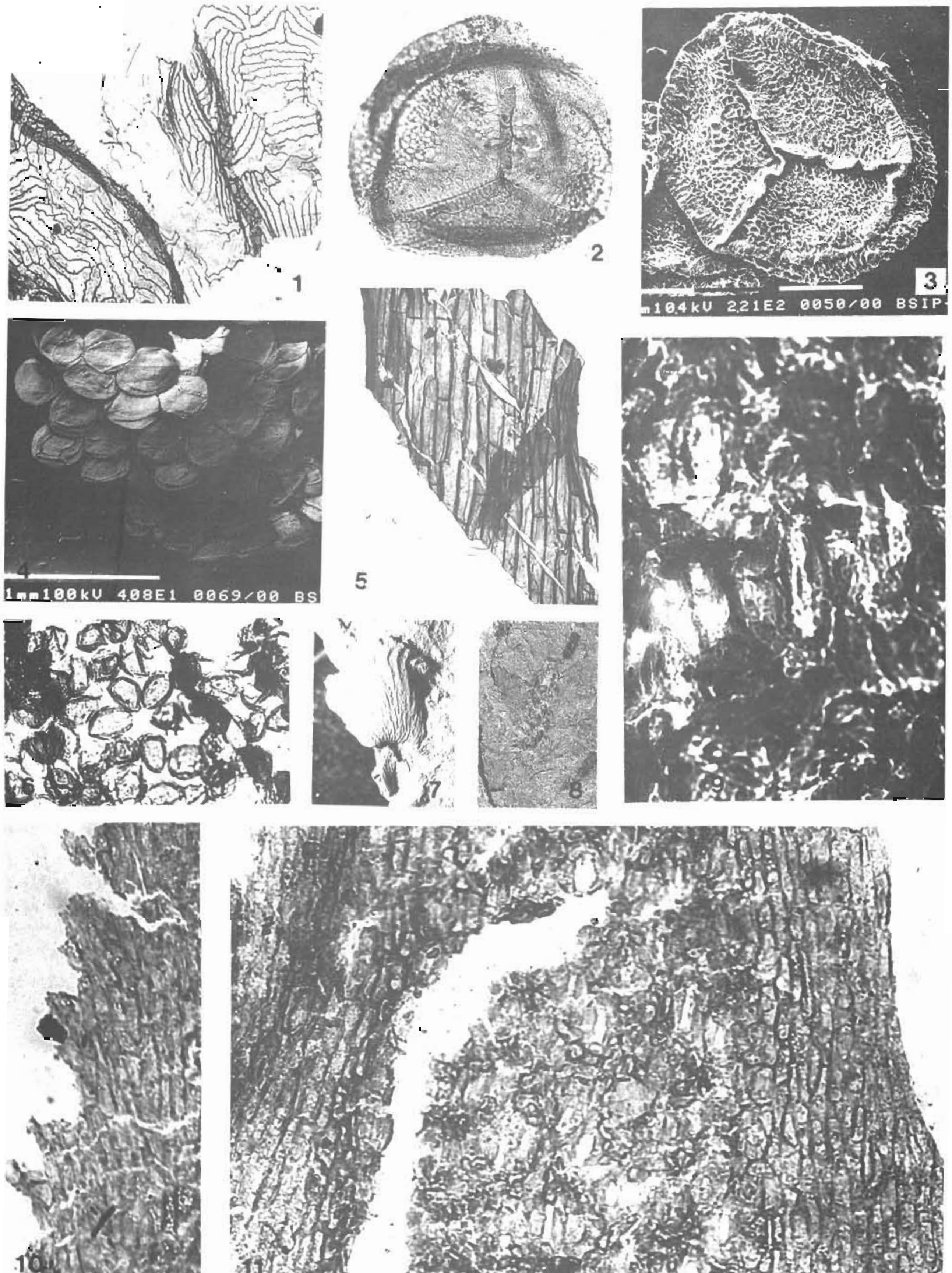
Comparison—In *Allocladus bansaensis* Bose & Banerji 1984 the leaves are rhomboidal, more or less similar in length and width and the stomata are confined to two lateral zones. In the present species the leaves are longer than broad and the stomata are confined only to the middle region. In gross features, *A. patensis* looks very much like *A. bansaensis* Sukh-Dev & Zeba-Bano 1977. In the latter species stomata are irregularly distributed over the entire upper surface. In *A. sahnianus* Sukh-Dev & Zeba-Bano stomata are present in two lateral zones closer to margin. *A. sahnianus* Sukh-Dev & Zeba-Bano also differs from *A. patensis* in having two irregular stomatal zones on lateral sides leaving a nonstomatal zone along the middle region.

DISCUSSION

Both Pur and Pat River sections exposed near Trambau and Nangor, respectively, expose the Bhuj Formation. According to Biswas (1977) the Bhuj Formation consists mainly of non-marine sediments which represent deltaic deposits with the front of delta towards west and fluvial region lying towards east. He also suggested that Bhuj Formation ranges in age from Post Oxfordian to Lower Cretaceous and it was the period of regression. Koshal *et al.* (1984) on the basis of numerous stacked bioturbated structures, marine trace fossils and heavily bioturbated and glauconitic horizons considered the entire Mesozoic Sequence in Kutch to be of marine origin. Their observations were based on certain sections of Mesozoic rocks in Kutch. They, however, did not mention the exact locations of these sections. During my field trips to Kutch I have seen numerous marine trace fossils but they were all

PLATE 2

1. *Isoetes* ... sp., epidermal cells of a sporangium. Slide no. BSIP 35835-2. × 100.
2. A megaspore of *Isoetes bansaensis* n. sp. after partial maceration. Slide no. BSIP 35835-4. × 100.
3. A microspore under SEM.
4. A mass of megaspores of *Isoetes bansaensis* n. sp. under SEM.
5. *Isoetes bansaensis* n. sp. showing epidermal cells of sporophyll. Slide no. BSIP 35835-1. × 100.
6. A mass of microspores of *Isoetes bansaensis* n. sp. Slide no. BSIP 35835-3. × 350.
7. *Cycadospadix* sp.; Specimen no. BSIP 35[illegible].
8. A portion of a twig of *Allocladus patensis* n. sp. Specimen no. BSIP 35838. × 1.
9. *Allocladus patensis* n. sp., showing stomata. Slide no. BSIP 35838-3. × 400.
10. *Allocladus patensis* showing scale-leaf margin towards base of lower surface. Slide no. BSIP 35838-2. × 150.
11. Upper cuticle of *Allocladus patensis* n. sp. showing stomatiferous and non-stomatiferous zones. Slide no. BSIP 35838-1. × 150.


1
2
3
m10.4kV 2.21E2 0050/00 BSIP
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5
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8
9
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11

PLATE 2

elsewhere in the Jaisalmer Formation of Biswas (1977) or in other older Mesozoic rocks. Trace fossils are abundant along the Bhuj-Mandvi Road (section exposed in the hillocks or in the road cuttings).

The presence of *Trambauthallites kachchhensis* in thin bed within an exposed section exceeding 120 m in length in Pur River Section is indicative of humid and non-marine condition. Here *T. kachchhensis* had formed a complete mat allowing only at places a few filamentous algae to grow. It seems that this liverwort mat was washed out during a single flood. In the bed lying below *T. kachchhensis* I came across *Isoetes panchananii* and below it a bed containing only root markings (Text-fig. 2D) both along longitudinal and horizontal beddings. The genus *Isoetes* is typically a fresh water plant. The root markings clearly indicate that there were the plants which were actually growing there. Moreover, the presence of *Isoetes panchananii* in a bed in the Pur River Section (quite a few were found in actual position of growth) further supports the view that the fossiliferous bed near Trambau and Nangor were definitely of fresh water origin, though there was perhaps a depositional time gap between the bed having *Trambauthallites* and the one with *Isoetes* near Nangor.

So far from the Bhuj Formation no Wealden plant megafossil like *Weichselia* has been recorded. Even the genus *Gleichenites* which is abundant in the Upper Jurassic-Lower Cretaceous beds of the Rajmahal, Gangapur, Gardeshwar, Than and Bansa formations is completely missing in the Bhuj Formation. The overall plant assemblage of Bhuj Formation is more like those from other known Middle-Upper Jurassic formations.

ACKNOWLEDGEMENTS

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Bengalia raniganjensis, a new sphenopsid from the Raniganj Formation (Upper Permian)

Hari K. Maheshwari, V. K. Singh & Usha Bajpai

Maheshwari, Hari K., Singh, V. K. & Bajpai, Usha [illegible]. *Bengalia raniganjensis*, a new sphenopsid from the Raniganj Formation (Upper Permian). *Palaeobotanist* **37**(2): [illegible].

A new genus of articulatae closely resembling the characteristic Barakar form *Trizygia* is reported from the shales associated with Nega Coal of Raniganj Formation in Raniganj Coalfield. It comprises [illegible] leaves with [illegible] apices [illegible] leaves are free [illegible] a small [illegible].

Key words — Sphenopsida, Equisetales, Raniganj Formation, [illegible].

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

सारांश

बंगालिया रानीगंजेंसिस, रानीगंज शैल-समूह (उपरि परमी) से एक नया स्फीनॉप्सिड

हरिकृष्ण माहेश्वरी, विजय कुमार सिंह एवं उषा बाजपेई

[illegible]

THE sphenopsids in the Lower Gondwana of India are represented by the genera *Trizygia* Royle, *Phyllotheca* Brongniart, *Schizoneura* Schimper & Mougeot, *Raniganjia* Rigby and *Lelstotheca* Maheshwari. A few specimens of *Sphenophyllum*-like foliage have also been reported, but in all likelihood these are sports of *Trizygia speciosa* Royle 1839. The genera *Schizoneura*, *Raniganjia* and *Trizygia*, each represented by one species, are normally found in the Raniganj or equivalent formations, except for an occasional report in the Barakar Formation. Of the three species of *Phyllotheca*, one each occurs in Karharbari (*sahnii*), Barakar (*australis*) and Raniganj (*griesbachii*) formations. *Lelstotheca robusta* (Feistmantel) Maheshwari 1972 and *Barakaria dichotoma* (Feistmantel) Seward & Sahni 1920, also a probable sphenopsid, are so far recorded only from the Barakar Formation. Pant and Nautiyal (1967) favoured the inclusion of *Phyllotheca sahnii* Saksena 1952 under *Raniganjia bengalensis* (Feistmantel) Rigby 1963 on the basis of similarity in microscopic details of leaf architecture in the two species. A somewhat similar microscopic detail is also seen in *Lelstotheca robusta* (Feistmantel) Maheshwari (Surange & Prakash, 1962; Maheshwari & Srivastava, 1987) and *Barakaria dichotoma* Mishra 1969, but it has not been suggested that these, too, belong to *Raniganjia*. In fact two of the specimens included by Pant and Nautiyal (1967, pl. 10, fig. 5; pl. 11, fig. 10; text-figs 16, 21) under *Raniganjia bengalensis* are very much unlike a typical *Raniganjia* in having leaves which are not only free up to their bases but also have apparent differences in insertion levels.

During the 1985-86 field season we collected a somewhat similar specimen from Pit East Raniganj Coalfield, West Bengal. As this specimen and the two above mentioned specimens from Pant and Nautiyal collection do not answer to diagnostic features of any of the known sphenopsid, a new taxon *Bengalia* *raniganjensis* is being proposed here to accommodate and classify them.

MATERIAL AND METHOD

A single hand specimen with counterpart, exhibiting compressions of 3 clusters of leaves in a simulated whorled arrangement, was collected from the shales intercalated with coals of Nega Seam (Raniganj Formation), Upper Permian. Due to natural oxidation, the coalified crust of the compression now remains only as a very thin carbonaceous film which appears brownish in colour in liquid paraffin under incident light. The carbonified film is so delicate that it did not give any cellulose pulls for the study of microscopic details. Except a few leaves, the counterpart is just an impression and replica of the part. A somewhat whitish 'halo' is seen round leaf whorls. Origin of this 'halo' is not known. Probably it resulted by exudation of some compound during natural oxidation of the carbonified leaf compression.

OBSERVATIONS

Though the three leaf clusters of the specimen are aligned in such a way as if they were part of a single plant, no connecting axis is seen, which is not very unusual for most Lower Gondwana Equisetales. The two more complete clusters, containing 13 and 14 leaves respectively, are compressed dorsiventrally. The leaves radiate from a shallow depression indicating the possibility of their attachment directly at the nodes with little or no adherent leaf-sheath. The actual point and manner of attachment of leaves could not be observed due to overlapping of leaves at base. Although, disposition of leaves is indicated around the point of attachment, yet in the specimen they are more in number, crowded and overlapping in one half which may suggest an asymmetrical arrangement of leaves on the live plant. Alternatively this asymmetry in disposition of leaves may be due to the partial preservation or due to loss of some leaves on the other half during opening of the specimen. In that case the number of leaves per cluster is estimated to be about 18. The leaves overlap at base in such a way as if they enated from the axis at different levels. The apparent asymmetry of the whorls and overlapping of the leaves in rock could also be due to oblique burial. The third, incomplete cluster shows remains of five leaves on one side of the radiating point. Three partly preserved leaves of opposite side of the same whorl are found on the counterpart. The distance between lower and middle whorls is 7 cm and that between middle and upper whorls is 5 cm.

The leaves are constricted towards the base (cuneate). They are neither joined by their marginal commissures nor seem to be united at or near the base. The nodal plates at the attachment point of leaves as in *Lelstotheca robusta* (Surange & Prakash, 1962; Maithy & Mandal, 1978) and in other stellate articulates, have also not been observed. Individual leaves are linear-lanceolate, 2.8 to 4 cm long and 3 to 5 mm at widest near about the middle of the leaf length. The lamina is flat, inflexed upwards on either side and with entire lateral margins. The prominent median vein extends right up to the apex and continues for a short distance beyond it to form a distinct and sometimes long mucro. The length of mucro averages at about 1 mm. The midvein is flat for most part of the leaf but near the tip it becomes swollen excluding mucro which is marked by the remains of blackish cylinder of carbonaceous substance along it. This indicates a straight spinous tip of the leaves. The leaf lamina shows indistinct and irregular transverse wrinkles.

DIAGNOSES

Bengalia gen. nov.

Type species—*Bengalia raniganjensis* gen. et sp. nov.

Diagnosis—Linear-lanceolate leaves radiating in clusters of about 18 from an undefined axis in verticillate whorls. Leaf lamina flat, with a single distinct median vein which protrudes as a distinct and long mucro. Leaves free up to cuneate base probably not forming an adpressing sheath. Axis, nodal disc and nature of leaf attachment unknown. Leaf lamina with irregular, mostly transversely placed wrinkles.

Bengalia raniganjensis sp. nov.

1967 *Raniganjia bengalensis* (Feistmantel) Rigby

PLATE 1

1. *Bengalia raniganjensis* gen. et sp. nov. Holotype. Specimen no. BSIP 35962, × 1.
2. Counterpart of the holotype. Specimen no. BSIP 35963, × 1.
3. Leaf whorls in specimen illustrated in figure 1 enlarged to show free nature and point of attachment of leaves, × 4.
4. Two of the leaves photographed under glycerine to show the mucro, × 4.

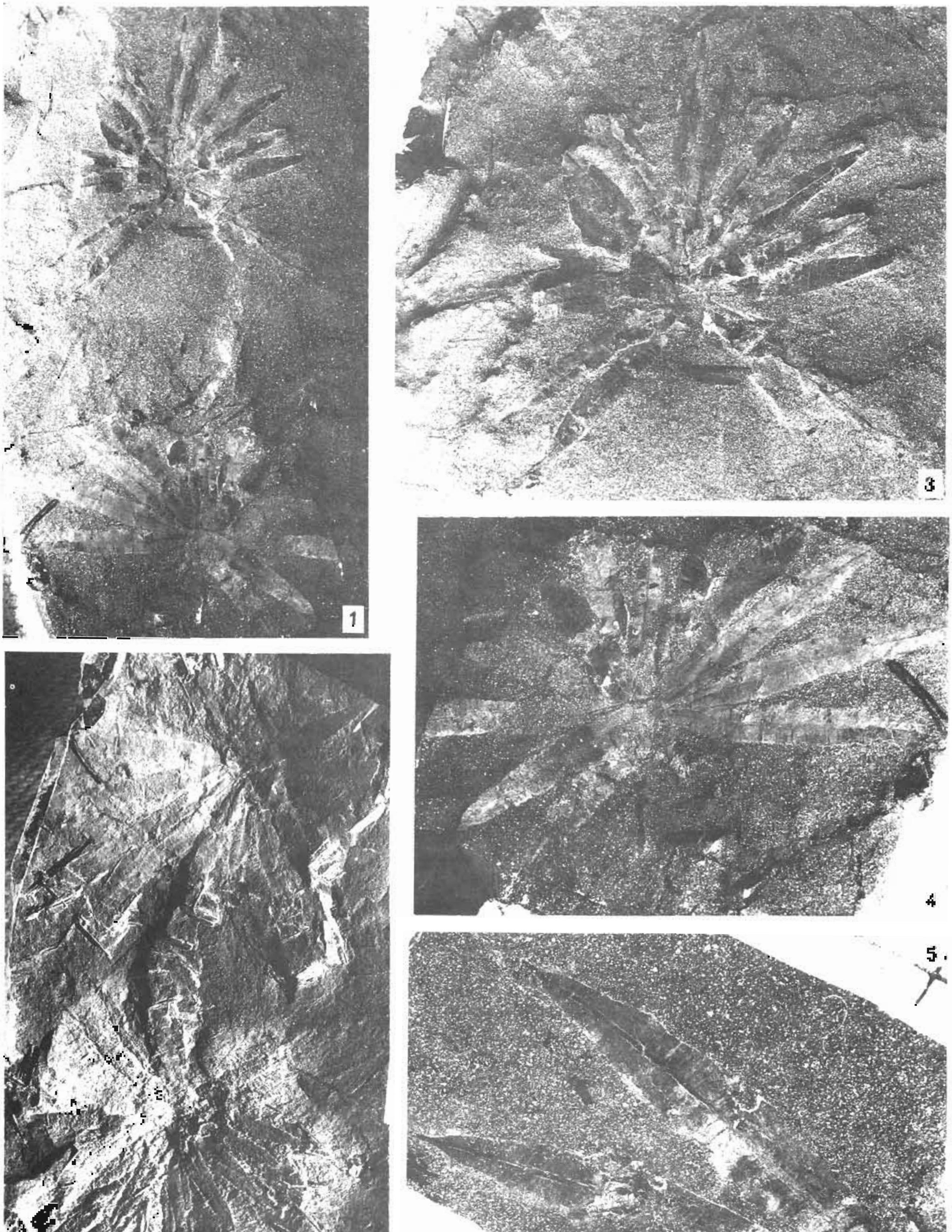

PLATE 1

Pant & Nautiyal (1967, pl. 10, fig. 5; pl. 11, fig. 10; specimen nos. 13524, 13602, *Palaeontographica* **B121**: 1-22).

Diagnosis—Verticillate whorls comprising more than 13-14, linear lanceolate leaves, more crowded in one half and overlapping each other; leaf base connate; leaf length 2.8 to 3 cm, width 3.5 mm around middle [illegible]. Midvein prominent from base to apex, depressed for three-fourths of leaf length but becomes swollen near acuminate apex and protrudes for about 1 mm [illegible]. Leaf lamina entire along the margins and flat or inflexed upwards on both sides of the midvein.

Holotype—Specimen no. BSIP 35904. Upper Permian, Raniganj Formation, Nega Seam, Damara Colliery, East Raniganj Coalfield, India.

REMARKS

The newly established genus *Bengalia* approaches very close to the articulate genera *Raniganjia*, *Lelstotheca* and to some extent to *Lobatannularia*. As compared to *Raniganjia* the number of leaves in *Bengalia* is much less and they are free from each other up to the node at least. *Raniganjia* shows 50-80 leaves united for most part of their length to form almost flat or saucer shaped sheaths (Feistmantel, 1881; Srivastava, 1954; Rigby, 1962; Pant & Nautiyal, 1967). Pant and Nautiyal (1967) reputed *Lelstotheca* to *Raniganjia* on the basis of analogy with leaf sheaths of modern *Equisetum* in which the number of leaves is reported to vary according to the position on the axis. They further implied that *Bengalia* type leaf sheaths illustrated by them rather represent a developmental stage or these sheaths became torn along the commissures during fossilization.

However, they have not put forth any convincing evidence or argument in support of such an implication. Whorls with few free leaves and whorls with numerous united leaves have so far not been found to occur on the same foliage shoot. Although the size of the leaves may vary, yet the number of segments will remain the same in a leaf sheath during development. Tearing of leaves along the commissures during fossilization should not be difficult to decipher; some of the segments will still remain united atleast near the base.

The genus *Lelstotheca* has smaller leaves widest at the base where they unite in the form of a disc and overlap in alternate verticils (Surange & Prakash, 1962) or may apparently be free up to the base (Maithy & Mandal, 1978). The genus *Bengalia* has larger leaves, widest near middle of the lamina but are free up to the base. Due to characteristic overlap the leaves seem to arise at different levels. The leaves show a prominent margin which protrudes as a distinct mucro unlike *Lelstotheca robusta*.

The true nature of transversely placed structures or wrinkles on the leaf lamina is not known as yet and hence it is premature to ascribe any taxonomic significance to this particular feature. It is reported from taxa as different as Gondwanan *Phyllotheca* [illegible], Angaran *Tschernovia* and Euramerican *Asterophyllites*.

Inspite of having verticils resembling those of most extinct and extant articulates, the exact botanical affinities of *Bengalia* yet remain enigmatic due to lack of knowledge about its leaf attachment, the axis and the nodal disc. The arrangement of leaves in somewhat close spirals as indicated by their characteristic overlapping may suggest its exclusion from articulatae but the general look of the specimen is that of an equisetaceous sphenopsid.

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Canarium palaeoluzonicum, a new fossil wood from the Neogene of Kerala with remarks on the nomenclature of fossil woods of Burseraceae

Nilamber Awasthi & Rashmi Srivastava

Awasthi, Nilamber & Srivastava, Rashmi 1989. *Canarium palaeoluzonicum*, a new fossil wood from the Neogene of Kerala with remarks on the nomenclature of fossil woods of Burseraceae. *Palaeobotanist* **37**(2) : 173-179.

A carbonised wood is described from the Neogene sediments (Varkala beds) of Varkala Coast, Kerala. It shows close resemblance with the wood of a Philippine species of *Canarium*, *C. luzonicum* of Burseraceae, particularly in having 1-2 horizontal gum canals in multiseriate rays. The carbonised wood is named as *Canarium palaeoluzonicum* sp. nov. Its presence along with some other Malaysian elements in the Neogene sediments of Kerala Coast suggests a phytogeographic link of the Indian subcontinent with southeast Asia during the Miocene-Pliocene. The problem of nomenclature of fossil woods of Burseraceae is also discussed.

Key-words—Xylotomy, Carbonised wood, Burseraceae, Varkala beds, Miocene-Pliocene (India).

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सारॉंश

केरल के पश्चनूतन कल्प से एक नवीन अश्मित काष्ठ–कैनेरियम पेलियोलुज़ोनिकम् तथा बर्सेरेसी कुल की काष्ठाश्मों की नामपद्धति पर टिप्पणियाँ

नीलाम्बर अवस्थी एवं रश्मि श्रीवास्तव

केरल में वरकला तट के पश्चनूतन अवसादों (वरकला संस्तरों) से एक कार्बनी काष्ठ वर्णित की गई है। इस काष्ठ में बहुपंक्तिक किरणों में एक से दो तक अनुप्रस्थ गोंद-नाल विद्यमान हैं तथा यह **कैनेरियम** की एक फिलीपीन जाति–**कै० लुज़ोनिकम्** से घनिष्ठ समानता व्यक्त करती है। इस कार्बनी काष्ठ को **कै० पेलियोलुज़ोनिकम्** नव जाति से नामाँकित किया गया है। केरल तट के पश्चनूतन कालीन अवसादों में अन्य मलेशियाई तत्वों के साथ-साथ इस वर्गक की उपस्थिति से मध्यनूतन-अतिनूतन काल में भारतीय उपमहाद्वीप का दक्षिण-पूर्व एशिया से पादप-भौगोलिक सम्बन्ध व्यक्त होता है। इसी शोध-पत्र में बर्सेरेसी कुल की अश्मित काष्ठों की नामपद्धति की समस्या पर भी विवेचना की गई है।

THE Neogene sediments in Kerala, exposed at several places along the western coast, abound in carbonised woods generally associated with clays and lignites. A number of such fossil woods have been described by Awasthi and Ahuja (1982) and Awasthi and Panjwani (1984) from the Varkala cliff section and Payangadi Super Clay Mine. They show close similarity with the woods of the extant genera *Calophyllum, Diospyros, Dryobalanops, Gluta, Gonystylus, Leea* and *Terminalia*. It is interesting to note that two of these genera, *Dryobalanops* and *Gonystylus* are now extinct in India and occur in the evergreen forests of Malaysia. To further explore this interesting aspect of phytogeographical distribution, we have taken up an extensive study of the carbonised woods of the Kerala-Lakshadweep Basin to build up the Neogene flora of this region. One more carbonised wood from Varkala showing close resemblance with that of *Canarium luzonicum* is described here in detail.

DESCRIPTION

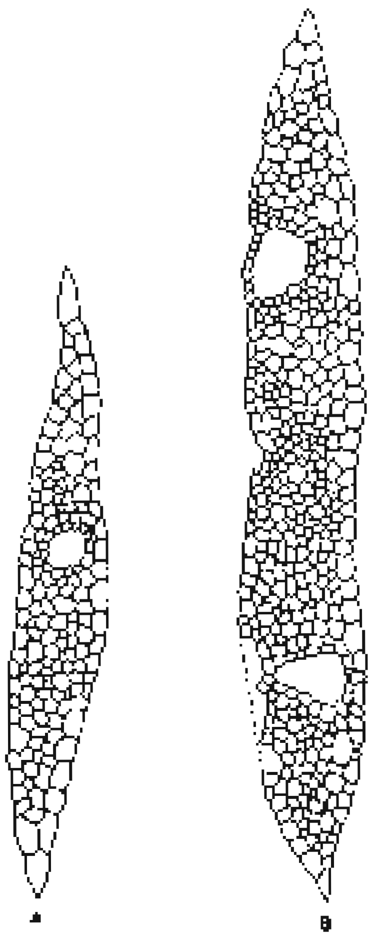
Family—Burseraceae

Genus—*Canarium* Linn.

Canarium palaeoluzonicum sp. nov.

Pl. 1, figs 1-4, 6, 8; Text-figs 1, 2

Wood diffuse-porous. *Growth rings* not seen.



Text-figure 1—A, Multiseriate ray with one radial gum canal × 80. **B,** Multiseriate ray with two radial gum canals × 80.

Vessels small to medium, t.d. 50-170 µm, r.d. 60-210 µm, solitary and in radial multiples of 2-3, solitary vessels circular to oval, multiple vessels flattened at the places of contact, 11-18 vessels per sq mm; tyloses present; vessel-members 320-480 µm in length with truncate ends; perforations simple; inter-vessel pits alternate, angular, 8-10 µm in diameter with linear apertures (Pl. 1, fig. 4). *Parenchyma* scanty, a few cells associated with vessels (Pl. 1, fig. 2), rarely forming uniseriate sheath around vessels. *Rays* fine to broad, 1-7 (mostly 3-4) seriate; uniseriate rays frequent; ray tissue heterogeneous; rays heterocellular consisting of procumbent cells and 1-2 or sometimes more marginal rows of upright cells at both the ends, up to 30 cells high; broad rays usually consisting of 1-2 radial gum ducts, fusiform, up to 40 cells high; cells crystalliferous; upright cells 48 µm in tangential height, 32 µm in radial length, procumbent cells 20 µm in tangential height, 64 µm in radial length. *Fibres* aligned in radial rows, 20-25 µm in diameter, semilibriform, moderately thick-walled, septate. *Gum canals* radial, 1-2, occurring in multiseriate rays (Pl. 1, figs 6-8; Text-figs 1, 3), about 48-56 µm in diameter.

Affinities — Such important anatomical features as heavily tylosed small to medium-sized vessels with inter-vessel pits having linear apertures, scanty paratracheal parenchyma, 1-7 (mostly 3-4) seriate xylem rays consisting of 1-2 gum canals in some multiseriate rays and septate fibres strongly suggest the affinity of the carbonised wood with the family Burseraceae.

Although the presence of radial gum canals in rays does suggest its affinities with some of the woods of Anacardiaceae, the absence of characteristic features of this family such as usually large amount of parenchyma, lenticular apertures of inter-vessel pits and the fibres being mostly non-septate (except in a few genera such as *Lannea*, *Odina*, *Spondias*) easily rules out this possibility.

All the available literature on the xylotomy of Burseraceae (Moseley, 1965; Desch, 1957; Henderson, 1953; Kribs, 1958; Metcalfe & Chalk, 1950; Miles, 1978; Moll & Janssonius, 1906; Pearson & Brown, 1932; Normand, 1960) and critical examination of thin sections of the woods of several

PLATE 1

Canarium palaeoluzonicum sp. nov.

1. Cross-section showing nature and distribution of vessels × 35. Slide no. BSIP 36231 I.
2. Cross-section magnified to show vessels and scanty paratracheal parenchyma × 80. Slide no. BSIP 36231 I.
3. Radial longitudinal section showing heterocellular ray × 80. Slide no. BSIP 36231 III.
4. Intervessel pits showing linear apertures × 700. Slide no. BSIP 36231 IV.

Canarium luzonicum (Bl.) A. Gray

5. Tangential longitudinal section showing multiseriate rays with single radial gum canals × 80. Slide no. BSIP Xylarium (Dispersed 1711).

Canarium palaeoluzonicum sp. nov.

6. Tangential longitudinal section showing similar radial gum canals in the multiseriate rays as in *Canarium luzonicum* shown in fig. 5 × 80. Slide no. BSIP 36231 II.

Canarium [illegible]

7. Tangential longitudinal section showing multiseriate ray with two radial gum canals × 80. Slide no. BSIP Xylarium (Dispersed 1711).

Canarium palaeoluzonicum sp. nov.

9. Tangential longitudinal section showing multiseriate ray with two radial gum canals as in *Canarium* [illegible] shown in fig. 7 × 80. Slide no. BSIP 36231 II.

burseraceous genera and species clearly indicate that this family is homogeneous in wood structure. Consequently, it is usually not possible to differentiate its members on the basis of wood anatomy except in some rare cases where some uncommon and characteristic features are noticeable. The Varkala carbonised wood has all the usual anatomical characters of Burseraceae including

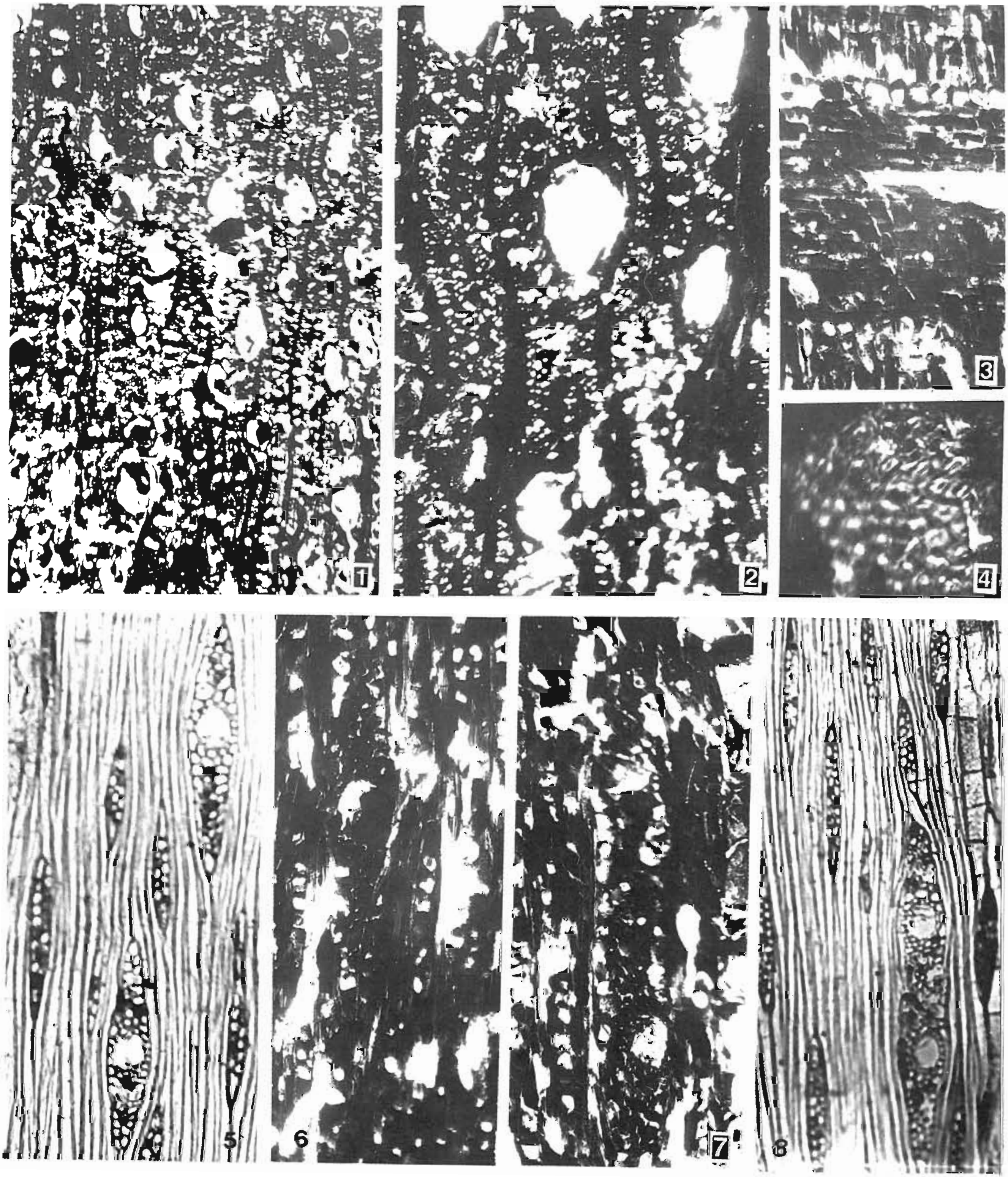


PLATE 1

one horizontal gum canal in its multiseriate rays. Some of these rays possess two gum canals, which is a unique feature so far found only in the modern wood of *C. luzonicum* (Bl.) A. Gray. Except uniseriate rays which are crystalliferous and more frequent, our carbonised wood and the wood of *C. luzonicum* are very similar in all the structural details such as shape, size and frequency of vessels, amount of vasicentric parenchyma, height of xylem rays and the frequency of multiseriate rays with 1-2 horizontal gum canals.

Eight fossil woods, referred so far to Burseraceae, are known from the different Tertiary localities of the world. Their important features are furnished below in a comparative form.

Table 1

NAME OF SPECIES	GROWTH RINGS	VESSELS	PAREN-CHYMA	XYLEM RAYS	GUM CANAL	FIBRES	LOCALITY AND AGE
Boswellioxylon indicum Dayal 1964	Absent	Small to medium, sometimes large, t.d. 60-180 µm, r.d. 75-210 µm, solitary and in multiples of 2-4	Paratracheal scanty, occurring as few cells around some of the vessels	1-6 (mostly 2-4) seriate, heterocellular, uniseriate less frequent, upright cells non-crystalliferous	Present	Thick-walled	Kota, Chhindwara District, M.P., India; Early Tertiary
Burseroxylon preserratum Prakash & Tripathi 1975; Bande & Prakash, 1983	Indistinct	Small to large, t.d. 80-200 µm, r.d. 150-280 µm, solitary and in radial multiples of 2-4, 12-10 per sq mm, tylosed, pits 8-10 µm	Paratracheal, scanty to 1-2 (mostly 1) celled vasicentric sheath	1-4 (mostly 2-3) seriate, heterocellular, crystalliferous	Absent	Non fibri-form, septate	Near Hailakandi, Assam (Mio-Pliocene); Mandla District, M.P., India (Early Tertiary)
Burseroxylon garugoides Lakhanpal, Prakash & Awasthi 1981	Indistinct	Mostly large to very large, sometimes medium, t.d. 105-345 µm, r.d. 75-420 µm, solitary and in radial multiples of 2-4, 5-13 vessels per sq mm, tylosed, pits 8-12 µm	Paratracheal scanty to narrow vasicentric, forming 1-2 celled sheath around vessels	1-5 (mostly 2-4) seriate, heterocellular, 6-26 cells in height, crystalliferous	Absent	Thick-walled septate	Deomali, Arunachal Pradesh, India; Miocene-Pliocene
Canarioxylon ceskobudejovicense Prakash, Březinová & Awasthi 1974	Indistinct	Large to medium or small, t.d. up to 225 µm, r.d. up to 280 µm, solitary and in radial multiples of 2-5, tylosed, pits 8-12 µm	Paratracheal scanty, a few cells associated with vessels	1-4 (mostly 2-3) seriate, heterocellular, ray cells occasionally crystalliferous	Absent	Semi fibri-form, septate	Bohemia, Czechoslovakia; Oligocene
C. indicum Ghosh & Roy 1978	Absent	Small to moderately large, t.d. 135-250 µm, solitary and in radial multiples of 2-5, tylosed, pits large	Paratracheal, scanty, forming narrow vasicentric sheath	1-5 (mostly 2-3) seriate, heterocellular	Absent	Thick-walled septate	Birbhum, West Bengal, India; Miocene-Pliocene

Contd.

C. shahpuraensis Trivedi & Srivastava 1985	Absent	Small to large, t.d. 75-250 μm, r.d. 75-295 μm, mostly solitary and in radial multiples of 2-4 with a tendency to an oblique pattern, 12-25 per sq mm	Paratracheal, scanty, 1-2 celled sheath around vessels	1-4 (mostly 2-3) seriate, heterocellular	Absent	Non-libriform to semilibriform, septate	Near Mandla, M.P., India; Early Tertiary
Sumatroxylon molli (Kräusel) Den Berger Syn. *Anacardioxylon* molli (Krausel) DenBerger, 1923	Present	Small to medium, t.d. 50-155 μm, r.d. 80-200 μm, solitary and in 2-3, 8-12 per sq mm	Paratracheal, scanty, 1-2 celled sheath around vessels	4-6 seriate, heterocellular, marginal cells crystalliferous	Present	Septate	Sumatra; Miocene
**Wood of Burseraceae	Present	Small to medium, mostly solitary and in multiples of 2-3, 5-6 per sq mm	Paratracheal, scanty	1-4 seriate, heterocellular	Absent	Septate	Mohgaonkalan, M.P., India; Early Tertiary

**This wood does not seem to belong to the family Burseraceae.

From a perusal of the anatomical features of all these fossil woods it is evident that the present carbonised wood is quite different in having 1-2 gui canals in multiseriate rays though in other characters it shows general resemblance with them. Hence, it is being assigned to a new species. In view of its close similarity with the wood of *Canarium luzonicum*, this fossil wood is being named as *Canarium palaeoluzonicum* sp. nov.

Holotype—Specimen no. BSIP 36221; Varkala Coast, Kerala; Mio-Pliocene.

DISCUSSION

Distribution of living and fossil Burseraceae

The family Burseraceae consists of 16 genera and about 500 species distributed in the tropical region (Willis, 1973, p. 172). In India, this family is represented by 5 genera, viz., *Boswellia, Canarium, Commiphora, Garuga* and *Protium*. The genus *Canarium* includes 75 species, widely distributed in the tropical regions of India, Sri Lanka, Mascarene, Madagascar, Africa, North Australia, Micronesia, Malaysia to Fiji Island. About 7 species are known to occur in India, mostly in the tropical evergreen forests of Assam, Kerala and Andaman Island. *Canarium luzonicum*, whose wood structure shows closest resemblance with the present carbonised wood from Varkala, commonly occurs in the Philippine Islands (Mindoro, Luzon, Alabat Island, Masbate, Tiaco Island and Bohol) in primary rain forest at low and medium altitudes (Leenhouts, 1955, p. 270).

Besides petrified woods described from the Tertiary of Czechoslovakia, Sumatra and India fossil leaves and fruits of Burseraceae are also known from several parts of the world. They are (i) *Burserites venezuelana* Berry 1921 from the Tertiary of Betijoque, Trujillo, Venezuela, (ii) *B. fayettensis* Berry 1924 from the Eocene of Fayette Sandstone, Louisiana, U.S.A., (iii) *Bursera inequilateralis* (Lesquereux) Mac Ginitie 1969 from the Eocene of Green River Formation, North-western Colorado and Wyoming, U.S.A., (iv) *Canarium californicum* Mac Ginitie 1941 from the Middle Eocene of Central Siera Nevada, Western U.S.A., and (v) *Icica pichileufuana* Berry 1938 from the Tertiary of Rio Pichileufu, Argentina. Leaflets comparable to *Canarium californicum* Mac Ginitie have been described by Tanai (1970) as *Canarium ezoanum* from the Kushiro Coalfield (Oligocene), Hokkaido, Japan. From the Upper Miocene of Western Honshu, Japan, Kakawa (1955) reported seeds of *Canarium album*.

A number of fruits and a carpel have been described in the Eocene flora of southern England by Reid and Chandler (1933), Chandler (1961, 1962, 1963) and Collinson (1983) under the genera *Tricarpellites, Protocommiphora, Bursericarpum* and *Palaeobursera*.

From the above records it is evident that the family Burseraceae was quite well established during Early Tertiary in the warmer regions of the old as well as the new world. In India, fossil plants of

Burseraceae have been found in Early Eocene, Deccan Intertrappean beds as well as in various Neogene deposits of southern and eastern parts of the country. The occurrence of *Canarium* [illegible] a species closely resembling *C.* [illegible] of [illegible], is of interesting phytogeographical significance. Its presence along with some other Malaysian elements viz. *Dipterocarpus*, [illegible] and [illegible] in the Neogene of Kerala Coast suggests a phytogeographical link of the Indian subcontinent with South-east Asia during Mio-Pliocene.

Nomenclature of the fossil woods of Burseraceae

So far the known remains of fossil woods of Burseraceae have been described under four genera, viz., (i) *Bursericoxylon* Dayal [illegible], (ii) *Canarioxylon* Prakash & Tripathi (1975), (iii) *Garugoxylon* Prakash *et al.* [illegible] and (iv) *Burseraceoxylon* Den Berger [illegible]. Of these the first three are instituted for the fossil woods supposedly resembling those of *Boswellia*, *Canarium* and *Garuga* respectively, and the fourth is for those showing affinities with Burseraceous woods in general. As already pointed out, the generic and specific determination among the woods of Burseraceae is not possible because of the homogeneity of their anatomical characters. Unfortunately, while creating the fossil genera their respective authors did not give due consideration to this fact bearing separate generic names. These fossil genera are supposed to be distinct from each other in their anatomical features. Now critically looking at the diagnoses of these four genera one can hardly find any difference between them. Thus these different generic names hardly any [illegible] differentiation are unwarranted. In this context, Lakhanpal and Prakash (1980) have suggested that in cases where it is not possible to identify the fossil woods beyond the family level, new genera should be created by adding -oxylon to the name of the family. Accordingly, we propose that all the fossil woods of Burseraceae listed in Table 1 should be placed under the form genus *Burseraceoxylon*. This genus would include all fossil woods of Burseraceae which possess the following general anatomical features of the family.

Wood diffuse-porous; *growth rings* distinct or indistinct. *Vessels* small to large, solitary as well as in radial multiples of 2-5 [illegible]; perforation simple; intervessel pits large. Parenchyma [illegible] *Parenchyma* paratracheal, scanty or [illegible] vasicentric. *Rays* fine to broad, [illegible] heterogeneous, [illegible] with [illegible] radial gum canals, cells often crystalliferous. *Fibres* [illegible] septate [illegible] septate. [illegible] *Canarium* present or absent. When present, [illegible] multiseriate rays.

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Fresh water diatoms from Kua Tal, district Nainital, Kumaon Himalaya, Uttar Pradesh

Asha Khandelwal & H. P. Gupta

Khandelwal, Asha & Gupta, H. P. 1989. Fresh water diatoms from Kua Tal, district Nainital, Kumaon Himalaya, Uttar Pradesh. *Palaeobotanist* **37**(2) : 180-184.

The present communication embodies the results of diatom analysis from lacustrine sediments of Kua Tal, district Naini Tal, Uttar Pradesh. The study reveals the predominance of Pennales which are represented by about one and a half dozen taxa. However, Centrales are infrequent and represented by two taxa only.

Key-words—Palynology, Diatoms, Pennales, Centrales, Kumaon Himalaya (India).

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सारॅांश

कुमायुँ हिमालय (उत्तर प्रदेश) में नैनीताल जनपद में स्थित कुआ ताल से अलवणी डाऐंटम

आशा खण्डेलवाल एवं हरीपाल गुप्ता

नैनीताल जनपद (उत्तर प्रदेश) में कुआ ताल के सरोवरी अवसादों से उपलब्ध डाऐंटम विश्लेषण के आँकड़े इस शोध-पत्र में प्रस्तुत किये गये हैं। इस अध्ययन से पिन्नेल्स की पूर्वबहुल्यता व्यक्त होती है जिनके कि इस समुच्चय में लगभग डेढ़ दर्जन वर्गक विद्यमान हैं। सॅन्ट्रेल्स अपेक्षाकृत लगातार नहीं मिलते तथा इनके केवल दो वर्गक विद्यमान हैं।

KUA TAL, remnant of an ancient lake, is situated about half a kilometer west of Bhim Tal on way to Naini Tal at an altitude of about 4,500′ between 79°40′ N longitude and 29°28′E latitude. Most of the peripheral area of Kua Tal has been dried up and brought under paddy cultivation leaving aside a shallow depresssion enabling to bore through about 0.75 m deep. As revealed by radiometric dates for other lake sediments in the basin, it is presumed that sediments of Kua Tal in question are not older than 400-500 yrs B.P.

In the Bhim Tal-Naukuchia Tal Basin it is a closed lake and has no outlet. According to Mathur (1955), the lakes in the basin originated due to differential earth movements. Wadia (1957) opined that lakes in Kumaon Himalaya are the result of landslides whereas, Raina (1965) advocated that they are of glacial origin.

Pollen analytical investigations have been carried out earlier in Naukuchia Tal (Vishnu-Mittre, Gupta & Robert, 1967), Naukuchia Tal and Bhim Tal (Gupta, 1973, 1977), Sat Tal (Gupta & Khandelwal, 1982) to reconstruct the palaeovegetation and palaeoenvironment. In addition to this, the occurrence of *Sphagnum papillosum* has also been recorded (Vishnu-Mittre & Gupta, 1971). Hitherto, no work on diatoms has been done. Obviously, this report is perhaps the first one to deal with the results of diatom analysis.

MATERIAL AND METHOD

Material from Kua Tal was procured by using Hiller's peat-auger with 50 cm long chamber. Samples from 0.75 m deep profile were collected in chronological sequence at an interval of 10 cm each. Only four samples, viz., 1, 3, 5 and 7 were subjected for diatom analysis.

The diatoms were extracted by boiling the matrix in concentrated H_2So_4. The treated sample was washed with distilled water several times and permanent slides were made in Styrax. In order to work out the diatom assemblage in each sample their relative abundance was calculated (Andrews, 1966). Each taxon is, thus, rated as follows :

Dominant—Numerous specimens in all fields of view.

Abundant—At least one specimen in all fields of view.

Common—At least one specimen in many fields of view.

Frequent—Several specimens on entire slide.

Rare—One or two specimens on entire slide.

SYSTEMATIC DESCRIPTION

All the four samples have yielded diatoms without much variation in number and diversity and hence their relative abundance has been considered collectively (Table 1).

Table 1—Showing relative distribution of diatom from Kua Tal, district Nainital

Diatom taxa	Dominant	Abundant	Common	Frequent	Rare
Caloneis silicula	+	+		+	+
Cocconeis placentula		+	+	+	
Cyclotella meneghiniana		+	+		+
Cymbella aspera	+	+	+		
Epithemia zebra		+	+		+
Eunotia pectinalis var. *neglecta*		+	+	+	+
Gomphonema acuminatum	+	+	+		
G. constrictum var. *capitatum*				+	
G. montanum var. *acuminatum*		+	+	+	+
Gyrosigma acuminatum	+	+	+	+	+
Hantzschia amphioxys				+	+
Melosira sp.	+	+		+	+
Navicula cuspidata var. *ambigua*		+		+	+
N. graciloides				+	+
N. rhynchocephala var. *amphiceros*	+			+	+
Nitzschia obtusa var. *parallela*	+	+		+	+
Pinnularia sp.	+	+	+		+
Surirella ovata	+	+	+		
Synedra ulna	+		+		+

Caloneis silicula (Ehr.) Cl.
Pl. 1, fig. 16

Valve 70-74 μm long, 13-15 μm broad, linear, margins slightly triundulate, distinctly tumid in the middle; ends broadly cuneate and slightly constricted, produced and rounded, raphe thin and straight, striae 9-10 in 10 μm, fine, slightly radial.

Cocconeis placentula Ehr.
Pl. 1, figs 9, 10

Valve 24-30 μm long, 15-20 μm broad, elliptical. Valve with raphe : raphe thin and straight, axial area very narrow, central area small roundish, striae 24-27 in 10 μm, finely punctate, marginal rim distinct. Valve with pseudo raphe: pseudoraphe narrow, linear, striae 23-25 in 10 μm, interrupted by several closely placed longitudinal, somewhat wavy hyaline bands.

Cyclotella meneghiniana Kutz.

Valve discoidal 11-19 in μm diameter, margin striated, striae wedge shaped, 9-11 in 10 μm.

Cymbella aspera (Ehr.) Cl.
Pl. 1, figs 5, 6

Valve 35-60 μm long, 9-11 μm broad, asymmetrical, dorsal side strongly convex and ventral side slightly convex, ends constricted and produced rounded, raphe thick, eccentric, axial area very narrow, central area slightly widened; striae 10-12 in 10 μm, radial, distinctly punctate and somewhat closer at the ends.

Epithemia zebra (Ehr.) Kutz.

Valve 30-35 μm long, 10-12 μm broad, arcuate, slightly recurved at the ends; dorsal line arcuate; striae distinctly punctate, 9-10 in 10 μm.

Eunotia pectinalis (Kutz.) Rabh. var. *neglecta* Grun.
Pl. 1, fig. 15

Valve 50-55 μm long, 9-10 μm broad, slightly curved with rounded ends; striae distinct, 11-12 in 10 μm.

Gomphonema acuminatum Ehr.
Pl. 1, fig. 7

Valve 56-57 μm long, 9-10 μm broad, wedge shaped with broad head pole and strongly narrowed foot pole, striae punctate and radial transapically, 10-13 in 10 μm.

Gomphonema constrictum Ehr. var. *capitatum* (Ehr.) Grun. in van Heurck
Pl. 1, fig. 13

Valve 40-44 μm long, 10-13 μm broad, club shaped with flat rounded head pole and more strongly narrowed foot pole, no transapical constriction, raphe thick and straight, striae fine, distinctly punctate and radial transapically, 11-12 in 10 μm.

Gomphonema montanum Schum. var. *acuminata* (Perag. M. & Herib. in Herib.) Mayer
Pl. 1, fig. 19

Valve 48-50 μm long, 16-18 μm broad, lanceolate, club shaped with broad bluntly rounded head pore are somewhat narrowed, hyaline; striae distinctly punctate, 7-9 in 10 µm.

Gyrosigma acuminatum (Kütz.) Rabh.
Pl. 1, fig. 2

Valve 80-100 µm long, 10-15 µm broad, S-shaped, lanceolate, gradually narrowed from the middle towards bluntly rounded apices; raphe correspondingly shaped; transverse and longitudinal striae faint.

Hantzschia amphioxys (Ehr.) Grun. in Cl. & Grun.
Pl. 1, fig. 11

Valve 40-80 µm long, 7-9 µm broad, slightly arcuate, linear; dorsal side slightly convex, ventral side slightly concave with slight depression in the middle; ends constricted, bluntly rostrate to weakly capitate; keel eccentric, keel punctae coarse, two of the middle punctae widely set, 7-10 in 10 µm; striae distinct, 14-18 in 10 µm.

Melosira sp.

Valve 25 µm long, 11 µm broad, cylindrical, generally found in girdle view.

Navicula cuspidata (Kütz.) Kütz. var. *ambigua* (Ehr.) Cl.
Pl. 1, fig. 17

Valve 85-98 µm long, 21-25 µm broad, elliptic-lanceolate with rostrate ends; raphe thin and straight; striae transverse, almost perpendicular to the middle line, 18-20 in 10 µm.

Navicula gracilioides Mayer
Pl. 1, fig. 8

Valve 55-60 µm long, 8-10 µm broad, lanceolate; raphe thin and straight; striae 12-14 in 10 µm.

Navicula rhynchocephala Kütz. var. *amphiceros* (Kütz.) Grun. in Van Heurck
Pl. 1, fig. 12

Valve 45-55 µm long, 11-13 µm broad, broadly lanceolate with constricted, produced, feebly capitate ends; raphe thin and straight; striae radial in the middle and convergent at the ends, 12-14 in 10 µm.

Neidium oblique-striatum (A. S.) Cleve var. *parallela* Gonzalves & Gandhi
Pl. 1, fig. 14

Valve 55-75 µm long, 13-16 µm broad, linear-elliptical with constricted, broadly produced, subcapitate ends; raphe thin and straight; striae fine, 15, hyaline longitudinal furrows near the margins; striae 22-26 in 10 µm.

Pinnularia gibba Ehr.
Pl. 1, figs 3, 4

Valve 60-75 µm long, 10-12 µm broad, linear-lanceolate with slight but noticeably convex sides and slightly swollen rounded ends; raphe thin and straight with central pore unilaterally bent and curved terminal fissures; axial area narrowly lanceolate, central area large rhombic, orbicular reaching to the sides; striae radial in the middle and convergent at the ends, 11-12 in 10 µm.

Surirella ovata Kütz.
Pl. 1, fig. 18

Valve 45-65 µm long, 18-30 µm broad, heteropolar, long-ovate with broadly rounded apex and gradually narrowed, well marked cuneate base; costae 3-5 in 10 µm; striae indistinct.

Synedra ulna (Nitz.) Ehr.
Pl. 1, fig. 1

Valve 90-200 µm long, 5-7 µm broad, linear, slender, strongly constricted and produced truncated ends; striae strong and uniformly placed, 9-10 in 10 µm.

DISCUSSION AND CONCLUSION

The diatom analysis of lacustrine sediments from Khurpa Tal profile in Naini Tal District, Kumaon Himalaya has revealed the overall dominance of Pennales both quantity-wise and quality-wise. However, Centrales are insignificantly found and represented only by two taxa, viz. *Cyclotella* and *Melosira*. Nineteen types of diatoms have been studied. On the basis of their relative abundance in

PLATE 1 →

1. *Synedra ulna* × 1000.
2. *Gyrosigma acuminatum* × 850.
3, 4. *Pinnularia gibba* × [illegible].
5, 6. *Cymbella aspera* × 1000.
7. *Gomphonema acuminatum* × 1000.
8. *Navicula gracilioides* × 1000.
9, 10. [illegible] × 850.
11. *Hantzschia amphioxys* × 850.
12. *Navicula rhynchocephala* var. *amphiceros* × 1000.
13. [illegible] var. *capitata* × 1000.
14. *Neidium oblique-striatum* var. *parallela* × 1000.
15. [illegible] × 800.
16. [illegible] × 850.
17. *Navicula cuspidata* var. *ambigua* × 800.
18. *Surirella ovata* × 1000.
19. [illegible] × 800.

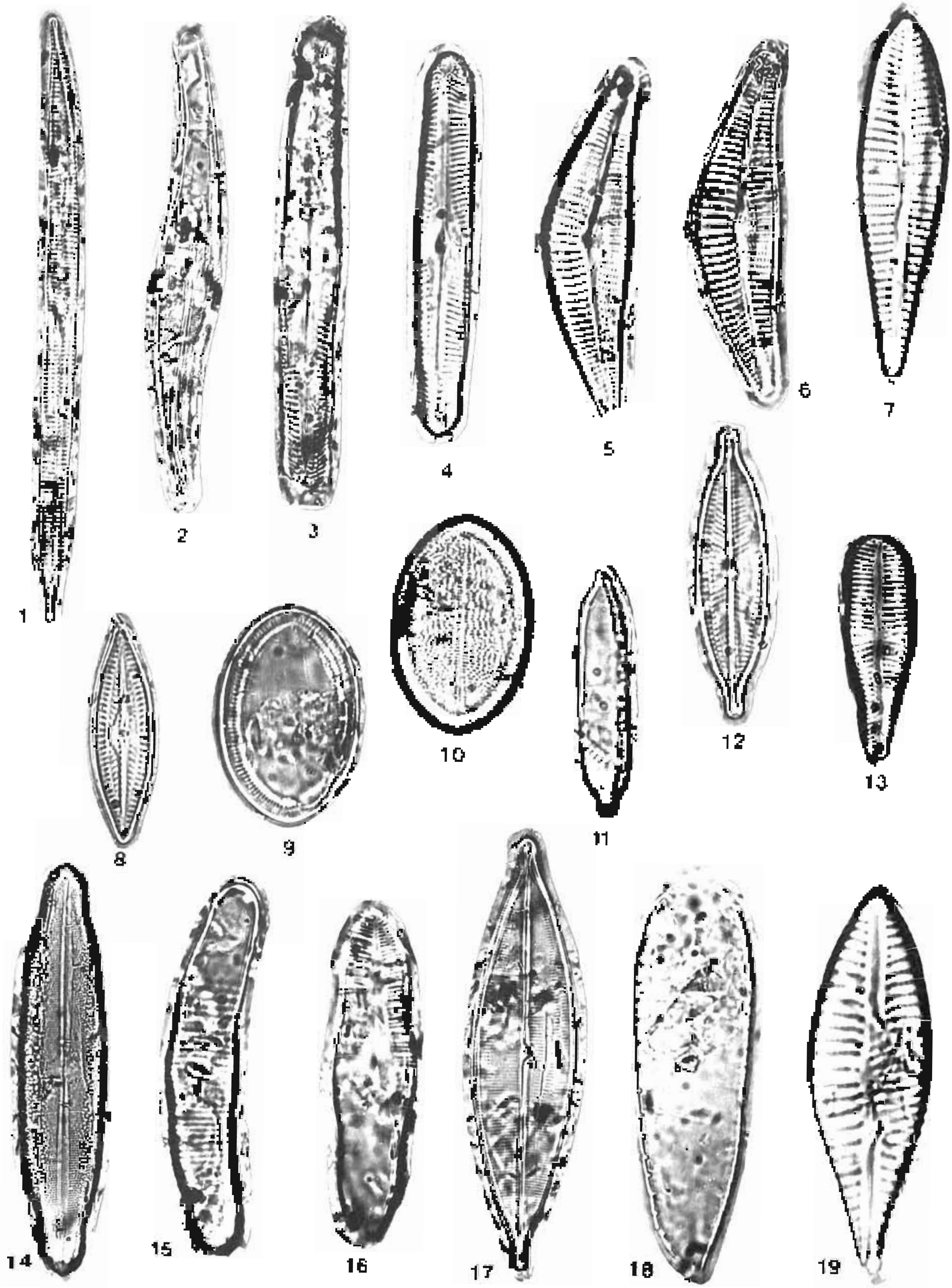

PLATE 1

the assemblage, five quantitative categories have been made to include individual taxa. Dominant taxa are *Cymbella* [illegible] and *Synedra ulna*; abundant taxa are *Cocconeis placentula*, *Navicula cuspidata* var. *ambigua*, *Neidium* [illegible] var. [illegible] and *Cymbella* sp.; common taxa are [illegible] *Surirella ovata*, *Eunotia pectinalis* var. [illegible], *Gomphonema constrictum* var. *capitatum*, *Gomphonema* [illegible] var. [illegible], *Hantzschia amphioxys*, *Melosira* sp., *Navicula* [illegible] and *Navicula cryptocephala* var. [illegible] are frequent. The rare forms are *Caloneis silicula*, [illegible] and *Epithemia zebra*.

The preservation of diatoms, irrespective of the type, is perfect and this may be accounted as due to the continual prevailing environment during the course of their development. The diatom assemblage in the sediments is also suggestive of fresh water depositional environment.

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Occurrence of a solenoporoid alga in the Deccan Intertrappean beds of Mohgaonkalan, Chhindwara District, Madhya Pradesh

R. C. Mehrotra

Mehrotra, R. C. 1989. Occurrence of a solenoporoid alga in the Deccan Intertrappean beds of Mohgaonkalan, Chhindwara District, Madhya Pradesh. *Palaeobotanist* **37**(2) : 185-188.

A fossil red alga *Solenopora* Dybowski of Solenoporaceae has been described for the first time from the Deccan Intertrappean beds of Mohgaonkalan, Chhindwara District, Madhya Pradesh. Its occurrence supports the presence of marine conditions in this area during the Early Tertiary period

Key-words—*Solenopora*, Red alga, Deccan Intertrappean beds, Early Tertiary (India).

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साराँश

छिंदवाड़ा जनपद (मध्य प्रदेश) में मोहगाँव कलाँ की दक्खिन अन्तर्ट्रैपी संस्तरों में एक सोलीनोपोरॉयडी शैवाल की उपस्थिति

राकेश चन्द्र मेहरोत्रा

छिंदवाड़ा जनपद (मध्य प्रदेश) में मोहगाँव कलाँ की दक्खिन अन्तर्ट्रैपी संस्तरो से सोलीनोपोरेसी कुल का **सोलीनोपोरा** डाइबास्की नामक एक लाल शैवाल पहली बार वर्णित किया गया है। इस शैवाल की उपस्थिति से प्रारम्भिक तृतीयक कल्प में इस क्षेत्र में समुद्री परिस्थितियों के होने की पुष्टी होती है।

A NUMBER of algal remains, known from various Deccan Intertrappean localities, have been listed by Prakash (1960) and Lakhanpal (1973). Majority of them belongs to Charophytes. In addition, some more algal forms in the last decade have been described by several other workers (Shivarudrappa, 1972a, 1972b, 1977, 1981; Bhatia & Mannikeri, 1976; Biradar, 1977; Bande, Prakash & Bonde, 1981; Barlinge & Paradkar, 1982; Marathe, Barlinge & Paradkar, 1984; Mishra & Maithy, 1984; Trivedi, Bajpai & Trivedi, 1985). Two of them, *Distichoplax raoi* Varma and *Peyssonnelia antiqua* Johnson, are important. The former is indicative of Palaeocene-Eocene age while the later indicates marine conditions.

SYSTEMATIC DESCRIPTION

Family—Solenoporaceae

Genus—*Solenopora* Dybowski 1878

Solenopora sp.
Pl. 1, figs 1-6

Material—While studying the slides of the chert material, several algal specimens almost similar in structure but differing in thickness of the thallus were discovered. Three of them have been selected for the present study.

Description—The thalli are nodular and crustose ranging in thickness from 170-1200 μm (Pl. 1, figs 1, 2, 6). The thallus is undifferentiated into hypothallus and perithallus and in vertical section the tissue is occurring as vertical files or tubules of more or less rectangular cells, with prominent vertical walls (Pl. 1, figs 3, 4, 6). Sometimes, cells appear variously shaped due to poor preservation. Their size varies from about 17-120 μm in length and 13-95 μm in width. Septa are present in the tubules but at irregular intervals (Pl. 1, fig. 5). Reproductive structures are absent.

DISCUSSION

The family Solenoporaceae is an extinct group of fossil marine organisms, nodular or encrusting in habit and formed internally of closely packed

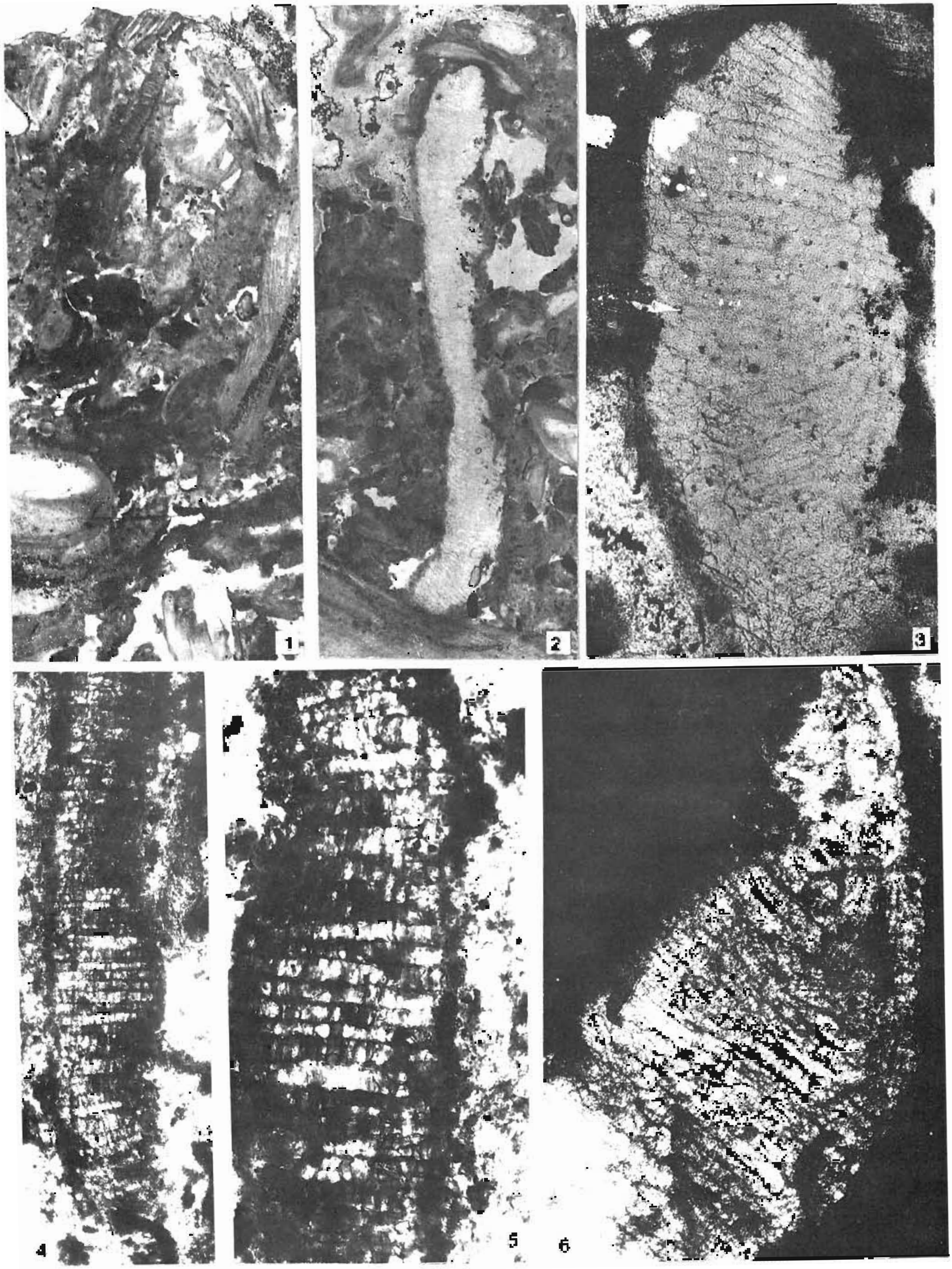

PLATE 1

radially or vertically divergent rows of elongate cells. Occasionally referred to various animal groups, they are usually interpreted as calcareous algae related to the living Corallinaceae, which resemble closely in growth form and general internal structure. The thallus is undifferentiated into hypothallus and perithallus and the cell diameters are almost always greater than those of corallines. In Solenoporaceae, though the vegetative tissue is similar to that of the corallines, reproductive structures are relatively uncommon and almost [illegible] and absent except in *Neosolenopora* (Elliott, 1965). The family consists of four valid taxa, viz., *Solenomeris*, *Parachaetetes*, *Solenopora* and *Neosolenopora*. They are classified almost entirely on the types of cellular tissue. The important aspects considered are: (1) presence or absence of filament partitions (horizontal cell walls), (ii) regular or irregular spacing of partitions and (iii) shape of cells in cross section (Wray, 1977).

Solenomeris is characterized by a marked irregularity in its cellular tissue. In vertical section individual cells appear to be irregular in shape, because cell partitions alternate in position with adjacent filaments giving a zig-zag effect. In *Parachaetetes* filaments have well defined regularly spaced partitions between cells, which give the tissue a grid-like pattern in vertical section (Wray, 1977). There is no regularity in the occurrence of septum in the fossil, therefore, it may be either *Solenopora* or *Neosolenopora*. As the reproductive structures are very common in the latter, a Mesozoic genus, the present fossil has been kept under the genus *Solenopora* which was instituted by Dybowski in 1878 (Elliott, 1973; Flügel, 1977).

The geologic range of Solenoporaceae is from Lower Palaeozoic to mid Tertiary (Elliott, 1973). So far five species of *Solenopora* have been described from various parts of the country. These are *Solenopora hookeri* from the Upper Permian of North Sikkim (Oakley, 1944), *S. jurassica* as well as *S. [illegible]* from the Jurassic of Cullygoody Limestone, Trichinopolly, Tamil Nadu (Narayana Rao, 1943), and *S. [illegible]* and *S. [illegible]* from the Cretaceous of Trichinopoly, Tamil Nadu (Rama Rao & Gowda, 1953). However, due to poor preservation the present fossil could not be compared with the above species. Therefore, under the circumstances, it has been described as *Solenopora* sp. Besides, *Parachaetetes asvapatii* from the Niniyur (Upper Cretaceous) Group of Trichinopoly, Tamil Nadu (Rama Rao & Pia, 1936), *Solenomeris* cf. *douvillei* from the Lower Eocene Hakri rocks of Nammal Gorge, Salt Range (Narayana Rao & Varma, 1953) and *Neosolenopora andamanensis* from the Miocene of Limestone Hut Bay Formation of Andaman Island (Gururaja, 1977) are also known from India.

The ecological distribution of the family Solenoporaceae is largely comparable to some modern coralline algae. The sedimentological record indicates that it occupied open-marine environments of normal salinities (Wray, 1977). The family Solenoporaceae has been described here for the first time from the Deccan Intertrappean beds of India. Based on the presence of fossils of coastal plants like *Cocos*, *Nypa* and *Sonneratia* from the Deccan Intertrappean beds of Mohgaonkalan in Chhindwara District, Lakhanpal (1970, 1974) has already envisaged the presence of an arm of Tethys sea in Central India during this period. A few years later, Bande, Prakash and Bonde (1981) described two marine red algal forms, *Peyssonnelia* and *Distichoplax*, from the same beds. Thus obviously the present finding of *Solenopora* of Solenoporaceae from the same beds gives further support to this theory.

Specimen—No. BSIP 35940, Mohgaonkalan, Deccan Intertrappean beds, Early Tertiary.

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PLATE 1

1. *Solenopora* sp.—Section of thallus in low power showing nature of thallus, × [illegible]. Slide no. BSIP 35940-I.
2. *Solenopora* sp.—Section of thallus in low power showing nature of another thallus, × [illegible]. Slide no. BSIP 35940-II.
3. *Solenopora* sp.—Vertical section of thallus (shown in fig. 1) in high power showing nature of filaments, × [illegible]. Slide no. BSIP 35940-I.
4. *Solenopora* sp.—Vertical section of thallus (shown in fig. 2) in high power showing nature of filaments, × [illegible]. Slide no. BSIP 35940-II.
5. *Solenopora* sp.—Magnified view of thallus (fig. [illegible]) showing nature of cells, × [illegible]. Slide no. BSIP 35940-I.
6. *Solenopora* sp.—Vertical section of another thallus in high power showing nature of filaments, × [illegible]. Slide no. BSIP 35940-III.

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Austroannularia gen. nov., an asymmetrical Permian sphenopsid leaf whorl from Gondwanaland

J. F. Rigby

Rigby, J. F. 1989. *Austroannularia gen.* nov., an asymmetrical Permian sphenopsid leaf whorl from Gondwanaland. *Palaeobotanist* **37**(2) : 189-191

Austroannularia gen. nov. is proposed for species of morphologically asymmetrical sphenopsid leaf whorls similar to those included in the Cathaysian genus *Lobatannularia*, but lacking the strongly bilobate character of the latter genus. The two species, *A. subcircularis* sp. nov. from eastern Australia and *A. qubuensis* from southern Tibet (Xizang) occur in Permian non-marine strata containing typical Gondwana species in the absence of Cathaysian species.

Key-words—Megafossils, Sphenopsida, *Austroannularia, Lobatannlaria,* Permian (Australia).

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सारॉश

गोंडवानाभूमि से एक असममित परमी युगीन स्फ़ीनॉप्सिड पर्ण-चक्र · ऑस्ट्रोऐंन्नुलेरिया नव प्रजाति

जे. एफ. रिगबी

आकारिकीय दृष्टि से असममित स्फ़ीनॉप्सिड पर्ण-चक्रों की जातियों के लिए जो कि कैथेसीय प्रजाति **लोबैटेन्नुलेरिया** प्रजाति के सदृश है तथा जिनमें द्विपालीय लक्षण अनुपस्थित हैं, के **ऑस्ट्रोऐंन्नुलेरिया** नव प्रजाति प्रस्तावित की गई है। कैथेसीय जातियो की अनुपस्थिति मे सामान्य गोंडवाना जातियों से युक्त परमी असमुद्री स्तरों में पूर्वी ऑस्ट्रेलिया मे **ऑ० सबसर्कुलेरिस** नव जाति एवं दक्षिणी तिब्बत मे **ऑ. क्यूबुयेन्सिस** नामक दो जातियां पाई जाती हैं।

SYSTEMATIC DESCRIPTION

Order—Sphenophyllales *incertae sedis*

Austroannularia gen. nov.

Diagnosis—Annularia-like to *Lobatannularia*-like leaf whorls, asymmetrical, with shorter leaves on one side of the whorl giving the whorl a reniform outline; longer leaves tending also to be broader, fused for half their length or less, shorter leaves fused to a lesser extent if at all; leaves linear-obovate, with an acute apex, possible mucronate, leaf tips or apical regions tending to droop or be lax, sheath probably absent.

Type species—*Austroannularia subcircularis* sp. nov.

Origin of name—Austro, derived from *Austrinus*, Latin for "southern". Annularia, a well known Late Palaeozoic sphenopsid genus, derived from *anulus*, Latin for "ring".

Comparison—The genus *Austroannularia* may be distinguished from the genus *Lobatannularia* by the lack of strong bilobation of the leaf whorl. In *Lobatannularia* there are usually two diametrically opposite pronounced gaps in the whorl whereas *Austroannularia* has one or two regions where the leaves are shorter, but there is no break. Both genera are restricted to the Permian.

Austroannularia subcircularis sp. nov.

1916 *Annularia stellata* (?), Walkom, pp. 233-234, pl. 25.

Description—Leaf whorls almost circular, longest leaf about 1½ times longer than shortest leaf, longest leaf about 16 mm, broken leaves may be longer. There is no apparent foreshortening on the slab bearing the type specimen where whorls are spaced at slightly less than the length of the longest

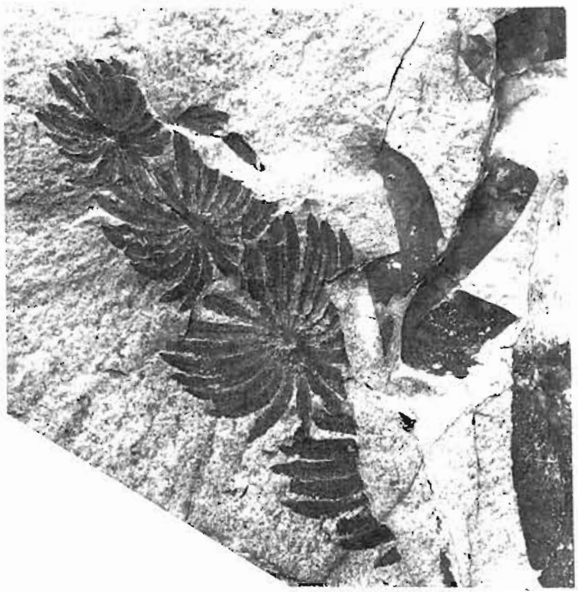

Figure 1—*Austroannularia subcircularis* gen. et sp. nov. Holotype, Specimen no. F15/985/5, Queensland Museum. Natural size.

leaf. The leaves are lax, but this character may have been exaggerated during burial. The individual leaves vary in breadth in proportion to their length in approximately the ratio of five times as long as broad. This implies that the whorl has not been foreshortened during compression, but the asymmetry is a natural phenomenon. Longer leaves are fused for up to one third of their length, shorter leaves appear free. Shorter leaves are restricted to one side of the whorl, although on some whorls leaves may be slightly shorter on the opposite side of the whorl (Figure 1).

Holotype—F/15/985/5, housed by the Queensland Museum.

Locality—The only information available was given by Walkom (1916), no additional data are available—12.8 km from Dunedoo, New South Wales (approximately 260 km NW of Sydney). The horizon is unknown.

The colour and texture of the host rock, a pinkish mudstone, suggests it may be from the same or a similar horizon to that from which Holmes (1974, 1977) has described elements of the Glossopteris Flora from the Late Permian Illawarra Coal Measures near Dunedoo. Some *Glossopteris* leaves on the slab bearing the holotype are virtually indistinguishable from an unnamed species of *Glossopteris* from the Rangal Coal Measures, Middle Permian of Queensland, which is probably very slightly older than the Illawarra Coal Measures. The possibility exists that the holotype was found in the Illawarra Coal Measures.

Other Specimens—Two specimens from the Nychum Volcanics near Chillagoe, north Queensland, identified by White (1972) as *Annularia* belong in *Austroannularia subcircularis*. These specimens, F24235 and F24240, form part of the collections of the Bureau of Mineral Resources, Canberra.

Age—Bailey *et al.* (1982) give an age of 270 Ma for the Nychum Volcanics which is in the region of the Sakmarian-Artinskian boundary. If the holotype was collected from the Illawarra Coal Measures then the range of *A. subcircularis* may extend over the middle half or longer of Permian time. Early Permian-(?)Late Permian is the only reasonable age range.

Comparison—This species cannot belong in *Annularia*, as thought by Walkom (1916), and by White (1972), as it has an asymmetrical leaf whorl, whereas *Annularia* has leaves of uniform length throughout the whorl. Even when whorls lying across the bedding planes are compressed, they still retain bilateral symmetry both on the major and minor elliptical axes as demonstrated for *Raniganjia* by Pant and Nautiyal (1967). Although *Austroannularia* whorls are bilaterally symmetrical, this symmetry is only along a single plane corresponding to the minor axis.

Austroannularia qubuensis (Hsü 1976) comb. nov.

1976 *Raniganjia qubuensis* Hsü: 324, pl. 1, figs 4-7, text-fig. 1.

1983 *Stellotheca qubuensis* (Hsü) Li: 130-131.

Diagnosis—See Hsü, 1976, p. 324.

Type Specimen—Specimen 4783a, Institute of Botany, Academia Sinica, Xiangshan, Beijing, figured by Hsü, 1976, pl. 1, fig. 4, is selected as lectotype.

Locality—From the Qubu Formation, at Dingjie, Horizon 3, fig. 1-12, p. 40, of Wang *et al.*, 1984 in southern Tibet (Xizang). Wang *et al.* (1984), date this horizon as Early Permian, as does Li (1983). Li *et al.* (in press) have listed all identifiable species in the flora from Dingjie.

Comparison—The leaves of this species are much narrower than in *A. subcircularis*, being approximately ten times as long as broad, decidedly linear instead of linear-obovate, and with an acute apex. The leaf tips are more erect with no apparent drooping, a feature that separates *A. qubuensis* from *Lobatannularia* as well as from *A. subcircularis*.

A POSSIBLE SOUTH AFRICAN SPECIES

Kovács-Endródy (1986) identified some leaf whorls from the Late Permian Ecca Group of South

Africa in a new species [illegible] *lanceolata*, comparing it with *C.* [illegible] from central Siberia. She was probably unaware that this latter species has disappeared into synonymy and is now included within *Annularia neuburgiana* (Radczenko) Neuburg 1964. This genus was suggested by Neuburg (1960) and later validated (Neuburg, 1964). *A. neuburgiana* also includes *Lobatannularia* [illegible] Zalessky & Chirkova 1938 as a synonym. The figured specimens of [illegible] *lanceolata* are symmetrical whorls but as leaves are fused basally they cannot be accommodated in either *Annularia* or the Gondwana genus *Stellotheca*. Future investigations may show the need to expand the definition of [illegible] to include specimens of "C." *lanceolata*. Her figured specimens demonstrate the South African species cannot be accommodated in either of the species of [illegible] discussed in this paper.

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Leaf cuticles from the Neyveli lignite of India

C. L. Verma, Nirmala Upadhyay & R. K. Srivastava

Verma, C. L., Upadhyay, Nirmala & Srivastava, R. K. 1989. Leaf cuticles from the Neyveli lignite of India. *Palaeobotanist* 37(2): 192-198.

The paper reports some leaf remains from the Neyveli lignite of South Arcot District, Tamil Nadu. The fossil cuticles resemble cuticles of extant *Shorea* (Dipterocarpaceae), *Cryptostegia* (Asclepiadaceae) and *Lagerstroemia* (Lythraceae).

Key-words—Morphology, Cuticles, *Shorea*, *Cryptostegia*, *Lagerstroemia*, Neyveli, Lignite, Tertiary.

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सारांश

भारत के नेवेली लिग्नाइट से अश्मित पर्णों की उपत्वचा

छेदी लाल वर्मा, निर्मला उपाध्याय एवं राजेन्द्र कुमार श्रीवास्तव

तमिल नाडु में दक्षिण आरकॉट जनपद के नेवेली लिग्नाइट से कुछ पर्णों के अवशेष वर्णित किये गये हैं। अश्मित उपत्वचायें शोरिया (डिप्टेरोकार्पेसी), क्रिप्टोस्टीजिया (एस्क्लीपियेडेसी) एवं लेगरस्ट्रोमिया (लाइथ्रेसी) नामक वर्तमान वंशों की उपत्वचाओं से समानता प्रदर्शित करती हैं।

NEYVELI lignite has been extensively worked out for the microfossils, such as spores and pollen grains, fungal and algal remains and wood tissues. The megafossils, however, have received little attention, though they are common in the lignite deposits (Singh & Mathew, 1951; Lakshmanan & Levey, 1956; Chatterjee & Bhattacharya, 1965; Ambwani, 1982; Awasthi, 1984).

The cuticles of these fossils have not received the attention they deserved. The only known reports are cuticles of Oleaceae (Jacob & Jacob, 1953), *Litsea* (Lauraceae, Srivastava, 1984) and *Phoenix* (Palmae, Upadhyay & Verma, 1986). Kulkarni and Phadtare (1980) and Dalvi and Kulkarni (1982) have reported few fossil cuticles from the Ratnagiri lignite, Maharashtra. In the present paper, leaf cuticles resembling *Shorea* (Dipterocarpaceae), *Cryptostegia* (Asclepiadaceae) and *Lagerstroemia* (Lythraceae) have been described.

MATERIAL AND METHODS

Some of the specimens contained well preserved leaves from which the cuticles were obtained by usual maceration method. They were mounted in canada balsam. The numerical data are based on an average of 20 random counts. The terminology as suggested by Dilcher (1974) has been adopted.

DESCRIPTION

Family—Dipterocarpaceae

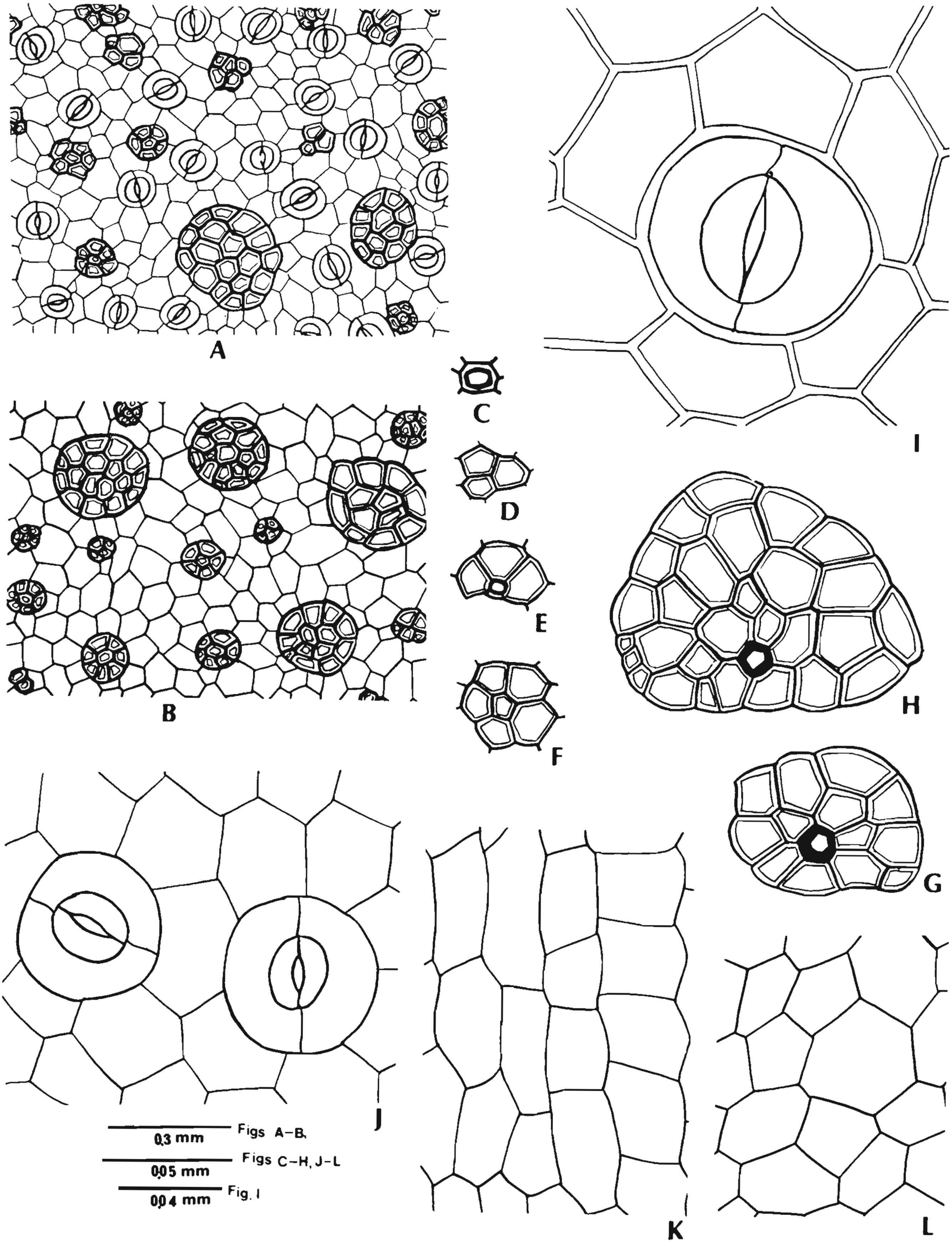
Genus—*Shorea* Roxb.

Fossil cuticle type 1

Pl. 1, figs 1-4; Text-fig. 1A-L

Description—Leaf hypostomatic; upper epidermal cells penta- to hexagonal, small, thick and smooth walled, elongated on the veins (Text-fig. 1

Text-figure 1—Fossil cuticle of *Shorea* sp. 1. **A**, Lower epidermis showing distribution of stomata and trichomes. **B**, Upper epidermis showing distribution of trichomes. **C-H**, Uni- to multicellular peltate trichomes. **I**, A stoma enlarged to show guard cells and subsidiary cells. **J**, An enlarged portion of lower epidermis showing stomata and epidermal cells. **K**, Cells overarching vein. **L**, Cells of the upper epidermis.



Text-figure 1

E, F); multicellular, rosette-like trichomes present all over the surface (Text-fig. 1B); smaller ones having only few cells, larger ones with 50 or more cells (Pl. 1, fig. 1; Text-fig. 1E, H).

Lower epidermal cells penta or hexagonal with slightly thickened walls, elongated round the trichomes, much elongated on the larger veins (Pl. 1, fig. 3); stomata irregularly distributed, round the peltate trichomes, paracytic; frequency 110-120/mm², size 20-30 × 25-35 µm (Text-fig. 1C, D); trichomes all over the surface similar to those occurring on the upper surface (Pl. 1, fig. 3; Text-fig. 1A).

Affinities with modern taxa—The important features of the fossil cuticle are: presence of peltate trichomes on both the surfaces, paracytic stomata and thick-walled, smooth epidermal cells.

Both paracytic stomata and peltate trichomes occur in 16 families of Angiosperms. However, the fossil cuticle comes closest to the cuticles of extant members of Dipterocarpaceae which have varied cuticular characters but genera like *Shorea* and *Vateria* have almost identical epidermal features. Both the genera have peltate trichomes which are distributed all over the foliar surface and paracytic stomata that are confined to the lower surface. Fossil cuticle shows maximum resemblance with *Shorea robusta* Gaertn. f. in structure and distribution of stomata, epidermal cells and structure and distribution of trichomes. A comparative account has been given in Table 1. However, in the fossil, frequency of stomata is slightly low, size is bigger and trichomes are much crowded and have varied number of cells.

Present day distribution—Of the 12 species of the genus *Shorea*, five are endemic to Sri Lanka, three are confined to Burma, two grow in south India and one in Assam. *S. robusta* (Sal) grows now-a-days in the foothills of Himalaya, south India and Orissa.

Family—Asclepiadaceae

Genus—*Cryptostegia* Br.

Fossil cuticle type 2

Pl. 1, figs 5-8; Text-fig. 2A-H

Description—Leaf hypostomatic; upper epidermal cells penta or hexagonal, small, smooth-walled (Pl. 1, fig. 6; Text-fig. 2B); marginal and veinal cells thickened (Text-fig. 2C); trichomes absent. Lower epidermal cells polygonal or elongated on the veins, smooth-walled, cells round the stomatal groups thick-walled (Text-fig. 2 D-F); stomata in groups, small, paracytic, bound by thick-walled cells; number of stomata in a group from 30 to 60, frequency 160-170/mm², size 20-26 × 15-20 µm (Pl. 1, figs 5, 8; Text-fig. 2A, D, G-H); trichomes absent.

Affinities with modern taxa—Amongst the important features such as paracytic stomata in groups bound by thick-walled cells and thick and smooth-walled epidermal cells, the fossil cuticle shows close affinity with the cuticle of modern *Cryptostegia grandiflora* R. Br. of Asclepiadaceae. Detailed comparison of the two is given in Table 1. In the fossil, frequency of the stomata is high and size smaller. In addition, the modern taxon has uniseriate hairs on the midrib but such hairs have not been observed in the fossil.

Present day distribution—Genus *Cryptostegia* is a native of Madagascar (Gamble, 1922). *Cryptostegia grandiflora*, the only species, is a large climbing shrub which is now cultivated in gardens or grows wild all over India.

Family—Lythraceae

Genus—*Lagerstroemia* Linn.

Fossil cuticle type 3

Pl. 1, figs 9-21; Text-fig. 2 I-M

Description—Leaf hypostomatic; upper epidermal cells penta to polygonal with slightly

PLATE 1

Fossil cuticle type 1

1. Upper epidermis of fossil showing epidermal cells and peltate trichomes. × 100.
2. Upper epidermis of *Shorea robusta* showing epidermal cells, veinal cells and peltate trichomes. × 100.
3. Lower epidermis of fossil showing paracytic type of stomata and peltate trichomes. × 250.
4. Lower epidermis of *S. robusta* showing paracytic stomata and peltate trichomes. × 250.

Fossil cuticle type 2

5. Lower epidermis of fossil showing distribution of stomata. × 100.
6. Upper epidermis of fossil showing marginal cells. × 250.
7. Lower epidermis of *C. grandiflora* showing paracytic stomata arranged in groups. × 250.
8. Lower epidermis of fossil showing paracytic stomata arranged in groups. × 250.

Fossil cuticle type 3

9. Lower epidermis of *Lagerstroemia* [illegible] showing anomocytic type of stomata. × 500.
10. Lower epidermis of fossil showing anomocytic stomata. × 500.
11. Upper epidermis of fossil showing cells. × 250.

sinuate walls (Text-fig. 2K), trichomes absent. Lower epidermal cells larger than the upper ones, penta-to polygonal walls, slightly sinuate, elongated and thick-walled on the larger veins (Pl 1, fig. 11, Text fig. 2J), stomata irregular, 3 to 6 cells apart, anomocytic, frequency 80-90/mm², size 40-50 × 26-33 μm (Pl 1, fig. 10; Text-fig. 2I, L), trichomes bases rounded on the midrib only (Text-fig. 2M).

Affinities with modern taxa—Fossil cuticle is characterised by the presence of anomocytic stomata

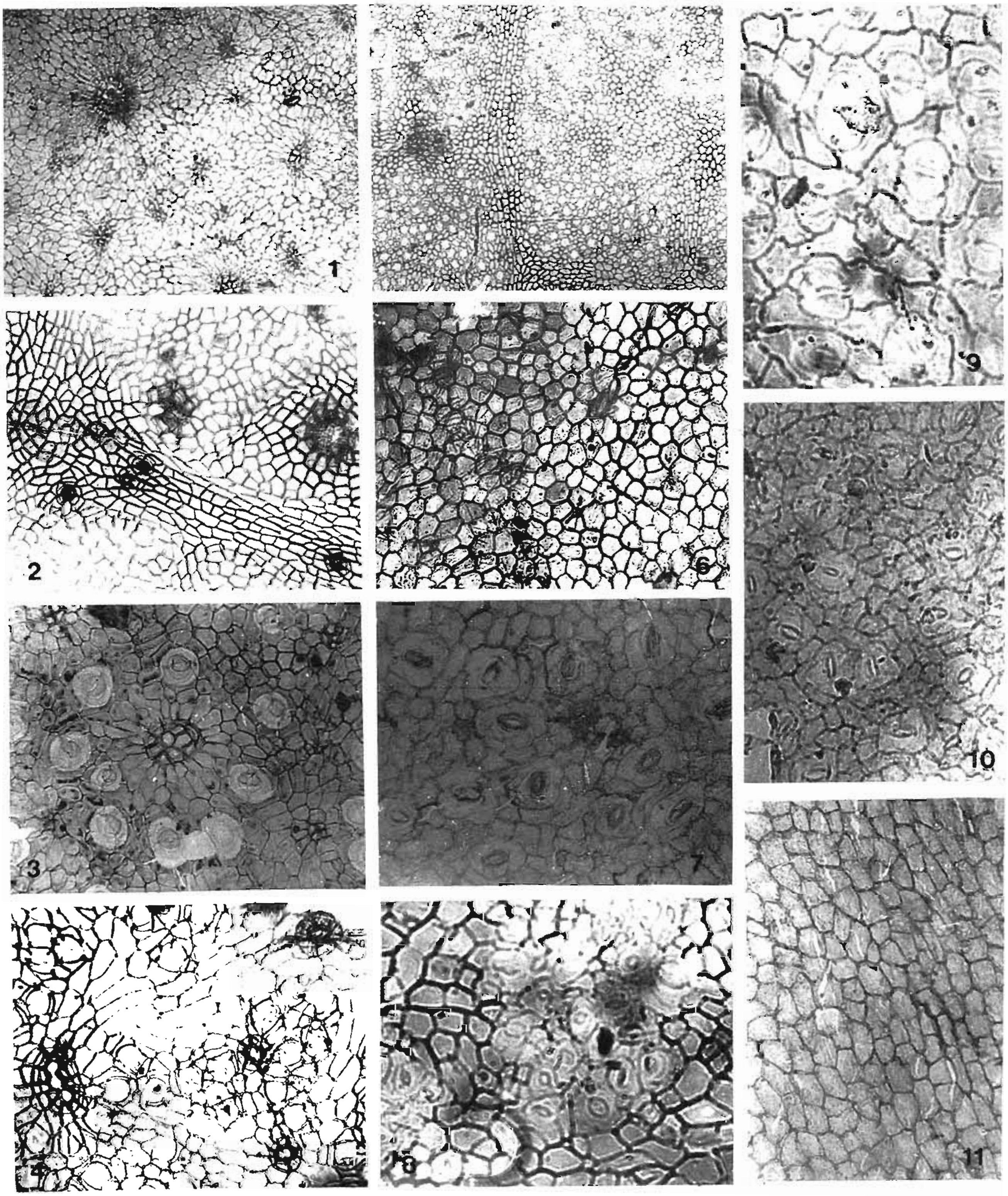
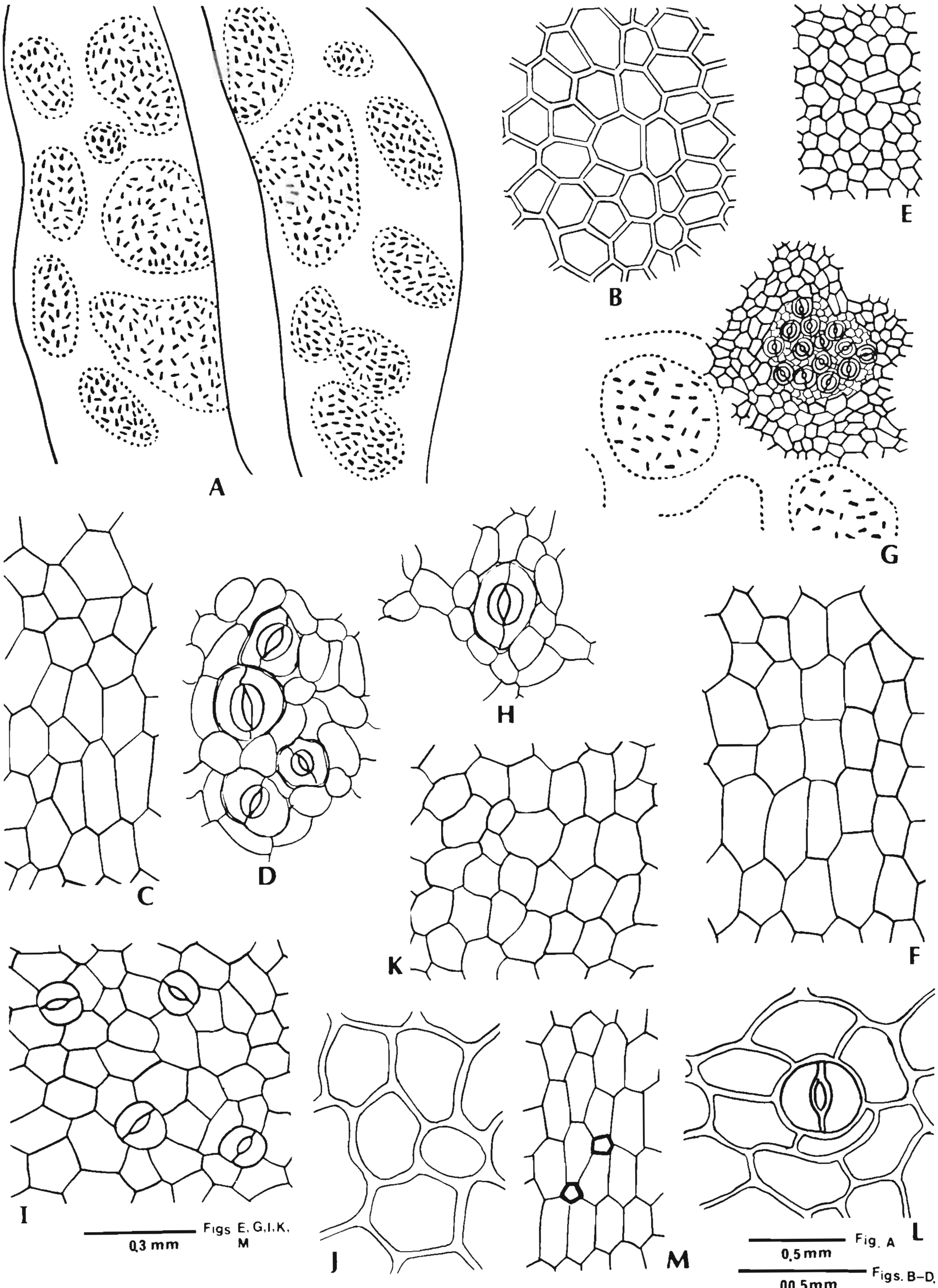


PLATE 1



Text-figure 2

Table 1

NAME OF SPECIES	LEAF	EPIDERMAL CELLS		STOMATA		FREQUENCY PER sq mm	SIZE IN µm	TRICHOMES
		UPPER	LOWER	DISTRIBUTION	TYPE			
Fossil cuticle 1	[illegible]	[illegible]	[illegible]	Irregular	[illegible]	[illegible]	[illegible]	[illegible]
Living [illegible]	Hypostomatic	[illegible]	[illegible]	Irregular all over the surface [illegible]	Paracytic	[illegible]	[illegible]	[illegible]
Fossil cuticle type 2	Hypostomatic	[illegible]	[illegible]	In groups between veins [illegible]	[illegible]	ca. 175	20.56 × 13.21	Not preserved
Living [illegible]	Hypostomatic	Pentagonal/hexagonal, small	Polygonal, thin walled, thick walled round stomata	In groups between veins	Paracytic	140-250	25.26 × 16.50	Trichome bases on the midrib
Fossil cuticle type 3	Hypostomatic	Angular to polygonal slightly sinuous walls	Polygonal sinuous walls	Irregular	Anomocytic	[illegible]	[illegible]	Trichome bases on the midrib region
Living *Lagerstroemia indica*	Hypostomatic	Pentagonal, sinuous walls	Polygonal sinuate walls	Irregular	Anomocytic	75-112	[illegible]	Trichome bases on the midrib

on the lower foliar surface and epidermal cells with slightly sinuate walls. It shows similarity with the cuticle of extant genus *Lagerstroemia indica* L. of the family Lythraceae.

Considerable variation is found in the epidermal features of Lythraceae with respect to the nature of trichomes (Metcalfe & Chalk, 1950). The genus *Lagerstroemia* has also varied types of trichomes. A detailed comparison is given in Table 1. In the fossil the frequency of stomata is low and size is bigger. On the midrib region of fossil cuticle a few hexagonal, thick walled areas have been observed and most probably they represent hair bases. There are no stomata on the upper epidermis.

Present day distribution — The genus *Lagerstroemia* with about 50 species is confined to the Old World (Pearson & Brown, 1932). Seven species, viz. *L. indica*, *L. parviflora*, *L. lanceolata*, *L. flos-reginae*, *L. hypoleuca*, *L. villosa* and *L. tomentosa* are found in India. *L. indica* with which the fossil cuticle resembles is a small deciduous tree indigenous to China. It is cultivated throughout India in the gardens (Gamble, 1922).

←

Text-figure 2 — Fossil cuticle of [illegible] type 2: **A**, A portion of cuticle showing distribution of stomata. **B**, Upper epidermal cells. **C**, Cells over the venal region. **D**, Stomata in groups between the small veinlets. **E**, Thick walled cells round the stomata. **F**, Cells of the midrib region. **G**, A portion of non-venal region enlarged to show the stomatal groups and **H**, A stomata enlarged to show the guard cells and subsidiary cells.

I-M, Fossil cuticle of *Lagerstroemia* type 3: **I**, Lower epidermis showing distribution of stomata and epidermal cells. **J**, Lower epidermal cells enlarged to show the sinuate walls. **K**, Upper epidermal cells. **L**, A stomata enlarged to show [illegible] and guard cells. **M**, Epidermal cells showing trichome bases.

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Palynostratigraphy of Lower Gondwana sediments in Godavari Graben, Andhra Pradesh, India

Suresh C. Srivastava & Neerja Jha

Srivastava, Suresh C. & Jha, Neerja 1986. Palynostratigraphy of Lower Gondwana sediments in Godavari Graben, Andhra Pradesh, India. *Palaeobotanist* **35**(2): 199-209.

The subsurface Lower Gondwana sediments of Ramagundam and Ramakrishnapuram areas of Godavari Graben, Andhra Pradesh comprise Talchir to Barren Measures formations present in two boreholes, viz., GBS-1 and GBS-2. The distribution of palynotaxa in time and space suggests the occurrence of six palynozones. Palynozone 1 is marked by the dominance of radial monosaccates chiefly *Parasaccites* representing the Talchir palynoflora. Palynozone 2 is characterised by the incoming of *Rhizomaspora* in addition to radial monosaccates representing Lower Karharbari palynoflora. Palynozone 3 is representative of Upper Karharbari and is marked by the dominance of radial monosaccates associated with non-striate disaccates. Palynozone 4—non-striate disaccates chiefly *Scheuringipollenites* attain the overall dominance representing the Lower Barakar palynoflora and incorporating the productive coal seams of the area. Palynozone 5—striate disaccate pollen chiefly *Faunipollenites* attaining overall dominance and representing the Upper Barakar palynoflora. Palynozone 6—characterised by the association of striate disaccate pollen and *Striasulcites* representing the youngest assemblage in the present investigation. These assemblages have been compared with known palynofloras. The existence of Karharbari and Barren Measures formations in Ramagundam and Ramakrishnapuram areas has been established with palynological evidence.

Key words—Palynostratigraphy, Karharbari Formation, Barren Measures Formation, Lower Gondwana, Permian, India.

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सारांश

आंध्र प्रदेश (भारत) में गोदावरी द्रोणिका के अधरि गोंडवाना अवसादों का परागाणुस्तरविज्ञान

सुरेश चन्द्र श्रीवास्तव एवं नीरजा झा

[illegible]

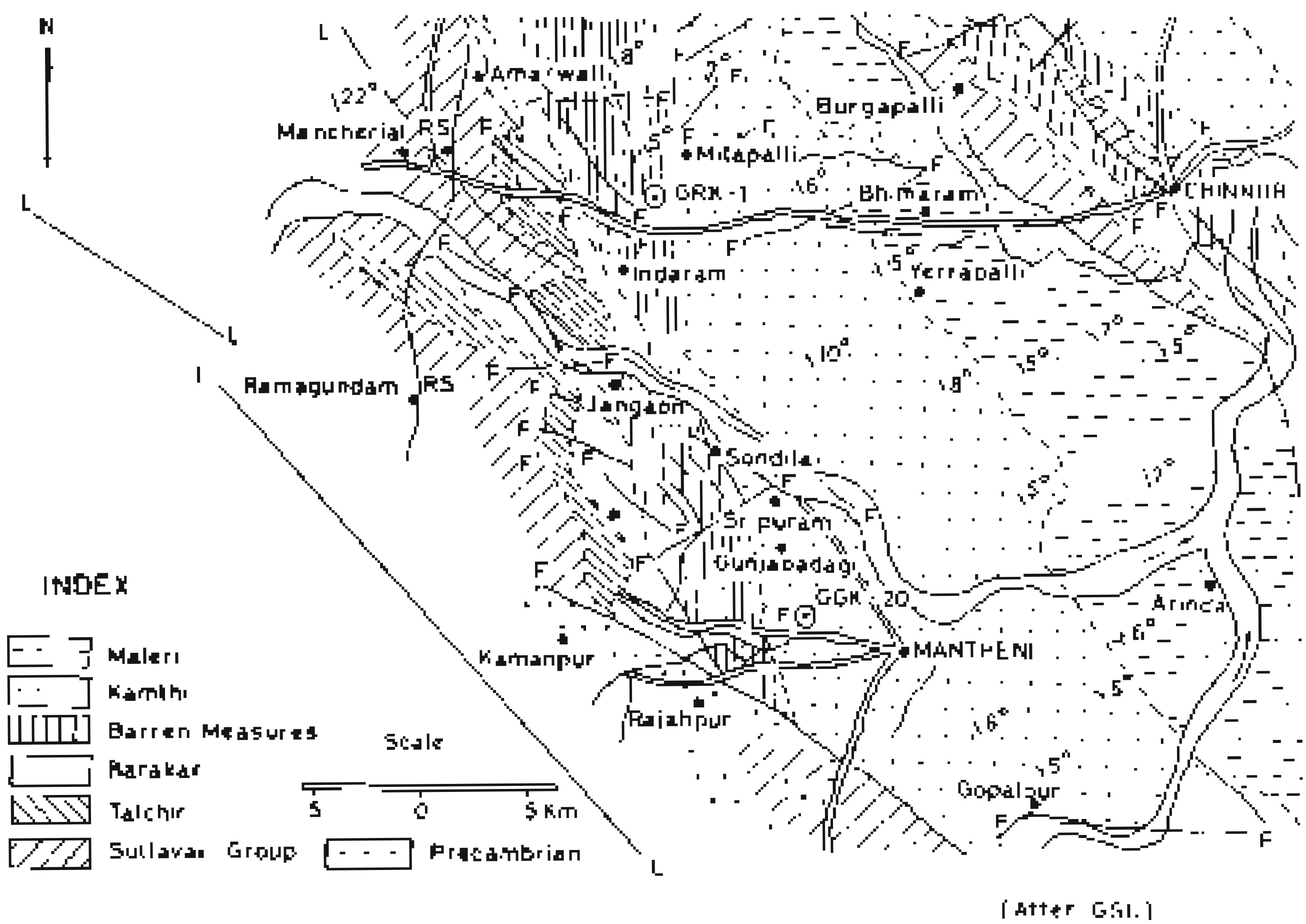
PALYNOLOGICAL studies of the Lower Gondwana sediments from many areas of the Peninsular India have been done during the last few years but in Godavari Valley coalfields it is rather meagre. Thiergart and Franz (1962) mentioned few taxa from the working coals in Kothagudem area. Ghosh (1968) described the distribution of miospore genera in Salarjung and Ross seams of Tandur area

Maz and Ramana Rao (1968) have made a preliminary study of Ramagundam coals. Tiwari and Maz (1971) again studied the working coals of Ramagundam area and described some new miospore genera. All these investigations available are incomplete as they are related to one or two coal seams only. Recently, Srivastava (1977) has described the sporae dispersae of working coal seams from a number of collieries in Godavari Valley and suggested their possible correlation on the basis of palynoflora. The present investigation has been carried out on subsurface sediments incorporating Talchir to Barren Measures formations from Ramagundam and Ramakrishnapuram areas in order to bring out the palynological succession hitherto unknown in these sediments. The bore core samples (bore hole GGK-20, GRK-1) investigated have been listed in Table 1 and 2 and the location of bore holes has been shown in Map 1.

GEOLOGICAL DETAILS OF THE AREA

Ramagundam is situated in Karimnagar District of Andhra Pradesh (Map 1). The oldest rocks in the area are Archaeans which are overlain by Pakhal limestones and shales and Sullavai sandstones. The lower Gondwana sediments overlie these rocks unconformably at different places. The basal most unit of the Lower Gondwana sequence, i.e. Talchir Formation, has been encountered in bore hole GGK-20, which was [illegible] through 29 m of the Talchir Formation which is characterised by coarse to medium grained greenish sandstone with pebbles of quartzite and [illegible]. This does not represent the complete thickness of the Talchir Formation as the bore hole has not reached the basement metamorphics. Hence, the total thickness of Talchir Formation is not represented in this bore hole.

The two overlying formations, i.e. Barakar and Barren Measures have been encountered in both the above bore holes. On the basis of lithological attributes, the Barakar Formation has been divided into two members. The Lower Member is characterised by the presence of coarse grained sandstone with lenses of conglomerates and is devoid of workable coal seams. The Upper Member consists of coarse grained sandstone with



Map 1— Geological map of the area showing location of bore holes.

subordinate shales and coal seams. In bore-hole GBK-1 the Barakar Formation has been delimited between 807.10-571.85 m while in bore-hole GGK-20 it has been delineated between 900.18-702.26 m.

A thick pile of sediments attributed to Barren Measures Formation has been marked above the Barakar Formation in bore-hole GGK-20 (702-200 m) and GBK-1 (571.85-108.30 m) which is lithologically characterised as medium to coarse-grained greenish grey and greyish white felspathic sandstone with grey to greyish-black shale and clay. The contact between the Barakar and Barren Measures is gradational and the latter is marked by the absence of coaly matter or coal seams. In both bore-holes Barren Measures Formation overlies the Barakar Formation through a gradational contact.

PALYNOLOGY

Out of a total of 68 samples macerated from bore-holes GBK-1 and GGK-20, only 29 samples have yielded a rich mioflora. The sporae dispersae distributed in the above sediments consists of 51 genera and 124 species which are listed below:

Indotriradites Tiwari 1964
- *I. korbaensis* Tiwari 1964
- *I. sparsus* Tiwari 1965
- *Indotriradites* sp.

Leiotriletes (Naumova) Potonié & Kremp 1954
- *Leiotriletes* sp.

Lophotriletes (Naumova) Potonié & Kremp 1954
- *L. rectus* Bharadwaj & Salujha 1964

Horriditriletes Bharadwaj & Salujha 1964
- *H. rampurensis* Tiwari 1965
- *H. ramosus* (Balme & Hennelly) Bharadwaj & Salujha 1964
- *H. concavus* Maheshwari 1967

Lundbladisporites Tiwari & Moiz 1971
- *L. gondwanensis* Tiwari & Moiz 1971

Brevitriletes Bharadwaj & Srivastava emend. Tiwari & Singh 1981
- *B. triangulatus* Kar & Bose 1976
- *B. unicus* (Tiwari 1965) emend. Bharadwaj & Srivastava 1969 emend. Tiwari & Singh 1981

Microfoveolatispora Bharadwaj 1962
- *M. foveolata* Tiwari 1965 emend. Tiwari & Singh 1981

Pseudoreticulatispora Bharadwaj & Srivastava 1969
- *P. barakarensis* Bharadwaj & Srivastava 1969

Verrucosisporites Ibrahim emend. Smith 1971
- *V. puridkeriensis* Srivastava 1970
- *V. surangei* Maheshwari & Banerji 1975

Osmundacidites Couper 1953
- *O. senectus* Balme 1963

Laevigatosporites Ibrahim 1933
- *L. colliensis* Balme & Hennelly emend. Venkatachala & Kar 1968

Densipollenites Bharadwaj 1962
- *D. indicus* Bharadwaj 1962
- *D. invisus* Bharadwaj & Salujha 1964
- *D. densus* Bharadwaj & Srivastava 1969

Callumispora Bharadwaj & Srivastava 1969
- *C. barakarensis* Bharadwaj & Srivastava 1969
- *C. tenuis* Bharadwaj & Srivastava 1969
- *C. tenuis* var. *minor* Bharadwaj & Srivastava 1969

Hennellysporites Tiwari 1968
- *H. diversiformis* (Balme & Hennelly) emend. Tiwari 1968

Tiwariasporis Maheshwari & Kar 1967
- *T. simplex* (Tiwari) emend. Maheshwari & Kar 1967
- *T. gondwanensis* Tiwari emend. Maheshwari & Kar 1967

Weylandites Bharadwaj & Srivastava 1969
- *W. magmus* (Bose & Kar) emend. Bharadwaj & Dwivedi 1981
- *W. indicus* Bharadwaj & Srivastava 1969
- *W. circularis* Bharadwaj & Srivastava 1969

Vesicaspora Schemel emend. Wilson & Venkatachala 1963
- *V. luteus* Salujha 1965

Divarisaccus Venkatachala & Kar 1966
- *Divarisaccus* sp.

Caheniasaccites Bose & Kar 1966
- *C. ellipticus* Bose & Maheshwari 1968
- *C. elongatus* Bose & Kar 1966
- *C. ovatus* Bose & Kar 1966

Parasaccites Bharadwaj & Tiwari 1964
- *P. korbaensis* Bharadwaj & Tiwari 1964
- *P. obscurus* Tiwari 1965
- *P. distinctus* Tiwari 1965
- *P. diffusus* Tiwari 1965
- *P. bilateralis* Tiwari 1965
- *P. perfectus* Bose & Maheshwari 1968
- *P. densicorpus* Lele 1975
- *P. talchirensis* Lele & Makada 1972
- *P. longus* Kar & Bose 1967

Plicatipollenites Lele 1964
- *P. indicus* Lele 1964
- *P. gondwanensis* (Balme & Hennelly) emend. Lele 1964
- *P. diffusus* Lele 1964
- *P. gangaensis* Saxena 1971

Virkkipollenites Lele 1964
- *V. triangularis* Tiwari 1968

Trochosporites Wilson 1962
- *Trochosporites* sp.

Striomonosaccites Bharadwaj 1962
- *S. ovatus* Bharadwaj 1962

Leuckisporites Potonié & Klaus emend. Bharadwaj 1974
- *L. microgranulatus* Klaus 1963
- *L. crassus* Sinha 1972

Crucisaccites Lele & Maithy 1964
- *C. indicus* Srivastava 1970
- *C. monoletus* Maithy 1965
- *C. medius* Lele & Maithy 1969

Lunatisporites Leschik emend. Bharadwaj 1974
- *L. pellucidus* Goubin 1965 emend. Maheshwari & Banerjee 1975
- *L. ovatus* (Goubin 1965) Meheshwari & Banerjee 1975

Corisaccites Venkatachala & Kar 1966
- *C. alutus* Venkatachala & Kar 1968
- *C. distinctus* Venkatachala & Kar 1968

Hamiapollenites Wilson emend. Tschudy & Kosanke 1966
- *Hamiapollenites* sp.

Striatites Pant emend. Bharadwaj 1962
- *S. rhombicus* Bharadwaj & Salujha 1964
- *S. tentulus* Tiwari 1965
- *S. naditoliensis* Bharadwaj & Dwivedi 1981
- *S. obliquus* Srivastava 1979
- *Striatites* sp. cf. *S. parvus* Tiwari 1965

Lahirites Bharadwaj 1962
- *L. rarus* Bharadwaj & Salujha 1964
- *L. parvus* Bharadwaj & Salujha 1964
- *L. karanpuraensis* Bharadwaj & Dwivedi 1981
- *L. parvus* Bharadwaj & Salujha 1964
- *L. fractus* Tiwari 1965
- *L. rhombicus* Maithy 1965

Verticipollenites Bharadwaj 1962
- *V. secretus* Bharadwaj 1962
- *V gibbosus* Bharadwaj 1962
- *V debilis* Venkatachala & Kar 1968
- *V crassus* Bharadwaj & Salujha 1964

Hindipollenites Bharadwaj 1962
- *H. indicus* Bharadwaj 1962
- *H. gibbosus* Kar 1968
- *Hindipollenites* sp. cf. *H. rajmahalensis* Maheshwari 1967

Striatopodocarpites Soritch. & Sedova emend. Bharadwaj 1962
- *S. brevis* Sinha, 1972
- *S. rotundus* Maheshwari emend. Bharadwaj & Dwivedi 1981
- *S. decorus* Bharadwaj & Salujha 1964
- *S. labrus* Tiwari 1965
- *S. subcircularis* Sinha 1972

Faunipollenites Bharadwaj 1962
- *F. goraiensis* Potonié & Lele emend. Maithy 1965
- *F. copiosus* Bharadwaj & Salujha 1965
- *F. varius* Bharadwaj 1962
- *F. bharadwajii* Maheshwari 1967
- *F singrauliensis* Singh 1972
- *F. gopadensis* Bharadwaj & Srivastava 1969

Strotersporites Wilson 1962
- *Strotersporites* sp.

Striapollenites Bharadwaj 1962
- *S. saccatus* Bharadwaj 1962

Distriatites Bharadwaj 1962
- *D. insolitus* Bharadwaj & Salujha 1964
- *D. distinctus* Sinha 1972

Rhizomaspora Wilson 1962
- *R. indica* Tiwari 1965
- *R. monosulcata* Tiwari 1968

Primuspollenites Tiwari 1964
- *P levis* Tiwari 1964

Crescentipollenites Bharadwaj, Tiwari & Kar 1974
- *C. talchirensis* Lele 1975

Circumstriatites Lele & Makada 1972
- *C. obscurus* Lele & Makada 1972
- *C. ovatus* Lele & Makada 1972

Marsupipollenites Balme & Hennelly emend. Pocock & Jansonius 1969
- *M. fasciolatus* Balme & Hennelly 1956

Potonieisporites Bhardwaj emend. Bharadwaj 1964
- *P neglectus* Potonié & Lele 1961
- *P barrelis* Tiwari 1965
- *P concinnus* Tiwari 1965
- *P lelei* Maheshwari 1967
- *P jayantiensis* Lele & Karim 1971
- *P distinctus* Lele & Makada 1972

Scheuringipollenites Tiwari 1973
- *S. maximus* Hart emend. Tiwari 1973
- *S. minutus* Sinha 1972
- *S. barakarensis* Tiwari 1965
- *S. tentulus* (Tiwari) Tiwari 1973

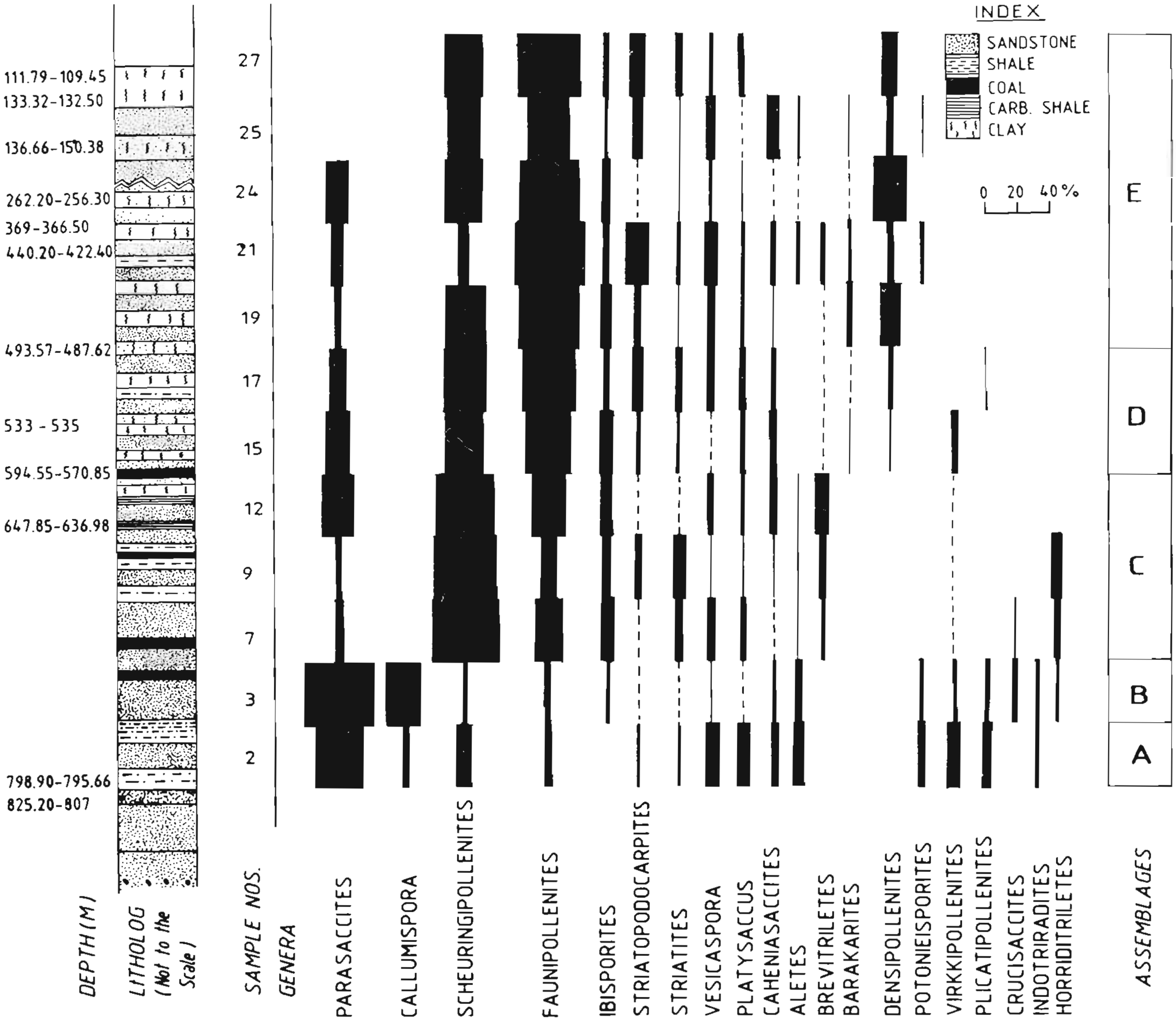
Ibisporites Tiwari 1968
- *I. diplosaccus* Tiwari 1968
- *I. jhingurdahiensis* Sinha 1972

Platysaccus Naumova emend. Potonié & Klaus 1954
- *P. papilionis* Potonié & Klaus 1954
- *P plicatus* Bharadwaj & Dwivedi 1981
- *P. leschiki* Hart 1960
- *P densicorpus* Anand-Prakash 1972

Paravesicaspora Klaus 1963
- *P. obliqua* Singh emend. Bharadwaj & Dwivedi 1981

Aurangapollenites Srivastava 1977
- *A. gurturiensis* Srivastava 1977

Barakarites Bharadwaj & Tiwari 1964
- *B. densicorpus* Tiwari 1965
- *B. crassus* Tiwari 1965
- *B. implicatus* Tiwari 1965
- *B. decorus* Tiwari 1965
- *B. rotatus* Balme & Hennelly emend. Bharadwaj & Tiwari 1964



Text-figure 1—Showing percentage frequency of palynotaxa in bore-hole GRK-1.

B. triquetrus Tiwari 1965

Parastriopollenites sp. cf. *P. triangularis* Maheshwari 1967

P. rajmahalensis Maheshwari 1967

The quantitative analysis of the palynoflora is based on a count of 200 spores in each sample at generic level. The criteria for marking the quantitative abundance of various miospore genera is comparative and the categories are dominant, subdominant, common and rare.

A critical appraisal of the vertical distribution of spore genera in the two bore-core samples (GGK-20, Text-fig. 2 & GRK-1, Text-fig. 1) of Ramagundam and Ramakrishnapuram areas, respectively has revealed *Callumispora, Parasaccites, Densipollenites, Faunipollenites, Scheuringipollenites* as the most important components.

These genera constitute the association of dominants and subdominants and have made possible to recognise the following six distinct palynozones distributed at various levels of the bore holes.

BORE-HOLE GRK-1

Assemblage A

Assemblage A is present in the bore-hole GRK-1 at the depth of 825-807 m (Text-fig. 1) lithologically represented by a shale/sandstone intercalation. The dominant component of this assemblage is *Parasaccites* (Text-fig. 1). Nonstriate and striate-disaccates in this assemblage are present in low amounts. The palynofloral assemblage on the whole is dominated by radial monosaccates (55%).

Assemblage B

Assemblage B is present between [illegible] m in sample no. [illegible] which is again a shale-sandstone intercalation. It consists of monosaccates, chiefly *Parasaccites* as a dominant element alongwith subdominant *Callumispora*. Striate and nonstriate disaccate pollen are quite low in percentage. The palynoflora in this assemblage is also dominated by radial monosaccate pollen ([illegible]) similar to Assemblage A but the association of *Callumispora* ([illegible]) distinguishes it from the latter.

Assemblage C

Assemblage C is present in bore-hole GKK-1 at [illegible] m, the dominant element being *Scheuringipollenites*. *Faunipollenites* among the striate disaccates pollen is the subdominant genus. In the younger part of this palynozone *Parasaccites* rises suddenly to become almost equal to *Faunipollenites*. However, the nonstriate disaccate pollen attain overall dominance ([illegible]) in this zone while monosaccates decline to become common. Striate disaccate pollen also rise to attain subdominance.

Assemblage D

This assemblage having striate disaccate pollen, chiefly *Faunipollenites* ([illegible]) as the dominant component, is present in GKK-1 between [illegible] m. *Scheuringipollenites* reduces to be subdominant ([illegible]). *Parasaccites* is slightly reduced to 15-[illegible] per cent and continues to reduce in further younger samples. *Densipollenites* appears for the first time in this assemblage although in rare amounts. Thus the dominant percentage is shared by striate disaccate pollen grains closely followed by nonstriate disaccate pollen.

Assemblage E

Assemblage E of the bore-hole GKK-1 present between [illegible] m is characterised by the dominance of striate disaccates, chiefly *Faunipollenites*. *Scheuringipollenites* remains as a subdominant element of the assemblage. The important feature of the assemblage is that it shows the episode of *Densipollenites*, i.e., in the beginning the percentage of *Densipollenites* is low ([illegible]), in the middle it increases up to 19 per cent and at the end it declines to [illegible] per cent again. *Parasaccites* although present between 2-12 per cent behaves irregularly. The bulk of the percentage is shared by striate disaccate pollen ([illegible]) and the subdominance is maintained by non-striate disaccate genera ([illegible]). Monosaccate pollen including *Densipollenites*, however, increase to [illegible] per cent.

BORE-HOLE GGK-20

Assemblage 1

Assemblage 1 has been demarcated between [illegible] m in bore-hole GGK-20 (Text-fig. 2). The dominant element of this assemblage is *Parasaccites* ([illegible]). The other monosaccate pollen occur between [illegible] per cent. The nonstriate-disaccate genera, e.g., *Scheuringipollenites*, *Primuspollenites*, *Platysaccus* and *Ibisporites* remain as subdominant elements. Among the striate-disaccates pollen *Faunipollenites* occurs between [illegible]-17 per cent. The striate-disaccates are common. The monosaccate pollen total up to [illegible] per cent, striate-disaccates [illegible] per cent and nonstriate disaccates average up to [illegible] per cent.

Assemblage 2

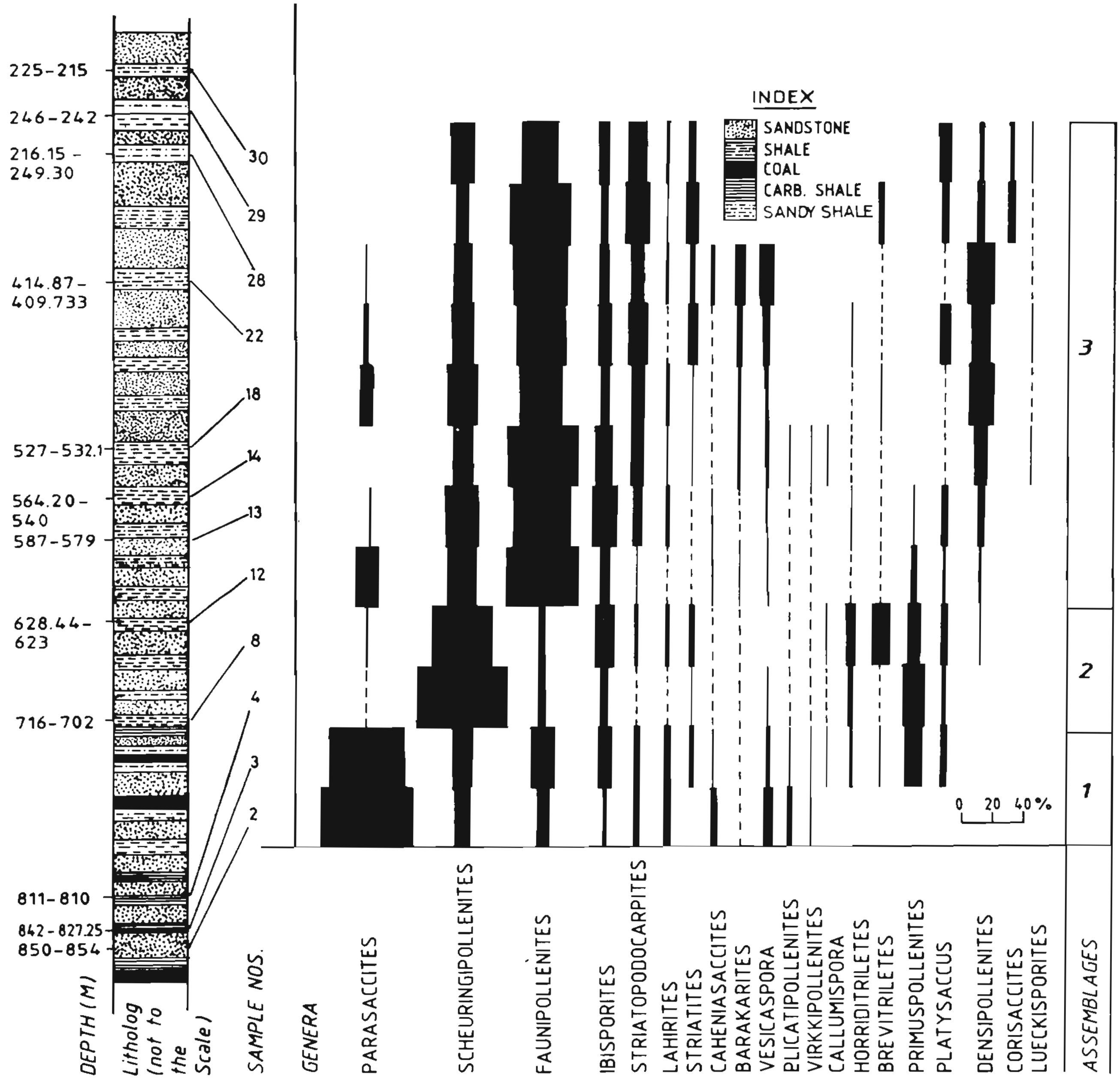
Assemblage 2 is present in the bore-hole GGK-20 between [illegible] m. The dominant element in this assemblage is *Scheuringipollenites*. *Primuspollenites* declines to [illegible] per cent. *Faunipollenites* also shows a declining tendency in the zone. Among the triletes, *Brevitriletes* and *Horriditriletes* appear in common alongwith monolete *Laevigatosporites*. The palynoassemblage is dominated by the nonstriate disaccate pollen ([illegible]) while the next group in order of dominance is triletes ([illegible]) spores.

Assemblage 3

Assemblage 3 is present in bore-hole GGK-20 between [illegible] m (sample nos. [illegible], 14, 18, 22, 28 [illegible]) in which *Faunipollenites* form the dominance. *Scheuringipollenites* reduces to subdominance. In addition to these *Densipollenites* shows significant increase being 2-8 per cent in the beginning, up to [illegible] per cent in the middle and then reduced to [illegible] per cent in the upper part of the bore-core. Triletes are rare in occurrence. *Parasaccites* is up to 15 per cent at the beginning but the same suddenly declines upwards and ultimately loses significance at [illegible] m. Thus, the palynoflora is dominated by the striate-disaccate pollen ([illegible]) followed by nonstriate-disaccate ([illegible]). The presence of *Densipollenites* in subdominance is a characteristic feature of this assemblage.

PALYNOZONATION AND STRATIGRAPHIC CORRELATION

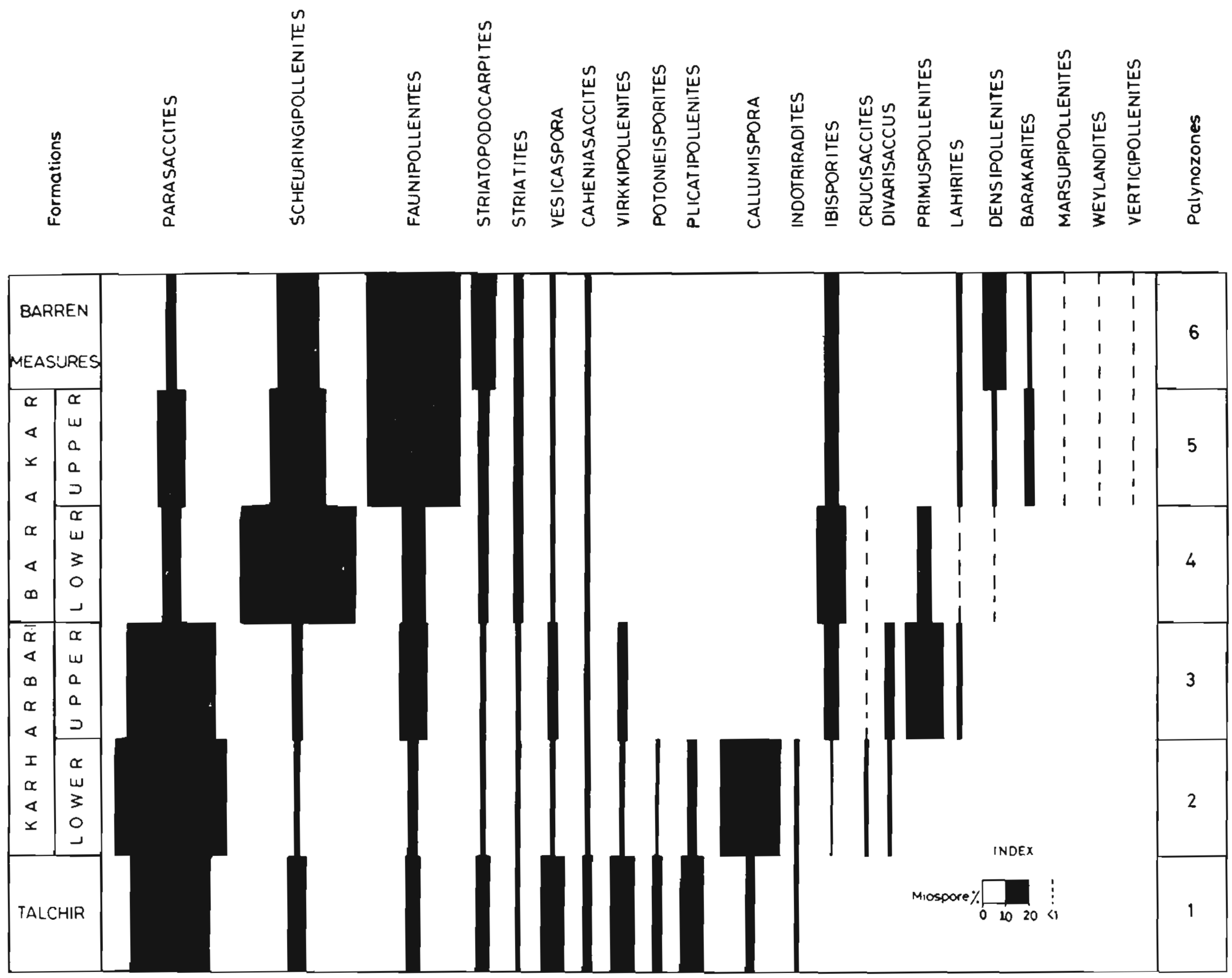
The present investigation has revealed that Assemblage A in bore-hole GKK-1 is dominant in *Parasaccites* and other monosaccate pollen grains and *Callumispora* is low in percentage ([illegible]). Hence



Text-figure 2—Showing percentage frequency of palynotaxa in bore-hole GGK-20.

Assemblage A represents palynoflora of the Talchir Formation. This assemblage has been referred to Palynozone 1 in this investigation (Text-fig. 3). Such an assemblage has not been observed in bore-hole GGK-20.

Karharbari sediments which overlie Talchir Formation, are palynologically divisible into two parts. The lower part of the older zone is characterised by a combination of *Callumispora* and *Parasaccites* (Bharadwaj, 1976) as is found in Korba Coalfield (Bharadwaj & Srivastava, 1973). The upper part or the younger zone contains a *Parasaccites* dominant assemblage with *Callumispora* sub-dominant and with some nonstriate-disaccates. However, in the present study samples between 798.90-795.6 m in bore-hole GRK-1 contain Assemblage B which has *Parasaccites* dominance as well as high incidence of *Callumispora* (22%) alongwith low disaccate pollen. Obviously, Assemblage B represents Lower Karharbari palynoflora (Palynozone 2). This palynozone has not been encountered in bore-hole GGK-20. Assemblage 1 in bore-hole GGK-20 is dominant in *Parasaccites*. *Callumispora* is negligible and nonstriate-disaccate and striate-disaccate pollen increase in percentage as compared to Assemblage B. Hence, it represents



Text-figure 3—Showing succession of palynofloras in Ramagundam and Ramakrishnapuram areas, Godavari Graben.

the Upper Karharbari palynoflora and is designated here as Palynozone 3.

The next formation of the Lower Gondwana sequence is the Barakar Formation, which is palynologically divisible into the older, *Scheuringipollenites* dominated palynoflora, and the younger with exclusively striate-disaccate dominated assemblage (Bharadwaj, 1975). In the present study the Assemblage C (bore-hole GRK-1) has dominant *Scheuringipollenites* and subdominant striate-disaccate pollen grains. Similar palynofloral assemblage is also found in Assemblage 2 (bore-hole GGK-20), hence, the two can be correlated. Both the assemblages demarcated in Palynozone 4, closely compare with the palynoflora of Barakar Formation. Assemblage D (bore-hole GRK-1) has dominant striate-disaccate chiefly *Faunipollenites* and subdominant *Scheuringipollenites*. Such an association (Palynozone 5) has not been found in bore-hole GGK-20 described here, hence not correlatable. Barren Measures palynoflora is characterised by *Densipollenites* associated with striate-disaccate pollen. Similar association has also been found in the present Assemblages E (bore-hole GRK-1) and Assemblage 3 (bore-hole GGK-20). Hence, these assemblages represent the Barren measures palynoflora (Palynozone 6). Evidently, there are six palynological assemblages each representing a distinct palynozone summarised below :

PALYNO-ZONE	ASSEMBLAGE	FORMATION
6	Striate-disaccate + *Densipollenites* (Assemblage E, Bore-hole GRK-1, depth 369-109.45 m; Assemblage 3, Bore-hole GGK-20, depth 628-215 m)	**Barren Measures**
5	Striate-disaccate (*Faunipollenites*) dominant, nonstriate-disaccate sub-dominant (Assemblage D, bore-hole GRK-1, depth 493.57-422.40 m)	Upper **Barakar**

4	Nonstriate-disaccate (*Scheuringipollenites*) dominant; Striate-disaccate subdominant (Assemblage C, bore-hole GRK-1, depth 647.85-533 m; Assemblage 2, bore-hole GGK-20, depth 811-702 m)	Lower
3	Radial monosaccate (*Parasaccites*) dominant, nonstriate-disaccate subdominant (Assemblage 1, bore-hole GGK-20, depth 854-827.25 m)	Upper
		Karharbari
2	Radial monosaccate (*Parasaccites*) dominant, *Callumispora* subdominant (Assemblage B, bore-hole GRK-1, depth 798.90-795.6 m)	Lower
1	Radial monosaccate (*Parasaccites*) dominant (Assemblage A, bore-hole GRK-1, depth 825-807 m)	**Talchir**

COMPARISON OF PALYNODATA WITH LITHODATA

Bore-hole GRK-1

The Talchir Formation has been delimited lithologically between 919.01-807.46 m. The palynoflora recovered between 825-807 m is characteristic of Talchir Formation. Thus, the palynological findings and lithological characters for Talchir Formation correspond with each other.

The Barakar Formation which overlies the Talchir Formation, has been marked lithologically between 807.46-571.85 m and the Barren Measures Formation has been demarcated between 571.85-105.30 m. However, the palynoflora present at the level of 798.90-795.6 m, is characteristic of upper part of Lower Karharbari and the palynoflora found at the level of 647.85-533 m is characteristic of Lower Barakar. Thus, the zone which has lithologically been marked as Barakar Formation, has yielded two palynological assemblages—the older characteristic of lower part of Karharbari Formation and the younger of Lower part of Barakar Formation. The palynodata has enabled finer differentiation in a lithologically undifferentiated sequence which is quite normal for Barakar sedimentation.

Further, the samples present at 493.57-422.40 m have yielded a palynoflora characteristic of upper part of Barakar Formation. The youngest assemblage present at the level of 369-109.45 m is characteristic of Barren Measures Formation. Hence, here also the palynological data do not correspond with the lithological characters wholly, the older part exhibiting Barakar time equivalence and only the younger part corresponding to Barren Measures time.

Bore-hole GGK-20

In this bore-hole the samples of Talchir Formation have not been obtained. The next Barakar Formation has been demarcated lithologically between 900.15-702.26 m. Palynologically, the samples between 854-827.25 m have yielded younger Upper Karharbari mioflora. The samples from 811-702 m have yielded a palynoflora characteristic of the Lower Barakar Formation. Thus, the palynodata do not correspond with the lithodata as the Barakar Formation is seen to include younger Karharbari palynoassemblage as well.

Above the Barakar Formation a thick stratum of Barren Measures Formation has been demarcated between the levels of 702-200 m. Palynoflora present in this zone is characteristic of Barren Measures Formation. Thus, obviously the palynodata correspond here with the lithodata.

DISCUSSION

The foregoing account of palynology of the Lower Gondwana Sequence in Ramagundam area of Godavari Valley coalfields suggests that a rich and diversified vegetation grew in the region during the formation of these sediments. The sporae dispersae recovered from different formations has been assigned to 52 genera and 124 species. The quantitative estimation of various taxa at generic level shows a marked change in mioflora from Talchir to Barren Measures Formation. A total of six palynological zones have been demarcated. The oldest Palynozone 1 is marked by the dominance of radial monosaccates (chiefly *Parasaccites*) and is present in bore-hole GRK-1 (between 825.20-807 m) which was drilled north of Godavari River. This assemblage compares with younger Talchir miofloras known from other basins of Peninsular Gondwanas (Bharadwaj, Srivastava & Anand-Prakash, 1979). This observation shows complete agreement with the lithological observation since the bore-hole was closed at 919.01 m after cutting nearly 111.35 m of Talchir sediments. This indicates that Talchir sediments continue further more down below containing in all probability the older Talchir palynofloras known from other basins.

The next younger Lower Karharbari palynoflora is observed above Palynozone 1 in bore-hole GRK-1 between 798.90-795.66 m. The lithological change-over from Talchir to Barakar Formation is gradational and there is no evidence of a break in sedimentation. Thus, the presence of a Lower Karharbari assemblage in a lithologically undifferentiated sequence is noteworthy. Further, the sediments between 795.66 to 647.85 m in bore-hole GRK-1 have not yielded palynofossils but the overlying sediments from 647.85 to 533 m contain Lower Barakar palynoflora dominated by nonstriate-disaccate, chiefly *Scheuringipollenites*. Thus, the palynoflora representing the Upper Karharbari has not been observed in bore-hole GRK-1. However, it is present in bore-hole GGK-20 between 854-827.25 m. The sediments between 795.66 to 647.85 m in bore-hole GRK-1 contain four thin bands of coal and several bands of shales and the Upper Karharbari mioflora in all probability is expected to be interpolated in between these sediments.

The Upper Karharbari palynoflora (Palynozone 3) is succeeded by Palynozone 4 which is present in both the bore-holes. This assemblage is similar to the Lower Barakar palynofloras known from other areas. It is observed that the mioflora of coal seams 1-4 presently being worked out in various collieries of Ramagundam area fall essentially within Assemblage C of bore-hole GRK-1 and Assemblage 2 of bore-hole GGK-20 in view of having a nonstriate-disaccate dominant assemblage and thus are correlatable. Besides, almost all the working coal seams of Yellandu, Kothagudem, Belampalli, Mandamari and Ramkrishnapuram areas can be accommodated within this zone in view of having nonstriate-disaccate dominant assemblages and represent Barakar (Lower) mioflora. However, the assemblages described by Srivastava (1987) contain better evidence of trilete miospores than that encountered in the present bore-holes.

In addition to these, the miospore Assemblage 1 in bore-hole GGK-20 is correlatable with the mioflora of King Seam being worked out in Yellandu area as both of them contain *Parasaccites* dominant assemblage representing Upper Karharbari mioflora.

The Upper Barakar palynoflora (Palynozone 5) has been observed in bore-hole GRK-1 between 493.57 to 422.40 m strata which is devoid of coal seams and was lithologically placed in Barren Measures Formation (Histogram 1). The palynological change from Lower Barakar to Upper Barakar is normal but the lithological sequence is, however, not in agreement with these palynological observations. The Upper Barakar assemblage has been differentiated in a lithologically differentiated Barren Measures sequence.

It is further noteworthy to observe that the Upper Barakar assemblage is not present in bore-hole GGK-20 as the Lower Barakar palynoflora is directly succeeded by Barren Measures palynoflora (Palynozone 6). The succession of palynofloras from Upper Barakar to Barren Measures, while being sequential in bore-hole GRK-1, is discordant in bore-hole GGK-20 in view of the absence of striate-disaccate dominant Upper Barakar palynoflora. Thus, the lithological change-over from Barakar to Barren Measures Formation in bore-hole GGK-20 is normal but palynologically it is not so.

The lithologically differentiated Lower Member of the Barakar Formation which is practically devoid of workable coal seams in the present bore-holes, in fact contains a Karharbari palynoflora. In other coal basins this is known to contain workable coal seams having high grade coal. The present finding thus, opens up new possibilities for the search of Karharbari coal in Godavari Basin which is known to contain the large better quality coal. The Upper Member of the Barakar Formation containing workable coal seams of the area corresponds palynologically with the Lower Barakar. The sediments containing Upper Barakar palynoflora are virtually devoid of coal facies in the present bore-hole investigated.

The Barren Measures palynoflora present in both the bore-holes shows a complete epibole and confirms palynologically the existence of Barren Measures Formation in Ramagundam area of Godavari Valley coalfields. Obviously, this parameter can help in delineating Barren Measures Formation in other areas of Godavari Valley coalfields indicating the possible evidence of underlying Barakar Formation and the overlying Lower Member of the Kamthi Formation, both of which are promising coal horizons in this basin.

CONCLUSIONS

The palynological investigation of the Lower Gondwana sediments in the subsurface sediments of Ramagundam and Ramakrishnapuram areas in Godavari Valley coalfields suggests the following points:

1. The palynological succession, in general, corresponds with the palynological successions known from other Lower Gondwana basins of India.
2. Karharbari palynoflora has been recognised palynologically in a lithologically undifferentiated Barakar sequence. Further, a slight discordance is apparent on the basis of palynological evidences in one of the bore-holes (GGK-20) before the commencement of Barren Measures sequence.
3. Existence of Barren Measures Formation in Ramagundam area has been confirmed by palynological evidences.

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Abundance of spore tetrads in the Early Triassic sediments of India and their significance

R. S. Tiwari & K. L. Meena

Tiwari, R. S. & Meena, K. L. 1989. Abundance of spore tetrads in the Early Triassic sediments of India and their significance. *Palaeobotanist* **37**(2) : 210-214.

A number of spore tetrads with variable ornamentation have been observed during the palynological study of Lower Panchet sediments (Early Triassic) of the Raniganj Coalfield. They are either cingulate (ornamented or smooth) or simple verrucose spores, and can be attributed to *Lundbladispora*, *Densoisporites* and *Verrucosisporites*. The abundance of tetrads in the assemblage may be assigned to the diminishing effect of callase due to change in climate. This perhaps resulted into the non-dissolution of the callose-wall which holds the spores together in a tetrad.

Key-words—Palynology, Spore tetrads, *Lundbladispora, Densoisporites, Verrucosisporites*, Raniganj Coalfield, Early Triassic (India).

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साराँश

भारत के प्रारम्भिक त्रिसंघी कालीन अवसादों में बीजाणु-चतुष्कों की बाहुल्यता तथा इनका महत्व

रामशंकर तिवारी एव किन्दु लाल मीना

रानीगंज कोयला-क्षेत्र के अधरि पंचेत अवसादों (प्रार्रम्भिक त्रिसंघी) का परागाणविक अध्ययन करते समय अस्थायी अलंकरण वाले अनेक बीजाणु-चतुष्क प्रेक्षित किये गये हैं। ये चतुष्क या तो सिंगुलेटी हैं अथवा सामान्य वेरुकोसी बीजाणु हैं तथा **लुन्ब्लाडिस्पोरा, डेन्सोस्पोराइटिस** एवं **वेरुकोसिस्पोराइटिस** से इन्हें नार्मांकित किया जा सकता है। समुच्चय में चतुष्कों की बाहुल्यता केलेज़ की न्यूनता क्रे कारण हो सकती है जो कि जलवायु परिवर्तन से संभव है। सम्भवत: केलेज़ भित्ति न टूटने के कारण ही ऐसा हो सकता है वास्तव में यही भित्ति चतुष्क रूप में बीजाणुओं को एक साथ विन्यस्त रखती है।

THE sporogenous tissue from which the spore mother cell originates normally gives rise to four spores after meiotic division. Subsequently, these four haploid bodies generally get free from each

PLATE 1 →

All figures. × 500.

1. *Densoisporites* : A tetrad in which one of the member spore is missing showing distorted smooth exine, contact areas and inner body; Slide no. BSIP 9313.
2. *Lundbladispora* : Tetrad showing small coni and thick exine of spore; Slide no. BSIP 9314.
3. *Lundbladispora* : Tetrad having coni with elongated tips; Slide no. BSIP 9314.
4. *Lundbladispora* : A tetrad bearing long coni; Slide no. BSIP 9313.
5. *Verrucosisporites* : A tetrad basically smooth and finely intrapunctate but bearing at places few globular smooth bodies irregularly attached on exine; Slide no. BSIP 9315.
6. *Lundbladispora* : Tetrad showing spars spines; Slide no. BSIP 9313.
7. *Lundbladispora* : Tetrad with elongated, narrow, closely placed spines; Slide no. BSIP 9606.
8. *Lundbladispora* : Spines on tetrads big, broad-based, massive; Slide no. BSIP 9606.
9. *Lundbladispora* : One of the members of tetrad missing; Slide no. BSIP 9608.
10. *Lundbladispora* : Exine partially distorted, spines present.
11. *Lundbladispora* : Similar to fig. 1; Slide no. BSIP 9312.
12. *Lundbladispora* : Similar to fig. 8; Slide no. BSIP 9313.

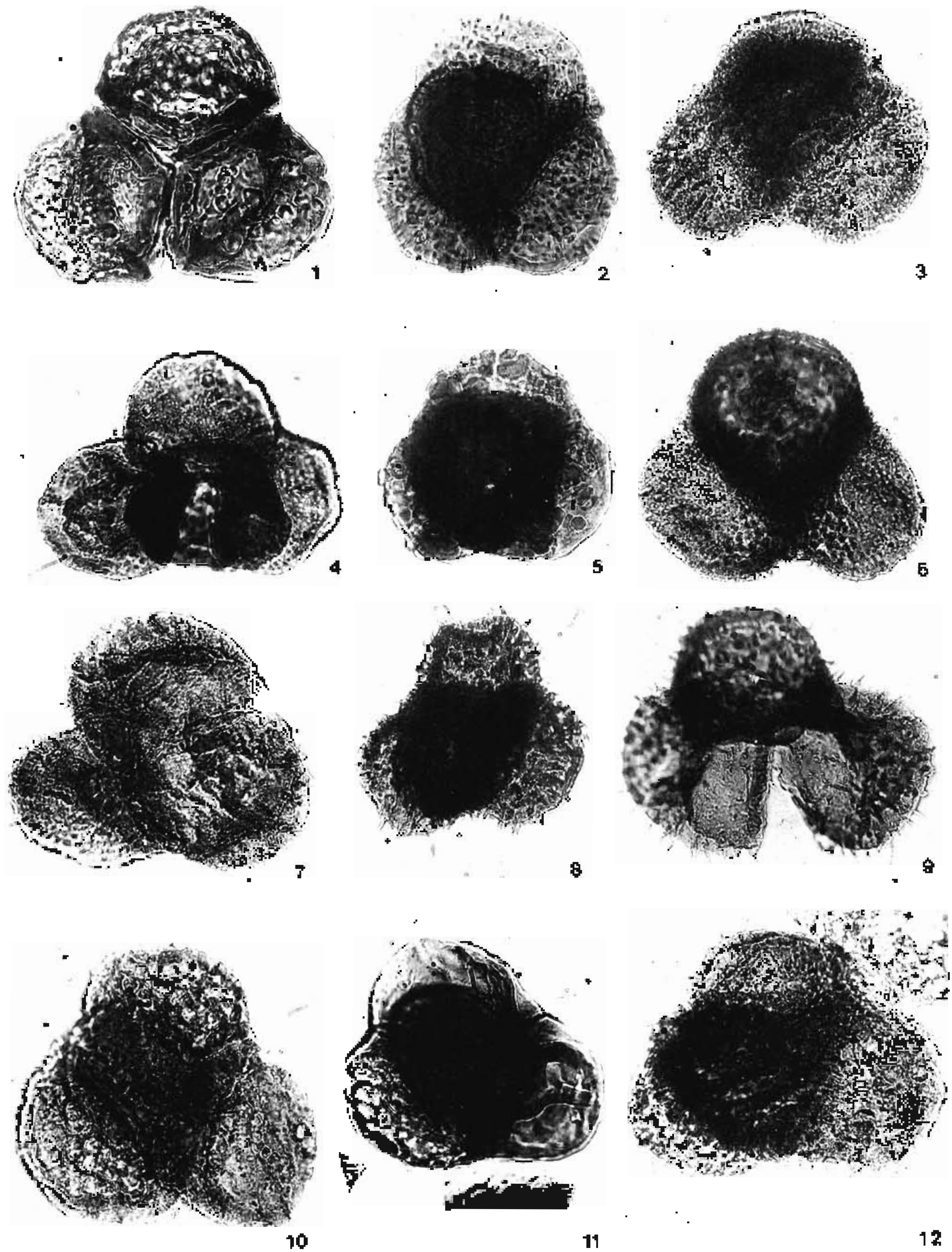

PLATE 1

other, but in certain cases they remain adhered together in the form of a tetrad (rarely dyads, polyads; Erdtman, 1945).

In the case of tetrahedral tetrads, the four spore members are arranged in two planes. Besides, the cross tetrad or linear tetrads are also found within the plant groups. It is well known that in the tetrahedral tetrads, the four member-spores are arranged as if each were on one apex of a pyramidal tetrahedron. Each of the cell touches the three other ones at three points and these three contact points form an isosceles triangle on the proximal polar region. In pteridophytes, the germinal apparatus is normally found at these contact lines (trilete mark).

In fossil condition, the occurrence of tetrads has been reported by several workers (Hennelly, 1958; Potonié & Lele, 1961; Visscher, 1968) and at times, given the status of a separate genus.

During the course of analysis of dispersed spores and pollen in the sediments of Panchet Formation, sampled from bore-hole no. RAD-7 and RAD-8 in the eastern part of East Raniganj Coalfield, West Bengal, a large number of tetrahedral tetrads were found. The individual spore-member of such tetrads, mostly cingulate, rarely non-cingulate, cavate organization, shows a wide variation in range of ornamentation. The abundance of such tetrads in dispersed condition is peculiar and needed discussion.

Following is the description of the major groups of tetrads found in the present study.

OBSERVATIONS

The tetrads which were found in the presently studied Panchet palynoflora, have been divided into two major groups:

1. Ornamented forms
2. Laevigate forms

In general, the spore members of tetrads are triangular to subtriangular in shape, bearing a distinct trilete mark having an equatorially thickened, well-defined cingulum. The exine of the body is finely structured showing infrapunctate to infragranulose structures. In case of ornamented forms, the sculpture is present only on the distal surface and to some extent on the cingulum but normally it is absent from the proximal surface. The inner body has been noticed in a number of specimens, particularly in the laterally flattened members of the tetrad, where it appears to be separate along the distal part of the cavity.

1. *Ornamented forms*—On the basis of ornamentation, described as under, five groups could be identified:

(a) *Setae-like spines*—2-5 μm long, less than 1 μm wide, 2-4 μm apart from each other, narrow setae-like appendages.

(b) *Coni*—1-2 μm wide at base, ± 2 μm high with fine projecting apex, closely packed, at places appearing as verrucae.

(c) *Mammoid globular process*—3-5 μm long × 2-3 μm wide, subcircular, obtusely elongated or nipple-shaped processes, with or without pointed tips.

(d) *Coni with elongated apex*—Processes up to 5 μm long and 3-4 μm wide at base, fusiform, generally rounded body with stretched elongated apex.

(e) *Verrucae*—1-3 μm verrucae generally indistinct in outline and compactly disposed on the surface, projecting out on the margin, non-cingulate.

2. *Laevigate forms*—Exine smooth, no ornamentation, cingulate. In some of the specimens the exine is affected by preservational factor and appears to possess coarse reticulum or foveolae. However, its secondary nature has been determined by the fact that at times only one or two spore-members of the tetrads show this type of deformity.

The cingulate ornamented forms of tetrads belong to the genus *Lundbladispora* Playford 1965; the spores in a tetrad having laevigate exine and a cingulum show their affinity with *Densoisporites* Weyland & Krieger emend. Dettmann 1963; those with verrucose exine and simple organization are of *Verrucosisporites* Ibrahim emend. Smith *et al.* 1967. The specific identification is not attempted here because it has been established now that although the major exine wall-pattern is formed during the tetrad condition, some changes in sculpture of the exine do take place even after the breaking up of tetrad. In view of this fact, the specific assignment of a tetrad to the individual spore species of the dispersed spores, could lead to erroneous identification.

DISCUSSION

Although Visscher (1966) proposed two tetrad genera, *Lapposisporites* and *Paralundbladispora* usually found in tetrahedral tetrads, these could be assigned to other taxa known in dispersed condition. The forms assigned to *Quadrisporites* (Hennelly, 1958; Potonié & Lele, 1961) are, however, entities in themselves and do not appear to be tetrads. Further study of *Quadrisporites* from the Lower Gondwana horizon suggested that the connecting material

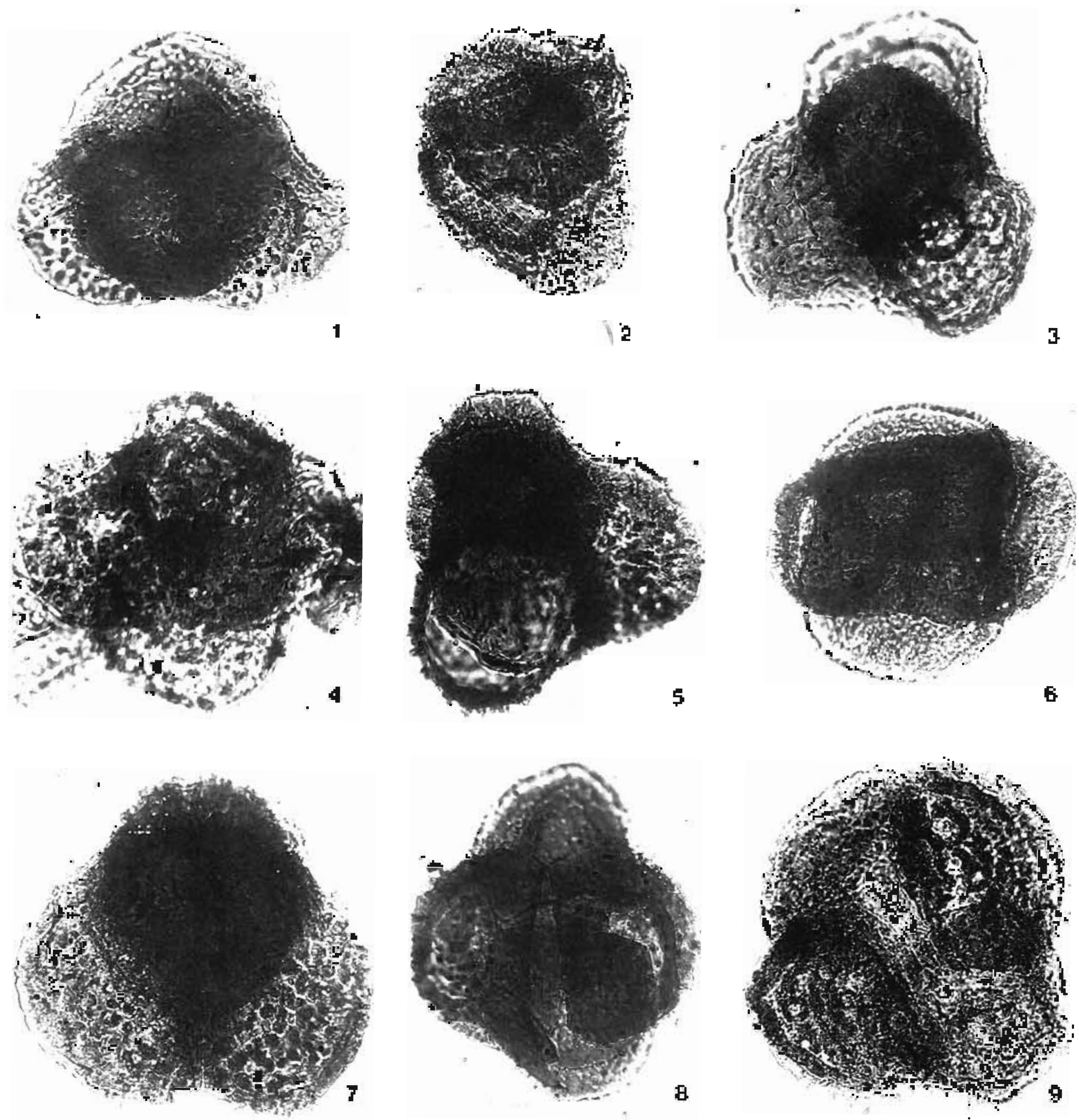

PLATE 2

(All figures × 500)

1. [illegible] — Tetrad showing presence of broad [illegible] [illegible] on proximal [illegible] and [illegible] processes. Slide no. BSIP [illegible].
2. [illegible] — Tetrad bearing small [illegible]. Slide no. BSIP [illegible].
5, 9. [illegible] — Tetrad bearing [illegible] like spines. Slide no. BSIP [illegible].
7. [illegible] — [illegible] [illegible] closely set [illegible]. Slide no. BSIP [illegible].
8. [illegible] — Tetrad bearing small [illegible]. Slide no. BSIP [illegible].

which joins four members of the so-called 'tetrad', is exinal in nature. Moreover, no single member of this kind has been ever found separately in the population of dispersed spores. The nature of *Quadrisporites* to be similar to an acritarch can also be suggested on this basis.

From sediments of Panchet Group, Banerjee and Maheshwari (1975) have reported tetrads comparable to the ones described here. They assigned their specimens to *Decisporis* sp. cf. *D. variabilis* Kar 1970. They have found both tetrahedral as well as crossed tetrads. Our studies on the Triassic material and a survey of literature suggest that in the Early Triassic, spore pollen assemblages show a general tendency to have more tetrads than that in the Permian. The morphographic analysis leads to conclude that the tetrads should be treated as single spore for taxonomic purpose, and they should not be regarded as separate genera only because they are found in tetrad condition; this means that the identification of such tetrads should be sought in taxa of *sporae dispersae* on the lines of organization and morphography of the individual units of the tetrad.

The tetrad-period is critical for the formation of wall pattern in the initial stage. In the formation of a tetrad, generally two successive cleavages take place. The wall produced after meiosis bisects the meiocytes to give rise the dyad configuration and the subsequent two walls form, following meiosis II, to complete the sub-division to give rise the tetrad. These walls of tetrad are made up of callose (Heslop-Harison, 1973). The spores are released from the tetrads by the rapid dissolution of callose wall through an enzyme called callase. The enzyme appears in the locular fluid and its action is a short-lived process and, hence, it can be visualised that if this reaction fails due to some reasons or the other, it will result in a condition where a number of tetrads will remain intact and consequently no individual spore gets released. Such a situation appears to have arisen during the Early Triassic times where the occurrence of tetrad is a common feature. On the contrary, in the Raniganj palynoflora (Upper Permian), predominantly a coal-bearing horizon, almost negligible number of tetrads are found. This phenomenon thus raises the question of separation of individual spores from a tetrad which has some relationship with the changes in climate—from Permian to Triassic times. It is well known that there had been changes in the temperatures, towards warmer side, in the beginning of Triassic and it could be probable that the warmer conditions with high temperature and less rainfalls were apparently the cause of diminishing the action of callase during the advent of Triassic period and, thus the production of high frequency of tetrads in the *sporae dispersae* has resulted. This could as well be an adaptation for the protection of spores during changing situations. It, however, is not to opine here that the climate in Early Triassic was severely desertic or arid (because rich, diversified palynofloras occur during this period). Such a phenomenon appears to be an adaptation to adjust in the changing phase of climate for certain group of taxa. This contention is supported by the fact that although the same genera (e.g., *Lundbladispora, Densoisporites*, etc.) occur at the later time-level in Triassic as individual specimens, their tetrads are abundant at earlier level when the climatic change must have taken place.

CONCLUSION

The beginning of Triassic records prominence of tetrads in the *sporae dispersae*; they are generally of the cavate cingulate spores or of simple trilete spores. On the basis of morphography these tetrads should be assigned to the taxa of dispersed individuals rather than to new taxa. The probable reason for profused occurrence of tetrads at the advent of Triassic appears to be the sudden change in climate having relatively warmer phase when callase fails to dissolve the callose wall of the tetrad. This is suggestive of a short term adaptation for new set of conditions.

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Morphographic study of Permian palynomorphs: *Callumispora, Parasaccites, Crucisaccites* and *Faunipollenites*

R. S. Tiwari, Suresh C. Srivastava, Archana Tripathi & Vijaya

Tiwari, R. S., Srivastava, Suresh C., Tripathi, Archana & Vijaya 1989. Morphographic study of Permian palynomorphs: *Callumispora, Parasaccites, Crucisaccites* and *Faunipollenites*. *Palaeobotanist* **37**(2) : 215-266.

Taxonomy is the primary requisite for biostratigraphy, and objective resolution of organisations as well as finer morphography leads to effective circumscription of taxa for taxonomy. Obviously, such an approach is critical for dispersed microfossils where *form* and *shape* remain the only tools for classification.

The palaeopalynology has come to its age and the inevitable discrepancies which had crept in during its initial stage, have been now identified in delimitation of taxa. In this catalogue, an attempt has been made to review the generic and specific groups in four Permian palynotaxa, .viz., *Callumispora, Parasaccites, Crucisaccites* and *Faunipollenites*. On this line of approach, more taxa will be taken up subsequently, with a view to streamline their taxonomic treatment. The ultimate aim is to evolve a simplar, logical and practical system of identification based on major qualitative expressions of spore-pollen construction and exine characters.

The relative abundance of these four genera through Lower Gondwana formations of India has also been determined and their index-value discussed. As such, the distribution of species of these genera is not known from the earlier works. It is therefore hoped that the future workers would deal each genus up to the specific level for determination of their distribution which will prove very useful for finer correlation. Only the selected species of distinct identity and restricted range have real practical value in biostratigraphy.

Key-words—Morphography, Palynology, *Callumispora, Parasaccites, Crucisaccites, Faunipollenites*, Permian, Lower Gondwana (India).

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साराँश

परमी युगीन परागाणविकरूपकों का आकारिकीय अध्ययनः केल्यूमिस्पोरा, पैरासेक्काइटिस, क्रूसिसेक्काइटिस एवं फ़ॉनिपॉलिनाइटिस

रामशंकर तिवारी, सुरेश चन्द्र श्रीवास्तव, अर्चना त्रिपाठी एवं विजया

जैवस्तरविन्यास के लिए वर्गिकीय अध्ययन अत्यन्त आवश्यक है, वर्गिकीय अध्ययन हेतु वर्गकों के परिसीमन करने में सूक्ष्म-आकारिकीय अध्ययन एवं अंगविन्यास के उद्देश्यात्मक विश्लेषण की महत्वपूर्ण भूमिका है। ऐसा दृष्टिकोण स्पष्टतया विकीरित सूक्ष्म-पादपाश्मों के लिए समालोचना का विषय है विशेषतया जहां वर्गीकरण प्ररूप एवं आकार पर ही आधारित हो।

पुरापरागाणविक अध्ययन में अब पर्याप्त कार्य किया जा चुका है तथा प्रारम्भ में जो अपरिहार्य असंगतियाँ रह गईं थीं वर्गकों के परिसीमन में उन सभी की पहचान कर ली गयी है। इस कैट्लॉग में परमी युगीन चार परागाणविक-वर्गकों के प्रजातीय एवं जातीय समूहों की विवेचना करने का प्रयास किया गया है ये वर्गक **केल्यूमिस्पोरा, पैरासेक्काइटिस, क्रूसिसेक्काइटिस** एवं **फ़ॉनिपॉलिनाइटिस** हैं। इसी दृष्टिकोण को ध्यान में रखते हुए और वर्गकों की वर्गीकीय स्थिति स्पष्ट करने के लिए उनका अध्ययन किया जायेगा। उक्त अध्ययन का मुख्य उद्देश्य बीजाणु-परागकणों की संरचना सम्बन्धी मुख्य गुणात्मक व्याख्याओं एवं बाह्यचोल के लक्षणों पर आधारित अभिनिर्धारण की एक सरलतम, तर्कसंगत तथा व्यावहारिक प्रणाली विकसित करना है।

प्रस्तुत कैटलॉग में भारत के अधरि गोंडवाना शैल-समूहों में विद्यमान इन चार प्रजातियों की आपेक्षिक बाहुल्यता सुनिश्चित की गई है तथा इनके सूचक-मान की विवेचना भी की गई है। वास्तव में पहले किये गये शोध-कार्यों से इन प्रजातियों की जातियों के वितरण का पता नहीं चलता। अतएव ऐसी आशा है कि भविष्य में शोधकर्त्ता प्रत्येक प्रजाति के वितरण को सुनिश्चित करने के लिए इनका जातीय स्तर तक विवेचन करेंगे जो कि यथार्थ सहसम्बन्धन करने में वहुत उपयोगी सिद्ध होगा। जैवस्तरिक अध्ययन में केवल विशिष्ट पहचान एवं सीमित विस्तार वाली जातियों की ही वास्तविक उपयोगिता है।

PALYNOLOGICAL studies of the Permian sediments in India started in nineteen thirtees, and by the turn of seventies the taxa-boom reached its culmination.

Such a situation was, however, inevitable at those initial stages because new palynofloras were being handled which contained very widely diversified pollen and spores produced by Glossopteris Flora. The numerosity of proposals for new species, and their loose circumscription in some cases, have led to diminish the utility of species as stratigraphic markers. It is now felt that the time has come when important generic groups must be redefined in view of the accumulated data, and the vague species should be recircumscribed so as to make them effective for zonations. This catalogue is the result of such an approach. It includes an annotated account of four Permian genera—*Callumispora, Parasaccites, Crucisaccites* and *Faunipollenites*. To achieve a better understanding, the data gathered in course of our studies during the last several years have been incorporated in the generic descriptions. Various species have also been resolved and re circumscribed. Such resolution has been based on the re-examination of types, where available, and also on the study of several comparable forms. In case where holotypes were not traceable, the lectotypes are designated to represent the taxa; similarly, isotypes are also proposed for such species where they were not identified in the original protocol. In these four genera some species have been identified which do not find their place in the genera to which they were originally assigned. This has made the systematics more comprehensive.

Callumispora, a more or less circular spore with laevigate exine having intrapunctate structure, is a characteristic taxon in Permian and Triassic of India and Australia. It has been ascertained that the structure of the exine is not a secondary deformity; it is the basic regular and organised character, which differentiates it from *Punctatisporites*. The size-range of spores and peculiar exine thickness are considered as criteria for species circumscription.

Parasaccites is a well defined monosaccate pollen in which the saccus encroaches on to the body on both the faces equally, giving rise to the 'para' condition of attachment. Various species of this genus have been resolved and only six well-defined species have been retained. Similarly *Crucisaccites*, markedly identified on the basis of its 'cruciate' organization of saccus attachment, has been restudied for the resolution of its species. Many new characters have been recorded in this taxon and the additional features of exine saccus-folds and monolete mark have been brought to light.

The striate-disaccate pollen in Permian assemblages constitute a complex population. The prolific variation in striations, body shape and saccus attachment makes the striate group a difficult area of delimitation for clean species which could be effectively used in stratigraphy. In this account, the genus *Faunipollenites* has been taken for resolution. The ill-defined body nexine characterizes this disaccate pollen. It is relatively a simpler group. Earlier the species were proposed usually on the basis of overall size, which, however, do not stand in view of merging boundaries of various size-clusters. The width of distal saccus-free area also guides for species identification.

Scanning electron microscopy, utilized in some cases, deciphered significant surface characters and organization. The protosaccate fill of the saccus in the saccate pollen could be ascertained in the transmitted light by L-O analysis (Tiwari, 1981). Such analysis has otherwise also indicated that almost all the Permian saccate pollen possess protosaccate condition of the saccus.

The type specimens, referred to as slide no. BSIP, are stored in BSIP Museum.

MORPHOTAXONOMY

Genus—Callumispora Bharadwaj & Srivastava 1969

Type species—*Callumispora barakarensis* Bharadwaj & Srivastava 1969.

Original diagnosis—"Circular, dark brown miospores; exine laevigate with tendency to become punctate and microverrucose in inter-ray area and elsewhere intrapunctate; exine 2·7 μ thick; trilete mark present" (after Bharadwaj & Srivastava, 1969; p. 220).

Discussion—The circular, subcircular or roundly triangular spores bearing a trilete mark with punctate exine were described under the genus *Punctatisporites* Ibrahim 1933. In the year 1969, Bharadwaj and Srivastava distinguished a group of spores which were characteristically trilete, spherical with differentially structured exine to accommodate them under a new name *Callumispora*. Subsequently, Bharadwaj and Varma (1974) further distinguished the genus *Callumispora* from *Punctatisporites* on the basis of overall shape and nature of exine. They also emended the diagnosis of *Punctatisporites* which reads as follows: "Trilete bearing spores, amb triangular, exine finely punctate sculptured" (after Bharadwaj & Varma, 1974: p. 107).

The genus *Callumispora* is thus referable to spores with circular shape, and laevigate, but with intrapunctate structure in the exine (Pl. 1, fig. 1), while *Punctatisporites* is punctate sculptured. The basic difference between the two taxa lies in the structured exine *vis a vis* sculptured exine.

The reassessment of morphography evolved during the recent years, and also in view of its comparative variation in different species, the diagnosis of *Callumispora* needs an emendment.

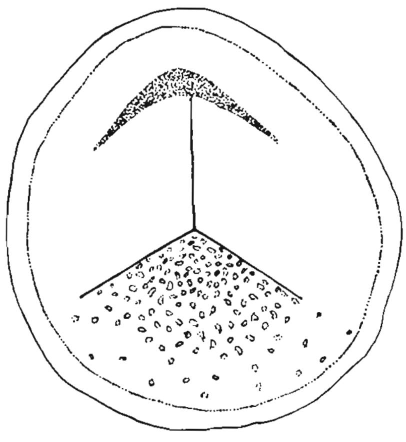
Emended diagnosis—Trilete spores with radial symmetry, spherical to sub-spherical in shape; trilete mark clear with distinct labra, arcuate rims absent; exine laevigate, intrapunctate structured, often exhibiting sharply defined exine thickness in optical section.

Description (*elaborated*)—Amb circular, trilete mark well-defined and never reduced or vestigial. Rays straight, traversing 3/4 spore radius or more, equal to each other in length and placed at equal angles. Ray-ends tapering. Labra thin and vertex slightly raised (Pl. 2, figs 1-3), but never associated with folds.

The exine thickness varying considerably (1-8 μm), the thickness demarcation line being distinctly visible in optical section along the amb margin in flattened specimens. The exine thickness in a group of spores appearing to be stratified, being divisible into two or more layers, the inner one thick and dark brown while the outer thin and yellowish brown (Pl. 1, fig. 1). In such cases, the concentric rings could be counted up to eight in number (Text-figs 2a, b). However, in another group of spores of this genus no such differentiation is perceptible even if the exine is considerably thick (Pl. 1, fig. 4).

Exine with various degrees of intrapunctate structure in different parts of specimen. In the inter-ray area the structure consisting of sparsely to closely distributed intrapuncta but elsewhere uniformly, hazily fine or distinctly fine. In certain cases the intrapuncta prominent, slightly sunken and densely set on the contact area but gradually reduced towards the margin (Pl. 1, fig. 5; Pl. 3, fig. 3). Between the puncta the exine surface simulating a microverrucose-like pattern, apparently differentiating a contact area (Pl. 1, figs 1, 2, 5). In other cases, the puncta uniformly distributed, being coarse to very fine in nature (Pl. 1, fig. 4).

Comparison—*Callumispora* compares closely with *Punctatisporites* Ibrahim 1933 emend. Bharadwaj & Varma 1974, but is distinguishable by its circular amb, and laevigate, structured exine. The exine in *Punctatisporites* is punctate sculptured. *Eupunctisporites* Bharadwaj 1962 reported from the Raniganj Stage (Upper Permian) of India is distinguishable by its circular shape and distinctly punctate (pitted) exine. *Ricaspora* Bharadwaj & Salujha 1964, also from Raniganj Stage of India, has a thin granulose perisporium all around. *Retusotriletes* Naumova 1953 bears a distinct, unstructured contact area.



Text-figure 1—Reconstruction of organisation of *Callumispora* Bharadwaj & Srivastava 1969, proximal view showing overall shape and thick intrapunctate exine.

Organisation (Text-fig. 1)—The overall shape of the spore is circular. However, subcircular to roundly triangular shapes may be assumed due to folding or flattening. The plane of flattening of the spore is not constant as is apparent from inconsistent position of the trilete mark with reference to the amb of the flattened spore. Trilete mark is distinct. Exine is intrapunctate structured.

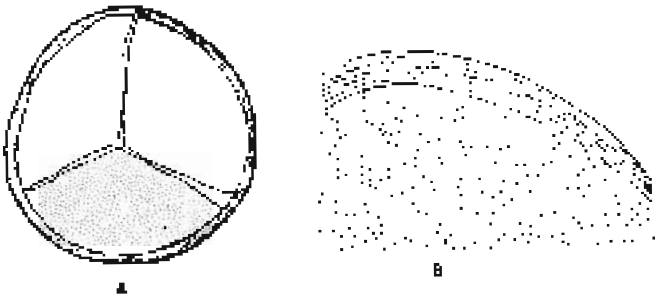
List of species on record:

- *Callumispora barakarensis* Bharadwaj & Srivastava 1969
- *C. tenuis* Bharadwaj & Srivastava 1969
- *C. tenuis* var. *minor* Bharadwaj & Srivastava 1969
- *C. gretensis* Balme & Hennelly 1956 emend. Bharadwaj & Srivastava 1969
- *C. fungosa* (Balme) Bharadwaj & Srivastava 1969 emend. Bharadwaj & Tiwari 1977
- *C. adensa* Bharadwaj, Kar & Navale 1976
- *C. uniformis* (Tiwari) Chandra & Lele 1979
- *C. magna* Kumaran & Maheshwari 1980
- *C. paliensis* Tiwari & Ram-Awatar 1989
- *C. saksenae* Tiwari & Ram-Awatar 1989

List of species resolved:

On the basis of exine structure, shape, overall size range, nature of trilete mark and exine thickness, the following species have been retained in this genus:

- *Callumispora barakarensis*
- *C. magnifica* (= *Callumispora paliensis*)
- *C. fungosa*
- *C. gretensis* (= *Punctatisporites lucidulus*, *P. subtritus*, *P. uniformis*, *P. ganjrensis*, *P. mukherjei*, *Callumispora tenuis*, *C. tenuis* var. *minor*)
- *C. adensa*



Text-figure 2A—Line drawing of holotype of *Callumispora magnifica* (Bose & Maheshwari) Bharadwaj & Srivastava showing overall shape and thick, uniformly intrapunctate structured exine. **2B**—Line drawing of part of Text-fig. 2A enlarged to show thick and stratified nature of exine.

Besides, the species of *Punctatisporites* which have been here considered under *Callumispora* are as follows:

Punctatisporites magnificus Bose & Maheshwari 1968

P. lacidatus Playford & Helby 1968

P. subtritus Playford & Helby 1968

P. gandaensis Lele & Maithy 1969

P. talchirensis Maheshwari 1980

P. mukherjeei Mukherji & Ghosh 1972

The following species do not find their place under the genus *Callumispora*.

Punctatisporites punjabensis Pant & Srivastava 1964

P. pyramidalis Singh 1964

P. spathulatus Singh 1964

P. reticulatus Pant & Srivastava 1965

P. plicatus Bose & Kar 1966

P. indicus Tiwari 1968

P. foveolatus Maheshwari & Bose 1969

P. bhattacharyai Maheshwari & Banerji 1975

P. difficilis Foster 1979

P. priscus Bharadwaj & Salujha 1965

Callumispora magna Kumaran & Maheshwari 1980

C. saksenae Tiwari & Ram-Awatar 1989

The exine of the above species are not intrapunctate structured, and hence they cannot find their place in the genus *Callumispora*. In *Punctatisporites pyramidalis* and *P. spathulatus* the exine is described to be smooth while in *P. punjabensis* and *P. reticulatus* it is sculptured. *P. plicatus* is a badly preserved specimen, hence it is difficult to ascertain the characters. In *P. foveolatus* the exine is very thin and inter-ray area is almost foveolate. *P. priscus* also has very thin, folded exine which is smooth and does not appear to be structured. *P. mukherjeei* bears forked ray ends. *Callumispora magna* bears verrucae-like sculpture over the exine. *C. saksenae* possesses flappy, acrune folds along the trilete rays; such a character is absent in *Callumispora*. Thus, most of these species bear supra-surface features, therefore, they even do not belong to the genus *Punctatisporites*.

Occurrence—Early Permian (Talchir Formation) to Early Triassic (Panchet Formation).

Provenance—Karharbari Formation (Early Permian).

Description of species resolved

Callumispora barakarensis Bharadwaj & Srivastava 1969 emend.

Pl. 1, figs 1-3

Holotype—Bharadwaj and Srivastava, 1969, pl. 1, fig. 1, size 117 μm; Slide no. BSIP 2974, Nandira Colliery, Talchir Coalfield, Orissa; Barakar Formation, Permian.

Isotype—Bharadwaj and Srivastava, 1969, pl. 1, fig. 2; Slide no. BSIP 2978.

Original diagnosis—"Circular, thick walled, trilete, size range 88-140 μ but mostly 100 μ. Trilete mark distinct, rays equal, 30-40 μ in length. Exine golden brown, 4-6 μ in optical section, stratified and laevigate. Inter-ray area microverrucose sculptured. Exine faintly structured all over but showing sparsely distributed intrapunctation in inter-ray area" (after Bharadwaj & Srivastava, 1969, p. 222).

Discussion—The distribution of exine structure in the present species is not uniform. The intrapuncta are prominent and sparsely set in inter-ray area but they gradually get reduced in number

PLATE 1 →

(Stage Co-ordinates are given as England Finder No.) × 750

1. *Callumispora barakarensis* Bharadwaj & Srivastava 1969, holotype in proximal view showing intrapuncta in inter-ray area and thick stratified exine, Slide no. BSIP 2974, EF – M46/2. × 750.
2. *Callumispora barakarensis* Bharadwaj & Srivastava 1969, proximal view showing coarse intrapuncta and thick stratified exine. Slide no. BSIP 9807, EF – Q44/2. × 750.
3. *Callumispora barakarensis* Bharadwaj & Srivastava 1969, proximal view showing thick exine. Slide no. BSIP 9808, EF – P46/1. × 750.
4. *Callumispora gretensis* (Balme) Bharadwaj & Srivastava 1969 here emended. Specimen illustrated by Bharadwaj and Srivastava (1969) as Holotype of *C. tenuis* in proximal view showing uniform intrapuncta and thick non-stratified exine. Slide no. BSIP 2970, EF – M51/1. × 750.
5. *Callumispora barakarensis* Bharadwaj & Srivastava 1969, inter-ray area of holotype enlarged showing densely set intrapunctate structure. × 1,000.

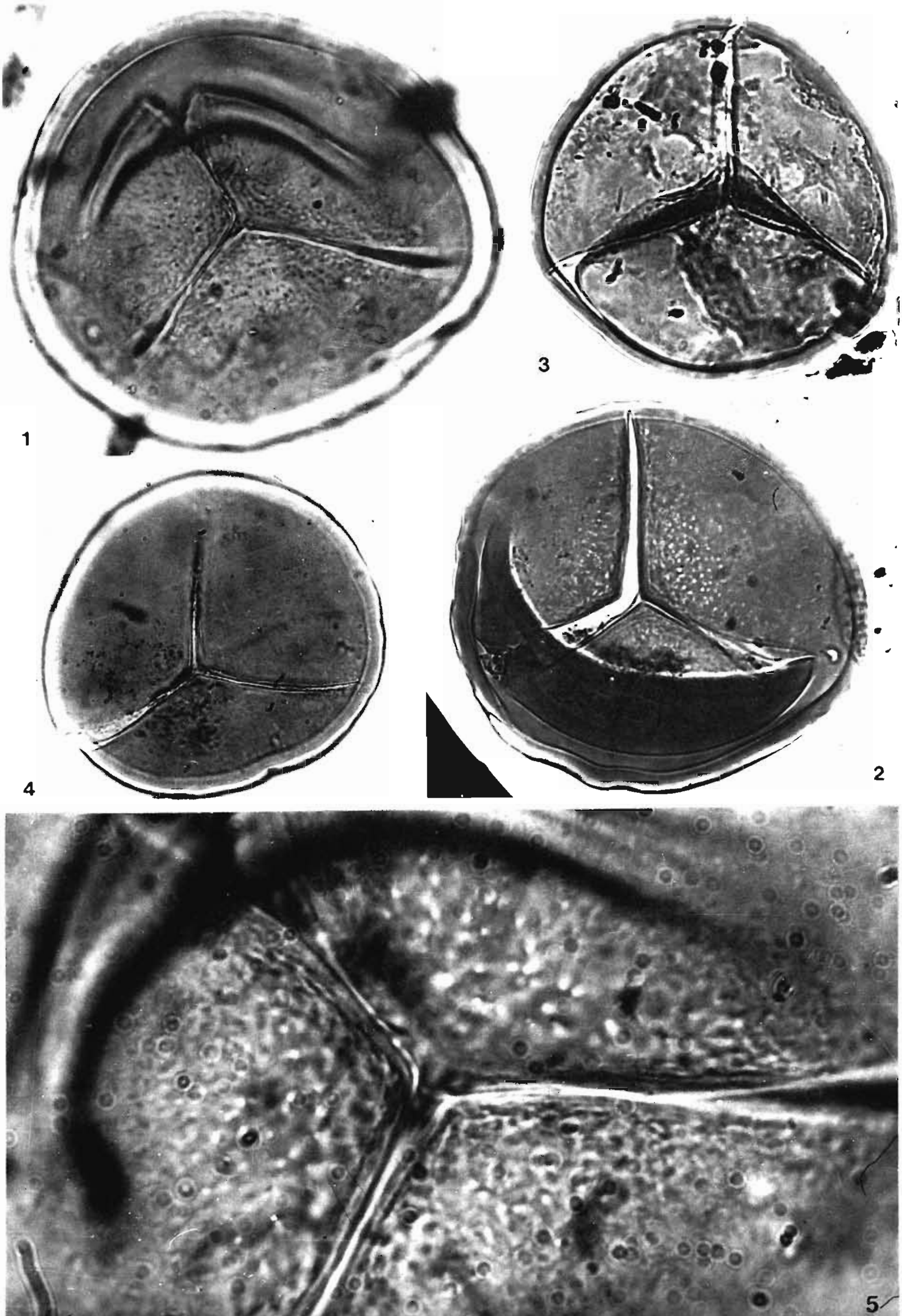
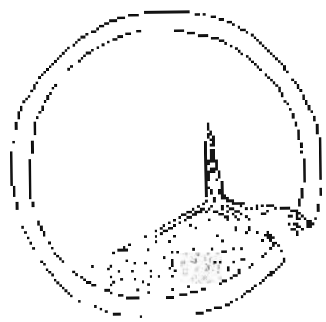


PLATE 1



Text-figure 3—Drawing of holotype of *Callumispora fungosa* (Balme) 1963 showing thickness of exine ... × 500.

towards periphery and disappear thus simulating to differentiate a contact area (Pl. 1, fig. 1). The puncta are sparsely set in the contact area and the exine between them are slightly scabrate (Pl. 1, fig. 5). Elsewhere the exine is moderately and faintly structured.

Emended diagnosis—Circular, thick walled trilete, size range 85-140 μm but mostly around 100 μm. Trilete mark distinct, rays equal, 3/4 radius in length. Exine in optical section up to ... μm thick, stratified and laevigate. Interray area marked with distinct sparsely set intrapuncta, apparently simulating an *area contagiosa*. Exine beyond the contact area faintly structured. *Exine and laesurae* smooth.

Description (Bilaterale)—Spores generally circular in overall shape. Trilete mark well defined, with equal rays ending abruptly. Laesurae simple, never associated with secondary exinal folds. Vertex slightly raised. Exine fairly thick, 4-6 μm in thickness (6 μm in holotype), slightly thicker along the rays than in interray areas. In optical section exine appearing stratified, divisible into two layers, the inner thick and dark brown and the outer thin, yellowish brown layer. Interray area marked with sparsely set distinct intrapuncta apparently simulating an *area contagiosa*. Exine beyond the contact area faintly structured. *Exinal laesurae* smooth.

Callumispora magnifica (Bose & Maheshwari) 1968 comb. nov.

Text-figs 2a, b

1968 *Punctatisporites magnificus* Bose & Maheshwari, pl. 3, figs 5-7, text-fig. 2.

1969 *Callumispora paliensis* Tiwari & Ram Awatar, pl. 1, figs 7-8, text-fig. 1.

Holotype—Bose and Maheshwari, 1968, pl. 3, fig. 5, size 102 μm, Slide no. 3C 14(5) S. Landa, after the fall (about 2.5 ft thick exposure in river bed), Sermian.

Original diagnosis—Spores circular or subcircular, trilete distinct, rays 2/3-4/5 spore radius long, exine thick with concentric rings, intramicropunctate, equator smooth (after Bose & Maheshwari, 1968, p. 19).

Discussion—The exine of the present species is 4-7 μm thick and shows distinct concentric rings (cf. Bose & Maheshwari, 1968, pl. 3, fig. 7). The surface of the exine is smooth but shows uniformly distributed fine intrapunctations all over. These two characters clearly indicate that this species must find its place in the genus *Callumispora*.

Description (Bilaterale)—Spores circular or subcircular in polar view, 58-140 μm in diameter; trilete rays distinct, sometimes slightly excentric, 2/3-4/5 spore radius long (22-56 μm), rarely attaining the spore equator, equal in length, tapering at the ends. Exine 4-7 μm thick, showing up to 6 concentric rings (Text-fig. 2a, b), the inner darker and the outer thin hyaline in colour. *Exine and laesurae* smooth. Intramicropunctate structure of exine uniformly distributed all over; intrapuncta fine, closely placed.

Comparison—The thickness of exine and size in this species is comparable with *C. keraharensis* and *C. fungosa*. However, *C. keraharensis* differs in having coarser intrapuncta in interray area apparently differentiating a contact area while *C. fungosa* contains coarser, anastomosing intrapuncta all over the body.

Remarks—*C. paliensis* is identical in the nature of exine and extent of trilete rays with *C. magnifica*. Hence, it has been considered as synonym of the latter.

Callumispora fungosa (Balme) Bharadwaj & Tiwari 1977

Pl. 3, figs 1, 2; Text-fig. 3

1963 *Punctatisporites fungosus* Balme, pl. 4, fig. 10.

Holotype—Balme, 1963, pl. 1, fig. 10, size 11-

PLATE 2

1-5. *Callumispora* Bharadwaj & Srivastava 1969, SEM photomicrographs.

1. Showing raised trilete mark on depressed contact area.

2. Showing shape, smooth exine and raised trilete mark.

3. Showing smooth surface and raised exine due to the presence of crescentoid fold inside the interray area.

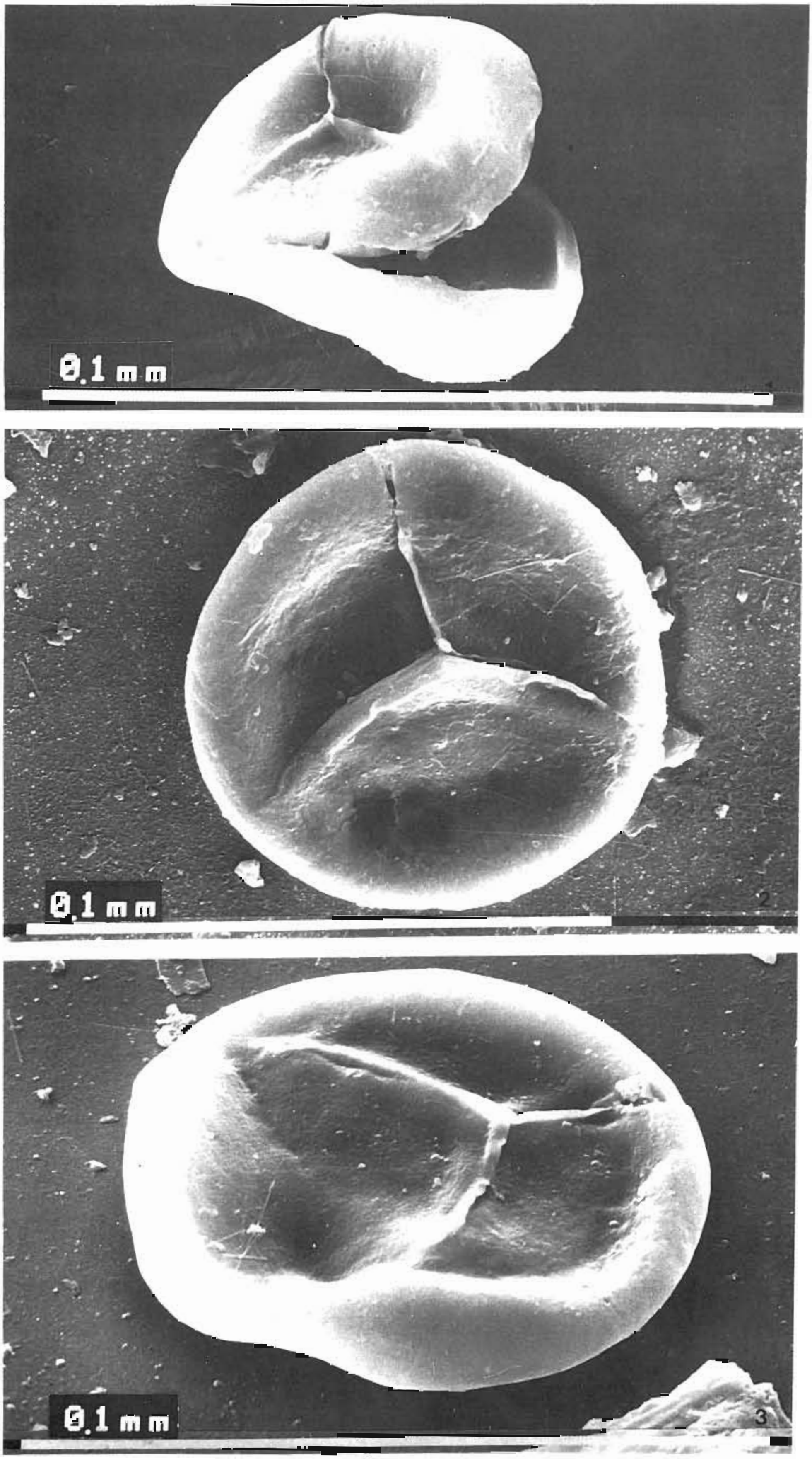


PLATE 2

µm, slide no. [illegible], Well at Point [illegible], Upper Greenough River area (Sample [illegible]), Western Australia; Kockatea Shale, Early Triassic.

Paratype—Balme 1963, pl. [illegible], fig. [illegible], slide no. [illegible].

Original diagnosis—"Amb circular, periphery smooth, oblique polar compressions common and exine frequently ruptured. Trilete scar distinct. Laesurae straight and often of unequal length but seldom extending more than about half-way to the equatorial margin. Groove of commissure visible in some specimens. Exine very thick, with fine irregularly distributed pits visible under oil immersion. Narrow anastomosing pits and channels sometimes developed particularly in the area of the proximal pole (pl. 4, fig. 11). These channels are probably due to partial destruction of the exine, either during fossilisation or as result of the maceration process" (after Balme, 1963, p. [illegible]).

Discussion—Bharadwaj and Tiwari (1977) considered that the exine of the above specimens is coarsely intrapunctate and emended the diagnosis of species to accommodate under the genus *Callumispora*. In such specimens the puncta are coarse and show anastomosing pattern as observed by Balme (1963). The anastomosing channels appear to be natural and are not developed during fossilisation or maceration process. Similar characters have also been observed by Bharadwaj and Tiwari (1977) from Permo-Triassic sediments of India. Therefore, *Punctatisporites fungosus* (Balme, 1963) was assigned to the genus *Callumispora*. The exine also is very thick in this species and exhibits concentric layers similar to the type species.

Emended diagnosis—"Circular, trilete, rays straight, half to two-third radius long, exine 4-7 µm thick with distinctly visible, somewhat coarse intrapunctation all over the body" (after Bharadwaj & Tiwari, 1977, p. [illegible]).

Description (elaborated)—Exine 6-7 µm thick showing distinct concentric rings in optical section. Intrapuncta coarse, shallow, less than 1 µm in diameter, irregularly dispersed and showing anastomosing channels, structure more pronounced in the vicinity of proximal pole.

Comparison—The thickness of exine is comparable with that of *Callumispora barakarensis* and *C. magnifica* but the uniformly distributed coarser intrapunctation distinguishes *C. fungosa* from the above two species.

Callumispora gretensis (Balme & Hennelly) Bharadwaj & Srivastava 1969 emend.

Pl. 1, fig. [illegible]; Pl. 3, figs 4, 5

1956 *Punctatisporites gretensis* Balme & Hennelly, pl. 2, figs 11-13.

1968 *Punctatisporites* [illegible] Playford & Helby, pl. 9, fig. [illegible].

1968 *Punctatisporites* [illegible] Playford & Helby, pl. 9, fig. [illegible].

1969 *Punctatisporites uniformis* Tiwari, pl. 1, fig. [illegible].

1969 *Callumispora tenuis* Bharadwaj & Srivastava, pl. 1, fig. 3.

1969 *Callumispora tenuis* var. *minor* Bharadwaj & Srivastava, pl. 1, fig. 5.

1969 *Punctatisporites gondwanensis* Lele & Maithy, pl. 1, fig. 2.

1969 *Punctatisporites* [illegible] Maheshwari, pl. 1, fig. 2.

1972 *Punctatisporites* [illegible] Mukherji & Ghosh, pl. 2, figs 2a, b.

Holotype—Balme and Hennelly, 1956, pl. 2, fig. 11, size 110 µm (ca.), (designated in Bharadwaj & Tiwari, 1977, p. [illegible]), Main Greta Seam, [illegible] no. 2 Colliery, New South Wales; Greta Coal Measures, Early Permian.

PLATE 3

1, 2. *Callumispora fungosa* (Balme) Bharadwaj & Tiwari 1977.

1. Specimen illustrated by Bharadwaj & Tiwari 1977 as *C. fungosa* in proximal view showing thick exine. Slide no. BSIP [illegible], EF [illegible] × 750.

2. A part of specimen in fig. 1 enlarged to show thick stratified nature of exine and coarser intrapuncta × 1000.

3. *Callumispora* Bharadwaj & Srivastava 1969. SEM photomicrograph of inter-ray area showing depressed nature of exine due to intrapuncta. The exine in between intrapuncta simulate verrucae-like pattern.

4, 5. *Callumispora gretensis* (Balme & Hennelly) Bharadwaj & Srivastava 1969 here emended.

4. Specimen illustrated by Lele and Maithy 1969 as holotype of *Punctatisporites gondwanensis* in proximal view. Slide no. BSIP [illegible], EF [illegible] × 750.

5. Proximal view of specimen illustrated by Tiwari 1968 as Holotype of *Punctatisporites uniformis*. Slide no. BSIP [illegible], EF [illegible] × 750.

6-8. *Callumispora magnifica* (Bose & Maheshwari) comb. nov. showing uniform intrapunctate exine structure and extent of trilete rays up to equator.

6. Specimen illustrated by Tiwari and Ram-Awatar 1989 as holotype of *Callumispora* [illegible] in proximal view. Slide no. BSIP [illegible], EF [illegible] × 500.

7. Slide no. BSIP [illegible], EF [illegible] × 500.

8. *Callumispora* [illegible] Bharadwaj, Kar & Navale 1976. Isotype in proximal view. Slide no. BSIP [illegible], EF [illegible] × 750.

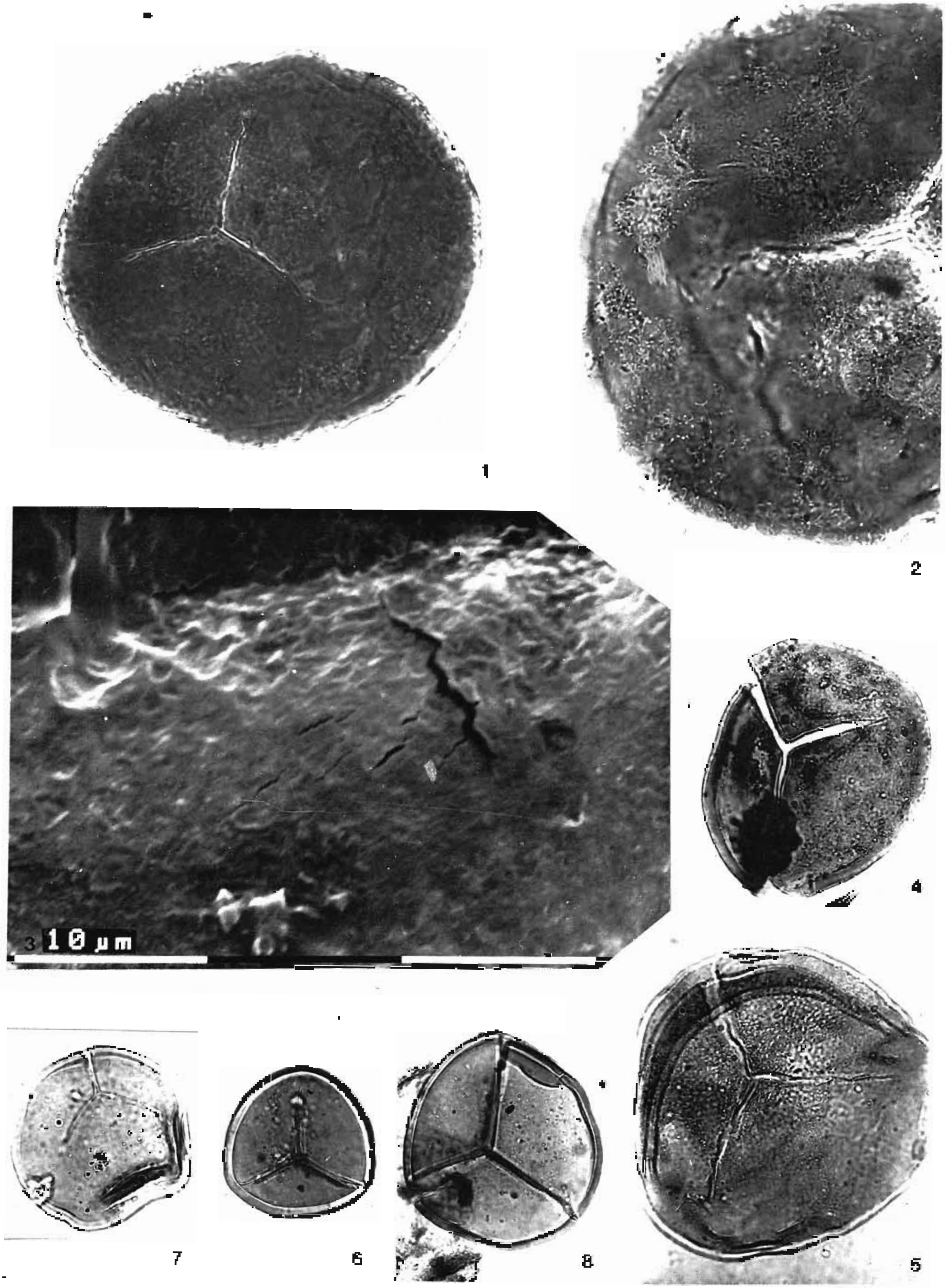


PLATE 3

Text-figure 4—[illegible] drawing of *Callumispora gretensis* (Balme & Hennelly) Bhardwaj & Srivastava [illegible] Specimen illustrated by Balme and Hennelly (1956) as *Punctatisporites gretensis* pl. 2, fig. 11 (holotype) showing uniformly intrapunctate exine.

Original diagnosis—"Amb circular. Trilete sutures straight and clearly defined extending about three quarters of the spore radius, lips prominent, sometimes slightly raised, short arcuate convergent folds occasionally present at the extremities of the rays. Exine about [illegible] μm thick, psilate or finely granulate" (after Balme & Hennelly, 1956, p. 245).

Discussion—Balme and Hennelly (1956) described *Punctatisporites gretensis* from the Lower Permian of New South Wales and considered its exine to be smooth or finely granulate. Later, Bharadwaj and Srivastava (1969) suggested that exine of these spores is intrapunctate structured, hence this species was accommodated in *Callumispora*. The exine of the first illustrated specimen by Balme and Hennelly (1956, pl. 2, fig. 11) appears to be finely intrapunctate in structure; it is not sculptured (Text-fig. 4). The exine is fairly thick but does not show concentric rings as is evident in the type specimen. Several other species have been described in subsequent years, which possess similar nature of exine, the only difference being in size ranges. These characters are, however, overlapping. The resolution through biometric analyses appears to be difficult in normal practice. Therefore, it has been concluded that they represent one species.

The characters considered here to be significant are:

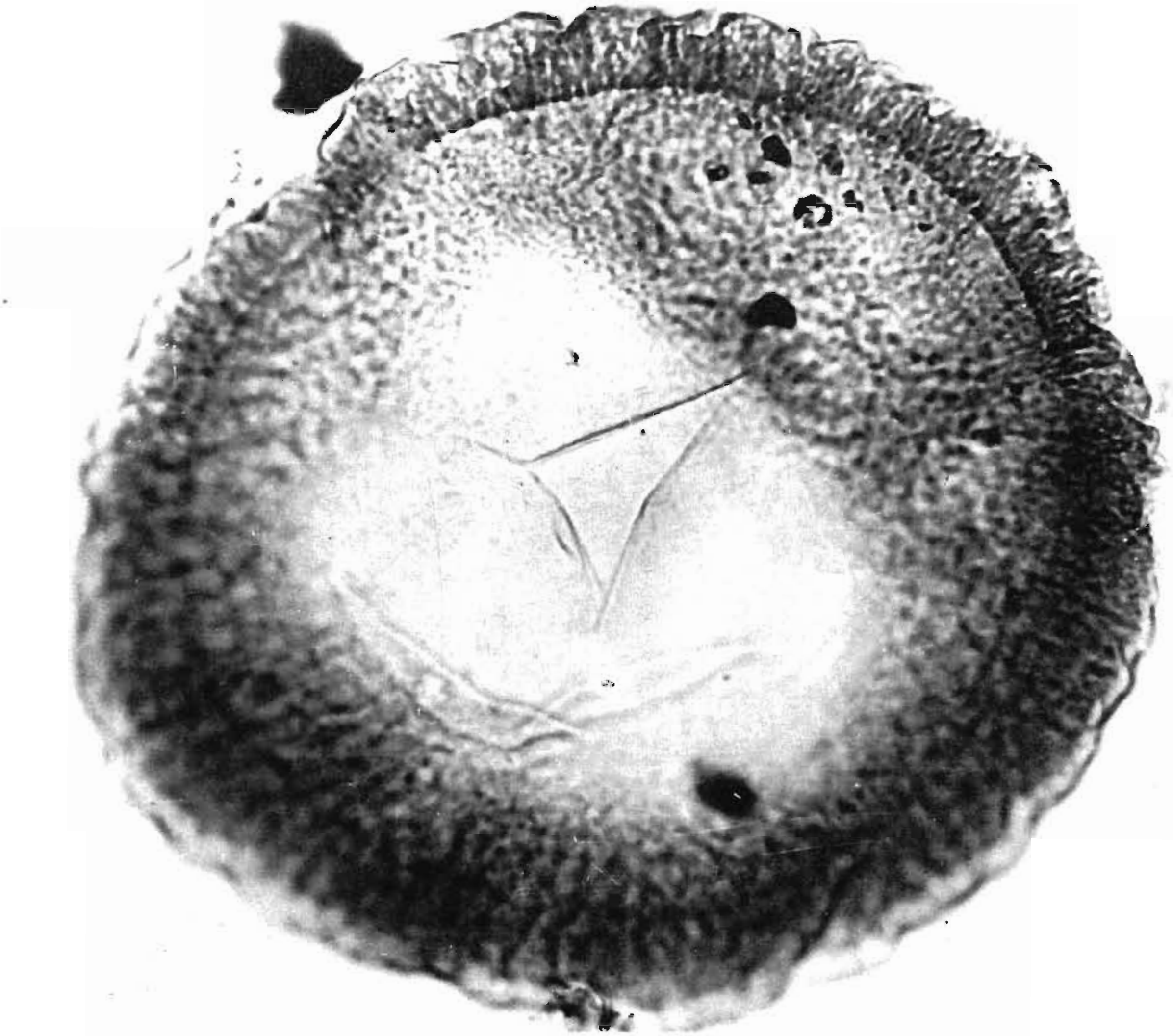
1. Finely, uniformly intrapunctate structured exine.
2. Thick to thin exine showing no concentric rings.

The bases for considering the synonymy of various species are described below:

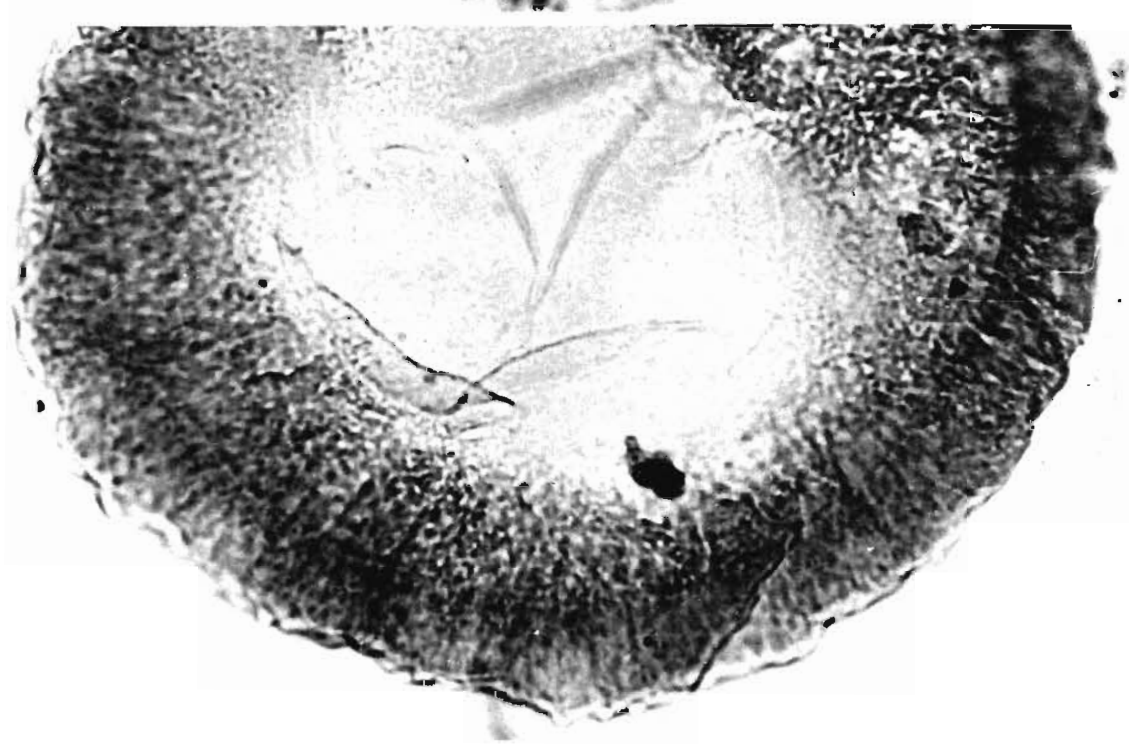
1. *Punctatisporites gretensis* Balme & Hennelly 1956—The specimens described by Balme and Hennelly (1956) appear to be heterogeneous with respect to the nature of exine. The first illustrated specimen (Balme & Hennelly, 1956, pl. 2, fig. 11) appears to be uniformly intrapunctate (Text-fig. 4) and not psilate or finely granulate. Such trilete spores from the Lower Gondwana sediments by and large have been observed to have a structured exine and are not sculptured. On this basis this species was considered by Bharadwaj and Srivastava (1969) under the genus *Callumispora*. Considering this similarity, Bharadwaj and Tiwari (1977, p. 34) have already designated the first specimen of Balme and Hennelly (1956, pl. 2, fig. 11) as its holotype which was not done earlier.
2. *Punctatisporites incidutus* Playford & Helby 1968—Playford and Helby (1968, p. 107) described this species as "laevigate, but with distinct to perceptible fine, dense infragranulation" which is similar to *P. subtritus*. These two species were not compared by the authors but the apparent differentiation was based on size and the exine thickness. The overall size and exine thickness was 42-6[illegible] μm and 2-4 μm in *P. incidutus* and 65-126 μm and 3.5-4.5 μm in *P. subtritus* respectively. Such an overlap in overall size ranges as well as thickness of exine is, however, not practicably differentiable and, hence, these species should be considered as junior synonym of *C. gretensis* (Balme & Hennelly) Bharadwaj & Srivastava 1969.
3. *Punctatisporites subtritus* Playford & Helby 1968—This species was considered by Playford and Helby (1968) to be similar to *Punctatisporites gretensis* in respect to size, shape, and apertural features but was differentiated because it was understood that the nature of exine in *P. gretensis* is non-structured. However, this is not tenable now because the exine in both the species is uniformly intrapunctate in structure and, hence

PLATE 4

1. *Callumispora* [illegible] Bharadwaj & Tiwari 1964. [illegible] type—proximal face showing the [illegible] central [illegible] ([illegible]) trilete [illegible] and [illegible] folds at [illegible]. Slide no. BSIP [illegible]
2. Distal face of specimen in fig. 1 showing intrapunctate structure of exine and [illegible] × 1000.



1



2

PLATE 4

P. sobrinus should be considered as a junior synonym of *Callumispora gretensis* (Balme & Hennelly) Bharadwaj & Srivastava 1969.

4. *Punctatisporites uniformis* Tiwari 1968—Chandra and Lele (1979) have transferred this species to the genus *Callumispora* on the basis of exine structure. The overall size and exine structure of *P. uniformis* (Pl. 5, fig. 5) compare closely to *Callumispora gretensis* except the thickness of exine which is again not well marked. Hence, *P. uniformis* is treated to be a junior synonym of *C. gretensis*.

5. *Callumispora tenuis* Bharadwaj & Srivastava 1969—The specimens described under *C. tenuis* (Pl. 1, fig. 4) were differentiated from *C. barakarensis* in being slightly smaller in size, having nonstratified exine and undifferentiated contact area. These characters encompass the specifications designated for *C. gretensis* and hence, *C. tenuis* is considered here to be a junior synonym of *C. gretensis*.

6. *Callumispora tenuis* var. *minor* Bharadwaj & Srivastava 1969—This variety was statistically differentiated from *C. tenuis* in having smaller size (60–90 µm) and much thinner exine (1.5 µm). However, spores having a uniformly distributed intrapunctate structured exine have been observed to vary greatly in their overall size range and it seems impracticable to differentiate such taxa on the basis of their size variations. Therefore, *C. tenuis* var. *minor* has been merged here alongwith *C. gretensis*.

7. *Punctatisporites gurgurensis* Lele & Maithy 1969—The specimens described by Lele and Maithy (1969) were differentiated from *P. gretensis* Balme & Hennelly in having circular to circular-triangular outline and marginal thickenings. The type specimen has been re-examined (Pl. 5, fig. 4) and no marginal thickening has been observed. The uniform intrapunctation in exine is similar to *C. gretensis* (Balme & Hennelly) Bharadwaj & Srivastava 1969, apart from the overall size and exine thickness.

8. *Punctatisporites mukherjei* Mukherji & Ghosh 1972—Two specimens illustrated by the authors however do not conform with the description. They are larger than the size range prescribed. Holotype is also not designated. The illustrations as well as the descriptions taken together suggest that this species also conforms to *C. gretensis*.

9. *Punctatisporites infrapunctus* Maheshwari 1969—The spores included in this species, though badly preserved, show uniformly intrapunctate exine and thus are not appreciably different from *C. gretensis* except their smaller size (50–71 µm) and thinner exine (1-2 µm).

Emended diagnosis—Circular spores. Trilete distinct, rays straight extending 3/4 radius long, tapering, lips prominent, sometimes raised. Exine 2-5 µm thick without showing concentric rings at the equatorial margin, finely and uniformly intrapunctate structured, surface smooth.

Description (*Emended*)—Circular to subcircular, dark brown spores. Size range 50-151 µm. Trilete mark well defined, rays equal in length and placed at equal angles, traversing generally 2/3 body radius, ray ends tapering, labra thin and simple, frequently ruptured and vertex slightly raised. Short arcuate folds occasionally present at the extremity of the rays. Exine fairly thick, 2-5 µm at the margin, nonstratified, without any recognisable differentiation into layers, sparsely intrapunctate but more pronounced along the rays and in the angles. Contact area not delimited. Exine elsewhere finely intrapunctate. *Excrescence lineaments* smooth.

Comparison—*Callumispora gretensis* (Balme & Hennelly) Bharadwaj & Srivastava 1969 is differentiable from *C. barakarensis* and *C. fungosa* in having thinner exine without showing any concentric layers in the exine thickness. Besides, *C. barakarensis* shows conspicuous intrapuncta between trilete rays apparently differentiating a contact region. In *C. fungosa*, the exine is coarsely intrapunctate. *C. adiense* is smaller in size range (54–56 µm) having thinner exine although the exine is uniformly and finely intrapunctate.

Callumispora adiense Bharadwaj,
Kar & Navale 1976 emend.
Pl. 5, fig. 7

Holotype—Bharadwaj, Kar and Navale 1976, pl. 3, fig. 15; size 42 µm; slide no. BSIP 5159/3;

PLATE 5

1-3. *Callumispora gretensis* (Balme & Hennelly) Bharadwaj & Srivastava 1969: [illegible] analysis showing [illegible] of [illegible]. Slide nos. [illegible]. [illegible]

1. Type [illegible] as [illegible] in [illegible] view.

2. Medium forms—Exine [illegible] structure finely intrapunctate.

3. [illegible]

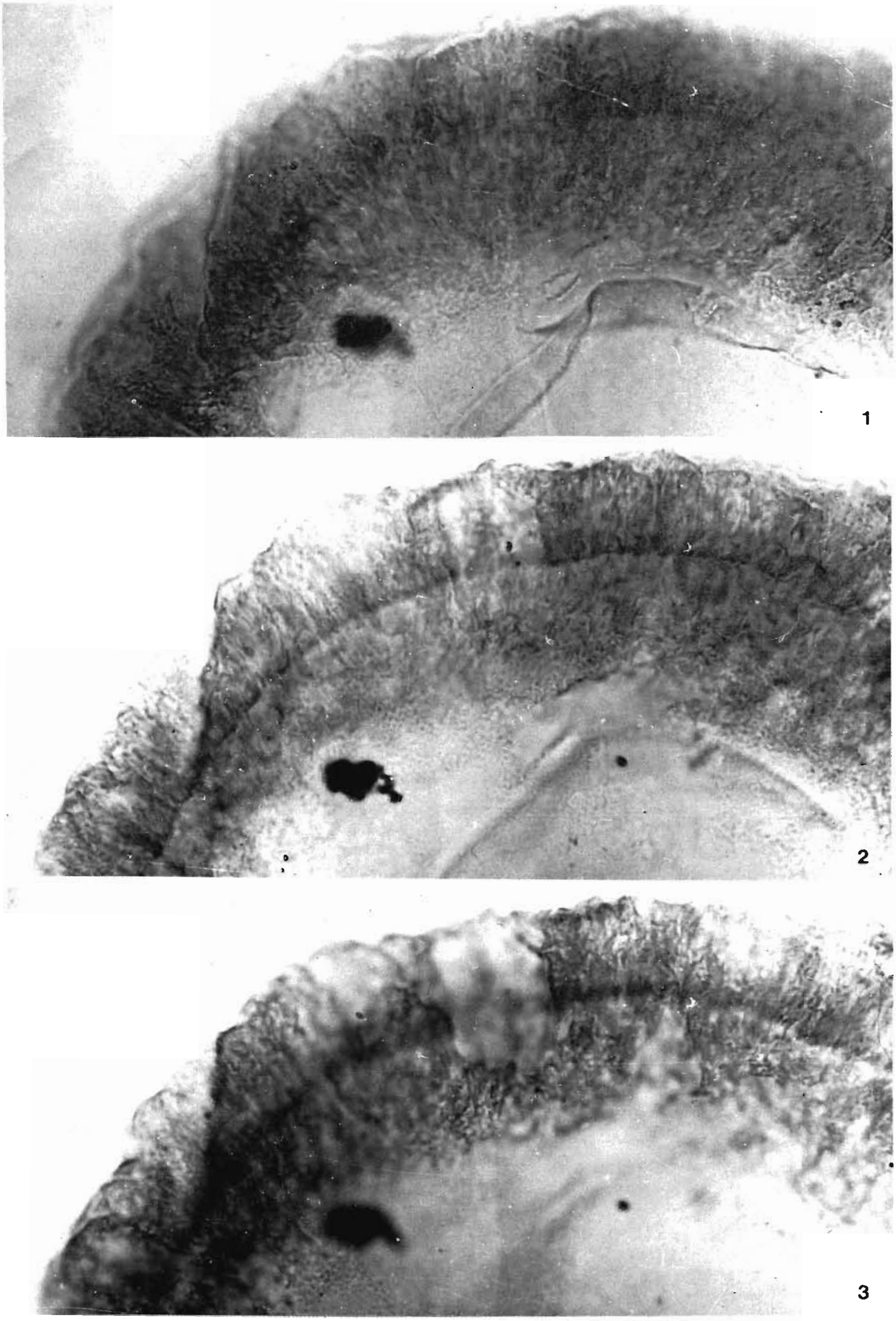
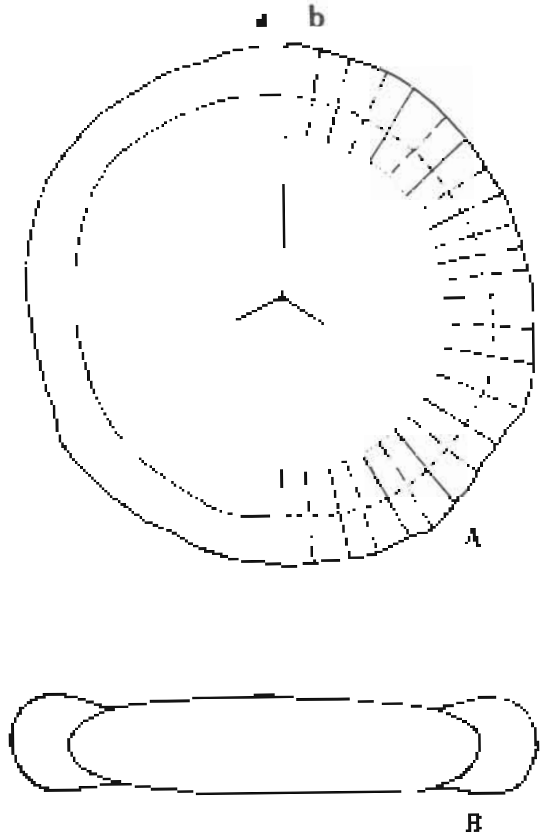


PLATE 5



Text-figure 8—Reconstruction of [illegible] *Parasaccites* (Bharadwaj & Tiwari) [illegible]: **A**, [illegible] equatorial plane; **a**, showing details of [illegible]; **b**, showing proximal saccus [illegible] between the [illegible]; **B**, Meridional section.

Maranhão Basin, Brazil; Paleozoic (Carboniferous–Permian).

Holotype—Bharadwaj, Kar & Navale, 1976, pl. 3, fig. [illegible]; Slide no. BSIP [illegible]; here designated.

Original Diagnosis—Spores subcircular, 81-89 μ. Laesurae not extending more than 1/4 length radius. Exine laevigate [illegible] (Bharadwaj, Kar & Navale, 1976, p. 74).

Discussion—The type specimen of *Cadiospora* [illegible] Bharadwaj, Kar & Navale 1976 has been re-examined which shows fine infrapunctation all over the exine. Since the size range of the specimens assigned to this species is very small (81-89 μm), hence the identity as a species remains unaffected.

In view of the observation that the exine of this species is infrapunctate the specific diagnosis is being emended here.

Emended diagnosis—Circular to subcircular spores, size range 81-89 μm. Trilete, distinct, rays equal, extending not more than 1/4 body radius, less than 1/4 [illegible] surface [illegible], uniformly and finely infrapunctate in structure.

Description (elaborated)—Spores circular to subcircular. Trilete mark distinctly defined, rays equal in length, extending not more than 3/4 of body radius, rays [illegible] at [illegible] angles; exine thin [illegible] without any perceptible difference in thickness, uniformly and finely infrapunctate structure all over the body of spore.

Comparison—The uniformly infrapunctate structure and [illegible] nature of exine in *C.* [illegible] compared to *C.* [illegible] and [illegible] is distinguishable in being extremely small in size.

Genus *Parasaccites* Bharadwaj & Tiwari 1964

Type Species—*Parasaccites korbaensis* Bharadwaj & Tiwari 1964.

Original diagnosis—Circular to subcircular, oval monosaccate with a saccus attached subequatorially on both the proximal as well as the distal face of the spore body, leaving almost circular equal bare area. [illegible] Body faces [illegible] of saccus attachment. Body distinct or diffused, exine intramicroreticulate. Proximally, sometimes a weak trilete mark present. Saccus intramicroreticulate (after Bharadwaj & Tiwari, 1964, p. 136).

Discussion—Re-examination of the type specimens of several species of this genus has revealed the presence of following characters:

1. Saccus is more or less frilled in nature at the equatorial region in most of the cases.
2. Saccus attachment with the central body is not sharp but gradually merging.
3. Saccus is of protosaccate nature, i.e., filled with coarse and fine alveoli as determined by LO analysis.

The SEM studies established the following additional characters and also confirmed the observations earlier made under light microscope.

1. Frilled nature of the saccus is noticed in almost all the specimens suggesting [illegible] nature of saccus in living condition (Pl. 15, figs 1, [illegible]).
2. Saccus surface is generally smooth but in some cases pimple-like structures are seen in high magnification (Pl. 15, figs 7, 8).
3. Central body surface is not smooth but shows [illegible] elevations [illegible] which appear to project out from within the saccus [illegible] of all the specimens (Pl. 15, figs [illegible]).

Description (elaborated)—Pollen circular, subcircular or bilaterally oval. Central body circular, subcircular, subtriangular or bilaterally oval with distinct or diffused outline. [illegible] with or without [illegible]. Saccus finely intramicroreticulate. Trilete rays weakly developed, ill-defined; [illegible] when [illegible] simple rays

PLATE 6

[illegible]

1/2 to 2/3 radius long, labra thin, vertex low. Saccus usually uniformly broad from body equator, 1/2-2/3 body radius wide in circular to subcircular forms but in bilateral forms it is narrower along the lateral sides. Zones of saccus attachment not sharply defined, sometimes being difficult to make out as the saccus gradually merge with the body. In L-O analyses para-condition of saccus attachment revealed distinctly, i.e., the extent of saccus invasion being more or less equal both on proximal and distal surfaces (Pl. 4, figs 1-3). Saccus strongly or weakly-frilled with radially oriented pleats, protosaccate, i.e., filled with alveoli, intramicroreticulate, muri generally polygonal and becoming radially elongated towards the periphery.

Comparison—Parastriopollenites Maheshwari 1967, although has para-condition of the saccus attachment, differs from the present genus in having reticuloid pattern of groves on both the faces of the central body.

Organisation (Text-fig. 5A, B)—So far, no specimen of *Parasaccites* has been found in lateral condition of preservation; the central body has also not been seen shifted from its central position. This suggests that the pollen had a wheel-like or disc-like construction in original condition. The para-condition of saccus attachment has already been established (Bharadwaj & Tiwari, 1964, text-fig. 4). The organisation of genus *Parasaccites* is deduced after studying number of specimens. The invasion of the saccus on both proximal and distal faces of central body is up to the same extent which was termed as para-condition by Bharadwaj and Tiwari (1964) suggesting an equatorial girdling nature. The frilled nature of saccus suggests that it was not flat but a swollen stucture in original condition before flattening.

List of species on record:

Parasaccites korbaensis Bharadwaj & Tiwari 1964
P. bilateralis Tiwari 1965
P. diffusus Tiwari 1965
P. distinctus Tiwari 1965
P. obscurus Tiwari 1965
P. karharbarensis Maithy 1965
P. radiplicatus Maithy 1965
P. densus Maheshwari 1967
P. longus Kar & Bose 1967
P. rimosus Venkatachala & Kar 1968
P. bellus Venkatachala & Kar 1968
P. ovatus Kar 1968
P. perfectus Bose & Maheshwari 1968
P. fimbriatus Maheshwari 1969
P. radialis Lele & Maithy 1969
P. gondwanensis (Balme & Hennelly) Segroves 1969
P. irregularis Sinha 1972
P. singrauliensis Sinha 1972
P. talchirensis Lele & Makada 1972
P. plicatus Lele & Makada 1972
P. densicorpus Lele 1975
P. lacinatus Chandra & Lele 1979

List of species resolved:

The criteria for retaining the species are para-condition of saccus attachment, intramicroreticulate exine of central body and simple trilete mark. On re-examination of the available type specimens of various species and critical analyses of the illustrations and descriptions of species, where the types are not available, only 6 species out of 22 species described so far have been retained in this genus. Rest of the species are either synonymous with the presently recognised species of *Parasaccites* or need placement in other genera on the basis of morphographic similarities (such transfers will be published elsewhere). Species retained in *Parasaccites* after present analysis are:

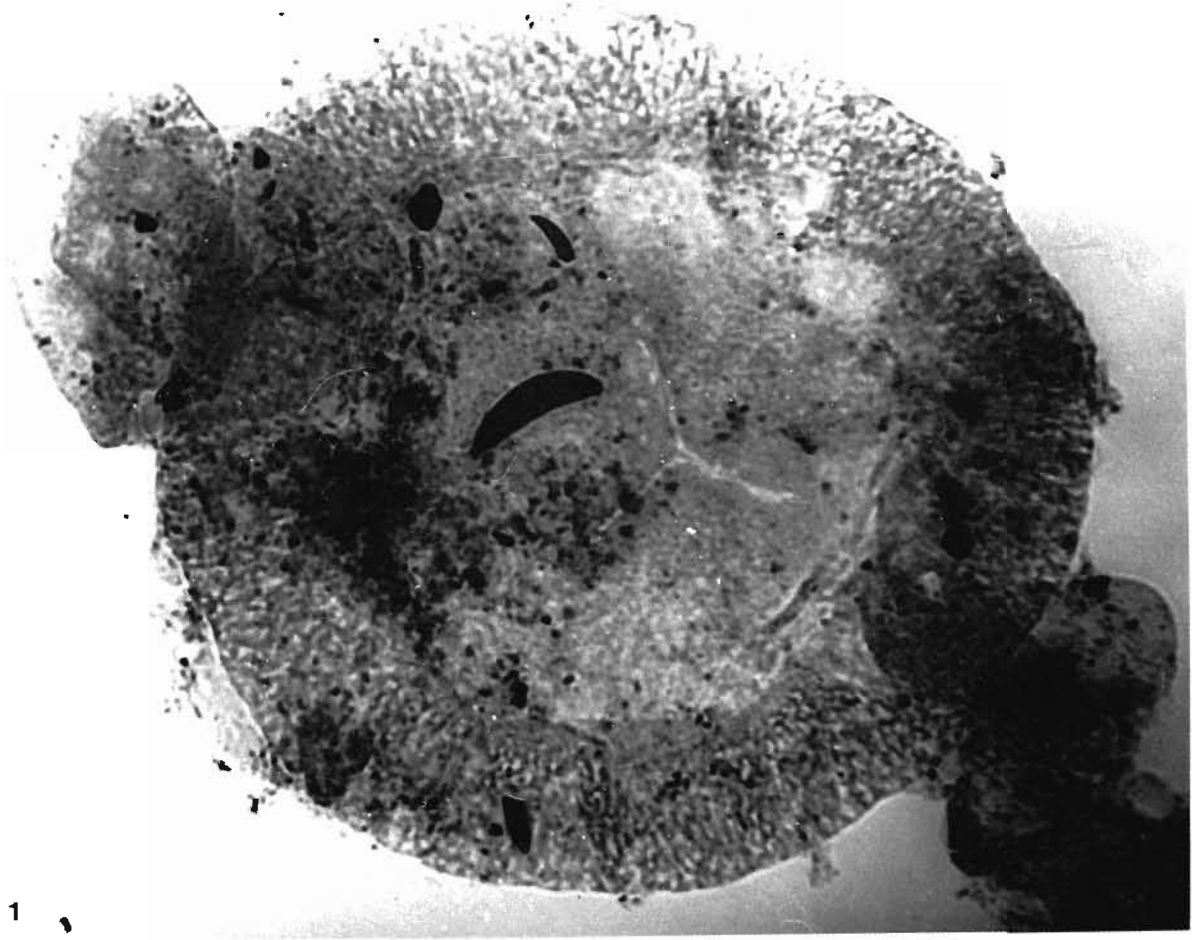
Parasaccites korbaensis (= *P. distinctus*, *P. karharbarensis*, *P. fimbriatus*, *P. singrauliensis*)
P. obscurus (= *P. diffusus*)
P. bilateralis (= *P. longus*)
P. ovatus
P. perfectus
P. densicorpus

Species which do not find their place under *Parasaccites* are: *Parasaccites radiplicatus*, *P. densus*, *P. rimosus*, *P. bellus*, *P. radialis*, *P. gondwanensis*, *P. irregularis*, *P. talchirensis*, *P. plicatus* and *P. lacinatus*.

The species *P. radiplicatus* and *P. radialis* show verrucoid sculpture on the central body and the distinct intrareticulation in the true sense of *Parasaccites* is not present. The holotype of *P.*

PLATE 7 →

1, 2. *Parasaccites obscurus* Tiwari 1965; Slide no. BSIP 9902, EF : Y35/1:
1. Lectotype showing indistinct central body outline and distinct trilete mark, × 1000.
2. Enlargement of specimen in fig. 1 showing intrareticulate pattern of central body, × 1500.



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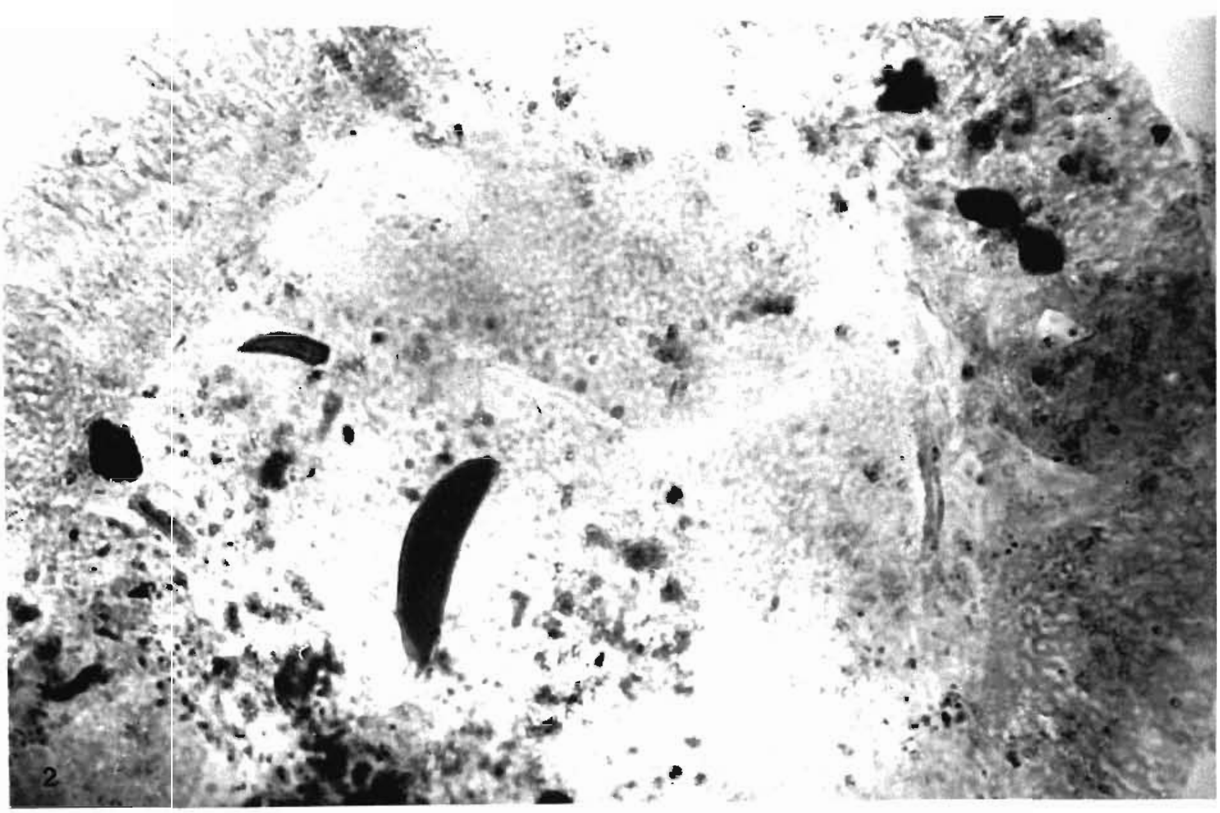


2

PLATE 7

diffusus although possesses intrareticulate exine shows rual crack pattern on the proximal side and loose exinal folds on the distal side hence, differs from *Parasaccites*. The species *P. rimosus* and *P. bolius* are nearer to genus *Potonieisporites* Bharadwaj 1954 because of body infold system. The species *P. gondwanensis* is based on the holotype of *Nuskoisporites gondwanensis*. This has already been transferred to the genus *Plicatipollenites* by Lele (1964). Because of the presence of body infold system. *P. irregularis* is distorted in nature and possesses 1-5 faint horizontal striations, the distal zone of saccus attachment being bilateral. *Parasaccites talchirensis* shows verrucoid nature of central body. The saccus attachment is more on distal face of central body thus the para-condition of saccus attachment is absent. In *P. plicatus* the central body is intramicroreticulate but the para-condition of saccus attachment is absent. *P. lacunatus* possesses lacunate folds along the trilete rays; such a character is absent in *Parasaccites*.

Occurrence—Early Permian (Talchir Formation) to Early Triassic (Panchet Formation).

Prominence—Talchir and Karharbari formations (Early Permian) and Late Permian-Early Triassic transition.

Description of species involved

Parasaccites korbaensis Bharadwaj & Tiwari 1964

Pl. 1, figs 1, 2; Pl. 5, figs 1-3; Pl. 8, fig. 2; Pl. 13, figs 1, 2, 4

1964 *Parasaccites korbaensis* Bharadwaj & Tiwari, pl. 2, figs 7, 8.

1965 *Parasaccites distinctus* Maithy, pl. 3, fig. 19.

1969 *Parasaccites fimbriatus* Maheshwari, pl. 3, fig. 10.

1972 *Parasaccites singrauliensis* Sinha, pl. 2, fig. 34.

Holotype—Bharadwaj & Tiwari, 1964; pl. 2, fig. 7; size 130 μm, Slide no. BSIP 9898, Ghordewa Sector (Bore-hole no. G 1010), Korba Coalfield, Barakar Formation, Permian.

Isotype—Bharadwaj and Tiwari, 1964, pl. 2, fig. 8, Slide no. BSIP 9898 (here designated).

Original diagnosis—± Circular miospores, 128-147 μm in size; central body distinct, 105-119 μm in size, circular, with mediumly thick intramicroreticulate exine. Trilete mark distinct, rays small, up to ⅓ the body radius long; labra thin, vertex low. Saccus 24-38 μ, uniformly wide all around the equator; zones of saccus attachment somewhat irregular, finely intrareticulate with apparently radially elongated muri (after Bharadwaj & Tiwari, 1964, p. 145).

Discussion—On re-examining the type specimen following additional observations are made:

1. The saccus margin is not smooth but wavy with weak pleats on the surface.
2. Saccus shows protosaccate condition.
3. Saccus attachment is merging with body without forming a sharp line.

The species listed in the synonymy have been found to be inseparable from *P. korbaensis*. The reassessment of the characters of the types or description and illustration of specimens have been made:

1. *P. distinctus* was originally distinguished from *P. korbaensis* because of wrinkled exine of the body. However, this character is considered here as a secondary feature of *P. korbaensis*; all other features are common.
2. *P. karharbariensis* was differentiated from type species by ± thick body and distinct zone of saccus attachment. However, a re-examination of the type specimen of this species revealed that the body is thin and the saccus attachment is not sharply defined.
3. *P. fimbriatus* was distinguished by the frilled nature of saccus and fimbriate roots. However, this feature is also noticed in *P. korbaensis*, may be the degree of frilling is relatively less pronounced. In all the frilled saccus the "roots" of saccus are fimbriate, only varying in degree of prominence. Also a reassessment of the illustration and description of this species suggest a distinct nature of central body and that the dark colour of muri is because of the preservation somewhat concealing the central body outline.
4. *P. singrauliensis* is shown to have smaller size range (65-110 μm) than *P. korbaensis* (128-147 μm). The data from subsequent studies indicate a wide range in size in the population of this kind encompassing both the species.

Description (elaborated)—Circular to subcircular pollen, 65-147 μm in size; central body outline sharply defined, conforming to the overall shape of pollen, thin to mediumly thick, with or without micro-folds or wrinkles, finely intramicroreticulate. Trilete mark generally distinct, sometimes weakly developed or obscure, simple, sometimes open, ray length not more than half of the body radius. Saccus almost uniformly broad not exceeding 1/4 of body radius (30 μm wide in holotype), finely intramicroreticulate, polygonal at the base, becoming radially elongated towards periphery, protosaccate, muri thick; saccus margin wavy, frilled with pleats of various degree. Zone of saccus attachment subequatorial proximally as well as distally, merging with the central body, not forming a sharp line of attachment.

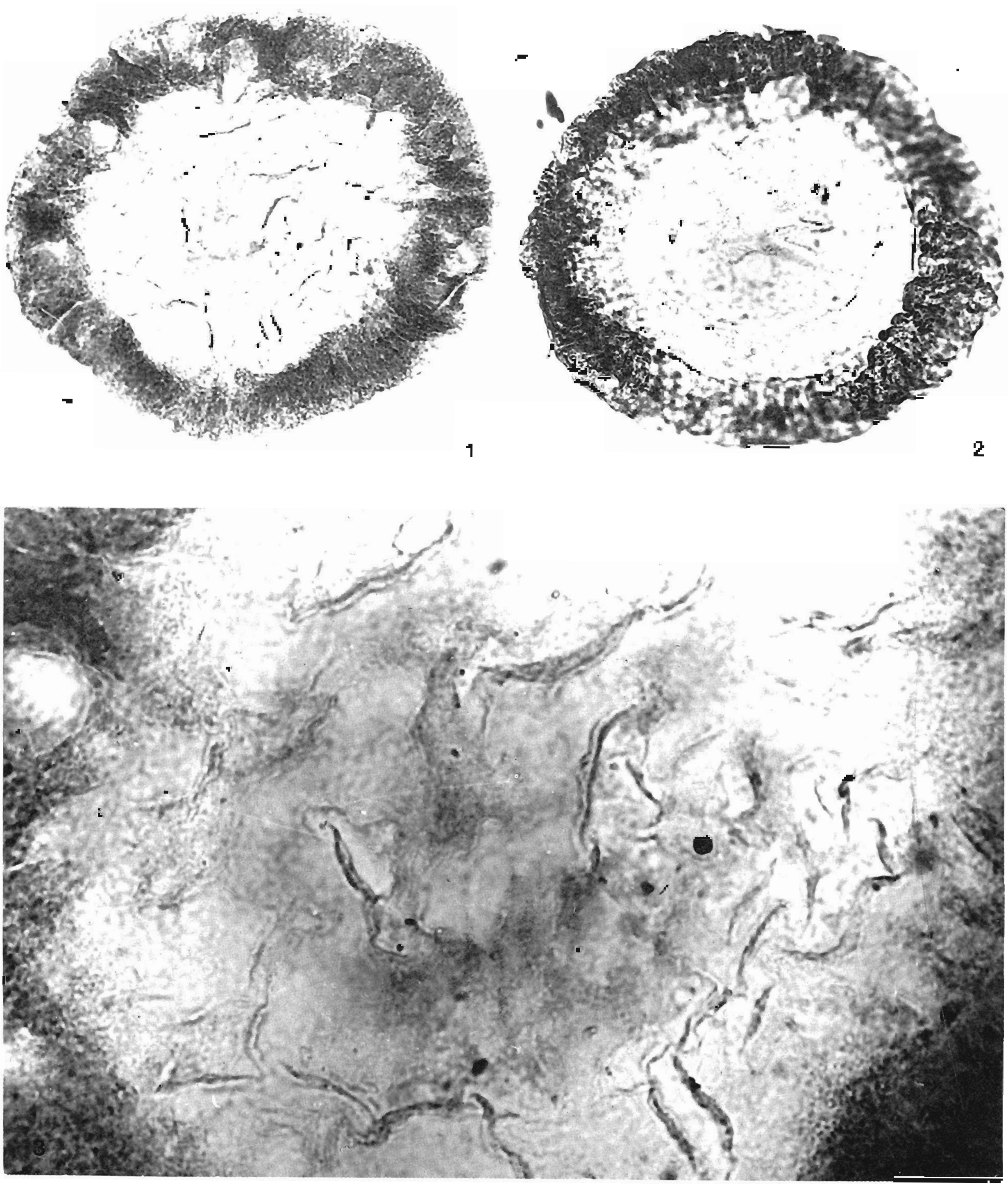


PLATE 8

[illegible]

Parasaccites obscurus Tiwari 1965

Pl. 7, figs 1, 2; Pl. 8, figs 1, 3; Pl. 10, figs 1-5

1965 *Parasaccites obscurus* Tiwari, pl. 4, figs 76, 78.
1965 *Parasaccites diffusus* Tiwari, Holotype in Bharadwaj & Tiwari 1964, pl. 2, fig. 11.

Holotype—Tiwari, 1965, pl. 4, fig. 76; size 150 µm; holotype now not traceable, 207 III Seam I, Bore-hole GT, Korba Coalfield, Madhya Pradesh; Barakar Formation, Permian.

Lectotype—Tiwari, 1965, pl. 4, fig. 78 (here designated), Slide no. BSIP 9902.

Original Diagnosis—"Subcircular, central body outline not distinguishable, exine thick, without wrinkles or folds, Y mark generally distinct, closed or open into a triangular window, rays 1/3 to 2/3 radius long, saccus narrow, finely intrareticulate with radially arranged muri" (after Tiwari, 1965, p. 182).

Discussion—The species *Parasaccites diffusus* was distinguished from *P. obscurus* by the presence of microfolds on the central body. However, on re-examining the holotype of *P. diffusus* it is observed that the microfolds are of secondary nature. They are formed by the micro-ruptures of the exine. Hence, *P. diffusus* is treated as synonym of *P. obscurus*.

Description (elaborated)—Circular to subcircular pollen grain, 107-165 µm in size. Central body outline indistinct, thin to mediumly thick with or without microfolds, finely intramicroreticulate, at times muri may be thick simulating a costate appearance. Trilete mark obscure to distinct, when present rays 1/2 to 2/3 radius long, simple with thin labra and low vertex, may be open leaving a triangular vent. Saccus with protosaccate fill, uniformly broad, 28 µm in holotype, saccus outline wavy, attachment subequatorial on both faces leaving subcircular area free, merging with central body, zone of attachment diffused, not forming a distinct line; saccus intrareticulation fine with polygonal meshes at the attachment zone becoming medium-sized and radially elongated towards periphery, muri thick or thin sometimes giving a feathery appearance to the saccus.

Comparison—*Parasaccites obscurus* is differentiated from *Parasaccites korbaensis* on the basis of diffused central body, i.e., without a distinct outline.

Parasaccites bilateralis Tiwari 1965

Pl. 9, figs 1, 2; Pl. 10, figs 1-3; Pl. 13, fig. 8

1964 *Parasaccites* Bharadwaj & Tiwari, pl. 2, fig. 12.
1965 *Parasaccites bilateralis* Tiwari, pl. 4, fig. 7.
1967 *Parasaccites longus* Sar & Bose, pl. 5, fig. 7.

Holotype—Bharadwaj and Tiwari, 1964, pl. 2, fig. 12; size 149 × 80 µm, Slide no. BSIP 9901, Topa Village Quarry, West Bokaro Coalfield, Bihar; Barakar Formation, Permian.

Isotype—Tiwari, 1965, pl. 4, fig. 73 (here designated). Slide no. BSIP 9903.

Original Diagnosis—"Central body subcircular, faintly visible, exine thin, Y mark not seen. Zones of saccus attachment ill-defined. Saccus broader at the terminal sides while narrower at the lateral sides, finely intrareticulate with a radial arrangement of muri" (after Tiwari, 1965, p. 183).

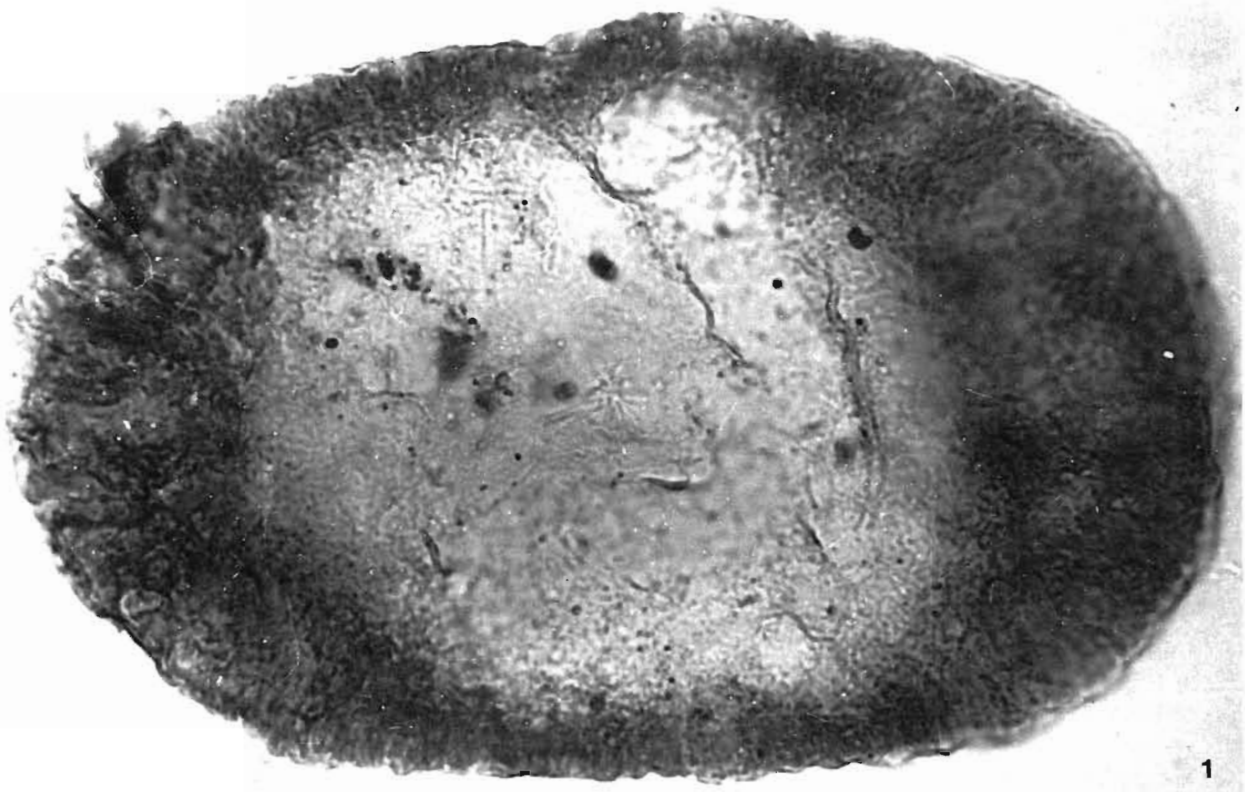
Discussion—The additional observations made during re-examination of the type specimen are: Saccus intrareticulation fine and polygonal at the base and progressively increases in size to become mediumly coarse and radially elongated towards the periphery. Saccus weakly pleated in appearance and with slightly wavy outline.

Basis for considering the synonyms are: *P. longus* was differentiated from *P. bilateralis* on the basis of length-width ratio of pollen having more length than double the width. This is not tenable because such a minor variation has been found to show a gradational incidences in the population of bilateral specimen of *Parasaccites*.

Description (elaborated)—Pollen grains bilaterally oval in outline, size range 124-193 (horizontal axis) × 68-128 µm (vertical axis). Central body thin, outline ill-defined, apparently oval to subcircular, finely intramicroreticulate. Sometimes thin microfolds present. Trilete mark not seen. Saccus with wavy outline, narrower along the lateral sides of the central body and broader at the terminal sides. Saccus attachment subequatorial on both the faces, diffused, leaving almost equal subcircular areas free. Saccus intrareticulation fine at the attachment zone and progressively becoming coarser towards the periphery, muri thick, meshes polygonal at base getting elongated with radially arranged muri towards the margin.

PLATE 9

1, 2. *Parasaccites bilateralis* Tiwari 1965 showing bilateral organization of pollen, indistinct central body outline and nature of body exine. × 1000.
1. Holotype. Slide no. BSIP 9901; [illegible]
2. Isotype. Slide no. BSIP 9903; [illegible]



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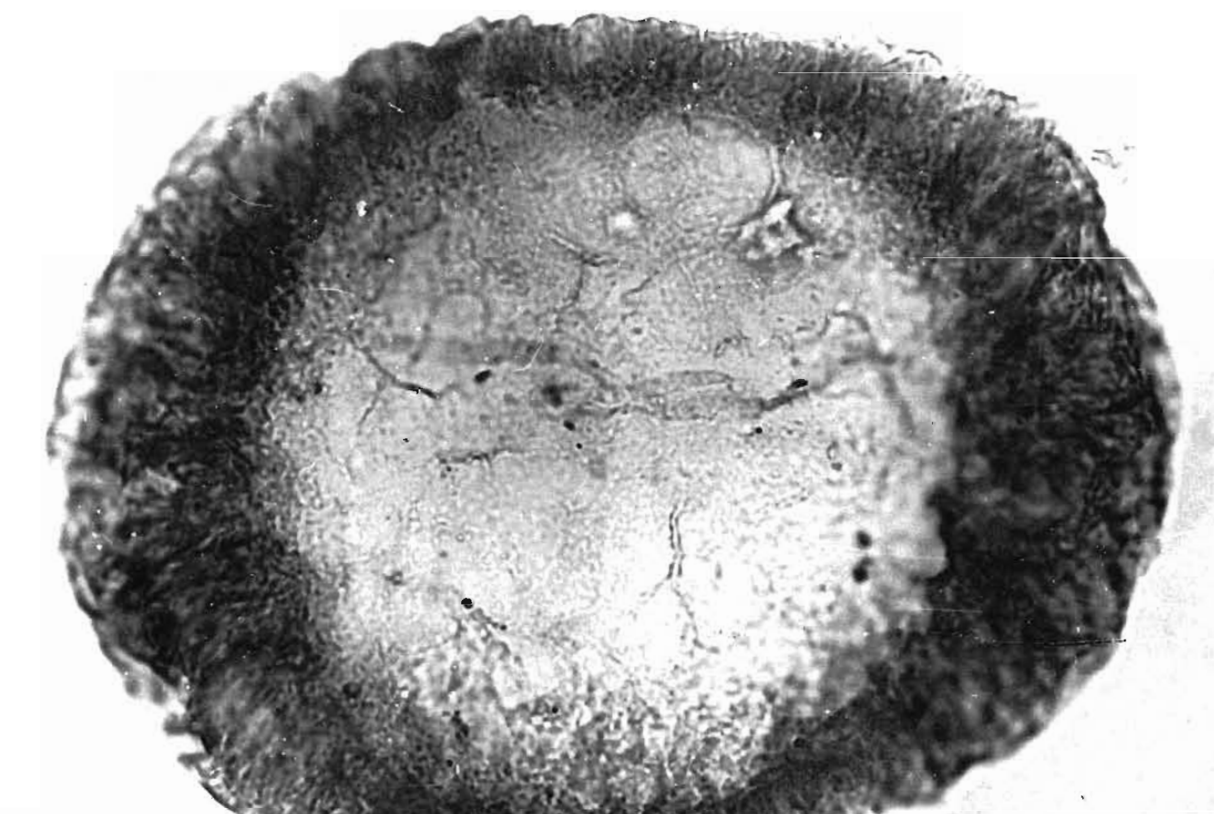


2

PLATE 9

Comparison—The present species differs from *P. korbaensis* Bharadwaj & Tiwari 1964 and *P. obscurus* Tiwari 1965 in having a bilateral symmetry.

Parasaccites ovatus Kar 1968

Pl. 12, fig. 1

Holotype—Kar 1968, Pl. 2, fig. 46; size 125 × 75 μm; slide no. BSIP 2262; Bore hole no. J. K. 3, Tiarra Coalfield, Permian, Kulti (Barren Measures) Formation.

Original diagnosis—Oval-elliptical pollen, central body well defined, circular to subcircular, intramicroreticulate. Proximal and distal attachment of saccus to central body subequatorial and ± in para-concentric (after Kar 1968, p. 124).

Discussion—On re-examination of the type specimen following additional information is recorded.

1. Saccus protosaccate, outline wavy, intrareticulation fine with polygonal meshes at the saccus root becoming slightly coarser, radially arranged towards periphery, muri thick giving leathery appearance.
2. Saccus attachment zone is of diffused and merging type.

Description (elaborated)—Pollen bilateral, oval to elliptical, 65-125 × 110-105 μm in size. Central body circular to subcircular, thin, outline distinct, finely intramicroreticulate, sometimes microfolds present. Trilete mark not seen. Saccus with protosaccate (?), having wavy outline, weakly pleated, narrower along the lateral sides and broader at terminal sides. Saccus attachment subequatorial on both faces, diffused leaving a subcircular saccus free area. Saccus intrareticulation fine with polygonal meshes at the attachment zone gradually becoming coarse with radially arranged muri towards periphery.

Remarks—The combination of the characters bilateral shape and distinct central body suggests an assignment of these forms to a separate species, otherwise in all other characters it resembles *P. bilateralis*. This species is very sporadic in the Gondwana assemblages.

Comparison—*P. ovatus* distinguishes itself from *P. obscurus* in having distinct central body. *P. korbaensis* and *P. obscurus* are differentiated from *P. ovatus* in having circular to subcircular shape.

Parasaccites perfectus Bose & Maheshwari 1968

Text-fig. 6

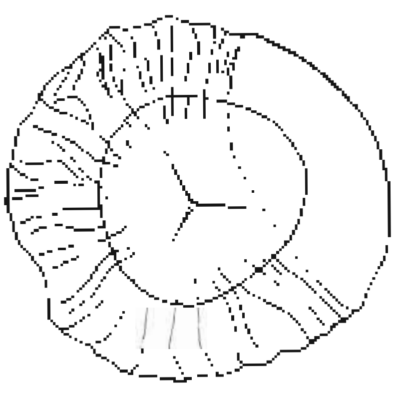
Holotype—Bose & Maheshwari 1968, pl. 9, fig. 1; size 98 μm; Slide no. 5(5)-1191-7, Luanda, after the fall (about 2·5 m) thick exposure in river beds, Early Permian.

Isotype—Bose and Maheshwari 1968, pl. 9, fig. 2 (here designated), Slide no. Ba. 1191-1.

Original diagnosis—"Monosporites, monosaccate, subcircular to circular, central body distinct, roundly triangular to subcircular, trilete weakly developed, saccus extent more than ½ body radius" (after Bose & Maheshwari 1968, p. 11).

Description (elaborated)—Pollen grains circular to subcircular in shape, 78-98 μm. Central body outline distinct, roundly triangular in shape with broad angles and convex sides (Text-fig. 6), intramicroreticulate. Trilete mark weak to distinct, simple, rays equal, reaching 1/2 central body radius. Saccus with wavy outline, frilled, uniformly wide, subequatorially attached proximally as well as distally, finely intramicroreticulate, meshes fine and polygonal at the base progressively becoming elongated with radially arranged muri towards periphery.

Comparison—The present species differs from all the species in having a characteristic roundly triangular body.



Text-figure 6—Line drawing of Holotype of *Parasaccites perfectus* Bose & Maheshwari 1968 showing roundly triangular nature of central body and fine radiating folds in saccus.

Parasaccites diffusus Lele 1975

Pl. 12, figs. 1-6

Holotype—Lele 1975, pl. 3, fig. 42; size 80 μm; Slide no. BSIP 4762; sample 80/662, Dudhi River Section, West Bokaro Coalfield, Bihar, Talchir Formation, Permian.

Isotype—Lele 1975, pl. 3, fig. 45 (here designated); Slide no. BSIP 4762.

Original diagnosis—"Circular-oval or roundly triangular monospore. Size 50-100 μm. Central body intramicropunctate to intramicroreticulate, 1·5-2 μm thick, outline distinct and smooth. Shape circular to roundly triangular, generally conforming with overall outline. Size 35-60 μm. Tetrad mark simple,

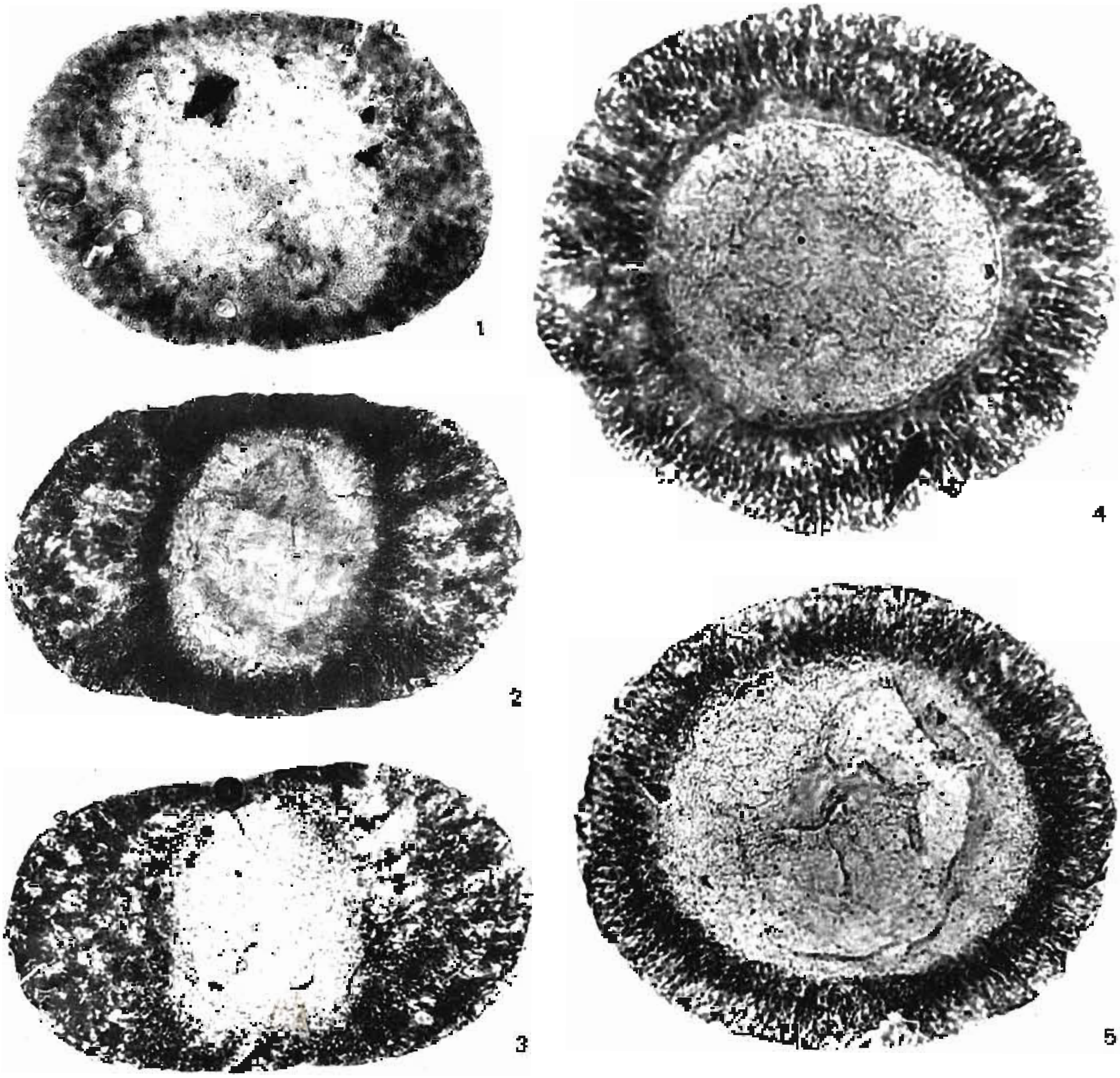


PLATE 10

1-3. *Parasaccites bilateralis* Tiwari 1965, showing indistinct central body outline and saccus attachment leaving sub-circular saccus free area. × 500.
1. Slide no. BSIP 1085, EF [illegible].
2. Slide no. BSIP 1085, EF [illegible].
3. Slide no. BSIP 1084, EF [illegible].
4. *Parasaccites obscurus* Tiwari 1965, slide no. BSIP 1085, EF [illegible]. × 500.
5. *Parasaccites* [illegible] Tiwari 1965, slide no. BSIP 1086, EF [illegible]. × 500.

weak to ± clear, rays 1/2 to 2/3 of body radius in length, with a tendency to become bilete or rarely monolete. Saccus width about 1/2 of body radius or more, prominently frilled by radial pleats arising from saccus roots, especially distally. Distal saccus overlap deep (about 2/3-1/3 of body radius), ± clear, root ± fimbriate and may be associated with partial exine folds of thickening (compressional); proximal saccus overlap narrow and relatively indistinct" (after Lele, 1975, p. 224).

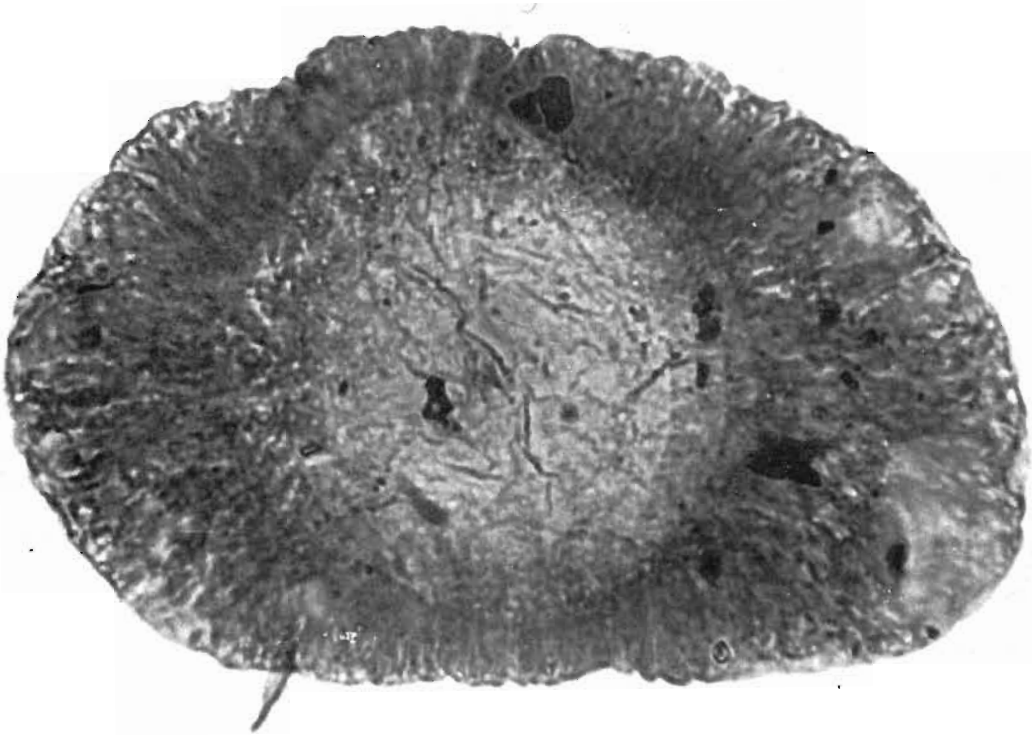


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PLATE 11

1. *Parasaccites ovatus* Kar 1968, Holotype showing distinct central body outline; Slide no. BSIP 2202, EF : K40/3, × 1000.

Discussion—After re-examining the type and similar forms some more details were recorded which are given below:

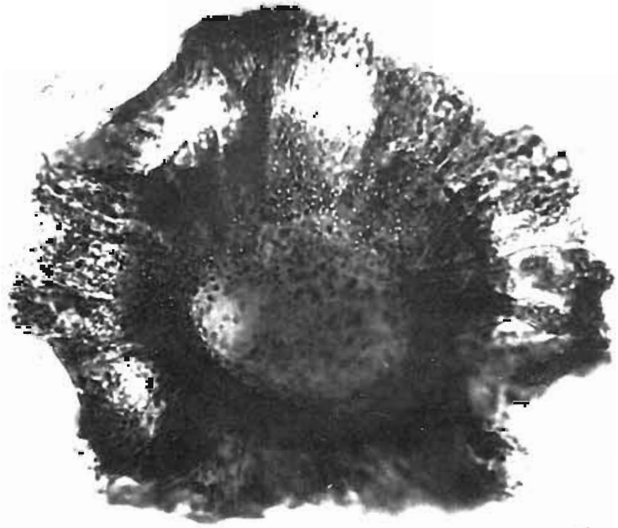
1. Central body exine and saccus structure are intrapunctate to intramicroreticulate.
2. The central body is dark, dense and mostly circular to subcircular; however, roundly triangular shape of body has also been included by the original author in this species. Their illustrations do not suggest that there exists a condition where typical triangular shape of the body is attained. It is, therefore, concluded that some specimens might show a tendency for triangularity of body, the overall shape remains circular.

Description (elaborated)—Pollen grains circular, subcircular, 50-120 μm in size. Central body dense, dark coloured with distinct outline, mostly conforming to the overall shape of pollen, finely intramicroreticulate; muri thick giving a punctate appearance. Trilete mark distinct or represented by a triradiate folds. Saccus with protosaccate fill, wavy

PLATE 12 →

1-6. *Parasaccites densicorpus* Lele 1975.

1. Holotype showing thick and leathery nature of saccus intrareticulation; Slide no. BSIP 4762, EF : T11/4, × 1000.
2. Specimen in fig. 1 showing distinct outline and intrareticulate structure of central body.
3. Isotype; Slide no. BSIP 4762, EF S16/1, × 850.
4. Slide no. BSIP 4757, EF : N10/2, × 1000.
5. Enlargement of specimen in fig. 6 showing trilete mark, intrareticulate structure and central body outline, × 1000.
6. Specimen showing distinct central body outline; Slide no. BSIP 4762, EF : N11/2, × 500.



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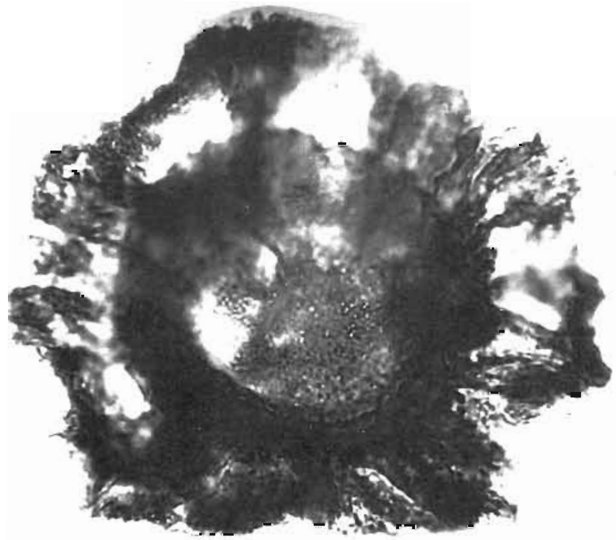

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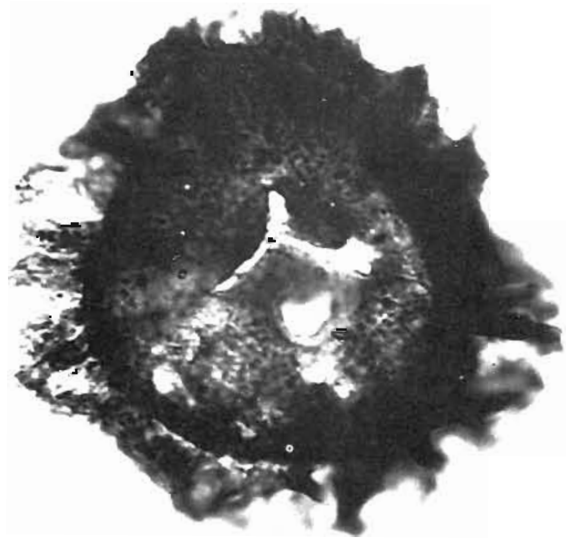

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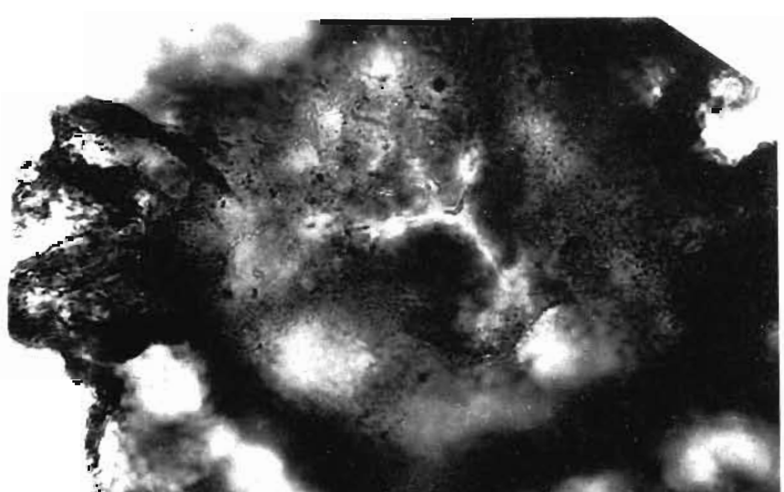

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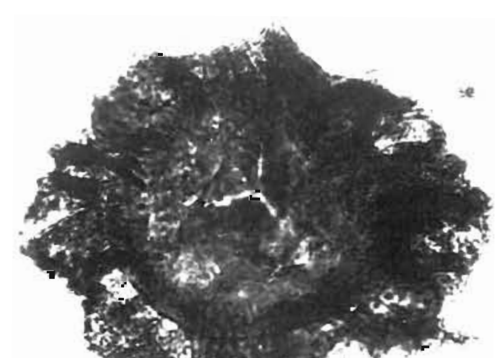


6

PLATE 12

outline, strongly folded, finely intramicroreticulate with thick muri imparting leathery and punctate nature. Saccus attachment subequatorial.

Comparison—*Parasaccites densicorpus* Lele 1975 differs from all other species in having a distinct, thick and dark coloured central body.

Genus—*Crucisaccites* Lele & Maithy 1964

Type species—*Crucisaccites latisulcatus* Lele & Maithy 1964

1910 Specimens in Vickki, pl. 5, fig. 49; pl. 10, figs 135, 136; pl. 11, figs 137, 138.

Original diagnosis—"Monosaccate grain circular to oval in outline, body distinct to indistinct, circular to ellipsoid; saccus encloses most of the body but leaves free a bilateral zone on both sides of the body along which it is attached; saccus free areas on the two sides of the body lie at right angles to each other; monolete mark present but inconsistently developed; body exine in the saccus free areas apparently thinner, with a tendency to rupture; body infolds near saccus attachment may be strongly developed or absent; saccus structure intrareticulate" (after Lele & Maithy 1964, p. 307, 308).

Discussion—It has been noticed that the central body in such pollen grains is mostly distinct (and not indistinct as mentioned in the diagnosis), however it is a possibility that the central body is lost in some specimens where only the cruciate saccus remains in the macerate. The shape of the nexine is variable being elongately oval with smooth curved outline to flat lateral and terminal side walls. The exine of the body is finely intramicroreticulate which could be best seen in the high power objective. The monolete mark is an inconsistent feature and the body exine usually ruptures along such weaker zone. In certain specimens this is also represented by a thinner linear area. The body infolds near saccus attachment have been found to occur in most of the specimens. They may be well developed or, at times, less pronounced or even partially so. When the folds are prominent they are ± lunar in outline with convex line towards the outer side. The saccus is frilled type, protosaccus with usually thick muri and very narrow, sometimes punctate-like lumen. At the periphery of saccus in flattened condition a narrow, denser zone is demarcated which exhibits thicker nature of muri.

The original generic diagnosis given by Lele and Maithy (1964) broadly encompasses the variability of species under *Crucisaccites*. The above mentioned characters are additional observations and are incorporated in elaborated description.

Description (elaborated)—Normally big, monosaccate pollen with well-developed sexine enclosing a thin, oval, ellipsoid to flat sided hexagonoid central body (nexine) (Pl. 13, figs 3, 2). No sulcus or tenuitas seen, except a thin, weak, elongated area being present in the body centre on one of its faces, which sometime rupturing to form a vent; a short monolete slit rarely seen. The central body is indistinctly to distinctly intramicroreticulate in structure. The cross attachment of saccus with the body very peculiar and distinctive, folds of nexine along the saccus attachment zone generally prominent. Saccus with protosaccate fill, alveoli of very minute size having thick walls of muri. Muri thickness increasing at the peripheral region of the saccus forming thicker zone. Width of saccus with relation to central body equator may be uniform or trending towards a wider span at the terminal sides on the longer axis.

Comparison—*Crucisaccites* is identifiable from other monosaccate genera on the basis of its cruciate nature of saccus attachment.

Organization—The crucisaccate mode of saccus attachment with the central body is the characteristic feature of organization in this genus (Text-fig. 7). Lele and Maithy (1964) have already given a detailed account of mode of saccus attachment, with crossed saccus free areas on the body. The monolete mark appears to be a variable character. The body folds along the zone of saccus attachment normally

PLATE 13

1-9. *Parasaccites* Bharadwaj & Tiwari 1964, SEM photomicrographs.

1, 2, 4. *Parasaccites korbaensis* Bharadwaj & Tiwari 1964 showing radiating folds of saccus and the nature of central body and saccus in surface view.

3. *Parasaccites bilateralis* Tiwari 1965 showing radiating folds of saccus and subcircular saccus free area.

5. Enlargement of a portion of pollen at the saccus attachment zone showing the leathery nature of saccus, fine reticulation with thick muri and the nature of central body.

6. Enlargement of pollen showing intrareticulate structure of central body in surface view with irregular and anastomosing muri.

7, 8. Portion of saccus enlarged to show small punctalike holes in surface view.

9. Portion of pollen showing intrareticulate nature of central body and radiating folds on the saccus attachment zone.

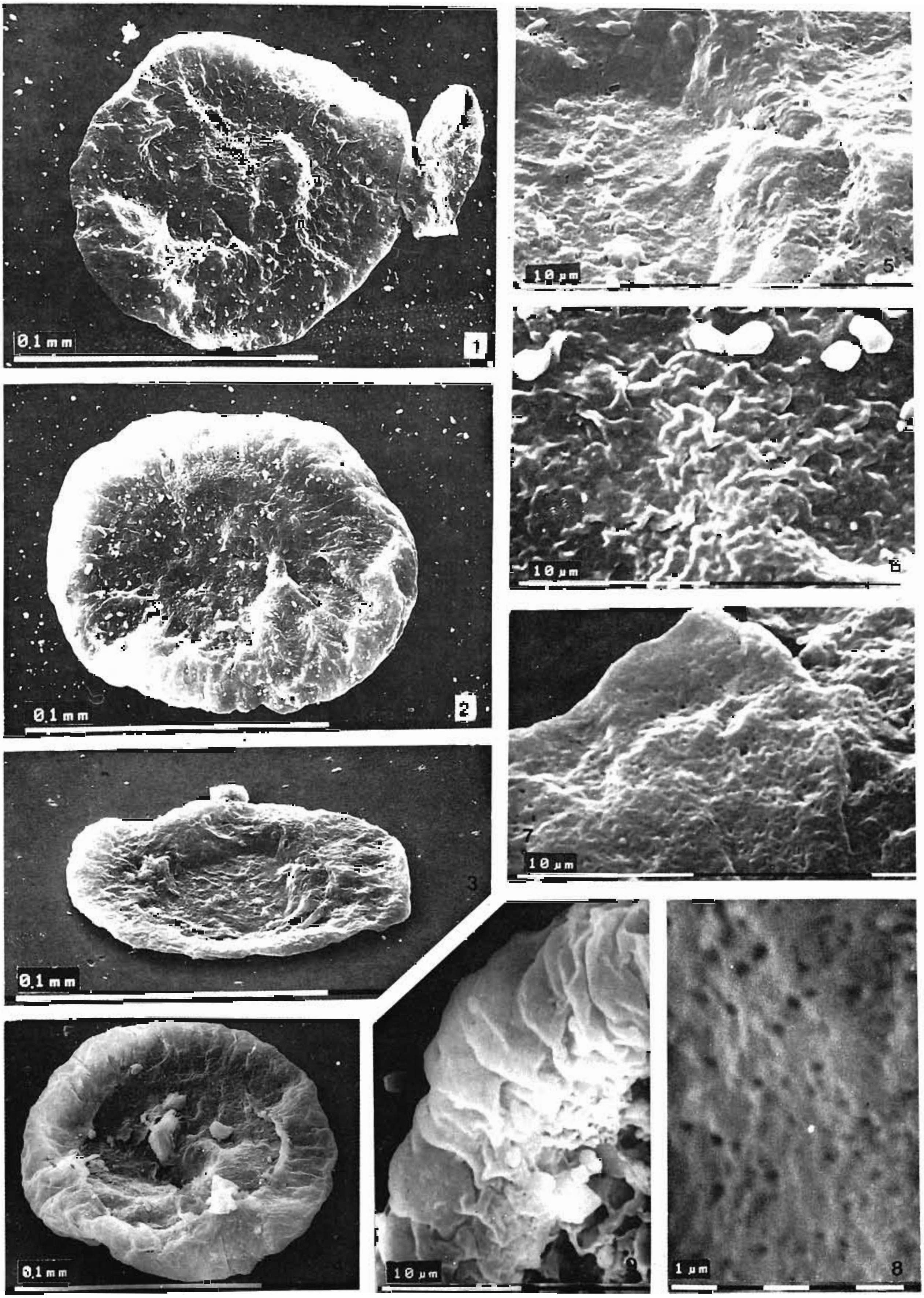
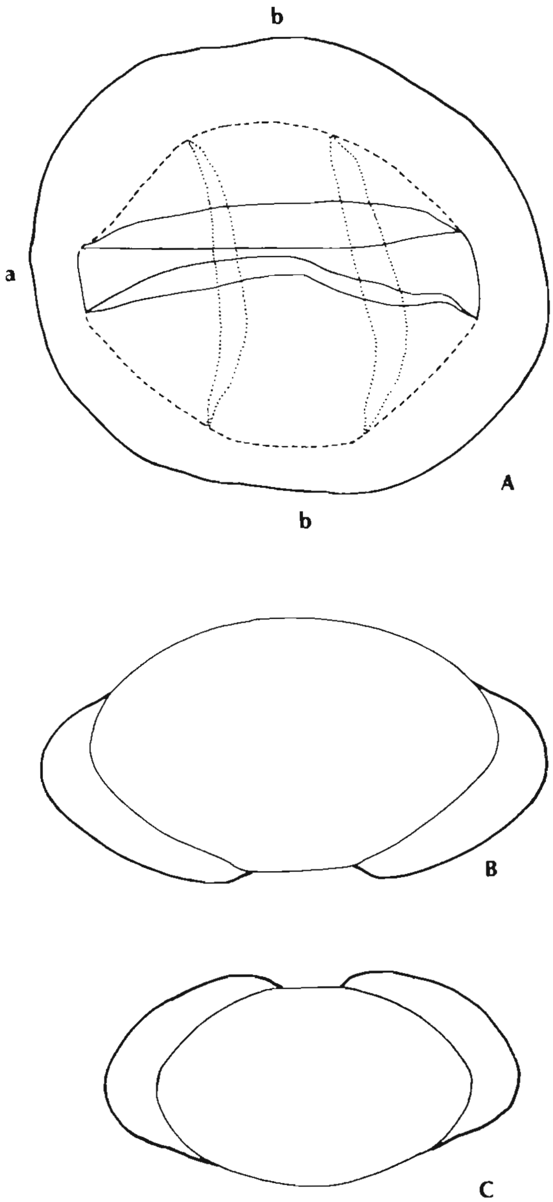


PLATE 13



Text-figure 7—Reconstruction of organisation of *Crucisaccites* Lele & Maithy 1964: **A**, Proximo-distal plane; **B**, Meridional section at aa plane; and **C**, Meridional section at bb plane.

develop prominently; sometimes, however, all are not pronounced due to flattening angle of the pollen or body orientation. The nexine (central body) is thin, elliptical to globoid which flattens to adjust its vertical plane.

Occurrence—Permian (Upper Talchir to Raniganj).

Prominence—Karharbari Formation.

List of species on record :

Crucisaccites latisulcatus Lele & Maithy 1964
C. monoletus Maithy 1965
C. medius Lele & Maithy 1969
C. indicus Srivastava 1970

List of species resolved :

The type specimens wherever available or other specimens from the type material, were examined and following species were retained in the genus.

1. *Crucisaccites latisulcatus*
2. *C. monoletus*
3. *C. indicus*

Crucisaccites medius Lele & Maithy 1969 does not find its place under this genus.

Remarks—Only three species, viz., *Crucisaccites latisulcatus, C. monoletus* and *C. indicus* have been retained in this genus. *C. latisulcatus* has generally a smaller body with relation to the overall pollen size, while in *C. monoletus* and *C. indicus* the body is bigger occupying most of the pollen area. The most distinguishing character is the body shape in *C. latisulcatus.* Only those forms have to be included here which exhibit the presence of a trapezoid, ellipsoid body with flat sides or hexagonoid rhomboidal configuration. In *C. indicus* the forms with subcircular body should be included. In *C. monoletus* the cruciate arrangement is not typical but the monolete mark is well-defined.

Other species of Crucisaccites—*Crucisaccites medius* Lele & Maithy 1969 does not show a cruciate construction of saccus. The type as well as other specimens illustrated by Lele and Maithy (1969, pl. 3, figs 25, 26) possesses the distorted configuration of *Plicatipollenites* in having a radially symmetrical saccus attachment rather than the cruciate-type. Evidently these pollen belong to the genus *Plicatipollenites.*

Description of species resolved :

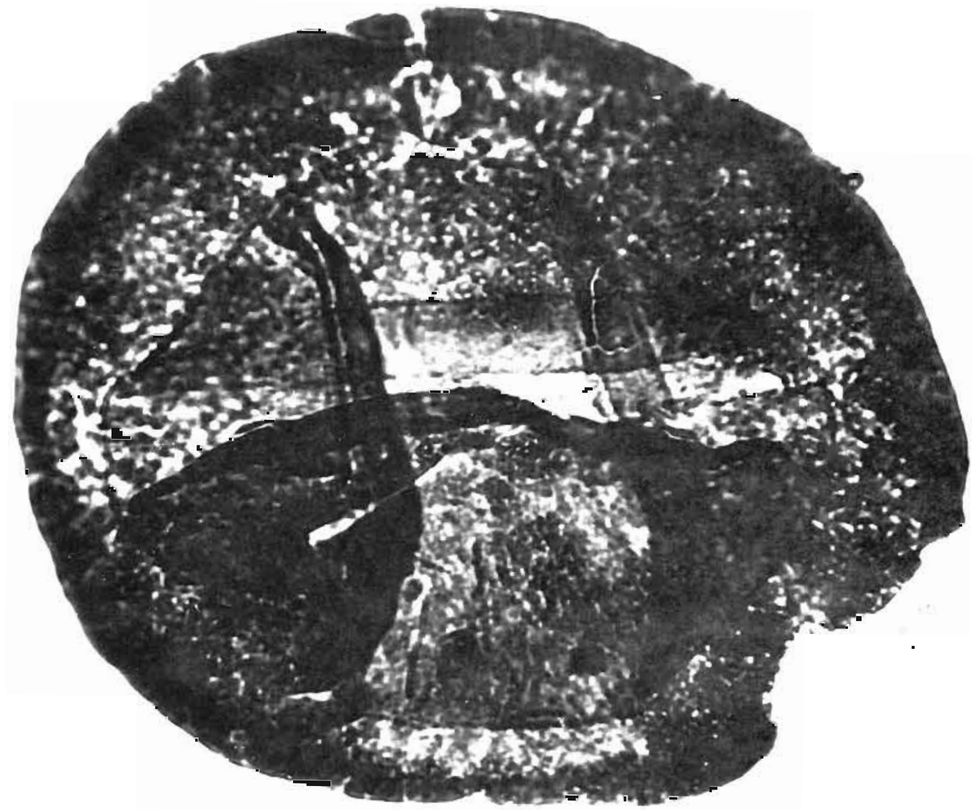
Crucisaccites latisulcatus Lele & Maithy 1964

Pl. 14, figs 1, 2; Pl. 16, figs 1, 2; Pl. 17, figs 1, 2; Pl. 18, figs 1, 2; Pl. 24, figs 1-6

PLATE 14 →

1, 2. *Crucisaccites latisulcatus* Lele & Maithy 1964 showing trapezoid nature of central body and cruciate nature of saccus attachment, × 500:

1. Holotype; Slide no. BSIP 1584, EF : S29/1.
2. Slide no. BSIP 1586, EF : N43.



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2

PLATE 14

Holotype—Lele and Maithy, 1964; pl. 1, fig. 1; size 207.5 × 240 μm; Slide no. BSIP 1584/3; Central Pit, Srirampur Colliery, Giridih Coalfield; Karharbari Formation, Early Permian.

Isotype—Lele and Maithy, 1964; pl. 1, fig. 2; Slide no. BSIP 1587 (here designated).

Original diagnosis—"Size range about 200-260 microns (along longer axis), outline ± circular to oval, body 160-190 microns (along the longer axis), mediumly thick, clear, subcircular to ellipsoid in shape, exine structure or sculpture obscure, saccus outside the body narrow, more or less uniformly wide; zones of attachment nearly reaching the body periphery, bilateral, cruciate with respect to each other on the two sides, saccus free areas of body ± wide, thinner, sulcus-like; body-infolds near saccus roots strongly developed; monolete mark rarely visible, body exine in the saccus free area may often rupture to simulate a monolete horizontal slit; saccus structure fine intrareticulate" (after Lele & Maithy, 1964, p. 309).

Discussion—On re-examination of the type specimen as well as other specimens in the type material, following additional observations are made for this species:

1. Central body thin, squarish, trapezoid or ellipsoid with ± hexagonal rhomboid appearance, infrareticulate. The structure is visible more clearly when seen under high power objective rather than under immersion oil.
2. Saccus has thick irregularly wide muri and very narrow, at times puncta-like or fine reticulum, with protosaccate filling.

Description (elaborated)—Central body thin, distinct, squarish to trapezoid generally with flat ends. Monolete mark not distinct but a rupture is generally visible. Exine smooth, folds in body prominent, mostly lunar in shape with pointed ends joining with the angles of the body contour in the cruciate set-up of folds; horizontal folds more prominent than the vertical. Sacci with thick irregularly wide muri and intrapunctate to intrareticulate (lumen less than 1 μm); ± 10 μm wide thicker zone in the peripheral region of the saccus seen; rest of the area relatively lighter. Saccus structure doubly intrareticulate, coarse framework of muri enclosing finer meshes; protosaccate.

Crucisaccites monoletus Maithy 1965 emend.

Pl. 19, figs 1, 2; Pl. 20, figs 1, 2

Holotype—Maithy, 1965; pl. 3, fig. 18; size 142 × 108 μm; Slide no. BSIP 1983; Central Pit, Srirampur Colliery, Giridih Coalfield, Bihar; Karharbari Formation, Early Permian.

Original diagnosis—"Size range about 120-160 μ (along longer axis), outline ± oval to circular, body 110-130 μ (along longer axis), thin, distinct, circular or oval in outline, body ornamentation intramicroreticulate, saccus outside the body extremely narrow, more or less uniformly wide; zone of attachment nearly reaching to the body periphery, bilateral, cruciate with respect to each other on the two sides, saccus free areas of body ± wide, thinner, sulcus-like; body infolds absent; an undoubted monolete mark demonstrable, sometimes the body exine in the saccus-free area may often rupture to a broad horizontal slit; saccus structure fine intra-reticulate" (Maithy, 1965, p. 295).

Discussion—The above given original diagnosis is too loose to circumscribe this species. Therefore, after the examination of the holotype following emended diagnosis is given.

Emended diagnosis—Horizontally oval pollen with monosaccoid construction of saccus having wider span at terminal sides. Folds not typical of cruciate, having prominent, long vertical pair of folds and short, insignificant horizontal folds leaving rectangular saccus-free area. Monolete mark distinct. Muri thick, meshes fine; protosaccate.

Description (elaborated)—Typical cruciate infold system of the type species not seen. Body exine indistinctly structured. Horizontally rectangular saccus-free space bearing well-defined straight monolete mark. Saccus having a tendency to be wider at the terminal sides with fairly thick muri and doubly intrareticulate structure, meshes less than 1 μm wide.

Comparison—This species differs from *C latisulcatus* in having a bigger oval central body bearing a distinct monolete mark.

Crucisaccites indicus Srivastava 1970

Pl. 21, fig. 1; Pl. 22, figs 1, 2

Holotype—Srivastava, 1970; pl. 2, fig. 18; size 138 μm; Slide no. BSIP 2935; Nandira Colliery, Talchir Coalfield; Barakar Formation, Permian.

Isotype—Srivastava, 1970; pl. 2, fig. 19; Slide no. BSIP 2899.

Original diagnosis—"Overall size range 110-188 μ (along the longer axis), roundly subcircular to sub-rectangular with wide angles in overall shape; central body weakly defined, monolete mark not discernible; saccus attachment well-defined" (after Srivastava, 1970, p. 161).

Discussion—The following additional characters have been observed in this species:

1. The central body is big, filling most of the pollen area, subcircular and very thin. In some

PLATE 15

1, 2. [illegible] Lele & Maithy 1964 showing shape and nature of central body and prominent lunar folds on the body. × 500.

1. Isotype, slide no. BSIP 1587, [illegible]
2. Slide no. BSIP 1587, [illegible]

cases it appears as if the body has been lost, but it is apparent rather than real, the structure of body ascertains its presence and its very thin nature.

2. Saccus beyond equator is narrow, muri short, thick, meshes narrow, protosaccate.
3. Folds of body are present at attachment zone.

Description (elaborated)—Big circular to oval pollen 100-130 μm. Central body thin, outline generally very faint but can be traced through L-O analysis occupying more than 3/4 of the pollen area, faintly structured; sometimes body appears to be missing because of highly thin nature; however, its presence can be ascertained because of the structured exine and microfolds in the central region. No mark or thinner area representing the monolete mark seen. Typical cruciate infold system generally not well-developed, encroachment of sacci cruciate type; in holotype horizontal folds are better represented; in other specimens studied, only narrow and short pleats in body exine noticed; in sacci also folding can be marked at the attachment zone. Saccus well-developed, with intrareticulate structure having thick muri and narrow meshes of ± 1 μm size; protosaccate fill ascertained; no peripheral zone in saccus.

Comparison—*C. latisulcatus* and *C. monoletus* differ from the present species in having distinct central body, the latter also has a well-defined monolete mark.

Genus—*Faunipollenites* Bharadwaj 1962

Type species—*Faunipollenites varius* Bharadwaj 1962.

Original diagnosis—"Disaccate, bilateral, haploxylonoid pollen grains. Central body outline ill-defined, proximally exine intramicroreticulate and bearing a number of horizontal, simple or forked striations, rarely with vertical, connecting striations also; distally a uniformly wide to biconvex area free from saccus, where the exine is thin and sparsely granulose. Distal zones of saccus attachment ill-defined" (after Bharadwaj, 1962, p. 95).

Discussion—Re-examination of the type specimens of several species of *Faunipollenites* has revealed the presence of following additional characters as well as variability:

1. The pollen, in most cases, are haploxylonoid but slightly diploxylonoid construction of sacci has also been noted in some cases.
2. The grooves are the "striations" in nature, i.e., they are uniformly wide, linear furrow-like structure; they are not taeniae bound by irregularly wide pathways.
3. The central body has no defined outline; only sometimes it is apparent, or visually delimited by free ends of striations.
4. The sacci are protosaccate.
5. The proximal body surface is finely intrareticulate and distal saccus free area is smooth, chagrinate or incipiently structured.

Description (elaborated)—Pollen disaccate, bilaterally oval, mostly haploxylonoid with hemispherical sacci broadly attached with body at lateral sides, rarely showing incipient tendency for diploxylonoid construction. Central body (nexine) not clearly demarcated, apparently oval or subcircular. Proximally bearing a number of simple or branched striations, vertical partitions in between them not observed. Striations linear, uniformly wide along their full length deciphering the limits of central body extension (Pl. 27, figs 6-8). Sexine in between striations finely intramicroreticulate. Sacci protosaccate, hemispherical or less than that, laterally rarely close to each other, merging with body, distally inclined to leave narrow to wide, generally ill-delimited, saccus-free area, which being thin and incipiently intramicroreticulate structured. No folds along zones of sacci attachment. Intrareticulation of sacci fine to coarse or even double in having coarser areas enclosing finer reticulation; saccus with protosaccate fill.

Comparison—Genus *Faunipollenites* Bharadwaj 1962 has been equated with *Protohaploxypinus* Samoilovich 1953 by Hart (1964) and Balme (1970) and to *Striatopiceites* Zoricheva & Sedova 1954 emend. Sedova 1956 by Venkatachala and Kar (1968) and Kar (1968). However, a critical review of the original description for those taxa has revealed the following morphotaxonomic differences.

The genus *Protohaploxypinus* as described and illustrated by Samoilovich (1953, pp. 42, 43; pl. 4, fig. 4), is not supplemented by the photomicrograph of the type specimen; only a semidiagrammatic figure of the same is given, wherein no distinct striations are depicted. The horizontal lines drawn by Samoilovich (1953) do not appear to be striations. As they are shorter than the body horizontal axis, they in all probability represent small folds. The central body appears to be distinct as in other species of the genus illustrated by Samoilovich (1953, pl. 6, figs 1-3; pl. 12, figs 1, 2; compare photographs with line drawings). In the generic description it has been mentioned that the central body is ellipsoidal and airsacks embrace the body deeply. It follows that the central body exine has been described as granular or granular-ribbed; as such, this is an ambiguous taxon. Later, Hart (1964) restudied the type designated to *P. latisimus*

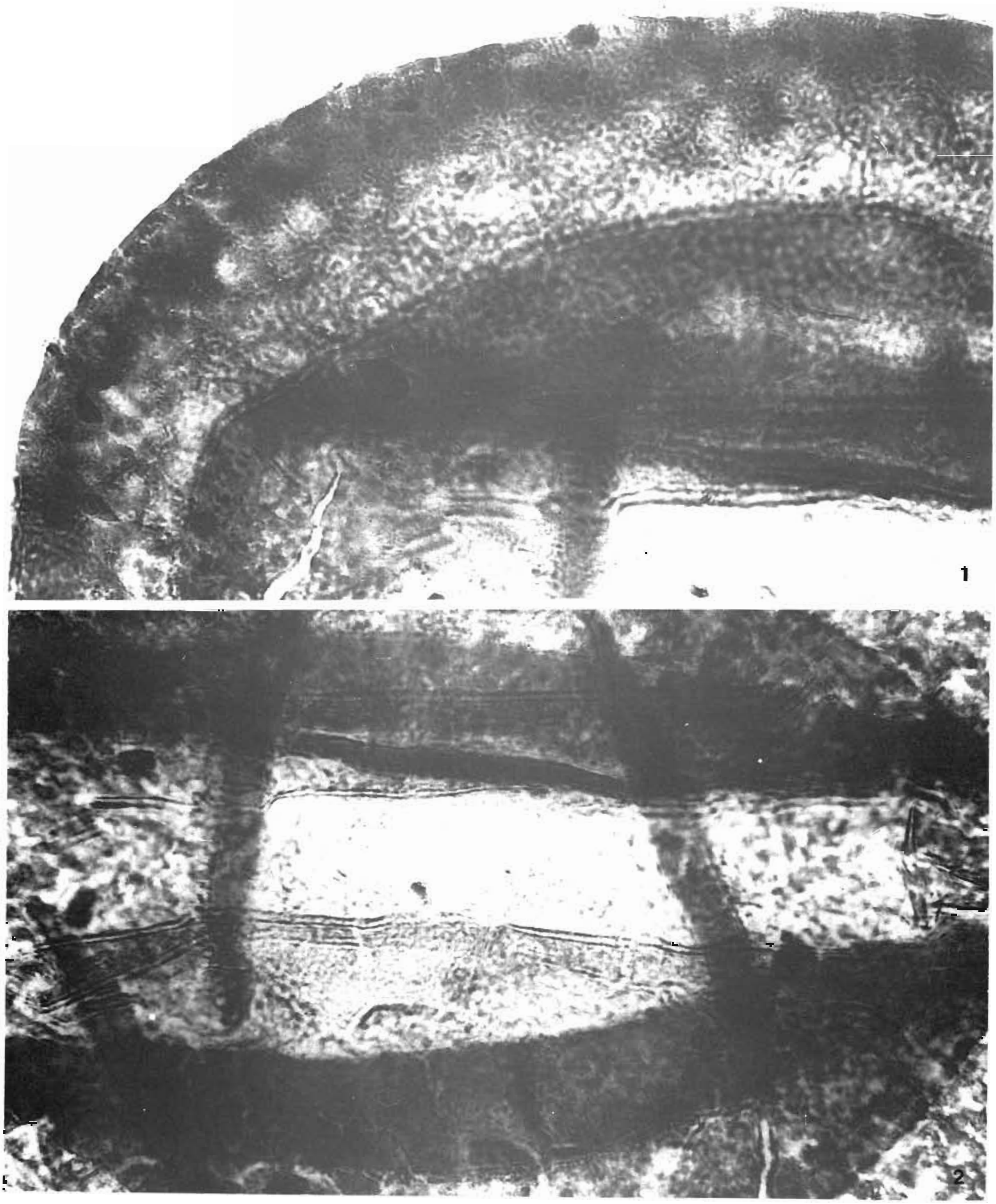
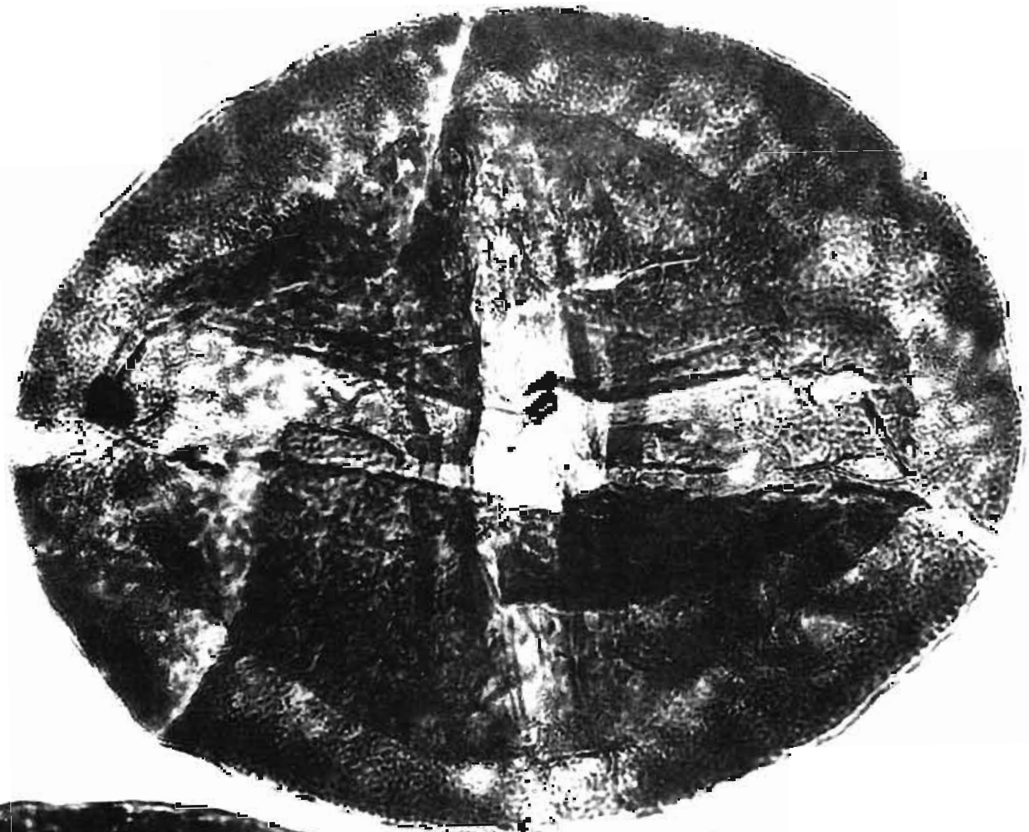


PLATE 16

1, 2. [illegible] Maithy [illegible], × 1500.

1. Portion of specimen in Plate 15, fig. 1 showing saccus [illegible] with [illegible].

2. [illegible] of folds and [illegible] of [illegible].



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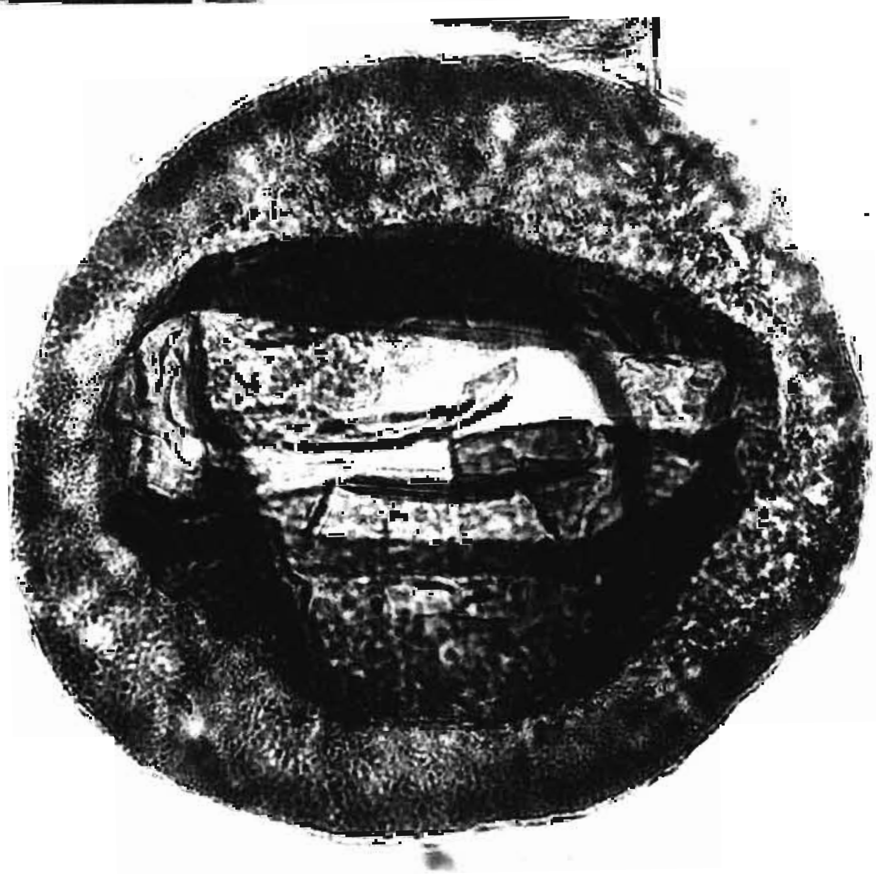

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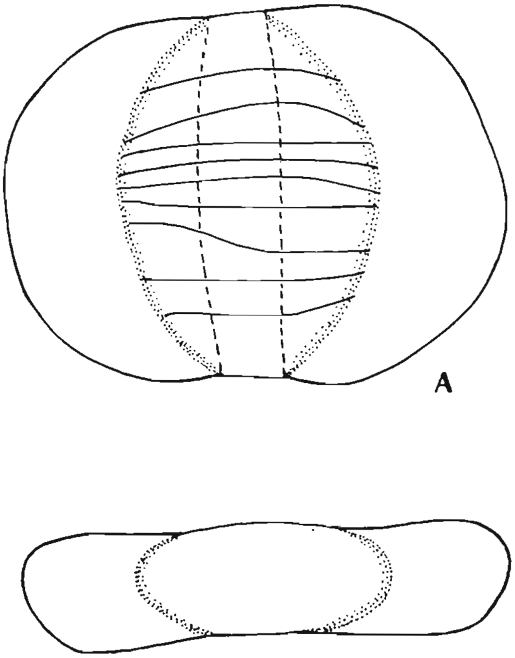
PLATE 17



A

B

Text-figure 8—Reconstruction of organisation of *Faunipollenites* Bharadwaj 1962: **A**, In proximodistal plane; **B**, Meridional section.

by A. A. Luber in 1941. He excluded non-striate grains and emended the diagnosis for the genus accordingly; he described the shape of the central body, meaning thereby the distinctness of the same. Thus, if the presence of striations is doubtful in the type specimen, the exclusion of non-striate forms from this genus is not justified. In any case, the central body is very well defined in *Protohaploxypinus* and exine structure could be different than the reticulation. This genus, therefore, does not compare with *Faunipollenites*.

Similarly, in the genus *Striatopiceites* as described and illustrated by Sedova (1956; Trans. Hart, 1964, pp. 6, 7; pl. XLI, fig. 7), the central body is thick with a distinct outline. Body is ribbed with a fine reticulation between the ribs. Besides, in few grains germinal furrow is seen varying in its direction either longitudinal or perpendicular to the air sacs. Such situations are not encountered in *Faunipollenites*.

In view of these observations, Tiwari (1974) commented that both the above mentioned genera have distinct central body, apart from other details, which make them different from *Faunipollenites*.

Hence, the present authors do not agree with the views of Hart (1964), Balme (1970), Venkatachala and Kar (1968) and Kar (1968) to consider the genus *Faunipollenites* Bharadwaj 1962 as synonym of *Protohaploxypinus* Samoilovich 1953 or *Striatopiceites* Sedova 1956 at any level of morphography.

The diffused nature of intramicroreticulate central body, common haploxylonoid organization of sacci, merging zones of sacci attachment on distal side, the free ends of striations simulating the body limit and the protosaccate nature of sacci remain the distinguishing features of the genus *Faunipollenites*.

Organization—The main character of the genus is a diffused central body, without marked outline (Text-fig. 8). The sacci are generally half of the sphere or subspherical with haploxylonoid construction. The zone of saccus attachment is also diffused without any body infold accompanying them. These features suggest that the central body did not have much area along proximo-distal line; it could be of lensoid rather than spheroid in sectional view. The sacci also do not appear to incline distally to a greater extent. There is no prominent blowing up of sacci as normally radially oriented pleats emerging from saccus roots are absent.

List of species on record:

Faunipollenites varius Bharadwaj 1962
F. perexiguus Bharadwaj & Salujha 1965
F. copiosus Bharadwaj & Salujha 1965
F. parvus Tiwari 1965
F. minor Salujha 1965
F. goraiensis (Potonié & Lele) Maithy 1965
F. bharadwajii Maheshwari 1967
F. circumstriatus Maheshwari 1969
F. enigmatus Maheshwari 1969
F. gopadensis Bharadwaj & Srivastava 1969
F. singrauliensis Sinha 1972
F. multistriatus Srivastava 1979

Some species assigned to *Striatopiceites* Zorich. & Sedova 1954 emend. Sedova 1956, have resemblance with *Faunipollenites*, hence considered here for resolution.

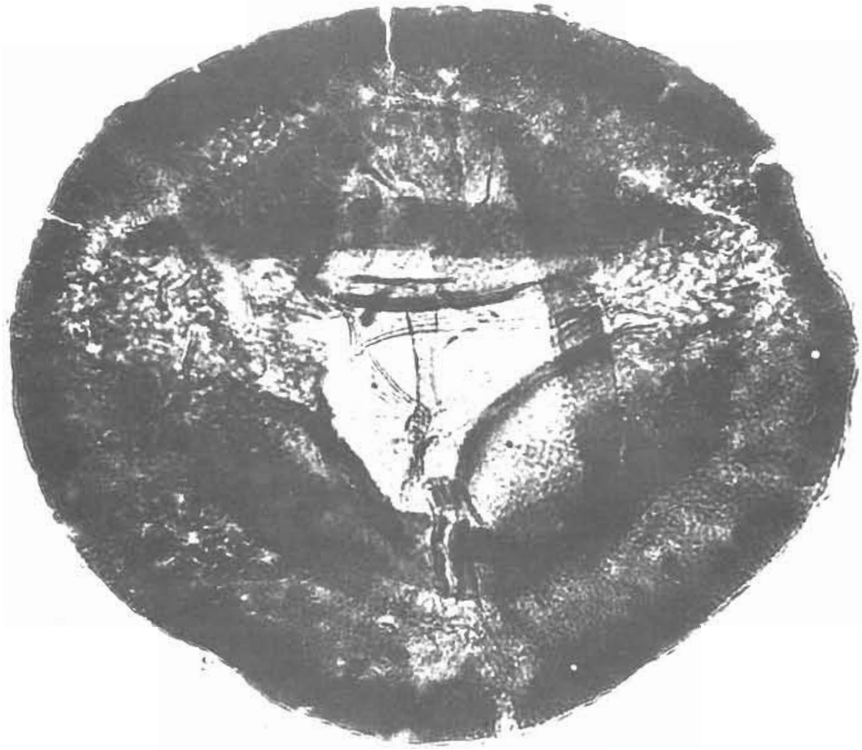
Striatopiceites magnus Bose & Kar 1966
S. congoensis Bose & Kar 1966

←

PLATE 17

1, 2. *Crucisaccites latisulcatus* Lele & Maithy 1964 showing trapezoid nature of central body, ruptured exine and cruciate nature of saccus attachment, × 500:

1. Slide no. BSIP 1587/1, EF : N31/4.
2. Slide no. BSIP 1588/1, EF : E44/1.



1

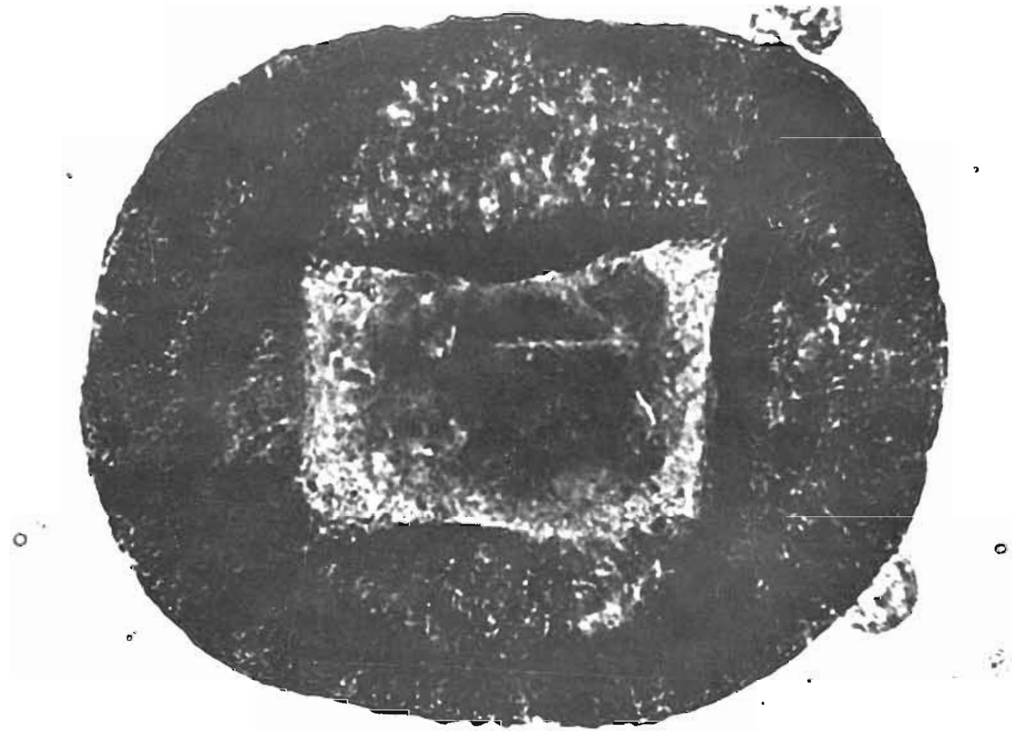
2

PLATE 18

1-2. [illegible] Maithy 1969.

1. Showing the [illegible] nature of central body and fold pattern. Slide no. BSIP [illegible] G38/3, × 500.

2. Showing [illegible] nature of central body, [illegible] attachment and [illegible]. Slide no. BSIP [illegible].



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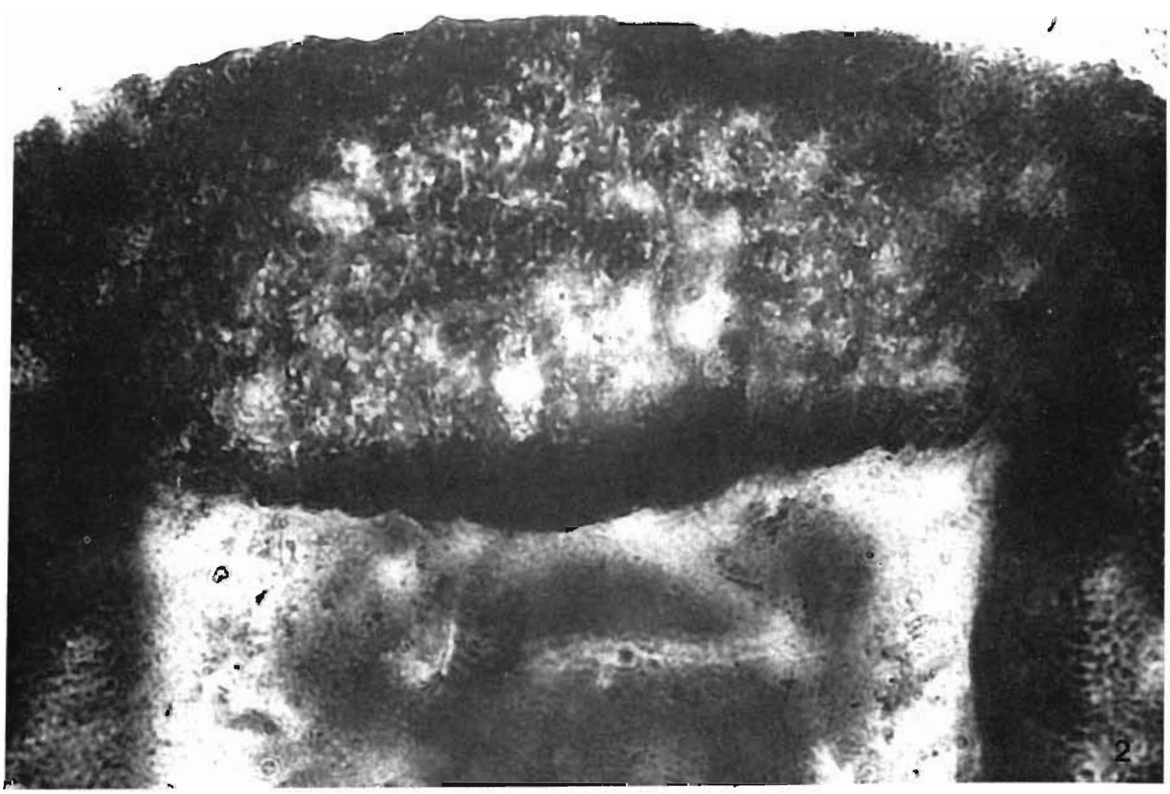


2

PLATE 19

1, 2. *Crucisaccites monoletus* Maithy 1965 here emended:

1. Holotype showing monolete mark on the central body and cruciate nature of saccus attachment; Slide no. BSIP 1984, EF : Q51/2, × 800.
2. Enlargement of a portion of holotype to show the nature of central body and saccus intrareticulation with thick muri, × 2000.

S. minutus Venkatachala & Kar 1968
S. digradius Kar 1968
S. rimosus Venkatachala & Kar 1968
S. granulatus Kar 1968
S. clarus Kar 1970
S. delicatus Kar & Bose 1976

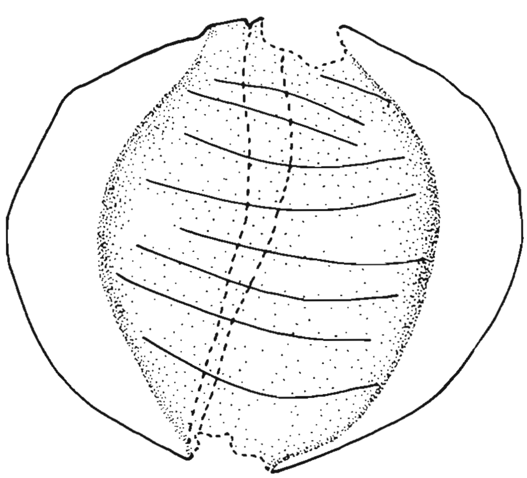
List of species resolved:

Re-examination of available type specimens and allied specimens of various species, and analysis of range of characters have led to circumscribe the following species under this genus. Consequently, out of 20 species, only five species have been retained in this genus. Rest of the species have either been treated as synonym or transferred to other genera.

Species retained in *Faunipollenites* after present analysis are:

Faunipollenites varius (= *F. bharadwajii, Striatopiceites digredius, Striatopiceites clarus*)
F. perexiguus (= *F. parvus, F. minor, Striatopiceites granulatus, Striatopiceites minutus, Striatopiceites delicatus*)
F. singrauliensis
Faunipollenites congoensis (= *Striatopiceites rimosus*)
Faunipollenites magnus

Species which do not find their place under *Faunipollenites* are:
Faunipollenites copiosus
F. circumstriatus
F. enigmatus
F. gopadensis
F. goraiensis
F. multistriatus



Text-figure 9—Line drawing of holotype of *Faunipollenites congoensis* (Bose & Kar) comb. nov. showing subcircular pollen outline and narrow saccus-free area.

Faunipollenites copiosus, F. gopadensis and *F. goraiensis* possess distinct central body with well-defined outline. *F. circumstriatus* and *F. enigmatus* exhibit the arrangement of striations similar to that described for the genus *Circumstriatites* Lele & Makada 1972. *F. multistriatus* is a badly-preserved, over-macerated specimen and the structure of the exine could not be determined.

Occurrence—Early Permian to Early Triassic.

Prominence—Upper Barakar and Lower Raniganj.

Description of species resolved:

Faunipollenites varius Bharadwaj 1962 emend.
Pl. 25, figs 1-4; Pl. 26, figs 4, 5; Pl. 27, figs 1-4, 6-8

1967 *Faunipollenites bharadwajii* Maheshwari, pl. 8, fig. 63.
1968 *Striatopiceites digradius* Kar, pl. 3, figs 73, 74.
1970 *Striatopiceites clarus* Kar, pl. 2, fig. 40.

Holotype—Bharadwaj, 1962; pl. 18, fig. 230 (not traceable); Samla seam, Samla Kendra Colliery, East Raniganj Coalfield; Raniganj Formation, Permian.

Lectotype—Bharadwaj, 1962; pl. 18, fig. 232; size 64 × 106 μm; Slide no. BSIP 9903.

Original diagnosis—"Central body apparently subcircular, 6-8 horizontal striations, distal channel wide, ill-defined. Sacci hemispherical" (after Bharadwaj, 1962, p. 95).

Discussion—The "apparent" shape of the central body cannot be taken as a criterion for delimiting this species as it may be deceptive. The width of the distal channel and the number of striations show a wide range, hence do not make an effective ground for defining this species. Therefore, the diagnosis is being altered here.

Emended diagnosis—Haploxylonoid, bisaccate, bilateral pollen grains. Central body ill-defined, proximally bearing 6-20 simple, rarely forked striations. Exine between the striations intramicroreticulate. Sacci hemispherical without radial pleats, distally leaving narrow to wide 5-20 μm ill-defined mostly unstructured saccus-free area. Saccus reticulation filling the cavity, hence protosaccate with variable sizes of the meshes.

Description (elaborated)—Basic shape of the pollen bilaterally oval, could be vertically oval to subcircular, 64-180 μm in size. Central body apparent, but thin and without marked outline so that its size cannot be measured. Apparent shape simulated due to ends of striations or structure differentiation. Distal attachment-lines of sacci merging with central body can be marked by structural differences; no folds along attachment line. Saccus-free area narrow to wide, straight to slightly convex. No pleating in sacci. Saccus medium to coarse with double network, protosaccate. Muri thickness may vary

Remarks—*Faunipollenites bharadwajii* Maheshwari 1967 does not have characteristic features which could separate it from *F. varius*. *Striatopiceites digredius* Kar 1968 is based on sublaterally preserved specimens, hence the distal attachment lines appear to go apart from each other; else, it is not different from *F. varius*.

Faunipollenites perexiguus Bharadwaj & Salujha 1965

Pl. 25, figs 5-8; Pl. 27, fig. 5

1965 *Faunipollenites parvus* Tiwari, pl. 6, fig. 125.
1965 *Faunipollenites minor* Salujha, pl. 2, fig. 30.
1968 *Striatopiceites granulatus* Kar, pl. 3, fig. 75.
1968 *Striatopiceites minutus* Venkatachala & Kar, pl. 8, fig. 135.
1976 *Striatopiceites delicatus* Kar & Bose, pl. 8, fig. 12.

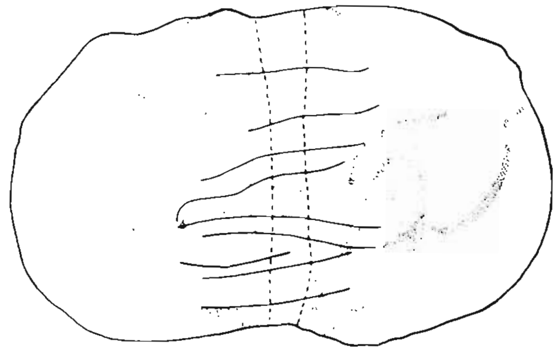
Holotype—Bharadwaj and Salujha 1965; pl. 2, fig. 42; size 43 × 54 μm; Slide no. BSIP 9904; VII (Bonbahal) Seam, Raniganj Coalfield, Bihar; Raniganj Formation, Late Permian.

Isotype—Bharadwaj and Salujha 1965; pl. 2, fig. 43 (here designated).

Original diagnosis—"Overall shape subcircular, size 54-74 μ; central body outline indistinct, horizontal striations 6-9; bladders with fine to medium intrareticulation, almost touching each other distally" (after Bharadwaj & Salujha, 1965, p. 37).

Discussion—There are several species enlisted above under "synonymy" which have been earlier separated on the basis of very minor differences. This group of species represents the smaller pollen with faint or completely diffused body and narrow to medium width of the distal saccus-free area.

F. perexiguus Bharadwaj & Salujha 1965, being the priority-bearer taxon, has been recognised. The type specimen of this species reveals that the body is completely ill-defined, hence no shape can be presumed. It is finely intrareticulate, the sacci are also finely intrareticulate but having slightly bigger meshes than those of body. Five unbranched striations are present. Sacci attachment lines are sharp as well as close to each other in the centre of the body distally. The type specimen is bilaterally ovoid while others are slightly circuloid. So also the distal saccus-free area varies in width in other specimens illustrated for this species.



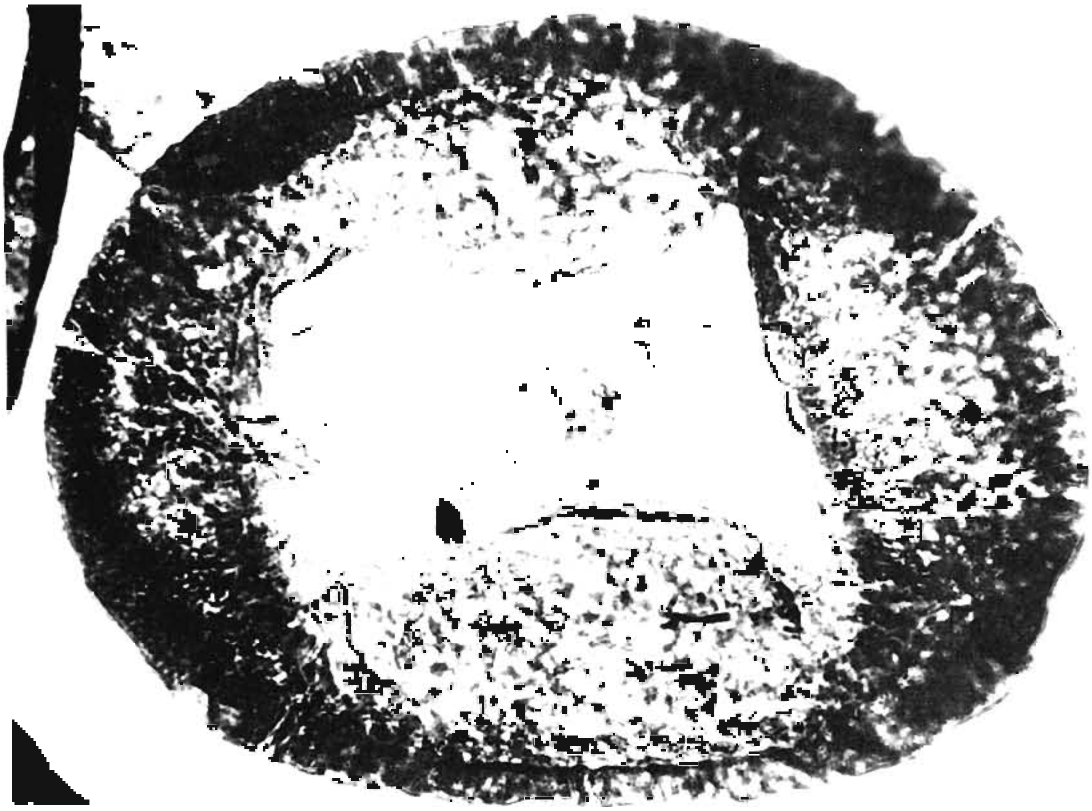
Text-figure 10—Line drawing of holotype of *Faunipollenites magnus* (Bose & Kar) comb. nov. showing indistinct outline of central body and bilateral saccus attachment.

1. In *F. parvus* Tiwari 1965 the distal saccus-free area is relatively wider than *F. perexiguus* but in all other characters they are indistinguishable.
2. The type of *F. minor* Salujha 1965 is unlike *Faunipollenites* in being diploxylonoid, having folds along one zone of attachment and body outline being somewhat clear. The isotype of *F. minor*, however, can not be distinguished from *F. perexiguus*.
3. *Striatopiceites minutus* Venkatachala & Kar 1968 and *S. granulatus* Kar 1968 have been differentiated from *F. perexiguus* on very minor differences. Types of both the former species are slightly sublaterally preserved, and hence overall shape is deceptive. The granulose sexine described for *S. granulatus* is not granulose; it is structureless. In all other characters they are similar to *F. perexiguus*.
4. *S. delicatus* Kar & Bose 1976 also does not differ from the present species; they fall under the range of smaller grains as discussed above.

On re-circumscription of the smaller group of pollen represented by *Faunipollenites perexiguus*, the following characters are to be taken as important for this species:

1. The pollen are generally small with a range along longer axis being 36-62 μm. They vary in shape from bilaterally oval to bilaterally subcircular.
2. Distal saccus-free area narrow.
3. Striations simple, rarely a few bifurcate.

Description (elaborated)—Overall shape of pollen bilaterally oval, sometimes vertical axis extended to impart a subcircular look. Size small, having haploxylonoid sacci. Body ill-defined, exine being finely intrareticulate. Distal saccus-free area very narrow (3-6 μm), lines of sacci attachment



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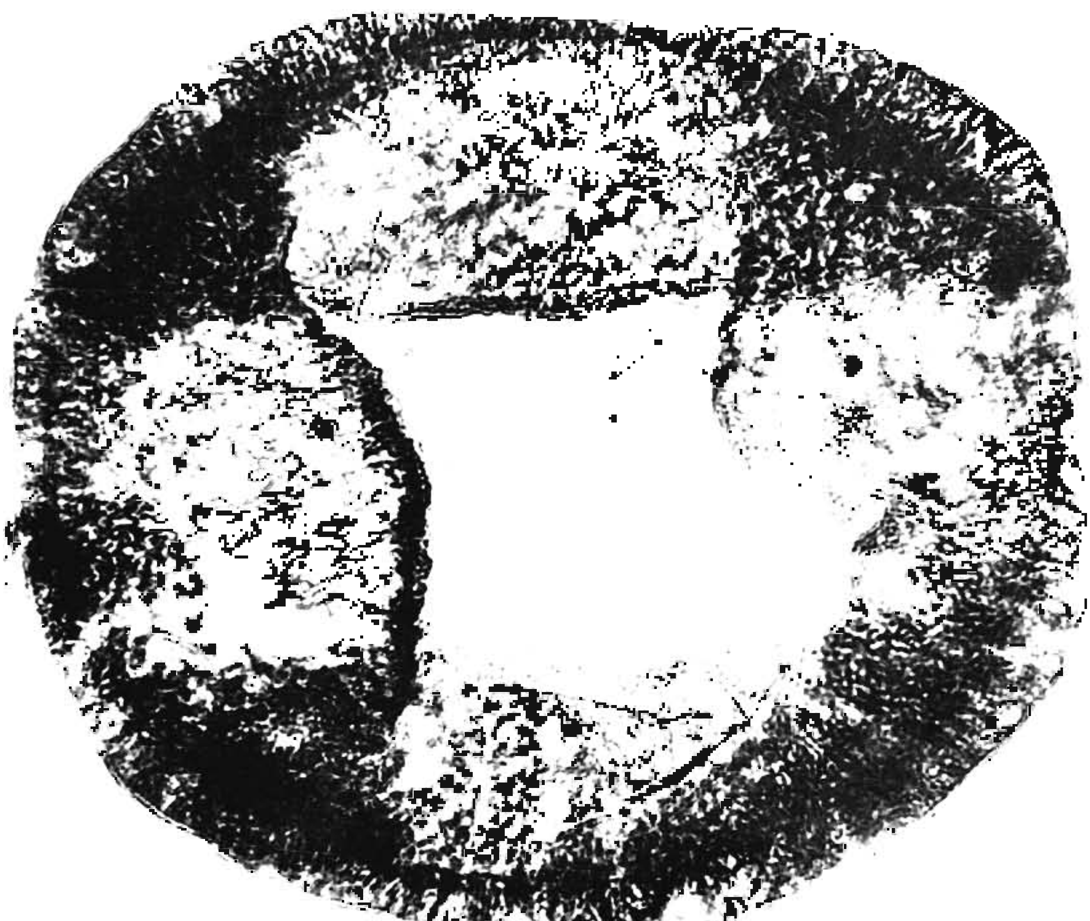

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PLATE 20

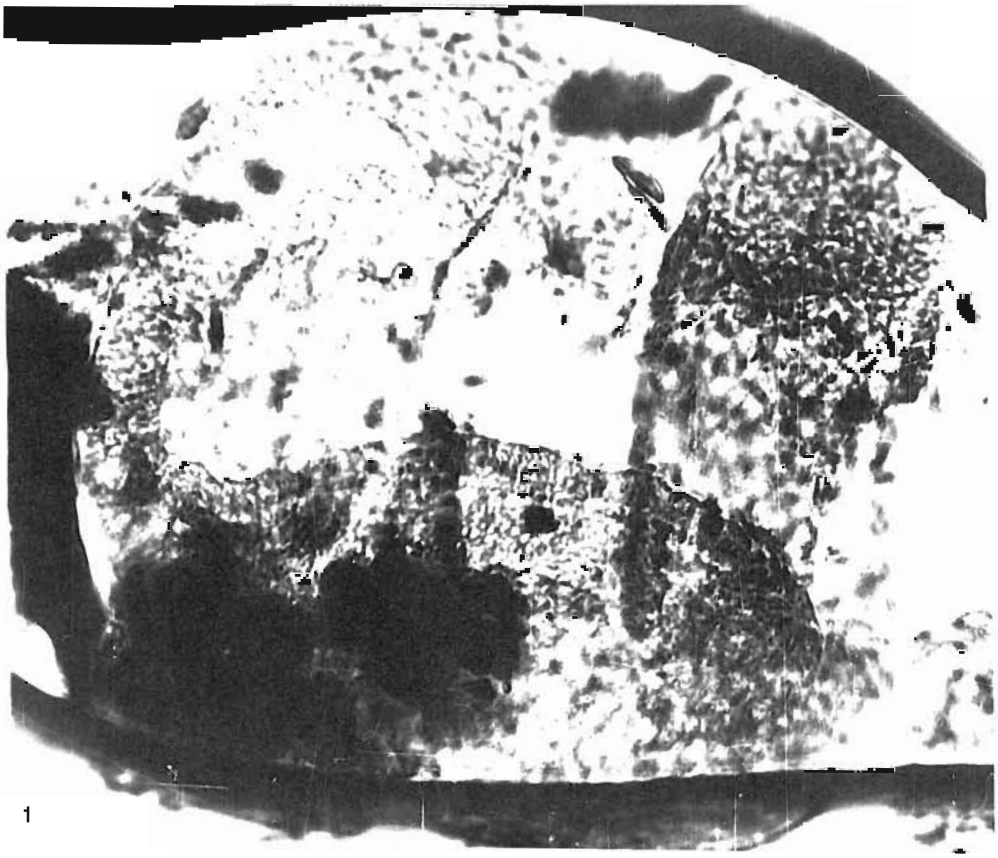


PLATE 21

Faunipollenites [illegible] 1972
1. Holotype showing striate nature of saccus attachment. Slide no. BSIP 2636 [illegible]

almost meeting in the centre, distinctly marked. Saccus also finely intrareticulate.

Comparison—*F. perexiguus* can be distinguished from *F. varius* by its much smaller size range and narrow saccus free area on the distal side.

Faunipollenites singrauliensis Sinha 1972 emend.
Pl. 26, figs 1-3, 6

Holotype—Sinha 1972, pl. 7, fig. 105; size 67 × 95 µm, Slide no. BSIP 4500, Bore Hole NCS 4, Sample no. 12b, Jhingurdah Seam, Singrauli Coalfield, Madhya Pradesh, Raniganj Formation, Late Permian.

Isotype—Sinha 1972, pl. 7, fig. 10, Slide no. BSIP 4[illegible] (here designated).

Original diagnosis—"Horizontally oval, bilateral pollen grains. Size 54-150 × 40-70 µ. Central body ill defined, proximally bearing well defined horizontal striations, 5-10 in number. Sacci haploxylonoid, zone of distal saccus attachment diffused, a median vertical groove or slit present" (after Sinha, 1972, p. 195).

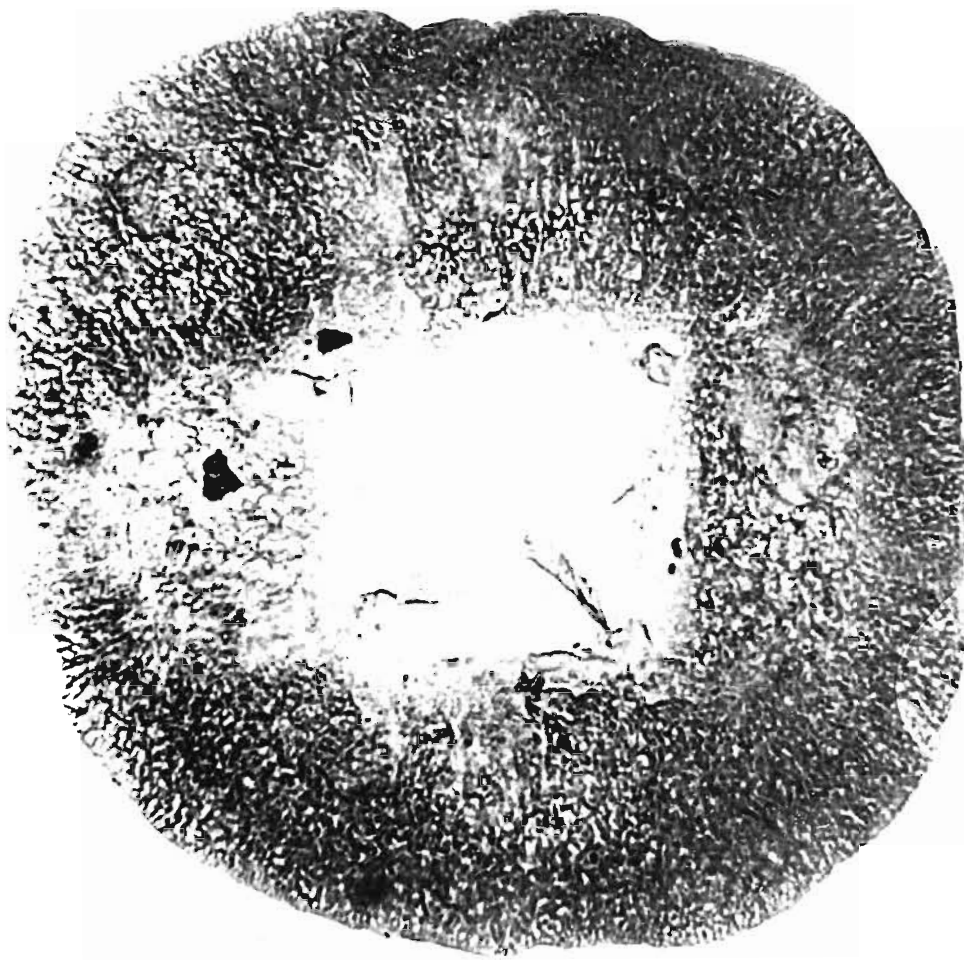
Discussion—The observations made by re-examining the type specimen are:

1. Central body outline invisible, apparently horizontally oval as visualized by the free ends of striations.
2. Body exine with thick muri, fine meshes giving leathery look to the proximal surface.
3. Striations deeply cut, some folded resulting

PLATE 20

1-2. *Striatopodocarpites* [illegible] Maheshwari 1985 here emended showing the distinct outline of the central body and striate nature of saccus attachment × 750.

3. Slide no. BSIP 1984 [illegible]
2. Slide no. BSIP 1984 [illegible]



1

PLATE 22

1. *Crucisaccites indicus* Srivastava 1970: Isotype showing indistinct nature of central body; Slide no. BSIP 2899, EF : O35/3, × 950.

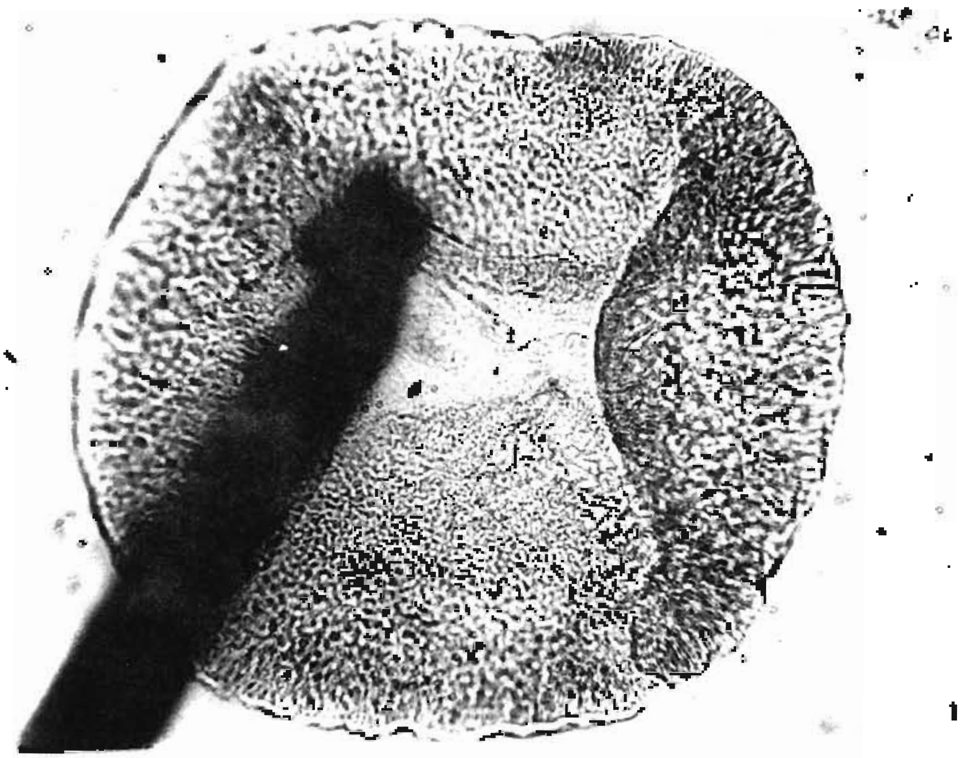
into narrow linear fold-like pleats after compression.

4. Sacci narrow beyond free ends of striations, protosaccate without double network.
5. Median vertical slit absent; sacci attachment zones close to each other, forming "slit-like" saccus-free area; separated apart from each other at one of their lateral sides.

Sinha (1972) separated *Faunipollenites singrauliensis* from *F. varius* on the basis of distal vertical slit in the centre; however, such a slit does not exist in the type specimen of the former species. On the other hand, a number of other characters, as enumerated above, have been observed which entitle this species to be a separate taxon from others. In view of these observations the diagnosis of *Faunipollenites singrauliensis* is being emended here.

Emended diagnosis—Bilateral, central body outline diffused, extent simulated through free ends of striations to be horizontally oval. Exine of central body finely intrareticulate with thick muri and fine meshes, imparting heavy leathery look; striations 5-10, deep-cut, some turning to be as liner narrow folds; sacci sub-hemispherical, narrow beyond free ends of striations, with medium-sized intrareticulations, distally inclined almost up to the centre. No slit on distal median region present.

Description (elaborated)—Size range 50-100 μm. Distally sacci close to each other so that a slit-like area simulated but these attachment lines separate apart from each other at one of the lateral sides. Striations being deep-cut in thick sexine on



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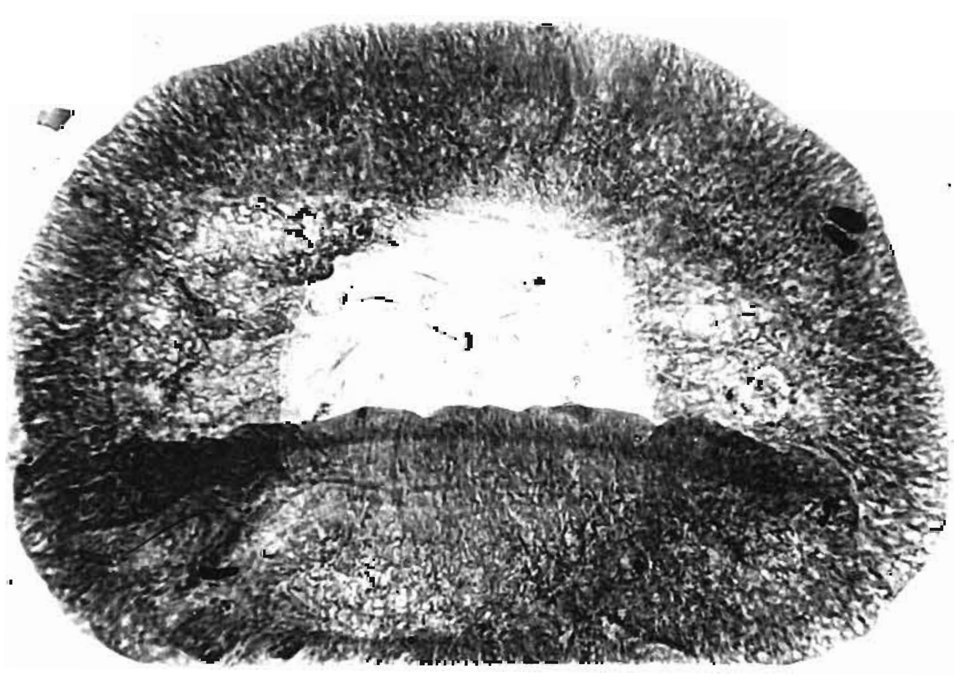


2

PLATE 25

1, 2. [illegible] indicus Srivastava 1970 showing [illegible] of central body [illegible].

1. Slide no. BSIP [illegible] × [illegible].
2. Slide no. BSIP [illegible] × [illegible].

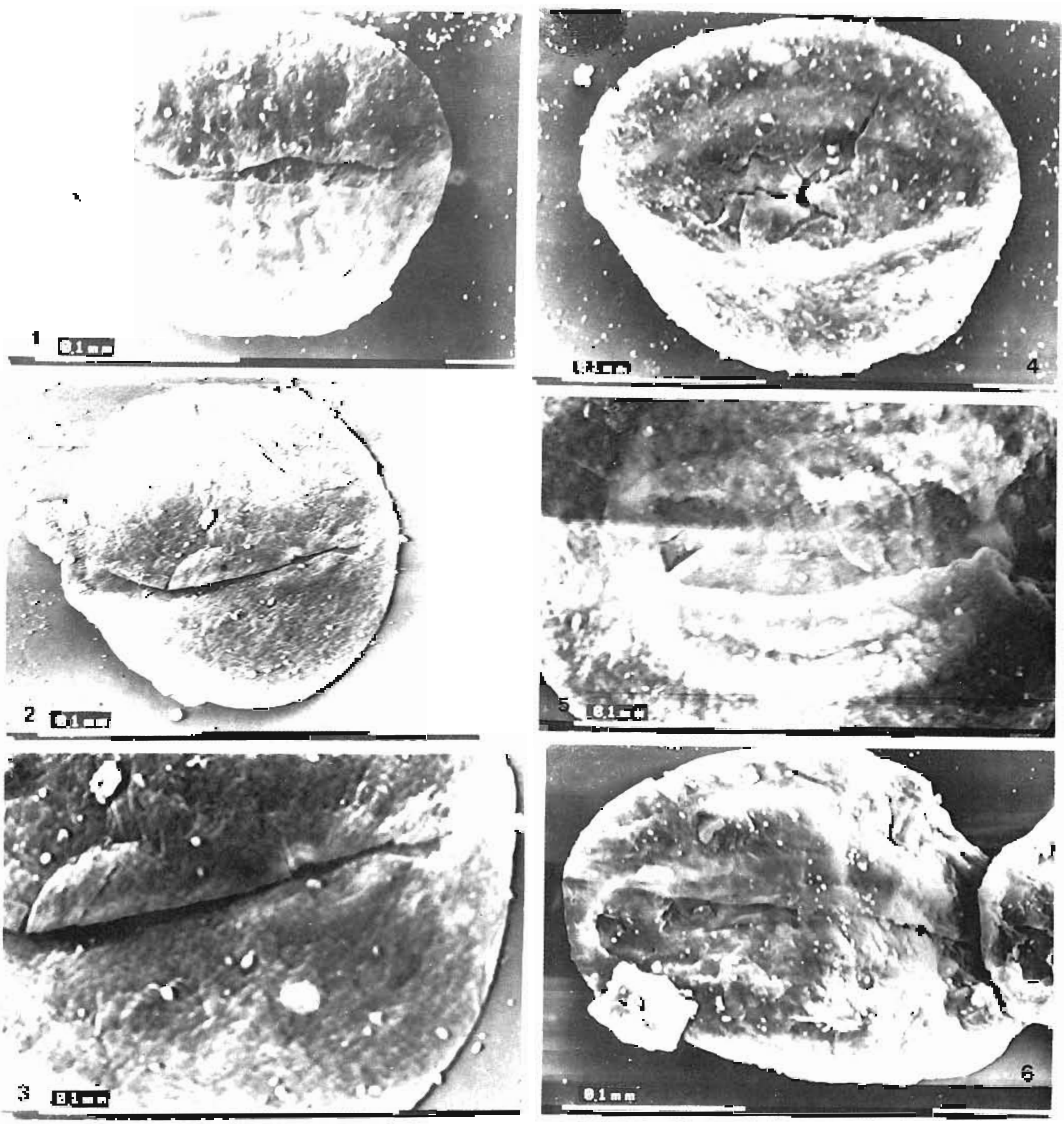


PLATE 24

1-6. Scanning electron photomicrographs of [illegible] Martin 1961.

1, 2. Showing [illegible]

3. Enlargement of specimen of fig. 2 showing the [illegible] and small [illegible]

4. Showing [illegible]

5. Showing the [illegible]

6. Showing the [illegible]

central body, get folded forming very narrow linear folds. Sacci peculiar in being narrow, laterally continuous, protosaccate having thick muri forming fine meshes.

Comparison—The nature of intrareticulation of the body with thicker muri, narrow sacci and deep-cut striations with folding tendency differentiate this species from the type species. The present species differs from *F. perexiguus*, apart from above characters, in being bigger in size.

Faunipollenites congoensis (Bose & Kar) comb. nov.
Text-fig. 9

1966 *Striatopiceites congoensis* Bose & Kar, pl. 13, fig. 1.
1968 *Striatopiceites rimosus* Venkatachala & Kar, pl. 2, fig. 23.

Holotype—Bose and Kar, 1966; pl. XIII, fig. 1; size 186 × 176 μm; Slide no. RG 14161-9; Elila River (right side, only 11) near Fundi Sadi, Congo; Permian.

Isotype—Bose and Kar, 1966; pl. 13, fig. 2; size 192 × 178 μm; Slide no. RG 14161-17.

Original diagnosis—"Bisaccate, subcircular to circular pollen grains, 192-154 × 134-178 μm. Central body ill-defined, intramicroreticulate, horizontally striate. Proximal attachment of sacci to central body seems to be equatorial; distal attachment juxtaposed. Sacci intrareticulate" (after Bose & Kar, 1966, p. 48).

Discussion—The holotype was not available for re-examination. The description and illustration suggest that big circular pollen with diffused central body and juxtaposed zones of sacci attachment find their place in this species.

The transfer of the species *Striatopiceites congoensis* to *Faunipollenites*, as *Faunipollenites congoensis* (Bose & Kar) comb. nov. has been made here in keeping with the lines of approach discussed in the beginning of this account. *Striatopiceites rimosus* Kar 1968 does not differ from *F. congoensis*, hence included in synonymy.

The photomicrograph of the holotype reveals the nature of saccus intrareticulation being medium-sized with thick muri and distinct meshes. The zones of sacci attachment appear to meet each other in central region while get apart from each other at lateral region.

Comparison—This species includes big circular pollen having narrow distal saccus-free area. *F. varius* is different in having bilaterally oval shape and broader distal saccus-free area. Other species recognised here also differ in being mostly bilaterally oval or being much smaller in size.

Faunipollenites magnus (Bose & Kar) comb. nov.
Text-fig. 10

1966 *Striatopiceites magnus* Bose & Kar, pl. 14, fig. 1.

Holotype—Bose and Kar, 1966; pl. XIV, fig. 1; size 220 × 124 μm; Slide no. RG 14161-15; Elila River (right side, only 11) near Fundi Sadi, Congo; Permian.

Isotype—Bose & Kar, 1966; pl. XIV, fig. 2; size 232 × 124 μm; Slide no. RG 14161-10.

Original diagnosis—"Pollen bisaccate, elliptical, 222-232 × 126-128 μm. Central body indistinct, intramicroreticulate, horizontal striations ill-developed. Proximal attachment of sacci to central body not clear, distal attachment juxtaposed. Sacci intrareticulate" (after Bose & Kar, 1966, p. 49).

Discussion—The type specimen was not available for re-study. The species is circumscribed for big bilateral pollen with diffused body and big sacci. Distal zones of saccus attachments are close to each other or slightly apart. Intrareticulation of sacci appears to be distinct with thick muri. The pollen seems to have a tendency to rotate sublaterally during preservation—apparently due to its big size and subcylindrical organization.

Comparison—In general shape and nature of striation, *F. magnus* is closely comparable to *F. varius*; however, the former is much bigger in size having coarser intrareticulation of the sacci.

PLATE 25 →

1-4. *Faunipollenites varius* Bharadwaj 1962 showing indistinct outline of central body, nature of horizontal striations and intrareticulate structure of central body:
1. Lectotype; Slide no. BSIP 9903, EF : R40/4, × 750.
2. Slide no. BSIP 9906, EF : N35/4, × 500.
3. Slide no. BSIP 2337, EF : O30/2 × 750.
4. Slide no. BSIP 9906, EF : H34/2, × 500.

5-8. *Faunipollenites perexiguus* Bharadwaj & Salujha 1965:
5. Showing proximal striations; Slide no. BSIP 9905 EF : 518/2, × 1000.
6. Showing distal saccus attachment; Slide no. BSIP 9900, EF : H19/4, × 1000.
7. Holotype proximal face showing indistinct central body outline and proximal horizontal striations; Slide no. BSIP 9904, EF : P30/2, × 1000.
8. Distal face of specimen in fig. 7 showing distal saccus attachment, × 1000.

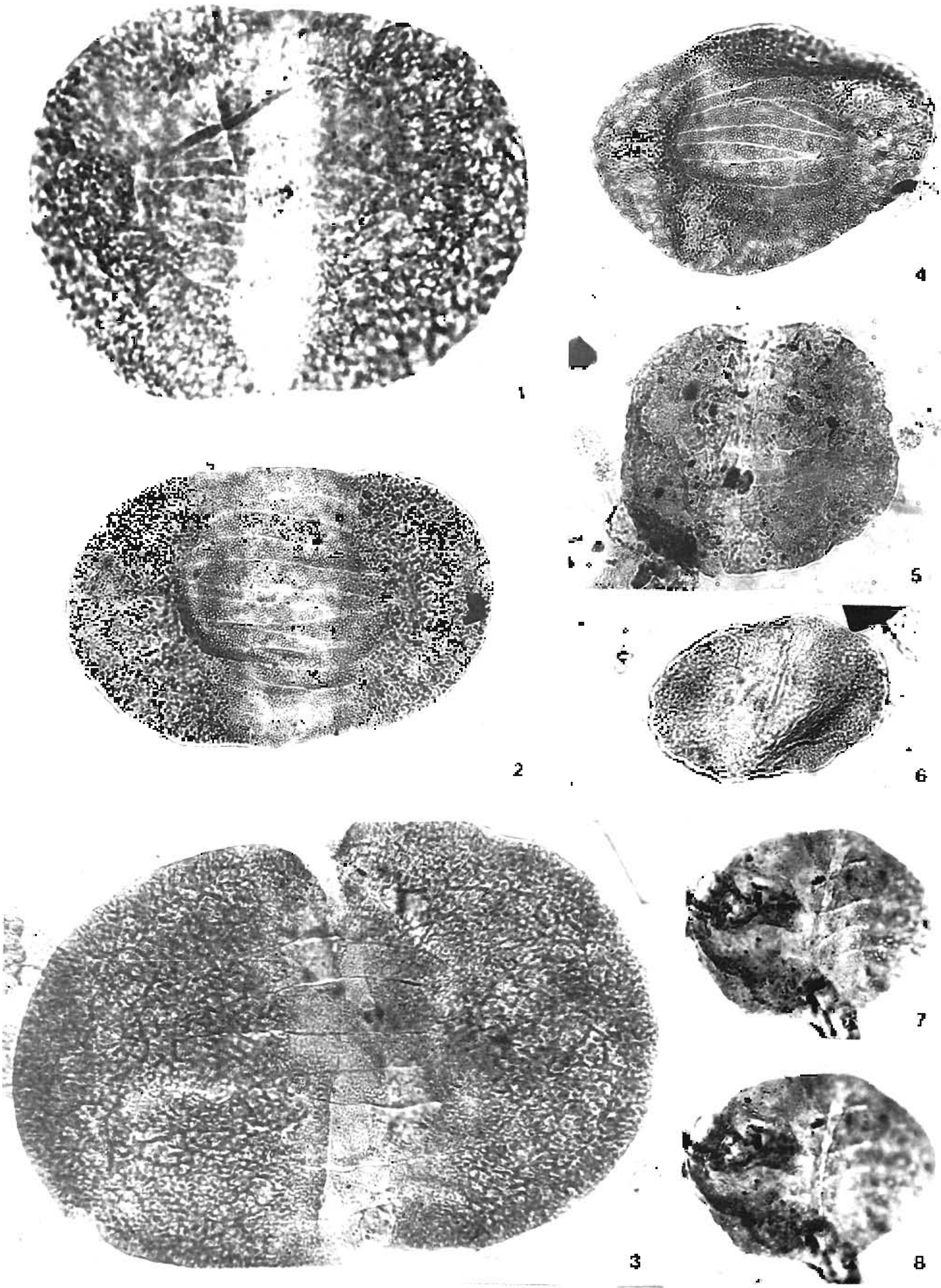


PLATE 25

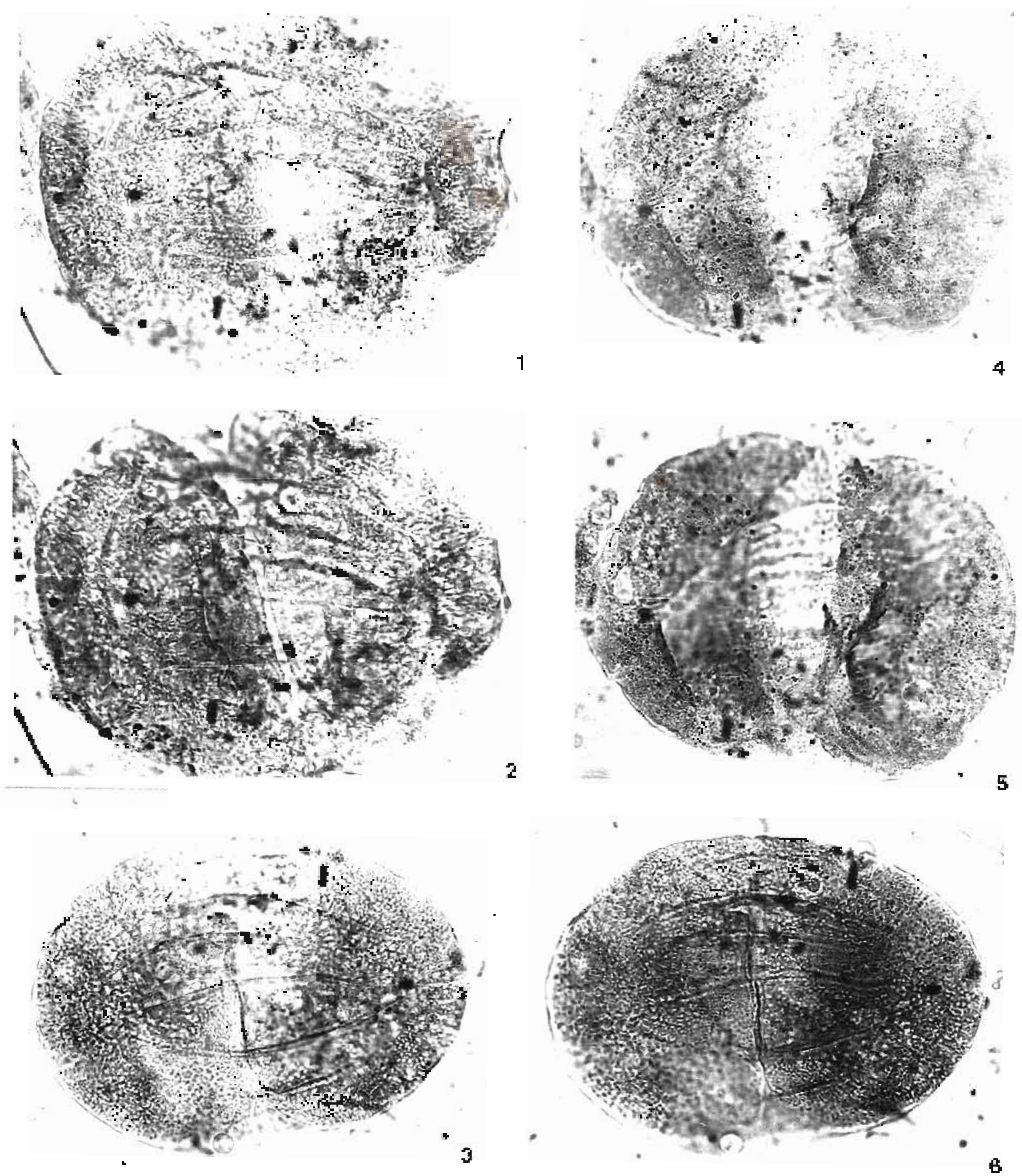


PLATE 26

1-3, 5. *Faunipollenites singrauliensis* Sinha 1972

1. Proximal view showing nature of striations and intrareticulate structure of central body exine. Slide no. BSIP [illegible] [illegible] × 750.
2. Distal view of specimen in fig. 1 showing nature of saccus attachment.
3. Holotype in proximal view showing indistinct nature of central body outline and horizontal striations. Slide no. BSIP [illegible] × 750.
5. Holotype in distal view showing bilateral, narrow sacci free area.

4, 6. *Faunipollenites varius* Bharadwaj 1962 here emended. Specimen illustrated by Srivastava 1970 as holotype of *Faunipollenites* [illegible]. Slide no. BSIP 5032 [illegible] × 750.

4. Proximal view showing nature of striations and central body.
6. Distal view showing distal saccus attachment.

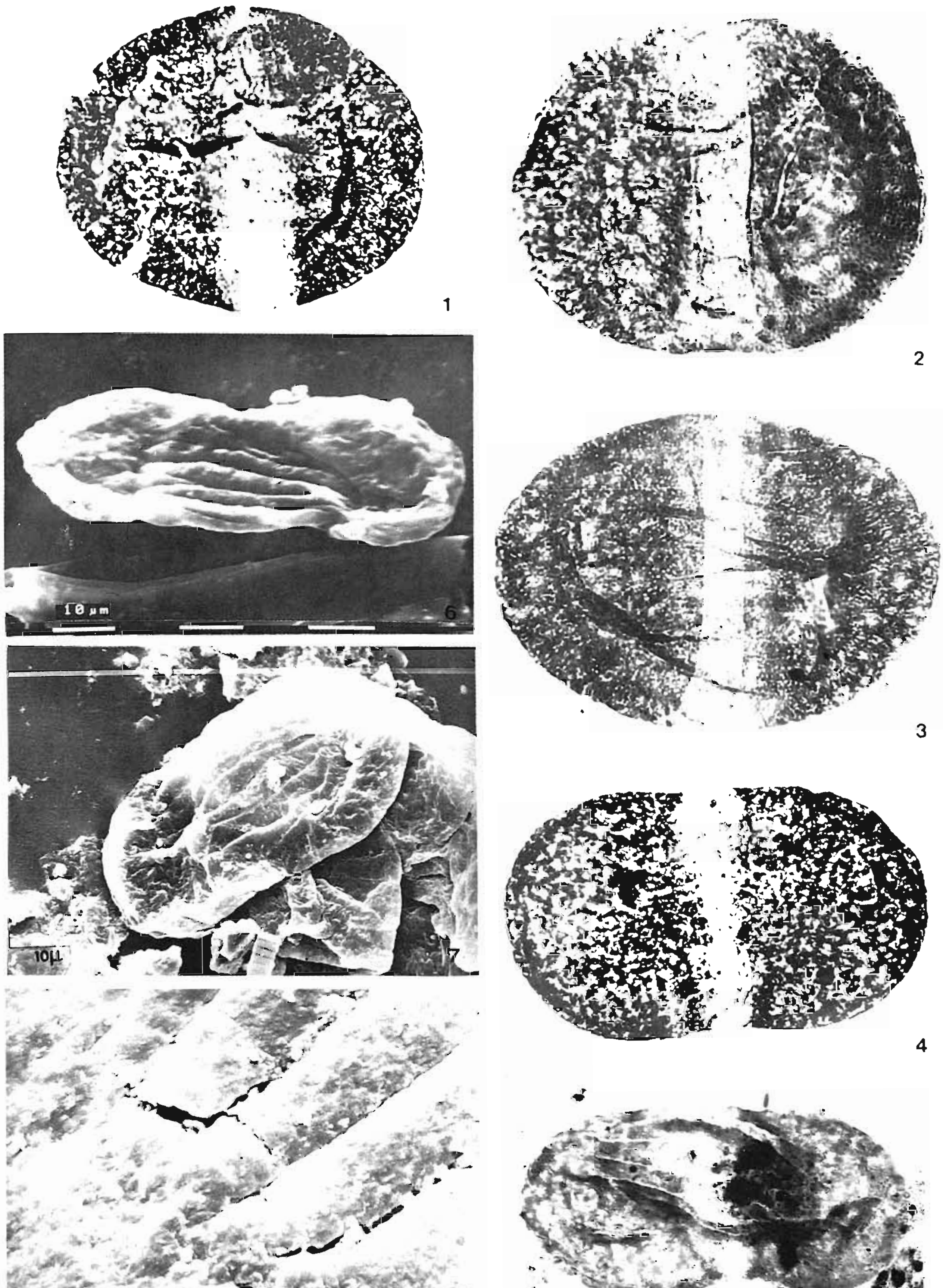


PLATE 27

DISTRIBUTION

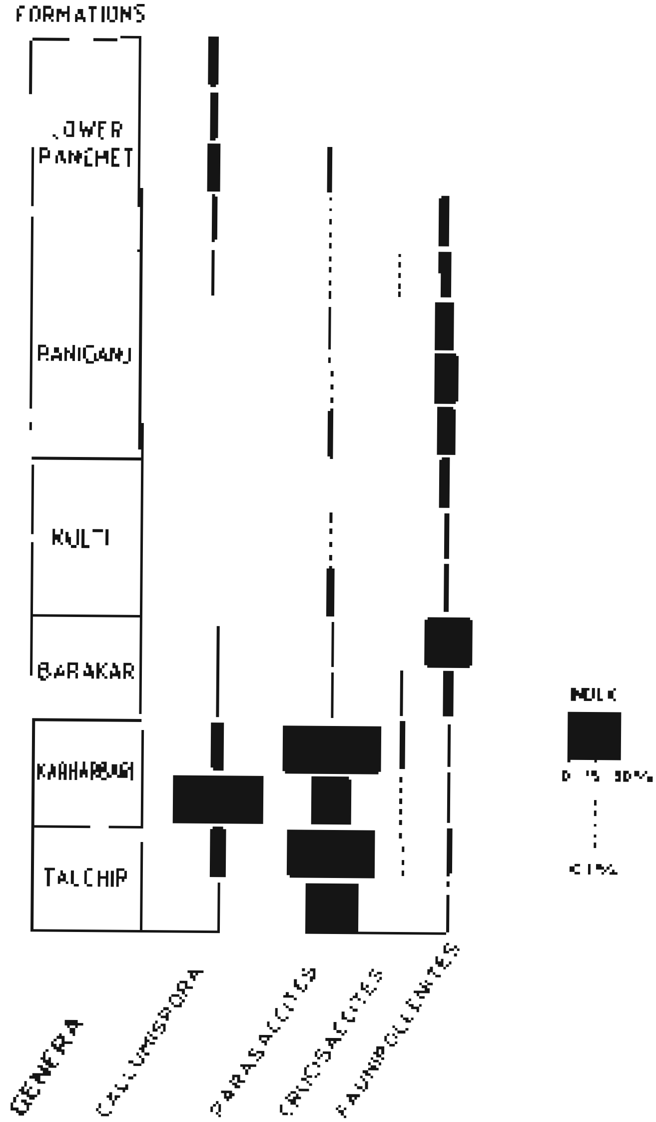
The four genera dealt here for their morphographic and species delimitation have characteristic distribution through Lower Gondwana formations. The precise distribution of species is not on record from various basins because most of the data is based on generic frequency. However, the relative abundance of these genera itself is diagnostic for different assemblages through Lower Gondwana formations of India.

The pattern of percentage frequency of *Callumispora*, *Parasaccites*, *Crucisaccites* and *Faunipollenites* is depicted in Text-figure 11.

The genus *Callumispora* is prominently represented in Early Permian. It is dominant in Talchir and prominent in Karharbari palynoflora. Within these formations its frequency is recorded by maximum representation in the Lower Karharbari Formation. In the overlying Barakar Formation it dwindles out and ultimately in the Kulti and Raniganj assemblages, it is generally not recorded. This genus once again appears in Upper Raniganj and becomes fairly abundant in the Lower Panchet Formation. Obviously some similarity of climatic conditions is reflected in the Early Permian and Early Triassic time as has been discussed by Tiwari and Tripathi (1988).

The prominence of *Parasaccites*, as such, is confined to the early Permian palynoflora. Along with other members of the radial monosaccate group (e.g. *Plicatipollenites*, *Virkkipollenites*) the genus *Parasaccites* is abundant in the Lower Talchir while in Upper Talchir it further increases in frequency. In the Lower Karharbari, the percentage of this genus declines but again in Upper Karharbari a maximum has been observed. In rest of the younger horizons of Lower Gondwana sequence the presence of the genus has been noticed but, by and large, it remains sporadic. It is interesting that its incidences continue up to the Lower Panchet, thereafter it ceases to exist.

The comparability of prominence between *Callumispora* and *Parasaccites* is very striking (Text-fig. 11) and this linkage is attributed to comparable climatic conditions.



Text-figure 11—Histogram showing distribution pattern of various genera through Lower Gondwana formations in India.

Numerically *Crucisaccites* is not a major element in the assemblages of Lower Gondwana formations. However, its typical construction signifies for a line of evolution directed from the

PLATE 27

1-4. *Faunipollenites varius* Bharadwaj 1962 showing nature of horizontal striation, indistinct central body outline and distal saccus attachment.
1. Slide no. BSIP [illegible] × 500.
2. Slide no. BSIP [illegible] × 500.
3. Slide no. BSIP [illegible] × 500.
4. Slide no. BSIP [illegible] × 500.
5. *Faunipollenites perexiguus* Bharadwaj & Salujha 1965, specimen illustrated by Venkatachala and Kar (1968) as *Striatopodocarpites* showing nature of central body and striations. Slide no. BSIP [illegible] × 750.

6-8. *Faunipollenites varius* Bharadwaj 1962—SEM photomicrographs showing nature of striations on central body.

8. Enlargement of specimen showing merging nature of striations.

girdling radial monosaccates. *Crucisaccites* is fairly represented in Upper Karharbari. In Talchir, Barakar and Raniganj only sporadic and inconsistent presence has been recorded, elsewhere normally it is absent. The first occurrence of this taxon is linked with the genera *Callumispora* and *Parasaccites*. Its diversification is an index for Karharbari Formation.

Faunipollenites is one of the important members of striate-disaccate pollen complex of Permian. The poorly defined nexine and general homo (equal) or haploxylonoid shape of sacci differentiate *Faunipollenites* from a scores of other striate genera. Besides, the ill-defined saccus attachment zones, mostly simple striations without vertical partitions, fine reticulation of body cappa and protosaccate lile of saccus further defines this genus. It is distributed throughout the Lower Gondwana and also occurs in Lower Panchets. The maximum incidences of *Faunipollenites* are recorded in Upper Barakar. In Raniganj palynoassemblages also this genus is abundantly present. Thus, in Talchir and Karharbari formations this genus is very meagre but from Barakar upwards it is one of the important constituents of the striate-disaccate population.

To conclude, it is emphasised that individually as well as jointly the genera *Callumispora*, *Parasaccites* and *Crucisaccites* identify various levels of stratigraphy in Talchir and Karharbari formations. *Faunipollenites*, however, can be of index value by virtue of its abundance only when pollen frequency of other disaccate pollen are determined.

ACKNOWLEDGEMENTS

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KEY FOR IDENTIFICATION OF SPECIES

Genus—*Callumispora* Bharadwaj & Srivastava 1969 emend.

Trilete spores, radially symmetrical and spheroidal in shape. Exine thick, laevigate, infrapunctate in structure. Trilete mark prominent.

a. Exine stratified, mostly 3-4 µm thick
   Interray areas marked by coarse and distinct structure simulating contact areas
      C. ***barakarensis*** Bharadwaj & Srivastava 1969 emend.
   2. Infrapunctate structure fine, uniformly distributed all over the body
      C. ***magnifica*** (Bose & Maheshwari) comb. nov.
   3. Infrapunctate structure coarse, irregularly distributed all over the body
      C. ***fungosa*** (Balme) Bharadwaj & Tiwari 1977

b. Exine non-stratified, mostly < 1 µm thick
   4. Infrapunctate structure fine and uniformly distributed all over the body
      C. ***gretensis*** (Balme & Hennelly) Bharadwaj & Srivastava 1969 emend.
   5. Fine infrapunctation all over, spore size very small (36-50 µm)
      C. ***adensa*** Bharadwaj, Kar & Navale 1976 emend.

Genus—*Parasaccites* Bharadwaj & Tiwari 1964

Monosaccate pollen, circular to bilateral, discoidal shape, trilete mark generally present. Saccus girdling type, attached with body in para-condition. Central body intramicroreticulate.

a. Central body distinct
   1. Circular, central body circular, thin, trilete mark distinct
      P. ***korbaensis*** Bharadwaj & Tiwari 1964
   2. Bilateral, oval to elliptical, central body circular to subcircular, thin, trilete mark indistinct
      P. ***ovatus*** Kar 1968
   3. Circular, central body roundly triangular, trilete mark generally distinct
      P. ***perfectus*** Bose & Maheshwari 1968
   4. Circular-circulo-triangular, central body generally conforming to overall outline, thick, intrareticulate, trilete mark distinct
      P. ***densicorpus*** Lele 1975

b. Central body indistinct
   5. Circular, central body outline ill-defined, apparently circular, trilete mark obscure, faint
      P. ***obscurus*** Tiwari 1965
   6. Bilaterally oval, central body ill-defined, apparently circular to oval, trilete mark obscure
      P. ***bilateralis*** Tiwari 1965

Genus—*Crucisaccites* Lele & Maithy 1964

Circular to oval monosaccate pollen, monolete mark obscure to distinct. Central body oval to hexagonal, intramicroreticulate. Saccus attachment cruciform. Zone of saccus attachment generally accompanied with secondary folds.

   1. Circular, central body thin, trapezoid to rhomboid
      C. ***latisulcatus*** Lele & Maithy 1964
   2. Oval, central body oval, thin, monolete mark prominent
      C. ***monoletus*** Maithy 1965 emend.
   3. Circular to oval, central body weakly defined, thin, apparently circular, infold not developed
      C. ***indicus*** Srivastava 1970

Genus—*Faunipollenites* Bharadwaj 1962

Bisaccate pollen, mostly bilaterally oval, central body not marked, apparently oval to subcircular, intramicroreticulate, proximally simple or branched horizontal striations, distally saccus-free area not sharply delimited.

   1. Oval, central body thin, 6-20 striations, distally saccus-free area 5-20 µm, size 65-180 µm
      F. ***varius*** Bharadwaj 1962 emend.
   2. Oval, 6-9 striations, distally sacci almost touching each other (5-7 µm apart), size 36-62 µm

F. perexiguus Bharadwaj & Salujha 1964

3. Oval, central body dark, 5-10 striations, distally sacci apart from each other
F. singrauliensis Sinha 1972
4. ± circular, img. 5-13 striations, distally sacci close to each other
F. conguensis (Bose & Kar) comb. nov.
5. Ellipsoidal, striations faint and few, distally sacci close to each other, size 225-342 µm
F. magnus (Bose & Kar) comb. nov.

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Singh, [illegible] spore assemblage [illegible] *Palaeontology* 7(2): [illegible]

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Srivastava, [illegible] *Palaeobotanist* 26(1): [illegible]

Srivastava, [illegible] *Palaeobotanist* 2[illegible]

Tiwari, R. S. [illegible] Miospore assemblage in some coals of Barakar Stage (Lower Gondwana) of India. *Palaeobotanist* 13(2): [illegible]

Tiwari, R. S. [illegible] Palynological investigations of some coal seams in [illegible] Orissa, India. *Palaeobotanist* 16(3): 222-242.

Tiwari, R. S. [illegible] K. R. Surange [illegible] *Aspects and appraisal of Indian Palaeobotany* [illegible] Birbal Sahni Institute of Palaeobotany, Lucknow.

[illegible] pollen [illegible]

[illegible] Sporae dispersae [illegible] *Palaeobotanist* [illegible]

Venkatachala, B. S. & Kar, R. K. [illegible] Palynology of [illegible] sediments [illegible] Basin [illegible] Stage [illegible] *Palaeobotanist* 16: [illegible]

Virkki, C. [illegible] Spores from the Lower Gondwanas of India and Australia. *Proc. natn. Acad. Sci. India* 15: 93-176.

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Observations on archaeopyle type in fossil dinoflagellate cyst species *Dingodinium cerviculum* Cookson & Eisenack 1958

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The archaeopyle type in fossil dinoflagellate cyst species *Dingodinium cerviculum* Cookson & Eisenack 1958 is interpreted based on the study of a rich suite of well-preserved specimens recovered from subsurface Lower Cretaceous sequence of Palar Basin, southern India. These cysts develop disimilar periarchaeopyle and endoarchaeopyle. The periarchaeopyle is intercalary, involving more than one, probably three, anterior intercalary paraplates with free perioperculum. The endoarchaeopyle is combination type involving all the four apical and three anterior intercalary paraplates. The endoperculum is compound and is represented in two parts, an apical part which is simple, polyplacoid and adnate while the other part comprising intercalary paraplates is polyplacoid, free and probably compound. The archaeopyle formula is suggested to be ?2-3 I/(4A) a3I. In view of these observations, the diagnosis of *D. cerviculum* is emended herein.

Key-words—Dinoflagellate cysts, Morphology, Early Cretaceous, Palar Basin (India).

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सारॉश

अश्मित घूर्णीकशाभ पुटी जाति डिंगोडीनियम सर्विकुलम् कुक्सन व आइज़ेनेक 1958 में आर्कियोपाइल के प्रकार पर प्रेक्षण

खोवाजा अतीकुज़्ज़माँ, राहुल गर्ग एवं कृष्ण प्रसाद जैन

अश्मित घूर्णीकशाभ पुटी जाति **डिंगोडीनियम सर्विकुलम्** कुक्सन व आइज़ेनेक 1958 में विद्यमान आर्कियोपाइल के विभिन्न प्रकारों की व्याख्या दक्षिणी भारत में पलार द्रोणी के अधरि क्रीटेशी अनुक्रम की उपसतह से उपलब्ध सघन सुपरिरक्षित प्रादर्शों के अध्ययन के आधार पर की गई है। ये पुटीयाँ विभिन्न प्रकार के पेरीआर्कियोपाइलों एवं अन्त:आर्कियोपाइलों का निर्माण करती हैं। पेरीआर्कियोपाइल अन्तर्वेशी है तथा इसमें एक से अधिक, सम्भवतया तीन स्वतंत्र प्रच्छदों से युक्त अग्रस्थ अन्तर्वेशी पैराप्लेट विद्यमान हैं। अन्त:आर्कियोपाइल संयोजित है जिसमें सभी चारों शीर्षस्थ एवं तीनों अगस्थ अन्तर्वेशी पैराप्लेट का संयोग है। अन्त:ओपर्कुलम संयुक्त प्रकार का है तथा दो भागों से बना है इसका शीर्षस्थ भाग सरल, पोलीप्लेकॉयडी एवं संलग्न है तथा दूसरा भाग, जो अन्तर्वेशी पैराप्लेटों से युक्त है, पोलीप्लेकॉयडी, स्वतंत्र तथा सम्भवतया संयुक्त प्रकार का है। आर्कियोपाइल का सूत्र ?2-3I/(4A)a3I प्रस्तावित किया गया है। उक्त प्रेक्षणों के आधार पर डिंगोडीनियम् सर्विकुलम् का निदान संशोधित किया गया है।

DINGODINIUM Cookson & Eisenack 1958 is a stratigraphically significant dinocyst genus with a wide geographic distribution during Late Jurassic-Early Cretaceous times. While erecting the genus, Cookson and Eisenack (1958, pp. 39-40) established two species, *D. jurassicum* and *D. cerviculum*, designating the former as the type species. Presence of an opening/archaeopyle was not described in any of these two species.

Subsequently several other species have been added to *Dingodinium* but there appears to be no unanimity among workers regarding the type of archaeopyle. Sarjeant (1966) first documented the presence of an archaeopyle in *?Dingodinium albertii* as intercalary. Later Haskell (1969) described variable type of archaeopyle, usually apical and rarely epicystal or precingular, in *D. cerviculum*. On the contrary, Dodekova (1971) interpreted that *D. jurassicum* and *D. albertii* both had apical arehaeopyle. Stover and Evitt (1978) in their generic analyses remarked that archaeopyle type in *Dingodinium* is uncertain, probably intercalary or combination type (AI). Different views regarding archaeopyle type in *Dingodinium* species putforth from time to time by various workers are summarized in Table 1.

Table 1—Different views on archaeopyle type in *Dingodinium* Cookson & Eisenack 1958

AUTHOR	SPECIES	ARCHAEOPYLE TYPE
Cookson & Eisenack, 1958	*D. jurassicum* *D. cerviculum*	No mention No mention
Eisenack, 1958	*D. europaeum*	No mention
Gitmez, 1970	*D. tuberosum* (= *Parvocavatus tuberosus*)	Apical
Dodekova, 1971	*D. jurassicum* *D. albertii*	Apical Apical
Davey, 1974	?*D. albertii*	Apical
Dodekova, 1975	*D. minutum*	Apical
Duxbury, 1977	*D. spinosum* (= *Parvocavatus spinosus*)	Apical
Stover & Helby, 1987a	*D. cerviculum* *D. jurassicum*	Apical Apical
Stover & Helby, 1987b	*D. swanense*	Apical
Brideaux, 1971	*D. cerviculum*	Intercalary/Apical
Sarjeant, 1966	? *D. albertii*	Intercalary
Habib, 1972	*D. cerviculum*	Intercalary
Habib, 1976	*D. cerviculum*	Intercalary
Jansonius, 1981 (in Mehrotra & Sarjeant, 1968)	*D. cooksoniae*	Intercalary (2a)
Pothe de Baldis & Ramos, 1983	*D. sanmartinoi*	Intercalary (2a)
Stover & Evitt, 1978 1978	*Dingodinium* Cookson & Eisenack	Intercalary or combination (Apical + Intercalary)
Haskell, 1969	*D. cerviculum*	Variable
Mehrotra & Sarjeant, 1984	*D. cerviculum*	Variable $4A\ (1\text{-}4)a/I_1$ or $4A\ (1\text{-}4)a/(I_1P_3)$ or $4A\ (1\text{-}4)a/I_{1a}+P_{3a}$
	Dingodinium	$4A(1\text{-}4)a/I_1$ $4A(1\text{-}4)a/(I_1P_3)$ or I_1+P_3 $4A(1\text{-}4)a/I_{1a}+P_{3a}$ $4A(1\text{-}4)a/(4A_1-4I_1)$?4A(1-4)/4A(1-4) or ?4A (1-4)a/4A(1-4)a

A perusal of published literature reveals that archaeopyle controversy in *D. cerviculum* is long existing. In earlier studies the periarchaeopyle and endoarchaeopyle were not differentiated in the camocavate cysts of *Dingodinium* and the archaeopyle in general was defined as apical, intercalary, epicystal, combination or variable. Mehrotra and Sarjeant (1984) pointed out the dissimilar nature of periarchaeopyle and endoarchaeopyle in *Dingodinium*. They based their observations on detailed study of *D. cerviculum* from subsurface Lower Cretaceous sequence of Cauvery Basin, East coast of India and review of published literature, documenting great variation in the archaeopyle type.

Recently a rich dinocyst assemblage containing well-preserved specimens of *Dingodinium cerviculum* has been recovered from subsurface Lower Cretaceous sediments from ca. 760 m deep bore-hole drilled near Puduvoyal in Chingleput District, Palar Basin. Our observations and interpretations of archaeopyle type in *D. cerviculum* based on this material, presented at the Brisbane meeting of the 7th International Palynological Congress (Khowaja-Ateequzzaman *et al.*, 1988), are discussed in the present paper.

All figured specimens are lodged with the museum, Birbal Sahni Institute of Palaeobotany, Lucknow, India. The specimen locations in the slides has the reference of mechanical stage coordinates of Olympus BH-2 microscope no. 274090.

OBSERVATIONS

More than 200 selected specimens of *Dingodinium cerviculum* have been examined under Phase Contrast and Nomarski Differential Interference Contrast Microscopy. The present suite of *D. cerviculum* is unique as it contains both excysted and unexcysted cysts, the former strikingly dominates the assemblage. Apart from these, a few well-preserved specimens also display partially opened up archaeopyle. Availability of such

PLATE 1 →

(All photomicrographs in Nomarski Differential Interference Contrast).

1-7. *Dingodinium cerviculum* Cookson & Eisenack 1958

1-3. Slide no. BSIP 10149, Coordinates: 20.4 × 159.3. 1. Complete specimen, ca × 800; 2, 3. Same specimen (portion magnified) in left lateral and right lateral views respectively, ca × 2000.

4-6. Slide no. BSIP 10150, Coordinates: 16.9 × 131.8. 4. Complete specimen ca × 800; 5-6. Same specimen (portion magnified) in left lateral and right lateral views respectively, ca × 2000.

7. Magnified portion of a specimen showing intercalary part of endoperculum in three pieces as well as paraplate 2a to be of standard hexa type, Slide no. BSIP 10151, Coordinates: 13.8 × 130.9, ca × 2000.

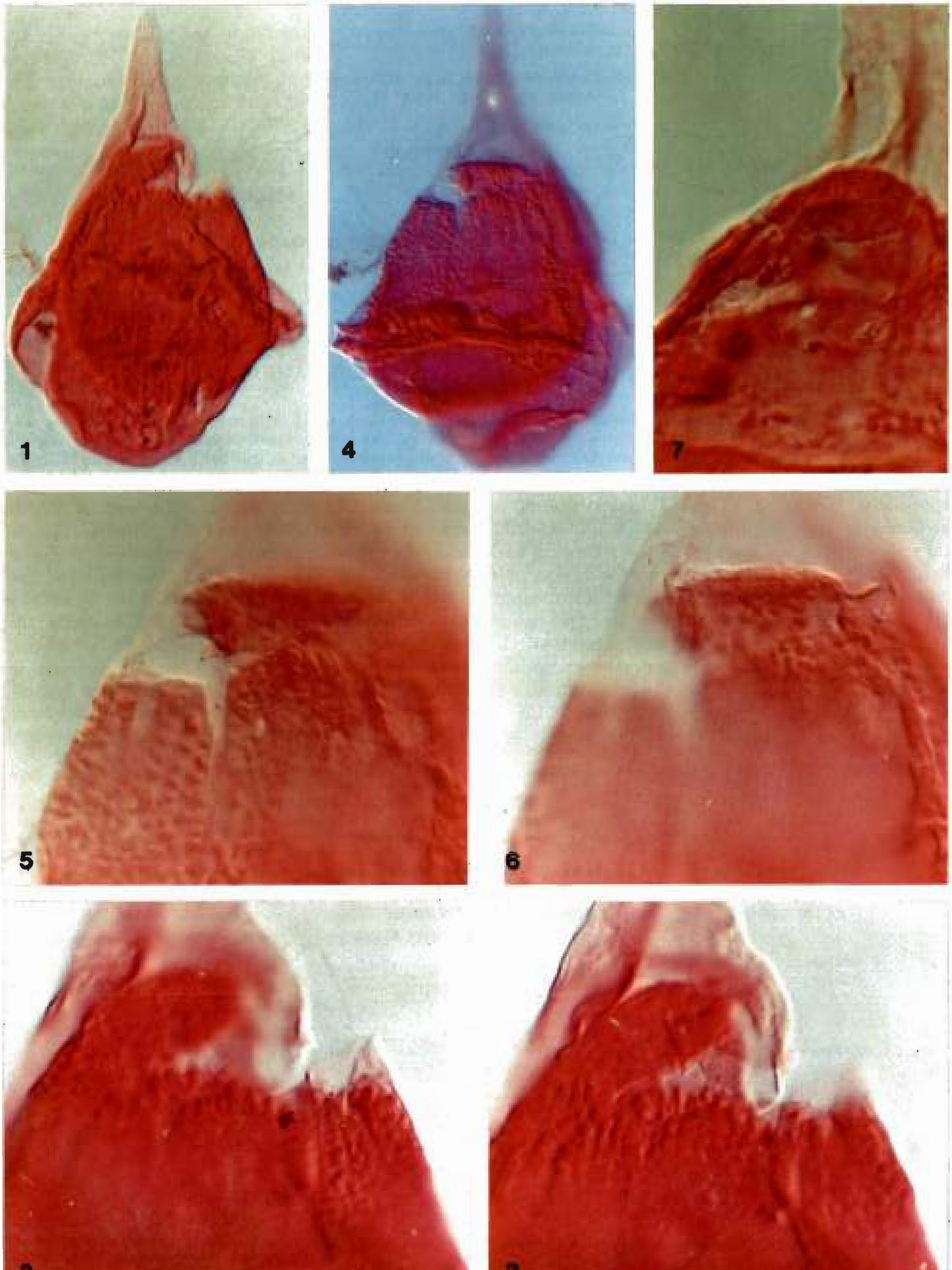
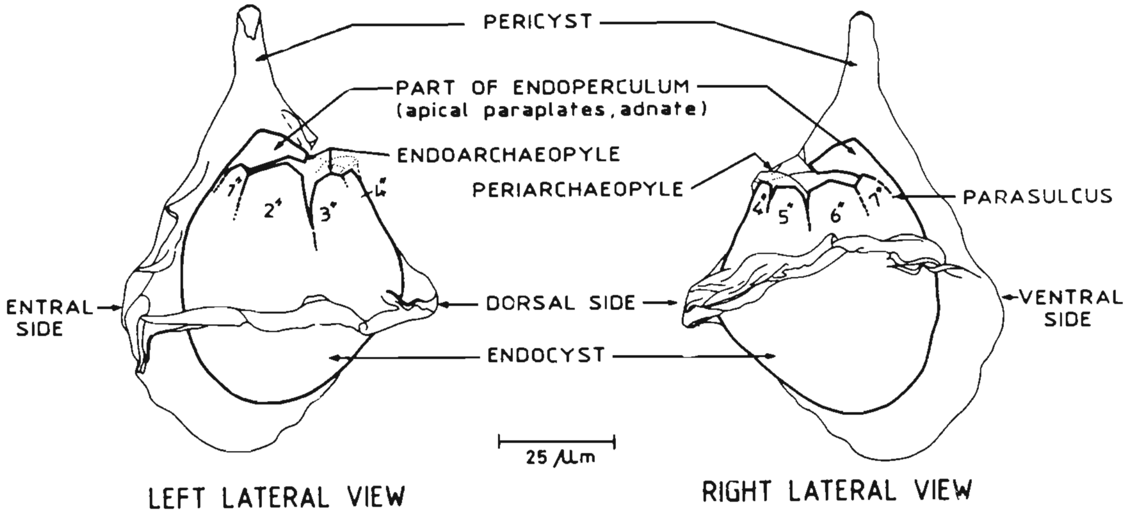


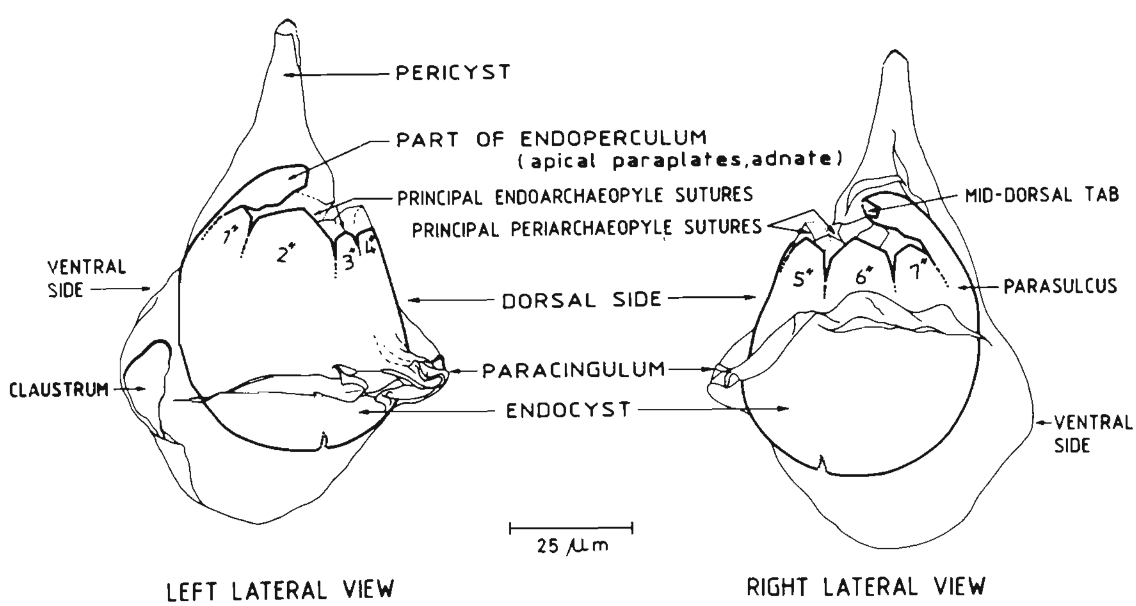
PLATE 1



Text-figure 1—*Dingodinium cerviculum* Cookson & Eisenack 1958: Camera lucida sketch of an excysted specimen showing offset endings of the helicoid periparacingulum, position of periarchaeopyle and endoarchaeopyle, disposition of pre-cingular paraplates with accessory endoarchaeopyle sutures and the adnate apical part of endoperculum, slide no. BSIP 10150; Coordinates: 17.0 × 131.5.

specimens facilitated a logical understanding of archaeopyle type in this species. While studying these specimens we considered the following four features most significant to interpret the archaeopyle type (i) cyst orientation, (ii) wall layer relationship, (iii) paraplate topology and shape, and (iv) nature and position of paracingulum and parasulcus.

D. cerviculum is one of the rare exceptions where the cyst is laterally compressed. As a result of lateral compression, the cyst in strewn slide is generally seen in lateral views. The ventral and dorsal sides lie along margins. The ventral side is marked by offset endings of the periparacingulum and the parasulcus with comparatively reduced ornamentation (Pl. 2, fig. 1; Text-fig. 1). The periphragm is extremely thin and smooth without any ornamentation or parasutures, whereas the endophragm is thick with extensively developed tabular ornamentation which is well-defined in epiendocyst (Pl. 1, figs 2, 3, 5, 6; Pl. 2, figs 2, 3, 6). The endocyst is eccentrically placed, shifted more towards dorsal side and is sometimes appressed



Text-figure 2—*Dingodinium cerviculum* Cookson & Eisenack 1958: Camera lucida sketch of an excysted specimen showing adnate apical part of endoperculum, mid-dorsal tab, and principal periarchaeopyle sutures, slide no. BSIP 10149; Coordinates: 20.4 × 159.3.

along the precingular and postcingular areas on the dorsal side (Pl. 1, figs 1, 4; Pl. 2, figs 1, 4, 7). The periphragm and endophragm are distinct from each other towards anterodorsal side where periarchaeopyle and endoarchaeopyle are developed.

Periarchaeopyle

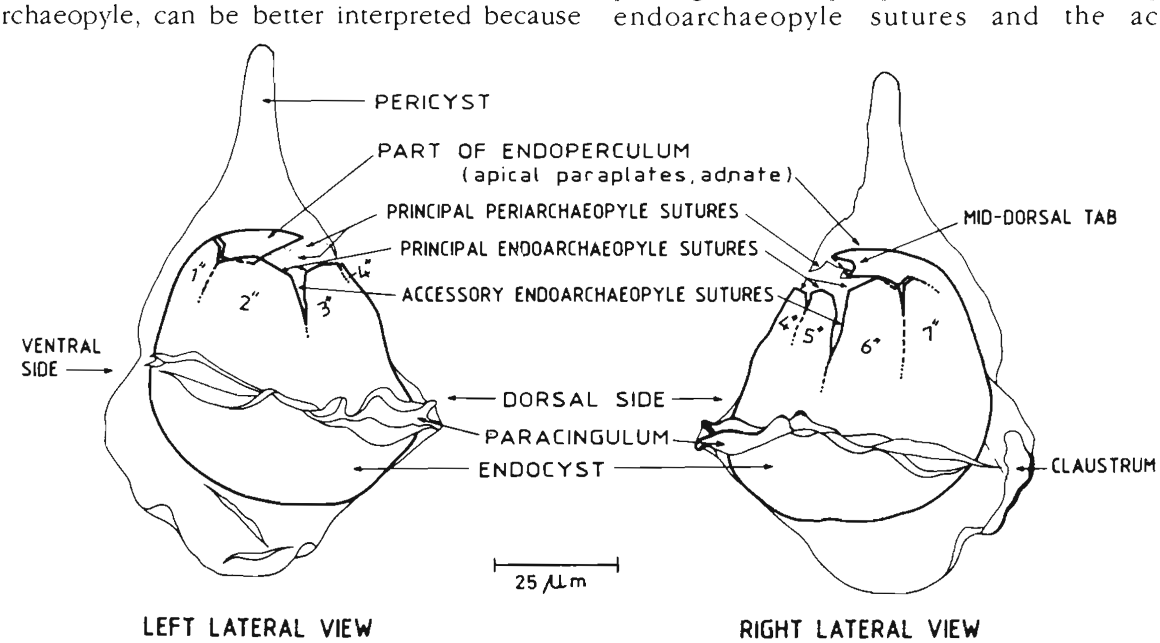
The periarchaeopyle is characterized by an opening invariably developed on the anterodorsal side of the epipericyst at the base of the apical horn and much above the periparacingulum, corresponding to anterior intercalary paraplate position (Pl. 2, figs 1-3; Text-fig. 1). The interpretation of periarchaeopyle type at times becomes difficult owing to distorted principal periarchaeopyle sutures along the adapical and adcingular margins of the opening. These archaeopyle sutures always remain confined exclusively on to the dorsal surface and are never found to extend beyond the middle of the epipericyst along the anticipated precingular and apical paraplate contact margins. The occurrence of many-angled principal periarchaeopyle sutures and large size of opening suggests that more than one, probably three, anterior intercalary paraplates must have been displaced (Pl. 1, figs 1-3; Text-fig. 2).

Endoarchaeopyle

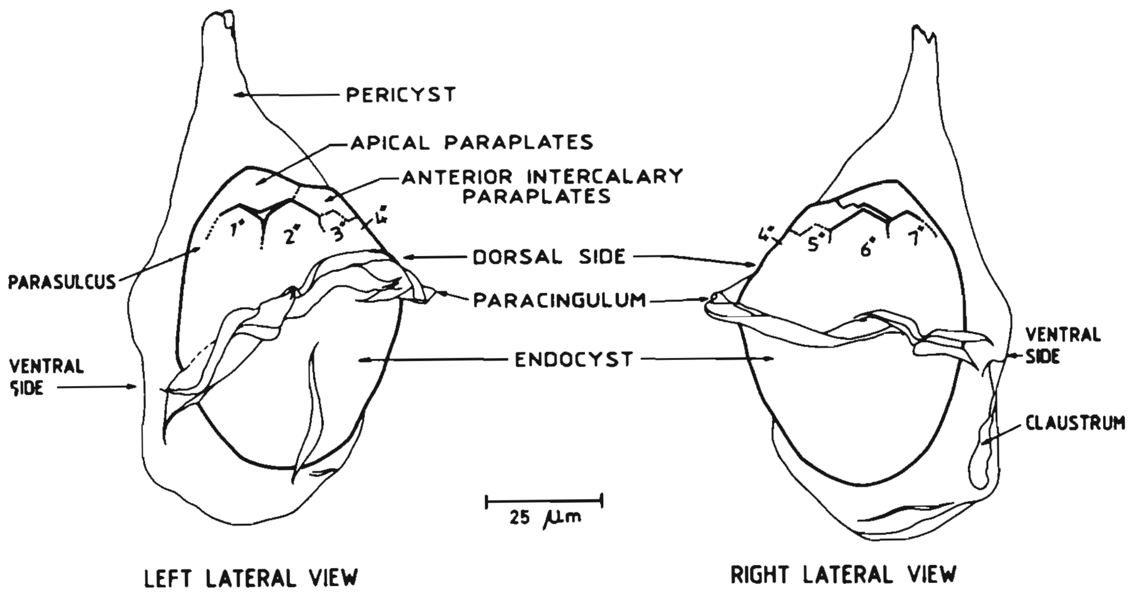
The endoarchaeopyle, in contrast to periarchaeopyle, can be better interpreted because of the distinctive paratabulation of epiendocyst. The paratabulation on epidocyst is marked by tabular ornamentation, adcingular and adapical margins of the apical and precingular paraplate series respectively and the occasional faint parasutural markings usually present between precingular paraplates.

The precingular series consists of seven paraplates which are larger than others on epiendocyst and are longitudinally elongate (higher than broad), differing in shape with unequal adapical margins (Pl. 1, figs 4-6; Pl. 2, figs 1-3, 6; Text-figs 1, 3). Paraplates 1″, 2″, 6″ and 7″ are longer than paraplates 3″, 4″ and 5″. Of these, paraplates 2″ and 6″ are comparatively broad occupying major areas on the left and right lateral sides respectively. The paraplate 4″ is characteristically four sided and flat topped (planate) whereas the rest are five sided (camerate) (Pl. 1, figs 4-6; Pl. 2, figs 1-3, 6; Text-figs 1, 3).

The apical series consists of four paraplates which in excysted specimens remain attached with the parasulcus through 1′, forming a hood like structure over precingular series. The paraplates 2′ and 4′ superimpose each other lying on left and right lateral sides respectively (Pl. 1, figs 1-3; Pl. 2, figs 1-3; Text-figs 1, 2). The most significant paraplate of the apical series is 3′ which projects into the broad endoarchaeopyle opening, forming a mid-dorsal tab (Pl. 1, figs 1-6; Text-figs 2, 3). This opening extends all along the adapical margin of the precingular paraplates. The principal endoarchaeopyle sutures and the accessory



Text-figure 3—*Dingodinium cerviculum* Cookson & Eisenack 1958: Camera lucida sketch of an excysted specimen showing disposition of precingular paraplates, mid-dorsal tab and planate 4″ in epiendocyst, principal endoarchaeopyle sutures and accessory endoarchaeopyle sutures, slide no. 10150; Coordinates: 16.9 × 131.8.



Text-figure 4—*Dingodinium cerviculum* Cookson & Eisenack 1958: Camera lucida sketch of an unopened cyst showing presence of anterior intercalary paraplates forming a hump-like structure on anterodorsal side of epiendocyst, slide no. BSIP 8092; Coordinates: 12.9 × 137.9.

endoarchaeopyle sutures are distinctly marked. The latter are characteristically developed, sometimes extending deep, between the precingular parplates 1″-2″, 2″-3″, 5″-6″ and 6″-7″

The relationship of apical and precingular paraplate series in the excysted specimens indicates close proximity between precingular paraplates 1″, 7″ and in part 2″, 6″ and the apical paraplates 1′ and in part 2′, 4′ only. The remaining adapical margin of the precingular paraplates 3″, 4″, 5″ and in part 2″, 6″ and adcingular margin of apical paraplates 3′ and in part 2′, 4′ remain separated apart leaving a broad gap on anterodorsal side (Pl. 1, figs 1-6; Pl. 2, figs 1-3, 6; Text-figs 1, 3). This gap with reference to paraplates involved obviously indicates the loss of some anterior intercalary paraplates which are seen intact in a few complete unexcysted specimens in the form of a hump like structure (Pl. 2, figs 4, 5; Text-fig. 4).

In view of the above observations with special reference to the presence of seven precingular paraplates, the mid-dorsal tab and planate 4″ precisely suggest displacement of three anterior intercalary paraplates, of which 2a should be of hexa type.

In one of the specimens the anterior intercalary paraplates could be seen marked by faint accessory sutures suggesting that the three intercalary paraplates might have separated independently and paraplate 2a is of standard hexa type (Pl. 1, fig. 7). This observation, for the time being, is kept open till more data is available.

We opine that the endoarchaeopyle is of combination type involving all the four apical and three anterior intercalary paraplates. The endoperculum is compound represented in two parts, the apical part being polyplacoid, simple and adnate while the intercalary part is polyplacoid, free

PLATE 2

→

(All photomicrographs in Nomarski Differential Interference Contrast).

1-7. *Dingodinium cerviculum* Cookson & Eisenack 1958.

1-3. Slide no. 10150, Coordinates: 17.0 × 131.5. 1. Complete specimen, ca × 800; 2, 3. Same specimen (portion magnified) in right lateral and left lateral views respectively, ca × 2000.

4-5. Slide no. BSIP 8092, Coordinates: 12.9 × 137.9. 4. Complete specimen, ca × 800; 5. Same specimen (portion magnified) showing presence of intercalary paraplates forming a hump-like structure, ca × 2000.

6. Magnified portion of a specimen in left lateral view showing paraplate disposition on epiendocyst and reduced ornamentation on parasulcus, slide no. BSIP 10149, Coordinates: 22.8 × 135.5, ca × 2000.

7. Complete specimen showing intercalary part of endoperculum in three pieces as well as paraplate 2a to be of standard hexa type, slide no. BSIP 10151; Coordinates: 13.8 × 130.9, ca × 800.

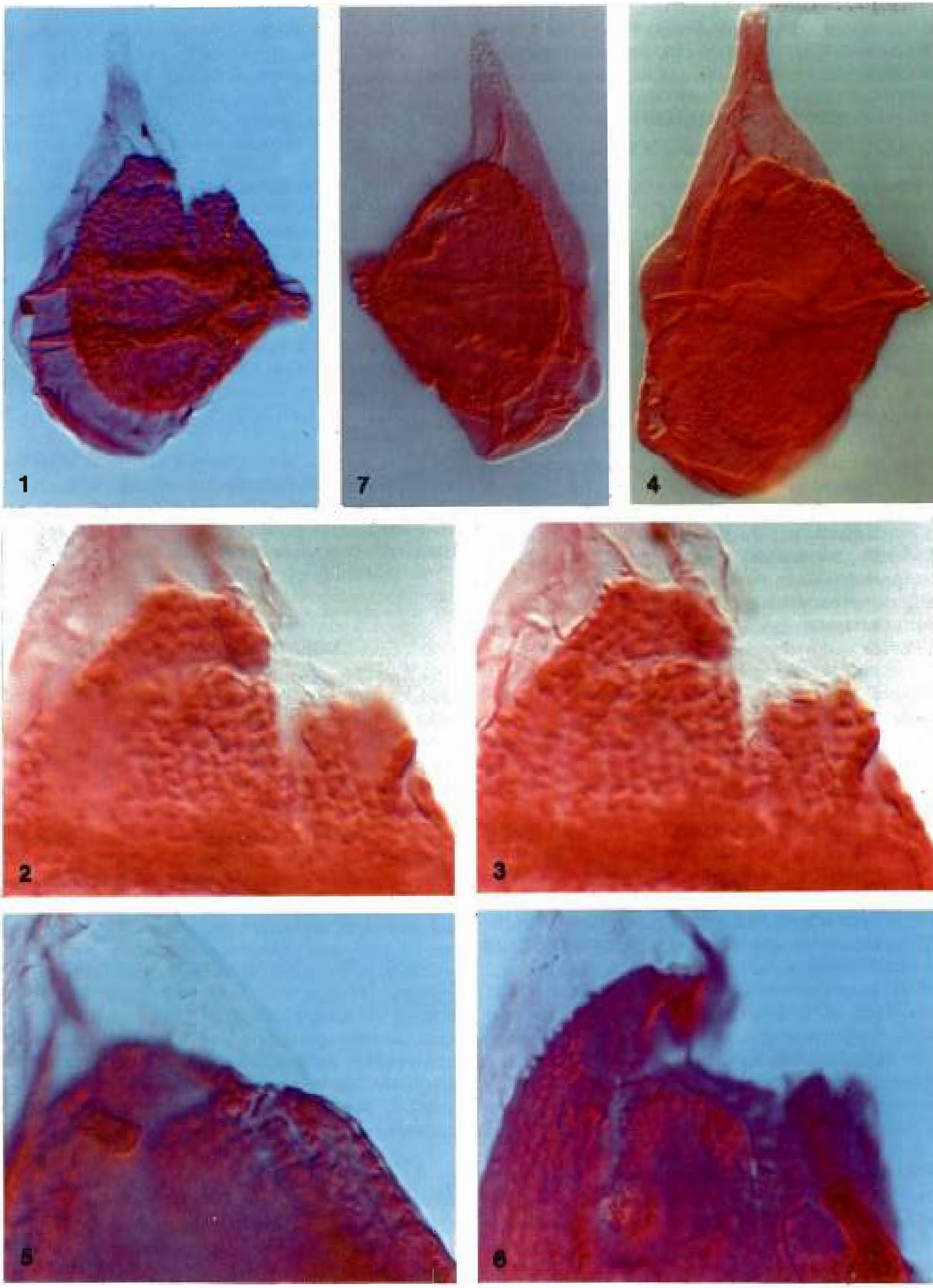


PLATE 2

and probably compound. The archaeopyle formula based on above observations has been derived as ?2-3I/(4A)a 3I:

SYSTEMATIC DESCRIPTION

Genus—*Dingodinium* Cookson & Eisenack 1958

Dingodinium cerviculum Cookson & Eisenack, 1958 emend. Mehrotra & Sarjeant, 1984; emend. herein

Pl. 1, figs 1-7; Pl. 2, figs 1-7; Text-figs 1-4

1958 *Dingodinium cerviculum* Cookson & Eisenack, p. 40; pl. 1, figs 12-14.
1961 *D. cerviculum* Cookson & Eisenack, *in* Alberti, p. 17; pl. 3, figs 14-15.
1961 *?Dingodinium* sp. A, *in* Alberti, pp. 17-18; pl. 3, fig. 16.
1966 *?D. albertii* Sarjeant, pp. 210-211; pl. 21, fig. 3; pl. 23, fig. 1.
1968 *D. cerviculum* Cookson & Eisenack, *in* Ingram, p. 103.
1969 *D. cerviculum* Cookson & Eisenack, *in* Haskell, p. 60; pl. 1, figs 1-4.
1969 *D. cerviculum* Cookson & Eisenack, *in* Millioud, p. 428.
1971 *D. cerviculum* Cookson & Eisenack, *in* Brideaux, pp. 101-102; pl. 30, fig. 104.
1971 *D. cerviculum* Cookson & Eisenack, *in* Singh, pp. 361-363; pl. 62, figs 1-4.
1972 *D. cerviculum* Cookson & Eisenack, *in* Habib, p. 379; pl. 12, figs 1-2.
1973 *D. cerviculum* Cookson & Eisenack, *in* Burger, pp. 37-38.
1974 *D. cerviculum* Cookson & Eisenack, *in* Davey & Verdier, p. 632; pl. 91, fig. 6.
1974 *D. albertii* Sarjeant, *in* Davey, p. 49.
1974 *?D. albertii* Sarjeant, *in* Wiseman & Williams, fig. 5.
1975 *D. cerviculum* Cookson & Eisenack, *in* Brideaux & McIntyre, p. 38; pl. 14, fig. 5.
1975 *D. cerviculum* Cookson & Eisenack, *in* Williams, pl. 14, fig. 11.
1976 *D. cerviculum* Cookson & Eisenack, *in* Habib, pp. 382-383; pl. 1, figs 6-8.
1976 *D. cerviculum* Cookson & Eisenack, *in* Kemp, pp. 33-35.
1976 *D. cerviculum* Cookson & Eisenack, *in* Harris, pl. 21, figs 1-2.
1976 *D. cerviculum* Cookson & Eisenack, *in* Williams & Bujak, p. 472; pl. 5, fig. 6.
1976 *D.* cf. *albertii* Sarjeant, *in* Ioannides, Stavrinos & Downie, p. 451; pl. 1, figs 10-12.
1977 *D. albertii* Sarjeant, *in* Duxbury, pp. 29-30; pl. 9, fig. 4; Text-fig. 6.
1978 *D. albertii* Sarjeant, *in* Davey, pp. 891-894.
1978 *D. cerviculum* Cookson & Eisenack, *in* Herngreen, pp. 275-276; pl. 1, fig. 1.
1980 *D. cerviculum* Cookson & Eisenack, *in* Burger, p. 72; pl. 22, figs 5-6.
1980 *D. albertii* Sarjeant, *in* Duxbury, pl. 3, fig. 10.
1980 *D. albertii* Sarjeant, *in* Antonescu & Avram, pl. 9, fig. 4.
1981 *?D. albertii* Sarjeant, *in* Below, p. 45; pl. 10, fig. 3.
1981 *D. cerviculum* Cookson & Eisenack, *in* Reneville & Raynaud, p. 5; pl. 2, fig. 16.
1982 *D. cerviculum* Cookson & Eisenack, *in* Burger, pl. 2, fig. 4.
1982 *D. cerviculum* Cookson & Eisenack, *in* Cookson & Eisenack, p. 34; pl. 2, figs 8-10.
1984 *D. cerviculum* Cookson & Eisenack emend. Mehrotra & Sarjeant, pp. 296-298; pl. 1, figs 1-6; pl. 2, figs 1-5; pl. 3, figs 1-4; pl. 4, figs 1-7; text-figs 1-2.
1987 *D. cerviculum* Cookson & Eisenack, *in* Helby, Morgan & Partridge, p. 46, fig. 28K.
1987a *D. cerviculum* Cookson & Eisenack, *in* Stover & Helby, p. 251; figs 23F-K.
1987b *D. cerviculum* Cookson & Eisenack, *in* Stover & Helby, pp. 281-282; figs 15A-K.

EMENDED DIAGNOSIS

Cyst camocavate, laterally compressed, endocyst eccentrically placed shifted towards dorsal side, sometimes appressed, pericoel prominent ventrally; pericyst ellipsoidal with a well-developed apical horn, periphragm thin, smooth, an opening (claustrum) generally developed on ventral side at posterior sulcal region; endocyst ellipsoidal, endophragm thick, ornamented with tubercles, verrucae and spines, usually arranged in longitudinal rows; archaeopyle differently developed on epicyst and endocyst, periarchaeopyle intercalary involving more than one anterior intercalary paraplates, probably 3, perioperculum free, endoarchaeopyle combination type involving four apical and three anterior intercalary paraplates, endoperculum in two parts, adnate apical and free intercalary, accessory archaeopyle sutures develop along precingular paraplates, paracingulum distinct on periphragm, helicoid, markedly offset ventrally; paratabulation incompletely discernible.

Description :

Shape—Cyst laterally compressed, ellipsoidal, epipericyst prolonged into an apical horn with a bluntly rounded tip, endocyst ellipsoidal.

Wall relationship—Cyst camocavate, endocyst eccentrically placed, shifted more towards dorsal side, some times almost appressed dorsally in precingular and post-cingular areas, pericoel well-developed ventrally.

Wall features—Periphragm extremely thin, smooth without any parasutural features, an opening (claustrum) invariably present on ventral surface somewhere in the posterior sulcal region, tip of the apical horn generally open, endophragm thick, ornamented with verrucae, tubercles and short spines arranged in longitudinal rows, ornamentation partly tabular, well-defined in endocyst.

Paracingulum—Distinct on periphragm, expressed by parallel transverse folds running high over endophragm, markedly offset ventrally.

Paratabulation—Incompletely indicated by periarchaeopyle and undivided periparacingulum on pericyst; differently developed on endocyst; complete on epiendocyst indicated by endoarchaeopyle and tabular ornamentation, poorly and incompletely expressed on hypoendocyst; endocyst formula 4′, 3a, 7″ Xc, X‴, X⁗

Archaeopyle—Differently developed on periphragm and endophragm; periarchaeopyle intercalary, involving more than one, probably three, anterior intercalary paraplates, operculum free; endoarchaeopyle combination type involving all four apical and three anterior intercalary paraplates; endoperculum compound, represented in two parts; an apical free part which is polyplacoid, simple and adnate while the other part comprising intercalary paraplates is polyplacoid, free and probably compound. Formula ?2-3I/(4A)a3I.

Dimensions—Overall cyst size	:	80-118 × 40-75 μm
Size of endocyst	:	40-60 × 37-57 μm
Length of apical horn	:	20-35 μm

DISCUSSION

Our observation and interpretation of the archaeopyle type in *Dingodinium cerviculum* should provide taxonomic stability to this morphologically distinctive taxon. Despite its characteristic morphology, the difference of opinion about the type of archaeopyle is bound to cause ambiguity in precise morphologic identification and taxonomic status of not only *D. cerviculum* but the genus *Dingodinium* itself. Mehrotra and Sarjeant (1984, p. 286), while advocating variability of archaeopyle character in *Dingodinium* species, have remarked that if archaeopyle alone is taken as a differentiating character, *Dingodinium* might be subdivided into as many as four genera. They, however, preferred to maintain *Dingodinium* as a single entity due to its morphological unity and also due to their conviction that involvement of intercalary paraplates is an essential feature in its archaeopyle formation.

Based on comprehensive study of *D. cerviculum* and critical review of earlier records of *Dingodinium* species, Mehrotra and Sarjeant (1984) documented five to seven types of archaeopyle in *Dingodinium* in general and at least three types in *D. cerviculum* and consequently proposed emendations of both. They concluded that in *D. cerviculum*, the periarchaeopyle is apical comprising all apical paraplates (the number of apical paraplates involved may be 3 instead of 4) with usually ventrally attached operculum closing after excystment. Variability is documented primarily in the endoarchaeopyle which is considered to be either single plate intercalary (?la or 2a) or combination type involving anterior intercalary paraplate and precingular paraplate with simple or compound, free or partly or completely attached endoperculum. However, all these variations are not visible in their illustrations. We observed no variability in archaeopyle character in our studied specimens.

Furthermore, the illustrations as well as the text-figures provided by Mehrotra and Sarjeant (1984, pl. 1, figs 1, 2, 4, 5; pl. 2, figs 4, 5; pl. 3, figs 1-4; text-figs 1, b-b′; 2 a-a′) suggest that lateral views of the cyst have been interpreted as dorsal or ventral sides. A careful observation reveals that ventral surface in their specimens is indicated by discontinuity of the helicoid paracingulum while on the dorsal side endocyst is closely appressed to the pericyst with the development of a prominent pericoel along paracingulum; obviously the cysts are laterally compressed and preserved in lateral view. As such their interpretations concerning archaeopyle type and paratabulation in *Dingodinium cerviculum* are not acceptable. Lentin and Williams (1985, p. 109) also remarked that variability in the number of paraplates involved in the formation of archaeopyle as well as the paratabulation and relationship between 3″ and 1a outlined by Mehrotra and Sarjeant is very unusual. Regarding the paratabulation outlined by Mehrotra and Sarjeant, we are of the opinion that hypocystal paratabulation in the endocyst is inconclusive.

Recently, Stover and Helby (1987b, pp. 281-282) have also studied archaeopyle type of *D. cerviculum* and *D. jurassicum* and concluded that *Dingodinium* possesses type (tA)a apical archaeopyle. They specifically mentioned that no intercalary paraplates are found in their specimens or in any earlier illustrated specimens. While describing the archaeopyle, they referred to the endoarchaeopyle and defined it by generally angular principal endoarchaeopyle sutures, accessory sutures and centrally attached operculum. As for the periarchaeopyle, Stover and Helby (1987b) mentioned that its outline is commonly uncertain owing to folding and tearing of the periphragm. However, at least one of the well preserved and complete specimens illustrated by them (fig. 15D, p. 280) shows small apical paraplate series forming a hood like structure over exceptionally elongate and large precingular paraplates. There is an indication of occurrence of anterior intercalary paraplates (seen as a bump). A restudy of such specimens should endorse our observations on Indian material.

The archaeopyle controversy in the genus *Dingodinium* primarily resulted from varying interpretations on *D. cerviculum* (including *D. albertii*) by earlier workers. Significantly, archaeopyle has been consistently noted to be apical in the type species *D. jurassicum* and rest of the species assigned to the genus except for *D. cooksoniae* and *D. [illegible]* which are described as having 2a intercalary archaeopyle (Table 1). However, archaeopyle type is insufficiently and incompletely documented in all these species, as periarchaeopyle and endoarchaeopyle have not been differentiated. It is recommended that restudy of various *Dingodinium* species should be carried out in the light of our observations on *D. cerviculum*.

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Additions to the Neogene florule from near Bhikhnathoree, West Champaran District, Bihar

Nilamber Awasthi & R. N. Lakhanpal

Awasthi, Nilamber & Lakhanpal, R. N. 1990. Additions to the Neogene florule from near Bhikhnathoree, West Champaran District, Bihar. *Palaeobotanist* **37**(3) : 278-283.

Eleven new species have been described from the Siwalik beds of Bhikhnathoree, West Champaran District, Bihar. These are based on leaf-impressions which show close resemblance with the leaves of modern *Urena lobata, Aphanamixis polystachya, Toona ciliata, Pterocarpus macrocarpus, Derris scandens, Pongamia pinnata, Cassia glauca, Syzygium bracteatum, Ardisia solanacea, Ipomoea eriocarpa* and *Phoebe lanceolata*.

Key-words—Morphology, Dicot leaf-impressions, Siwalik.

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साराँश

पश्चिम चम्पारन जनपद (बिहार) में भिखनाथोरी के समीप से पश्चनूतन कालीन वनस्पतिजात में योगदान

नीलाम्बर अवस्थी एवं राजेन्द्र नाथ लखनपाल

बिहार में पश्चिम चम्पारन जनपद में भिखनाथोरी की शिवालिक संस्तरों से अश्मित पत्तीयों की 11 नई जातियाँ वर्णित की गई हैं। ये सभी पत्तीयों की छापें हैं तथा वर्तमान **यूरेना लोबेटा, एफ़ेनामिक्सिस पोलिस्टेकिया, तूना सिलियेटा, टेरोकार्पस मेक्रोकार्पस, डेरिस स्केन्डेन्स, पोंगेमिआ पिन्नाटा, केसिआ ग्लॉका, सिज़ीजियम ब्रेक्टिएटम्, आर्डिसिआ सोलेनेसिआ, आइपोमोइआ इरिओकार्पा** एवं **फ़ोयबे लेन्सिओलेटा** की पत्तीयों से घनिष्ठ समानता प्रदर्शित करती हैं।

A FEW years ago, we described some leaf-impressions from a Siwalik deposit from near Bhikhnathoree in West Champaran District, Bihar. Although this small contribution was submitted in 1979, considerable time elapsed before it was published (Lakhanpal & Awasthi, 1984). In the meantime more leaf-impressions from this locality were collected by one of us (N.A.). Although not all the specimens so far collected have been identified, there are some eleven new species which are being described in the present communication.

In our earlier paper (Lakhanpal & Awasthi, 1984) we had suggested that the age of the Siwalik beds at Bhikhnathoree might be Middle Pliocene. However, an overall examination of the presently available data warrants a more critical consideration of this important aspect. It is also felt that a fresh visit to the locality should be made to collect field observations which may throw more light on the stratigraphy of these sediments. Thus we propose to present a more comprehensible and final account of the composition, palaeoecology and age of the Bhikhnathoree flora in our next publication.

We are thankful to the authorities of the Forest Research Institute, Dehradun for permission to consult their herbarium for identifying the fossil leaves.

SYSTEMATIC DESCRIPTION

Family—Malvaceae

Urena palaeolobata sp. nov.
Pl. 1, figs 1-4

Description—Leaves are of two kinds, small and medium-sized. *Small leaf* (only one available, Pl. 1, fig. 3) symmetrical, rounded oblate, size 1.9-2.1 cm; apex rounded; base rounded; margin entire with possible incipient indentations; texture coriaceous; petiole not preserved; venation actinodromous, perfect, basal five primary veins arising from a basal point, each primary vein stout to moderate, the middle and two upper primaries running straight to the margin, the lower lateral primaries slightly curving upward towards margin, four pairs of sub-opposite secondaries discernible, arising at an angle of about 60° in the lower pairs, moderately thick, curving upwards and branched near the margin; tertiaries branched near the margin and forming indefinable reticulum. *Medium-sized leaves* (Pl. 1, figs 1, 2) almost symmetrical, 3-lobed with shallow sinuses, median broadly acute, lateral lobes obtuse, size 3.5 × 3.00 to 4.5 × 4.7 cm; base cordate; margin entire to finely serrate; texture coriaceous; petiole not preserved, displaying a clear point of attachment; venation actinodromous, perfect, basal five primary veins arising from a basal point, middle and the upper two primaries stout, running straight towards margin and ending at the tip of each lobe, the lower lateral primaries running in a slightly curved course towards the margin and their branches merging with those of the adjacent primaries, 4-5 alternate to sub-opposite pairs of secondaries arising from the median primary at an angle of about 45° in the lower pair increasing to about 80° in those towards the apex, 6-7 pairs of secondaries arising from the two lateral primaries at an angle of 80-90°; tertiaries percurrent or forming orthogonal reticulate pattern; higher order of venation forming reticulum not easily recognisable; marginal ultimate venation looped; areoles seemingly well-developed, oriented, quadrangular to pentagonal, medium in size.

Holotype—Specimen no. BSIP 36114.

Discussion—Medium-sized three-lobed leaves with pentanerved cordate base are found in *Kydia calycina* Roxb., *Thespesia lampas* Dalz. et Gibs. and *Urena lobata* Linn. However, the leaves of *K. calycina* and *T. lampas* being about 12.5 × 10.0 cm are much bigger in size than our fossil leaves. In this respect leaves of *Urena lobata* measuring 2.5-5.0 × 7-7.5 cm are very similar. Moreover, the lobes in *Thespesia lampas* are much longer than in the fossil specimens. In *Kydia calycina* the tertiary veins are more closely spaced than in *Urena lobata*. In this character also our fossil leaves are closer to *Urena lobata*. It may further be mentioned that in addition to the normal 3-lobed leaves borne on the main axis of *Urena lobata* there are also some very small leaves borne on axillary branches. In our collection we also have a small leaf which in size and shape is very similar to the small leaves of *Urena lobata*. Considering all these characters we are assigning our fossil leaves to the genus *Urena* under a new species named *Urena palaeolobata*, suggesting the similarity of the fossil leaves with those of *Urena lobata*.

The genus *Urena* consists of 6 species (Willis, 1973, p. 1196) distributed in tropical and sub-tropical regions of both the hemispheres. *Urena lobata* is a tall erect undershrub. In India, it is generally distributed in waste land over the northern parts of the country (Duthie, 1960, p. 80).

Family—Meliaceae

Aphanamixis bhikhnathoriensis sp. nov.
Pl. 1, fig. 5

Description—Leaflet almost complete, asymmetrical, ovate, size 7.6 × 3.0 cm; apex broken, appearing to be short acuminate; base oblique; margin entire; texture thick, chartaceous; petiole normal with longitudinal furrow; preserved length 0.6 cm; venation pinnate, eucamptodromous, mid vein stout, markedly curved; secondaries 14-15 pairs, angle of divergence 60-80°, course more straight in the wider side of the lamina and curved in the narrower side, sub-opposite, turning up before reaching the margin and meet the next higher secondaries, inter-secondaries rare, simple; tertiaries hardly discernible at places, seeming to be percurrent; finer details not preserved.

Holotype—Specimen no. BSIP 36117.

Discussion—This asymmetrical leaflet with oblique base and pinnate eucamptodromous venation indicates strong affinities with Meliaceae. On critical comparison it shows close resemblance with the leaflet of *Aphanamixis polystachya* (Wall.) Parker (previously known as *Amoora rohituka* W. & A.) in all respects except the size. The fossil leaflet is smaller than those of the modern *A. polystachya*. In this regard it must be mentioned that the fossil leaves of Bhikhnathoree, in general, are smaller in size than their corresponding modern taxa. Most probably this reflects a general drier aspect of this florule.

Aphanamixis polystachya is a moderate-sized evergreen tree, occurring along the sub-Himalayan tracts in eastern Uttar Pradesh, Bihar, northern West Bengal, Assam and extending into Andaman and Nicobar Islands. Further east, it spreads from Chittagong in Bangladesh to Burma and Malay Peninsula. It is also found in the Western Ghats and adjoining hill ranges from North Kanara to Tinnevelley (Tirunelveli), extending southward to Sri Lanka (Gamble, 1972).

Toona siwalika sp. nov.
Pl. 1, fig. 6

Description—Leaflet almost complete,

asymmetrical, narrow-elliptic, preserved size 11.0 × 3.5 cm; apex acuminate, base oblique, margin entire, texture chartaceous, petiole not preserved, venation pinnate, eucamptodromous; midvein stout, curved; secondaries 10-12 pairs, alternate to sub-opposite, angle of divergence nearly uniform, 60-70°, moderate to fine, curving up near the margin to meet the next higher secondaries; tertiaries random reticulate; veinlets branched; areoles well developed, oriented, quadrangular to pentagonal, small.

Holotype—Specimen no. BSIP 36118.

Discussion—In being asymmetrical with oblique base this fossil leaflet also shows affinities with the family Meliaceae. However, in its structural details it is distinct from the leaflet of *Aphanamixis bhikhnathoriensis* of Meliaceae. The texture of this leaflet is not as thick as that of *A. bhikhnathoriensis* as apparent from the details of finer venation discernible in the present fossil. The angle of divergence of secondaries is more in *Aphanamixis* than in *Toona*. Moreover, the course of secondaries is comparatively straight in *Aphanamixis* while more curved in *Toona*.

This fossil leaflet closely resembles those of *Toona ciliata* Roxb., hence it has been placed under the genus *Toona* and assigned to a new species *T. siwalika*.

Toona ciliata Roxb. is a large deciduous tree distributed up to about 1,200 m along the sub-Himalayan tracts from Indus eastward to Bengal and Burma. It also occurs at low elevations in South India and extends to Java and Australia (Guthrie, 1969, p. 144).

Family—Fabaceae

Pterocarpus ovatus sp. nov.

Pl. 1, fig. 7

Description—Leaflet complete, symmetrical, narrow ovate, size 16 × 2.5 cm; apex acute, tending to be acuminate, base obtuse, margin entire, texture stiff chartaceous; petiolule short, smooth pulvinus; venation eucamptodromous; midvein moderate in thickness, solid, course straight; secondaries very faint, 8-10 pairs, alternate to sub-opposite, angle of divergence 40-50°; tertiaries not visible.

Holotype—Specimen no. BSIP 36119.

Discussion—The presence of pulvinus at the base strongly indicates its affinity with the family Leguminosae. Amongst various comparable leguminous taxa the leaflets of *Pterocarpus macrocarpus* match with the fossil leaflet closely. The similarity between the two is noticeable in their shape, apex, base, margin and midvein. However, the fossil is smaller in size than the living counterparts. As far as we are aware there is no previous record of fossil leaves assignable to *Pterocarpus*. Therefore, this Siwalik leaflet is being described as a new species, *Pterocarpus ovatus*, the specific epithet indicating the shape of the lamina.

The comparable modern species *Pterocarpus macrocarpus* is a deciduous tree found in the upper mixed forest of Burma.

Derris champarensis sp. nov.

Pl. 1, fig. 8

Description—Leaflet complete, symmetrical, elliptic-lanceolate, size 11.5 × 3.5 cm; apex broadly acute to retuse, base obtuse, almost rounded, margin entire, texture thinly coriaceous, petiole not preserved; venation pinnate, eucamptodromous; midvein stiff, moderate, straight; secondaries faint, 10 pairs arising at an angle of about 50°, curving up towards the margin; intersecondaries discernible; tertiaries not very clear, probably random reticulate.

Holotype—Specimen no. BSIP 36120.

Discussion—General features of the leaflet are obviously suggestive of the family Fabaceae. On critical examination, the most favourable comparison is noticeable of the leaflets of *Derris scandens* specially in shape, size, texture and venation pattern. The leaflets of *Millettia brandisiana* are also comparable, but differ in texture and venation pattern.

As far as we are aware there is no known fossil record of *Derris* leaves. The specific name of the

PLATE 1

(All figures are of natural size except otherwise mentioned)

1-4. [illegible] sp. nov.
5. *Aphanamixis bhikhnathoriensis* sp. nov.
6. *Toona siwalika* sp. nov.
7. *Pterocarpus ovatus* sp. nov.
8. *Derris champarensis* sp. nov.
9. *Pongamia siwalika* sp. nov. × 1.25.
10. [illegible] sp. nov.
11. [illegible] sp. nov.
12. [illegible] sp. nov.
13. [illegible] sp. nov.
14. [illegible] *champarensis* sp. nov.

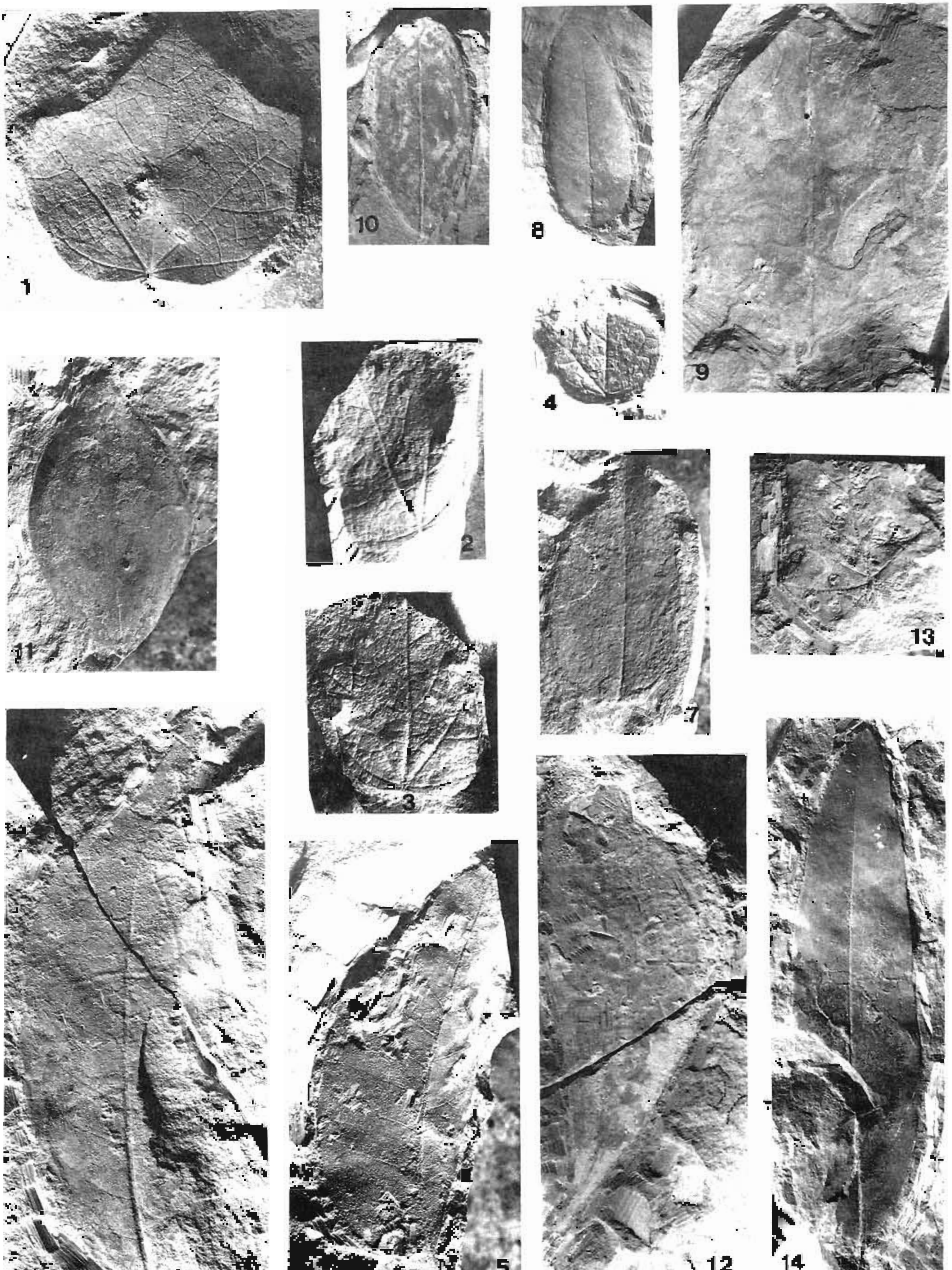

PLATE 1

new fossil, *Derris champarensis* is after Champaran District, from where it has been collected.

Derris scandens (Roxb.) Benth. is a large evergreen climbing shrub distributed in the sub-Himalayan tract from Uttar Pradesh eastward to Assam, Chittagong, Burma, Andamans, south India, Sri Lanka, Malay Peninsula and China.

Pongamia siwalika sp. nov.
Pl. 1, fig. 9

Description—Leaflet complete, symmetrical, ovate, size 4.8 × 3.5 cm; apex shortly acuminate; base obtuse; margin entire; texture chartaceous to thinly coriaceous; petiolule short, 2 mm in length, slightly curved; venation eucamptodromous; midvein thick, thinning out toward apex; course almost straight; secondaries about 6 pairs, alternate, arising at about 45°, running curved up to the margin, further details of venation not discernible.

Holotype—Specimen no. BSIP 36121.

Discussion—In its shape, apex, base, margin and the number and course of secondaries this fossil leaflet resembles the smaller leaflets of *Pongamia*. Therefore, it is being described as a new species, *P. siwalika*, indicating its occurrence in Siwaliks.

Pongamia pinnata is a moderate-sized tree growing near banks of streams and water course in peninsular and extra-peninsular India ascending to an elevation about 650 to 1,000 m. It is also common in tidal and beach forests of Sri Lanka, Malaysia, extending to the coast of South China, Fiji and tropical Australia.

Cassia antiqua sp. nov.
Pl. 1, fig. 10

Description—Leaflet complete, symmetrical, elliptic, 4.0 × 2.0 cm in size, obtuse; base acute; margin entire; texture chartaceous; petiole not preserved; venation pinnate, eucamptodromous; midvein stout; secondaries 11 pairs, angle of divergence about 45-55°, fine, curving upward along the margin, higher order of venation not discernible.

Holotype—Specimen no. BSIP 36122.

Discussion—General shape and size of the leaflet suggest that it belongs to the family Fabaceae. On closer comparison with the leaflets of various modern legumes it was found that in shape, size, apex, base, margin and general venation the fossil leaflet resembles those of *Cassia glauca* L.

Leaves of *Cassia* have so far not been reported from India. However, about a dozen species of this genus have been described by Berry (1916) from the Lower Eocene of south-eastern North America. A few other reports from the Tertiary of United States have been made by Brown (1929, 1934) and Becker (1969) The shape, size and venation pattern of these fossil cassias of America are distinct from the present fossil leaflet. Therefore, it is being described as a new species *Cassia antiqua*, suggesting its antiquity in India.

Cassia glauca (Roxb.) O. Ktze is a shrub or small tree growing wild in the forest of western south India, Burma and Malaysia.

Family—Myrtaceae

Syzygium palaeobracteatum sp. nov.
Pl. 1, fig. 11

Description—Leaf symmetrical, complete, wide elliptic, size 0.5 × 3.0 cm; apex shortly acuminate; base acute; margin entire; texture smooth, coriaceous; petiole not preserved; venation pinnate, hyphodromous, only a faint and straight midvein discernible, other details not preserved due to thick texture.

Holotype—Specimen no. BSIP 36123.

Discussion—In shape, size, apex, margin, base and coriaceous texture this leaf-impression shows a close resemblance with the leaves of *Syzygium bracteatum*. In this comparable modern species the secondary and tertiary veins are very faint which due to thick texture of leaf could hardly be preserved in fossil state. Due to the marked similarity with *S. bracteatum* this Siwalik leaf is being described as *Syzygium palaeobracteatum* sp. nov.

Syzygium bracteatum is a shrub or small tree found in the peninsula as well as in Assam and Khasi Hills. In the peninsula, on the east side it occurs as semi-evergreen scrub as far north as Orissa. On the west side it grows in evergreen forests ascending to about 1,600 m (Brandis, 1906, p. 325).

Family—Myrsinaceae

Ardisia antiqua sp. nov.
Pl. 1, fig. 12

Description—Leaf incomplete, about 1/4 apical part missing, oblanceolate, preserved length 9.5 cm, width 3.4 cm; apex missing; base cuneate; margin entire; texture coriaceous; petiole normal, preserved length about 7.5 mm, width 1.5 mm; venation pinnate, hyphodromous, midvein massive, slightly curved in the lower portion; secondaries not discernible.

Holotype—Specimen no. BSIP 36124.

Discussion—The oblanceolate shape, cuneate base, coriaceous texture and massive midvein are the characteristic features of this leaf which strongly indicate its resemblance with the leaves of *Ardisia*. Amongst the various species of this genus the closest resemblance is exhibited by the leaves of *A. solanacea* Roxb. (syn. *A. humulis* Vahl).

Geyler (1887) described some leaf fragments from the Eocene of Borneo as *Ardisiophyllum* sp. Obviously, the details preserved in those fragments were not sufficient for establishing a definite species. Unfortunately, Geyler's publication is not available to us for proper comparison. The present fossil is far remote from the *Ardisiophyllum* belonging to the Eocene of Borneo in space as well as time. Therefore, it is being described under a new taxon, *Ardisia antiqua*.

The extant *Ardisia solanacea* Roxb. is a shrub found throughout eastwards to Assam, central India, Konkan, Kanara and south India. It also extends into Bangladesh, Burma and Sri Lanka. It occurs in the forest undergrowths in moist places along streams.

Family—Convolvulaceae

Ipomoea eriocarpoides sp. nov.
Pl. 1, fig. 13

Description—Leaf symmetrical, incomplete, only about half (basal) leaf preserved, cordate ovate, preserved length 2.4 cm from the base of the lobe, width 3.0 cm; apex missing; base cordate; margin entire; texture membranaceous; petiole not preserved; venation actinodromous, 7 primaries (1 median and 3 pairs of lateral) arising from the base of the lamina, median primary running towards apex, 2 upper pairs of lateral primaries running towards the margin and the third into the lobe, thickness stiff; 2 pairs of secondaries preserved, arising from the median primary at an angle of about 50°; tertiaries comming out at an angle of 70°-80°; further details of venation not visible.

Holotype—Specimen no. BSIP 36125.

Discussion—Such characteristic features as a cordate base, 7 primaries, entire margin and membranaceous texture indicate the affinity of the fossil leaf with the leaves of *Ipomoea* of the family Convolvulaceae. On critical examination its closest resemblance is found with the leaves of *I. eriocarpa* R. Br. Therefore, the fossil is described as *Ipomoea eriocarpoides* sp. nov.

Ipomoea eriocarpa is a climbing shrub widely distributed in India growing up to an altitude 1,200 m. It is also common in the adjoining parts of Sri Lanka and Afghanistan.

Family—Lauraceae

Phoebe champarensis sp. nov.
Pl. 1, fig. 14

Description—Leaf symmetrical, complete, lanceolate, size 10.0 × 2.5 cm; apex shortly acuminate; base broadly acute; margin entire; texture coriaceous; petiole preserved, 3 mm in length; venation eucamptodromous, curving towards apex; secondaries slender, hardly 7 pairs discernible, angle of divergence 50°-60°, curving up towards margin; higher order of venation not visible

Holotype—Specimen no. BSIP 36126.

Discussion—In its shape, size, apex, base, margin and texture the fossil leaf shows favourable comparison with those of Lauraceae. However, in Lauraceae there are two types of leaves: (i) those having triplinerved base, and (ii) having common alternate type of secondaries. The present leaf-impression obviously belongs to the second type of venation. Among the modern genera of Lauraceae the fossil leaf shows closest resemblance with those of *Phoebe lanceolata* Nees. This fossil leaf, collected from Champaran District, is being named as *Phoebe champarensis* sp. nov.

Phoebe lanceolata Nees, the comparable modern species, is a medium-sized evergreen tree growing in the sub-Himalayan tract and outer ranges from Beas eastward up to Khasi Hills, Bangladesh and Upper Burma. In south India, it is distributed in Annamalai, Tirunelveli and Kerala.

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On some plant fossils from Gondwana equivalent sediments of Eastern Himalaya

Trilochan Singh* & Usha Bajpai**

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The plant fossils reported here were recovered from Gondwana equivalent continental facies outcropping in Kameng District (Arunachal Pradesh), South Sikkim District (Sikkim) and Darjeeling District (West Bengal). The flora comprising equisetalean axes, *Phyllotheca* sp., *Glossopteris stenoneura* Feistmantel, *G. communis* Feistmantel, *G.* sp. cf. *G. leptoneura* Bunbury, *G. syaldiensis* Chandra & Surange, *G. formosa* Feistmantel and *Vertebraria indica* Royle resembles that of the Late Permian Raniganj Formation of peninsular India.

Key-words—Glossopteris Flora, Gondwana Supercontinent, Eastern Himalaya, Late Permian.

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सारांश

पूर्वी हिमालय के गोंडवाना समतुल्य अवसादों से कुछ पादप-अवशेष

त्रिलोचन सिंह एवं ऊषा बाजपेयी

दार्जिलिंग जनपद (पश्चिम बंगाल), दक्षिण सिक्किम जनपद (सिक्किम) एवं कामेंग जनपद (अरुणाचल प्रदेश) में गोंडवाना समतुल्य महाद्वीपीय संलक्षणी दृश्यांशों से प्राप्त पादपाश्मों का इस शोध-पत्र में वर्णन किया गया है। उपलब्ध वनस्पतिजात में इक्वीसिटेली अक्ष—**फिल्लोथीका** जाति, **ग्लॉसॉप्टेरिस स्टीनोन्यूरा** फ़ाइस्टमेन्टेल, **ग्लॉ० कम्युनिस** फ़ाइस्टमेन्टेल, **ग्लॉ०** जाति सजातीय **ग्लॉ० लेप्टोन्यूरा** बनबरी, **ग्लॉ० स्यालदियेन्सिस** चन्द्रा व सुरंगे, **ग्लॉ० फॉर्मोसा** फ़ाइस्टमेन्टेल एवं **वर्टीब्रेरिया इन्डिका** रॉयलें नामक पादपाश्म सम्मिलित हैं तथा यह प्रायद्वीपीय भारत के अन्तिम रानीगंज शैल-समूह से अनुरूपता प्रदर्शित करता है।

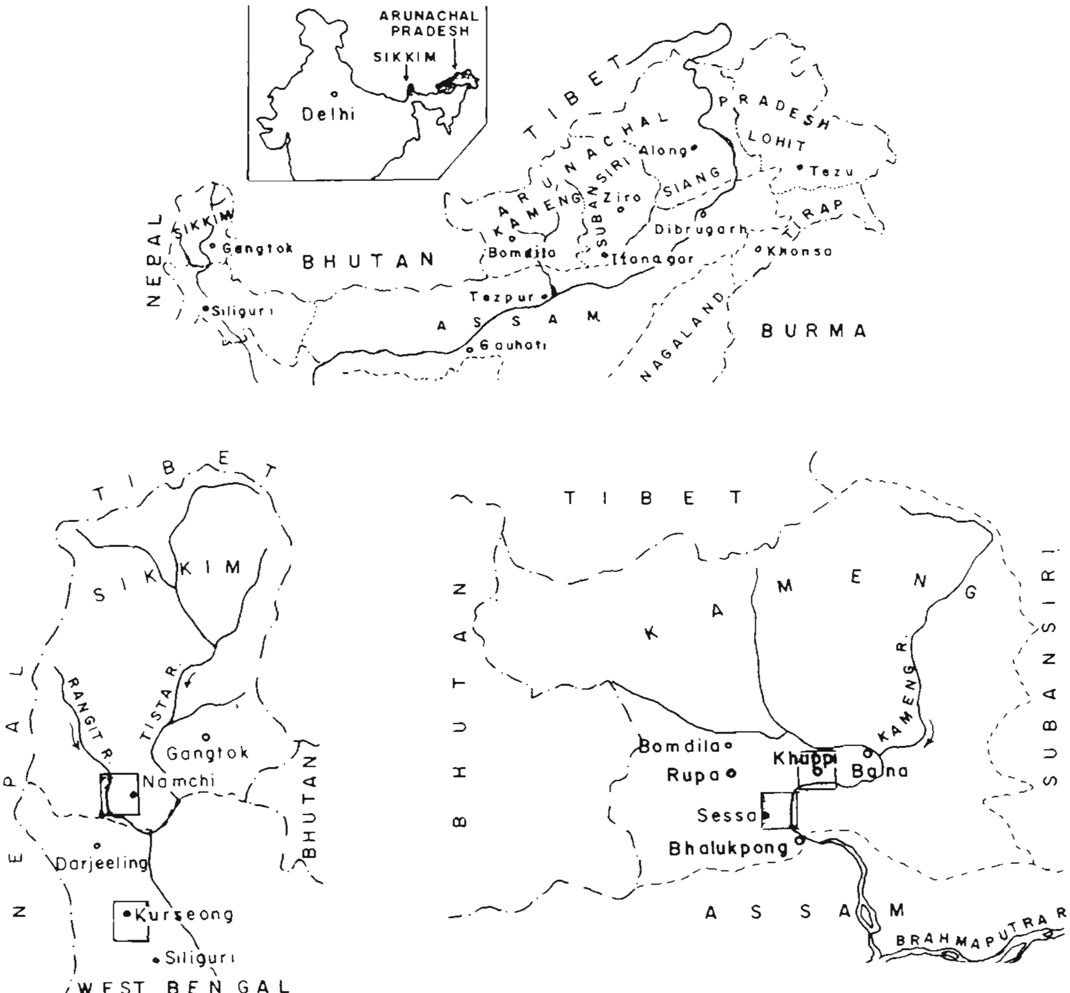
OCCURRENCE of *Glossopteris* leaves in the Permian sediments of Arunachal Himalaya was first reported by Jacob and Banerjee (1954), though plant fossils of Gondwana affinity were recorded much earlier from the Darjeeling—Sikkim Himalaya (Hooker, 1854; Mallet, 1874). Though a number of workers has also subsequently recorded plant fossils, yet no systematic description has been attempted so far.

The plant fossils investigated by us were collected from three widely separated localities in the Eastern Himalaya, that is, Kameng District in Arunachal Pradesh, South Sikkim District in Sikkim and Tindharia in Darjeeling District, West Bengal (Text-fig. 1).

The plant-bearing rocks form a part of Gondwana equivalent sediments, which are tectonically disposed in a linear and narrow belt except in the Sikkim Himalaya where these are exposed in a tectonic window. These rocks occur in the frontal part of the foot-hills, trending east-west on a regional scale, are thrusted over the Siwalik Group of sediments, and are in turn thrusted over by the sedimentaries of Miri (= Buxa) Group or by the metamorphic rocks of Bomdila (= Daling) Group. The Gondwana equivalent sediments of Eastern Himalaya exhibit continental, marginal marine (coastal), and glacio-marine facies (Singh, MS). However, present interest lies in the sediments of continental facies.

GEOLOGICAL OUTLINE

A brief geological outline of the three areas from where plant fossils have been collected by one of us (TS) is given below:

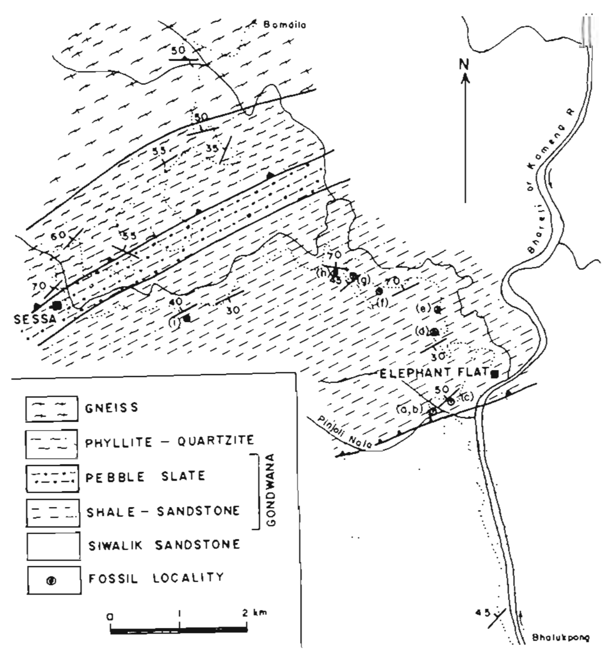


Text-figure 1—Location maps.

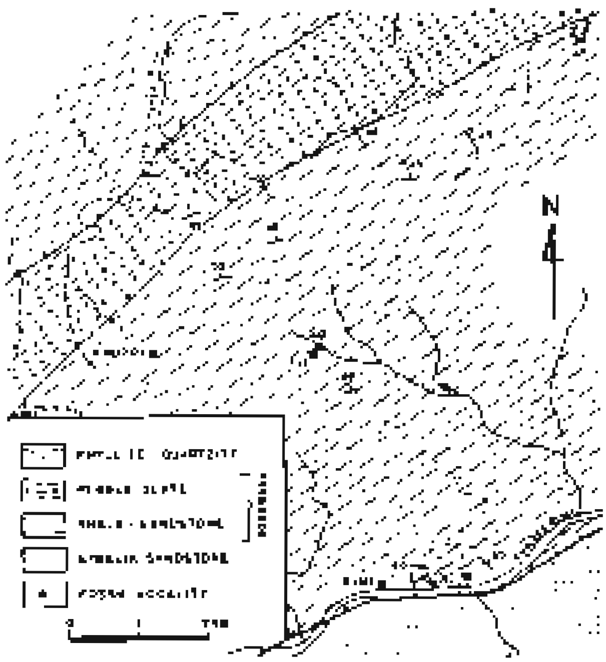
Kameng District (Arunachal Pradesh)

Gondwana equivalent sediments are exposed all along the frontal margin of the foot-hill bounded by the Siwalik sediments towards south by the thrust contact. Towards north, near Sessa in Bhalukpong-Sessa section, and near Khuppi Camp in Khuppi section, these sediments are overlain by the pebble-slate unit, the Rangit Formation. These are overlain by the Phyllite-Quartzite and Gneissic units of the Bomdila Group.

The fresh-water sediments (Bhareli Formation) comprise alternating beds of sandstone and slaty shales, with thin beds of coal in between. The sandstone is light-grey to bluish-grey in colour and is medium-to coarse-grained, sometimes gritty in nature. The sandstone is thinly laminated, often micaceous and contains carbonaceous matter and plant remains. The shales are mostly slaty in character, and sometimes contain pyrite specks. Sandy shales are also common. The carbonaceous shale and coal occur as lenses and/or persistent beds in between the sandstone and slaty shales.



Text-figure 2—Geological map of a part of Bhalukpong-Sessa-Bomdila road section, Kameng District.



Text-figure 3—Geological map of a part of N. Phu Khuppi Bana road section, Kameng District.

These rocks have suffered much disturbance and have been somewhat metamorphosed.

Plant fossils are fairly well distributed in the shaly horizons exposed from Pinjoli stream to Sessa on Bhalukpong-Sessa-Jamiri road section (Text-fig. 2), and from Kimi Power House to Khuppi Camp on N. Phu-Khuppi-Bana road section (Text-fig. 3). Collections have been made from a number of localities in this area, viz., (i) At the Pinjoli Stream II (a) just at the bridge, and (b) about 50 m downstream; (ii) Pinjoli-Sessa road: (a) nearly 100 m before 53 kmst, (b) at about 53.5 kmst, (c) at 54 kmst, (d) about 55.5 kmst and about 100 m before 56 kmst, (e) about 56.5 kmst, (f) about 58 kmst, and (g) about 62.5 kmst. (iii) Khuppi section: (a) nearly 10 km from Khuppi Camp on Khuppi-Kimi Power House road section, after crossing a major stream, and (b) just at the top of the river bed, on way from Kimi Power House towards Kameng River.

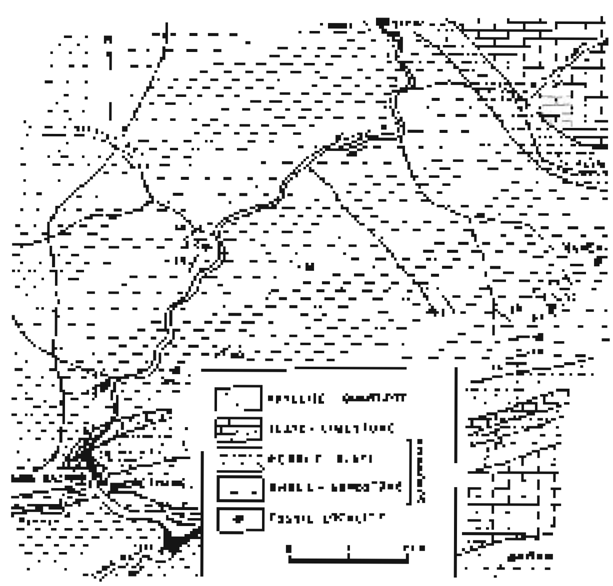
Rangit Valley (Sikkim)

Gondwana equivalent sediments are exposed in a tectonic window, wherein these sediments are covered by the older rocks viz., Buxa and Daling Group of rocks (Text-fig. 4). Fresh water rocks are exposed in Naya Bazar-Legship, Naya Bazar-Namchi and Namchi-Kitam road sections. These comprise sandstones with inter-beds of carbonaceous shales, slaty shales and coal. The sandstones are fine to coarse grained to gritty, dark grey to bluish-grey in colour, hard and well-bedded, occasionally quartzitic in nature. The slaty shales often contain plant impressions. Coal, that grades from semi-anthracitic to graphitic, occurs as thin beds and/or lenses in between shales and sandstone.

Plant fossils have been collected from two localities on Naya Bazar-Legship road section, (i) about 2 km from Naya Bazar bridge just at the road turn towards the Nala, and (ii) just at the road bend to Rishtak Khola. The third locality falls on Namchi-Kitam road section, about 1.75 km from Namchi. However, the preservation is very poor at this locality and is also not rich in fossils.

Darjeeling (West Bengal)

Gondwana equivalent sediments comprising glacio-marine and continental facies have been



Text-figure 4—Geological map of a part of Rangit window, South Sikkim District.

PLATE 1

1. *Glossopteris spathulata* Chandra & Surange; specimen no. BSIP 36517, × 1.
2. *Glossopteris* sp. cf. *G. browniana* Bunbury; specimen no. BSIP 36518, × 1.
3. *Phyllotheca* sp.; a group of linear leaves; specimen no. BSIP 36519, × 1.
4. *G. browniana* Feistmantel; details of venation pattern from specimen no. BSIP 36520, × 1.5.

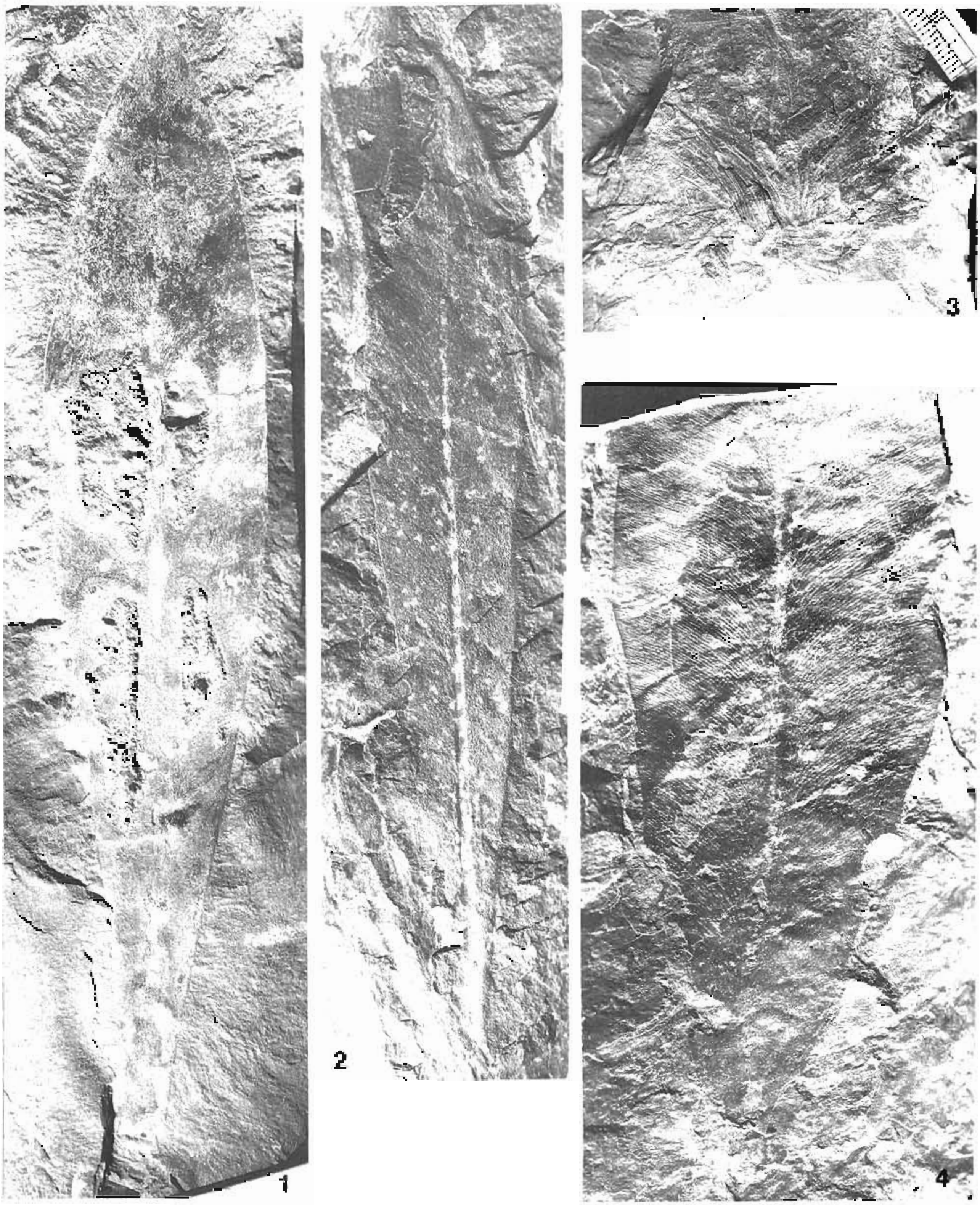
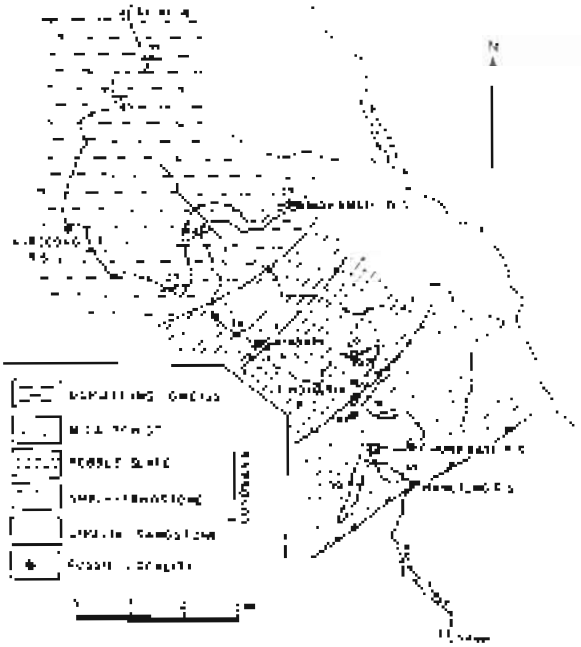


PLATE 1



Text-figure 5—Geological map of a part of Siliguri–Darjeeling road section, Darjeeling District.

studied around Tindharia on Siliguri–Darjeeling road (Text-fig. 5).

The sediments are thrusted over the Siwalik sediments which in turn are overlain by the older metasediments, mainly phyllites, schists and quartzites. The sediments of continental facies are represented by sandstones, shales and quartzites with a few limestone bands interbedded. The sandstones and shales are coal-bearing. The sandstones are fine to medium-grained, micaceous and feldspathic at places, and are bluish-grey and/or brownish in colour. The shale intercalations are splintery and occasionally resemble slate. The shales often yield well-preserved plant fossils. The carbonaceous shales are metamorphosed to graphitic schist near the thrust contact. The coal in the Tindharia area is more or less powdery.

Plant fossils have been collected from a locality just at the start of the footpath to Inspection Bungalow, Tindharia, from the main road opposite Assistant Mechanical Engineer's Bungalow.

DESCRIPTION

Equisetalean axes
Pl. 2, figs 4, 5

Description—Axes are unbranched, articulate with 12-14 longitudinal ridges and furrows at each internode. Ridges of adjacent internodes are continuous. The axes are 4-7 cm long and 1-1.4 cm wide. No attached leaf sheath is seen.

Occurrence—Specimen no. BSIP 36517 from a locality about 2 km from Nava Bazar bridge on Nava Bazar–Legship road section in South Sikkim District and specimen no. BSIP 36522 from the locality on Bhalukpong–Kimin road section in Kameng District.

Phyllotheca sp.
Pl. 1, fig. 3

Description—A group of several, 20-35 mm long, linear leaves, each with a midvein, is assigned to this genus. No axis or leaf sheath is seen. It is possible that the equisetalean axes described above bore these leaves.

Comparison—The leaves are reminiscent of those of *Phyllotheca griesbachii* Zeiller 1902.

Occurrence—Specimen no. BSIP 36518 from a locality about 2 km from Nava Bazar bridge on Nava Bazar–Legship road section in South Sikkim District.

Glossopteris stenoneura Feistmantel 1881
Pl. 1, fig. 4; Pl. 3, fig. 1

Description—The specimen is incomplete, only the basal part is preserved. It is presumed that the leaf was simple, spathulate in shape, broadest near the middle region and gradually narrowing towards the base. The preserved length and maximum width of the leaf are 8 cm and 4 cm, respectively. The midrib is distinct, 2 mm wide and is present throughout the preserved length. At places the midrib shows a few striations paralleling its course. The veins leave the midrib at narrow angles, which become 20°-35° within a millimeter distance, gradually arch out to the margin dichotomise once or twice. The concentration of veins near the midrib is 35 per cm and 40 per cm near the margin. The veins show rather scarce anastomosing and form very [illegible] and narrow meshes of uniform size. No cuticle could be recovered.

Comparison—The leaf resembles those of *Glossopteris communis* Feistmantel, *G. rangiganjensis* Chandra & Surange, *G. sahnii* Chandra & Surange and *G. stenoneura* Feistmantel in having a distinct midrib, similar angle of emergence of veins and elongate narrow meshes. However, *G. communis*, *G. raniganjensis* and *G. sahnii* differ in leaf shape; only *G. stenoneura* shows a striking resemblance (Feistmantel, 1881, p. 59, pl. 32, fig. 3; pl. 41, fig. 1; pl. 38, fig. 8; Barbier–Maheshwari & Bose, 1976, pl. 2, fig. 1, pl. 2, figs [illegible]; Text-fig. 3 A-D).

Occurrence—Specimen no. BSIP 36520 from a locality near Kimin Power House in Kameng District.

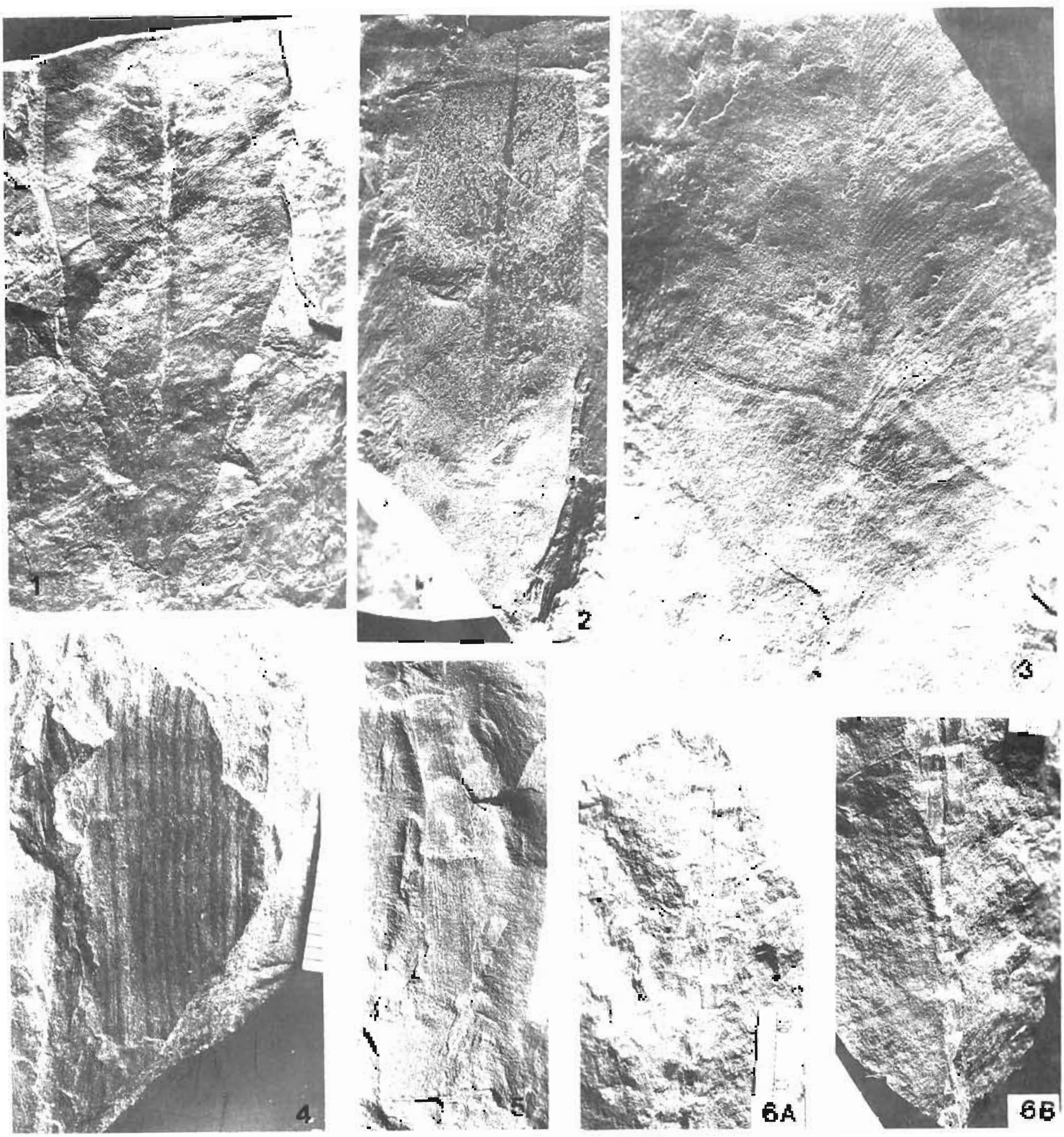


PLATE 2

1. *Glossopteris stenoneura* Feistmantel, specimen no. BSIP 36520, × 1.
2. *Glossopteris formosa* Feistmantel, specimen no. BSIP 36521, × 1.
3. *Glossopteris communis* Feistmantel, specimen no. BSIP 36522, × 2.
4. Equisetalean axis showing nodes and internode, specimen no. BSIP 36522, × 2.5.
5. An unidentified axis, specimen no. BSIP 36524, × 1.
6. *Vertebraria indica* Royle, specimen no. BSIP 36525, × 1, illustrated in two parts A and B.

Glossopteris communis Feistmantel 1876
Pl. 2, fig. 3

Description—The preserved length and maximum width of the leaves are 3-11 cm and 6-6.5 cm, respectively. The midrib is distinct and is 5 mm wide in the lower and 3 mm wide in the upper regions. At places it shows a number of strands running parallel to it. The veins leave the midrib at acute angles (15°-20°) and after dichotomising and anastomosing 2-3 times form long, elongate and narrow meshes of more or less uniform size. The number of dichotomies is more near the midrib than away from it.

Comparison—In shape and venation the leaves compare with those of *Glossopteris communis* (Feistmantel, 1881, p. 26, figs 1-4, pl. 27, fig. 1, pl. 36, figs 1-2).

Occurrence—Specimen no. BSIP 36520 from the locality near Kimi Power House in Kameng District, 10 km from Khoppi on Khoppi-Kimi road section after crossing a stream, in Kameng District.

Glossopteris sp. cf. *G. leptoneura* Bunbury 1861
Pl. 1, fig. 2

Description—Five leaves have been referred to this species on the basis of external morphology. All the specimens are incomplete. The leaves are simple, linear-lanceolate with acute apices and a gradually tapering base. The petiole is not seen. The preserved length and maximum width of the leaves are 8.5-18 × 1.5-2.5 cm, respectively. The midrib is distinct, persists right up to the apex and measures 1-2 mm in width. The secondary veins are not well preserved and are faintly seen, that too only at few places. The veins emerge at narrow angles and after dichotomising a few times meet the margins at oblique angles. The meshes are narrow, polygonal. The concentration of veins could not be ascertained.

Comparison—In overall shape and venation pattern the leaves compare with *Glossopteris leptoneura* Bunbury (1861, p. 330-331, pl. 9, figs 2-4).

Occurrence—Specimen no. BSIP 36518 from a locality about 2 km from Nava Bazar bridge on Nava Bazar-Legship road section in South Sikkim District.

Glossopteris sikkimensis Chandra & Surange 1979
Pl. 1, fig. 1

Description—The species is represented by one specimen, both in part and counterpart. The leaf is more or less complete but is without any carbonified crust. The leaf is simple and lanceolate/spathulate in shape, with an acute apex and basal portion gradually tapering into a broad base. The leaf is 17.5 cm long and 4 cm at the widest part which is about 2/3 length from the base. The midrib is broad but flat and persistent up to the apex. The secondary venation is indistinct but comprises long, narrow meshes.

Comparison—The venation of the leaf is of *Glossopteris communis* type. However, in overall shape it resembles *G. sikkimensis* (Chandra & Surange, 1979, pl. 2, fig. 1, pl. 15, fig. 5, pl. 13, fig. 4).

Occurrence—Specimen no. BSIP 36517 from a locality about 2 km from Nava Bazar bridge on Nava Bazar-Legship road section in South Sikkim District.

Glossopteris formosa Feistmantel 1881
Pl. 2, fig. 2

Description—Incomplete specimen measuring 8 cm in length and 3 cm in width, linear in shape. Venation open, meshes longish, polygonal, of almost equal size throughout.

Occurrence—Specimen no. BSIP 36521 from Tindharia in Darjeeling District.

Vertebraria indica Royle 1839
Pl. 2, figs 6a, b

Description—The axis is 12.5 cm long and 8 mm broad, and shows rectangular blocks arranged one on the other in longitudinal direction.

Occurrence—Specimen no. BSIP 36525 from a locality about 2 km from Nava Bazar bridge on Nava Bazar-Legship road section in South Sikkim District.

DISCUSSION

The plant megafossil assemblage reported herein is meagre for a meaningful age determination. *Glossopteris leptoneura* and *G. sikkimensis* have so far not been reported from sediments other than the Raniganj Formation. The presence of a species comparable with *[illegible]* also points to a Raniganj equivalent age. More material needs to be investigated for arriving at the age or stratigraphical position of these beds. However, evidence supporting a Raniganj equivalent age is also provided by Mishra *et al.* (1987) on the basis of vitrinite/inertinite (V/I) ratio pattern of the coal together with typical dominance of vitrinite material over inertinite and the rarity or absence of fusinized resins. This contention is also corroborated by the palynofossil assemblages from the underlying Permian sediments from which assemblages resembling those of the Talchir and Barakar formations of peninsular India have been recorded (Srivastava *et al.*, 1987).

The association of glacigene diamictites with sediments bearing Early Permian marine fauna, and elements of the Glossopteris Flora is significant for correlating these sediments with the sequences of peninsular India and the Tibetan Autonomous Region.

The Permian sediments of Eastern Himalaya have a depositional history different from that of peninsular India (Srivastava *et al.*, 1987). Even the coals associated with Permian sediments of Kameng District have petrographical and chemical properties different from peninsular Permian coal (Misra *et al.*, 1987). On the other hand, the Permian sequences of Eastern Himalaya show resemblance to those of Tibetan Block.

ACKNOWLEDGEMENTS

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Problem of fungal contamination in Precambrian palaeobiology : a cautionary note-I

C. Manoharachary, Manoj Shukla & Mukund Sharma

Manoharachari, C., Shukla, Manoj & Sharma, Mukund 1990. Problem of fungal contamination in Precambrian palaeobiology: a cautionary note-I. *Palaeobotanist* **37**(3) : 292-298.

The paper deals with the problem of fungal contamination in palaeopalynological preparations specially from the Precambrian sediments. The vegetative and reproductive structures of extant fungal groups show a broad similarity in morphology with the morphotypes described from the Precambrian. The recent fungi when subjected to chemical treatment similar to palynological preparations (maceration) do not show major physical and morphological changes. Nine common fungal genera were selected for this study. It has been observed that they withstand hydrochloric acid and hydrofluoric acid treatment without losing much of their morphocharacters. As these are common in soil profiles, one can easily be mislead when they occur amongst macerated residues. This data serves as a cautionary note to all palaeobiologists and specially dealing with Precambrian material, where every new evidence is important in adding to the meagre knowledge.

Key-words—Fungal contamination, Microfossils, Precambrian.

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साराँश

कॅम्ब्रिय-पूर्व पुराजैविक अध्ययन में कवकीय संदूषण की समस्या: सतर्कता हेतु उपलेख

सी० मनोहराचारी, मनोज शुक्ला एवं मुकुन्द शर्मा

प्रस्तुत शोध-पत्र में पुरापरागाणविक निर्मितियों में, विशेषतया कॅम्ब्रिय-पूर्व अवसादों से, कवकीय संदूषण की समस्या पर विवेचना की गई है। वर्तमान कवकीय समूहों की शाकीय एवं जननांगी संरचनायें कॅम्ब्रिय-पूर्व से वर्णित प्ररूपों से मोटे तौर पर आकारिकीय समानता प्रदर्शित करती हैं। वर्तमान कवकों पर जब परागाणविक मसृणन की तरह रासायनिक प्रक्रियायें की जाती हैं तो इनमें कोई विशेष आकारिकीय एवं भौतिक परिवर्तन व्यक्त नहीं होता। उक्त अध्ययन हेतु नौ सामान्य प्रजातियों को छाँटा गया है और यह प्रेक्षित किया गया है कि इनके आकारिकीय लक्षणों पर हाइड्रोक्लोरिक अम्ल एवं हाइड्रोफ्लोरिक अम्ल का कोई विशेष प्रभाव नहीं पड़ता। चूंकि ये मिट्टी की सतह में सामान्य रूप से मिलते हैं, अतः मसृणित-अवशेषों में विद्यमान होने के कारण कोई भी सरलता से भूल कर सकता है। प्रस्तुत शोध-पत्र सभी पुराजीव विज्ञानीयों जो कॅम्ब्रिय-पूर्व नमूनों के अध्ययन में कार्यरत हैं, के लिए एक सतर्कतापूर्ण उपलेख है जहाँ कि प्रत्येक नया प्रमाण संकुचित ज्ञान में योगदान हेतु अत्यन्त महत्वपूर्ण है।

BIOGENIC activity during Precambrian is evidenced by the occurrence of forms with simple morphologies. Bacteria and cyanophytes, viz., coccoids (spheroidal-ellipsoidal), septate, unbranched filaments, tubular, unbranched microstructures, branched filaments and bizarre

PLATE 1 →

Bar in fig. 3B represents 50 μm for each photograph except 1B.

1A. *Aspergillus niger* van Tiegham: Conidiophores, vesicles and conidia. 1B. *Aspergillus niger* after treatment.

2A. *Alternaria alternata* Keissler, Hyphae, conidiophores and conidia; Fig. 1B, *A. alternata* after treatment showing hyphal fragment and conidia.

3A. *Cladosporium cladosporioides* de Veries. Hyphae and conidia: 3B, *C. cladosporioides* after treatment showing hyphal fragment and conidia.

4A. *Chaetomium aureum* Chievers. Ascospores and hairs; 4B & C, *C. aureum* showing hairs and ascospores respectively after treatment.

5A. *Curvularia lunata* (Wakker) Boedijin. Hyphae, conidiophore and conidia; 5B, *C. lunata* conidia and hyphae after treatment.

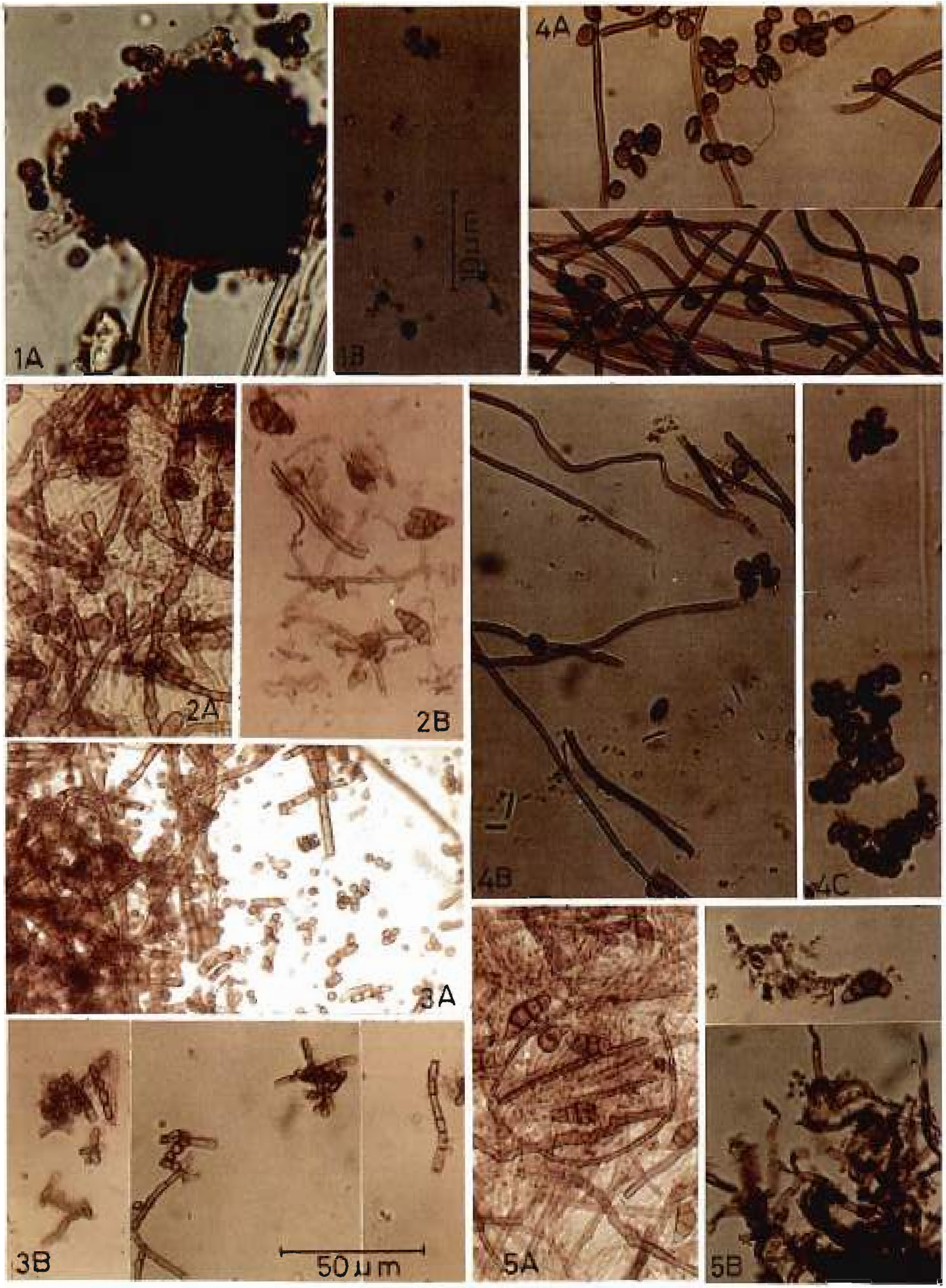

PLATE 1

forms, etc. are recorded (Hofmann & Schopf, 1983).

These fossil remains are meagre and often highly degraded. Due to this fact any new evidence is very important as it has a great bearing on the understanding of evolution of life and various other associated processes. Every new evidence of Precambrian microbiota requires close scrutiny.

Several of the 'fossils'—morphotypes described from the Precambrian sediments also compare morphologically with extant fungi. Instances of extant micro-organisms, artifacts and pseudofossils described as Precambrian microbiota have been put forward by Schopf (1975), Cloud (1976), Cloud and Morrison (1979), Schopf and Walter (1983), Fuxing and Qiling (1982), Horodyski (1981) and Karkhanis (1977). The frequency of misidentification depends upon the common soil organisms available in the sampled area and processing techniques. After the initiation of a multidisciplinary project on Indian Archaean palaeobiology a study on degradational aspect of extant micro-organisms was initiated with an idea to prepare a checklist of common modern contaminants. In this paper our results on the study of some common fungi are presented.

Fungi are known from a wide variety of habitats (Webster, 1980). They form a part of the air habitat (Gregory, 1971) and have also been reported up to the depth of 30 cm (Galiah, 1985; Manoharachary, 1986), in rock crevices and from surface samples such as laterite, sandstone, granite and alluvial soils (Manoharachary, 1986; Jarzen & Elsik, 1986). The vegetative hyphae and reproductive structures of these fungi which are often brown-black in colour have been confused with thermally altered fossil algal filaments and unicells. Such mistakes are more likely to occur when one is using maceration method (acid digestion of rock for concentration of organic matter) for fossil recovery. Since in the maceration method the organic remains are released from the rock matrix, it is not possible to make out the relationship of the detached organic matter whether, it is synsedimentary and syngenetic with the rock treated.

MATERIAL AND METHOD

Nine common fungi which commonly occur as soil biota, viz., *Aspergillus niger* van Tiegham, *Alternaria alternata* (Fr.) Keissler, *Cladosporium cladosporioides* (Fres) de Vries, *Chaetomium aureum* Chivers, *Curvularia lunata* (Wakker) Boedijin, *Drechselera rostrata* (Drechseler) Richardson & Fraser, *Phoma nebulosa* (Pers. ex S.F. Gray) Berk, *Rhizopus nigrecans* Ehrenberg and *Trichoderma viride* (Pers. E.M. Fries), were subjected to chemical degradation through inorganic acids, viz., HCl and HF which are commonly used for maceration of rocks. These fungi were taken from well-identified monosporic stock cultures available in the laboratory and grown on PDA medium (potato dextrose agar) under laboratory conditions. The fungi were treated initially with hydrochloric acid (40%) for two days and then after washing with distilled water were subsequently treated with hydrofluoric acid (commercial-40%) for 10 days. The residual fungal material was finally washed with distilled water and mounted in lectophenol. This chemical treatment is the same as used for maceration of rocks. Another set of slides was also prepared from untreated material of the same culture for reference and comparison.

All the photographs presented in Plate 1 and 2 have been taken on Leitz Orthoplan microscope in normal light using only natural density filter to enable the maximum exposures of natural colours of fungi without acid treatment and after treatment on Kodacolor-Kodak Gold film with the help of Vario orthomat 2 photographic attachment.

OBSERVATIONS

Following characters were observed in control and treated material.

Aspergillus niger van Tieghem
Pl. 1, fig. 1A, B

Description—Hyphae pale, smooth

PLATE 2 →

(Bar in Fig. 1C represents 50 μm for each photograph)

1A, 1B. *Drechslera rostrata* (Drechsler) Richardson & Fraser. Hyphae, conidiophores and conidia; 1C, *D. rostrata* hyphae, conidiophores and conidia after treatment.

2A, 2B. *Phoma nebulosa* (Pera ex SF Gray) Berk. Pycnidia pseudoparenchymatous wall and pycnidia; 2C, *P. nebulosa* showing pseudoparenchymatous pycnidial wall after treatment.

3A. *Trichoderma viride* Pers ex. Fries. Hyphae and conidial mass; 3B, *T. viride* showing conidial mass after treatment.

4A, 4D. *Rhizopus nigricans* Ehrenberg. Columella, spores and hyphae; 4B & 4C, showing hyphae, columella and spore mass after treatment.

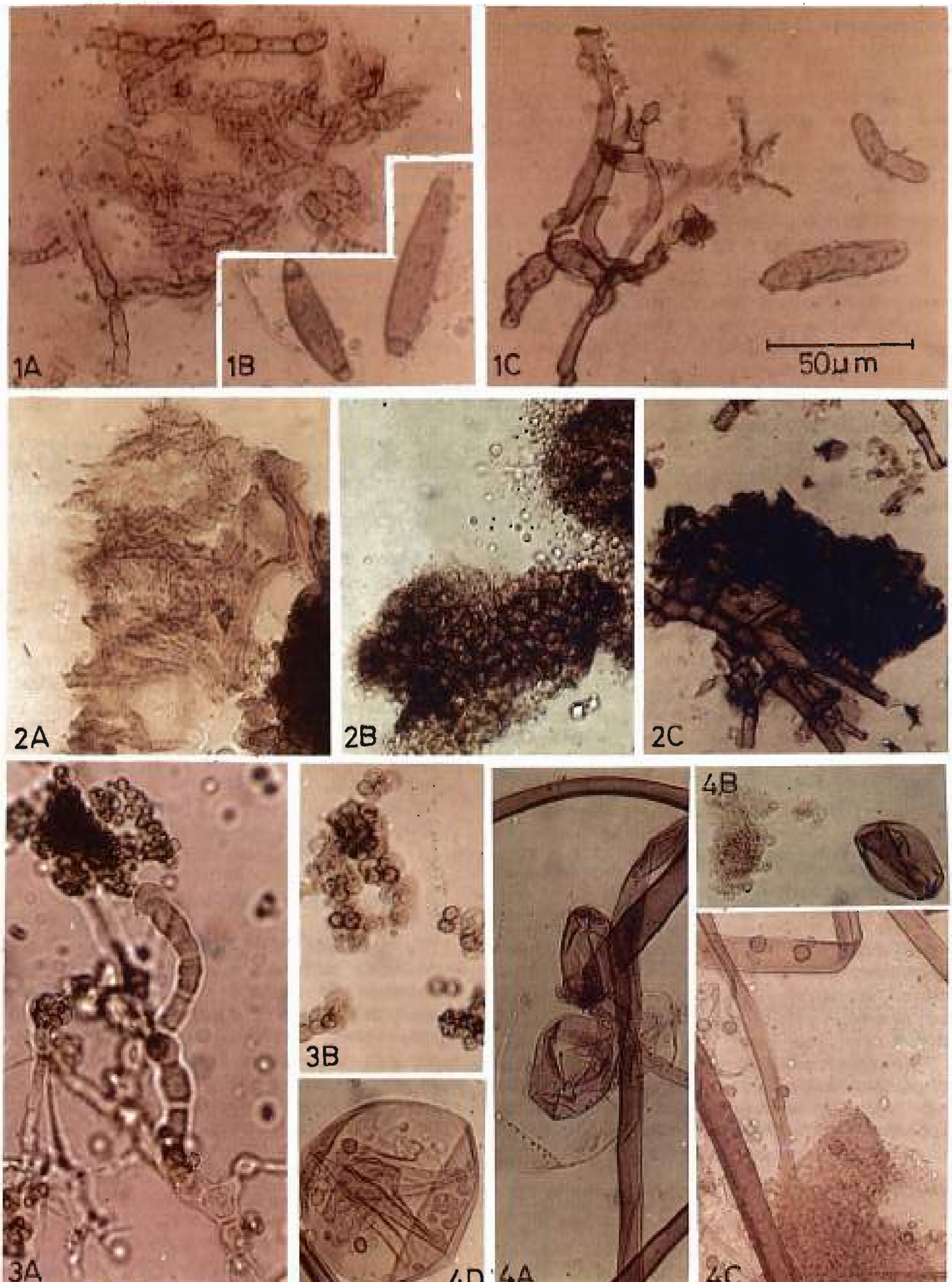

PLATE 2

conidiophores 1-2 mm long, vesicles globose, sterigmata in two series, conidia globose and spinulose, black in colour, spherical, 6.2-7.5 μm.

Observations—In treated material the hyphae and conidia showed loss of pigmentation as compared to the control. Conidiophores were dissolved and conidia became almost colourless. Therefore no remains were visible.

Alternaria alternata (Fr.) Keissler
Pl. 1, fig. 2A, B

Description—Hyphae pale brown to brown, branched, septate, conidia dictyosporous.

Observations—In treated material the hyphae got fragmented and gave deceptive appearance of fossilized algal filament, black or brown, with longitudinal transverse septa.

Cladosporium cladosporioides (Fres) de Vries
Pl. 1, fig. 3A, B

Description—Hyphae brown, septate, branched hyphal cells thick-walled; conidia unicellular or two-celled, found in chain, brown in colour.

Observations—Partial loss of pigmentation and reduction in the thickening of the septa were observed in treated material.

Chaetomium aureum Chievers
Pl. 1, fig. 4A, B, C

Description—Perithecia dark, olive brown with an ostiole and appendages or hairs, as a 8-spored, ascospores olive brown, ovate or elliptical, 12.7 × 5.9-6.8 μm in size.

Observations—Reduction in the size of ascospores and thickening of wall layers were observed in the treated material.

Curvularia lunata (Wakker) Boedijin
Pl. 1, fig. 5A, B

Description—Hyphae septate, brown, branched, conidiophores unbranched, erect, septate, brown, geniculate. Conidia with three transverse septae, curved, apical cell rounded, pale brown, basal cell sub-hyaline to pale brown, middle cell broader and darker than other parts.

Observations—The treated material showed loss of pigmentation both in hyphae and conidia which was higher in this fungus along with wrinkled appearance in the hypha wall, which was apparently due to loss of internal contents.

Drechslera rostrata (Drechsler) Richardson & Fraser
Pl. 2, fig. 1A, B, C

Description—Hyphae brown, septate, branched conidiophores flexuous, dark brown, septate, conidia clavate, elliptical, rostrate, 5-18 μm. Pseudoseptate, septa dark, end cells hyaline, middle cells brown.

Observations—Partial loss of pigmentation, internal contents and rigidity in the wall layers of hyphae as well as in conidia were observed in treated material.

Phoma nebulosa (Pers. ex SF. Gray) Berk
Pl. 2, fig. 2A, B, C

Description—Pycnidia brown, w. pseudoparenchymatous and brown, conidia hyaline.

Observations—Partial loss of pigmentation was observed in pseudoparenchymatous wall layers of pycnidia of the treated material.

Rhizopus nigrecans Ehrenberg
Pl. 2, fig. 4A-D

Description—Hyphae branched, brown, coenocytic, sporangiophores in clusters, up to 2 mm long, 10.5-17 μm wide, sporangia almost spherical, 85-195 μm in diameter, blackish brown, spores rounded, 5-6 × 3-4.6 μm in size.

Observations—Loss of contents resulting in an irregular shaped columella and also partial reduction of pigmentation in general were the effects in treated material.

Trichoderma viride Pers. ex. Fries
Pl. 2, fig. 3A, B

Description—Hyphae pale or light green, branched, septate, conidiophores not distinct, phialidic, conidia in groups, green, smooth, thick-walled, globose or ovoid.

Observations—Reduction in the compaction of globular cell masses and also in pigmentation have been observed in treated material.

DISCUSSION AND CONCLUSIONS

In general, the material treated with hydrofluoric acid and hydrochloric acid shows reduction and loss in pigmentation both in reproductive structures as well as in hyphae. Loss of rigidity in the wall layers resulting in wrinkled appearance of hyphae is also common. Size of the hyphae and reproductive structures were not affected in general. Compaction of the cells and the parenchyma formed by the hyphae were affected. The fragmented hyphae which lost septa or coenocytic (Pl. 1, figs 4B, 5B) do show comparison with the algal sheaths described in Precambrian literature and may be mistaken for *Eomycetopsis* and *Animikiea*. The septate hyphae which get fragmented can be mistaken for algal trichomes. The easiest method to differentiate them from true fossil algal trichomes is to watch for bulbous or knuckle-shaped structure conspicuous in fungal hyphae. The globular conidial masses as found in *Trichoderma viride* (Pl. 2, fig. 3A, B) can be mistaken for *Myxococcoides* and *Sphaerocongregus* like taxa described from Precambrian sediments. The fragmented conidial spores (Pl. 2, figs 4C, 3B) compare closely with unicellular taxa such as *Eomyelopsoides*, *Huroniospora*, etc. The sporangia with broken columella (Pl. 2, fig. 1C) can mislead Precambrian palaeobiologists into identifying them as *Kildinosphaera* and various other acritarch taxa that are commonly recorded amidst shale biotas. The chances of contamination are more in shale biotas.

Doubts were expressed by Schopf (1975a, 1975b), Cloud (1976), Venkatachala (1986, 1987) and Schopf and Walter (1983) earlier about the possibility of fungal contaminants being introduced during material preparation and described as Precambrian microorganisms. The extant fungal remains which are normally available in soil, rock crevices and in humid areas such as river banks and outcrops in the valley region, mines and weathered outcrops where post-depositional concentration of ores have taken place, can withstand treatment by inorganic acids. They take morphological shapes which are broadly comparable with the morphotypes generally described from the Precambrian. The present work establishes beyond doubt that fungal contamination can pose a serious problem. The Precambrian biologists should take note of this major source of contamination and acquaint themselves with the extant algal and fungal flora. The problem of contamination is not only with the macerations but also with the preparation of stubs for SEM studies particularly when the replica method is used. The process provides more exposures to the atmosphere which can introduce the contaminants (Oberlies & Prashnowsky, 1968; Schopf, 1975, p. 235; Cloud, 1976, p. 357; Cloud & Morrison, 1979, p. 89; Schopf *et al.*, 1983; Hofmann & Schopf, 1983, p. 329). "To quote—It is either due to over enthusiasm or due to the thrill associated with such findings, such reports are increasing and the net gain in the advancement of Archaean and Precambrian palaeobiology remains static. The mistakes of earlier workers was due to lack of available literature and experience but it is not just liable to commit such mistake in this age of advanced knowledge and instrumentation. If only we could interact with botanists engaged in the study of extant algae and fungi such erroneous identification can be avoided" (Venkatachala, 1987).

In view of above it is recommended that the results are checked for the possibility of extant taxa when we work on surface samples using the maceration method. Some of the precautions needed are: Preparation of a checklist of fungal taxa present in the fossil localities and their aerospora, the checking of fungal growth and avoidance of growth promoting conditions during curating.

These safety measures can minimise misleading reports. Some of the biotic remains recovered from maceration are closely comparable to the fungal hyphae and spores which withstand acid treatment. In this situation, this paper we hope will help avoid unintentional reporting of extant contaminations as Precambrian microbiota.

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Some more leaf-impressions from the Lower Siwalik sediments of Koilabas, Nepal

Mahesh Prasad

Prasad, Mahesh 1990. Some more leaf-impressions from the Lower Siwalik sediments of Koilabas, Nepal. *Palaeobotanist* **37**(3) : 299-305.

Four species of leaf-impressions are described from the Lower Siwalik sediments of Koilabas, Nepal. They are: *Dipterocarpus siwalicus* Lakhanpal & Guleria of Dipterocarpaceae and *Albizia siwalica* sp. nov., *Millettia koilabasensis* sp. nov., and *Ormosia robustoides* sp. nov. of Fabaceae.

Key-words—Leaf-impressions, *Dipterocarpus, Albizia, Millettia, Ormosia*, Lower Siwalik, Miocene (Nepal).

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सारांश

नेपाल में कोइलाबास के अधरि शिवालिक अवसादों से कुछ और पर्ण-छाप

महेश प्रसाद

नेपाल में कोइलाबास के अधरि शिवालिक अवसादों से पर्ण-छापों की चार जातियाँ वर्णित की गई हैं। ये डिप्टेरोकार्पेसी कुल के **डिप्टेरोकार्पस शिवालिकस** लखनपाल व गुलेरिया तथा फ़ैबेसी कुल के **ऐल्बिज़िया शिवालिका** नव जाति, **मिलेशिया कोइलाबासेन्सिस** नव जाति एवं **ओर्मोसिआ रोबस्टॉयडिस** नव जाति नामक वर्गक हैं।

A FEW years ago, the leaf-impressions of *Dillenia palaeoindica, Anogeissus eosericea* and *Syzygium miocenicum* were described from the Lower Siwalik sediments of Koilabas (27°42′N : 82°20′E), Nepal (Prasad & Prakash, 1984: pp. 246-256). From the same locality four more species have been presented in this paper. The terminology used here is after Hickey (1973) and Dilcher (1974).

SYSTEMATIC DESCRIPTION

Family—Dipterocarpaceae

Genus—*Dipterocarpus* Gaertn. f.

Dipterocarpus siwalicus Lakhanpal & Guleria 1986
Pl. 1, figs 1, 3, 4

Three almost complete leaf-impressions and two fragments represent this species.

Description—Leaf simple, symmetrical ovate; lamina length 11.0 cm, maximum width 6.0 cm; apex acute; base obtuse to cordate, normal; margin entire, slightly undulate; texture chartaceous; petiole 0.8 cm in length, venation pinnate, simple eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 16 pairs visible with angle of divergence acute, moderate (50-60°), upper ones more acute than lower, alternate to rarely sub-opposite, 0.5-1.2 cm apart, lowermost two pairs of secondaries closely placed, uniformly curved up and run almost parallel to each other, moderately thick, unbranched; tertiary veins (3°) fine with angle of origin AR-RO, pattern percurrent, simple, almost unbranched, straight, oblique in relation to midvein, alternate to opposite, close; higher order venation indistinct.

Discussion—In overall characters the fossil leaves show close resemblance with *Dipterocarpus siwalicus* Lakhanpal & Guleria 1986, a species already described from the Lower Siwalik beds near Jwalamukhi, Himachal Pradesh. Besides, the present fossil possesses a small petiole which is not preserved in *D. siwalicus* Lakhanpal & Guleria.

Because of its close similarity with *P. siwalicus* it has been assigned to the same species.

The modern species *P. macrocarpus* Kurz, with which the fossil shows closest similarity, is a large deciduous tree growing in plains and low hills in the valley of Burma. It also grows in Southern China and Thailand.

Figured specimens—Specimen nos. BSIP 35945, 35947.

Family—Fabaceae

Genus—*Albizia* Durazz.

Albizia siwalica sp. nov.
Pl. 1, figs 5, 7

The present species is based on three well preserved and almost complete impressions.

Description—Leaflet asymmetrical, wide obovate, preserved length 3.0-4.7 cm with petiolule 0.2 cm long, lamina length 3.0-4.5 cm, maximum width 2.0-3.0 cm; apex obtuse, base obtuse, inequilateral; margin entire; texture chartaceous; venation pinnate, brochidodromous; primary vein (1°) single, prominent, moderate, straight to slightly curved; secondary veins (2°) 7 pairs visible with angle of divergence acute, moderate (about 60°), uniformly curved up joining superadjacent secondaries, alternate to opposite, 0.6-2.0 cm apart, occasionally branched; tertiary veins (3°) fine with angle of origin nearly RR, pattern percurrent, straight to sinuous, rarely branched, oblique in relation to midvein, predominantly alternate and close; quaternary veins (4°) not visible.

Discussion—A survey of modern plants indicates that similar leaflets are found in *Swietenia mahagoni* Jacq. of Meliaceae, *Pterospermum blumeanum* Korth. of Sterculiaceae and *Albizia* Durazz. of the family Fabaceae. Of these, the leaflets of *Swietenia mahagoni* Jacq. and *Pterospermum blumeanum* Korth. resemble the fossil leaflets in possessing similar shape, size and the type of venation but differ distinctly in nature and arrangement of tertiary veins which are random reticulate in contrast to percurrent in the present fossil impressions. Thus the fossil specimens compare closely with the modern leaflets of the genus *Albizia* Durazz. Detailed study of about 30 species of the modern leaflets of *Albizia* was done and it has been observed that the leaflets of *Albizia gamblei* Prain (F.R.I. Herbarium sheet no. 16739) show similarity with the fossil leaflets in possessing similar shape, size and venation pattern.

Fossil records and comparison—So far only two fossil leaflets resembling those of *Albizia* have been described from abroad. They are *Albizia miokalkora* (Hu & Chaney) Ishida, 1970 from the Miocene of central Japan and *Leguminosites* (*Albizzia*) sp. Geyler, 1875 from the Tertiary of Borneo. Of these, the latter is a fragment only in which the venation is not visible. However, *Albizia miokalkora* differs in being much smaller in size (about 1-2.5 cm in length) and with oblong shape as against larger size (about 3.0-7.0 cm in length) and obovate shape of the present fossil leaflets. Since the fossil leaflet is entirely different from the known fossil species of *Albizia*, it is being described here as *Albizia siwalica* sp. nov. Though this is the first record of a leaflet impression of *Albizia* from India, petrified wood of *Albizia* is already known from the Lower Siwalik beds of Nalagarh in Himachal Pradesh (Prakash, 1975). This wood also shows closest resemblance with the modern *Albizia lebbek* (now known as *A. gamblei*) confirming again the occurrence of this taxon during the Lower Siwalik in India.

The genus *Albizia* Durazz. consists of 150 species which are distributed in tropical and subtropical regions of the Old World (Willis, 1973). In India, its 16 species are reported to occur. *A. gamblei* Prain (syn. *A. lebbek* Gamble), with which *A. siwalica* shows closest resemblance, is a deciduous tree attaining about 18 m in hills of Burma (Brandis, 1971, p. 259; Gamble, 1972, p. 301).

Holotype—Specimen no. BSIP 35946.

PLATE 1

1. *Pterocarpus siwalicus* Lakhanpal & Guleria—Fossil leaf in natural size; specimen no. BSIP 35945.
2. *Pterocarpus macrocarpus*—Modern leaf in natural size showing similar shape, size and venation.
3. *Pterocarpus siwalicus* Lakhanpal & Guleria—Another fossil leaf in natural size showing nature of petiole; specimen no. BSIP 35946.
4. *P. siwalicus* Lakhanpal & Guleria—Basal part of another fossil leaf showing cordate base; specimen no. BSIP 35947.
5. *Albizia siwalica* sp. nov.—Fossil leaflet in natural size; specimen no. BSIP 35946.
6. *Albizia gamblei*—A modern leaflet in natural size showing similar shape, size and venation.
7. *Albizia siwalica* sp. nov.—Another fossil leaflet in natural size showing variation in shape; specimen no. BSIP 35948.
8. *Albizia gamblei*—Another modern leaflet in natural size showing close similarity with fig. 7.

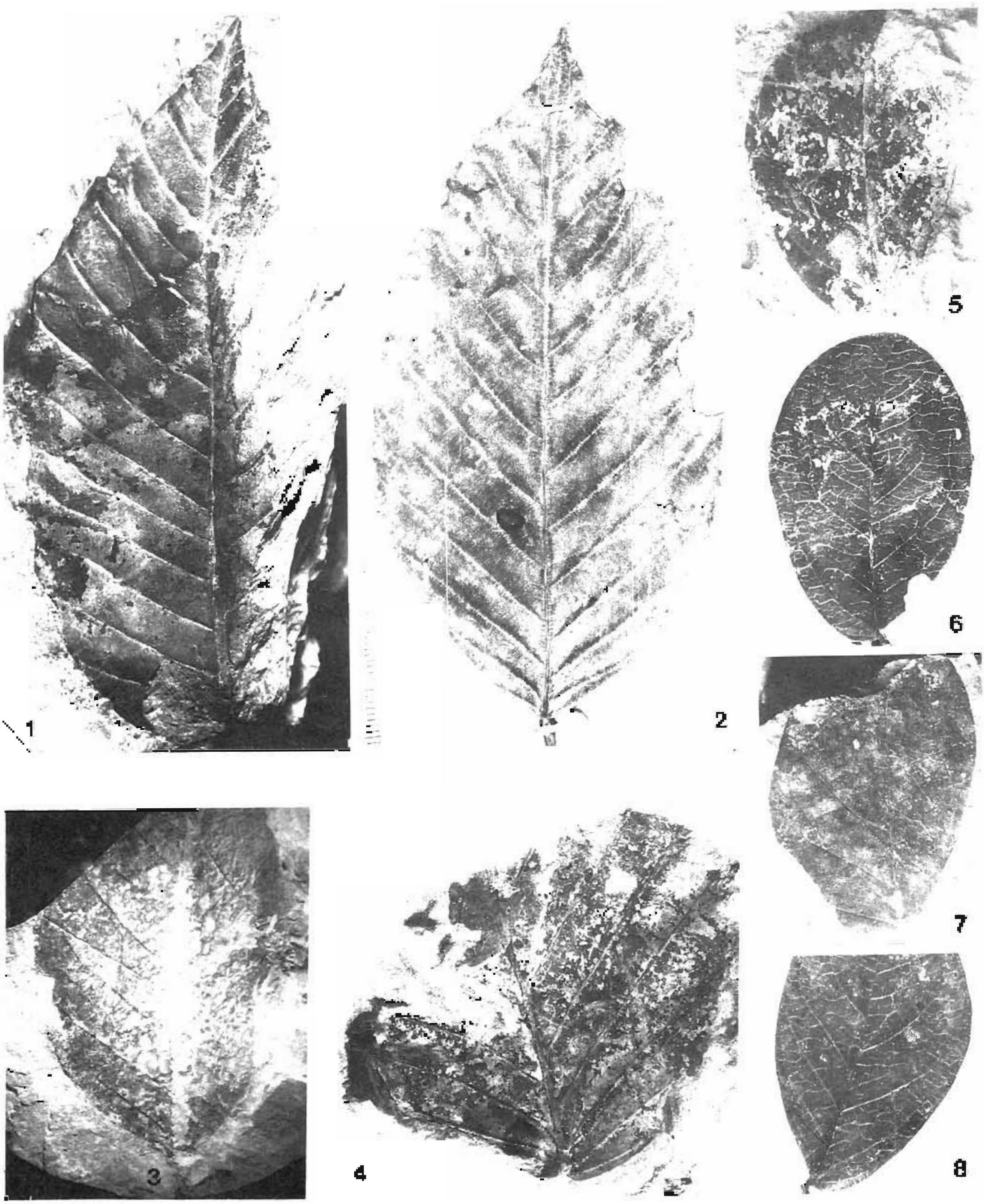

PLATE 1

Genus—*Millettia* W. & A.

Millettia koilabasensis sp. nov.
Pl. 2, fig. 1

The present species consists of a single well-preserved impression of a leaflet.

Description—Leaflet symmetrical, narrow obovate; lamina length 8.0 cm, maximum width 3.5 cm; apex acute; base somewhat acute; margin entire; texture chartaceous; petiolule not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, straight; secondary veins (2°) 8 pairs visible with angle of divergence acute, moderate (about 50°), alternate, 1.0-1.4 cm apart, uniformly curved, unbranched; intersecondary veins present, simple, rare; tertiary veins (3°) fine with angle of origin AR-RO, pattern percurrent, sometimes branched, straight to sinuous, oblique in relation to midvein, alternate to opposite, close to distant; quaternary veins (4°) indistinct.

Discussion—The characteristic features of the present fossil, such as obovate shape, acute base, chartaceous texture, presence of intersecondary veins and eucamptodromous type of venation are common in the modern leaves/leaflets of *Alphonsea lucida* King of Anonaceae, *Claoxylon purpureum* Merr. of Euphorbiaceae, *Combretum decandrum* Roxb. of Combretaceae, *Saprosma ternatum* Benth. & Hook. of Rubiaceae and *Millettia* W. & A. of the family Fabaceae. Out of these, the leaves of *Alphonsea lucida* King differ from the present fossil leaflet in having only 6 pairs of widely spaced (about 2.5 cm apart) secondaries as against more than 8 pairs of secondaries which are comparatively closely placed (1.0-1.4 cm apart). Similarly the leaves of *Combretum decandrum* Roxb., although similar in shape and size, differ from the fossil leaflet in the arrangement of closely placed tertiary veins as well as in the nature of apex. These leaves possess acuminate apex as against acute apex in the fossil. The leaf of *Claoxylon purpureum* Merr. is also close to the fossil leaflet but slightly differs from it in having serrate margin while the present leaflet impression has entire margin. In the leaves of *Saprosma ternatum* Benth. & Hook. all the secondaries arising from the midrib join the superadjacent secondaries and form prominent loops, whereas in the fossil only a few pairs of secondaries towards apex seem to form loops.

A large number of leaflets of the genus *Millettia* were compared with the present fossil and it was found that the modern leaflets of *M. tetraptera* Kurz. and *M. macrostachya* Call. & Hemsl. show resemblance with the fossil. However, *M. tetraptera* Kurz. slightly differs from the fossil in possessing lamina with comparatively more width towards apex. Thus, the fossil leaflets shows closest resemblance with the modern leaflets of *M. macrostachya* Call. & Hemsl. (F.R.I. Herbarium specimen no. 53602; Pl. 2, fig. 12).

Fossil records and comparison—The impressions showing resemblance with the modern leaflets of *Millettia* have been described under the genus *Millettia* W. & A. So far, there are only five species of *Millettia* known from India and abroad. These are *Millettia impressa* (Harms) Mengel 1920 from Kamerum, West Africa (?Cenozoic), *M. notoensis* Ishida 1970 from the Mid-Miocene of central Japan, *Millettia* sp. Huzioka & Takahasi 1970 from the late Eocene of Southeast Honshu, Japan and *M. asymmetrica* and *M. miocenica* (Lakhanpal & Guleria, 1982) from the Miocene of Kachchh, western India. Since *M. impressa* is unaccompanied by any description or photograph, it is not possible to compare it with the present fossil. However, *M. notoensis* differs in its shape and number of secondaries. The shape of *M. notoensis* is ovate whereas it is obovate in the present fossil and there are only 4-5 pairs of secondaries in contrast to more than 8 pairs of secondaries in the present fossil specimen. *Millettia* sp. from Japan can easily be differentiated in being lanceolate in shape with inequilateral obtuse base in contrast to obovate shape with acute base in the present fossil. Further, *M. asymmetrica* differs from the present fossil leaflet in its elliptic shape. Similarly, *M. miocenica* is also distinct in having oblong shape without inter-

PLATE 2 →

1. *Millettia koilabasensis* sp. nov.—Fossil leaflet in natural size, specimen no. BSIP 35951.
2. *Millettia macrostachya*—Modern leaflet in natural size showing similar shape, size and venation.
3. *Ormosia robustoides* sp. nov.—Fossil leaflet in natural size, specimen no. BSIP 35952.
4. *Ormosia robusta*—Modern leaflet in natural size showing similar shape, size and venation.
5. *Ormosia robustoides* sp. nov.—Another fossil leaflet showing variation in shape and size, × 1, specimen no. BSIP 35953.
6. *Ormosia robusta*—Another modern leaflet showing similar variation in shape and size, × 1.
7. *O. robustoides* sp. nov.—A fossil leaflet (fig. 5) magnified to show details of venation, × 4; specimen no. BSIP 35952.
8. *Ormosia robusta*—Modern leaflet (fig. 6) magnified to show similar details of venation, × 4.

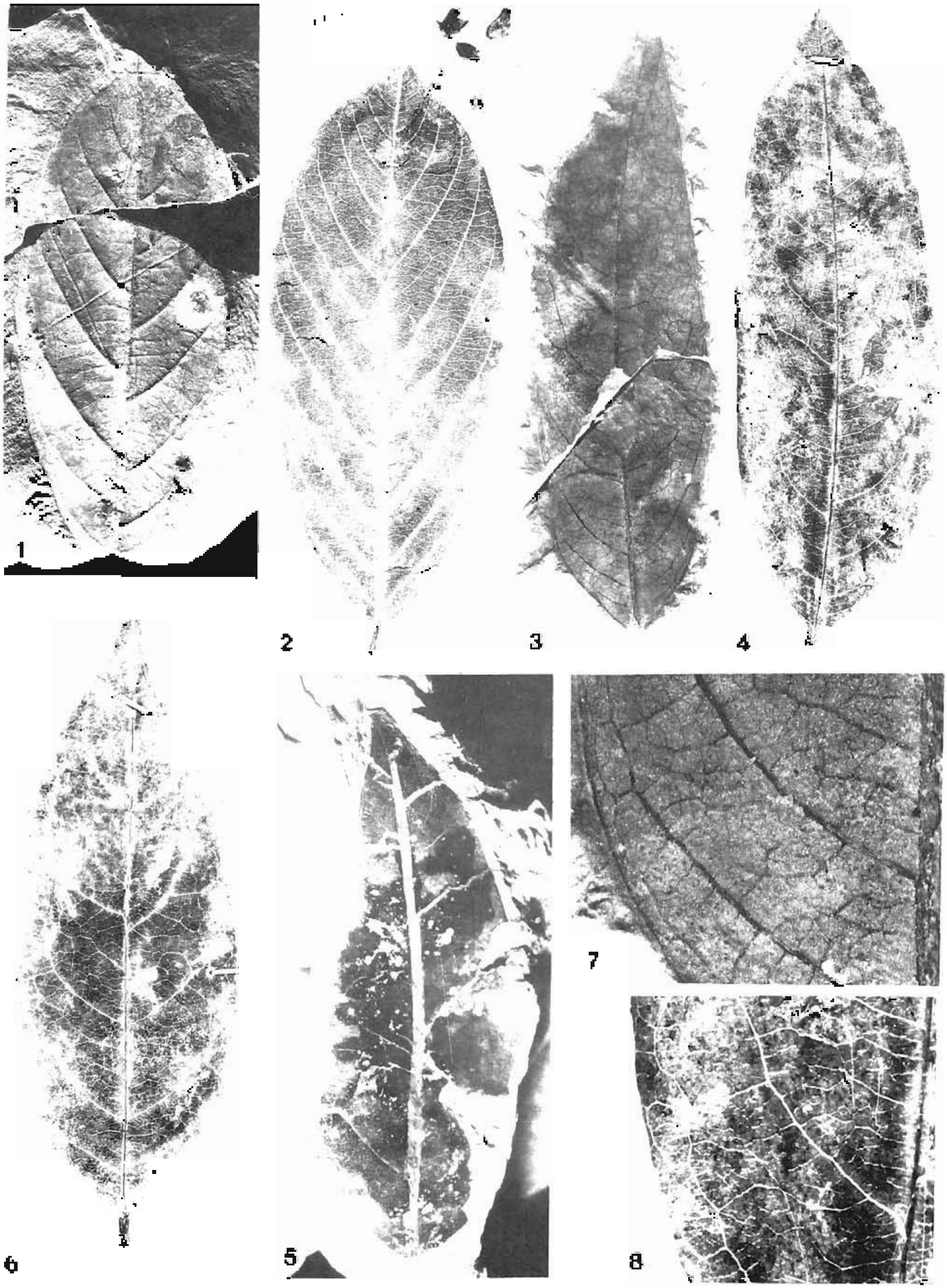

PLATE 2

secondary veins which are present in the present fossil leaflet.

Thus, the present fossil is quite different from the already known fossil species of *Millettia* and is being assigned to a new species, *Millettia koilabasensis*. Its specific name is after the locality from which the material was collected.

The genus *Millettia* W. & A. consists of 180 species (Willis, 1973, p. 754) of trees, shrubs and woody climbers distributed in the warmer region of Africa, Asia and Australia. About 30 species are reported to occur in India and Burma. *Millettia macrostachya* Coll. & Hemsl. with which the present leaflet impression resembles closely is a tree of Shan Hills of Upper Burma (Gamble, 1972, p. 242).

Holotype—Specimen no. BSIP 35951.

Genus—*Ormosia* Jack

Ormosia robustoides sp. nov.
Pl. 2, figs 3, 5, 7

This species is based on two well preserved, almost complete impressions of leaflets.

Description—Leaflets symmetrical, lanceolate; lamina length 9-10 cm, maximum width 2.7-3.5 cm; apex acute; base obtuse; margin entire; texture chartaceous; petiolule broken; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 12 pairs visible with angle of divergence acute, moderate to wide (60°-75°), alternate to opposite, 0.5 to 2.0 cm apart, uniformly curved up and running parallel to margin for a short distance, moderately thick, rarely branched; intersecondary veins present, simple, abundant and branched; tertiary veins (3°) fine with angle of origin AR-RR, pattern percurrent, branched, almost straight, oblique in relation to midvein, predominantly alternate and close; quaternary veins (4°) very fine, abundant, usually forming orthogonal meshes.

Discussion—The most important characters exhibited by the present fossil leaflets are lanceolate shape, acute apex, obtuse base, margin entire, chartaceous texture, eucamptodromous venation and the presence of intersecondary veins. These characters are found in the modern leaves/leaflets of *Evodia meliaefolia* Benth., *Glycosmis cymosa* Zipp. ex Span. and *Tetradium fraxinifolium* Wall. ex Royle of Rutaceae, *Rhus punjabensis* Stew. ex Brandis and *Pistacia integerrima* Stew. of Anacardiaceae, *Heritiera fomes* Buch. of Sterculiaceae, *Heynea trijuga* Roxb. of Meliaceae, *Cananga odorata* Hook. of Annonaceae and *Dialium indicum* Linn. and *Ormosia* Jack of Fabaceae. Of these, the leaflets of *Evodia meliaefolia* Benth., although similar in shape and size, differs in having secondaries which do not run parallel to the margin forming distinct loops. In the leaflets of *Glycosmis cymosa* Zipp. ex Span. the secondaries arise straight from the midrib with comparatively more acute angle of divergence. *Tetradium fraxinifolium* Wall. ex Royle can easily be differentiated in having serrate margin as against entire margin in the fossil leaflets. The modern leaflets of *Rhus punjabensis* Stew. ex Brandis and *Pistacia integerrima* Stew. both differ in having very few intersecondaries in comparison to abundant intersecondaries in the present fossil. Besides, in *Pistacia integerrima* Stew., the secondaries are comparatively more in number (about 18 pairs) and more closely placed too. The leaves of *Heritiera fomes* Buch. are similar in venation pattern but differ in its shape and size. Here the shape is narrow elliptic with greater width in the middle part of the lamina, whereas the present fossil leaflets are lanceolate in shape with almost uniform lamina width. The leaflets of *Heynea trijuga* Roxb., although almost similar in shape and size, can also be differentiated in possessing narrow sharply acute apex in comparison to bluntly acute apex in the fossil leaflets. Moreover, the tertiary veins are comparatively wide in the leaves of *Heynea trijuga* Roxb. The modern leaves of *Cananga odorata* Hook. possess only 8 pairs of secondaries in comparison to more than 12 pairs of secondaries in the present fossil. *Dialium indicum* Linn. also differs from the present fossil in having tertiaries which are randomly oriented forming reticulum; these are not percurrent as seen in the fossil leaves. Thus, it is only the modern leaflets of *Ormosia* Jack with which the fossil leaflet-impressions show close resemblance. However, in order to find out the nearest modern equivalent of the fossil leaflets, the modern leaflets of a large number of species of *Ormosia* Jack have been studied. Out of them, four species of *Ormosia*, viz., *O. robusta* Wight, *O. fordiana* Olive., *O. calavensis* Azaola, and *O. watsonii* show near resemblance with the present leaflet-impressions. Latter three species of *Ormosia* can easily be differentiated on the basis of gross features. The leaflets of *O. fordiana* Oliv. differ in having only 7-8 pairs of secondaries which are comparatively widely spaced. The leaflets of *O. calavensis* Azaola possess narrow acute apex instead of bluntly acute apex in the present fossil. Besides, the intersecondaries are comparatively few in the modern leaflets than in the present fossil leaflets. Similarly the leaflets of *O. watsonii* also differ in possessing ovate to wide-ovate shape as against lanceolate shape of the present fossils. Thus the leaflets of *Ormosia robusta* Wight (Pl. 2, figs 4, 6, 9) show closest resemblance with the fossil-impression.

Fossil records and comparison—As there is no record of the fossil leaflets of *Ormosia* from India and abroad the present finding from the Lower Siwalik beds of Koilabas in western Nepal forms its first record. The fossil woods resembling *Ormosia robusta* Wight have already been described from the Tertiary of Bengal (Bande & Prakash, 1981) and the Siwalik beds of Nalagarh and Kalagarh in Himachal Pradesh and Uttar Pradesh respectively (Prasad, 1988; Ratan, 1989).

As the fossil leaflets closely resemble those of modern *Ormosia robusta*, it has been described here as *Ormosia robustoides* sp. nov.

The genus *Ormosia* Jack consists of about 50 species found in tropical Asia and America. Out of these, eight species are recorded from India and Burma. *Ormosia robusta* Wight, with which the fossil impressions show close resemblance, is a large tree up to 30 m in height growing in Arunachal Pradesh, Sibsagar and Cachar districts of Assam, Sylhet and Chittagong in Bangladesh and Burma (Ramesh Rao & Purkayastha, 1972, pp. 118-119).

Holotype—Specimen no. BSIP 35952.

CONCLUSION

The modern equivalents of the four leaf-impressions, viz., *Dipterocarpus tuberculatus* of Dipterocarpaceae and *Albizia gamblei, Millettia macrostachya* and *Ormosia robusta* of Fabaceae (Leguminosae) described here from the Lower Siwalik sediments now grow in the moist evergreen forest of Burma. Prasad and Prakash (1984) described three more fossil taxa resembling *Dillenia indica* of Dilleniaceae, *Anogeisus sericea* of Combretaceae and *Syzygium claviflorum* of Myrtaceae from the same sediments, which also show the presence of evergreen to moist deciduous forest during the deposition of the sediments. Thus the present distribution of their modern equivalent taxa collectively indicate the prevalence of evergreen to moist deciduous tropical vegetation around Koilabas during Lower Siwaliks.

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Floristics, age and stratigraphical position of fossiliferous band in Chitra Mine Area, Saharjuri Outlier, Deogarh Coalfield, Bihar[1]

Usha Bajpai

Bajpai, Usha 1990. Floristics, age and stratigraphical position of fossiliferous band in Chitra Mine Area, Saharjuri Outlier, Deogarh Coalfield, Bihar *Palaeobotanist* **37**(3) : 306-315.

The Saharjuri Outlier is one of the three coal-bearing areas in the Deogarh Coalfield. There have been doubts about the age and stratigraphical position of these beds. A recent collection of plant megafossils from Chitra Mine Area in the Saharjuri Outlier shows the presence of *Gangamopteris maheshwarii* sp. nov., *Gangamopteris obovata* Carruthers, *Glossopteris deogarhensis* sp nov., *Glossopteris linearis* Feistmantel, *Glossopteris decipiens* Feistmantel, *Noeggerathiopsis conspicua* Lele & Makada, *Noeggerathiopsis saharjuriensis* sp. nov., *Noeggerathiopsis bihariensis* sp. nov., *Cordaicarpus* sp., *Samaropsis* sp. and *Vertebraria indica* Royle. Overall assemblage is characteristically basal Barakar in composition, having close similarity to some of the known assemblages from the Karharbari "Formation"/"Stage" (*Noeggerathiopsis-Gangamopteris* Assemblage Zone).

Key-words—Stratigraphy, Floristics, Deogarh Coalfield, Basal Barakar (India).

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सारॉंश

बिहार में देवगढ़ कोयला-क्षेत्र में सहरजुरी पुरान्तःशायी के चित्रा खान क्षेत्र में पादपाश्ममय पट्टी का वनस्पतिजात, इसकी आयु तथा स्तरिकीय स्थिति

ऊषा बाजपेयी

देवगढ़ कोयला-क्षेत्र में सहरजुरी पुरान्तःशायी तीन कोयला-धारक क्षेत्रों में से एक है। इन संस्तरों की आयु एवं स्तरिकीय स्थिति के बारे में संदेह है। इसी पुरान्तःशायी में चित्रा खान क्षेत्र से अभी हाल में गुरुपादपाश्मों के संग्रह में **गंगामॉप्टेरिस माहेश्वराई** नव जाति, **गं० ओबोवेटा केरुथर्स**, **ग्लॉसॉप्टेरिस देवगढ़ेन्सिस** नव जाति, **ग्लॉ० लाइनियेरिस** फाइस्टमॅन्टेल, **ग्लॉ० डेसीपियन्स** फ़ाइस्टमॅन्टेल, **नैग्रेथिऑप्सिस कॉन्सपिकुआ** लेले व मकाडा, **नै० सहरजुरीयेन्सिस** नव जाति, **नै० बिहारीयेन्सिस** नव जाति, **कोर्डेकार्पस** जाति, **समारोप्सिस** जाति एवं **वर्टीब्रेरिया इंडिका** रॉयले नामक वर्गक विद्यमान हैं। कुल मिलाकर यह समुच्चय लाक्षणिक रूप से आधारी बराकार है तथा करहरबारी "शैल-समूह"/"चरण" (नैग्रेथिऑप्सिस-गंगामॉप्टेरिस समुच्चय मंडल) से कुछ ज्ञात समुच्चयों से घनिष्ठ समानता प्रदर्शित करता है।

THE Deogarh Coalfield comprises three outliers, viz., Jainti, Saharjuri and Kundit Kuraiah, stretching between 86°37′-87°5E′ and 24°5′-24°15′N. In all the outliers sediments of Talchir and Damuda groups are represented; the latter by the Barakar Formation only. The area was first mapped by Hughes (1869). Later Niyogi and Sanyal (1962) and Niyogi (1966) worked on stratigraphy of the Jainti and Saharjuri outliers respectively.

The Talchir Formation lies with a profound unconformity on the Archaeans and covers a major part of the basin. The usual succession of sediments is conglomerate, silt, shale and sandstone. In Jainti area the formation is chiefly represented by silty shales, in Kundit Kuraiah area the conglomerate is more conspicuously exposed with slight preponderance of sandstones over shales and around Saharjuri as many as five conglomerate beds have been reported.

The Barakar Formation has thick beds of carbonaceous shales at places but few coal seams of economic viability. Recent surveys, however, have shown presence of many more seams, particularly in the Chitra area of Saharjuri Outlier.

There has been controversy about the

[1]Contribution to I.G.C.P. Project 237—Floras of the Gondwanic continents.

stratigraphic position and age of the coal-bearing beds of Deogarh Coalfield. This problem was resolved to some extent in Jainti Outlier by Lele and Makada (1974). Palaeobotanical and palynological investigations revealed the presence of elements usually characteristic of the Karharbari "Formation". These elements are *Botrychiopsis valida* Kurtz, *Buriadia sewardii* Sahni, *Noeggerathiopsis spatulata* (Dana) Feistmantel and species of pollen genera *Crucisaccites, Potonieisporites* and *Plicatipollenites* (Puri, 1952; Niyogi & Sanyal, 1962; Lele & Makada, 1972). No palaeobotanical information is so far available from the Saharjuri Outlier.

The coal outcrops in Saharjuri area are located between 86°50′-86°55′E and 24°5′-24°10′N. The topography is rugged and contours vary between 200 to 230 meters. The Talchir Formation is overlain by coal-bearing beds which have usually been referred to Barakar by the field geologists. General sedimentary sequence in the Saharjuri Outlier is as follows (after, Niyogi, 1966):

	Upper arkoses Upper (Chitla) coal seams and shales Concretionary arkoses
Barakar	Lower (Bhawanipur) coal seams and shales Lower arkoses Conglomerate
Talchir	Siltstone and silty shales Boulder conglomerate

UNCONFORMITY

Archaeans

As many as five boulder conglomerate beds have been reported in the Talchir Formation (Niyogi, 1964, p. 268). The Barakar sediments are generally conformable to the under-lying siltstones of Talchir Formation (Niyogi, 1966, p. 963). The sandstone is the dominant rock type. Shales are insignificant except in coal-bearing portions which contain two groups of major seams, viz., Bhawanipur and Chitla; 2 seams in the former and 3 in the latter. Recent reports record the presence of thirteen workable coal seams which form 2 groups, viz., Saharjuri Group and Chitra Group. Following is the general geological succession in the Chitra Mine Area (courtesy Project Office, Chitra Mine):

Formation	*Thickness*	*Lithology*
Recent	0–10 m	Soil and sandy soil, laterite
	UNCONFORMITY	
Barakar	400 m ±	Coarse-grained white to slightly grey sand-stone, gritty sand-stone, conglomerate, shales, grey shales and coal
Talchir	50 m ±	Coarse-grained sand-stone, green shales, fine grained sand-stone with felspars
	UNCONFORMITY	
Archaeans		

MATERIAL AND METHODS

Material was collected from two collieries, viz., Girija and Chitra Patrika. Plant remains were found only in the shale dumps of Chitra Patrika abandoned incline whereas the coal seam at Girija was sampled for bulk macerations which yielded only isolated tracheid pieces. For cuticular preparations from megafossils collected from Chitra Patrika a thin film of cellulose acetate was spread on the carbonified crust. After 2-3 hours, the dry peel was taken off and oxidized in concentrated nitric acid for about 24-48 hours. The carbonified pieces turned brown on oxidation. These were thoroughly washed in water and then digested in a dilute solution of potassium hydroxide to clear cuticles. The cuticle pieces were washed in distilled water till the alkali was removed. During the process the upper and lower cuticular layers generally separated. Sometimes the two layers had to be separated with a needle and/or a single hair brush. The cuticle pieces were stained in 10 per cent aqueous safranin 0 and mounted in polyvinyl alcohol and canada balsam. All specimens and slide have been deposited with the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

DESCRIPTION

***Noeggeratbiopsis* Feistmantel 1879 emend. Pant & Verma 1964**

1984 *Pantophyllum* Rigby: *Mem. 3rd Congr. Latinoamer. Paleont. Mexico*: 142.

Type species—*Noeggerathiopsis spatulata* (Dana) Feistmantel 1879.

Remarks—The genus *Noeggerathiopsis* was proposed by Feistmantel (1879) for cordaitean-type leaves from the Talchir-Lower Barakar sediments of peninsular India. He included in it *Noeggerathia?*

Noeggerathiopsis hislopi Bunbury 1861, a fragment of a leaf from the Kamthi Formation, alongwith well-preserved leaves from the Talchir and Lower Barakar Formations. It is however doubtful if the cordaitean type of leaf survived up to the Kamthi times. The other leaves have been shown to be indistinguishable from *Noeggerathia spathulata* Dana 1849 which was believed to be a species of the genus *Cordaites* Unger (Rigby, Maheshwari & Schopf, 1980). Rigby (1984) hence assumed that the genus *Noeggerathiopsis* is a junior synonym of *Cordaites*. On this assumption he proposed a new genus *Pantophyllum* to encompass all those cordaitean type of leaves from the Permian Gondwana for which cuticular information is available and which were earlier ascribed to the genus *Noeggerathiopsis*.

Rigby's argument for creating the new genus is not acceptable because though the leaves of the genus *Noeggerathiopsis* may be morphologically indistinct from those of *Cordaites* yet the former have a uniform epidermal pattern all through Gondwana Supercontinent. There is neither any evidence nor any reason to presume that had the type specimen of *Noeggerathiopsis spathulata* (Dana) Feistmantel possessed a carbonified crust, it would have shown epidermal features different from those of other species which have been transferred under *Pantophyllum*. It is neither plausible nor advisable to create new leaf genera simply on the basis of presence or absence of a cuticle, or one would have to look for new genera for all those specimens which though possess a cuticle, yet are morphographically inseparable from *Gangamopteris*, *Glossopteris*, *Palaeovittaria*, *Rubidgea*, *Euryphyllum* etc.

The name *Pantophyllum* Rigby 1984 is therefore considered to be a junior synonym of *Noeggerathiopsis*. The circumscription and diagnosis of the genus *Noeggerathiopsis* as given by Pant and Verma (1964) are accepted and followed. The genus is easily identifiable on the basis of gross morphography. In species delimitation, the cuticle plays an important role because there is a perceptible variation in epidermal configuration.

Noeggerathiopsis saharpurensis sp. nov.

Pl. 1, figs 2-4

Diagnosis—Leaves simple, linear spathulate in shape, margin entire, tapering towards base, apex not known; veins straight, dichotomising but not anastomosing.

Cuticles thick. Stomata present only on one surface; vein and intervein areas not marked on non-stomatiferous surface; cells rectangular, arranged end-to-end in linear rows, lateral walls straight, surface walls unspecialised.

Stomatiferous surface with distinct alternating stomatiferous and nonstomatiferous linear bands; cells of nonstomatiferous band rectangular, arranged end-to-end; those of stomatiferous band polygonal. Stomata anomocytic (haplocheilic), arranged in 2-5 linear rows, stomatal apparatus monocyclic; subsidiary cells 1-8 in number, unspecialised, almost all cells of stomatiferous band having a denser surface wall.

Holotype—Specimen no. BSIP 35935, Chora Pandra Colliery, Saharpur Outlier, Deogarh Coalfield, Bihar; Lower Permian, basal part of Barakar ("Karharbari") Formation.

Description—Four specimens can be referred to this species on the basis of general morphography. However, cuticle has been recovered from only one specimen which is designated as the type specimen. All the specimens are incomplete and none shows either the apex or the base. However, it can be presumed that the leaves were simple and linear lanceolate in shape. The leaf margin is entire, broken and the carbonified crust has a shiny surface. As the actual leaf base is not preserved the number of veins entering it is not known. The concentration of veins at the basal region is 14 per cm. The veins dichotomise once or twice and proceed straight to

PLATE 1

1. *Noeggerathiopsis [illegible]* sp. nov.—Isotype specimen no. BSIP [illegible], × 1.
2. *N. saharpurensis* sp. nov.—Upper cuticle. Slide no. BSIP [illegible], × [illegible].
3. *N. saharpurensis* sp. nov.—Lower cuticle showing a stomatiferous band with thickened surface walls. Note unspecialised surface walls in some cells. Slide no. BSIP [illegible], × 400.
4. *N. saharpurensis* sp. nov.—Holotype specimen no. BSIP [illegible], × 1.
5. *N. saharpurensis* sp. nov.—Lower cuticle showing a stomatiferous band with a number of stomata in rows. On both the sides of stomatiferous rows nonstomatiferous bands are present. Slide no. BSIP [illegible], × 200.
6. *N. saharpurensis* sp. nov.—Lower cuticle showing regular pitting on the lateral walls. Slide no. BSIP [illegible], × 400.
7. *N. saharpurensis* sp. nov.—Lower cuticle showing number of stomatiferous and nonstomatiferous bands. Number of stomata rows in each row. Slide no. BSIP [illegible], × 75.
8. *N. saharpurensis* sp. nov.—Lower cuticle showing stomatiferous band; subsidiary cells are rectangular in shape. Slide no. BSIP [illegible], × 200.

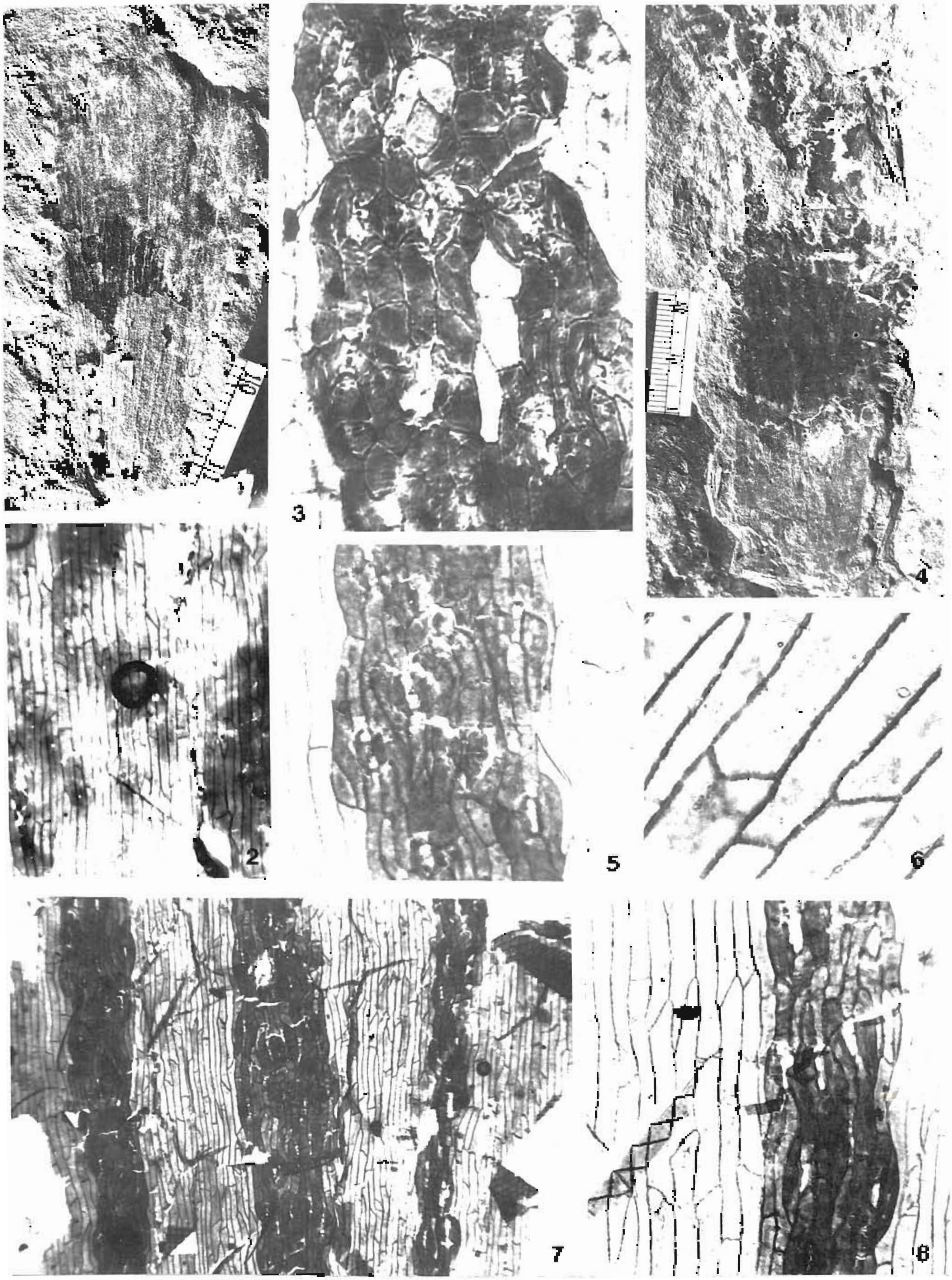

PLATE 1

the apical margin, concentration in the middle region being 26 per cm. The preserved length and maximum width of the leaves vary from 10-12 cm and 4-4.5 cm respectively.

The cuticular layers are well-preserved, both surfaces showing distinct cellular features. Only one surface is stomatiferous. All the cells of the nonstomatiferous surface are similar, being rectangular in shape and arranged end-to-end in linear rows and thus do not mark vein and intervein areas. The cells are 13-19 μm wide and 120-213 μm long. On the other hand, the vein and intervein areas on the stomatiferous surface are marked by nonstomatiferous and stomatiferous linear bands, respectively. The cells of the nonstomatiferous bands are similar to those of nonstomatiferous surface. The cells in the stomatiferous band are polygonal to elongate-polygonal with their surface walls being comparatively dense. However, there are exceptional cells in this band that do not have dense surface walls. The lateral walls show regular pits. The cells are 18-31 × 48 μm in size. The stomata are linearly arranged in 2-5 rows, their orientation being along the course of the veins. Guard cells are rarely seen. Subsidiary cells are 4-8 in number average (6), size being 19-29 × 37-87 μm. Guard cells measure 12-13 μm in length. All the cells of the cuticle are unspecialised, i.e., do not possess papillae.

Comparison—Due to the fragmentary nature of the specimen its exact external morphology is not known. The comparison is therefore mostly based upon the cuticular characters. The concentration of veins in the present specimen closely resembles that of *Noeggerathiopsis bunburyana* Pant & Verma 1964 and *N. papillosa* Pant & Verma 1964 (10-13 per cm in basal region), but the cuticular features of both *N. bunburyana* and *N. papillosa* are different. In *N. papillosa* the subsidiary cells are always papillate while in the present specimen the ordinary epidermal cells and the subsidiary cells are nonpapillate. In *N. bunburyana* the subsidiary cells are nonpapillate but number of stomatiferous rows vary and the cuticle is amphistomatic; in *N. saharjuriensis* the cuticle is hypostomatic. The cuticle of the present specimen shows some interesting characters. The cells of the stomatiferous zone take a comparatively much darker stain in Safranin O. However, some of the cells in this zone behave differently and take a lighter stain similar to that taken by the cells of the nonstomatiferous zone (Pl. 1, fig. 3).

Noeggerathiopsis bihariensis sp. nov.
Pl. 1, figs 1, 5-8

Diagnosis—Leaf simple, small, spathulate in shape, margin entire, slightly tapering towards the base, nature of apex and base not known. Veins thick, fibrous, dichotomising but no anastomoses seen. Leaves hypostomatic.

Upper cuticle thick, vein and intervein areas not marked on nonstomatiferous surface, cells elongated, rectangular, arranged in linear rows, straight-walled, lateral walls pitted, surface walls unspecialised.

Lower cuticle shows distinct, alternating, stomatiferous and non-stomatiferous linear bands. Cells of non-stomatiferous bands narrow, elongate, arranged end-to-end. Cells of stomatiferous band narrow, elongate, rectangular, often curved, cell walls pitted, somata anomocytic, arranged in 1-5 linear rows, subsidiary cells 4-6, unspecialised.

Holotype—Specimen no. BSIP 35934, Chitra Patrika Colliery, Saharjuri Outlier, Deogarh Coalfield, Bihar; Lower Permian, basal part of Barakar ("Karharbari") Formation.

Description—Only one specimen has been referred to this species on the basis of morphological and cuticular characters. The specimen is incomplete, without base and apex. Leaf is simple, small and spathulate in shape. The preserved length of the leaf is 5 cm and the width is 2.5 cm. The leaf margin is entire. The carbonified crust on the leaf gives it a glossy appearance. As the leaf base is not preserved the number of veins entering the leaf is not known. The concentration of veins in the basal region is 10 per cm. Veins are

PLATE 2 →

1. *Gangamopteris maheshwarii* sp. nov.: Holotype; Specimen no. BSIP 35935, × 1
2. *G maheshwarii* sp. nov. : Lower cuticle showing stomatiferous and nonstomatiferous bands; Slide no. BSIP 35935-1, × 200.
3. *G. maheshwarii* sp. nov. : A stoma with eight subsidiary cells. All the subsidiary cells are of different shape; Slide no. BSIP 35935-1, × 600.
4. *G. maheshwarii* sp. nov. : Lower cuticle showing the distribution and orientation of stomata; Slide no. BSIP 35935-1, × 100.
5. *Glossopteris deogarhensis* sp. nov. : Holotype; Specimen no. BSIP 35936, × 1
6. *G. deogarhensis* sp. nov. : Upper cuticle showing slightly wavy walls of intervein areas; Slide no. BSIP 35936-1, × 100.
7. *G. deogarhensis* sp. nov. : Lower cuticle showing stomata and papillate epidermal cells; Slide no. BSIP 35936-1, × 300.
8. *G. deogarhensis* sp. nov. : Lower cuticle showing distribution and orientation of stomata; Slide no. BSIP 35937-1, × 200.

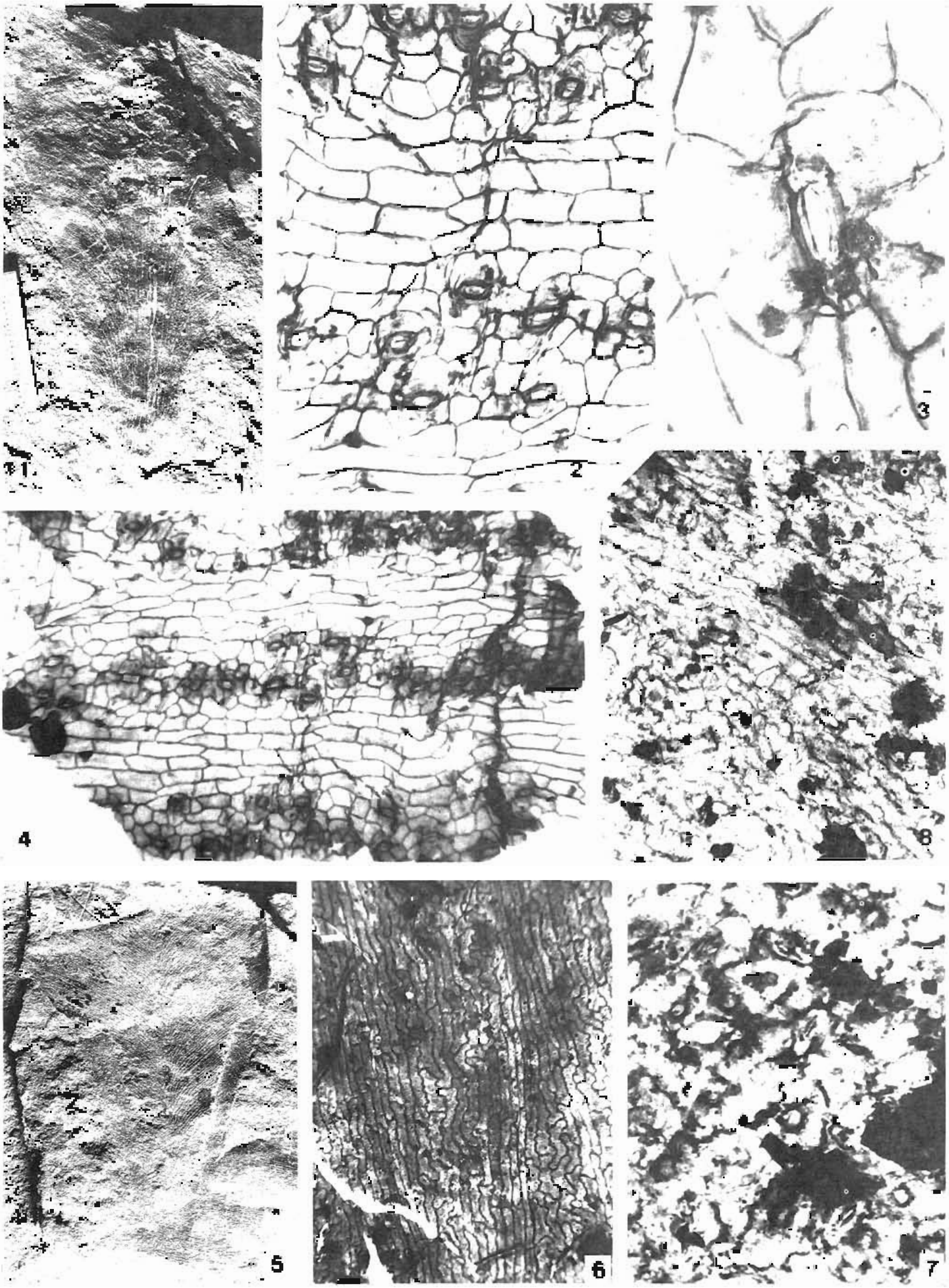

PLATE 2

distinct and thick due to presence of fibers. They dichotomise only once or twice, concentration of veins becoming 22 per cm in the middle region of the leaf.

The cuticle recovered from the specimen is well-preserved, both the surfaces showing distinct cellular outlines. Only one surface is stomatiferous. The cells of upper cuticle are rectangular in shape, arranged end-to-end in linear rows, 12-23 μm wide and 120-213 μm long. Vein and intervein areas are not marked. The lateral walls of the cells exhibit distinct pits.

The lower cuticle shows two distinct bands, non-stomatiferous and stomatiferous, which are also distinguished by differential staining in Safranin O. The non-stomatiferous bands are 12-14 cells wide, cells are narrow, elongate, with straight lateral walls and oblique end walls. The cells of the stomatiferous bands are elongate, rectangular, 12-25 μm wide, 132-213 μm long. The lateral walls are pitted.

The stomata are anomocytic (haplocheilic), distributed in linear rows and orientated parallel to the course of the veins. The guard cells are rarely seen. Subsidiary cells are usually 4 in number, occasionally up to 6, two lateral subsidiary cells surrounding the guard cells are often crescentic in shape.

Comparison—In gross morphography the specimen resembles one species or the other of the genus *Noeggerathiopsis* : for example, the number of veins per cm in the basal region is almost same as in *N. bunburyana* and *N. papillosa* while the concentration of veins in the middle region resembles that of *N. gondwanensis.*

However, the cuticle recovered from the specimen has distinctive features separating it from the known species. In differential stain taken by the non-stomatiferous and stomatiferous bands, the species resembles *N. papillosa* and *N. bunburyana.* The former is distinguished by its papillate cells whereas the latter is an amphistomatic leaf. *N. saharjuriensis* sp. nov. also takes a similar stain but is distinguished by comparatively robust cells. In *N. indica,* the stomatiferous band has comparatively many more rows of stomata.

Gangamopteris McCoy 1847

Gangamopteris maheshwarii sp. nov.
Pl. 2, figs 1-4

Diagnosis—Specimen incomplete, leaf simple, margin entire, base and apical region not preserved, shape apparently spathulate, a few veins entering the leaf base, dichotomising and anastomosing to form meshes all over, median veins run almost parallel up to the apical part but without forming a solid strand, lateral veins run towards the margin taking a graceful curve.

Leaf hypostomatic, stomata confined to intervein areas, irregularly distributed, orientated more or less parallel to vein course, subsidiary cells 4-8 in number, unspecialised, guard cells showing lateral and polar thickenings.

Holotype—Specimen no. BSIP 35935, Chitra Patrika Colliery, Saharjuri Outlier, Deogarh Coalfield, Bihar; Lower Permian, basal part of Barakar ("Karharbari") Formation.

Description—The species is represented by only one specimen. The preserved length of the leaf is 4.2 cm and width of the leaf is 3.5 cm. Concentration of lateral veins in the basal region is 20 per cm and 25 per cm near the middle region. The lateral veins meet the margin approximately at an angle of 60°-70°

Leaf is hypostomatic. Both the cuticles are almost of the same thickness. All the cells of non-stomatiferous surface are rectangular in shape and arranged end-to-end in linear rows and thus do not mark vein and intervein area. The cells are 19-37 μm wide and 80-139 μm long.

Lower cuticle has stomata only in the mesh areas. The cells of the non-stomatiferous bands, i.e., over the veins, resemble those of upper surface and measure 120-169 μm in length and 18-43 μm in width. The cells of stomatiferous bands, i.e., in the mesh areas, are polygonoid and measure 31-38 μm in width and 49-58 μm in length. The stomata are arranged in 1-3 rows. Stomatal apparatus is monocyclic though the subsidiary cells, which are 4-8 in number, do not form a ring being different in shape and size. Guard cell measures 6.2-12 × 37-43 μm. Surface of the guard cells shows distinct radiating striations or thickenings similar to the ones seen in certain extant species of the genus *Equisetum.*

Comparison—In external features the leaf apparently has a superficial resemblance with *Gangamopteris obovata* Carruthers, cuticular characters of which are hardly known. The cuticular morphology of the leaf closely resembles that of *G. obtusifolia* Pant & Singh 1968 in the distribution of stomata and the thickening and striations on the guard cells. However, the *G. obtusifolia* leaf is amphistomatic.

All other species of the genus *Gangamopteris* investigated by Pant and Singh (1968), too are amphistomatic, have papillate cells and lack radiating striae on the guard cells.

***Glossopteris* Brongniart 1828**

Glossopteris deogarhensis sp. nov.
Pl. 2, figs 5-8

Diagnosis—Leaves simple, spathulate in shape, margin entire, tapering towards base. Midrib faintly marked, flat, veins fine, closely placed, arising at an acute angle from midrib, dichotomising and anastomosing to form narrow elongate meshes.

Leaves hypostomatic. Vein and intervein areas demarcated on both surfaces. Cells of non-stomatiferous surface (upper) rectanguloid, lateral walls sinuous, surface walls unspecialised, stomata confined to intervein (mesh) areas on lower surface. Cells over veins rectanguloid, relatively straight-walled. Cells of stomatiferous bands polygonoid, walls sinuous. Stomata haplocheilic, irregular in distribution and orientation, subsidiary cells 4-6 (mostly 4), not forming a ring and similar to ordinary epidermal cells.

Holotype—Specimen no. BSIP 35936, Chitra Patrika Colliery, Saharjuri Outlier, Deogarh Coalfield, Bihar; Lower Permian, basal part of Barakar ("Karharbari") Formation.

Description—Four specimens have been referred to this species on the basis of external morphology, of these three specimens also yielded cuticles.

All the specimens are incomplete and do not show the apex and the base. However, it can be presumed that the leaves were simple, broader in the middle region and gradually narrowed towards the base. The leaves were probably spathulate in shape.

The preserved length and maximum width of the leaves are 6.2-8.5 and 3.4-6 cm, respectively. Midrib is not very distinct, at places shows a number of longitudinal parallel running strands. Veins leave midrib at acute angles, 10°-15°, and form long, elongate and narrow meshes of more or less uniform size. Leaves are hypostomatic, upper and lower cuticles are almost of the same thickness. The cells of the upper cuticle are rectanguloid in shape, sinuous in outline, measure $29\text{-}43 \times 101\text{-}181\ \mu m$, are arranged end-to-end in linear rows over the veins, walls of cells in intervein areas are comparatively more sinuous.

The cell outlines over veins and in intervein areas on the stomatiferous surface differ in shape. The cells over the veins are rectanguloid and arranged end-to-end. Their walls are slightly wavy. The cells in the intervein areas are polygonoid in shape with sinuous to wavy walls. The stomata are haplocheilic and do not exhibit any regularity in distribution and orientation. The subsidiary cells do not differ from ordinary epidermal cells, their number and placement varies a lot. At places the subsidiary cells give a "winged" look. The guard cells are usually not well-preserved, sometimes a thickening is noticed towards the pole.

Comparison—In leaf morphography and cuticular features *Glossopteris deogarhensis* resembles most *G. harrisii* Pant & Gupta 1968. In both, the lateral veins leave the midrib at acute angles and dichotomise and anastomose to form narrow elongate meshes. The cell walls are sinuous on both the surfaces and the stomatal frequency is almost the same. However, *G. harrisii* differs due to the presence of a short median papilla on the surface wall of each cell. Further, the subsidiary cells in the Saharjuri specimen do not form a ring, whereas in *G. harrisii* a monocyclic or partly "amphicyclic" condition is reported.

DISCUSSION AND REMARKS

As stated earlier, the stratigraphical relationship of beds containing a glossopterid flora in Deogarh group of coalfields has been a matter of controversy, that is, whether the lower most beds of the Permian coal measures are lithologically a part of the Barakar Formation or they comprise an independent formation, i.e., the Karharbari Formation.

The shale associated with the coal seam in Chitra Patrika abandoned shaft has yielded following identifiable species :

Glossopteris deogarhensis sp. nov.
G. linearis Feistmantel
G. decipiens Feistmantel
Gangamopteris maheshwarii sp. nov.
Noeggerathiopsis conspicua Lele & Makada
N. saharjuriensis sp. nov.
N. bihariensis sp. nov.
Cordaicarpus sp.
Samaropsis sp. and
Vertebraria indica Royle, etc.

The genera *Noeggerathiopsis* and *Glossopteris* are almost equally represented. The genus *Gangamopteris* is rather scarce. The overall assemblage is characteristic of a Lower Barakar megaflora as known from many localities under the Karharbari "Stage" Two important elements that mark the Karharbari "Stage" are, however, missing. These are *Botrychiopsis valida* Kürtz and *Buriadia sewardii* Sahni. A survey of literature shows that though these two taxa are reported from many areas, their illustrations are few. In fact, it seems that some of the specimens placed under *Buriadia sewardii* may be tufts of rootlets of *Vertebraria*. The report of

Botrychiopsis from Jainti Outlier (Lele & Makada, 1974) is also not very convincing. It would thus seem that *Botrychiopsis valida* and *Buriadia sewardii* are associated in a very localised flora presently known from the Giridih Coalfield. The main question is whether the Chitra Patrika megafloral assemblage is to be referred to the Karharbari Stage or to the Lower Barakar Stage. Here it may be mentioned that chronostratigraphy of peninsular Permian deposits has not yet been worked out and hence the term "Stage" cannot be conveniently used at present.

Opinion differs as to the problem whether the Karharbari Formation can be identified on lithological grounds. According to Fox (1931, p. 96) "The Karharbari group ... which was regarded as an upper horizon of the Talchir series is merely an early phase of the Barakar and scarcely merits separation therefrom". A perusal of earlier data shows that initially the Karharbari unit was identified on the basis of contained megaflora (Feistmantel, 1879). Later, lithological differences were sought to separate it from the Barakar sediments (Ghosh, Deekshitulu & Mitra, 1964) though earlier geologists accepted that there was hardly any lithological separation between the Karharbari and the Barakar sediments (Blanford, 1878). According to Pareek (1956, p. 76) the Karharbari sandstones contain angular to subangular pieces and fragments of quartz and usually kaolinised felspar whereas in the Barakar sandstones the quartz and felspar pieces are partially well rounded. He also noticed a pebble bed, 0.15-3.5 metre thick, marking the boundary between the Karharbari and Barakar sediments in the Ray-Bachra area of North Karanpura Coalfield, Bihar. Ghosh (1958) recorded a conglomeratic band between the Karharbari and the Talchir sediments near Ray in the same coalfield. There, however, does seem to be an identifiable biostratigraphic unit at the base of Coal Measures that roughly corresponds with Karharbari "Stage/Formation". This biostratigraphic unit was named as *Gondwanidium-Buriadia* Assemblage Subzone by Shah, Singh and Sastry (1971). This assemblage subzone is virtually similar to the lower *Noeggerathiopsis-Paracalamites* Assemblage Subzone found in the Talchir Formation except for occasional and irregular finds of the genera *Botrychiopsis* and *Buriadia* (Feistmantel, 1879; Pant, 1958; Ganguly, 1959) which are also not found in the undisputed Barakar sediments.

The available palaeobotanical data from Saharjuri Outlier favours a close comparison with the basal Barakar flora. Following identifiable spore/pollen taxa that have been found attached on the plant cuticles also support this contention: *Callumispora*, *Dentatispora*(?), *Brevitriletes*, *Horriditriletes*, *Plicatipollenites*, *Cannanoropollis*, *Parasaccites*, *Potonieisporites*, *Crucisaccites*, *Ginkgocycadophytus*, etc. The palynoflora of the basal Barakar beds has usually been referred as the palynoflora of Karharbari Stage (see Bharadwaj, 1974).

It is therefore concluded that though the flora of the shales associated with coal in Chitra Mine area of Saharjuri Outlier belongs to an identifiable basal assemblage zone, i.e., *Noeggerathiopsis-Gangamopteris* Assemblage Zone the evidence in itself is not strong enough to assign a formation rank to basal Barakar sediments which have a prevalence of reworked material from Talchir Formation. In age it seems to be homotaxial with Middle Ecca flora of Bubye Coalfield, Zimbabwe from where Sutton and Bond (1962 in Bond, 1967) have reported *Glossopteris* associated with *Gangamopteris* and *Noeggerathiopsis hislopi* (= *Noeggerathiopsis spathulata* (Dana) Feistmantel). A more or less similar association—*Schizoneura gondwanensis*, *Glossopteris indica*, *Ottokaria* sp., *Noeggerathiopsis* sp. cf. *N. hislopii*, *Gangamopteris obovata* and *Cordaicarpus zeilleri* is known from the couches à charbons de la Sakoa (Singh & Shah, 1977).

According to Bond (1967, p. 189), the association of *Glossopteris* spp. with *Gangamopteris* spp. probably implies a cold sub-arctic climate. Bharadwaj (1974) also identifies a cold climate (1st interglacial) for the Damuda sediments (his basal Karharbari) in the adjacent Jainti Outlier. It may be recalled here that all the glossopterid species recorded in this paper are small in size and have closely placed veins and high stomatal frequency.

Leaf development is remarkably consistent and majority of higher plants can be recognised by the leaf shape. On the other hand, leaf size, vein density, trichome density and stomatal frequency are sensitive to environment; the last three increase with increased xeromorphy. This would apparently indicate a xeric environment for the Chitra Patrika fossils.

However, leaf development and growth are complex processes. Leaf size is reduced not only due to water deficit but even high irradiance or higher insolation level may cause small leaf size. Deficient nutrient level may also dramatically decrease leaf elongation rates. The final size of a leaf is the product of the rate and duration of expansion, but it is the extension of cells that must contribute to increase in leaf size. Therefore, small leaf size need not always indicate a xeric or water deficit environment.

The dense venation and high stomatal frequency in the Chitra Parinka leaves also indicate a xeric environment. It is known that within the same species leaf extension growth between lateral veins is much greater in shade than in sun leaves resulting in a higher stomatal frequency in the latter. It is therefore, probable that only sun leaves are represented in the present collection. Trichomes have also so far not been found on any of the Chitra Parinka leaves though the surface walls of intervein cells on stomatiferous surface of *Noeggerathiopsis* leaves are characteristically thickened. Xeromorphy is also reported to be accompanied by amphistomaty, a character not observed so far in this material. Rather all the leaves are hypostomatic. Therefore, a xeric condition may be ruled out.

At present dominance of complete hypostomaty is observed only in temperate deciduous trees. The presence and preponderance of stomata only on the lower surface may also be a reflection of heavy precipitation, simply being an adaptation for preventing clogging of stomatal pores by rain drops. This data read together with occurrence of workable coalseams indicates a temperate climate with increased rainfall.

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Charophyta from the Deccan Intertrappean beds near Rangapur, Andhra Pradesh, India

S. B. Bhatia, Janine Riveline & R. S. Rana

Bhatia, S. B., Riveline, Janine & Rana, R. S. 1990. Charophyta from the Deccan Intertrappean beds near Rangapur, Andhra Pradesh, India. *Palaeobotanist* **37**(3) : 316-323.

Two charophytes—*Platychara perlata* (Peck & Reker) Grambast and *Nemegtichara grambasti* sp. nov.—are described and illustrated from the Deccan Intertrappean beds near Rangapur, district Rangareddi, Andhra Pradesh. The genus *Nemegtichara* Karczewska & Ziembinska-Tworzydlo, first described from the Palaeogene "White Beds" of the Nemegt Basin in Mongolia and also known from the Cretaceous-Middle Eocene of China, is being recorded for the first time from India. The age and palaeobiogeographic implications of the assemblage are also discussed.

Key-words—Charophyta, *Platychara*, *Nemegtichara*, Deccan Intertrappean beds, Tertiary (India).

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साराँश

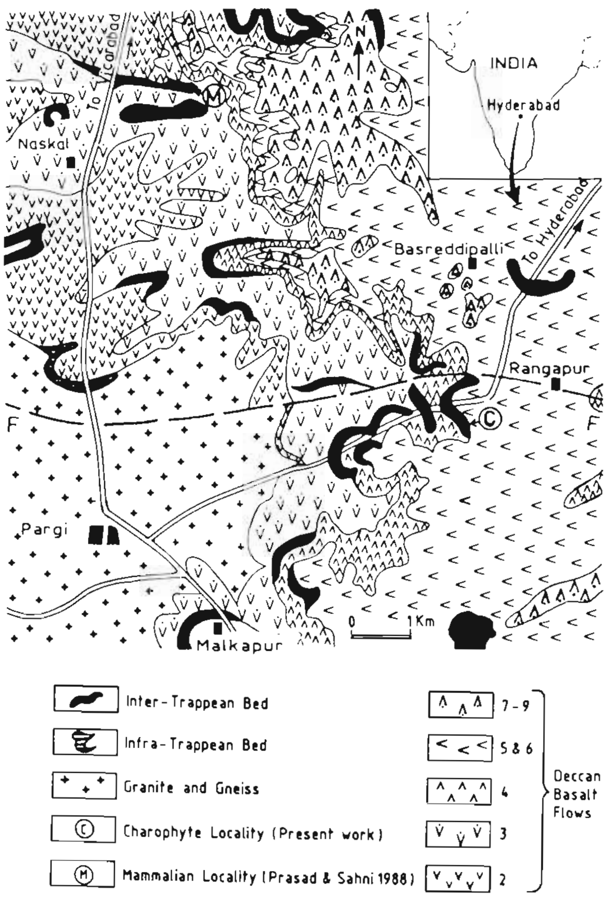
आँध्र प्रदेश (भारत) में रंगापुर के समीपस्थ दक्खिन अन्तर्ट्रैपी संस्तरों से केरोफ़ाइटा की प्राप्ति

ऍस० बी० भाटिया, जेनी रिवेलीन एवं आर० ऍस० राना

आँध्र प्रदेश में रंगारेड्डी जनपद में रंगापुर के समीपस्थ दक्खिन अन्तर्ट्रैपी संस्तरों से दो केरोफ़ाइटीयों—**प्लेटिकारा पर्लेटा** (पेक व रेकर) ग्रामबास्ट एवं **निमेग्टीकारा ग्रामबस्टाई** नव जाति का चित्रण एवं वर्णन किया गया है। **निमेग्टीकारा** कार्सजेस्का व जिम्बिन्स्का-ट्वोर्ज़िडलो नामक प्रजाति, जो पहले मंगोलिया में निमेग्ट द्रोणी के पुरानूतन कालीन ''व्हाइट संस्तरों'' से तथा चीन के क्रीटेशी-मध्य आदिनूतन से ज्ञात थी, इस शोध-पत्र में पहली बार अभिलिखित की जा रही है। इस समुच्चय की आयु तथा पुराभौगोलिक महत्वों पर भी विवेचना की गई है।

IN recent years, the charophytes have played a significant role in the biostratigraphy of continental deposits (Feist & Ringeade, 1977; Feist-Castel, 1977; Bhatia & Mathur, 1978; Kyansep-Romashkina, 1980; Massieux *et al.*, 1981; Berger, 1983; Karczewska & Ziembinska-Tworzydlo, 1983; Riveline, 1986). Similarly they are proving useful in delimiting the Cretaceous-Tertiary boundary (Feist, 1979; Feist & Colombo, 1983; Lepicard *et al.*, 1985; Huang, 1979, 1985; Weitong, 1985), in working out global events (Feist, 1986; Martin-Closas & Serra-Kiel, 1986), and in palaeobiogeographic studies (Bhatia & Rana, 1984). It is in these contexts that a study of the charophyta of the well-known Deccan Intertrappean beds assumes great importance. Although charophytes have been known since 1837 when Sowerby first described and illustrated *Chara malcolmsoni* from Nagpur, and through subsequent works of Sahni and Rao (1934), Rao and Rao (1939), Mahadevan and Sarma (1948), Rao (1955), Bhatia and Mannikeri (1976), Shivarudrappa (1972 *et seq.*), Singh and Mathur (1979) and Singh (1980), there is apparently a need for a thorough revision of the flora as emphasized by Bhatia (1982), who also discussed the entire gamut of the Post-Palaeozoic charophyta of India. In a recent communication, Bhatia and Rana (1984) recorded for the first time the occurrence of the cosmopolitan taxon *Platychara perlata* (Peck & Recker) Grambast from Nagpur and discussed the palaeobiogeographic implications of the charophytic flora and the fresh-water ostracode fauna.

In the present paper, the authors describe and illustrate two species—*Platychara perlata* (Peck & Reker) Grambast and *Nemegtichara grambasti* sp. nov., from the Intertrappean beds near Rangapur,

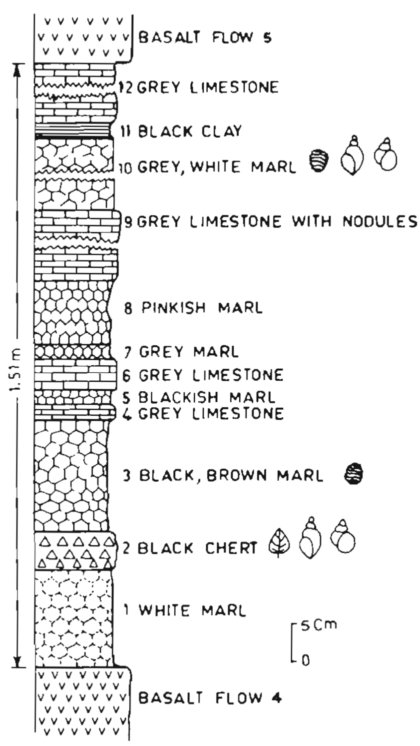


Text-figure 1—Geological map of the area, west of Rangapur, district Rangareddi, Andhra Pradesh (after Dutt, 1975).

district Rangareddi, Andhra Pradesh (Survey of India Toposheet no. 56G/16, 1 : 50,000; Text-fig. 1). The area has been geologically mapped by Dutt (1975) and a reference may be made to his work for details of geology. Dutt recognized nine flows in the region with four distinct Intertrappean beds (between flows 1 and 5), besides the so-called Infratrappeans occupying a position between the lowermost flow and the Proterozoic sedimentaries (Bhima Group) or the Archaean granites and gneisses. Of the four Intertrappean beds recorded and mapped by Dutt, only the one between flows 4 and 5 is richly fossiliferous and contains abundant angiospermic leaf-impressions, fish remains and molluscs belonging to the genera *Physa* and *Viviparus*. In this connection it is interesting to recall that the first charophyte from the area under investigation was recorded by Mahadevan and Sarma (1948) who identified abundant gyrogonites belonging to *Chara malcolmsoni* Sowerby from near Vicarabad. The exact location and horizon of the sample, however, was not mentioned by these authors. More recently, the Inter-trappean beds of this region have yielded abundant fossil vertebrate remains including osteoglossid fish (Prasad, 1987), first Cretaceous mammal (Prasad & Sahni, 1988) and fish otoliths (Rana, 1988), while the Infratrappeans have yielded dyrosaurid crocodile remains (Rana, 1987). The age implications and stratigraphic significance of the fossil assemblages in general from the Intertrappean beds of Andhra Pradesh have been discussed by Rao and Yadagiri (1981) and Prasad *et al.* (1986), while the entire gamut of Deccan Volcanism and Cretaceous-tertiary boundary events have been discussed by Sahni *et al.* (1986) and Sahni (1988)

LITHOSTRATIGRAPHY AND LOCATION OF SAMPLES

The Intertrappean bed near Rangapur (Text-fig. 1) from which the charophytes are being described, and from which Rana (1988) has found a rich suite of fish otoliths, is located between lava flows 4 and 5 (*sensu* Dutt, 1975). At this locality 1.75 km WSW of Rangapur, a 1.51 m thick section was measured (Text-fig. 2). The sequence comprises essentially of white, pink and brownish-black marls and grey limestones with a 5 cm thick black chert band towards the base. The charophytes occur in beds no.



Text-figure 2—Lithostratigraphic section of the Intertrappean Bed (between Basalt flow 4 and 5) exposed 1.75 km WSW of Rangapur.

3 and 10. The associated faunas in these two beds include fish otoliths molluscs and freshwater ostracodes. The black chert band also contains leaf-impressions and molluscs. The samples were collected by one of us (RSR) who is responsible for details of geology and lithostratigraphic section.

All the specimens illustrated in this paper are at present in the collection of Dr Janine Riveline of Paris VI University. These will eventually be deposited in the Geology Museum of that University. Representative samples are also in the personal collections of the other authors.

SYSTEMATIC DESCRIPTIONS

Genus—*Platychara* Grambast 1962

Platychara perlata (Peck & Reker) Grambast
Pl. 1, figs 1-5

1924 *Chara elliptica* Fritzche, p. 28, pl. 2, fig. 3
1937 ?*Chara oehlerti* (Dollfus) Rao & Rao, p. 8, pl. 1, fig. 9; pl. 3, fig. 2.
1947 *Chara perlata* Peck & Reker, p. 3, figs 19-21.
1951 *Chara perlata* Horn af Rantzien, p. 661.
1951 ?*Aclistochara cruciana*, new name, Horn af Rantzien, p. 672.
1967 *Platychara perlata* (Peck & Reker) Grambast *et al.*, p. 2.
1972 ?*Platychara cruciana* (Horn af Rantzien) Musacchio, p. 229, text-figs 1-4, pl. 1, figs 1-4-7; pl. 2, figs 15-17.
1979 *Platychara perlata* (Peck & Reker) Grambast, Peck & Forester, p. 230, pl. 2, figs 5-7-8.
1984 *Platychara perlata* (Peck & Reker) Grambast, Bhatia & Rana, p. 30, pl. 1, figs 2, 3.

Description—Gyrogonites subglobular in shape, flattened longitudinally, typically wider than long, rounded at the top and base. Lime spirals: smooth, generally convex, sometimes flat, thin intercellular ridges, 6 to 8 convolutions of (89) 102-153 μm width visible in lateral view. Apex: lime spirals narrow and constricted at about 250 μm from the margins, swollen and convex in the centre forming a distinct apical rosette: 435-692 μm in diameter. Base: rounded, very rarely tapering, basal pore opening narrow, 25-50 μm wide, basal plaque not observed.

Dimensions—Length 640-925 μm, width 760-1050 μm. L/W ratio 0.73-0.94, average 0.84.

Locality—Material comes from a locality 1.75 km WSW of Rangapur, Andhra Pradesh.

Generic affinities—The oblate shape of the gyrogonites and the extreme rareness of the basal tapering could possibly lead one to think of generic affinities with either some species of the genus *Dughiella* (eg. *D. obtusa* Grambast & Gutierrez or *D. pomeroli* Gutierrez & Lauverjat) having smooth lime spirals, or with some species of the genus *Gyrogona* (eg. *G. morelleti* Grambast), also with smooth lime spirals. The similarities, however, are superficial as it is possible to distinguish the Indian material from the above mentioned species of *Dughiella* by its large overall dimensions, particularly the width of the gyrogonites and also by the presence of a large and distinct apical rosette. In the genus *Dughiella*, the lime spirals are only slightly modified in the apical region. The distinction between the Indian material and genus *Gyrogona* is based also on the apical structure. In *Gyrogona*, almost the entire apical area is occupied by terminal nodules and the constriction of the lime spirals is located close to the margins or periphery. In our specimens, the constriction occurs at a distance more than 250 μm from the periphery. In view of the above attributes, we have no hesitation in assigning our material to the genus *Platychara* Grambast.

Specific affinities—The absence of a tapering base, the absence of ornamentation and the length/width ratio suggest the placement of our material in *Platychara* group *compressa-perlata*. According to Peck and Forester (1979), the average ratio for *P. compressa* is around 0.75, while for *P. perlata* is more than 0.81. Since in our material the average ratio is 0.84, we have assigned our species to *P. perlata*. Our specimens are identical to those described by Bhatia and Rana (1984) from Nagpur.

Genus—*Nemegtichara* Karczewska & Ziembinska-Tworzydlo 1972

Nemegtichara grambasti sp. nov.
Pl. 1, figs 6-9

Diagnosis—Gyrogonites of *Nemegtichara* characterised by an ovoid shape with very slightly calcified lime spirals in the apical part.

Description—Gyrogonites with an ovoid shape, summit rounded, slightly protruding in the centre, base progressively tapering. Lime spirals: smooth, slightly concave, 8-11 convolutions visible in lateral view, 51-90 μm wide, thick intercellular ridges. Apex: very slight calcification of lime spirals in the apical part, lime spirals narrow near the apical periphery, wide at the centre, strongly concave with tapering intercellular ridges. Base: progressively tapering, basal pore situated in the centre of a "pseudochannel" constituted by the thickening of lime spirals, pentagonal basal pore 25-100 μm wide, basal plaque not observed.

Dimensions—Length 640-770 μm, width 487-564 μm, L/W ratio 1.23/1.62.

Type material—Holotype, figures 6 and 7;

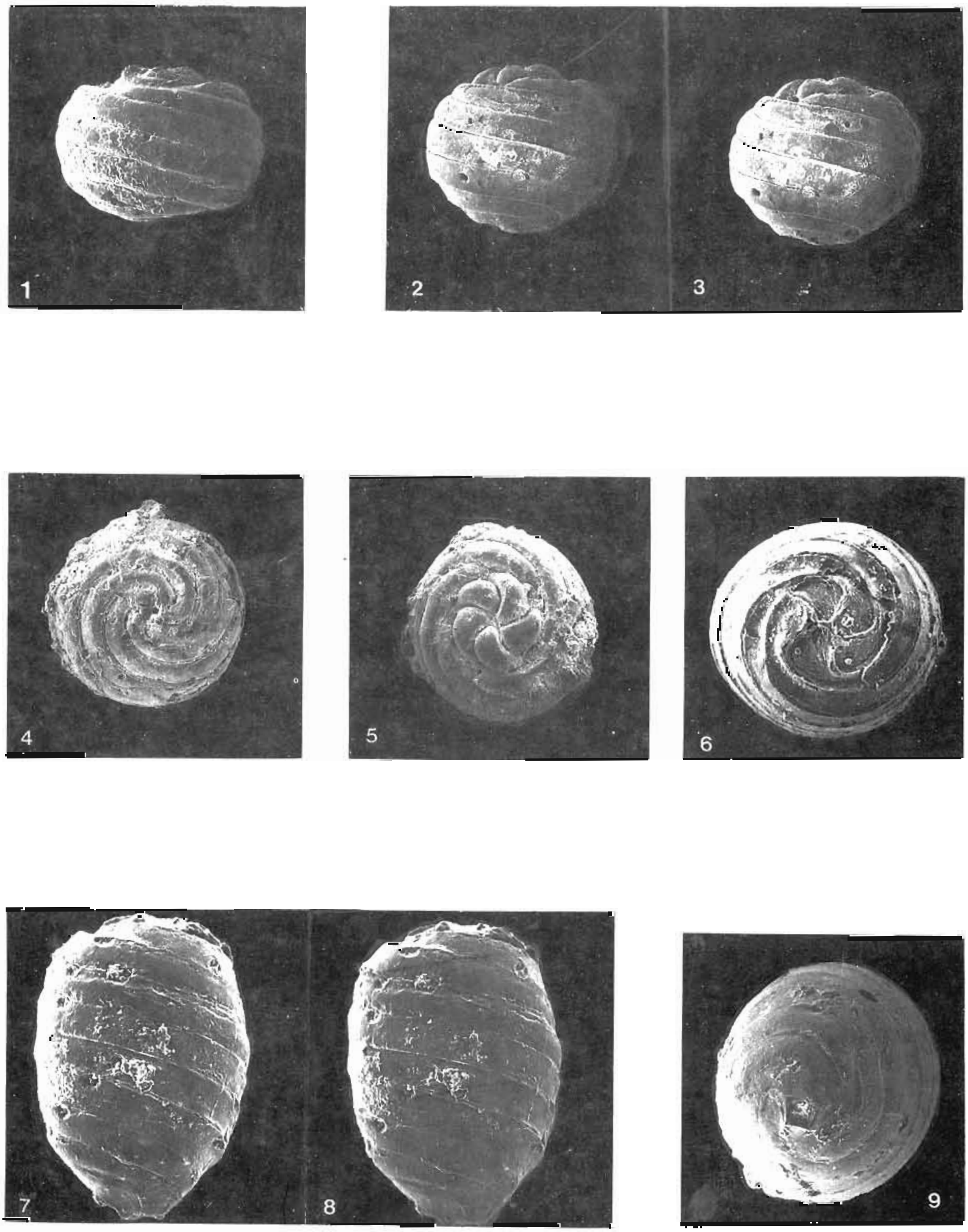


PLATE 1

1-5. *Platychara perlata* (Peck & Reker) Grambast × 50
1. Lateral view
2, 3. Stereoscopic view
4. Apical view
5. Basal view

6-9. *Nemegtichara grambasti* sp. nov., × 70
6, 7. Stereoscopic view
8. Basal view
9. Apical view

Paratype I, figure 8; Paratype II, figure 9.

Type Locality—1.75 km WSW of Rangapur, district Rangareddi, Andhra Pradesh, India.

Type level—Intertrappean bed between Lava flows 4 and 5 (*sensu* Dutt, 1975).

Generic Affinities—The apical structure described above suggests 'Lamprothamnoide' type of gyrogonites (*sensu* Feist & Grambast-Fessard, 1982) with characteristic protruding summit and absence of apical nodules. The periapical depression, however, is not so well-marked in our material, suggesting affinities with either *Pseudolatochara* (Wang Zhen, 1978a) or *Mongolichara* (Kyansep-Romashkina, 1975) emend. Karczewska and Kyansep-Romashkina, 1979. The Indian material, however, can neither be ascribed to *Pseudolatochara* because of the less protruding summit, nor to *Mongolichara* because it lacks the slightly thickened lime spirals at the apex and also the surface ornamentation. In view of the above facts, we have assigned our material to the genus *Nemegtichara*.

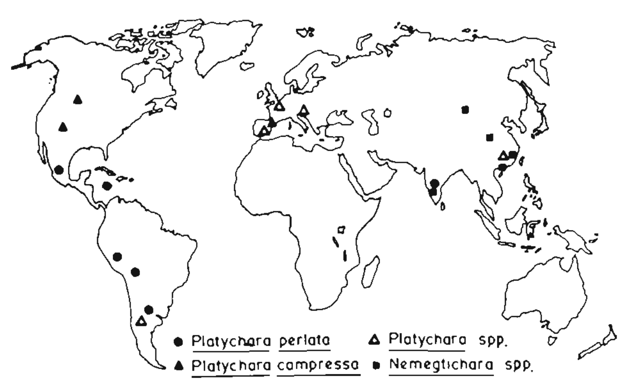
Specific affinities—The new species of *Nemegtichara* described herein is bigger in overall dimensions than any other described in the literature, particularly insofar as the length is concerned. The length/width ratio, however, falls partially within the values for *N. prima* and completely within those for *N. quarta*, both described by Karczewska and Ziembinska-Tworzydlo (1972). From the former, our species differs in having a tapering base rather than a rounded one, while from the latter, it differs in details of basal part, and in having the maximum width in the upper third of the gyrogonite, rather than in the middle. The above characteristics may also be used for distinguishing our species from *Nemegtichara* sp. described by Wang Zhen *et al.* (1983) from China.

Etymology—The species is named in honour of the Late Prof. L. Grambast, Montpellier, France.

PALAEOBIOGEOGRAPHIC AND AGE IMPLICATIONS

The morphologically distinctive genus *Platychara* occurs abundantly in the Late Cretaceous lacustrine sediments in North and South America (Musacchio, 1973; Peck & Forester, 1979), in Europe (Bignot & Grambast, 1969; Grambast & Gutierrez, 1973; Massieux *et al.*, 1985) and possibly also in China, where some species belonging to the genus *Gyrogona* (particularly *G. hubeiensis* Wang Zhen, 1978a) may belong to *Platychara* (*fide* Grambast-Fessard, 1980; Weitong, 1985). According to Karczewska and Ziembinska-Tworzydlo (1983), the apparent absence of *Platychara* in China is due to the different taxonomical approach of the Chinese authors and, that, on the other hand, *Platychara* is definitely absent from the Upper Cretaceous assemblages of Charophyta from Mongolia. It is, therefore, obvious that a taxonomic revision of the Chinese material is necessary to help arrive at a clearer palaeobiogeographic picture. However, be that as it may, the genus *Platychara* does persist up to the Lower Palaeocene with certainty in Europe (Stratotype of Montian in Belgium, Grambast-Fessard, 1980; Massieux *et al.*, 1985), and in North America (Willow Creek Formation, Member E in Canada, Peck & Forester, 1979), but with uncertainty in Argentina in South America (Musacchio, 1973). In India, the genus has been recorded from the Deccan Intertrappean beds of Nagpur (Bhatia & Mannikeri, 1976; Bhatia & Rana, 1984). The precise age of these beds remains controversial and probably straddles the Cretaceous-Tertiary Boundary. The present record from Andhra Pradesh extends the geographic range of the genus within the Peninsular India. The taxon has a cosmopolitan distribution, as is apparent from the above discussion (Text-fig. 3). However, its absence from Africa is significant and may be attributed either to incomplete charophyte inventories, which is true, or to lack of favourable lacustrine systems with charophyte vegetation. At the specific level, *Platychara perlata* has been recorded from Upper Cretaceous localities in Mexico and South America (Musacchio, 1973; Peck & Forester, 1979). Bhatia and Rana (1984) have recorded this species from the Intertrappean beds of Nagpur.

The genus *Nemegtichara* was first described by Karczewska and Ziembinska-Tworzydlo (1972) from the "White Beds" of the Nemegt Basin in Mongolia. These beds have been variously assigned, either to Palaeocene (Gradzinski *et al.*, 1977; Szalay & Mckenna, 1971) or to Eocene (Karczewska & Ziembinska-Tworzydlo, 1972). In China, however,



Text-figure 3—Map showing geographic distribution of the charophyte genera *Platychara* and *Nemegtichara*.

the genus first appears in the Turonian-Maestrichtian (Wang Zheng, 1978; Huang, 1979; Wang Zhen *et al.*, 1983; Wang Zhen & Wang Ke-Yong, 1985) and continues into Palaeocene and Eocene (Wang Zhen, 1978b, 1981; Huang, 1985). The present record of the genus from India extends its geographic distribution. As at present, the genus has been recorded only from Mongolia, China and India.

In so far as the age of the Intertrappean beds is concerned, it is not possible to give a precise age based entirely on the hitherto known charophyte assemblages. As already stated, at the generic level, both *Platychara* and *Nemegtichara* occur abundantly in the Upper Cretaceous and persist into the Lower part of Palaeocene, and in the case of latter, even up to Eocene, as in China. Since we have a new species of *Nemegtichara* in our material, its stratigraphical value at present is uncertain. *P. perlata*, which occurs abundantly in our material is known to range from Upper Cretaceous to Palaeocene from Mexico through South America, while its close ally *P. compressa* also has a similar stratigraphic range in North America (Peck & Forester, 1979) and in localities north of Pyrenees in Europe (Massieux *et al.*, 1985). Notwithstanding the lack of clear relationship between these two species as stated by Peck and Forester (1979), it is certain that they both occur abundantly in the Upper Cretaceous and persist into the Lower Palaeocene. On the basis of negative evidence, it is worth noting that the genus *Septorella*, indicative of Maestrichtian in western Europe, is absent in the Upper Cretaceous deposits of not only Mongolia and China (*fide* Karczewska & Ziembinska-Tworzydlo, 1981) but of India also. Similarly, characteristic Paleocene species of Europe, like *Sphaerochara edda/elongata* group and *Dughiella bacillaris* (*fide* Feist, 1979), as also the characteristic components of the Mongolian Palaeocene assemblages comprising *Gobichara* and *Grovesichara* (*fide* Karczewska & Ziembinska-Tworzydlo, 1981), are absent in the Intertrappean beds. According to Feist and Grambast-Fessard (1982) the genus *Gobichara* is a junior synonym of the genus *Microchara*. If this contention is correct, then the genus *Gobichara* is no more a characteristic component of the Mongolian Palaeocene assemblages. We thus see that from our present state of knowledge concerning the charophytan assemblages, it is not possible to fix precisely the age of the Deccan Intertrappean beds.

However, be that as it may, in the Intertrappean beds of Nagpur (= Takli Formation in which *P. perlata* occurs abundantly, *fide* Bhatia & Rana, 1984), Asifabad and Anjar (in Gujarat), dinosaur dental and egg-shell fragments and limb bones occur abundantly (*fide* Sahni *et al.*, 1986; Rao & Yadagiri, 1981; Ghevaria, 1988). More recently, Prasad and Sahni (1988) have described the first Cretaceous mammal, a new taxon, from the Intertrappean beds between lava flows 2 and 3 from a locality north-east of Naskal, close to our charophyte locality near Rangapur (*see* Text-fig. 1). These finds suggest a Late Maestrichtian rather than a Tertiary age for the Intertrappean beds (Prasad & Sahni, 1988). Similarly, the recent ^{40}Ar-^{30}Ar isochron ages (mean 67.4 ± 0.7 Myr) for Deccan basalts by Duncan and Pyle (1988) show that the Deccan volcanism occurred within a very short span of time (perhaps one million years) very close to the Cretaceous-Tertiary Boundary. Similar results were obtained earlier by Courtillot *et al.* (1986) and confirmed subsequently by Courtillot *et al.* (1988). The charophytan evidence is not inconsistent with the radiometric and palaeomagnetic data and the evidence of vertebrate fossils.

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Palynological investigation of Palaeocene sediments from Thanjinath, Meghalaya

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Mandal, J. 1990. Palynological investigation of Palaeocene sediments from Thanjinath, Meghalaya. *Palaeobotanist* **37**(3) : 324-330.

Palynofloral investigation of the Palaeocene sediments exposed near the village Thanjinath, Meghalaya reveals that pteridophytic spores are dominant in the lower seam while angiospermous pollen increase gradually towards the upper seam. No cenozone has been recognised in the assemblage as the change of palynofloral constituents in different seams are gradual. The quantitative and qualitative analyses of the assemblage, depositional environment and regional correlation on the basis of palynofossils have also been discussed.

Key-words—Palynology, Palaeoenvironment, Palaeocene, Meghalaya (India).

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साराँश

मेघालय में थाँजीनाथ के पुरानूतन अवसादों का परागाणविक अन्वेषण

जगन्नाथ प्रसाद मंडल

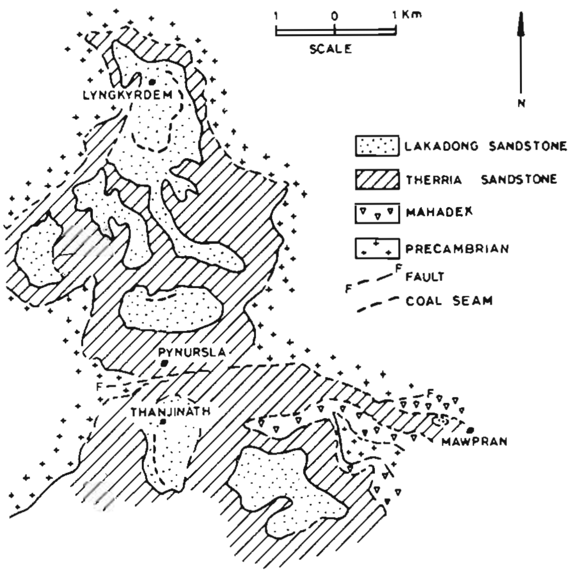
मेघालय में थाँजीनाथ गाँव के समीपस्थ विगोपित पुरानूतन कालीन अवसादों के परागाणविक अन्वेषण से व्यक्त होता है कि निचली सीम में टेरिडोफ़ाइटी बीजाणुओं की बाहुल्यता है जबकि अनावृतबीजी परागकणों की संख्या ऊपरी सीम की ओर शनैः शनैः बढ़ती जाती है। चूँकि विभिन्न सीमों में परागाणविक परिवर्तन मन्द-मन्द है अतः इस समुच्चय में कोई नवमंडल अभिनिर्धारित नहीं किया जा सका। इसके अतिरिक्त समुच्चय के परिमाणात्मक एवं गुणात्मक विश्लेषणों, निक्षेपणीय वातावरण तथा परागाणविकरूपकों के आधार पर क्षेत्रीय सहसम्बन्धों की विवेचना की गई है।

PALYNOLOGICAL investigations of the Lower Tertiary sequence of Khasi and Jaintia Hills, Meghalaya were carried out by Biswas (1962), Sah and Dutta (1968), Dutta and Sah (1970), Salujha *et al.* (1974), Tripathi and Singh (1984) and others. However, very little information is available from the southern margin of Shillong Plateau. Recently, Kar and Kumar (1986) published a spore-pollen assemblage from Laitryngew and Mawlong coalfields. The present work deals with the palynofloral investigation of the sediments from Thanjinath. The investigation was taken up to evaluate the palynofloral behaviour and to decipher the history of past vegetation in the depositional area.

BRIEF GEOLOGY OF THE AREA

Lower Tertiary sequence of rocks are well-exposed in the Khasi and Jaintia Hills. These sediments are laid down over Shillong Group of rocks and range from Upper Cretaceous to Upper Eocene in the shelf facies. The Lower Tertiary succession in Khasi Hills is divided into Langpar, Sylhet Limestone and Kopili formations in ascending order. Coal seams are developed in discontinuous patches within the Lakadong Sandstone throughout the Shillong Plateau. Stratigraphically, Sylhet Limestone Formation contains three limestone and three clastic interbands. They are Therria Sandstone, Lakadong Limestone, Lakadong Sandstone, Umlatdoh Limestone, Narpuh Sandstone and Prang Limestone in ascending order. Lakadong Sandstone is massive, light grey to greyish white and brown, hard consolidated, noncalcareous and medium to fine grained with intercalation of coal at places.

Important foraminifera like *Miscellanea miscella*, *Discocyclina* sp., *Assilina* sp., occur in abundance within Lakadong Limestone. Umlatdoh Limestone which overlies the Lakadong Sandstone is nummulitic in nature and has been dated as Lower Eocene in presence of *Nummulites* spp., *Discocyclina* sp., *Alveolina* sp., etc. (Nagappa, 1962;



Map 1—Geological map of Thanjinath area.

Biswas, 1962). Samanta and Roychoudhury (1983) have dated Lama Formation (this formation includes Therria Sandstone, Lakadong Limestone and Lakadong Sandstone) as Middle to Upper Palaeocene on larger foraminiferal evidences.

Lakadong Sandstone contains spore-pollen in good number which collectively indicate Palaeocene age (Biswas, 1962; Dutta & Sah, 1970; Singh, 1977; Kar and Kumar, 1986). Jain (1982) also proposed Palaeocene age of these sediments on the basis of dinoflagellate cysts.

MATERIAL

The present palynological study of the coal seams was undertaken around Thanjinath (25°18′ 00 : 91°53′ 30″). The locality is situated about 12 km south-east of Cherrapunji on Cherrapunji-Dauki Road (Map 1). Three ill-developed coal seams are present in this area, which are intercalated with shale, massive sandstone and carbonaceous shale. None of the seams is more than one meter thick. The lower, middle and upper seams are 0.5 m, 1.0 m and 0.6 m thick, respectively.

PALYNOLOGICAL ASSEMBLAGE

The following is the list of spore-pollen genera recovered from this area :

Lycopodiumsporites speciosus Dutta & Sah 1970
L. palaeocenicus Dutta & Sah 1970
L. parvireticulatus Sah & Dutta 1966
Dandotiaspora dilata Sah, Kar & Singh 1971
D. telonata Sah, Kar & Singh 1971
Foveosporites triangulus Dutta & Sah 1970
Todisporites major Couper 1958
Cyathidites australis Couper 1953
Foveotriletes pachyexinous Dutta & Sah 1970
Biretisporites bellus Sah & Kar 1969
Corrugatisporites formosus Dutta & Sah 1970
Osmundacidites sp.
Lygodiumsporites lakiensis Sah & Kar 1969
L. eocenicus Dutta & Sah 1970
Laevigatosporites lakiensis Sah & Kar 1969
Polypodiisporites repandus Takahashi 1964
Schizaeoisporites phaseolus Sah & Kar 1972
S. crassimurus Dutta & Sah 1970
Psiloschizosporis psilata Kar & Saxena 1981
P punctata Kar & Saxena 1981
Palmidites maximus Couper 1953
Palmaepollenites ovatus Sah & Kar 1970
P. nadhamunii Venkatachala & Kar 1969
P. communis Sah & Dutta 1966
Arecipites bellus Sah & Kar 1970
Spinizonocolpites echinatus Muller 1968
Matanomadhiasulcites maximus (Saxena) Kar 1985
M. kutchensis (Saxena) Kar 1985
Retimonosulcites ellipticus (Venkatachala & Kar) Kar 1985
Racemonocolpites thanjinathensis sp. nov.
R. trichotomosulcatus sp. nov.
Neocouperipollis kutchensis (Venkatachala & Kar) Kar & Kumar 1986
N. echinatus (Sah & Kar) Kar & Kumar 1986
N. wodehousei (Venkatachala & Kar) comb. nov.
Proxapertites emendatus (Sah & Dutta) Kar & Kumar 1986
P. operculatus van der Hammen 1953
P. microreticulatus Jain, Kar & Singh 1973
Tricolpites crassireticulatus Dutta & Sah 1970
Tricolpites reticulatus Cookson ex Couper emend. Potonié
T. globus Dutta & Sah 1970
T. levis Sah & Dutta 1966
Retitribrevicolporites rubra (Dutta & Sah) Kar & Kumar 1986
Myricipites harisii (Couper) Dutta & Sah 1970
Psilastephanocolporites psilatus Kar & Kumar 1986
Kielmeyerapollenites eocenicus Sah & Kar 1972
Retitrescolpites typicus Sah 1967
Retitrescolpites sp.
Rhoipites kutchensis Venkatachala & Kar 1969

Proteacidites excertus Dutta & Sah 1970
Podocarpidites khasiensis Dutta & Sah 1970

SYSTEMATIC DESCRIPTION

Genus—*Racemonocolpites* Guzmán 1967

Type species—*Racemonocolpites racematus* (van der Hammen) Guzmán 1967.

Racemonocolpites thanjinathensis sp. nov.
Pl. 1, figs 5-10

Holotype—Pl. 1, fig. 5; size 42.1 × 60.8 μm; Slide no. BSIP 9580.

Occurrence—Thanjinath (middle seam), Lakadong Sandstone Member, Sylhet Limestone Formation, Meghalaya.

Diagnosis—Pollen grains elliptical in polar view; monosulcate, sulcus distinct, extending up to margin. Exine sculptured with closely placed clava, bacula and gemmae, intersculptural exine granulose/microbaculose.

Description—Symmetry and form—elliptical, margin uneven due to projection of sculptural elements, 42-56 × 50-82 μm in size. Aperture monosulcate, sulcus distinct, extending up to margin in polar view. Exine intectate, 1.0-1.5 μm thick, layers not separable due to dense sculptural elements; sculptural elements clava, bacula and few gemmae; clava 3-5.5 μm long and 2.5-2 μm broad, bacula 2-4.4 μm long and 1-3.2 μm broad, gemmae 3-5.2 μm broad, inter-sculptural area microbaculose, sculptural elements densely distributed on both the surfaces even on aperture margin.

Remarks—*Racemonocolpites racematus* Guzmán 1967 closely resembles the present species. However, in *R. racematus* intersculptural exine is laevigate and sculptural elements dominantly gemmate. *Racemonocolpites facilis* Guzmán 1967 and *R. romanus* Guzmán 1967 possess grana between the sculptural elements as in the present species but differ having indistinct sulcus and exine mainly gemmate.

Racemonocolpites trichotomosulcatus sp. nov.
Pl. 1, figs 1-4

Holotype—Pl. 1, figs 1, 2; size 59.2 × 60.8 μm; Slide no. BSIP 9581.

Occurrence—Thanjinath (middle seam), Lakadong Sandstone Member, Sylhet Limestone Formation, Meghalaya.

Diagnosis—Pollen grains triangular to subcircular in polar view, trichotomosulcate; exine sculptured with clava, bacula and gemmae, intersculptural elements microbaculose/granulose.

Description—Symmetry and form—triangular to subcircular, margin uneven due to projection of sculptural elements, 50-59 × 56-62 μm in size. Aperture trichotomosulcate, sulcus narrow at equator and wide towards pole. Exine intectate, 1.0-1.5 μm thick, different layers not observed due to dense sculptural elements; sculptural elements: clava, bacula and few gemmae; clava 3-5.5 μm long and 2-5.2 μm broad, bacula 2-3.5 μm long and 1-3 μm wide, gemmae 3.0-6.2 μm; intersculptural area granulose/microbaculose.

Remarks—*Trichotomocolpites* van der Hammen 1956 and *Trichotomosulcites* Couper 1953 were instituted to accommodate trichotomosulcate aperturate pollen. However, van der Hammen (1956) designated a recent palm pollen *Pyrenoglyphis major* as the holotype for *Trichotomocolpites.* Jansonius and Hill (1976) considered this name as illegitimate. In 1960, Couper considered that the type species of *Trichotomosulcites* (*Trichotomosulcites subgranulatus*) is actually *Trisaccites microsaccatus* (Couper) Couper 1960 with very poorly developed saccus and thus this name also stands superfluous (Jansonius & Hill, 1976).

According to Muller (1979), *Racemonocolpites* is closely comparable to *Iriartia* pollen. *Iriartia* pollen though morphologically comparable with the present taxa is much smaller in size (26-40 μm). Sculptural elements of *Racemonocolpites thanjinathensis* and *R. trichotomosulcatus* resemble

PLATE 1 →

1-4. *Racemonocolpites trichotomosulcatus*
1, 2. Showing grana on intersculptural areas, Slide no. BSIP 9581 (L54/3); fig. 1, × 1000 and fig. 2, × 500.
3, 4. Showing trichotomosulcate aperture, Slide no. BSIP 9579 (041/3); fig. 3, × 500 and fig. 4, × 1000.
5-10. *Racemonocolpites thanjinathensis*
5. Depicts the exomorphic features, Slide no. BSIP 9580 (T46/3), × 1000.
6. Shows monosulcate aperture and sculptural elements, Slide no. 9582 (T44/2), × 1000.
7. Illustrates intersculptural exinal ornamentation, Slide no. BSIP 10250 (V41), × 1000.
8-10. SEM photographs showing exinal features particularly ornamentation in intersculptural areas; fig. 8, × 1600; fig. 9, × ca. 3055; fig. 10, × ca. 4000.

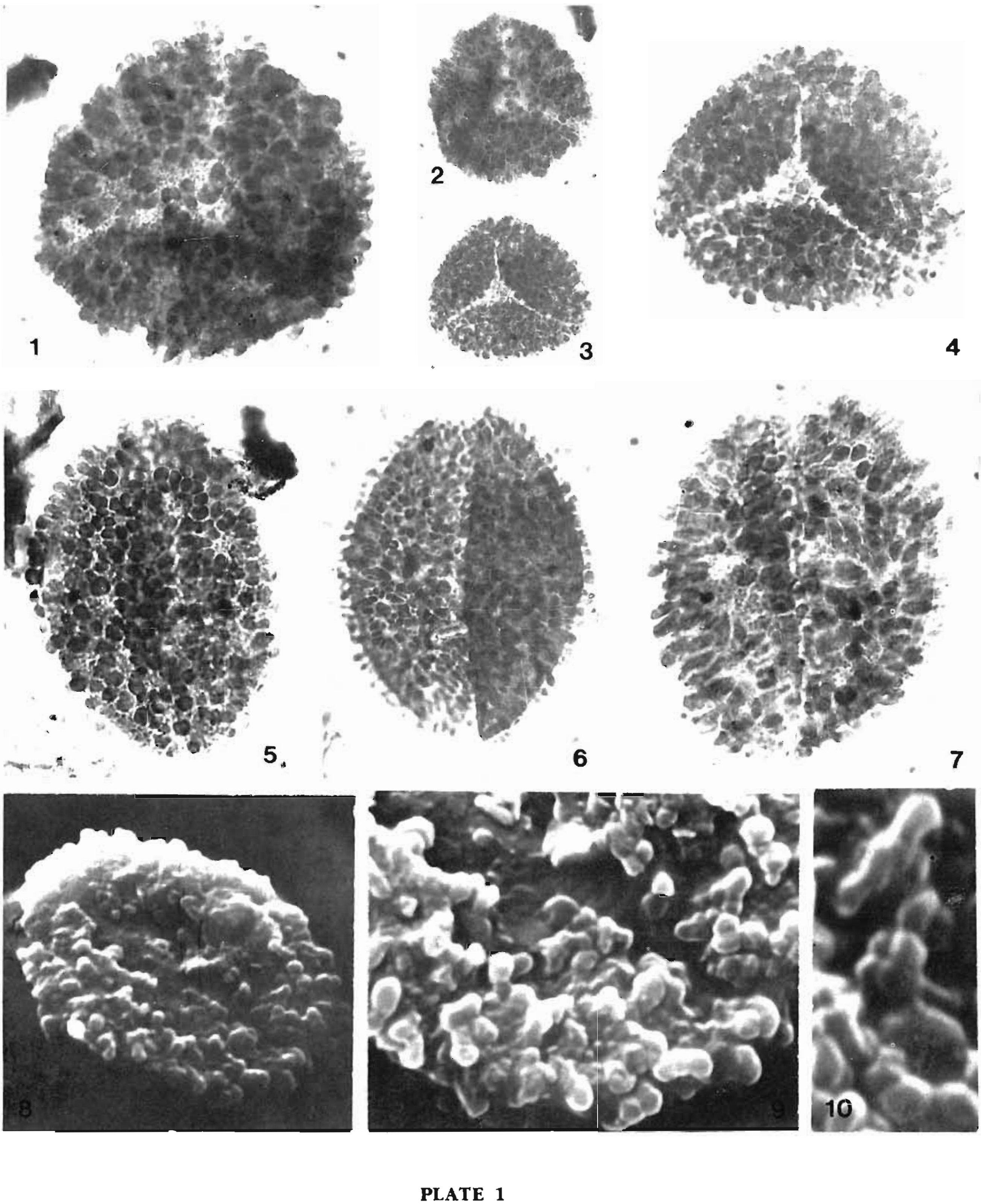
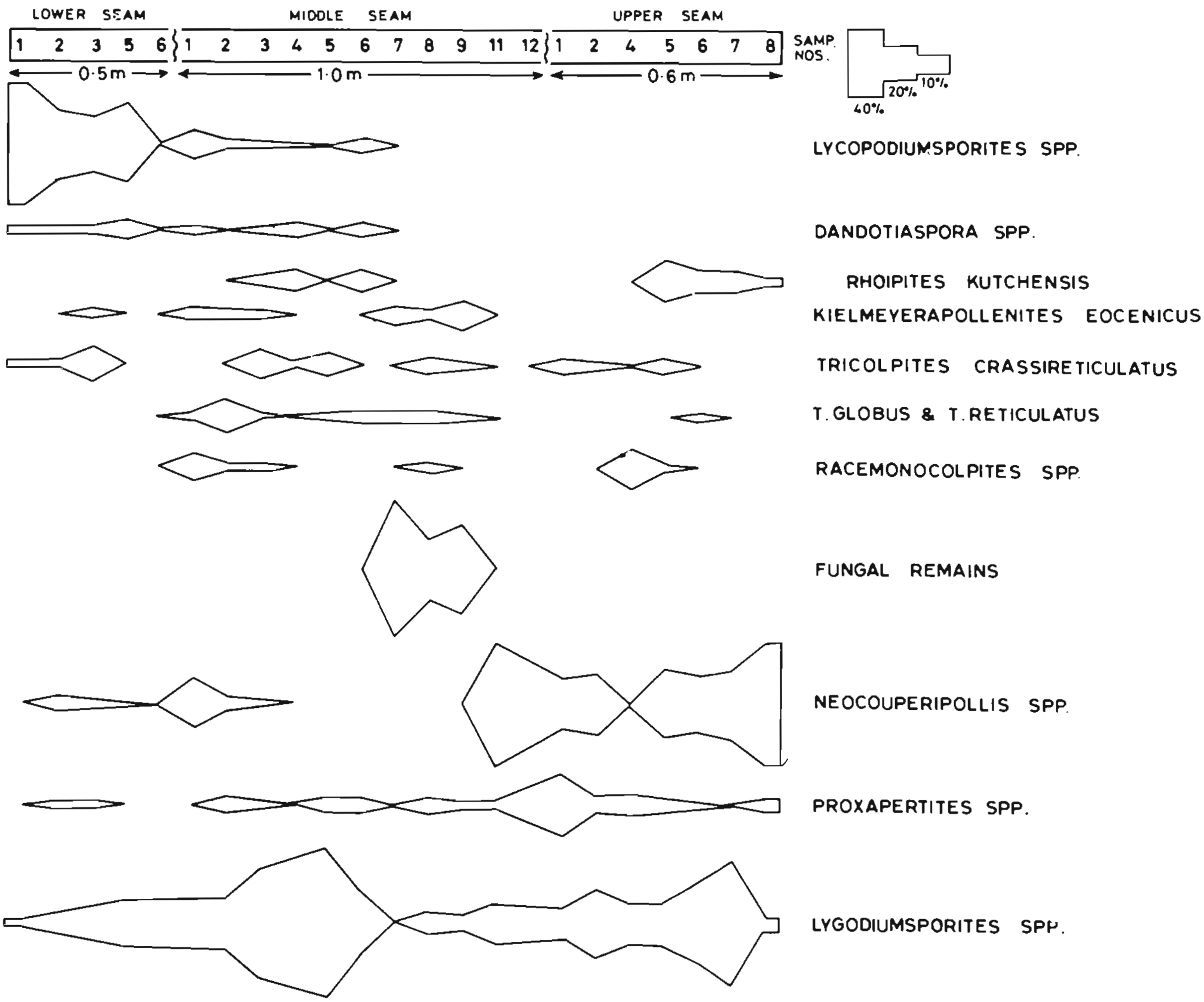


PLATE 1



Text-figure 1—Showing the frequency of important palynotaxa in different seams.

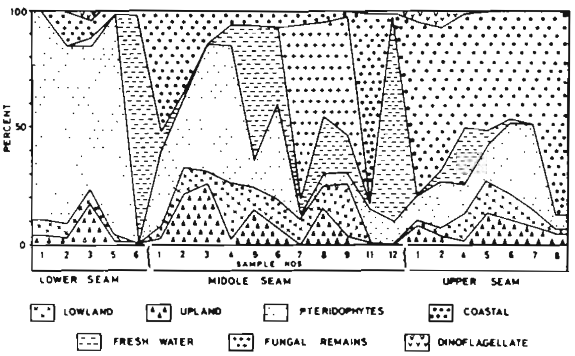
pollen of *Pinanga coronata* described by Thanikaimoni, 1970 (pl. 2, figs 18-24). *Pinanga coronata* also produces both mono- and trichotomosulcate aperturate pollen. *Pinanga* now (115 species) grows in India to southern China, and eastward to New Guinea as a forest undergrowth. *Pinanga coronata* now a days is restricted to Malaysia.

The present specimens have been described under *Racemonocolpites* because of their exomorphic features and in having both nono- and trichotomosulcate aperture.

DISCUSSION

The palynoflora recovered from Thanjinath area consists of 34 genera and 55 species. Pteridophytic spores (36%) in the assemblage are represented by 13 genera and 19 species, angiospermous pollen (57%) by 19 genera and 33 species and gymnospermous pollen poorly by single species. Algal remains comparable to *Tetraporina* and microthyriaceous fungi occur in good numbers. Phytoplanktons are also encountered but insignificantly. Lower seam consists of 25 species belonging to 21 genera. Pteridophytic spores with 49 per cent dominate over angiospermous pollen which occupy only 32 per cent. *Lycopodiumsporites* is the dominant genus and is recorded up to 65 per cent in some samples followed by *Dandotiaspora dilata* (10%). Monocot pollen, dominated by *Neocouperipollis* and *Proxapertites*, are represented by 20 per cent while dicotyledonous pollen are poorly represented.

The assemblage of middle seam is rich in variety and consists of 29 genera and 41 species. Angiosperm pollen contribute 55 per cent followed by spores (37%). *Lygodiumsporites* and *Cyathidites* are the dominant taxa and the remaining spore genera behave like the lower seam except



Text-figure 2—Showing the behaviour of spores, palm pollen and dicotyledonous pollen grains from Lower to Upper seams.

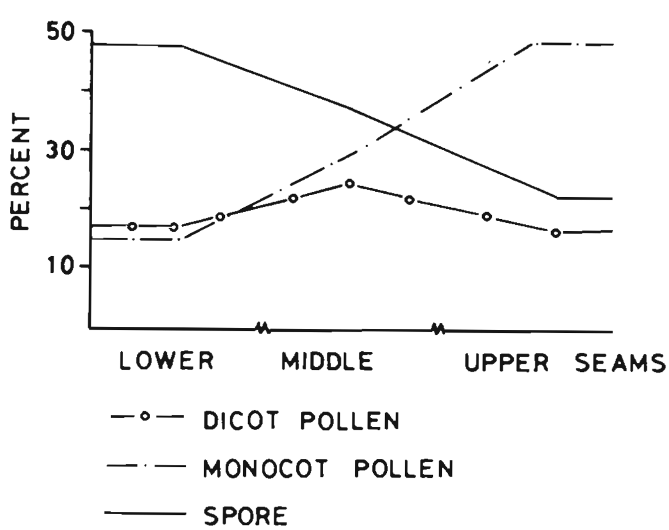
Lycopodiumsporites which declines significantly. Palm pollen exhibit their gradual abundance upward and are dominated by *Neocouperipollis*. *Kielmeyerapollenites* and *Tricolpites* are major elements among the dicot and the dicot pollen grains are far less than the palm pollen both quantitatively and qualitatively. A few genera appear in this seam and significant amongst them is trichotomosulcate palm pollen. These pollen have been designated as *Racemonocolpites trichotomosulcatus* and *R. thanjinathensis*. In the upper seam the assemblage consists of 22 genera and 29 species and spores. Monocot genera are less diversified but are rich (48%). Dicotyledonous pollen occur insignificantly, only *Rhoipites* contributes up to 12 per cent. *Podocarpidites*, the only gymnosperm member present poorly in this seam.

The above analysis shows that the pteridophytic spores are dominant in the lower seam and the angiosperms pollen in the upper seams (Text-fig. 2). *Lycopodiumsporites* overwhelmingly represents in the lower seam but absent in the upper seam. Likewise *Kielmeyerapollenites*, one of the dominant taxa of the middle seam, does not occur in other seams. Fungal remains confined to the middle seam while gymnospermous pollen have been recovered from upper seam only. The distribution of the major spore-pollen taxa is shown in Text-figure 1. It is also evident that the change of palynofloral succession in different seams is gradual and there is no break during deposition of sediments.

The present spore-pollen assemblage is closely comparable with the palynological association reported by Salujha *et al.* (1972), Singh (1977) from Tura Formation, Saxena (1980) and Kar (1985) from Matanomadh Formation and Kar and Kumar (1986) from Lakadong sandstone as the significant taxa are common in the assemblages. Some of the taxa recovered here could be tagged with the undermentioned families. Lycopodiaceae—*Lycopodiumsporites, Foveosporites*; Schizeaceae—*Schizaeoisporites, Lygodiumsporites*; Osmundaceae—*Osmundacidites*; Cyathiaceae—*Cyathidites*; Polypodiaceae—*Polypodiisporites* and *Laevigatosporites*; Podocarpaceae—*Podocarpidites*; Arecaceae—*Neocouperipollis, Proxapertites, Spinizonocolpites* and *Racemonocolpites*; Annonaceae—*Matanomadhiasulcites*; Fabaceae—*Tricolpites crassireticulatus*; Brassicaceae—*Tricolpites globus*; Polygonaceae—*Tricolpites levis*; Bombacaceae—*Lakiapollis*; Clusiaceae—*Kielmeyerapollenites*; Gunneriaceae—*Tricolpites reticulatus, Retistephanocolpites*; Polygalaceae—*Psilastephanocolporites*; Anacardiaceae—*Rhoipites*. These families are known to grow chiefly in tropical areas (Lakhanpal, 1970; Dutta & Sah, 1970; Saxena, 1980).

Thus it seems that Thanjinath enjoyed a tropical climate during the time of deposition. Presence of palm pollen in abundance, in particular, indicates near coastal environment. Rich pteridophytic flora suggests a swamp type of vegetation with high humidity. Low land elements and fresh water algae were carried from the surroundings of the depositional area. The coal seams were deposited near shore in shallow marine condition. The presence of dinoflagellates also corroborates this assumption.

The Thanjinath palynoflora has been classified under seven groups according to their habitat and the data plotted in the form of a diagram (Text-fig. 3). The diagram shows that there was not much of upland flora. Pteridophytes dominate in lower seam



Text-figure 3—Showing the distribution pattern of major palynofloral-ecological complexes.

and gradually decline upward, whereas the coastal elements invade upwards slowly.

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Late Cenozoic plant-impressions from Mahuadanr Valley, Palamu District, Bihar

M. B. Bande & G. P. Srivastava

Bande, M. B. & Srivastava, G. P. 1990. Late Cenozoic plant-impressions from Mahuadanr Valley, Palamu District, Bihar. *Palaeobotanist*, **37**(3) : 331-366.

Impressions of leaves, fruits and a flower have been described from the Late Cenozoic beds from near Mahuadanr, Palamu District, Bihar. The assemblage consists of 25 species belonging to 22 genera and 16 families of the dicotyledons. Family Asclepiadaceae and the genera *Spondias, Erythrina, Combretum, Mitragyna, Alstonia* and *Cryptolepis* have been described for the first time from the Cenozoic of India. The data have been used to decipher the palaeoecology and depositional environment of the region. A comparison of this flora with other Neogene floras of India has also been made.

Key-words—Megafossils, Plant-impressions, Dicotyledons, Late Cenozoic, India.

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साराँश

बिहार में पलामु जनपद में महुआडाँड़ घाटी से अनंतिम नूतनजीवी पादप-अवशेष

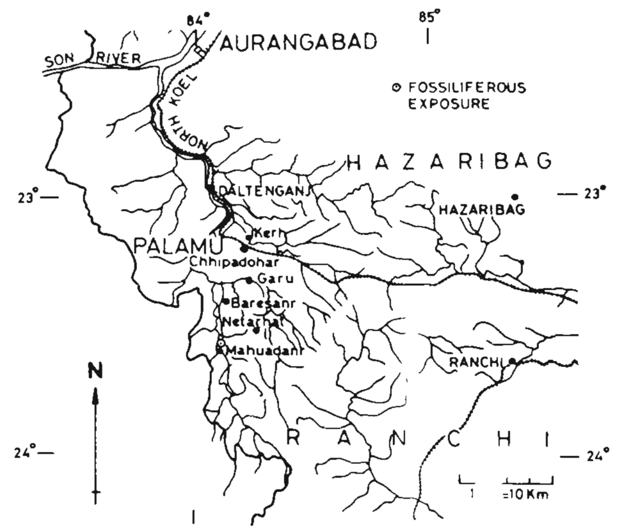
मोहन बलवंत बाँडे एवं गजेन्द्र प्रताप श्रीवास्तव

पलामु जनपद (बिहार) में महुआडाँड़ के पास स्थित अनंतिम नूतनजीवी संस्तरों से पत्तीयों, फलों एवं फूलों की छाप उपलब्ध हुई हैं। इस समुच्चय में 16 द्विबीजपत्री कुलों से सम्बद्ध 22 प्रजातियों की 25 जातियाँ विद्यमान हैं। भारत के नूतनजीवी कल्प से ऐस्क्लीपियेडेसी कुल एवं **स्पोन्डियास**, **ऐरिथ्राइना**, **कोम्ब्रीटम**, **मित्रागाइना**, **आल्सटोनिया** एवं **क्रिप्टोलेपिस** का इस शोध-पत्र में पहली बार वर्णन किया गया है। इस क्षेत्र की पुरापारिस्थितिकी एवं निक्षेपणीय वातावरण को सुनिश्चित करने में उपलब्ध आँकड़ों का उपयोग किया गया है। भारत के अन्य पश्चनूतन युगीन वनस्पतिजातों से भी उक्त पुरावनस्पतिजात की तुलना की गई है।

ANGIOSPERMOUS Plant fossils from the Late Cenozoic beds near Mahuadanr, Palamu District, Bihar were first reported by Puri (1976). The plant fossils so far described from these beds are very meagre and consist of leaf-impressions of *Grewia*, *Murraya*, *Schleichera*, *Mangifera* and *Vitex* (Bande, Srivastava & Mishra, 1989). Impressions of flowers and fruits, besides those of fishes, birds and insects, have also been reported from these beds (Puri & Misra, 1982). In the present paper impressions of leaves, fruits and a flower have been described. In all, this assemblage comprises 25 species belonging to 22 genera of 16 families of the dicotyledons.

The present investigation has added a number of new taxa to the Late Cenozoic flora of Bihar on the basis of which palaeovegetation, palaeoclimate, and palaeoecology of this region during the Late Cenozoic period have been reconstructed. In almost all the cases the leaf-impressions have been found to resemble the modern leaves of the plants growing in the vicinity of the fossiliferous locality. For the description of leaf-impressions the terminology given by Hickey (1973) and Dilcher (1974) has been adopted with certain amendments.

Geography—The area of investigation is Chhechari Valley. It is also known as Mahuadanr Valley and is situated in Chotanagpur plateau region of south Bihar in Palamu District (Survey of India toposheet no. 73A/3: North latitudes 23°24′00″ and 23°27′30″ and East longitudes 84°06′20″ and 84°09′10″). Mahuadanr is the largest village in this area and situated about 116 km south of Daltonganj. The nearest railway station is Chhipodohar on Gomoh-Dehri-on-Sone loop line of the Eastern



Map 1—Locality map of Mahuadanr, Bihar.

Railway (Map 1). The Chotanagpur plateau mostly consists of hilly tracts with an average altitude of 600-650 m. It is deeply dissected around its edges giving rise to the ghats (steep escarpments). The subplateaues of Ranchi, Hazaribagh and Surguja throw out long spurs and hill ranges far into Palamu District on which are situated the Baresand, Betla and other reserve forests. Another important feature of this area is a number of isolated, flat topped, steep sided and laterite covered pats which rise above 1,000 m from sea level. The fossiliferous area (Mahuadanr Valley) lies at an altitude of 655-680 m above sea level and forms a part of flat Chhechari basin surrounded on all sides by hills rising up to a height of about 1,070 m. The usual direction of hill ranges is from East to West (Bhagat, 1980; Misra, 1979, 1982). The area is drained by several *nalas* and *nadis* (rivers). Burha is the main and perennial river of the valley, which flows into the North Koel River at Begum Champa near Kutku.

Climate—The area enjoys a tropical climate characterised by a dry and comparatively cool season (winter) from the middle of October to middle of February, a dry and hot season (summer) from the middle of February to sometime in May-June and a warm and wet season (rainy) from June to September. The low lying lands at the foot of the main hill ranges and narrow valleys on the higher plateau occasionally experience frost during the winter. The rainfall is derived mainly from the Bay of Bengal currents of monsoon. The occurrence of rains is of bixeric type.

Vegetation—The vegetation of Chotanagpur region, except its southern part and valleys of Baresand, is of deciduous Sal—*Shorea robusta*-forest type. Obviously, *Sal* is the dominant species. The associates vary from place to place according to their ecological requirements (Meher-Homji, 1971).

The floristic studies of the Chotanagpur region have been carried out by Anderson (1863), Wood (1903), Haines (1910), Mooney (1944), Kapoor (1964-65), and Paul (1984). Some of these workers have also made some ecological observations on the forest types of this region. Mooney (1944) recognised only one type—Plateau *Sal*-forest. Rao and Panigrahi (1961) recognised moist and dry deciduous forests of tropical stock. Kapoor (1964-65) divides the forests under low hill regions and higher hill regions. In both these types *Shorea robusta* stands as the main type. Meher-Homji (1971) recognised the vegetation of Chotanagpur plateau as of the deciduous *Shorea robusta* forest type consisting of *Shorea-Cleistocalyx operculatus-Toona-Symplocos* type (occurring mainly where the rainfall is bixeric and over 1,500 mm; length of dry season of six months and mean temperature of the coldest month being in the vicinity of 10°-15°C and 15°-20°C) and *Shorea-Terminalia-Adina* type (occurring where rainfall is between 1,300-1,500 mm; length of dry season being seven months and mean temperature of the coldest month 15°-20°C). Champion and Seth (1968) broadly described two types of forests, viz., moist tropical forests and dry tropical forests in the Daltenganj South Forest Division.

Geology—The present area of investigation comes under Chotanagpur granite gneiss terrain (Roy Chowdhury *in* West, 1948). The geology of this area has been worked out in detail by Puri and Misra (1982). The sedimentary formations in the area, forming an outlier within the Pre-cambrian Chotanagpur granite Gneiss country, are exposed over a length of about 2.6 km and a width of 1.5 km along Birha River and its tributaries (Map 2) between Rajdanda (84°07′30″ : 23°25′43″) and Mahuadanr (84°06′40″ : 23°23′15″) villages. Pyroclastic sediments, conglomerates, sandstones and shales occur as the rock types.

The stratigraphic sequence proposed by Puri

PLATE 1 →

Shorea robusta Gaertn. f.

1. Fossil leaf in natural size; Specimen no. BSIP 36272.
2. Another fossil specimen. × ½; Specimen no. BSIP 36273.
3. Modern leaf, natural size.
4. Venation pattern of fossil leaf (fig. 2) near midrib. × 7.
5. Venation pattern of fossil leaf (fig. 2) near margin. × 7.

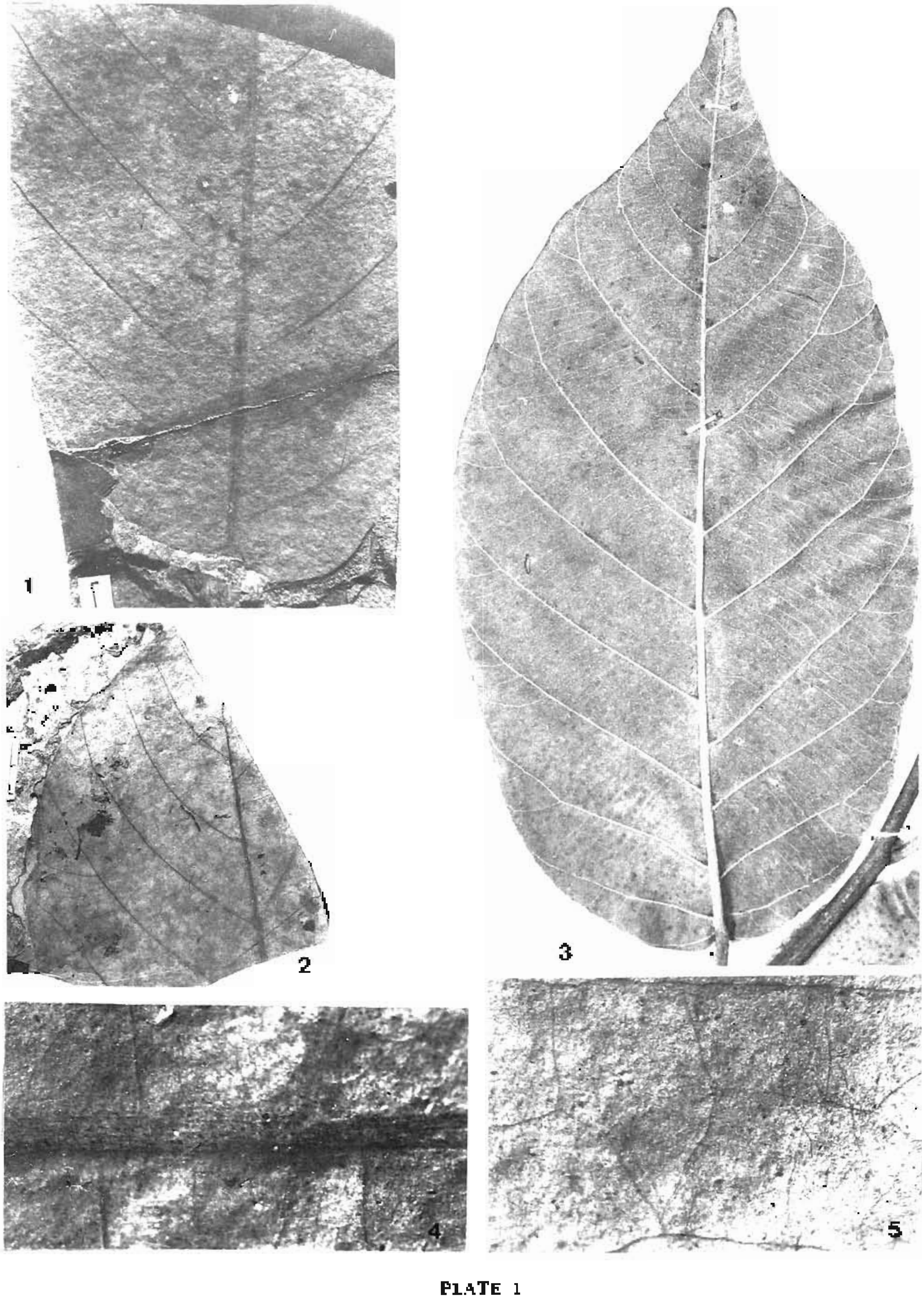
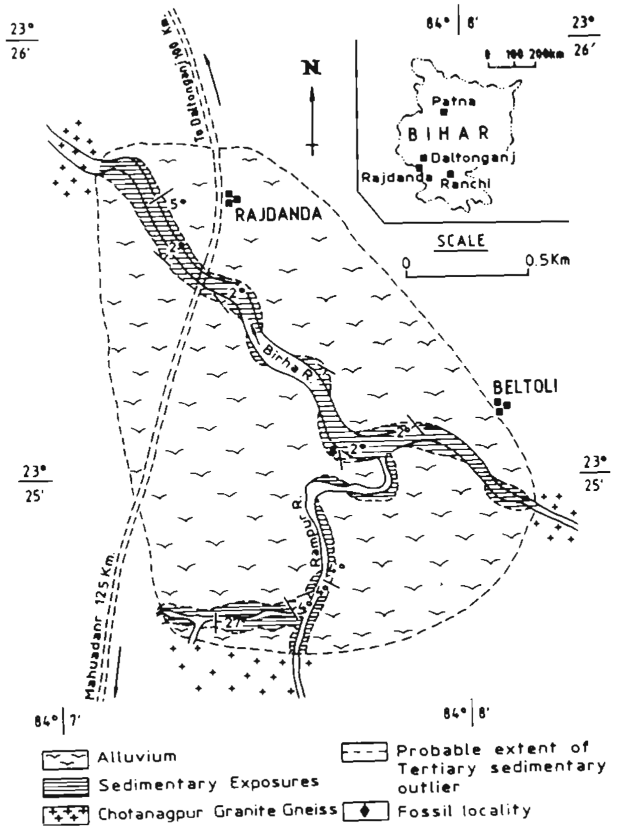


PLATE 1



Map 2—Geological map showing fossiliferous locality near Mahuadanr, Palamu District, Bihar.

and Misra (1982) for the rocks exposed in the area is as under:

		Maximum thickness
Recent	Loose pebbles, soil etc.	3.4 m
	..........Unconformity..........	
	Shale bed	3.2 m
Upper Tertiary	Sandstone bed	3.0 m
	Conglomerate bed	2.0 m
	..........Unconformity..........	
	Pyroclastic rocks	6.0 m
	..........Unconformity..........	
Pre-cambrian Chotanagpur granite gneiss		

The fossiliferous shales with plant and animal fossils are prominently exposed on the left bank of the Birha River south of Rajdanda Village and partly in the adjoining Rampur nala. Among the sedimentary rocks exposed in the area, the shales have yielded provided fossils of fishes, birds, leaves, flowers, fruits and insects while petrified woods have been recovered from the conglomerate/ sandstones.

LEAF-IMPRESSIONS

Family—Dipterocarpaceae

Genus—*Shorea* Roxb.

Shorea robusta Gaertn. f.
Pl. 1, figs 1, 2, 4, 5

Material—Two incomplete leaf-impressions, one showing the basal part of leaf and the other with a part near the apex. Preservation satisfactory; insect eaten holes visible.

Description—Leaf simple, length 9.7 and 13 cm, maximum width on one side of the midrib 8 and 7.5 cm respectively; nothing could be said about form and apex; base cordate; margin entire; texture chartaceous; glands not visible; petiole normal; venation pinnate, craspedodromous, simple; primary vein (1°) stout, straight; secondary vein (2°) with acute (moderate) angle of divergence, variation in divergence angle nearly uniform, moderate, in some secondaries bifurcation near the margin present, both inter-secondary and intramarginal veins absent; tertiary veins (3°) AO, percurrent, mostly simple (at places forked also), relationship with midvein oblique, constant, predominantly alternate and closely spaced; highest vein order of leaf (4°), it is also the highest vein order showing excurrent branching, quaternary veins thin, orthogonal, marginal ultimate venation incomplete; areoles well-developed, oriented, quadrangular to pentagonal (mostly quadrangular), veinlets none.

Discussion—Craspedodromous venation with some forked secondary veins near the margin and percurrent tertiaries are the important characters of the fossil leaves. The impressions show resemblance with the modern leaves of *Anthocephalus cadamba, Terminalia tomentosa, Schleichera oleosa, Shorea*

PLATE 2 →

Sterculia villosa Roxb.

1. Fossil leaf. × ½; Specimen no. BSIP 36274.
2. Modern leaf. × ½.

Combretum decandrum Roxb.

3. Fossil leaf, natural size; Specimen no. BSIP 36275.
4. Modern leaf, natural size.

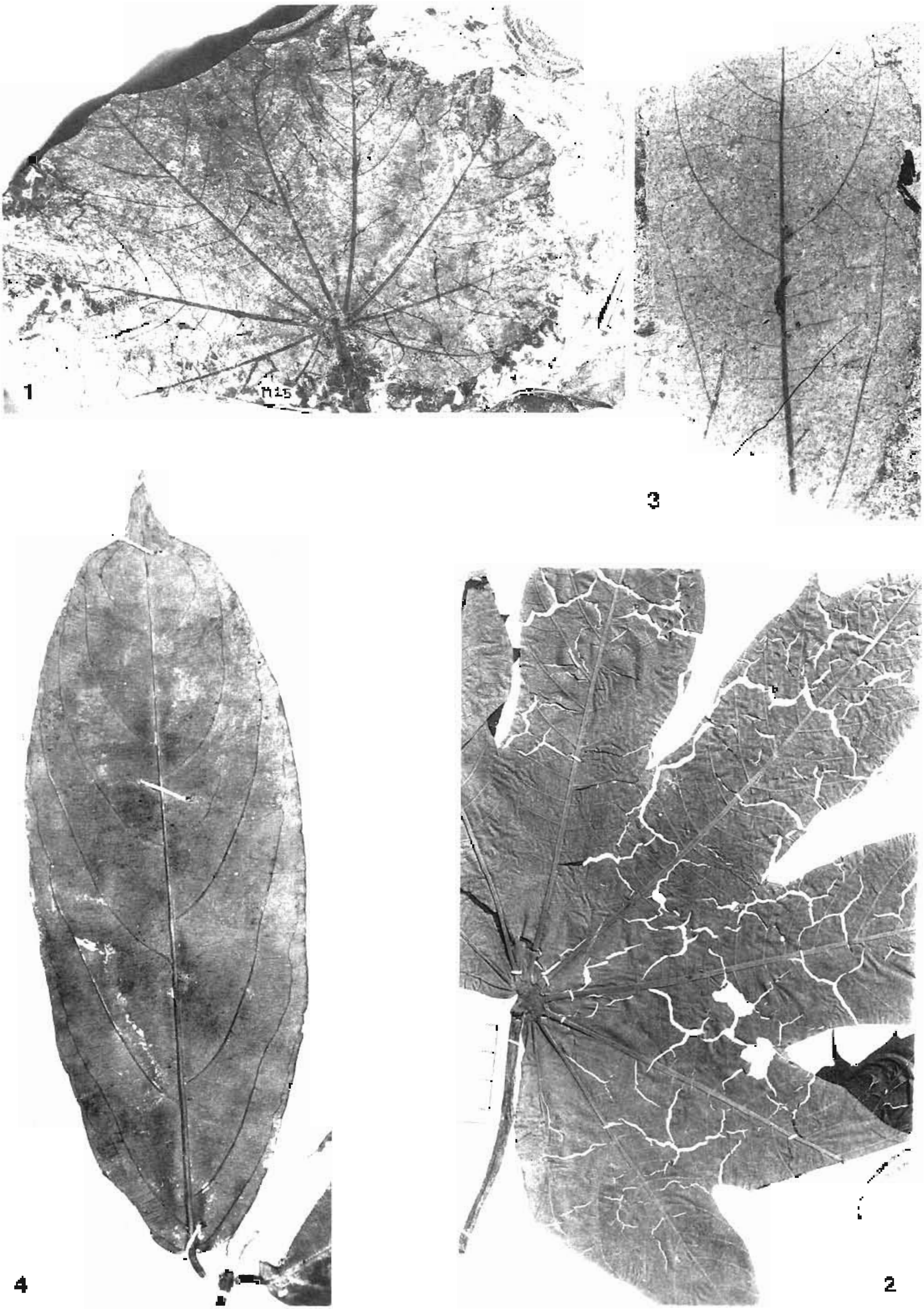


PLATE 2

robusta and *Buchanania lanzan*. However, a close similarity of these leaves is with those of *Shorea robusta* Gaertn. f. (F.R.I. Herbarium sheet no. 138303; Pl. 1, fig. 3).

Only fossil woods of *Shorea*, described under the generic name *Shoreoxylon* Berger, are known from various Tertiary localities of India, viz., Cuddalore sandstones, Tipam sandstones, Tertiary formations of West Bengal, Dupitila Series and the Siwalik beds (Lakhanpal *et al.*, 1976; Awasthi, 1982; Bande & Prakash, 1984). About 13 species of *Shoreoxylon* are so far known from the Tertiary of India but only two of them, i.e., *Shoreoxylon robustoides* described by Roy and Ghosh (1981) from West Bengal and *Shoreoxylon evidens* described by Eyde (1963) from the Tipam sandstones have been shown to bear close affinity with the woods of *Shorea robusta*.

Shorea Roxb. includes about 167 species which are widely distributed in the Old World from Sri Lanka and India on the West and throughout Burma, China, western Malaysia, Moluccas and Sunda Islands in the East (Willis, 1973). Out of these, nearly 100 species of trees grow throughout the tropical parts of Indo-Malayan region (Pearson & Brown, 1932). *Shorea robusta*, the Sal, is a large gregarious tree. The distribution of Sal in India is of considerable interest because it indicates the north-western limit of the family Dipterocarpaceae. In India, the area occupied by *Shorea robusta* forms two irregular but fairly defined belts, separated by the Gangetic plain. The northern sub-Himalayan belt extends from the Kangra Valley in Punjab to Darrang and Nowgong districts in Assam. The southern or central Indian belt extends from Coromandel coast west to the Pachmarhi sandstone hills and south to the Godavari River (Brandis, 1906; Chowdhury & Ghosh, 1958). In the Chotanagpur region, this is the most dominant species of the forest, both on the top of hills as well as in valleys. However, it is also well distributed in rest of the area (Wood, 1903; Haines, 1910; Meher-Homji, 1971; Paul, 1984).

Family—Sterculiaceae

Genus—*Sterculia* Linn.

Sterculia villosa Roxb.
Pl. 2, fig. 1

Material—Two incomplete specimens, counterpart of one of the specimens is also present.

Description—Leaves simple, length 12 cm and 4.5 cm, width 22 cm and 8.5 cm respectively; lamina and base symmetrical, ovate and lobed, apex not preserved; base cordate; margin entire; texture coriaceous; glands not visible; petiole normal; venation actinodromous, nine primaries arising from a single point, basal, perfect, marginal; primary veins (1°) appear to be stout, the middle primaries are almost straight whereas lateral primaries are markedly curved; secondary veins (2°) with angle of divergence varying from right angle or so to acute, upper pairs of secondary veins more acute than pairs below, secondaries arising from middle primaries seen uniting with secondaries arising from adjacent primaries in the basal part of the leaf, the secondaries arising from the lower most primary veins are seen forming loops, otherwise in general no loop formation; both intersecondary and intramarginal veins absent; tertiary veins (3°) AR, reticulate; highest vein order of leaf 4°, highest vein order showing excurrent branching 3°; quaternary veins thin, orthogonal, marginal ultimate venation incomplete; areoles well developed, oriented, quadrangular in shape; veinlets none.

Discussion—Actinodromous venation with nine primaries arising from a single point, stout petiole and joining of basal secondaries of one primary vein with secondary veins of adjacent primary vein are the important characters of the fossil leaves, which show near resemblance with the modern leaves of *Sterculia*, *Pterygota* and *Firmiana*. However, a detailed comparison with the modern leaves of *Sterculia foetida*, *Sterculia urens*, *S. villosa*,

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PLATE 3 →

Pterygota alata (Roxb.) R. Br.

1. Fossil leaf, natural size; Specimen no. BSIP 36276.
2. Line drawing of modern leaf showing similar shape and size.
3. Fossil leaf showing venation details near middle primary. × 7.
4. Venation details of fossil leaf showing higher order venation. × 2.5.

Garuga pinnata Roxb.

5. Fossil specimen, natural size; Specimen no. BSIP 36277.
6. Venation details of fossil leaflet (Pl. 4, fig. 6) near margin. × 7.
7. Venation details of fossil leaflet (Pl. 4, fig. 6) near midvein. × 7.

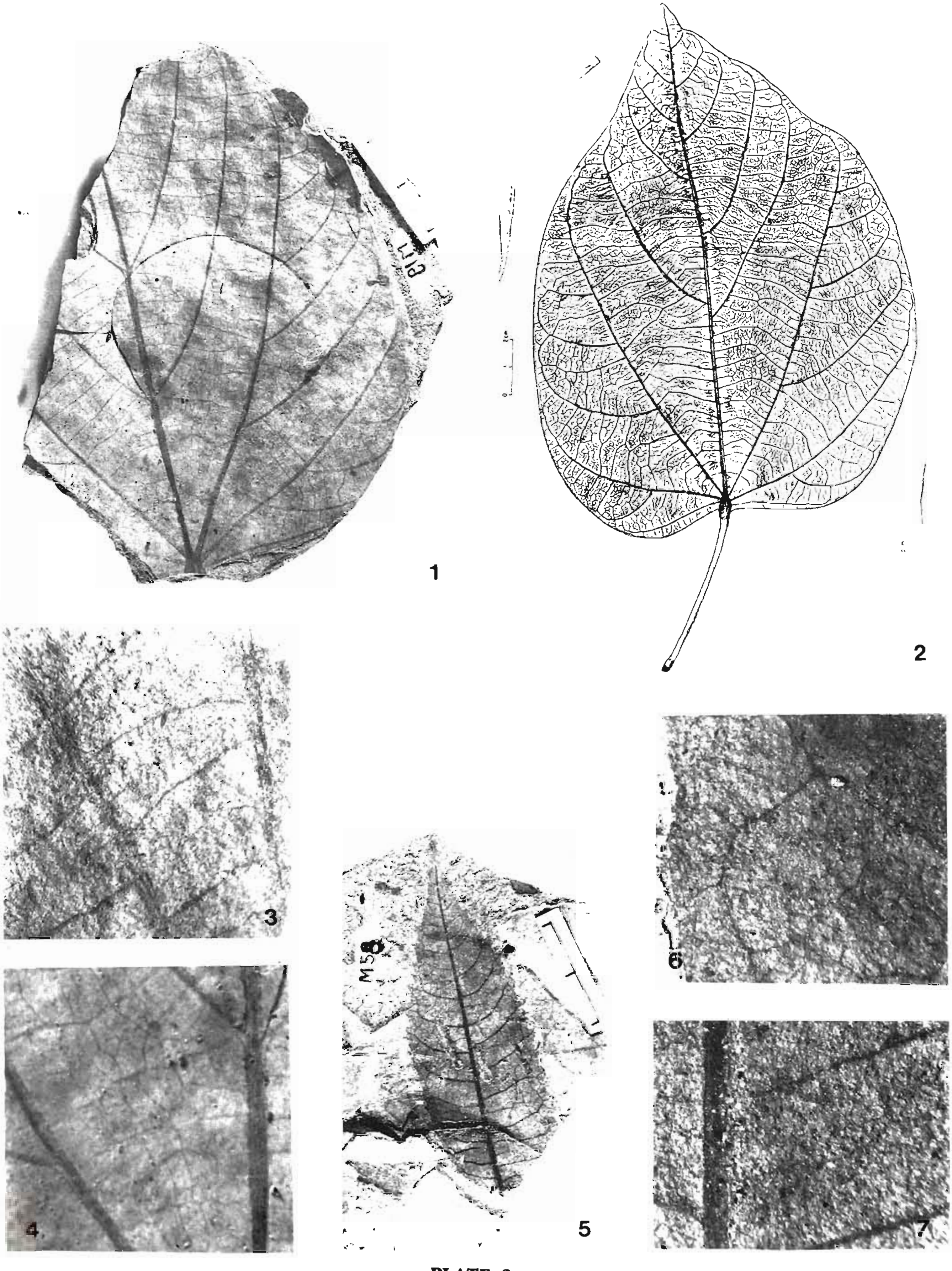

PLATE 3

Firmiana pallens syn. *Sterculia pallens* and *Pterygota alata* syn. *Sterculia alata* shows their closest resemblance with the leaves of *Sterculia villosa* (F.R.I. Herbarium sheet no. 5520/3173; Pl. 2, fig. 2).

Although the present finding forms the first record of the leaf-impression, fossil woods of *Sterculia* are known from various Tertiary localities of India, viz., the Deccan Intertrappean beds, Siwaliks beds, Cuddalore sandstones, Tipam sandstones and Namsang beds (Guleria, 1983; Lakhanpal *et al.*, 1984). All of them were earlier described under the generic name *Sterculioxylon* Kräusel 1939 but Guleria (1983) while describing fossil woods from Kachchh instituted another genus *Sterculinium* for the fossil woods of *Sterculia* and allied genera. Of the various species of *Sterculinium* so far described from India only *S. dattai* (Prakash & Tripathi) Guleria from Tipam sandstones shows a close similarity with the wood of *Sterculia villosa*.

The genus *Sterculia* Linn. consists of about 300 species (Willis, 1973) distributed throughout the tropics and reaches its best development in tropical Asia (Pearson & Brown, 1932). *Sterculia villosa* is a moderate-sized deciduous tree found in the sub-Himalayan tract and outer hills from the Indus eastward, ascending to 900 m, Punjab, Oudh, Central Provinces, Chotanagpur, western Peninsula, Sikkim, Assam, Khasi, Andamans and Burma (Wood, 1903; Brandis, 1906; Haines, 1910; Paul, 1984).

Genus—*Pterygota* Schott & Lendl.

Pterygota alata (Roxb.) R. Br. syn.
Sterculia alata Roxb.
Pl. 3, figs 1, 3, 4

Material—A single incomplete leaf-impression with good preservation. The apex and base both are not preserved.

Description—Leaf simple, length 9.4 cm, width 6.5 cm; margin entire; texture chartaceous; glands absent; petiole present, inflated; venation actinodromous, suprabasal, perfect; primary veins (1°) moderate, middle primary straight, lateral primary veins markedly curved; secondary veins (2°) with acute (moderate) angle of divergence, nearly uniform, moderately thick, curved abruptly, joining with superadjacent secondary at right angle; tertiary veins (3°) RR to RA, percurrent, simple, relationship with midvein oblique, decreasing outward, predominantly alternate, closely spaced; highest vein order 4° which also shows highest vein order of the leaf showing excurrent branching, quaternary veins thin, orthogonal, marginal ultimate venation looped; areoles well-developed, oriented, quadrangular, veinlets none.

Discussion—Actinodromous suprabasal venation, with loop formation by secondary veins and percurrent tertiaries are the important characters of the fossil leaf. A comparison with a large number of modern leaves indicates that it shows somewhat near resemblance with the modern leaves of *Mallotus philippensis, Oroxylum indicum, Moghamia chappar, Pterygota alata, Ougenia oojeinensis, Kleinhovia hospita* and *Sterculia urens*. However, it shows close resemblance with that of *Pterygota alata* (N.B.R.I. Herbarium sheet no. 19027; Pascal & Ramesh, 1987, p. 200; Pl. 3, fig. 2).

Lakhanpal *et al.* (1981) described a fossil wood *Sterculioxylon varmaii* from the Namsang beds of Arunachal Pradesh which was later renamed by Guleria (1983) as *Sterculinium varmaii* (Lakhanpal *et al.*) Guleria. The fossil wood was shown to bear close resemblance with the modern woods of *Pterygota alata* syn. *Sterculia alata*. The present study constitutes the first record of fossil leaf of *Pterygota alata* from the Cenozoic beds of India.

The genus *Pterygota* consists of about 200 species and is distributed throughout the tropics of the Old World (Willis, 1973), out of which only one species *Pterygota alata* is known to occur in India (Santapau & Henry, 1973). It is found in the evergreen forests of North-east India and in the Western Ghats from North Canara to Kerala up to 900 m but reaches its best development in Chittagong (Bangla Desh), Burma and Andamans (Chowdhury & Ghosh, 1958). It is also found in the forests of Chotanagpur region (Wood, 1903; Haines, 1910).

Family—Rutaceae

Genus—*Evodia* Forst.

Evodia meliaefolia Benth.
Pl. 4, figs 1, 2, 4, 5

PLATE 4 →

Evodia meliaefolia Benth.

1. Fossil leaflet showing unequal base, natural size; Specimen no. BSIP 36278.
2. Another specimen showing symmetrical base, natural size; Specimen no. BSIP 36279.
3. Modern leaf, natural size.
4. Venation details of fossil leaflet (fig. 2) near midvein. × 7.
5. Venation details of fossil leaflet (fig. 2) near the margin. × 7.

Garuga pinnata

6. Another fossil specimen, natural size, BSIP specimen no. 36280.
7. Modern leaflet, natural size.

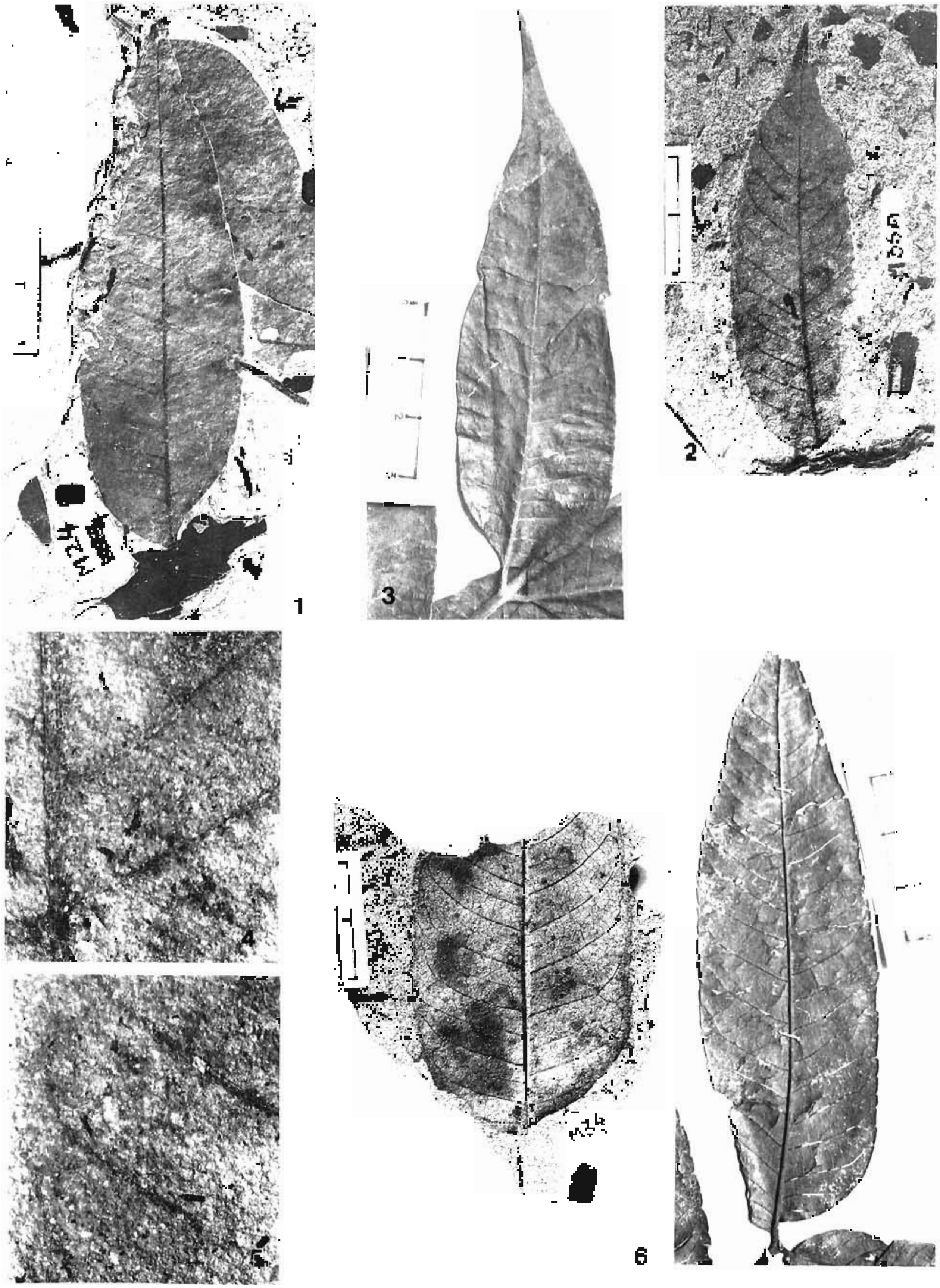

PLATE 4

Material—Two almost complete well-preserved leaflet-impressions.

Description—Leaf compound, leaflet length 7.6 and 9 cm, width 2.3 and 3 cm respectively, lamina and base in one specimen asymmetrical, whereas in the other it is symmetrical, oblong (narrow oblong), apex attenuate, base obtuse in one, obtuse (oblique) in the other specimen; margin entire; texture chartaceous; petiole normal; venation pinnate, camptodromous—brochidodromous; primary vein (1°) stout, markedly curved; secondary veins (2°) with acute (moderate) angle of divergence, uniform, moderate, curved abruptly joining superadjacent secondary at right angle, intersecondary and intramarginal veins both absent; tertiary veins (3°) RR, reticulate, orthogonal; highest vein order of leaf 4°, highest vein order showing excurrent branching 3°; quaternary (4°) veins moderate, orthogonal, marginal ultimate venation incomplete; areoles well-developed, oriented, mostly quadrangular to rectangular in shape.

Discussion—Asymmetrical to symmetrical lamina, obtuse (oblique) base, attenuate apex and brochidodromous venation are the important characters of the present leaflets which show near resemblance with the modern leaves/leaflets of *Vitex negundo, Evodia meliaefolia, Toona ciliata, Garuga pinnata* and *Pistacia integrrima*. However, they show strong resemblance with the leaflets of *Evodia meliaefolia* (F.R.I. Herbarium sheet no. 81222; Pl. 4, fig. 3). A large number of herbarium sheets of *Evodia meliaefolia* were consulted and it was observed that the base of leaflets is a variable character in this species. It may be either symmetrical or asymmetrical (unequal) as is also in the fossil leaflets.

Fossil record of the genus *Evodia* is very meagre. Bande and Prakash (1984a) described a fossil wood *Evodinium indicum* (modern comparable form *Evodia roxburghiana*) from the Deccan Intertrappean beds of Nawargaon of Maharashtra. Shete and Kulkarni (1982) also described a fossil wood of *Evodia* from the same locality.

The genus *Evodia* Forst. consists of about 50 species distributed mainly from Madagascar through South East Asia to Australia and Pacific islands (Willis, 1973; Negi, 1963). Only four species are known from India, out of which only *Evodia melifolia*, a large tree, grows in the forests of Chotanagpur region (Wood, 1903; Haines, 1910; Santapau & Henry, 1973). Besides Chotanagpur region, this species is also found in Assam, Cachar and China (Brandis, 1906).

Family—Burseraceae

Genus—*Garuga* Roxb.

Garuga pinnata Roxb.

Pl. 3, figs 5-7; Pl. 4, fig. 6

Material—Two leaflet-impressions with good preservation.

Description—Leaf compound, leaflets length 6.4 cm and 5 cm, width 2.2 cm and 3.6 cm respectively; whole lamina and base slightly asymmetrical, ovate (lanceolate); apex attenuate, base obtuse; margin toothed-serrate, serrate axis inclined to the tangent of the margins, apical angle acute, serration convex/concave, sinuses angular, spacing regular, teeth simple, basal part of leaf without serration; texture chartaceous; glands craspedodromous-semicraspedodromous, brochidodromous in other specimens without sinuses; primary vein (1°) massive, straight, slightly curved near the apex; secondary veins (2°) with acute (wide) angle of divergence, variation in angle of divergence nearly uniform, moderately thick, curved abruptly joining superadjacent secondary at acute angle, one branch enters in the sinuses when present, inter-secondary and intramarginal veins absent; tertiary veins (3°) RR, reticulate, orthogonal; highest vein order of leaf 4°, highest vein order of leaf showing excurrent branching 3°, quaternary veins thin, orthogonal, marginal ultimate venation incomplete; areoles well-developed, random, quadrangular to pentagonal, veinlets none.

Discussion—The important diagnostic features of the fossil leaflets indicate their near resemblance with the modern leaves/leaflets of *Boswellia serrata, Garuga pinnata, Pistacia integrrima* and *Azadirachta indica*. However, a detailed comparison

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PLATE 5

Spondias pinnata (L.F.) Kurz.

1. Fossil leaflet, natural size; Specimen no. BSIP 36281.
2. Another specimen, natural size; Specimen no. BSIP 36282.
3. Line drawing of modern leaflet (from Pascal & Ramesh, 1987).
4. Venation details of fossil leaflet (fig. 2) near midvein. × 7.
5. Venation details of fossil leaf (fig. 2) near margin. × 7.

Erythrina suberosa Roxb.

6. Fossil leaflet, natural size; Specimen no. BSIP 36283.
7. Modern leaflet, natural size.

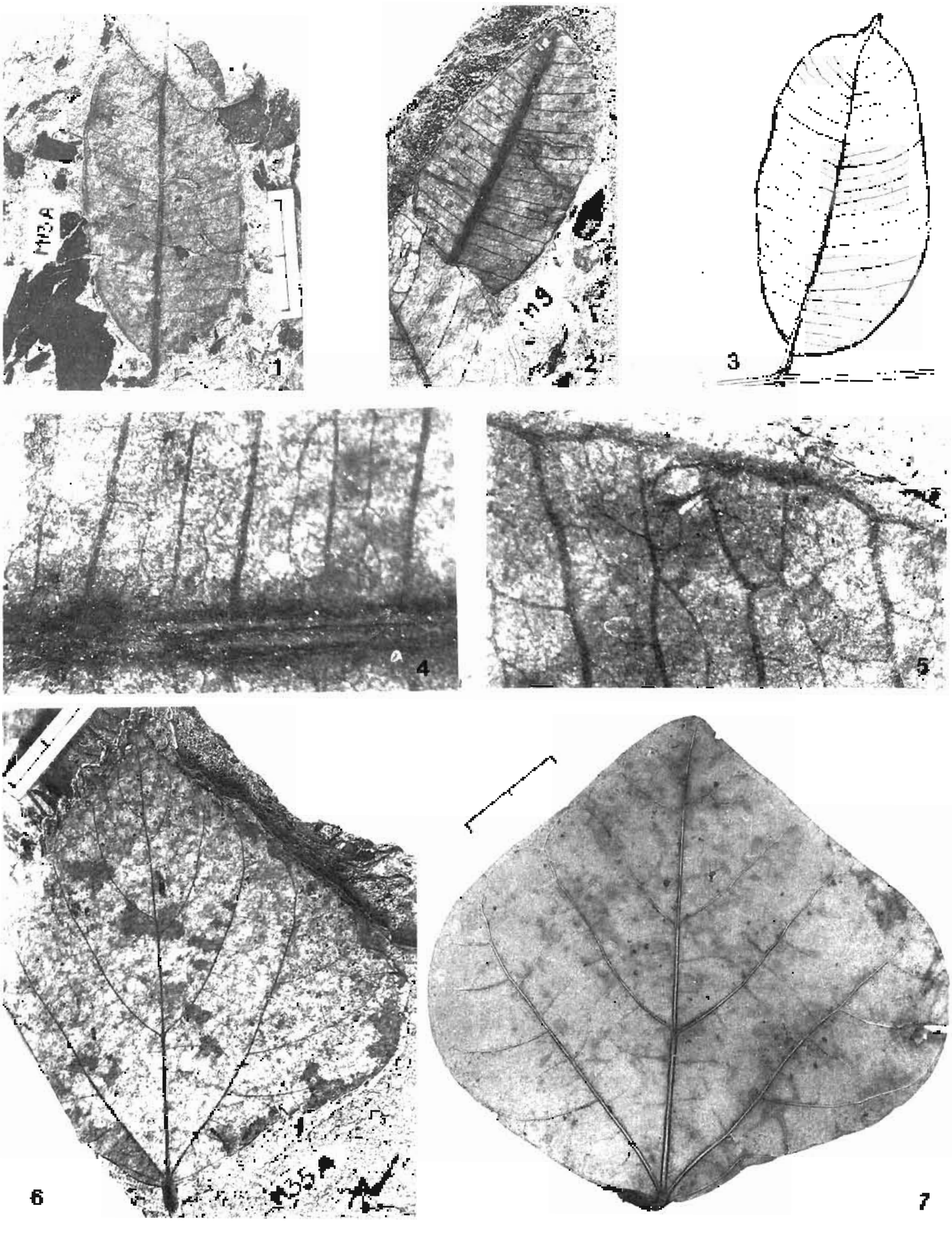

PLATE 5

shows close resemblance with the modern leaflets of *Garuga pinnata*. The leaflets of *Garuga pinnata* show dentate margin which is a variable character. In some of the leaflets the dentation is restricted to the apical region whereas in others there is no dentation (F.R.I. Herbarium sheet nos. 57030, 76120; Pl. 4, fig. 7; BSIP coll. no. 14088).

Fossil woods comparable to *Bursera/Garuga* have been described from the Tertiary of India. Woods of *Garuga* and *Bursera* are nearly similar (Lakhanpal *et al.*, 1981) and have been described under the generic name *Burseroxylon* Prakash & Tripathi 1975. *Burseroxylon preserratum* (modern comparable form *Bursera serrata*) has been described by Prakash and Tripathi (1975) from the Tipam sandstones of Assam and Bande and Prakash (1983) from the Deccan Intertrappean beds. Lakhanpal *et al.* (1981) described *Burseroxylon garugoides* from the Namsang beds of Arunachal Pradesh and compared it with the modern wood of *Garuga pinnata* Roxb.

Garuga Roxb. is a small genus of about five species of medium-sized trees, distributed in Madagascar, India, South East Asia, north-western Australia and the Pacific Islands (Willis, 1973). Two species are indigenous to India (Pearson & Brown, 1932; Santapau & Henry, 1973). *Garuga pinnata* is widely distributed from sub-Himalayan tract and outer valleys, ascending to about 1,100 m from Yamuna eastward, often mixed with Sal. It is a common tree in the dry deciduous forests of Madhya Pradesh, Chotanagpur, Andhra Pradesh, Karnataka and extends into the moist zone of Western Ghats and Satpuras. It is also found in Andaman Islands, Bangla Desh (Chittagong) and Burma in mixed forests (Wood, 1903; Haines, 1910; Ghosh *et al.*, 1963).

Family—Anacardiaceae

Genus—*Spondias* Linn.

Spondias pinnata (L.f.) Kurz. syn.
S. mangifera Willd.
Pl. 5, figs 1, 2, 4, 5

Material—Two incomplete leaflet-impressions with a counterpart of one of them. Apex is not preserved.

Description—Leaves compound, leaflet length 6.1 cm, width 3.5 cm of both the specimens; lamina and base symmetrical, oblong; apex not preserved; base acute (normal); margin appears to be revolute; texture coriaceous; glands not seen; petiole normal; venation pinnate, camptodromous—brochidodromous; primary vein (1°) stout, straight; secondary veins (2°) with angle of divergence right angle or so, nearly uniform, fine to hair-like, curved, joining superadjacent secondary at obtuse angle, intersecondary veins absent; intramarginal vein present; tertiary veins (3°), RO, random reticulate; highest vein order of leaf 4°, highest vein order of leaf showing excurrent branching 3°, quaternary veins thick, orthogonal, ultimate marginal venation fimbriate; areoles well-developed, oriented, quadrangular in shape, veinlets none.

Discussion—Oblong form, brochidodromous venation, fine to hair-like secondary veins joining superadjacent secondary veins at obtuse angle and fimbriate marginal venation are the important characters of the fossil leaflets. A detailed comparison shows that the fossil leaflets indicate near resemblance with the modern leaves/leaflets of *Alstonia scholaris, Spondias indica, S. pinnata, Syzygium oblatum, Mimusops elengii* and *Cryptolepis buchanani*. However, they bear a close affinity with the modern leaflets of *Spondias pinnata* (Pascal & Ramesh, 1987, p. 76; Pl. 5, fig. 63; N.B.R.I. Herbarium sheet no. 19027).

As per authors' information there is no previous fossil record of the genus *Spondias* from India. However, fossils of *Gluta, Melanorrhoea, Mangifera, Swintonia, Lannea, Dracantomelum* and *Holigrana* of Anacardiaceae are known from various Tertiary localities of India (Awasthi, 1982; Bande & Prakash, 1984; Guleria, 1984).

The genus *Spondias* L. comprises about 12 species distributed mainly in the Indo-Malayan region, southeast Asia and tropical America (Willis, 1973). In India, only four species are known to occur (Santapau & Henry, 1973). *Spondias pinnata* is a large deciduous tree, found in the sub-Himalayan tract and outer valleys up to 850 m, from Chenab

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PLATE 6 →

Bauhinia sp. cf. *B. purpurea* Linn.
1. Fossil leaf, natural size; Specimen no. BSIP 36284.
2. Modern leaf, natural size.

Millettia auriculata Baker ex. Brandis
3. Fossil leaflet, natural size; Specimen no. BSIP 36285.
4. Modern leaflet, natural size.

Ougenia oojeinensis (Roxb.) Hochr.
5. Fossil leaflet, natural size; Specimen no. BSIP 36286.
6. Modern leaflet, natural size.

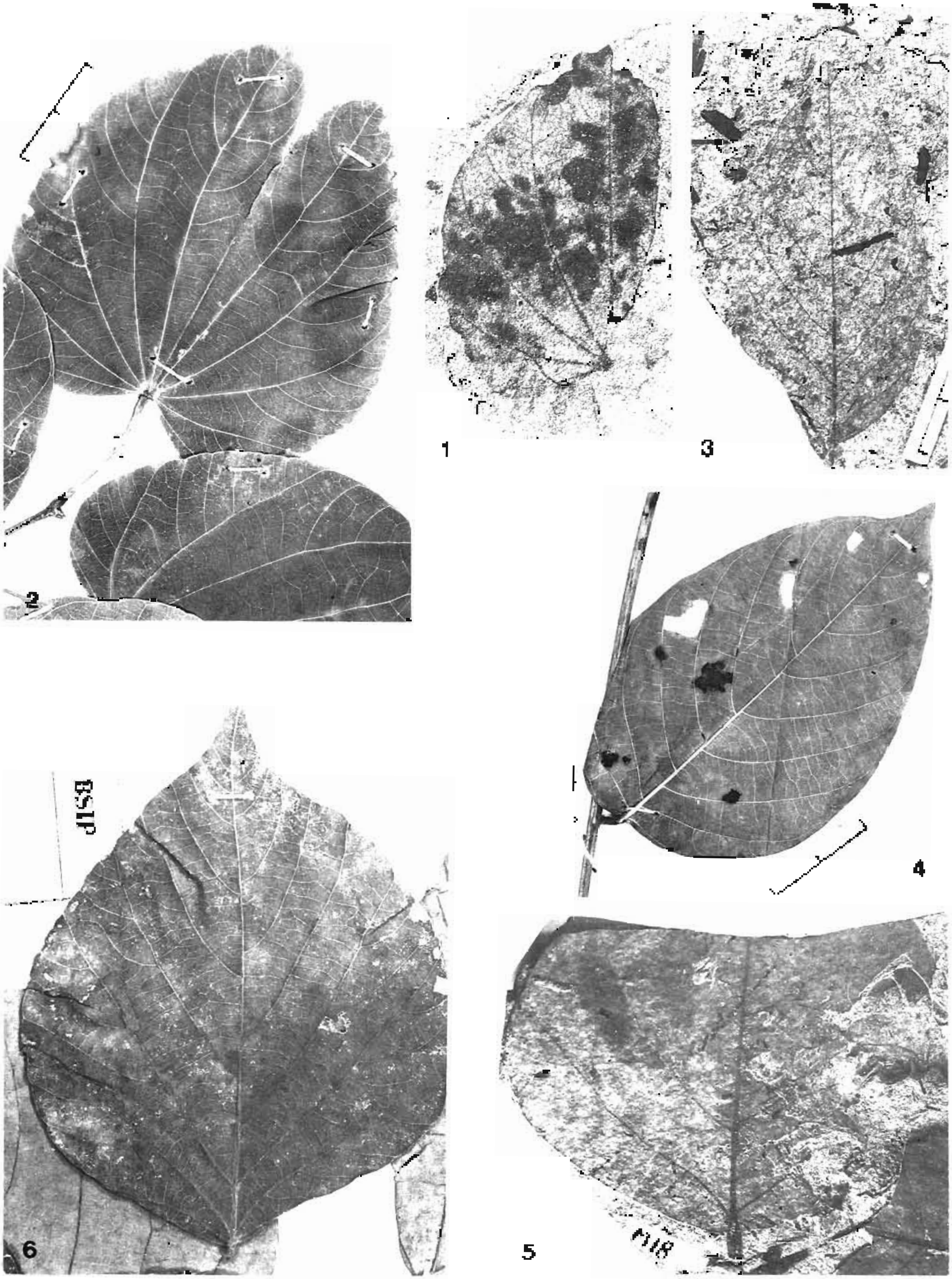

PLATE 6

eastwards, Salt Range in Pakistan, deciduous forests of Burma and the western Peninsula, Chotanagpur region and Sri Lanka (Wood, 1903; Brandis, 1906; Haines, 1910).

Family—Leguminosae (Fabaceae)

Genus—*Erythrina* Linn.

Erythrina suberosa Roxb.
Pl. 5, fig. 6

Material—A single almost complete, well-preserved leaflet-impression with its counter part.

Description—Leaf compound, leaflet length 9.0 cm and maximum width on one side of the midrib 4.5 cm; lamina and base both symmetrical, wide ovate; apex acute; base rounded; margin entire, texture coriaceous; glands could not be seen; petiole inflated; venation acrodromous, position of primaries basal, perfect, marginal; primary veins (1°) weak, middle primary vein straight and lateral primaries markedly curved; secondary veins (2°) with acute (moderate) angle of divergence, lowest pair of secondaries which arises from the point of divergence of primaries more obtuse than pairs above, thick, abruptly curved, joining superadjacent secondary at acute angle, intersecondary veins absent; tertiary veins (3°) AR to RR, percurrent, retroflexed, relationship with midvein oblique, decreases towards margin, predominantly alternate, distantly spaced; highest vein order of leaf 4°, showing highest vein order with excurrent branching; quaternary veins thick, orthogonal, marginal ultimate venation incomplete; areoles well-developed, oriented, irregular but mostly quadrangular, veinlets none.

Discussion—Wide ovate lamina, inflated petiole, acrodromous venation and percurrent tertiary veins are the important characters of the present fossil leaflet which has been compared with the leaves/leaflets of *Ougenia oojeinensis, Erythrina suberosa, Mallotus philippensis* and *Oroxylum indicum*. However, it shows closest resemblance with the leaflets of *Erythrina suberosa* (B.S.I.P. Herbarium sheet no. 11302; Pl. 5, fig. 7).

As far as the authors are aware, no fossil of *Erythrina* is so far known from India. However, several fossils of Leguminosae have been recorded from various Tertiary localities of the country (Bande & Prakash, 1984; Awasthi, 1982).

The genus *Erythrina* consists of about 100 species of trees and shrubs distributed in the tropics and subtropics of the World (Willis, 1973). *Erythrina suberosa* is a middle sized tree, found in the sub-Himalayan tract from Ravi to Sharda ascending to 900 m, Oudh forests, Burma, Chotanagpur, Kumaon, Sikkim (Wood, 1903; Brandis, 1906; Haines, 1910).

Genus—*Millettia* Wight & Arn.

Millettia auriculata Baker ex Brandis
Pl. 6, fig. 3

Material—Two incomplete leaflet-impressions with fair preservation.

Description—Leaf compound, leaflets length 7 and 5 cm, width 3.6 and 6.3 cm; lamina and base asymmetrical, ovate; apex acute, base obtuse, unequal; margin entire; texture chartaceous; glands not visible; petiole present, normal, only partly preserved; venation pinnate-camptodromous-eucamptodromous; primary vein (1°) moderate, straight; secondary veins (2°) with acute (moderate) angle of divergence, variation in angle of divergence nearly uniform, moderately thick, secondaries upturn and gradually diminishing inside the margin connected to superadjacent secondaries by series of cross-veins; both intersecondary and intramarginal veins present; tertiary veins (3°) with RR, reticulate to percurrent, reticulate orthogonal, percurrent, straight to retroflexed, oblique, constant, predominantly alternate, closely spaced; highest vein order of leaf 4°, further details could not be studied due to preservational factor.

Discussion—Ovate form, eucamptodromous venation, upturning and gradual diminishing of secondary veins near the margin, and presence of reticulate and percurrent tertiaries are the important characters of the present fossil leaflets which show near resemblance with the modern leaves/leaflets of *Mitragyna parvifolia, Psychortia truncata, Millettia auriculata* and *Aglaia exstipulata*. However, a detailed examination of fossil leaflets indicates a

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PLATE 7 →

Terminalia tomentosa Wt. & Arn.
1. Fossil leaf, natural size; Specimen no. BSIP 36287.
2. Details of venation of fossil leaf near margin. × 7.
3. Details of venation near midvein. × 7.
4. Modern leaf, natural size.

Mitragyna parvifolia (Roxb.) Korth.

5. Fossil leaf, natural size; Specimen no. BSIP 36288.
6. Details of venation near midvein. × 7.
7. Further details showing higher order venation. × 7.
8. Modern leaf, natural size.

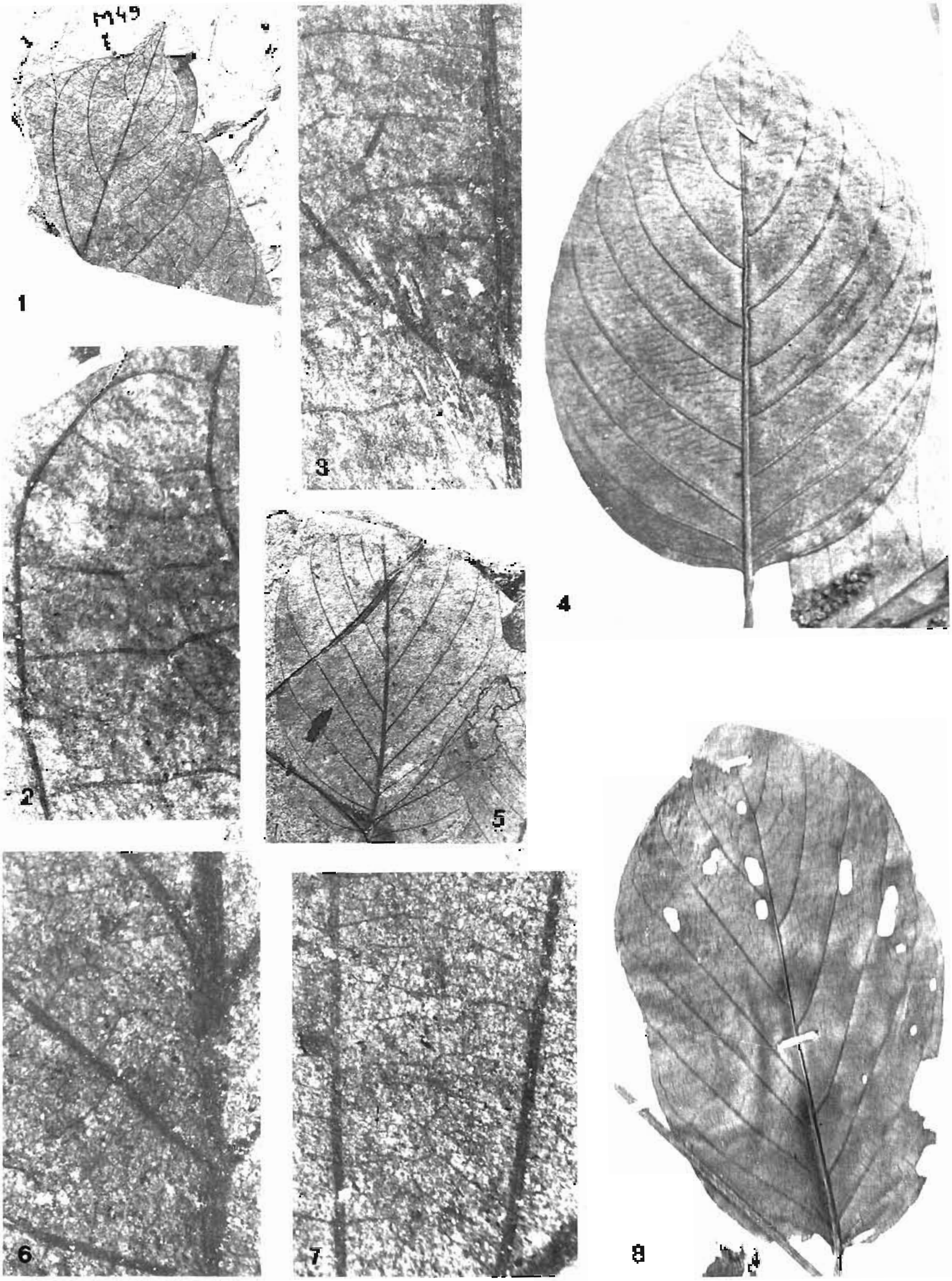

PLATE 7

close resemblance with those of *Millettia auriculata* (BSIP Herbarium sheet no. 14024; Pl. 6, fig. 4), although the shape, form and base of the leaflets vary considerably in the modern species.

The genus *Millettia* is fairly well-represented in the Tertiary of India known both by fossil woods as well as leaf-impressions. The fossil woods have been described under the generic name *Millettioxylon* Awasthi 1967 which represents the fossil woods of both *Millettia* and *Pongamia* as they are anatomically indistinguishable. Awasthi (1967) described *Millettioxylon indicum* (modern comparable form *Millettia pendula*) from the Cuddalore sandstones. Prakash (1975, 1978) described *Millettioxylon pongamiensis* (modern comparable form *Millettia prainii*) from the Siwalik beds of Nalagarh, Himachal Pradesh. The same species was later on described by Bande and Prakash (1980) from West Bengal. Ghosh and Roy (1979) also described one more species *Millettioxylon bengalensis* (modern comparable form *Millettia prainii*) from West Bengal. Lakhanpal *et al.* (1981) described *Millettioxylon palaeopulchera* (modern comparable form *Millettia pulchera*) from the Dupitila Series of Arunachal Pradesh. *Millettioxylon indicum* Awasthi 1967 was also reported by Lakhanpal *et al.* (1984) from Kachchh and compared with *Millettia pendula, M. prainii* and *Pongamia glabra*.

Fossil leaf-impressions, so far known, have been described under the generic name *Millettia* with four species. These are *Millettia asymmetrica* (modern comparable form *Millettia pendula, M. prainii, Pongamia glabra*) and *M. miocenica* (modern comparable form *Millettia auriculata* and *M. macrostachya*) described by Lakhanpal and Guleria (1982) and Lakhanpal *et al.* (1984) from Kachchh, *Millettia koilabasensis* (modern comparable form *Millettia macrostachys*) and *Millettia siwalicus* (modern comparable form *Millettia ovalifolia*) described by Prasad (1986) from the Siwalik beds of Koilabas, Nepal.

The genus *Millettia* consists of 180 species of trees, shrubs and woody climbers, distributed in the warmer regions of Africa, Asia and Australia (Willis, 1973). Twelve species occur in India (Santapau & Henry, 1973). *Millettia auriculata* is a woody climber found in the sub-Himalayan tract from Sutlej eastward, Bihar, central India, south to the Godavari and commonly occurs in Sal forest (Brandis, 1906). It is also very common in the forests of Chotanagpur region (Wood, 1903; Haines, 1910).

Genus— *Ougenia* Benth.

Ougenia oojeinensis (Roxb.) Hochr. syn.
O. dalbergioides Roxb.
Pl. 6, fig. 5

Material—A single incomplete leaflet-impression, the apical half of the leaflet not preserved.

Description—Leaf compound, leaflet length 6.0 cm, width 8.00 cm, appears symmetrical, ovate; apex not preserved; base rounded; margin entire; texture chartaceous; petiole present, inflated; venation pinnate, craspedodromous, simple; primary vein (1°) weak, straight, secondary veins (2°) with acute (moderate) angle of divergence, slightly recurved near the point of divergence, nearly uniform, curved uniformly, the lowest pair of secondary vein more obtuse and arise from the base of midvein; tertiary veins (3°) RO, further details not visible due to bad preservation.

Discussion—Ovate form, craspedodromous venation and inflated petiole are the important characters of the fossil leaflet which show its near affinity with the modern leaves/leaflets of *Erythrina suberosa, Pterygota alata, Ougenia oojeinensis, Oroxylum indicum* and *Mallotus philippensis*. However, it shows close resemblance with the leaflets of *Ougenia oojeinensis* (BSIP Herbarium sheet no. 14030; Pl. 6, fig. 6). The base and form of leaflets are variable in this species.

The only fossil wood of *Ougenia* from India is *Ougenioxylon tertiarum* described by Prakash and Tripathi (1977) from the Tipam sandstone of Assam and compared with *Ougenia oojeinensis*.

Ougenia Benth. is a monotypic genus distributed only in India (Willis, 1973; Santapau & Henry, 1973). It is found from Ravi eastward to Bhutan, not common in Bihar and Orissa except in Sambalpur, occurring throughout the central provinces, central India, Rajputana, Khandesh,

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PLATE 8 →

Madhuca indica J. F. Gmel.

1. Fossil leaf, natural size; Specimen no. BSIP 36289.
2. Another specimen, natural size; Specimen no. BSIP 36290.
3. Fossil leaf (fig. 2) magnified to show details of venation. × 1.5.
4. Fossil leaf (fig. 1) magnified to show details of venation. × 1.5.
5. Modern leaf, natural size.

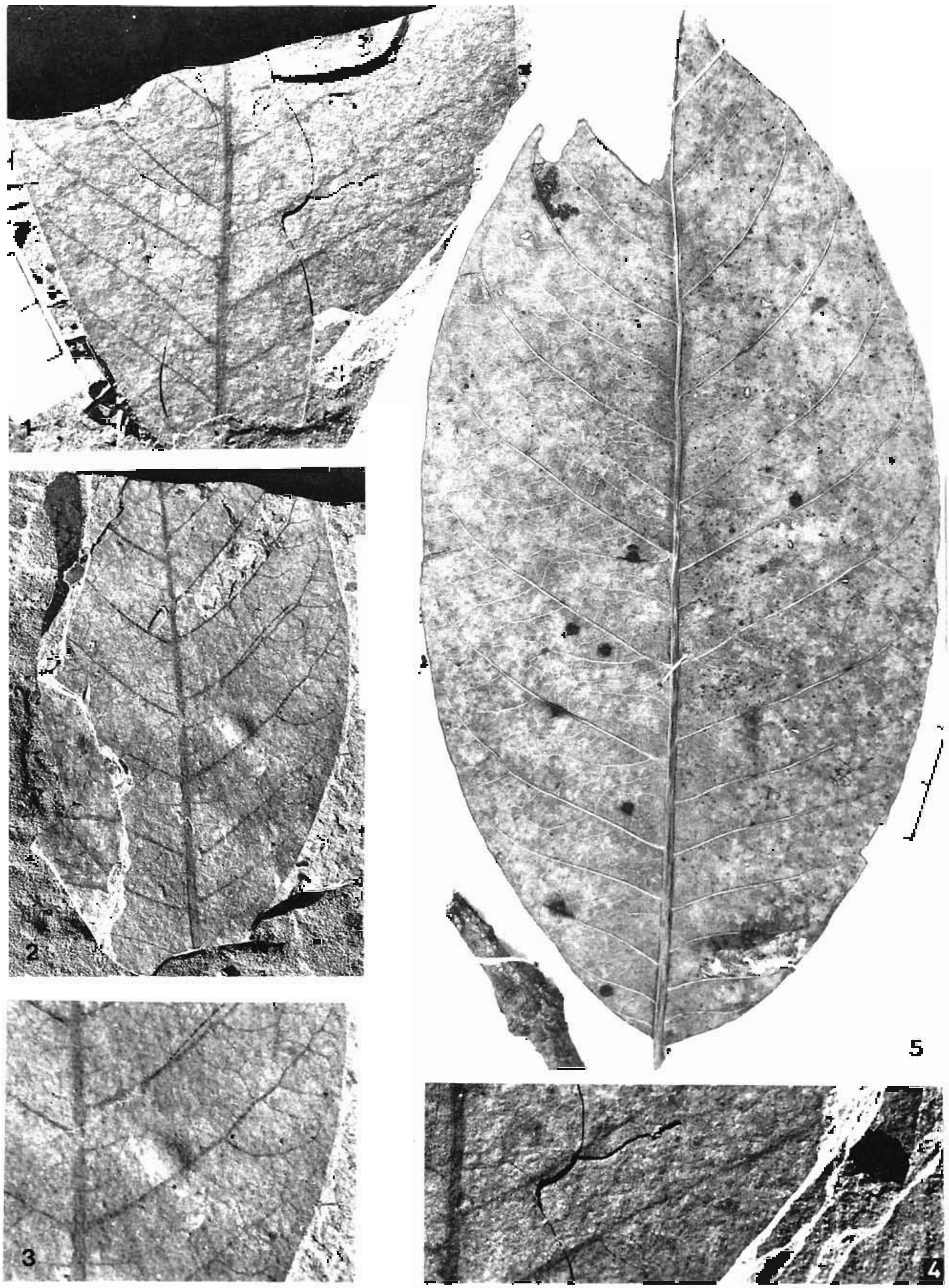

PLATE 6

Bombay, Deccan, Panch Mahalls, Deccan and North Kanara. It is not so common in south India, though found in central and north Coimbatore, Ganjam, Madura, Coorg, Hyderabad and Mysore (Pearson & Brown, 1932). It is also found in the forests of Chotanagpur region (Wood, 1903; Haines, 1910).

Family—Leguminosae (Caesalpinaceae)

Genus—*Bauhinia* Linn.

Bauhinia sp. cf. *B. purpurea* Linn.
Pl. 9, Fig. 1

Material—A single leaf-impression with its counterpart. Preservation at places is fair. The specimen represents a folded leaf and the tertiary veins are only visible at some places.

Description—Leaf simple, length 5.5 cm, width 3.5 cm, lamina and base both asymmetrical, ovate, apex rounded, base also approximately rounded, margin entire, texture coriaceous, glands not visible, petiole not preserved; venation actinodromous, position of primaries basal, perfect, primary veins (1) weak, one of the primary veins straight, while remaining four markedly curved; secondary veins (2°) with acute (moderate) angle of divergence, variation in angle of divergence nearly uniform, moderately thick, loop formation visible in the apical part, joining the superadjacent secondary at right angle, intersecondary and intramarginal veins absent, tertiary veins (3°) (R), reticulate, orthogonal, highest visible vein order of leaf 3°, highest vein order showing excurrent branching 3°, further details not visible.

Discussion—Actinodromous venation and entire margin are important features of the fossil leaf. The specimen is a folded leaf or may be one half of the leaf as clearly indicated by one of the margins of the fossil leaf which is running almost straight like an edge, whereas the other margin of the leaf shows curvature. Hence it indicates that the fossil leaf has been folded up from the side of sharp straight edge. This type of leaf is found in *Hardwickia* Roxb. and *Bauhinia* Linn. The leaves of *Hardwickia binata* although show some resemblance with the fossil leaf, differ in having almost acute apex. Thus the leaves of *Bauhinia* species namely *Bauhinia retusa*, *B. purpurea* and *B. vahlii* show somewhat close resemblance with the fossil, amongst which *B. purpurea* is the closest. Because of poor preservation the fossil is being described as *Bauhinia* sp. cf. *B. purpurea* (NBRI Herbarium sheet no. 52236).

Both leaf-impressions and petrified woods of *Bauhinia* have been recorded from various Neogene localities of India. Rawat (1964) described *Bauhinioxylon indicum* from the Siwalik beds of Mohand near Dehradun but because there are no figure and description, it was discarded as an invalid name, according to ICBN. However, fossil woods of *Bauhinia* have also been described from the Siwalik sediments of Uttar Pradesh by Prakash and Prasad (1984) and Trivedi and Panjwani (1986). Ramanujam and Rao (1966) described a fossil wood of *Bauhinia* from the Cuddalore sandstones but its affinities are doubtful. According to Prakash and Prasad (1984) it might belong to *Millettia*. Guleria (1980) has reported the occurrence of a fossil wood of *Bauhinia* from the Tertiary of Rajasthan. Recently a fossil wood of *Bauhinia deomalica* has also been described from the Namsang beds of Arunachal Pradesh (Awasthi & Prakash, 1986).

Lakhanpal and Awasthi (1984) described fossil leaves of *Bauhinia siwalika* from the Siwalik beds of Uttar Pradesh (comparable forms—*B. diptera*, *B. hookeri*, *B. tomentosa* and *B. corymbosa*). Lakhanpal and Guleria (1982) described *B. kachchhensis* (modern comparable forms *B. phoenicea* and *B. purpurea*) from the Miocene of Kachchh, Gujarat. A *Bauhinia* type of leaf was reported by Lakhanpal (1970) from the Siwalik beds but it was not substantiated by any description and photograph.

Genus *Bauhinia* Linn. consists of about 300 species of shrubs, small trees and woody climbers widely distributed throughout the tropics of the World (Ramesh Rao & Purkayastha, 1972; Willis, 1973) and about 40 species occur in India and Burma (Brandis, 1906).

Bauhinia purpurea which compares closely with the fossil leaf, is a moderate sized tree found from the Indus eastwards in the forests of sub-Himalayas to Assam, in Chittagong (Bangla Desh), hills of Upper Burma, throughout the forests of Bihar

PLATE 9 →

Diospyros montana Roxb.
1. Fossil leaf, natural size, Specimen no. BSIP 36291.
2. Details of venation near midvein × 7.
3. Details of venation near margin × 7.
4. Modern leaf, natural size.

Alstonia scholaris Brown
5. Fossil leaf, natural size, specimen no. BSIP 36292.
6. Modern leaf, natural size.
7. Fossil leaf (fig. 5) further enlarged to show details of venation × 2.

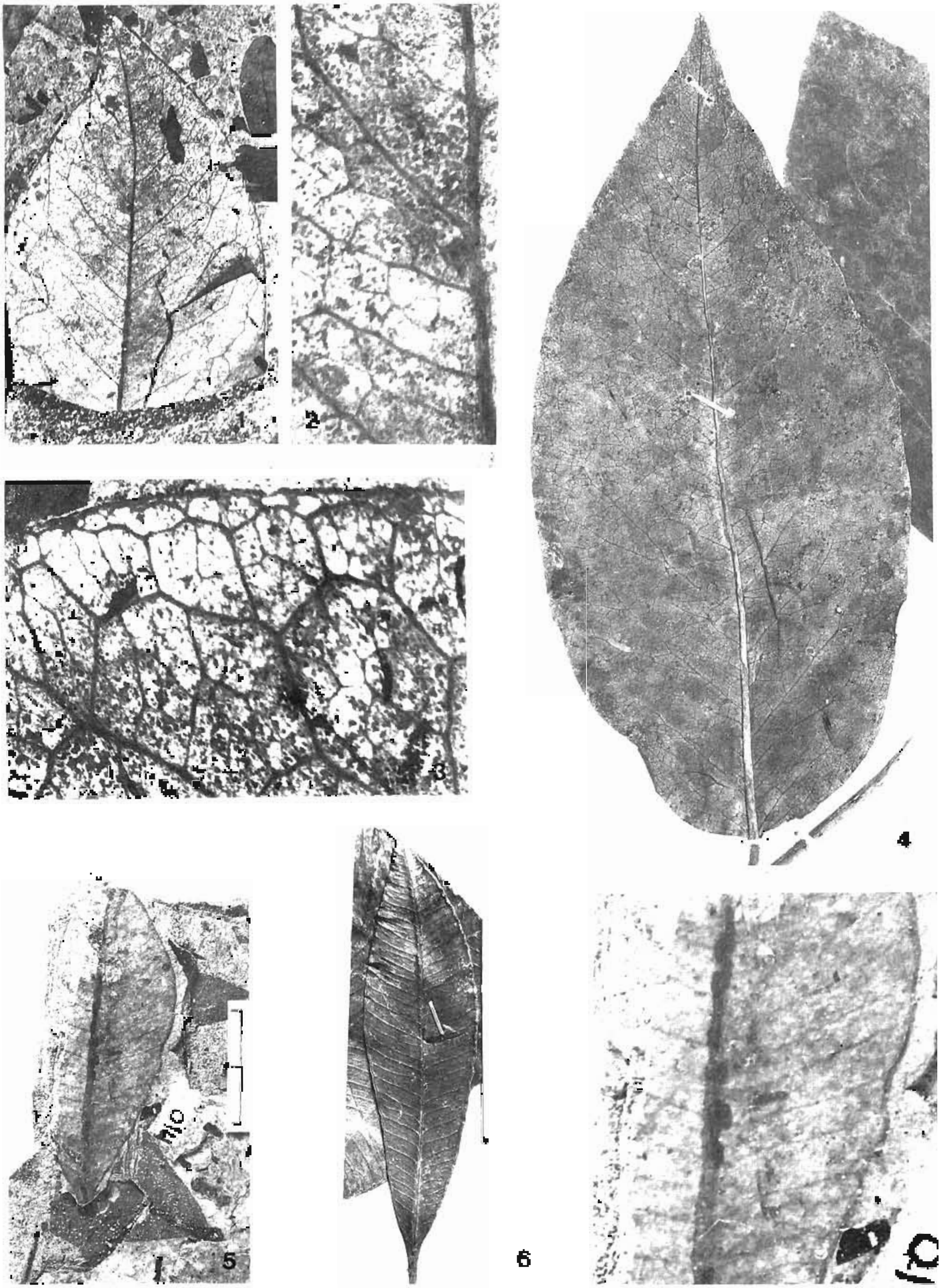

PLATE 9

and Orissa, the central Provinces, Khandesh, Deccan, Konkan, Northern Circars, Karnataka and on the West Coast in the drier areas. It is also found in the forests of Chotanagpur region (Wood, 1903; Brandis, 1906; Haines, 1910).

Family—Combretaceae

Genus—*Combretum* Loefl.

Combretum decandrum Roxb.
Pl. 2, figs 1, 3

Material—Two incomplete fairly well-preserved leaf-impressions.

Description—Leaf simple, length 12.00 cm and 8.4 cm, width 3.5 and 5 cm respectively; lamina and base symmetrical, oblong (narrow oblong); apex not preserved, base acute normal; margin entire; texture chartaceous; glands not visible; petiole normal; venation pinnate-camptodromous-eucamptodromous; primary vein (1°) stout, markedly curved; secondary veins (2°) with acute (narrow) angle of divergence, uniform, thick, upturned and gradually diminishing inside the margin connected to superadjacent secondary by a series of cross veins, enclosed by arches of 3°; tertiary veins (3°) RR, percurrent, retroflexed, approximately at right angle, predominantly alternate; closely spaced; highest vein order of leaf 4°; highest vein order showing excurrent branching 4°; quaternary veins thick, orthogonal, marginal ultimate venation looped; areoles well-developed, oriented, quadranglar to pentagonal, veinlets none.

Discussion—Oblong form, eucamptodromous venation and percurrent tertiary veins are the important characters of the fossil leaves which show its near resemblance with the leaves of various genera of Lauraceae, *Cocculus* spp., *Ryparosa kunstleri* and with *Combretum decandrum*. However, in details of leaf architecture they show close resemblance with the modern leaves of *Combretum decandrum* (BSIP Herbarium sheet no. 11025; Pl. 2, fig. 4).

As per our information no fossil of *Combretum* has been described so far from India, although fossils of *Anogeissus*, *Terminalia* and *Calycopteris* of the family Combretaceae are known to occur from the Tertiary of India (Bande & Prakash 1984; Prasad, 1986).

The genus *Combretum* comprises about 260 species found in the tropical and subtropical regions of the old and new world, the majority in Africa (Brandis, 1906). *Combretum decandrum* is a large climbing shrub, found in the sub-Himalayan tract from Jamuna eastwards, Sikkim up to 650 m, Assam, Chittagong (Bangla Desh), Burma, Bihar, central Provinces, northern Circars and the northern Deccan (Brandis, 1906). It is also a common climber in the forests of Chotanagpur region (Wood, 1903; Haines, 1910).

Genus—*Terminalia* Linn.

Terminalia tomentosa Wight & Arn.
Pl. 7, figs 1-3

Material—Single incomplete leaf-impression with apical half preserved.

Description—Leaf simple, length 4.4 cm, width 4.5 cm, nothing could be stated about the balance, form and base of the leaf as only the apical half of the leaf is preserved; apex acuminate; margin entire; texture chartaceous; glands not visible; petiole not preserved; venation pinnate-camptodromous-eucamptodromous; primary vein (1°) straight; secondary veins (2°) with acute (moderate) angle of divergence, variation in angle of divergence nearly uniform, moderately thick, secondaries upturned and gradually diminishing apically inside the margin, connected to the superadjacent secondaries by a series of cross veins without forming prominent marginal loopes; intersecondary and intramarginal veins absent; tertiary veins (3°) with angle of divergence AR, percurrent, retroflexed, relationship with midvein oblique, constant, alternate to opposite in about equal numbers, closely spaced; highest vein order of leaf 4°, highest vein order showing excurrent branching 4°, quaternary veins thick, orthogonal, marginal ultimate venation looped; areoles well-developed, oriented, quadrangular to pentagonal (mostly quadrangular), veinlets none.

PLATE 10 →

Cryptolepis buchanani Roem. & Schult.

1. Fossil specimen, natural size; Specimen no. BSIP 36293.
2. Another fossil specimen, natural size; Specimen no. BSIP 36294.
3. Counterpart of fig. 2.
4. Details of venation of fossil lef (fig. 2) near margin. × 7.
5. Details of venation of fossil leaf (fig. 1) near midvein. × 7.
6. Modern leaf, natural size.

Mallotus philippensis Muell-Arg.

7. Fossil leaf natural size; Specimen no. BSIP 36295.
8. Details of venation of fossil leaf. × 7.
9. Modern leaf, natural size.

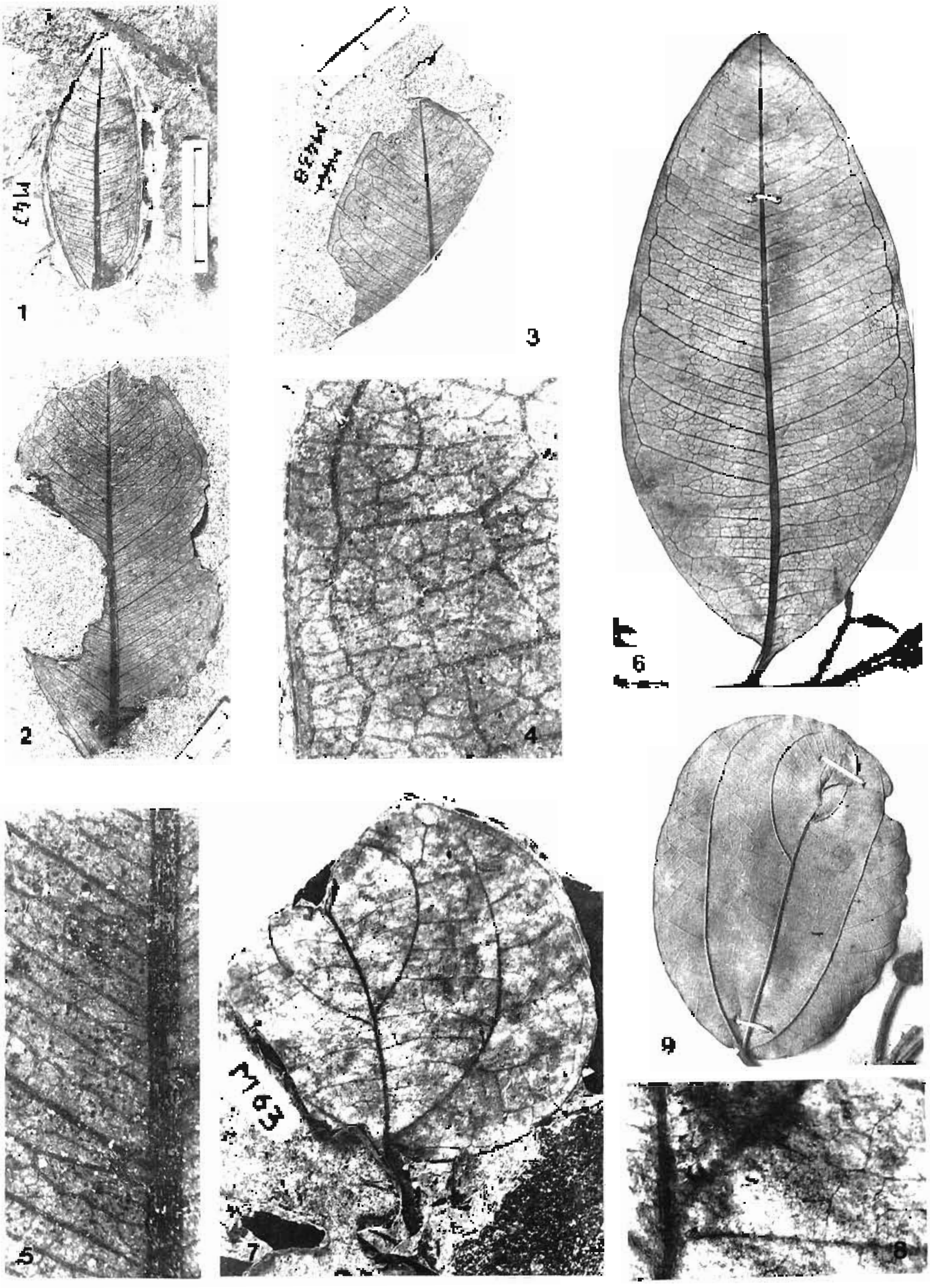

PLATE 10

Discussion—Eucamptodromous venation with percurrent tertiary veins are the important features of the fossil leaf. Such characters have been found in the leaves of *Terminalia* spp., *Anthocephalus cadamba* and *Artocarpus chaplasa*. However, the leaves of *Anthocephalus cadamba* differ from the present fossil in having predominantly alternate arrangement of tertiaries which are distantly spaced. In *Artocarpus chaplasa* the secondaries are with prominent marginal loops which distinguish it from the fossil leaf. A detailed examination reveals that it only shows close resemblance with the modern leaves of *Terminalia tomentosa* in almost all characters (F.R.I. Herbarium sheet no. Kef. III; Pl. 7, fig. 4).

Both fossil woods and leaf-impressions of *Terminalia* are known from various Tertiary localities of India. Most of the fossil woods have been described under the generic name *Terminalioxylon* Schonfeld of which 16 species are known from different Indian Cenozoic horizons, viz., Cuddalore sandstones, Tipam sandstones, Dupitila series of Arunachal Pradesh, the Siwalik beds, Tertiary beds of West Bengal, Andhra Pradesh, Kachchh, Ghala (Surat District of Gujarat) and from Kerala (Mahabale & Deshpande, 1965; Prakash, 1966; Ramanujam, 1966; Awasthi, 1982; Guleria, 1983; Bande & Prakash, 1984; Lakhanpal *et al.*, 1984). Out of these, *Terminalioxylon felixii, T. tertiarum, T. tomentosum* and fossil wood of *Terminalia tomentosa* have been shown to bear close resemblance with the modern woods of *Terminalia tomentosa*.

Fossil leaves of *Terminalia* have been described under the modern generic name. Lakhanpal (1970) has reported a leaf-impression resembling *Terminalia* from the Siwalik beds of Himachal Pradesh. Lakhanpal and Guleria (1981) and Lakhanpal *et al.* (1984) have described two species, viz., *Terminalia panandhroensis* (modern comparable form *T. crenulata*) and *T. kachchhensis* (modern comparable form *T. chebula*) from Tertiary of Kachchh. Tripathi and Tiwari (1983) have described a leaf-impression cf. *T. arjuna* from the Siwalik beds of Koilabas. Recently Prasad (1986) has also described *T. koilabasensis* (modern comparable from *T. angustifolia* Jacq.) and *T. siwalica* (modern comparable form *T pyrifolia*) from the Siwalik beds of Koilabas, Nepal.

The genus *Terminalia* comprises about 250 species (Willis, 1973). They are large trees distributed widely in the tropics of the world. In India, 12 species are known to occur (Santapau & Henry, 1973). The species which grow wild in the Chotanagpur region are *Terminalia catappa, T. belerica, T. chebula, T. arjuna* and *T. tomentosa*. *Terminalia tomentosa* is a large tree found in the sub-Himalayan tract from Ravi eastward, ascending up to 1,300 m, commonly throughout India including Chotanagpur region (except in arid regions) and Burma. It thrives best in heavy clay soil (Brandis, 1906).

Terminalia tomentosa has been described as a complex in various publications by atleast four authors, viz., Beddome, Clarke, Cooke and Wight and Arnold (Ramesh Rao & Purkayastha, 1972). This complex comprises several plant groups showing wide range of variation. Hitherto botanists and foresters were generally content to regard this plant complex as one species. However, a critical examination of this complex by Parkinson (1937) shows that *Terminalia tomentosa* auct. div. is actually a mixture of: (i) *Terminalia crenulata*, (ii) *T. coriacea*, and (iii) *T. alata*.

Family—Rubiaceae

Genus—*Mitragyna* Korth.

Mitragyna parvifolia (Roxb.) Korth.
Pl. 7, figs 5-7

Material—Single incomplete leaf-impression, apex is not preserved.

Description—Leaf simple, leaf length 5.6 cm, width 3.8 cm, lamina and base slightly asymmetrical, oblong (wide oblong); apex not preserved; base appearing rounded, one side seems cuneate; margin entire; texture chartaceous; glands not visible; petiole not preserved; venation pinnate-camptodromous-eucamptodromous; primary vein (1°) moderate, almost straight; secondary veins (2°) with acute (narrow) angle of divergence, lowest pair of secondary veins more obtuse than pairs above; secondaries gradually diminishing apically inside

PLATE 11 →

Mallotus philippensis Muell-Arg.

1. Another fossil leaf specimen, natural size; Specimen no. BSIP 36296.
2. Venation details of fossil leaf. × 7.

Ficus foveolata Wall. ex Miq.

3-5. Fossil leaves, natural size; Specimen nos. BSIP 36297, 36298, 36299.
6. Details of venation of fossil leaf (fig. 3) near midvein. × 7.
7. Details of venation of fossil leaf (fig. 3) near margin. × 7.
8. Modern leaf, natural size.

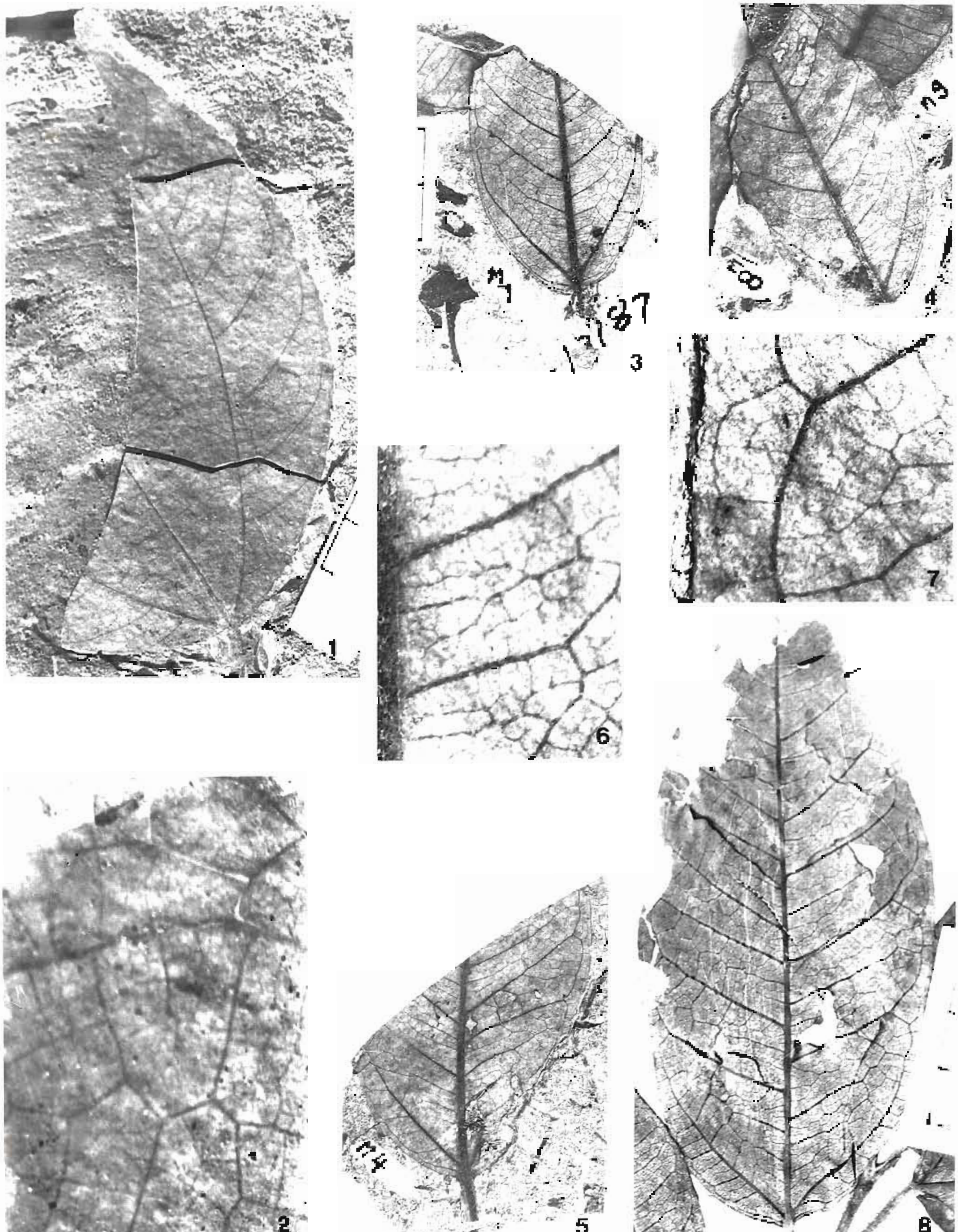

PLATE 11

the margin, connected to the superadjacent secondary by a series of cross veins without forming prominent loops, intersecondary and intra-marginal veins absent; tertiary veins (3°) RA, reticulate and percurrent both, reticulate orthogonal, retroflexed, percurrent retroflexed, oblique, constant, closely spaced; highest vein order of leaf 4°; highest vein. order showing excurrent branching 3°, quaternary veins thin, orthogonal, marginal ultimate venation incomplete; areoles well-developed, oriented, mostly quadrangular, veinlets none.

Discussion—Wide oblong leaf with eucamptodromous venation without loop formation by secondary veins and reticulate as well as percurrent tertiaries are the important characters of fossil leaf. It indicates near resemblance with the leaves of *Millettia auriculata, Shorea robusta, Mitragyna parvifolia* and *Psychortia truncata.* However, it shows close resemblance with that of *Mitragyna parvifolia.* The shape and base of leaf is quite variable in this species (F.R.I. Herbarium sheet nos. 105400, 1343/111465; Pl. 7, fig. 8; BSIP Herbarium sheet no. 14080).

From the Tertiary of India, only two genera of family Rubiaceae are known. Lakhanpal and Awasthi (1984) described a leaf-impression of *Gardenia palaeoturgida* (modern comparable form *Gardenia turgida*) from Siwalik beds near Bhikhnathoree, West Champaran District, Bihar; while Prasad (1986) described a leaf-impression of *Randia miowallichii* (modern comparable form *Randia wallichii*) from the Siwalik beds of Koilabas.

The genus *Mitragyna* comprises about 15 species of trees and shrubs distributed from tropical Africa through the Indo-Malayan region to New Guinea (Willis, 1973; Pearson & Brown, 1932). Three species are known to occur in India (Santapau & Henry, 1973). *Mitragyna parvifolia* is a large dedicuous tree found throughout India, distributed from foot- and outer hills of north-west Himalaya from Bias eastwards, ascending to 1,250 m, Bihar, central India, common in both peninsulas (Brandis, 1906). It is also common in the forests of Chotanagpur region, often gregarious in moist places (Wood, 1903; Haines, 1910).

Family—Sapotaceae

Genus—*Madhuca* J. F. Gmel.

Madhuca indica J. F. Gmel.
Pl. 8, figs 1-4

Material—Two incomplete leaf-impressions without base and apex. Preservation is fair enough to reveal the finer details of the leaf architecture.

Description—Leaf simple, length 6.5 and 8 cm, maximum width on one side of midrib 5 and 3 cm respectively; nothing can be stated about the base and apex, the leaf appears to be elliptic; margin entire; texture chartaceous, glands not visible; petiole not preserved; venation pinnate-camptodromous-eucamptodromous; primary vein (1°) massive, straight; secondary veins (2°) with acute (moderate) angle of divergence, variation in angle of divergence uniform, moderately thick, secondaries upturned and gradually diminishing inside the margin connected to superadjacent secondaries by a series of cross veins without forming prominent loops, intersecondary veins present, simple intra-marginal vein absent; tertiary veins (3°) with angle of divergence AA, pattern generally reticulate but few tertiaries also show exmedial ramified pattern, predominantly alternate, closely spaced; highest vein order of leaf 4° which also shows the highest vein order showing excurrent branching, quaternary veins thin, orthogonal, marginal ultimate venation looped; areoles well-developed, random, quadrangular to rectangular, veinlets none.

Discussion—Eucamptodromous venation, massive primary vein, and some tertiaries with exmedial ramified pattern are the important characters of the fossil leaves, which show a near resemblance with the leaves of various species of *Terminalia, Dipterocarpus tuberculatus, Madhuca indica, Anthocephalus cadamba* and *Semecarpus anacardium.* However, the detailed comparison shows their close similarity with that of *Madhuca indica* (BSIP Herbarium sheet no. 14041; Pl. 8, fig. 5).

So far, only fossil wood of *Madhuca* is known

PLATE 12 →

Ficus glaberrima Blume

1. Fossil leaf, natural size; Specimen no. BSIP 36300.
2. Modern leaf, natural size.
3. Details of venation of fossil leaf near midvein. × 7
4. Details of venation of fossil leaf near margin. × 7

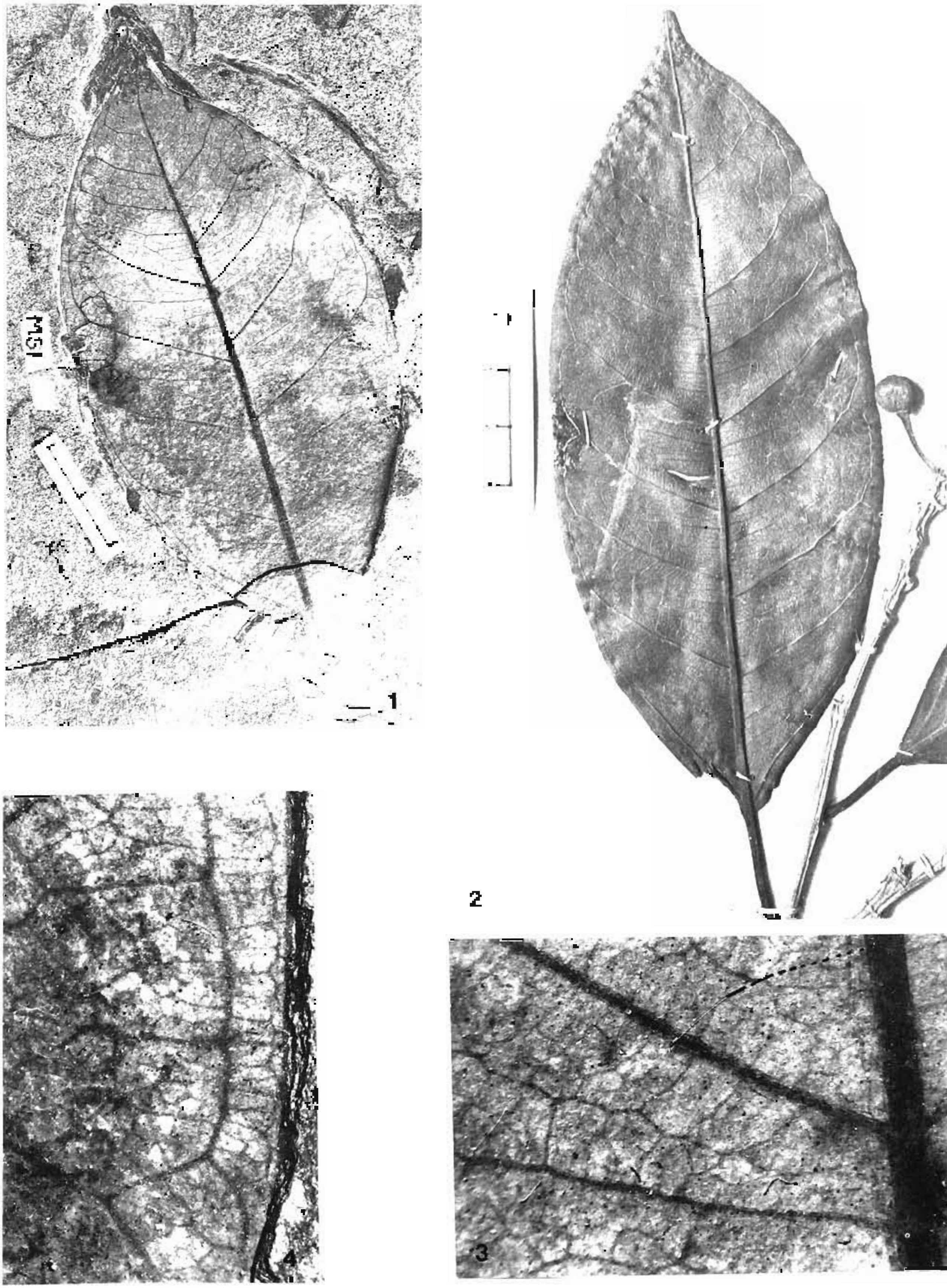

PLATE 12

from India. Prakash and Tripathi (1977) described *Madhucoxylon cacharense* (modern comparable form *Madhuca butyracea*) from the Tipam sandstones of Assam.

The genus *Madhuca* consists of 85 species distributed in Indochina, Indo-Malayan region especially in West Malaysia and Australia (Willis, 1973). Only five species are known to occur in India (Santapau & Henry, 1973), out of which two including *M. indica* grow in the Chotanagpur region (Wood, 1903; Haines, 1910; Paul, 1984). *Madhuca indica* is a large tree found from Ravi eastward, in Oudh and Kumaon in the foot-hills of Himalayas, extending to Chotanagpur and Orissa; throughout central Provinces, Khandesh, Gujarat, Konkan and Deccan; scarce in Kanara, north Circars especially in Godavari, southward Salem and Coimbatore. It is also, widely cultivated (Pearson & Brown, 1932).

Family—Ebenaceae

Genus—*Diospyros* Linn.

Diospyros montana Roxb.
Pl. 9, figs 1-3

Material—Single incomplete leaf-impression, only the upper half of the leaf with apex present. Preservation is fair.

Description—Leaf simple, length 5.3 cm, width 3.5 cm, nothing can be stated about balance, form and base of the leaf, as the whole leaf is not preserved; apex acute; margin entire; texture chartaceous; glands absent; petiole not preserved; venation pinnate-camptodromous-cladodromous; primary vein (1°) moderately thick, markedly curved; secondary veins (2°) with acute angle of divergence, variation in angle of divergence nearly uniform, fine to hair-like, curved abruptly, secondaries freely ramified toward the margin, intersecondary veins present, composite; tertiary veins (3°) RR to RO, reticulate; orthogonal; highest vein order of leaf 4°, highest vein order showing excurrent branching 3°, quaternary veins moderate, orthogonal, marginal ultimate venation looped; areoles appear to be well-developed.

Discussion—Cladodromous venation with fine to hair-like secondary veins freely ramified towards the margin are the important characters of the fossil leaf, which show its near resemblance with the leaves of *Garcinia gummigutta, Garcinia indica, Diospyros montana, Schefflera stellata, Cyathocalyx zeylanicus* and *Chloroxylon swietenia*. However, in the details of leaf architecture the fossil shows strong resemblance with the modern leaves of *Diospyros montana* (BSIP Herbarium sheet no. 14070; Pl. 9, fig. 4)

The genus *Diospyros* is fairly well known from various Tertiary localities of India both in the form of fossil woods and leaf-impressions. The woods assignable to *Diospyros* have been described under the generic name *Ebenoxylon* Felix whereas fossil leaves have been described under *Diospyros*. From the Lower Siwalik sediments Prakash (1978, 1981) described two species *Ebenoxylon miocenicum* (modern comparable form *Diospyros kurzii*) and *E. siwalicus* (modern comparable form *D. disiana*), from Tipam sandstones Prakash and Tripathi (1970) described *Ebenoxylon kartikcheriense* (modern comparable form *D. ehretioides*), from Cuddalore sandstones Awasthi (1970) described *Ebenoxylon arcotense* (modern comparable form *Diospyros assimilis*), and from Dupitila Series Ghosh and Kazmi (1958) described *Ebenoxylon indicus* (modern comparable form *Diospyros* sp.). However, leaf-impressions are known only from the Siwalik beds. Prasad (1986) described two fossil leaves namely *Diospyros koilabasensis* (modern comparable form *D. montana*) and *D. pretoposia* (modern comparable form *D. toposia*).

The genus *Diospyros* consists of about 500 species of trees, rarely shrubs, distributed in tropical and mild temperate regions of the world (Willis, 1973). About 40 species are known from India, out of which 10 including *D. montana* occur in the Chotanagpur region (Wood, 1903; Haines, 1910; Santapau & Henry, 1973; Paul, 1984). *Diospyros montana* is a small or moderate-sized tree growing throughout most parts of India and Burma from Ravi eastward along the Himalayas, in central, western and southern India (Gamble, 1922).

Family—Apocynaceae

Genus—*Alstonia* R. Brown

Alstonia scholaris Brown
Pl. 9, figs 5, 7

Material—Single incomplete leaf-impression; preservation satisfactory.

Description—Leaf simple, length 4.5 cm, maximum width on one side of midrib 1.4 cm, lamina and base symmetrical; narrow obovate; apex nearly obtuse; complete base not preserved, appears to be acute (cuneate); margin revolute; texture chartaceous; petiole not preserved; venation pinnate-camptodromous-brochidodromous but the loops are not prominent; primary vein (1°) stout, straight; secondary veins (2°) arising at acute (wide) angle, variation in angle of divergence nearly uniform, fine, curved, bending in arc uniform, loop forming branches joining superadjacent secondary at an obtuse angle; intersecondary veins not visible, intramarginal vein absent; tertiary veins (3°) with angle of divergence RR, more prominent on exmedial side, pattern ramified (admedial) predominantly alternate, closely spaced; highest vein order visible 3°, highest vein order showing excurrent branching 3°, marginal ultimate venation fimbriate; areoles well-developed, oriented, quadrangular to pentagonal, veinlets none.

Discussion—Important characters of the fossil leaf are narrow obovate form, revolute margin, wide acute secondaries and ramified (admedial) pattern of tertiary veins. These characters of the fossil show its resemblance with the modern leaves of *Holigarna beddomei, Semecarpus anacardium, Spondias pinnata, Alstonia scholaris* and *Garcinia travancorica*. But on the basis of all important characters it closely resembles the modern leaf of *Alstonia scholaris* (F.R.I. Herbarium sheet no. 7123; Pl. 9, fig. 6).

As far as the authors are aware there is no fossil record of the genus *Alstonia* from India. The only fossil of the family Apocynaceae known from India is *Tabernaemontana precoronaria* from the Siwalik sediments by Prasad (1986). This fossil leaf according to author shows closest affinity with the modern leaves of *Tabernaemontana coronaria* Willd.

The genus *Alstonia* consists of over 30 species of trees or rarely upright shrubs mostly distributed through the Indo-Malayan region, Australia and Polynesia. Only one species occurs in the tropical Africa (Willis, 1973). *Alstonia-scholaris* is a very large tree found mostly in deciduous forests, from the Yamuna eastwards through Uttar Pradesh, Bengal, Assam, scarce in Bihar, Orissa and Chotanagpur but common in the west coasts. It also extends to Sri Lanka in south and in the east up to Philippines through Burma and Malay Peninsula and Archipelago (Brandis, 1906; Pearson & Brown, 1932).

Family—Asclepiadaceae

Genus—*Cryptolepis* R. Br.

Cryptolepis buchanani Roem. & Schult.
Pl. 10, figs 1-5

Material—Two leaf-impressions with their counterparts. Preservation is excellent.

Description—Leaf simple, length 8.0 and 4.5 cm, width 4 and 1.6 cm respectively; lamina and base both symmetrical, elliptic, apex acute; base not fully preserved but appears to be normal acute; margin entire; texture coriaceous; petiole not preserved; venation pinnate-camptodromous-brochidodromous; primary vein (1°) stout, straight, secondary veins (2°) with acute (moderate) angle of divergence, variation in angle of divergence nearly uniform, moderately thick, curved abruptly, joining superadjacent secondary at obtuse angle, intersecondary veins present, composite, intramarginal vein absent; tertiary veins (3°) with angle of divergence AR to RR, orthogonal, reticulate; highest vein order 4°, highest vein order showing excurrent branching 3°, quaternary veins thick, orthogonal, marginal ultimate venation looped; areoles well-developed, random, irregular in shape (mostly quadrangular), veinlets none.

Discussion—Elliptic form, acute apex, brochidodromous venation and looped marginal ultimate venation are the prominent characters of the fossil leaves which indicate their near resemblance with the leaves of *Syzygium cumini, Cassia fistula, Cryptolepis buchanani, Ochna squammosa* and *Ficus microcarpa* syn. *F. retusa*. However, on the basis of leaf architecture they closely resemble *Cryptolepis buchanani* (BSIP Herbarium sheet no. 14014, F.R.I Herbarium sheet no. 9/11837; Pl. 10, fig. 6).

As per authors' information, so far there is no fossil record of the family Asclepiadaceae from the Tertiary of India.

The genus *Cryptolepis* consists of about 15 species and is confined to the tropics of Asia, Malaysia, and Pacific Islands (Willis, 1973). According to Santapau and Henry (1973), three species are known from India *Cryptolepis buchanani* is a climbing shrub found throughout India and common in the sub-Himalayan tract and outer hills from Kashmir eastward, ascending to 1,600 m, Oudh, Bihar (including Chotanagpur), central provinces, Singhbhum and western Peninsula (Wood, 1963; Brandis, 1906; Haines, 1910).

Family—Euphorbiaceae

Genus—*Mallotus* Lour.

Mallotus philippensis Muell-Arg.
Pl. 10, figs 7, 8; Pl. 11, figs 1, 2

Material—Two incomplete well-preserved leaf-impressions, one of them with its counterpart; apex in none of the specimens present.

Description—Leaf simple, length 10.5 and 4 cm, maximum width on one side of the midrib 5.1 and 2.8 cm respectively; ovate, lamina appears to be symmetrical; base symmetrical, rounded; apex not preserved; margin entire; texture chartaceous; glands not visible; petiole present, normal; venation acrodromous, basal, perfect; primary veins (1°) with middle primary vein moderately thick, markedly curved in one whereas straight in the other specimen; secondary veins (2°) originate from one side (marginal side) of lateral primaries and from the upper half of middle primary, with acute (moderate) angle of divergence, nearly uniform, moderately thick, curved abruptly, joining superadjacent secondary at obtuse angle, also enclosed by secondary arches of 3° near the margin, intersecondary and intramarginal veins absent; tertiary veins (3°) RR, percurrent, simple (the tertiaries which arise from the middle are at right angle with the middle primary while the marginal tertiary veins are oblique in relationship with the midvein); angle of divergence varies from right angle to oblique, predominantly alternate, closely spaced; highest vein order of leaf 4°, highest vein order showing excurrent branching 4°, quaternary veins thick, orthogonal, marginal ultimate venation looped; areoles well-developed, random, quadrangular to polygonal, veinlets none.

Discussion—Ovate form, acrodromous venation, loop forming secondary veins and percurrent tertiary veins are the important characters of the fossil leaves. These indicate their near resemblance with the modern leaves of *Pterygota alata, Mallotus philippensis, Moghamia chappar, Erythrina suberosa* and *Oroxylum indicum*. However, a detailed comparison shows their close resemblance with those of *Mallotus philippensis* (F.R.I. Herbarium sheet no. 8649; Pl. 10, fig.9). The shape and size in the leaves of *Mallotus philippense* vary to a great extent.

Fossil woods as well as leaf-impressions of *Mallotus* are known from India. Fossil woods have been described under the generic name *Mallotoxylon* Lakhanpal & Dayal 1964, whereas leaf-impressions are known under the generic name *Mallotus* itself. Lakhanpal and Dayal (1964) described *Mallotoxylon keriense* (modern comparable form *Mallotus philippensis*) from the Deccan Intertrappean beds of Keria in Chhindwara District of Madhya Pradesh and Prakash and Tripathi (1975) described *Mallotoxylon assamicum* (modern comparable form *M. philippensis*) from the Tipam sandstones of Assam. Later, Roy and Ghosh (1982) described *Mallotoxylon cleidinoides* from the Tertiary beds of Shantiniketan in West Bengal and traced the affinities of their fossil wood with *Cleidion javanicum*.

Leaf-impressions of *Mallotus* have so far been described only from the Siwaliks and the Karewa beds. Puri (1947a) described leaf-impressions of *M. philippensis* from the Karewa beds of Kashmir, whereas Pathak (1969) described the same species from the Siwalik beds of Mahanadi River Section near Darjeeling, West Bengal. Mathur (1978) also described leaf-impressions resembling *Mallotus* sp. from the Siwalik beds near Jawalamukhi, Himachal Pradesh.

The genus *Mallotus* Lour. consists of about 150 species confined to the tropical Africa, Madagascar, East and south-east Asia, Indo-Malaya to new Caledonia, Fiji and north-east Australia (Willis, 1973). In India, 20 species are found (Santapau & Henry, 1973). *Mallotus philippensis* is a large shrub or small tree found in the sub-Himalayan tract from Punjab eastwards ascending to 1,400 m, Bengal, central provinces and in both peninsulas (Brandis, 1906). It also occurs in the forests of Chotanagpur region and is considered to be a close associate of *Shorea robusta* (Wood, 1903; Haines, 1910).

Family—Urticaceae (Moraceae)

Genus—*Ficus* Linn.

Ficus foveolata Wall. ex Miq.
Pl. 11, figs 3-7

Material—Two incomplete leaf-impressions, one of them with its counterpart. Apex is absent in both the specimens. Preservation is good.

Description—Leaf simple, length of leaves 4.8 and 4 cm, width 3.2 and 3 cm, lamina and base

PLATE 13 →

Ficus tomentosa Roxb.
1. Fossil leaf, natural size; Specimen no. BSIP 36301.
2. Modern leaf, natural size.
3. Venation details of fossil leaf. × 2.
4. Higher order venation details. × 7.

Dalbergia sissoo Roxb.
5. Fossil fruit cf. *Dalbergia sissoo*, natural size; Specimen no. BSIP 36302.
6. Modern fruit, natural size.

Zizyphus mauritiana Lamk.
7. Fossil fruit cf. *Zizyphus mauritiana*, natural size; Specimen no. BSIP 36303.
8. Modern seed, natural size.

Zizyphus xylopyrus Willd
9. Fossil fruit cf. *Zizyphus xylopyrus*, natural size; Specimen no. BSIP 36304.
10. Modern fruit, longitudinal section, natural size.
11. Dicot flower, natural size; Specimen no. BSIP 36305.

Dillenia sp.
12. Fossil fruit cf. *Dillenia* sp. natural size, Specimen no. BSIP 36306.
13. Modern fruit of *Dillenia*, natural size.

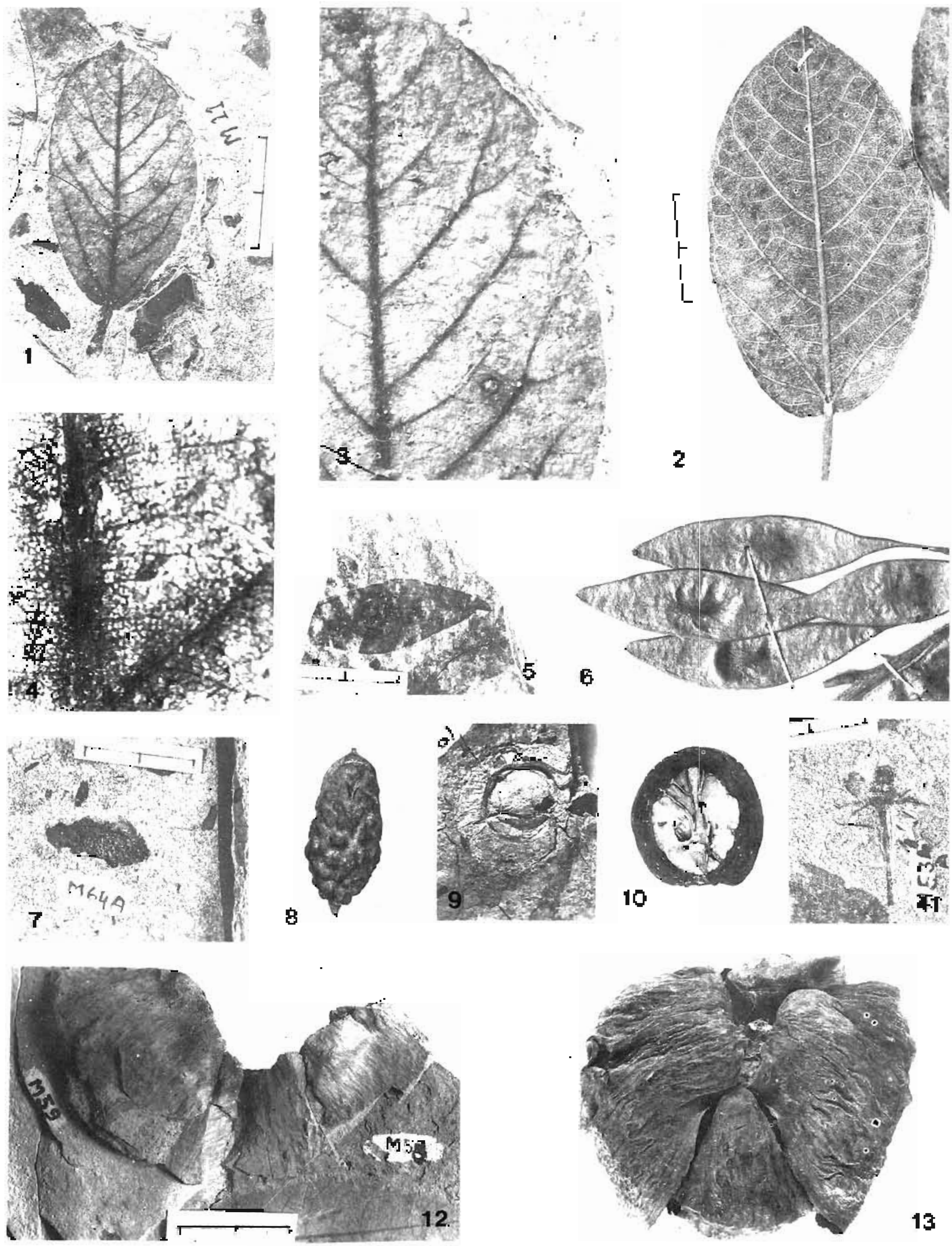

PLATE 13

symmetrical, elliptic; apex not preserved; base rounded; margin entire; glands not seen; texture coriaceous; petiole normal, venation pinnate-camptodromous-brochidodromous; primary vein (1°) massive, straight; secondary veins (2°) acute (wide), lowest pair of secondary veins more acute than pairs above, distance between lowest pair and pair above is much more than in the remaining pairs, moderate, curved abruptly, joining superadjacent secondary at right angle, also enclosed by secondary arches of 3°, intersecondary veins present, simple, tertiary veins (3°) RR, orthogonal, reticulate, predominantly alternate, closely spaced; highest vein order of leaf 4°, highest vein order showing excurrent branching 3°, quaternary veins normal, orthogonal, marginal ultimate venation looped; areoles well-developed, oriented, quadrangular to pentangular, veinlets none.

Discussion—Chartaceous leaf with elliptic form, brochidodromous venation with lowest pair of secondary veins more acute than pairs above, wide gap between the lowest pair of secondaries and the pair above are the most important characters of fossil leaves which indicate their near resemblance with the modern leaves of *Croton oblongifolius, Mallotus philippensis* and with various species of *Ficus.* However, they show strong resemblance with those of *Ficus foveolata* (F. R.I. Herbarium sheet no. nil; Pl. 11, fig. 8).

Quite a good number of fossil leaves belonging to *Ficus* are known from India. Puri (1947, 1948) described two fossil leaves resembling *Ficus cunia* Buch-Ham. and *F. nemoralis* Wall. from the Karewa beds of Kashmir. Lakhanpal (1968) described *Ficus precunia* (modern comparable form *F. cunia*) from the Siwalik beds of Jawalamukhi. Later, Gupta and Jiwan (1972) also described *Ficus cunia* from the Siwalik beds of Bilaspur, Himachal Pradesh. *Ficus arnottiana* Miq. and *F glomerata* Roxb. were described by Mahajan and Mahabale (1973) from the Quaternary deposits of Maharashtra. Lakhanpal and Guleria (1981) described *Ficus kachchhensis* (modern comparable form *Ficus tomentosa* Roxb.) from the Eocene of Kachchh and again in the year (1982) they described *Ficus khariensis* (modern comparable *Ficus infectoria*) from the same beds. Lakhanpal and Awasthi (1984) described another species *Ficus champarensis* (modern comparable form *Ficus cunia*) from the Siwalik beds from near Bhikhnathoree in West Champaran District, Bihar. Recently, Prasad (1986) has also described three species of *Ficus,* viz., *Ficus retusoides* (modern comparable form *Ficus retusa*), *Ficus precunia* (modern comparable form *F. cunia*) and *Ficus nepalensis* (modern comparable form *Ficus glaberrima*) from the Siwalik beds of Koilabas near Indo-Nepal border.

The genus *Ficus* Linn. consisting of about 800 species (Willis, 1973) is widely distributed throughout the tropics of both hemispheres but most abundant in the islands of Indian Archipelago and the Pacific Ocean. A few species are extended beyond the tropics into the southern Florida (U.S.A.), Mexico, Argentina, southern Japan and China, the Canary Islands and South Africa. About 70 species are reported to occur in India (Santapau & Henry, 1973), out of which about 18 species including *Ficus foveolata* grow in Chotanagpur region (Wood, 1903; Haines, 1910) *Ficus foveolata* is a creeping or climbing shrub rooting at nodes, sometimes erect and is distributed from Himalaya (Hazara) eastward ascending up to 850 m, Assam, Khasi Hills, Bihar (including Chotanagpur) up to Bangla Desh (Chittagong), Burma, China and Japan (Wood, 1903; Brandis, 1906; Haines, 1910).

Ficus glaberrima Bl. syn. *F. infectoria* Roxb.
Pl. 12, figs 1, 3, 4

Material—Single complete leaf-impression with good preservation showing all the architectural details of the leaf.

Description—Leaf simple, length 11 cm and width 5.5 cm, lamina and base symmetrical, elliptic; apex acuminate; base acute, normal; margin entire; texture coriaceous; glands not visible; petiole present, normal; venation pinnate, camptodromous-brochidodromous; primary vein (1°) stout, markedly curved; secondary veins (2°) with acute (moderate) angle of divergence, lowest pair more acute than the pairs above, moderately thick, curved abruptly joining superadjacent secondary at right angle, loop forming branches are also enclosed by secondary arches of 3°, inter-secondary veins present, composite; tertiary veins (3°) AO, reticulate, orthogonal; highest vein order of leaf 4°, highest vein order showing excurrent branching 3°, quaternary veins moderate, orthogonal, marginal ultimate venation looped; areoles well-developed, oriented, quadrangular to pentagonal, veinlets none.

Discussion—The important morphological details of the leaf indicate its affinity with the modern leaves of various species of *Ficus* Linn., amongst which it closely resembles the leaves of *Ficus glaberrima* Bl. (F.R.I. Herbarium sheet no. 1902; Pl. 12, fig. 2).

The fossil records of the genus *Ficus* in India has already been discussed in detail while describing the leaf of *Ficus foveolata.* Lakhanpal and Guleria (1982) and Prasad (1986) have described *Ficus khariensis* and *F. nepalensis* from Kachchh, western India and from the Siwalik beds of Koilabas, Nepal respectively. Both these forms have been shown to bear close resemblance with the leaves of *Ficus glaberrima* syn. *F. infectoria*.

Ficus glaberrima is a large deciduous tree found in sub-Himalayan tract from Yamuna eastward, common in northern India, central Provinces, Berar, western Peninsula; Khasi Hills, Bangla Desh (Chittagong), Burma (Tenasserim), Andamans and Malayan Archipelago (Brandis, 1906).

Ficus tomentosa Roxb.
Pl. 13, figs 1, 3, 4

Material—Single complete well-preserved leaf-impression.

Description—Leaf simple, length 5.0 cm, width 2.5 cm; whole lamina and base both symmetrical, elliptic; apex mucronate; base obtuse (normal); margin entire; texture coriaceous; glands not seen; petiole present, normal; venation pinnate, craspedodromous, mixed; primary vein (1°) stout, straight; secondary veins (2°) with acute (moderate) angle of divergence, lowest pair of secondary veins more acute than pairs above, curved uniformly, the secondaries bifurcate near the margin and in the apical region take part in loop formation, intersecondary veins present, composite; intramarginal vein absent; tertiary veins (3°), AR, reticulate to percurrent, reticulate orthogonal, percurrent veins straight, oblique with midvein, alternate to opposite in equal numbers, closely spaced; highest vein order of leaf 4°, highest vein order showing excurrent branching 4°; quaternary veins orthogonal, marginal ultimate venation incomplete; areoles well-developed, oriented, quadrangular, veinlets none.

Discussion—Elliptic form, mixed craspedodromous venation, more acute angle of divergence of lowest pair of secondaries, bifurcation of secondaries near the margin and well-developed areoles are the important characters of the fossil leaf which indicate its close affinity with the leaves of *Ficus tomentosa* Roxb. (BSIP Herbarium sheet no. 14056; Pl. 13, fig. 2).

The fossil record of *Ficus* in India has already been discussed in the previous pages. Of the various species of *Ficus* leaves described from the Cenozoic of India, only *Ficus kachchhensis* belonging to the Eocene of Kachchh has been shown to possess close affinity with *Ficus tomentosa* (Lakhanpal & Guleria, 1981).

Ficus tomentosa is a large shady tree found in Bundelkhand, Banda, Bihar, Chotanagpur, central provinces and western Peninsula (Brandis, 1906).

IMPRESSIONS OF FLOWER AND FRUITS

The assemblage has yielded a dicot flower and four types of fruit-impressions. It has been possible to identify the fruit-impressions while the impression of the flower could not be identified with certainty. Hence, it has been described as a dicotyledonous flower.

Dicot Flower
Pl. 13, fig. 11

Flower pedicellate, length of pedicel 1.7 cm with hypogynous insertion of floral organs; calyx polysepalous with four preserved sepals, each sepal thick at the base and pointed towards the apex, sepals appear to have valvate aestivation; corolla polypetalous with two preserved petals, which are elliptic in shape.

Dicot Fruit Type-1
cf. *Dillenia* sp.
Pl. 13, fig. 12

The study is based on a single incomplete impression of the persistent calyx; the length of preserved sepals 2.6 cm and width 2.8 cm.

In a number of fruits like those of *Dillenia, Physalis* and *Shorea*, etc., the calyx is not only persistent but also grows in size. On detailed comparison it was found that in the structure of calyx the fossil resembles the fruits of *Dillenia*. In the forests of Chotanagpur region three species of *Dillenia* are found, viz., *Dillenia indica, D. aurea* and *D. pentagyna*. On the basis of fruits these species can not be differentiated.

From India, only fossil leaf *Dillenia palaeoindica* (modern comparable form *D. indica*) has been described by Prasad and Prakash (1984) from the Siwalik beds of Koilabas, Nepal.

The genus *Dillenia* consists of 60 species of trees and shrubs distributed widely in the tropical regions of the world, the largest number of species being confined to India and South-east Asia. About 11 species of trees are known to grow in the Indian region (Chowdhury & Ghosh, 1958).

Dicot Fruit Type-2
cf. *Ziziphus xylopyrus* Willd
Pl. 13, fig. 9

The study is based on a complete fruit-impression. The fruit is a drupe and all the three layers of fruit wall are present. The mesocarp is fibrous, 0.35 cm in thickness, while the endocarp is stony. Such type of fruits occur in *Mangifera indica, Prunus domestica, P persica, P. armenia* and various species of *Ziziphus*. On detailed comparison it has been found that the fossil fruit shows near resemblance with the modern fruit of *Ziziphus xylopyrus* (BSIP Herbarium sheet no. 14027; Pl. 13, fig. 12).

From India only fossil leaves of *Ziziphus* are so far known. Lakhanpal (1965, 1967) described *Ziziphus siwalicus* from the Siwalik beds of Balugoloa near Jawalamukhi, Himachal Pradesh. Singh and Prakash (1980) described *Ziziphus indicus* (modern comparable form *Z. mauritiana*) from the Siwalik beds of Arunachal Pradesh.

The genus *Ziziphus* includes about 100 species widely distributed in tropical America, Africa, Mediterranean, Indo-Malaya and Australia (Willis, 1973). *Ziziphus xylopyrus* is a large struggling shrub or small tree found in the forest of north-west Himalaya, central India and western peninsula (Brandis, 1906). It is also found in the forests of Chotanagpur region (Wood, 1903; Haines, 1910).

Dicot Fruit Type-3
cf. *Ziziphus mauritiana* Lamk.
Pl. 13, fig. 7

The study is based on an incomplete fruit-impression. The fruit is drupe, mesocarp is partially preserved, while the endocarp with rough surface is well preserved. The impression shows its near resemblance with the modern fruit of *Z. mauritiana* in shape and size and a rough endocarp too.

The fossil record of *Ziziphus* has already been given while dealing with the fruit-impression Type-2. *Ziziphus mauritiana* is a small tree and is found throughout India from north-west Frontier, Sindh, base of Himalaya to Sri Lanka and Malacca. It is also found in Afghanistan, tropical Africa, the Malaya Archipelago, China and Australia (Hooker, 1872). In the forests of Chotanagpur region, six species of *Ziziphus* are met with including *Z. mauritiana* (Wood, 1903; Haines, 1910).

Dicot Fruit Type-4
cf. *Dalbergia sissoo* Roxb.
Pl. 13, fig. 5

The study is based on a single complete fruit-impression which is elliptic in shape. The fruit is a pod with a single seed. The length of preserved specimen is 3.5 cm and width 1.2 cm.

The family Leguminosae is characterized by the presence of pod-like fruits. Amongst Legumes, the fossil fruit has been found to bear a near resemblance with the modern fruits of *Dalbergia sissoo* in shape and size (F.R.I. Herbarium sheet no. 11055; Pl. 13, fig. 6).

Both fossil fruits and leaves of *Dalbergia* have been described from the Siwalik beds. Lakhanpal and Dayal (1966) described the fossil fruit of *Dalbergia sissoo* from the Siwalik beds from near Jawalamukhi in Himachal Pradesh. In 1984, Lakhanpal and Awasthi described a fossil leaf of *Dalbergia* sp. from the Siwalik beds from near Bhikhnathoree, West Champaran District, Bihar. Recently, Prasad (1986) described *D. miosericea* (modern comparable form *D. sericea*) from the Siwalik beds of Koilabas, Nepal.

The genus *Dalbergia* Linn. f. consists of 120 species of trees or climbing shrubs, distributed in tropical regions of the world (Willis, 1973), out of which about 36 species are reported to occur in India (Gamble, 1922). *Dalbergia sisoo* is a large deciduous tree found in the sub-Himalayan tract and in the outer valleys from Indus to Assam, ascending generally to 950 m, at places to 1,650 m, extending far into the plains along river banks, Baluchistan Suleman range (Brandis, 1906).

DISCUSSION

Considering the large number of plant taxa recovered from these beds it would be interesting to analyse the floral composition of this assemblage and use it in deciphering palaeoecology, depositional environment and age of these deposits. In addition to the taxa described above from these fossiliferous shales, leaf-impressions of *Grewia tiliaefolia* (Tiliaceae), *Murraya paniculata* (Rutaceae), *Schleichera oleosa* (Sapindaceae), *Mangifera indica* (Anacardiaceae) and *Vitex negundo* (Verbenaceae) have also been described by Bande, Srivastava and Misra (1989, in press). From the underlying sandstone unit petrified woods of *Sindora siamea* (Leguminosae, Prakash *et al.*, 1988), *Terminalia tomentosa* (Combretaceae) and *Lagerstroemia* sp. (Lythraceae) have been recovered (unpublished personal collection).

Floristic composition—The present study is the first detailed work on the fossil flora of this area. Including the taxa described by earlier workers (Prakash *et al.*, 1988; Bande, Srivastava & Misra, 1989) so far 32 species belonging to 29 genera and 20 families of dicotyledons have been recovered from these fossiliferous beds. Monocotyledons are totally absent.

Leguminosae (with five genera) is the most dominant family in this assemblage. Dominance of Leguminosae and presence of Dipterocarpaceae clearly indicate that the assemblage is post Palaeogene (Lakhanpal, 1970) in age. Thus comparison of the Mahuadanr assemblage with the different Neogene megafossil floras of India is pertinent. The Neogene floras are widely distributed all over the country, viz., Tipam sandstones, Dupitila Series and Tertiary of West Bengal in the East; Tertiary of Kachchh, Gujarat and Rajasthan in the West; Siwalik beds in the North and Cuddalore sandstones, Neyveli lignites and Varkala beds of Kerala coast in the South.

A comparison of the present assemblage with these various Indian Neogene floras indicates that it is closely comparable to the Lower Siwalik flora. Thirteen genera—*Dillenia, Shorea, Sterculia, Ziziphus, Mangifera, Dalbergia, Millettia, Bauhinia, Terminalia, Diospyros, Vitex, Mallotus* and *Ficus* are common in both. This assemblage is also comparable to the flora recovered from the Tipam sandstones wherein 9 genera are common. They are: *Shorea, Sterculia, Mangifera, Ougenia, Terminalia, Madhuca, Diospyros, Vitex* and *Mallotus*. Only four genera, viz., *Shorea, Mangifera, Millettia* and *Terminalia* are common with the Tertiary flora of the peninsular region of the adjoining West Bengal.

It is interesting to note that fossils of *Spondias, Erythrina, Combretum, Mitragyna, Alstonia* and *Cryptolepis* are reported for the first time from the Cenozoic of India. The occurrence of *Cryptolepis buchanani* constitutes the first fossil record of family Asclepiadaceae from India. Amongst rest of the genera, *Grewia* is known from the Palaeogene (Deccan Intertrappean beds and Eocene of Assam) and from the Karewa beds of Kashmir, while *Evodia* is known only from the Deccan Intertrappean beds.

Palaeoecology—Plant communities especially the climax vegetation reflects an achievement of harmony or a balance with the environment. Thus the study of any fossil assemblage can be used to reconstruct the palaeo-environmental conditions. Reconstruction of palaeoclimates and palaeoedaphic conditions is also possible by a judicious study and interpretation of fossil floras. This inferential information is useful in understanding the sequential development of the present day phytogeography.

The present assemblage can be subdivided into two divisions: (i) silicified woods recovered from the sandstone unit, and (ii) impressions of leaves, flowers and fruits recovered from the shale unit. Only three genera are represented in the form of silicified woods, viz., *Sindora, Terminalia* and *Lagerstroemia. Sindora siamea* is a typical element of the tropical wet evergreen forests and is found only in Thailand (Ridley, 1967). The other two taxa, *Terminalia tomentosa* and *Lagerstroemia* sp. cf. *parviflora* are common constituents of the tropical forests in the country. This indicates that till the deposition of the sandstone unit the vegetation was wet evergreen in nature. On the contrary the present day distribution of the genera and species recovered from the shale unit indicates that all of them still grow in the nearby forests of Chotanagpur plateau.

Champion and Seth (1968) have divided the tropical forests of India into (i) wet evergreen forests, (ii) semi-evergreen forests, (iii) moist deciduous forests, (iv) littoral and swamp forests, (v) dry deciduous forests, (vi) thorn forests, and (vii) dry evergreen forest types on the basis of moisture conditions.

The South Daltenganj Forest Division under which the fossiliferous beds are exposed has both moist and dry deciduous forests. Both types of forests can be met within the same area depending on the site, etc. The distribution of various taxa constituting the present fossil assemblage in the moist as well as dry deciduous forests of Chotanagpur plateau is as follows :

Table 1

	Moist deciduous forest	Dry deciduous forest
Dillenia sp.	+	+
Shorea robusta	+	+
Sterculia villosa	+	–
Pterygota alata	+	+
Grewia tiliaefolia	+	–
Murraya paniculata	+	–
Evodia meliaefolia	+	–
Garuga pinnata	+	+
Ziziphus xylopyrus	+	+
Ziziphus sp. cf. *Z. mauritiana*	+	+
Schleichera oleosa	+	+
Mangifera indica	+	–
Spondias pinnata	+	+
Dalbergia sissoo	+	+
Erythrina suberosa	–	+
Millettia auriculata	+	–
Ougenia oojeinensis	+	–
**Sindora siamea*	–	–
Bauhinia purpurea	+	+
Combretum decandrum	+	+
Terminalia tomentosa	+	+
Lagerstroemia parviflora	+	+
Mitragyna parvifolia	+	+
Madhuca indica	+	+
Diospyros montana	–	+
Alstonia scholaris	+	+
Cryptolepis buchanani	+	+
Vitex negundo var. *incisa*	–	+
Mallotus philippensis	+	+
Ficus foveolata	+	+
F. glaberimma	+	+
F. tomentosa	+	+

*Found in wet evergreen forest

Thus, it is evident that the elements of both moist and dry deciduous forests were also growing together during the past in the Chotanagpur region. This evidence of fossil plants also indicates that the climate around this basin was subtropical at the time of deposition of shales from which these impressions have been described. It must have been relatively more moist at the time of deposition of underlying sandstone unit from which *Sindora siamea*, a characteristic evergreen species, has been described. Since the deposition of these shales the same tropical climate has continued around this valley without any significant change.

Depositional environment—The fossiliferous beds of the area are composed of two units—the sandstone and shale. The sandstone unit overlying the conglomerates is fine to medium grained and attains a thickeness varying from 1 to 3 m. It contains thin intercalations of sandy shales and siltstone. The shales are thinly bedded, grey coloured, somewhat arenaceous and attain a maximum thickness of about 3.2 m in which sand rich and clay rich bands alternate. From the pattern of depositional sequence it may be inferred that these fossiliferous shales were alternately deposited by high energy sedimentation followed by low energy sedimentation. Both sand rich and clay rich bands in the shale unit suggest that the sand rich bands are the result of annual flooding while clay rich bands are due to the deposition in a quiet body of water. The thinly bedded nature of shale unit further indicates that the deposition took place in rhythmic conditions in a shallow body of water, probably a lake, under stable conditions. Most of the plant fossils are well-preserved and do not show much disturbance. Besides, the presence of well-preserved flowers indicate that the material was not transported from a long distance before deposition.

Age—Fox (1923) was the first to record the presence of shales and other sedimentary beds near Mahuadanr. The fossiliferous nature of the beds was first recorded by Roy Chowdhury (in West, 1948, p. 22). Puri (1976) collected from them a fossil fish alongwith some leaf-impressions and assigned an Upper Tertiary or Quaternary age to these beds. Later, Puri and Mishra (1982) further mapped this area in detail and reported the occurrence of fossil fishes, birds and insects alongwith impressions of angiospermous leaves and petrified woods. Although animal fossils have been collected from the shales, they are not of much use in deciphering their age. However, the evidence from the fossil flora can be of some use as we know that the similarities of the fossil forms with modern taxa are inversely proportional to the age of the beds. Close similarity of fossil taxa up to specific level with the modern forms suggests that the beds are not of great antiquity.

Presence of *Sindora siamea* in the sandstone unit of these beds is interesting in this context. *Sindora* has so far been reported from the Mio-Pliocene (Cuddalore Sandstone, Tipam Sandstone, Siwalik beds and Rajasthan) of India (Prakash, Misra & Srivastava, 1988). This suggests that the sandstone unit is in all probability Mio-Pliocene in age and obviously the shales are younger. However, more evidences, especially from the radiometric dating and organic matter maturation studies, are required to decide the absolute age of these beds.

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Palynology of the subsurface Mesozoic sediments in Rajmahal Basin, Bihar

Archana Tripathi, R. S. Tiwari & Pramod Kumar

Tripathi, Archana, Tiwari, R. S. & Kumar, Pramod 1990. Palynology of the subsurface Mesozoic sediments in Rajmahal Basin, Bihar. *Palaeobotanist* **37** (3) : 367-388.

Palynological study of Mesozoic sediments (Late Triassic to Late Jurassic/Early Cretaceous) from a bore-hole RJR-2 drilled near Kazigaon Village in Rajmahal Basin has been done and 76 genera and 132 species have been recognised. Of them, one genus and 13 species are new. A check-list along with descriptions of new proposals have been given. The distribution of various species in Rajmahal and Dubrajpur formations is distinct. Palynological succession denotes three identifiable associations of the Late Carnian, Early Norian and Late Jurassic/Early Cretaceous age.

Key-words—Palynology, Dubrajpur Formation, Rajmahal Basin, Mesozoic (India).

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साराँश

बिहार में राजमहल द्रोणी में विद्यमान उपसतही मध्यजीवी अवसादों का परागाणविक अध्ययन

अर्चना त्रिपाठी, राम शंकर तिवारी एवं प्रमोद कुमार

राजमहल द्रोणी में काज़ीगाँव के समीप आर-जे-आर०-2 नामक वेध-छिद्र से प्राप्त मध्यजीवी अवसादों (अनंतिम त्रिसंघी से अनंतिम जूराई/प्रारम्भिक क्रीटेशी) का परागाणविक अध्ययन किया गया है तथा इनमें 76 प्रजातियाँ एवं 132 जातियाँ अभिनिर्धारित की गई हैं। इनमें से एक प्रजाति तथा 13 जातियाँ नई हैं। नई जातियों सहित सभी वर्गकों की एक तालिका भी प्रस्तुत की गई है। उक्त अध्ययन से पता चलता है कि राजमहल एवं दुबराजपुर शैल-समूहों में विभिन्न जातियों का वितरण भिन्न-भिन्न है। उपलब्ध परागाणविक अनुक्रम में अनंतिम जूराई/प्रारम्भिक क्रीटेशी कालीन तीन अभिनिर्धारणीय साहचर्य प्रदर्शित होते हैं।

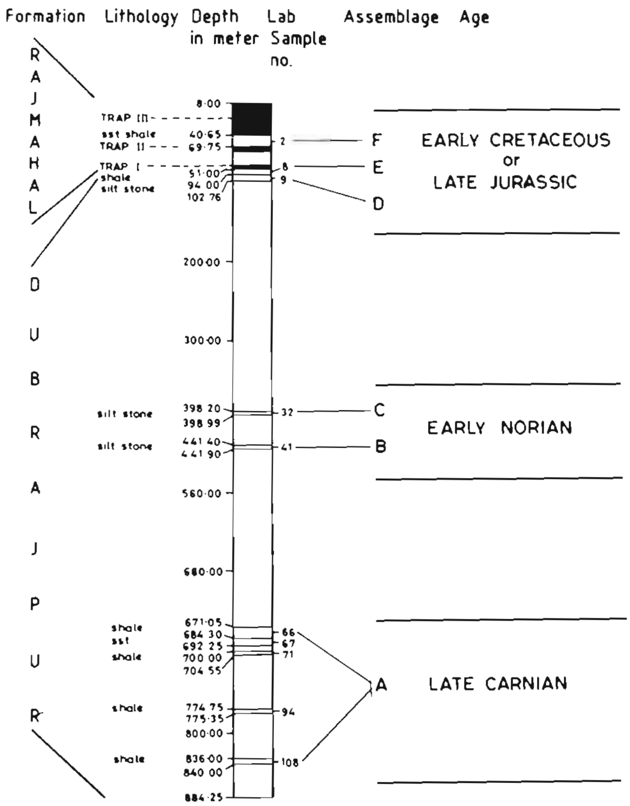
STUDY of dispersed spores and pollen in Mesozoic sediments of Rajmahal Basin dates back to nineteen-thirties when Rao (1936) analysed these strata for their palynological contents. A few more studies were made (Rao, 1943; Vishnu-Mittre, 1953, 1954) in the subsequent years till Sah and Jain (1965) systematically described spores and pollen from Rajmahal Intertrappean beds and dated it to be Late Jurassic.

Tiwari, Kumar and Tripathi (1984) analysed a palynological succession in the bore-hole RJR-2 and revealed the occurrence of five distinct assemblage zones (Text-fig. 2, p. 210) ranging in age from Late Carnian to Late Jurassic/Early Cretaceous. These palynological assemblages are highly diversified. Sequel to this study, the range of variation in delimitation of various species on the basis of finer morphological characters were recorded. The distribution of species through the succession of Dubrajpur and Rajmahal formations denotes their changing pattern which resulted in the identification of Late Triassic, Late Jurassic/Early Cretaceous strata.

The material comprises samples from the bore-hole RJR-2 (Tiwari *et al.*, 1984, table 1, samples marked with asterisks) representing Dubrajpur and Rajmahal formations (Text-fig. 1). This bore-hole is located in the north-eastern part of the basin near Kazigaon, between Rajmahal and Tinpahar, and represents a total depth of 884.25 m.

SYSTEMATIC PALYNOLOGY

A complete check-list of the palynotaxa found in assemblages A-F in bore-hole RJR-2 is given below. The taxa marked with an asterisk have been



Text-figure 1—Litholog showing various miospore assemblages recorded from yielding samples at corresponding depth levels.

commented upon in the text for their morphotaxonomy and nomenclature.

TRIASSIC ASSEMBLAGE

Todisporites major Couper 1958
Callumispora fungosa (Balme) Bharadwaj & Srivastava emend. Bharadwaj & Tiwari 1977
C. gretensis (Balme & Hennelly) Bharadwaj & Srivastava 1969 (Pl. 1, fig. 1)
Orbella indica Tiwari & Rana 1980
Converrucosisporites lunzensis Bharadwaj & Singh 1964 (Pl. 1, fig. 3; Pl. 6, fig. 7)
C. jenensis Reinhardt 1964
Guttatisporites guttatus Visscher 1966 (Pl. 1, fig. 2)
G. elegans Visscher 1966
Verrucosisporites densus Bharadwaj & Tiwari 1977
V. narmianus Balme 1970
V. carnarvonensis de Jersey & Hamilton 1967
V. bosei Maheshwari & Banerji 1975 (Pl. 1, fig. 4)
V. racemus (Peppers) Smith 1971
**V. kazigaonensis* sp. nov. (Pl. 1, figs 7, 8)
Osmundacidites senectus Balme 1963
O. pilatus Tiwari & Rana 1981 (Pl. 1, fig. 6)
Conbaculatisporites baculatus Bharadwaj & Singh 1964 (Pl. 1, fig. 10)
Convolutispora perfecta Kumaran & Maheshwari 1980 (Pl. 1, fig. 11)
Foveosporites triassicus Kumaran & Maheshwari 1980 (Pl. 1, fig. 12)
F. mimosae de Jersey & Hamilton 1967
Dictyotriletes aulius Rigby 1977 (Pl. 1, fig. 14)
Dubrajisporites triassicus Tiwari & Tripathi 1987 (Pl. 6, fig. 14)
D. bulbosus Tiwari & Tripathi 1987 (Pl. 6, fig. 4)
**D. unicus* sp. nov. (Pl. 1, figs 18, 22)
**D. isolatus* sp. nov. (Pl. 1, figs 17, 20, 21)
**Gabonisporis vigourouxii* Boltenhagen 1967 (Pl. 1, fig. 5)
**G. papillosus* sp. nov. (Pl. 1, figs 9, 13)
Densoisporites contactus Bharadwaj & Tiwari 1977
Rajmahalispora rugulata Tiwari, Tripathi & Kumar 1984 (Pl. 6, fig. 3)
R. triassicus Tiwari, Tripathi & Kumar 1984 (Pl. 6, figs 1, 2)
R. reticulata Tiwari, Tripathi & Kumar 1984
**Polycingulatisporites* sp. (Pl. 1, fig. 16)
**Indotriradites* sp. (Pl. 1, fig. 19)
Polypodiisporites mutabilis Balme 1970
Punctatosporites walkomi de Jersey 1962
**Divarisaccus* sp. cf. *D. strengeri* Bose & Kar 1966 (Pl. 2, fig. 10; Pl. 6, fig. 8)
Playfordiaspora cancellosa Maheshwari & Banerji 1975 (Pl. 1, fig. 23)
**Tetrasaccus* sp. (Pl. 2, fig. 13)
Platysaccus fuscus Goubin 1965
Podocarpidites alareticulatus Sah & Jain 1965 (Pl. 2, fig. 5)
P. rarus Singh, Srivastava & Roy 1964
P. grandis Sah & Jain 1965 (Pl. 2, fig. 2)
P. typicus Sah & Jain 1965 (Pl. 2, fig. 6; Pl. 6, fig. 11)
Alisporites landianus Balme 1970
A. grobus Bharadwaj & Tiwari 1977 (Pl. 2, fig. 4)
**Falcisporites minutosaccus* Kumaran & Maheshwari 1980 (Pl. 2, fig. 7)
F. nuthalensis (Clarke) Balme 1970 (Pl. 2, fig. 12)
F. snopkovae Visscher 1966 (Pl. 2, fig. 8)
Scheuringipollenites maximus (Hart) Tiwari 1973
Klausipollenites schaubergeri (Potonié & Klaus) Jansonius 1962
K. staplinii Jansonius 1962
K. vestitus Jansonius 1962
Brachysaccus ovalis Mädler 1964 (Pl. 2, fig. 18)

**B. triassicus* sp. nov. (Pl. 2, figs 16, 17)
Satsangisaccites nidpurensis Bharadwaj & Srivastava 1969 (Pl. 2, fig. 9; Pl. 6, figs 5, 6)
S. triassicus Bharadwaj & Srivastava 1969
Nidipollenites monoletus Bharadwaj & Srivastava 1969 (Pl. 2, fig. 1)
Staurosaccites quadrifidus Dolby 1976 (Pl. 3, fig. 5)
S. tharipatharensis Maheshwari & Kumaran 1979 (Pl. 3, fig. 2)
S. marginalis Kumaran & Maheshwari 1980 (Pl. 3, fig. 1)
**S. densus* Kumaran & Maheshwari, emend. (Pl. 3, fig. 3)
Striatopodocarpites decorus Bharadwaj & Salujha 1964
**S. dubrajpurensis* sp. nov. (Pl. 3, figs 4, 7, 8, 10)
**Striatopodocarpites* sp. (Pl. 3, fig. 13)
Lahirites sp. (Pl. 3, fig. 6)
Lunatisporites pellucidus (Goubin) Maheshwari & Banerji 1975 (Pl. 2, fig. 14)
Infernopollenites claustratus Dolby & Balme 1976 (Pl. 2, fig. 3)
Chordasporites minutus Kar, Kieser & Jain 1972 (Pl. 2, fig. 15)
C. australiensis de Jersey 1962
Goubinispora indica Tiwari & Rana 1980 (Pl. 3, fig. 11)
G. morandavensis (Goubin) Tiwari & Rana 1980
Inaperturopollenites nebulosus Balme 1970
Pretricolpipollenites bharadwajii Balme 1970 (Pl. 2, fig. 11)
Incertae sedis
*Type A (Pl. 2, fig. 19)
*Type B (Pl. 1, fig. 15)

JURASSIC/CRETACEOUS ASSEMBLAGE

Concavisporites novicus Kumar 1973
Orbella colliculoides Maljavkina 1949
Dictyophyllidites haradensis Kumar 1973
Haradisporites mineri Singh & Kumar 1972
Cyathidites australis Couper 1953
C. minor Couper 1953
**C. punctatus* (Delcourt & Sprumont) Delcourt, Dettmann & Hughes 1963 (Pl. 4, fig. 1)
Todisporites minor Couper 1958
**Divisisporites* sp. (Pl. 4, fig. 3)
Osmundacidites wellmanii Couper 1953
**Foraminisporis* sp. (Pl. 4, fig. 2)
Baculatisporites comaumensis (Cookson) Potonié 1956
Concavissimisporites penolaènsis Dettmann 1963 (Pl. 4, fig. 8)
Leptolepidites verrucatus Couper 1953 (Pl. 4, fig. 20)
L. major Couper 1958
**L. rimatus* sp. nov. (Pl. 4, figs 21-23)
**Santhalisporites* gen. nov.
**S. bulbosus* sp. nov. (Pl. 4, figs 5, 6, 10, 11, 17)
**S. baskoensis* (Sah & Jain) comb. nov. & emend. (Pl. 4, figs 18, 19)
**S. imperfectus* sp. nov. (Pl. 4, figs 7, 12-14)
**Santhalisporites* sp. (Pl. 4, figs 15, 16)
Retitriletes reticulumsporites (Rouse) Döring, Krutzsch, Mai & Schulz 1963
R. austroclavatidites (Cookson) Döring, Krutzsch, Mai & Schulz 1963
Klukisporites varigatus Couper 1958 (Pl. 5, fig. 1)
**K. venkatachalae* sp. nov. (Pl. 5, figs 2, 3)
Cicatricosisporites australiensis (Cookson) Potonié 1952 (Pl. 4, fig. 9; Pl. 6, fig. 12)
C. ludbrooki Dettmann 1963 (Pl. 4, fig. 4)
Matonisporites dubius Kumar 1973 (Pl. 5, fig. 4)
**Callispora potoniei* Dev emend. Bharadwaj & Kumar 1972 (Pl. 5, fig. 5)
Contignisporites dettmannii Singh & Kumar 1966 (Pl. 5, fig. 16)
**Murospora florida* Balme emend. Dettmann 1963 (Pl. 5, fig. 8)
Gleicheniidites mundus Sah & Jain 1965 (Pl. 5, fig. 15)
Monolites indicus Kumar 1973
Alisporites grandis (Cookson) Dettmann 1963
Vitreisporites pallidus (Reissinger) Nilsson 1958
Podocarpidites ellipticus Cookson 1947 (Pl. 3, fig. 9)
P. multesimus (Bolkhovitina) Pocock 1962
P. cristiexinus Sah & Jain 1965 (Pl. 6, fig. 13)
Callialasporites dampieri (Balme) Dev 1961
C. lametaensis Kumar 1973 (Pl. 3, fig. 12)
C. segmentatus (Balme) Srivastava 1963 (Pl. 3, fig. 16)
C. circumplectus Kumar 1973
C. trilobatus (Balme) Bharadwaj & Kumar 1972 (Pl. 3, fig. 15)
Podosporites tripakshi Rao emend. Kumar 1983 (Pl. 5, fig. 12)
P. microsaccatus (Couper) Dettmann 1963
Araucariacites australis Cookson 1947 (Pl. 5, fig. 24)
A. cooksonii Singh, Srivastava & Roy 1964 (Pl. 5, figs 22, 23)
A. ghuneriensis Singh, Srivastava & Roy 1964
Classopollis indicus Maheshwari 1974 (Pl. 5, fig. 19)
Cycadopites sakrigaliensis Sah & Jain 1965 (Pl. 3,

fig. 14)
C. *folliculatus* Wilson & Webster 1946
Monosulcites ellipticus Kumar 1973
Labiapollis mesozoicus Madler 1964 (Pl. 5, fig. 17)
L. granulatus Madler 1964 (Pl. 5, fig. 20)
Coptospora kutchensis Venkatachala 1969 (Pl. 5, fig. 13)
*C. *verrucosa* sp. nov. (Pl. 5, figs 6, 9, 11)
**Couperisporites rajmahalensis* sp. nov. (Pl. 5, figs 16, 18)
Aequitriradites spinulosus (Cookson & Dettmann) Cookson & Dettmann 1956 (Pl. 5, fig. 21)
A. verrucosus (Cookson & Dettmann) Cookson & Dettmann 1961
Triporoletes reticulatus (Pocock) Playford 1971 (Pl. 5, fig. 7)

Lower Gondwana palynotaxa in Mesozoic sediments

During the course of present analysis of dispersed spores and pollen in bore-hole RJR-2, some of the taxa typical of Lower Gondwana assemblages have also been encountered, viz., *Parasaccites* Bharadwaj & Tiwari 1964, *Plicatipollenites* Lele 1964, *Densipollenites* Bharadwaj 1962, *Striatopodocarpites* Sorinh & Sedova emend. Bharadwaj 1962, *Crescentipollenites* Bharadwaj, Tiwari & Kar 1974 and *Lunatisporites* Leschik emend. Scheuring 1970. These genera are found in the assemblage which is dated to be Jurassic-Cretaceous by virtue of its major components. They are well preserved with full details of exine structure and have no corrosion effect as such. The presence of similar forms in the sediments younger than the Lower Gondwana has also been recorded from other basins (Potonié & Sah, 1960; Dutta, 1979; Kar, 1980; Dev, 1961; Vijaya *et al.*, 1988), and have been considered as reworked.

DESCRIPTION

Genus—*Cyathidites* Couper 1953

Cyathidites punctatus (Delcourt & Sprumont) Delcourt, Dettmann & Hughes 1963
Pl. 4, fig. 1

Remarks—The specimens closely compare to those described by Delcourt and Sprumont (1955, pl. 1, fig. 8) and Delcourt, Dettman and Hughes (1963, pl. 42, fig. 5) in exhibiting similar nature of broadly rounded angles and concavity of the side walls but differ in being bigger in size, ranging up to 120 µm and also in greater thickness of exine (up to 4 µm thick).

Genus—*Divisisporites* Thomson in Thomson & Pflug emend. Potonie 1956

Divisisporites sp.
Pl. 4, fig. 3

Remarks—Subcircular spore, 58 µm, trilete in size with forked ray ends. Exine 3 µm thick, covered with less than 1 µm verrucae. Among the comparable forms, *Divisisporites ovalis* Sah & Jain 1965 differs in being smaller in size and having less thickened, infrapunctate exine. *D. rajmahalensis* Jain & Sah 1969 differs from the studied specimen in showing margo along the trilete mark.

PLATE 1

(All photomicrographs are × 500 unless otherwise stated)

1. *Callumispora gretensis*, Slide no. BSIP 8481
2. *Cyclogranisporites gibbosus*, Slide no. BSIP 8472
3. *Concavissimisporites* [illegible], Slide no. BSIP 95[illegible]
4. [illegible], Slide no. BSIP 9651
5. *Callumispora* [illegible], Slide no. BSIP 8475
6. *Osmundacidites* [illegible], Slide no. BSIP 9554
7, 8. [illegible] sp. nov., fig. 7 Holotype Slide no. BSIP 8474, fig. 8 Isotype, Slide no. BSIP 84[illegible]
9, 13. *Callumispora papillata* sp. nov., fig. 9 Holotype, Slide no. BSIP 9522, fig. 13 Isotype, Slide no. BSIP 9521
10. [illegible], Slide no. BSIP 9548
11. *Callumispora* [illegible], Slide no. BSIP 8473
12. *Punctatisporites* [illegible], Slide no. BSIP 8490
14. [illegible], Slide no. BSIP 9524
15. Type B showing a weak zone in the middle, Slide no. BSIP 8477
16. [illegible] sp., Slide no. BSIP 9563
17, 20, 21. [illegible] sp. nov., showing nature and arrangement of sculptures.
17. Isotype, Slide no. BSIP 9528
20. Holotype, Slide no. BSIP 9525
21. Enlargement of a portion of holotype showing the arrangement of sculptures × 1500
18, 22. [illegible] sp. nov. (composite figure) showing many big spines in one corner, fig. 18, Holotype Slide no. BSIP 9528 × 570, fig. 22 Isotype, Slide no. BSIP 9521, × 425
19. *Indotriradites* sp., Slide no. BSIP 8471
23. *Playfordiaspora cancellosa*, Slide no. BSIP 8476

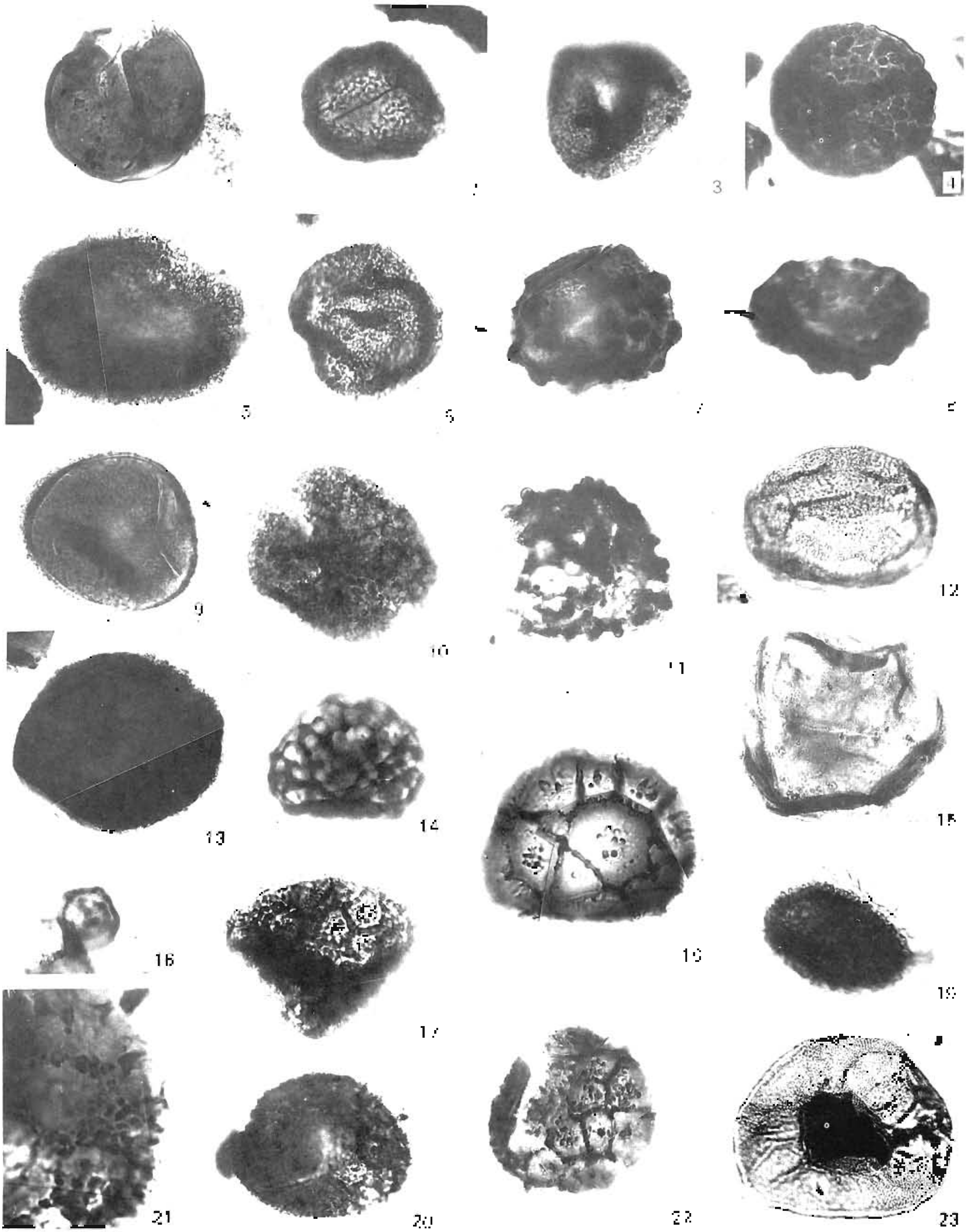


PLATE 1

Genus—*Verrucosisporites* Ibrahim emend. Smith 1971

Verrucosisporites kazigaonensis sp. nov.
Pl. 1, figs 7, 8

Holotype—Pl. 1, fig. 7; size 61.5 μm; Slide no. BSIP 8474.

Isotype—Pl. 1, fig. 8; size 71 μm; Slide no. BSIP 8475.

Type locality—Bore-hole RJR-2 (sample no. 41, depth 441.40-441.90 m), near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Triassic.

Diagnosis—Circular to roundly triangular. Rays up to half the body radius long, thick-lipped, wavy. Exine all over covered with sparse but massive verrucae or tubercles, intermixed with small and low verrucae; at places low verrucae fuse to form a rugulate pattern; low verrucae also present on the tubercles; in the inter-ray areas only small verrucae present. Exine 2-3 μm thick.

Description—Size 61.5-71.0 μm; usually dark brown in colour. Trilete distinct, lips up to 1-2 μm thick as if formed by fusion of verrucae, slightly wavy; tubercle size 3-5 μm high, 7-11 μm wide; size of small verrucae 1-3 μm high and 1-3 μm wide; tubercles also beset with less than 0.5 μm high verrucae. On the surface verrucae and tubercles irregular in shape but at the periphery projecting out as round-headed elements. Exine unstructured.

Comparison—This species is comparable with *V. carnarvonensis* de Jersey & Hamilton 1967, *V. densus* Bharadwaj & Tiwari 1977 and *V. surangei* Maheshwari & Banerji 1975 in having robust verrucae, but differs in their being sparser and intermixed with smaller verrucae. The nature of robust tubercles which in their turn also bear low verrucae on them, and the thick-lipped trilete mark are also important distinguishing characters of *V. kazigaonensis*.

Genus—*Foraminisporis* Krutzsch 1959

Foraminisporis sp.
Pl. 4, fig. 2

Description—Roundly triangular trilete spore, 44.5 μm in size. Leasurae almost straight extending 3/4 of the spore radius with 2.5 μm thick lips. Exine 1.5 μm thick, irregularly beset with low verrucae and coni of less than 1 μm size. Sculpture reduced on proximal face; clusters of granules (each granule 1-3 μm in diameter) present on contact area.

Remarks—The genus *Foraminisporis* is a non-cingulate form (Krutzsch, 1959); however, Dettmann (1963) has assigned some cingulate specimens to this genus. Presently studied specimen conforms to the generic circumscription of the genus. It differs from the species *F. foraminis* Krutzsch 1959 in the nature of exine sculpture being verrucose and conate, and thick-lipped trilete rays, hence referred to as *Foraminisporis* sp.

Genus—*Concavissimisporites* Delcourt & Sprumont emend. Delcourt, Dettmann & Hughes 1963

Concavissimisporites penolaensis Dettmann 1963
Pl. 4, fig. 8

Remarks—Some of the presently studied specimens possess very low verrucae which do not project out prominently on the margin, unlike the specimens described by Dettmann (1963).

Genus—*Leptolepidites* Couper 1953

Leptolepidites rimatus sp. nov.
Pl. 4, figs 21-23

Holotype—Pl. 4, fig. 21; size 85 μm; Slide no. BSIP 9547.

Isotype—Pl. 4, fig. 23; size 78 μm; Slide no. BSIP 8469.

Type Locality—Bore-hole RJR-2 (Sample no. 9,

PLATE 2 →

(All photomicrographs are × 500, unless otherwise stated)

1. *Nidipollenites monoletus*, Slide no. BSIP 8471.
2. *Podocarpidites grandis*, Slide no. BSIP 9321.
3. *Infernopollenites claustratus*, Slide no. BSIP 8474.
4. *Alisporites grobus*, Slide no. BSIP 8473.
5. *Podocarpidites alareticulatus*, Slide no. BSIP 9544.
6. *Podocarpidites typicus*, Slide no BSIP 8473.
7. *Falcisporites minutosaccus*, Slide no. BSIP 8472.
8. *Falcisporites snopkovae*, Slide no. BSIP 9554.
9. *Satsangisaccites nidpurensis*, Slide no. BSIP 8474.
10. *Divarisaccus* sp. cf. *D. strengeri*, Slide no. BSIP 8475.
11. *Pretricolpipollenites bharadwajii*, Slide no. BSIP 9542.
12. *Falcisporites nuthalensis*, Slide no. BSIP 8090.
13. *Tetrasaccus* sp., Slide no. BSIP 8478.
14. *Lunatisporites pellucidus*, Slide no. BSIP 8474.
15. *Chordasporites minutus*, Slide no. BSIP 8089.

16, 17. *Brachysaccus triassicus* sp. nov., fig. 16 Holotype, Slide no. BSIP 8471; fig. 17 Isotype, Slide no. BSIP 8472.

18. *Brachysaccus ovalis*, Slide no. BSIP 8471.
19. Type-A, Slide no. BSIP 8478.

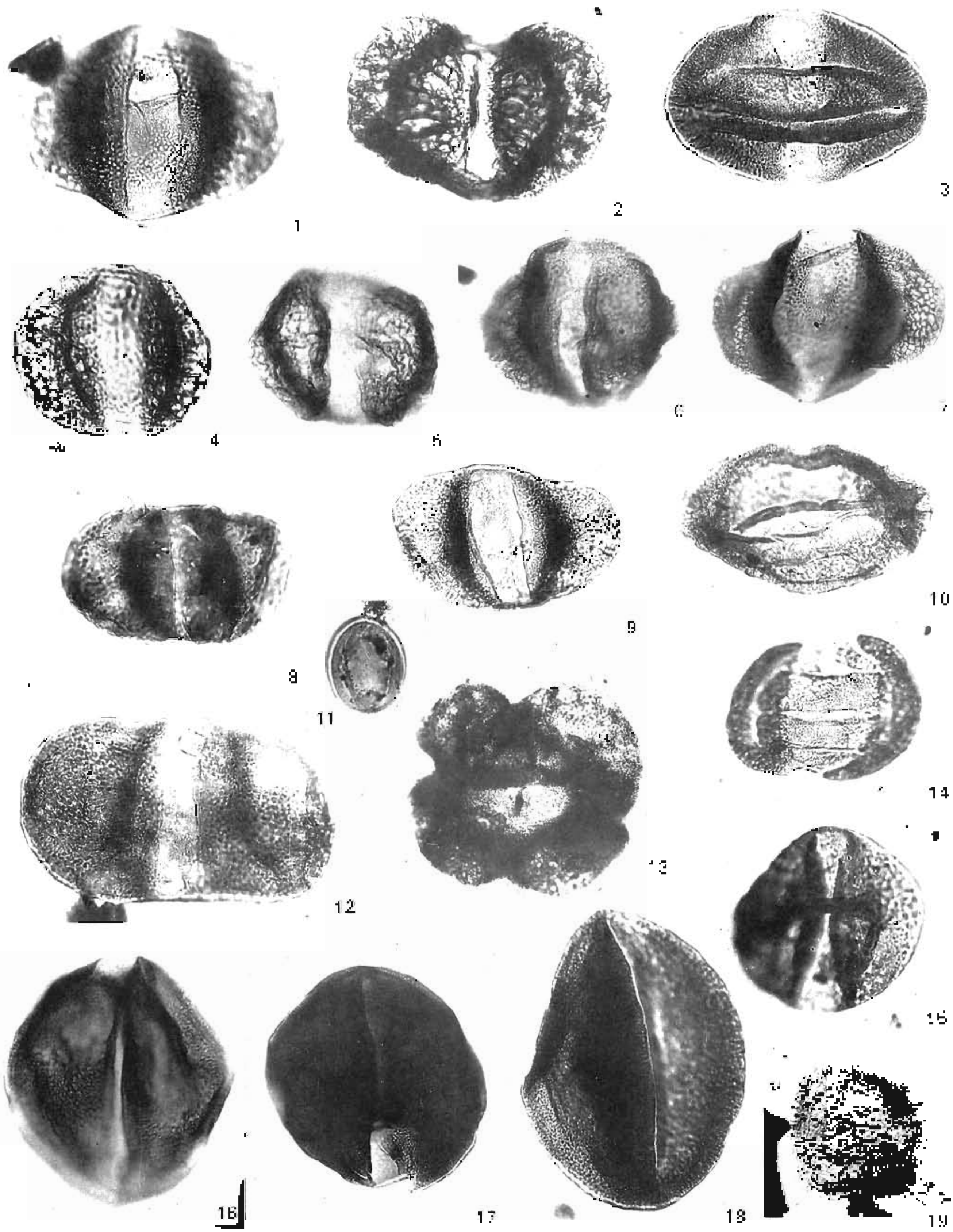


PLATE 2

depth 94-102.76 m), near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Jurassic/Early Cretaceous.

Diagnosis—Convexly triangular, trilete miospores. Exine verrucose, verrucae differentially disposed, closely packed simulating a rim-like structure at the equator.

Description—Miospores convexly triangular in equatorial outline. Size 78-85 μm in diameter (including sculpture). Trilete mark faintly perceptible, rays reaching up to 3/4 of the spore radius. Exine 1.5 μm thick, verrucose, verrucae at the distal and equatorial region large, 5-10 μm in diameter, and reduced at the proximal polar region, 2.5-5 μm in diameter. Equatorial verrucae closely packed forming a rim-like structure.

Comparison—*Leptolepidites major* Couper 1958 differs from *L. rimatus* sp. nov. in having linear arrangement of verrucae along the trilete rays, smaller size (36-50 μm) and uniform distribution of verrucae on both faces. *Leptolepidites verrucatus* Couper 1953 is distinct in being smaller in size (28-45 μm) and having smaller verrucae also (3-5 μm in diameter).

Santhalisporites gen. nov.

Type species—*Santhalisporites bulbosus* sp. nov.

Diagnosis—Roundly triangular to subcircular, trilete, curvaturate spores; trilete-mark distinct, Exine spinose all over except on the contact areas where ornament considerably reduced or even absent; spines with broad, conical or bulbous bases and long, straight or curved, hook-like apices.

Description—Miospores broadly subcircular to circulo-triangular in shape, generally with broad round angles; trilete rays reaching 3/4 or more of the spore radius but never reaching the equator, thick-lipped, sinuous, forming a well-defined contact area which being differentiated by the absence or reduced nature of ornament and occupying three-fourth of the proximal surface. Exine sculptured with straight or curved, 2-10 μm long spines having 1-5 μm wide, conical or bulbous bases and straight, hook-like or anchor-shaped apices; 1 μm high and 1 μm broad coni also present. Curvaturae well-developed, rarely faintly perceptible.

Comparison—The genus *Santhalisporites* is comparable with *Godavarisporites* Tiwari & Moiz 1971 in subcircular shape and the presence of curvaturae but differs in the nature of exine ornamentation; the exine of the former bears spines and coni while that of the latter is only conate having very short (1-2 μm high) coni. The present genus also resembles *Aneurospora* Streel 1964 in having curvaturae and sculptured exine, but differs due to the spinose rather than conate nature of the ornament. Moreover, in *Aneurospora* the contact area occupies almost the whole proximal surface and the curvaturae coincide with equator of the miospore; hence the difference is well-marked. *Brevitriletes* Bharadwaj & Srivastava emend. Tiwari & Singh 1981 is similar to the present genus in having spinose exine but can be differentiated due to absence of curvaturae as well as spines on proximal face.

Balme and Hassel (1962) instituted the genus *Pulvinispora* to include forms having depressed contact area, thickened ray-ends and scabrate or irregularly granulose exine. Obviously, the present genus differs in the nature of exine ornamentation and the trilete rays. *Carnisporites* Mädler 1964, although apparently resembling *Santhalisporites* in having curvaturae, differs in having rough to scabrate exine and prominently thickened ray-ends (*see* Holotype, Klaus, 1960, pl. 28, fig. 6). *Apiculatisporis* Potonié & Kremp 1956, although superficially appears to be similar to *Santhalisporites*, differs in the absence of curvaturae and the presence of coni rather than spines.

PLATE 3 →

(All photomicrographs are × 500, unless otherwise stated)

1. *Staurosaccites marginalis*, Slide no. BSIP 9543.
2. *Staurosaccites tharipatharensis*, Slide no. BSIP 8474.
3. *Staurosaccites densus*, Slide no. BSIP 8475.

4,7,8,10. *Striatopodocarpites dubrajpurensis* sp. nov., fig. 4 Isotype, Slide no. BSIP 8471; fig. 7 Slide no. BSIP 8322; fig. 8 Slide no BSIP 8476; fig. 10 Holotype Slide no. BSIP 9323.

5. *Staurosaccites quadrifidus*, Slide no. BSIP 8474.
6. *Lahirites* sp., Slide no. BSIP 9543.
9. *Podocarpidites ellipticus*, Slide no. BSIP 8464.
11. *Goubinispora indica*, Slide no. BSIP 9541.
12. *Callialasporites lametaensis*, Slide no. BSIP 8459.
13. *Striatopodocarpites* sp., Slide no. BSIP 8471.
14. *Cycadopites sakarigaliensis*, Slide no. BSIP 8466.
15. *Callialasporites trilobatus*, Slide no. BSIP 9551.
16. *Callialasporites segmentatus*, Slide no. BSIP 9551

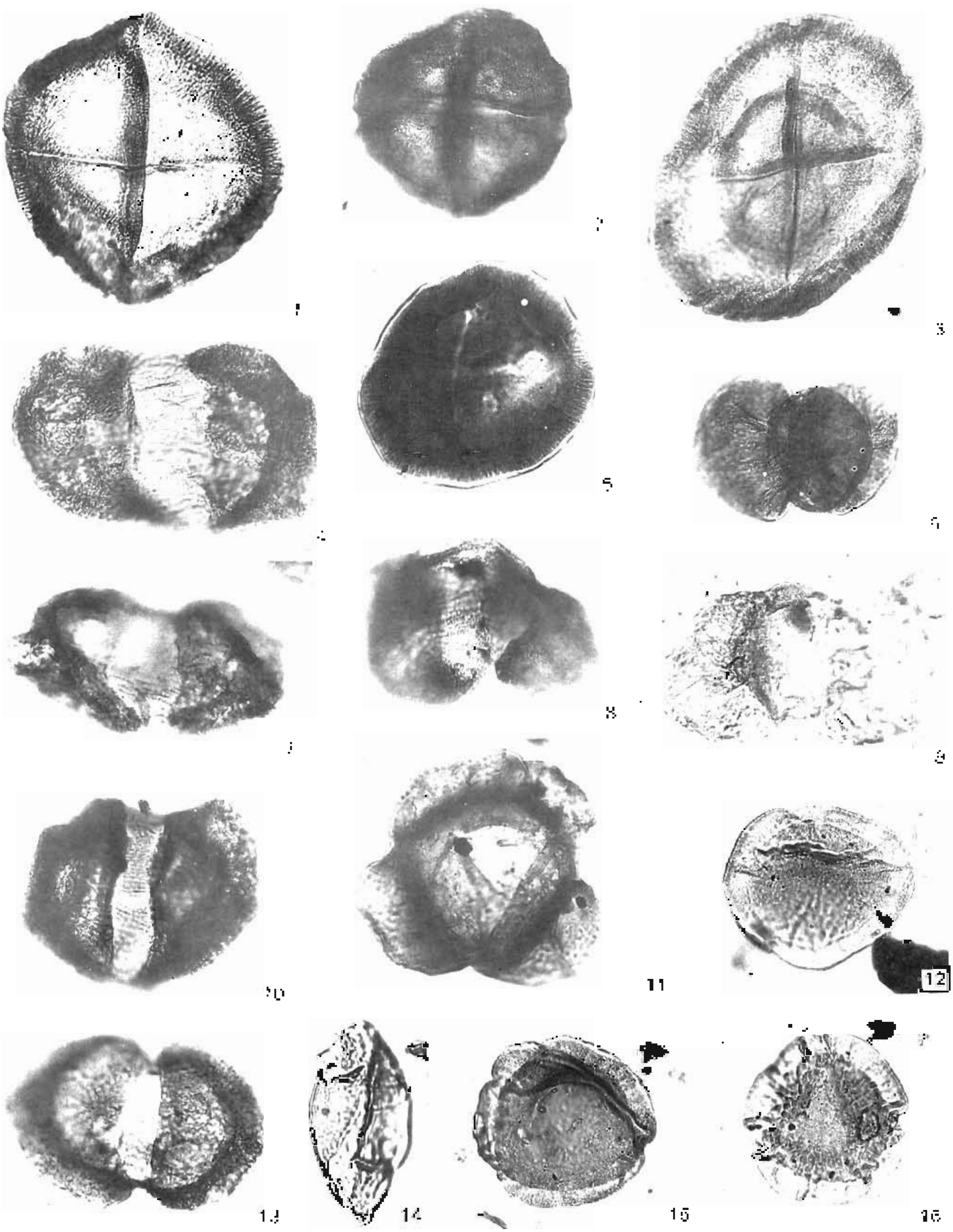


PLATE 3

Santhalisporites bulbosus sp. nov.
Pl. 4, figs 5, 6, 10, 11, 17

Holotype—Pl. 4, figs 10, 11; size 50.5 μm; Slide no. BSIP 8468.

Isotype—Pl. 4, fig. 5; size 49.0 μm; Slide no. BSIP 8466.

Type locality—Bore-hole RJR-2 (Sample no. 8, depth 91-94 m), near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Jurassic/Early Cretaceous.

Diagnosis—Roundly triangular spores with trilete rays ± reaching up to the equator; curvaturae distinct, demarcated with reduced and densely packed ornaments. Exine 1-2 μm thick, ornamented with hook-shaped spines having bulbous base and stretched apices with pointed or broadly rounded tips, 2.5-4.5 μm long and 1-2 μm wide at base; contact area bearing only coni.

Description—Spores measuring 40-57.5 μm in diameter, trilete rays slightly wavy with raised lips, curvaturae well-marked, rarely faintly perceptible. Contact area bearing up to 1 μm high coni; ornaments densely distributed.

Santhalisporites baskoensis (Sah & Jain) comb. nov., emend.
Pl. 4, figs 18, 19

Basionym—Acanthotriletes baskoensis Sah & Jain 1965, pl. 2, fig. 52; *Palaeobotanist* **13** (3), p. 272.

Synonym—Carnisporites spiniger (Leschik) Morbey 1975 *in* Achilles, 1981, pl. 3, figs 4, 5.

Holotype—In: Sah & Jain, 1965, pl. 2, fig. 52; Basko, Rajmahal hills, Bihar, India, Jurassic (Specimen lost).

Neotype—Pl. 4, fig. 18; size 37.5 μm; Slide no. BSIP 9549.

Type locality for Neotype—Bore-hole RJR-2 (Sample no. 9, depth 94-102.76 m), near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Jurassic/Early Cretaceous.

Diagnosis (emended)—Roundly triangular spores with well-defined curvaturae. Trilete rays slightly sinuous, ± 1 μm thick lips. Exine spinose, spines finger-shaped with straight to curved apices, 3-5 μm long and 1-2 μm wide at the base; contact area smooth.

Description—Size-range 31-50 μm in diameter. Exine ± 1 μm thick in optical section, spines sparsely distributed, contact area without sculptural elements.

Comparison—Santhalisporites baskoensis (Sah & Jain) comb. nov. differs from *S. bulbosus* sp. nov. in having long, curved spines with narrow bases, thin exine and non-ornamented contact area.

Remarks—The type specimen as well as the type material for this species is not traceable; therefore, a Neotype is proposed.

Santhalisporites imperfectus sp. nov.
Pl. 4, figs 7, 12-14

Holotype—Pl. 4, fig. 12; size 41.5 μm; Slide no. BSIP 9555.

Isotype—Pl. 4, fig. 7; size 33.5 μm; Slide no. BSIP 9551.

Type locality—Bore-hole RJR-2 (Sample no. 9,

PLATE 4 →

(All photomicrographs are. × 500, unless otherwise stated)

1. *Cyathidites punctatus*, Slide no. BSIP 9552.
2. *Foraminisporis* sp., Slide no. BSIP 9548.
3. *Divisisporites* sp., Slide no. BSIP 9550.
4. *Cicatricosisporites ludbrooki*, Slide no. BSIP 8458.

5,6, 10,11,17. *Santhalisporites bulbosus* gen. et. sp. nov., fig. 5 Isotype. Slide no. BSIP 8466. × 1000, fig. 6 portion of Isotype enlarged to show nature of spines, × 2000.

10. Holotype, proximal face showing coni in contact area, Slide no. BSIP 8468. × 1000.
11. Holotype distal face.
17. Slide no. BSIP 9595.

7,12-14. *Santhalisporites imperfectus* sp. nov.

7. Isotype, Slide no BSIP 9552.
12. Holotype—Proximal face showing smooth contact area, Slide no. BSIP 9555.
13. Holotype—distal face
14. Showing nature of sculptures in *Santhalisporites imperfectus* sp. nov. × 2500.
8. *Concavissimisporites penolaensis*, Slide no. BSIP 9549.
9. *Cicatricosisporites australiensis*, Slide no. BSIP 8468.

15,16. *Santhalisporites* sp., Slide no. BSIP 9545; fig. 16 showing anchor-shaped nature of sculptures.

18,19. *Santhalisporites baskoensis* comb. nov., fig. 18 Neotype Slide no. BSIP 9549; fig. 19 showing nature of sculptures, × 2000.

20. *Leptolepidites verrucatus*, Slide no. BSIP 9546.

21-23. *Leptolepidites rimatus* sp. nov.

21. Holotype showing nature of varrucae forming a rim like structure at the periphery, Slide no. BSIP 9547.
22. Holotype showing nature of verrucae in the centre and margin. fig. 23 Isotype, Slide no. BSIP 8469.

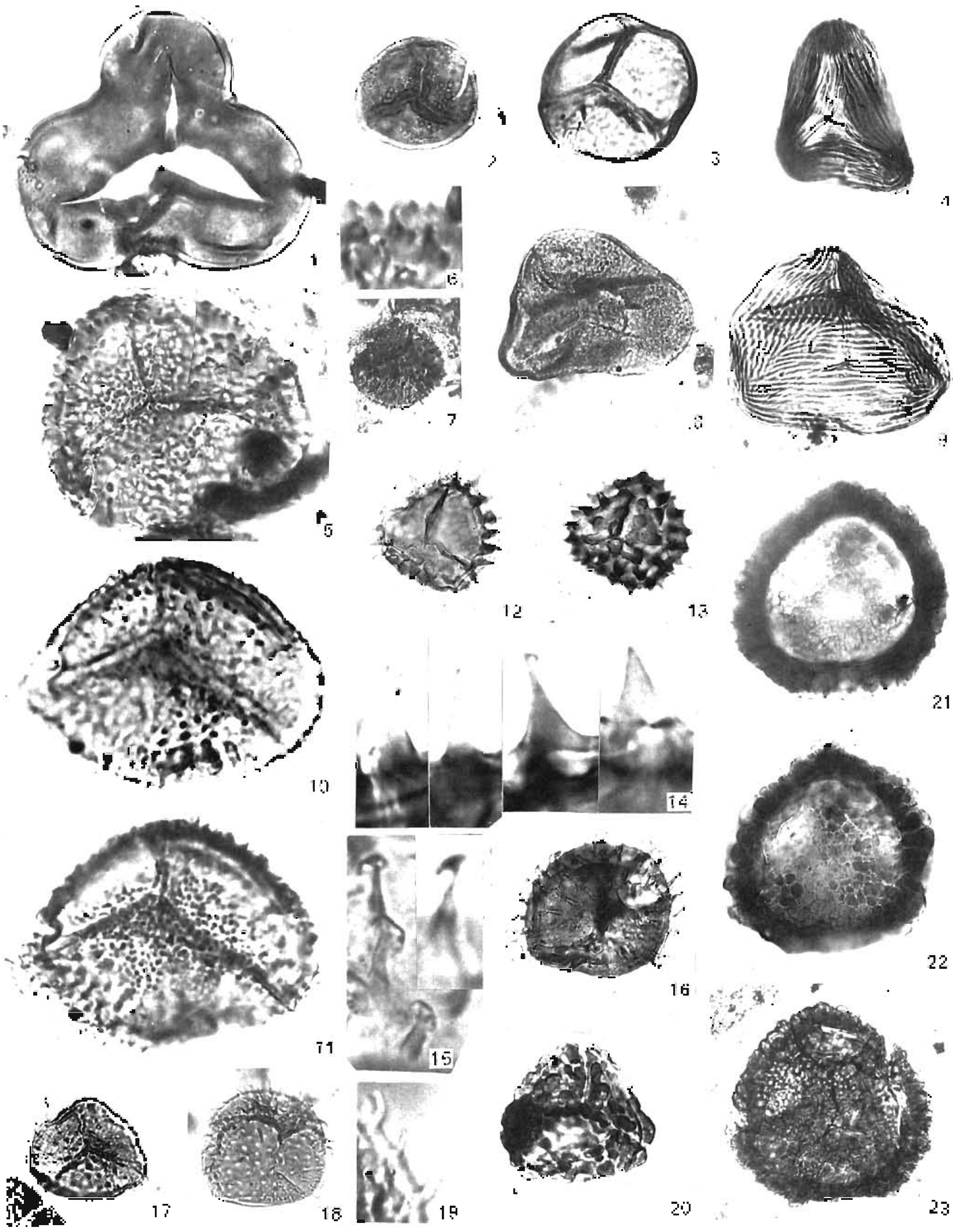


PLATE 4

depth 94-102.76 m), near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Jurassic/Early Cretaceous.

Diagnosis—Spores triangular to subcircular, trilete rays ± 3/4 of spore radius, sinuous. Exine covered with spines of variable shapes, conical, straight or curved with knob-shaped or blunt tips, bases of spines narrow to broad or slightly bulbous, coni up to 6 μm high and 5 μm wide at bases, spines 8-10 μm high and 2.5-3.5 μm wide at bases; curvaturae imperfectly developed and contact area smooth.

Description—Spores triangular with broadly rounded angles and convex sides, sometimes appearing as roundly triangular in shape, size 28-58 μm in diameter. Lips of trilete rays often raised, wavy, sometimes associated with folds. Exine 1-2 μm thick; characteristic nature of spines developed all over the surface but aligned densely along the margin of curvaturae.

Comparison—*Santhalisporites imperfectus* sp. nov differs from *S. bulbosus* sp. nov. in its imperfectly developed curvaturae, smooth contact area, simple, broad-based spines and coni. *Santhalisporites baskoensis* (Sah & Jain) comb. nov., although similar in having smooth contact area, can be differentiated by the presence of finger-shaped spines with narrow base, and perfect curvaturae.

Santhalisporites sp.
Pl. 4, figs 15, 16

Remarks—The anchor-shaped, 5-8 μm high and 3-5 μm wide at base, spines of these specimens restrict their placement in other newly described species. However, because of insufficient number of specimens they have been referred to as *Santhalisporites* sp.

Genus—*Dubrajisporites* Tiwari & Tripathi 1987

Dubrajisporites unicus sp. nov.
Pl. 1, figs 18, 22

Holotype—Pl. 1, fig. 18; size 58.0 μm; Slide no. BSIP 9323.

Isotype—Pl. 1, fig. 22; size 80.5 μm; Slide no. BSIP 9321.

Type locality—Bore-hole RJR-2 (Sample no. 32, depth 398.20-398.99 m) near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Jurassic/Early Cretaceous.

Diagnosis—Subtriangular to subcircular; trilete mark distinct, rays reaching 2/3 radius, almost straight. Exine 2-3 μm thick, coarsely reticulate all over excepting contact area. Muri surmounted with finger-shaped, round-tipped spines imparting a deeply and variably dissected nature; lumen bearing many big spines intermixed with small verrucae or coni; size of bigger elements 4-7 μm high and 1.5-3 μm wide; smaller elements 1.5-2.5 μm high and 1-2.5 μm wide. Exine unstructured.

Description—Dark-coloured spores, mostly subcircular, rarely subtriangular, 58-81 μm in size. Trilete rays closed or open, straight to slightly wavy, thick-lipped. Exine reticulate, mesh-size 9-28 μm, muri 4-5 μm high as seen at the equator, their free-ends bearing spines or coni—mostly with round-headed tips. Luminar area bearing many (4-6) straight or curved, round-tipped spines, mixed with small verrucae or coni; contact area bearing isolated verrucae or coni only. Inner body not seen.

Comparison—This species differs from the type species *D. triassicus* Tiwari & Tripathi 1987 and *D. bulbosus* Tiwari & Tripathi 1987 in the nature of muri and arrangement pattern of ornament of luminar area.

Dubrajisporites isolatus sp. nov.
Pl. 1, figs 17, 20, 21

Holotype—Pl. 1, fig. 20; size 65 μm (including ornaments); Slide no. BSIP 9323.

Isotype—Pl. 1, fig. 17; size 68.5 μm (including ornaments); Slide no. BSIP 9323.

Type locality—Bore-hole RJR-2 (Sample no. 32, depth 398.20-398.99 m), near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Jurassic/Early Cretaceous.

Diagnosis—Subtriangular to subcircular; trilete mark distinct, rays reaching 2/3 radius, straight, thick-lipped. Exine sculptured all over with isolated coni, spines and verrucae arranged in reticuloid pattern to enclose polygonal areas. Processes sometimes fusing at basal portion on both faces, except the contact area; polygonal areas bearing number of spines, coni and verrucae, sculptural elements 2-5.5 μm long and 1-4.5 μm wide at the base. Exine unstructured. Inner body not seen.

Description—Dark-coloured spores, mostly subtriangular rarely subcircular, 53-68.5 μm in size. Trilete rays closed or open, distinctly visible in the proximally up grains only. Exine thick, inter-ray areas bearing isolated spines, coni, bacula or verrucae and rest of the surface possessing similar sculptural elements arranged in reticuloid pattern to enclose polygons of 5-15 μm diameter; a number of processes present at the junction of polygons. Sometimes elements fusing at the bases to form muri-like, continuous but loose sculpture. Several elements including coni, verrucae and spines of variable size present within the polygonal areas.

Comparison—Dubrajisporites isolatus sp. nov. differs from *D. triassicus* Tiwari & Tripathi, 1987, *D. bulbosus* Tiwari & Tripathi 1987 and *D. unicus* sp. nov. in the nature of muri as it is constituted by isolated processes arranged in the form of coarse meshes thus the muri remains a loose organization and not a solid ridge as in other cases.

Genus—*Klukisporites* Couper 1958

Klukisporites venkatachalae sp. nov.
Pl. 5, figs 2, 3

Holotype—Pl. 5, fig. 2; size 52.5 μm; Slide no. BSIP 8466.

Isotype—Pl. 5, fig. 3; size 69.5 μm; Slide no. BSIP 9547.

Type locality—Bore-hole RJR-2 (Sample no. 8, depth 91.00-94.00 m), near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Jurassic/Early Cretaceous.

Diagnosis—Triangular, trilete mark prominent, labra thick, valvae absent. Exine with irregular foveo-reticulum, prominently disposed at the angles but faintly represented on the distal polar region. Margin wavy at the angles only, sides smooth.

Description—Spore triangular with broadly rounded angles and concave sides, measuring 45-69.5 μm. Trilete rays reaching up to the equator, showing 3-7 μm thick labra, slightly narrowing down towards the end. Angular region of spores covered with irregularly reticulate ornament appearing to be formed by fusion of 2-3 μm high verrucae. Distal polar region possessing very low and indistinct reticulum. *Extrema lineamenta* at inter-radial sides smooth.

Comparison—Klukisporites typically represents those forms which exhibit a uniform foveo-reticulate ornamentation on distal face. In the present species the reticulate sculpture is not uniform and regular; it is more crowded and prominently exhibited at the apices. Obviously, it is a variability from the typical *Klukisporites* species but the basic nature of reticulum determined its inclusion in this genus. By virtue of the characters described above, this species differs from other known species of this genus.

Genus—*Callispora* Dev emend. Bharadwaj & Kumar 1972

Callispora potoniei Dev emend. Bharadwaj & Kumar 1972
Pl. 5, fig. 5

Remarks—Specimens of *Callispora potoniei* Dev emend. Bharadwaj & Kumar 1972 encountered in the present assemblage possess thread-like fine ridges as scultpure at the interapical region. This character becomes all the more clear in the differential interference-phase contrast. However, the punctate nature of the exine is distinctly observed on the surface as described by Bharadwaj and Kumar (1972).

Genus—*Gabonisporis* Boltenhagen 1967

Gabonisporis vigourouxii Boltenhagen 1967
Pl. 1, fig. 5

Remarks—The presently studied specimens closely answer to the specific diagnosis of the speices given by Boltenhagen (1967). However, the size-range of the spores is more (72.0-99.5 μm) than that given by Boltenhagen (30-45 μm). The genus is reported from the Senonian (Upper Cretaceous) sediments from Gabon, Africa while the present specimens are recorded from Early Norian (Upper Triassic) sediments.

Gabonisporis papillosus sp. nov.
Pl. 1, figs 9, 13

Holotype—Pl. 1, fig. 9; size 70 μm; Slide no. BSIP 9322.

Isotype—Pl. 1, fig. 13; size 78 μm; Slide no. BSIP 9321.

Type locality—Bore-hole RJR-2 (Sample no. 32, depth 398.20-398.99 m) near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Triassic.

Diagnosis—Subtriangular to subcircular, ranging 70-90 μm in size. Trilete mark distinct, rays 3/4 radius long, straight, may be thick-lipped. Perisporial covering frilly enveloping the body completely, or sometimes leaving the contact area free. Perine densely ornamented with clusters of small, tongue-shaped papillae, or verrucae, measuring 1-3 μm high and 1-3 μm wide at base. Body exine smooth to scabrate.

Description—Perinous covering imparts a frilly nature and subcircular shape to the spore and a zonate appearance at the peripheral region. Spore body roundly triangular. Trilete mark may become indistinct because of the perine, sometimes open, trilete rays slightly elevated. Perispore ornamented with compactly disposed group of tongue-shaped, spatulate, round-headed papillae and verrucae; sometimes perine absent on the contact area. In surface view round heads of papillae and verrucae clearly observed.

Comparison—The present species differs from the type species, *Gabonisporis vigourouxii* Boltenhagen 1967, in the nature of sculptural elements of perine. In the former, the elements are verrucae and papillae while in the latter they are setae described as bacula by Boltenhagen (1967).

Genus—*Polycingulatisporites* Simoncsics & Kedves emend. Playford & Dettmann 1965

Polycingulatisporites sp.
Pl. 1, fig. 16

Remarks—The specimens closely compare with *Polycingulatisporites mooniensis* de Jersey & Paten 1964. However, due to the presence of only one concentric ridge on the distal face and many verrucae on the distal polar region they differ from the latter.

Genus—*Murospora* Somers 1952

Murospora florida Balme emend. Dettmann 1963
Pl. 5, fig. 8

Remarks—Some of presently studied specimens show punctate nature of cingulum. The puncta may traverse through the cingulum thickness so as to appear like narrow canals. Such structures have not been described in *M. florida* to which these specimens resemble in all other characters.

Genus—*Indotriradites* Tiwari 1964

Indotriradites sp.
Pl. 1, fig. 19

Remarks—The presently studied specimens differ from all the described species of *Indotriradites* in having finger-shaped processes mixed with few spines.

Genus—*Divarisaccus* Venkatachala & Kar 1966

Divarisaccus sp. cf. *D. strengeri* Bose & Kar 1966
Pl. 2, fig. 10; Pl. 6, fig. 8

Remarks—The studied specimens come under the circumscription of the species *Divarisaccus strengeri* given by Bose and Kar (1966). However, the size range originally described by Bose and Kar (1966) is greater (140-214 × 98-130 μm) than the range observed here (120-125 × 70-85 μm). Similarly, the nature of intrareticulation of central body and saccus is finer in the present specimens, rather than coarse as described by Bose and Kar (1966). This species has been originally described from Permo-Carboniferous sediments of Congo while here they are being described from the Upper Triassic sediments.

Genus—*Tetrasaccus* Pant emend. Maithy 1965

Tetrasaccus sp.
Pl. 2, fig. 13

Remarks—The present specimens conform to the generic diagnosis of the genus *Tetrasaccus*. However, it differs from the type species *T. karharbarensis* Maithy 1965 in having exine with vermiculate appearance having incomplete meshes on the central body, folds on the equatorial region of central body and a subcircular saccus-free area. Only a few specimens have been found in the present assemblage.

Genus—*Falcisporites* Leschik emend. Klaus 1963

Falcisporites minutosaccus
Kumaran & Maheshwari 1980
Pl. 2, fig. 7

Remarks—In our earlier study on the

PLATE 5

→

(All photomicrographs are. × 500, unless otherwise stated)

1. *Klukisporites varigatus*, Slide no. BSIP 8465.
2, 3. *Klukisporites venkatachalae* sp. nov., fig. 2 Holotype Slide no. BSIP 8466; fig. 3 Isotype, Slide no. BSIP 9547.
4. *Matonisporites dubius*, Slide no. BSIP 9549.
5. *Callispora potoniei*, Slide no. BSIP 8456.
6, 9-11. *Coptospora verrucosa* sp. nov.
6. Isotype, Slide no. BSIP 9551; figs 9,10 Holotype showing nature of verrucae, Slide no. BSIP 8469; fig. 11 specimen showing ruptured area or hilum, Slide no BSIP 9550.
7. *Triporoletes reticulatus*, Slide no. BSIP 9552.
8. *Murospora florida*, Slide no. BSIP 9550.
12. *Podosporites tripakshii*, Slide no. BSIP 9553.
13. *Coptospora kutchensis*, Slide no. BSIP 9548.
14, 18. *Cooksonites rajmahalensis* sp. nov., fig. 14 Holotype, Slide no. BSIP 8468; fig. 18 Isotype, Slide no. BSIP 9545.
15. *Gleicheniidites mundus*, Slide no. BSIP 8460.
16. *Contignisporites dettmanni*, Slide no. BSIP 9547.
17. *Labiipollis mesozoicus*, Slide no BSIP 8468.
19. *Classopollis indicus*, Slide no. BSIP 8466.
20. *Labiipollis granulatus*, Slide no. BSIP 9550.
21. *Aequitriradites spinulosus*, Slide no. BSIP 8469.
22, 23. *Araucariacites cooksoni*, Slide no. BSIP 8467.
24. *Araucariacites australis*, Slide no BSIP 9551.

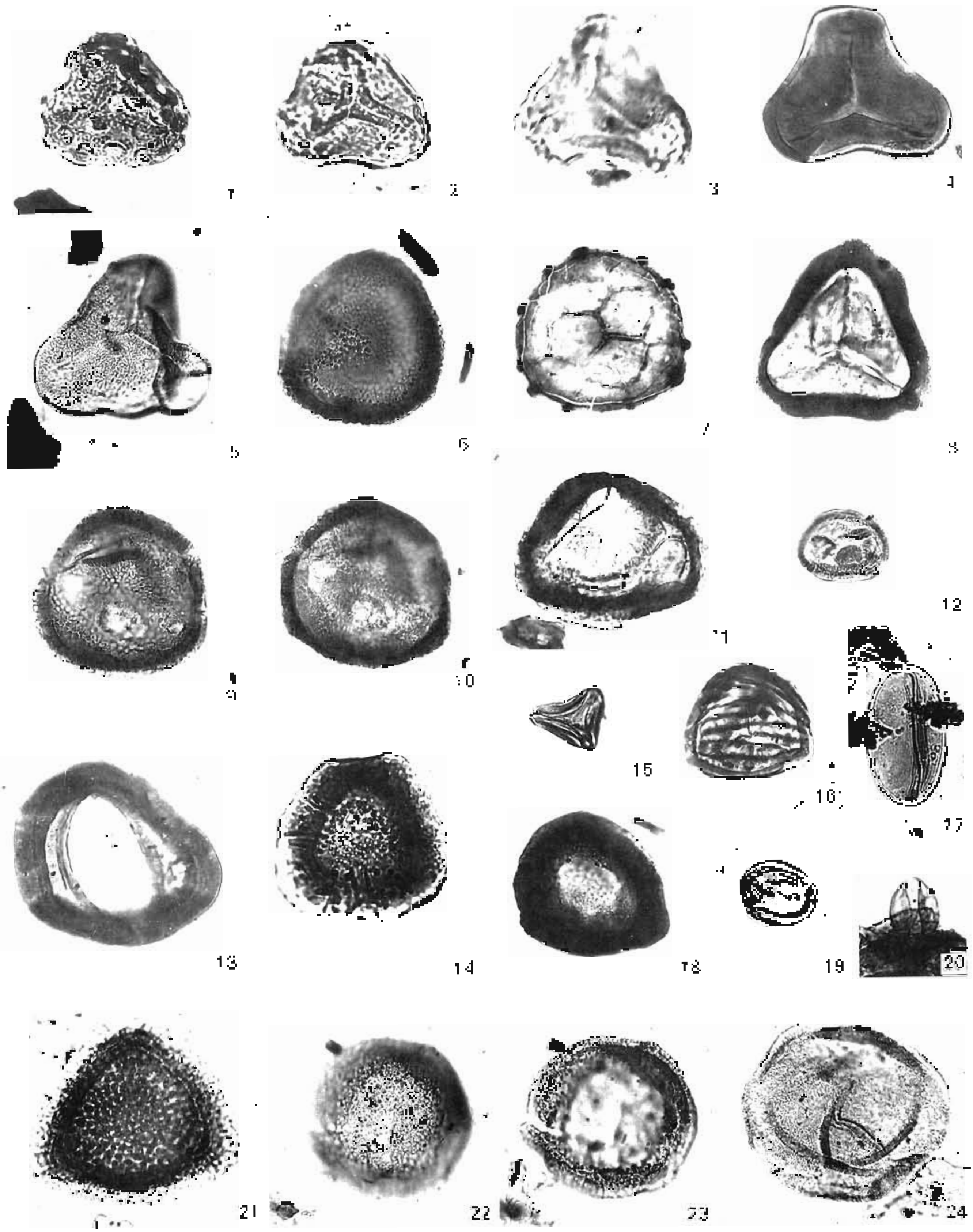


PLATE 5

palynodating of Dubrajpur and Intertrappean beds in Bore-hole RJR-2 (Tiwari, Kumar & Tripathi, 1984) similar forms were identified as *Minutosaccus* Mädler 1964. However, presently a re-allocation is made and they are referred to as *Falcisporites minutosaccus*.

Genus—*Brachysaccus* Madler 1964

Brachysaccus triassicus sp. nov.
Pl. 2, figs 16, 17

Holotype—Pl. 2, fig. 16; size 87.5 × 92.5 μm; Slide no. BSIP 8472.

Isotype—Pl. 2, fig. 17; size 110 × 110 μm; Slide no. BSIP 8471.

Type Locality—Bore-hole RJR-2 (Sample no. 32, depth 398.20-398.99 m) near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Triassic.

Diagnosis—Bisaccate pollen, broadly oval, 85-115 μm broad, 92.5-120 μm long; central body outline generally distinct, sometimes obscure; exine finely intramicroreticulate. Saccus attachment proximally subequatorial, distally bilateral and sometimes associated with folds. Saccus bearing medium-sized intra-reticulate structure with radially arranged thick muri giving a columellate appearance to the saccus at the margin.

Description—Subcircular to vertically oval pollen grains. Central body, when distinct conforming to the overall shape of the pollen, central body exine finely intramicroreticulate with relatively thick muri and small polygonal to subcircular lumen. Saccus un-notched, proximal attachment subequatorial covering a narrow peripheral area of the central body, distal attachment straight leaving a 10-25 μm broad sulcus, sometimes sulcus diverge at lateral ends. In optical section at the peripheral region of the saccus a thick zone marked by branched and unbranched radially arranged muri appearing to be columellate. Laterally preserved grains indicate a globular shape of the pollen.

Comparison— Present species is comparable to the type species, *Brachysaccus ovalis* Mädler 1964 in the overall shape. However, it differs in being smaller in size, and in having different structure of the saccus with radially arranged thick muri and elongated lumen, instead of polygonal ones.

Brachysaccus indicus Kumaran & Maheshwari 1980 is a heterogeneous taxon comprising elongate oval to spindle-shaped specimens. The holotype of *B. indicus* (pl. 7, fig. 2) is spindle-shaped, hence, only such forms should be considered in this species and the elongate oval forms should be referred to other species. Thus, *B. triassicus* differs from *B. indicus* sp. nov. in the overall shape and columellate appearance of saccus structure.

Genus—*Staurosaccites* Dolby in Dolby & Balme 1976

Remarks—A careful examination of the specimens referable to this genus clearly indicates the monosaccoidal construction of the pollen grains with a disaccate type of attachment. The central body outline is distinct or indistinct, may possess an inner body, having a long median cleft on the proximal face. The saccus is proximally sub-equatorially attached and distally reaching up to the centre of the body, forming linear saccus-free area. The scanning electron micrographs of the specimen (Pl. 6, figs 9, 10) show that the central body and saccus surface is not smooth but has chagranate appearance. Besides, small pits or depressions are also observed all over the surface of the pollen.

Staurosaccites densus Kumaran & Maheshwari emend.
Pl. 3, fig. 3

Holotype—Pl. 8, fig. 1; Kumaran & Maheshwari, 1980.

Type locality—Eastern bank of Janar Nala, about

PLATE 6 →

(Scanning electron micrographs)

1, 2. *Rajmahalispora triassica*, fig. 1. × 625.
2. Enlargement of specimen in fig. 1 proximal face showing scabrate surface with few low rugulae, × 2812.
3. *Rajmahalispora rugulata*, × 1010.
4. *Dubrajisporites bulbosus*, × 775.
5, 6. *Satsangisaccites nidpurensis*, fig. 5, × 625; fig. 6 enlargement of specimen in fig. 5 showing chagrenate nature of sulcus, × 2062.
7. *Converrucosisporites lunzensis*, × 1250.
8. *Divarisaccus* sp. cf. *D. strengeri*, × 625.
9, 10. *Staurosaccites*, fig. 9 complete grain, × 1050; fig. 10 enlargement of specimen showing chagrenate nature and presence of puncta on the surface, × 2500.
11. *Podocarpidites typicus*, × 925.
12. *Cicatricosisporites australiensis*, × 965.
13. *Podocarpidites cristiexinus*, the nature of central body exine, × 1250.
14. *Dubrajisporites triassicus*, × 1250.

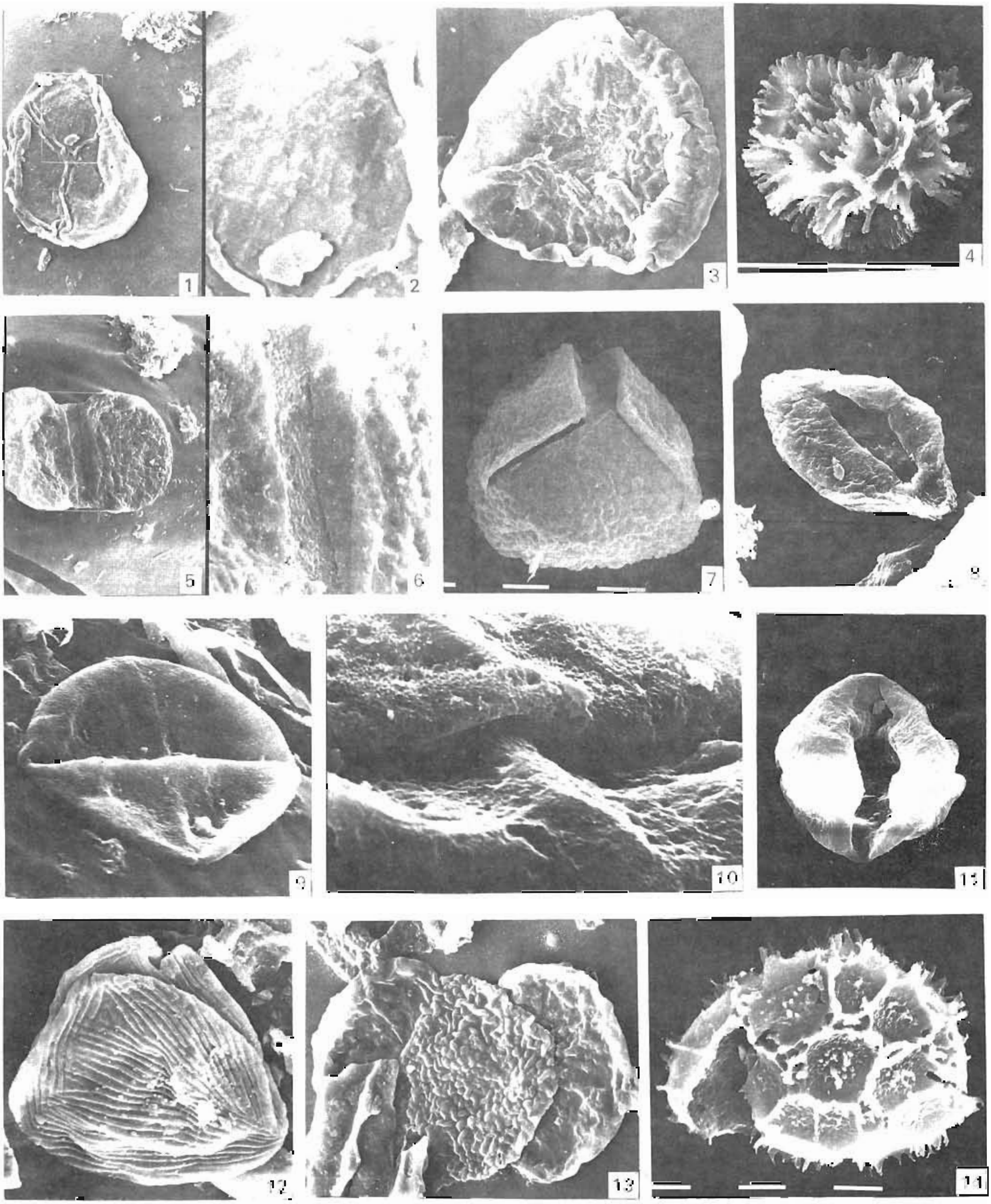


PLATE 6

2 km south east of Bijouri, district Shahdol, Madhya Pradesh.

Horizon & age—Tiki Formation, Late Triassic.

Emended diagnosis—Subcircular bisaccate pollen, central body outline indistinct, apparently conforming to the overall shape, divided by a narrow cleft; exine thick, intramicroreticulate. Inner body outline indistinct with irregular folds, laevigate. Saccus proximally subequatorially attached simulating an equatorial thick zone, distal attachment full-length. Saccus-free area making a cross-shaped pattern with polar cleft. Saccus finely intramicroreticulate.

Description—Pollen haploxylonoid, monosaccoidal subcircular in shape, size 100-128 μm. Central body appearing to be circular to subcircular, intramicroreticulate with thick muri and polygonal meshes. Inner body presented by denser area but without sharp outline, 55-75 μm in size, having many irregular folds arranged in circular pattern, laevigate. Polar cleft extending beyond the denser area. Sacci hemispherical, rigid, subequatorially attached proximally appearing as 3-11 μm wide equatorial zone, distally attached closely to each other, full length, leaving a narrow saccus-free area giving rise to a cross-shaped pattern in relation to the proximal polar cleft. In surface view saccus structure with polygonal meshes but at the peripheral region narrow elongated meshes and radially arranged thick muri impart an intrabaculate nature.

Comparison—In view of the present emended diagnosis, this species differs from the so far described species, viz., *S. quadrifidus* Dolby (in: Dolby & Balme, 1976), *S. marginalis* Kumaran & Maheshwari 1980, *S. ovalis* Kumaran & Maheshwari 1980 and *S. minutus* Kumaran & Maheshwari 1980, in having an inner body, apart from other differences. Kumaran and Maheshwari (1980) have interpreted the inner denser area as the central body. However, a re-examination of the holotype and the characters recorded from the presently observed specimens show that the polar cleft extends much beyond the outline of denser area which is difficult to explain if this denser area is considered as central body; also the full-length distal saccus attachment which makes a cross-shaped pattern with the proximal polar cleft, supports that denser area does not represent the spore body. Hence, the inner denser area is being considered here as the inner body within the central body.

Genus—*Striatopodocarpites* Soritsch & Sedova emend. Bharadwaj 1962

Striatopodocarpites dubrajpurensis sp. nov.
Pl. 3, figs 4, 7, 8, 10

Holotype—Pl. 3, fig. 10; size 91 × 71 μm, central body size 66 × 77 μm; Slide no. BSIP 9323.

Isotype—Pl. 3, fig. 4; size 112 × 67.5 μm, central body size 70 × 67.5 μm; Slide no BSIP 8471.

Type locality—Bore-hole RJR-2 (Sample no. 32, depth 398.20-398.99 m) near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Triassic.

Diagnosis—Diploxylonoid 91-126 μm; 57-57 μm. Central body distinct, dense, subcircular, 47-70 × 45-71 μm, proximally striate with 15-21 horizontal striations, finely intramicroreticulate. Sacci more than hemisphere, coarsely intrareticulate having meshes up to 6 μm wide; distal sulcus 15-30 μm broad.

Description—Bilateral, central body without an equatorial rim, exine 1.5-2 μm thick as seen at the lateral ends; some striations branched, vertical partitions absent. Exine finely intramicroreticulate, muri thick. Sacci more than hemispherical, proximally equatorially attached, distal attachment subequatorial along full length of central body, almost straight, distal saccus-free area broad and bilateral, 16 μm wide in holotype. Saccus intrareticulation coarse, mesh polygonal, 3-6 μm in size, muri thick.

Comparison—The present species is closely comparable to *S. multistriatus* (Banerji & Maheshwari) Bharadwaj & Dwivedi 1982 in having many striations, but differs in having larger size-range, and more horizontal striations (15-21), absence of vertical partitions and coarse intrareticulation of the saccus. *Striatopodocarpites auriculatus* Vijaya & Tiwari 1988 (in Vijaya *et al.*, 1988) is different from the present species due to auriculate nature of sacci and striations tending to impart an incipient taeniate appearance.

Striatopodocarpites sp.
Pl. 3, fig. 13

Remarks—Pollen measuring 100 × 64 μm with horizontally oval, 70 × 50 μm, equatorially thickened (2.5 μm thick) central body bearing 7 horizontal striations, without vertical partitions. Sacci kidney-shaped. However, the combination of the central body characters—the striations, equatorial rim and the nature of saccus reticulation with thick muri, small lumen with partial radial arrangement does not allow its assignment to any of the already described species. Therefore, it is described here as *Striatopodocarpites* sp.

Genus—*Coptospora* Dettmann 1963

Coptospora verrucosa sp. nov.
Pl. 5, figs 6, 9-11

Holotype—Pl. 5, figs 9, 10; size 65 μm; Slide no. BSIP 8469.

Isotype—Pl. 5, fig. 6; size 65 μm; Slide no. BSIP 9551.

Type locality—Bore-hole RJR-2 (Sample no. 9, depth 94-102.76 m) near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Jurassic/Early Cretaceous.

Diagnosis—Spores hilate, subtriangular to subcircular. Exine verrucose all over except on one pole where rupturing to form subcircular area; verrucae prominent with round and conical tips.

Description—Size 63-66 μm in diameter. Hilum subcircular, measuring 25-35 μm in diameter. Exine thickness difficult to measure due to presence of prominent and densely disposed ornaments Verrucae 1-3 μm wide at base and 1.5-3 μm high. Equatorial girdle or rim broader at the angles being 3-8 μm wide.

Comparison—*Coptospora verrucosa* sp. nov. differs from *C. striata* Dettmann 1963 in the absence of striate pattern in the exine, beside the presence of massive verrucae; *C. paradoxa* Dettmann 1963 has scabrate exine and hence it is different from the present species. *Coptospora* sp. A, described by Dettmann (1963, pl. 20, figs 6-8) resembles the present species in having verrucose sculpture, although in the present specimens they are with round and pointed tips. *Coptospora* sp., recorded by Maheshwari and Jana (1983) from Rajmahal Basin (pl. 2, figs 26, 27), resembles the present species to a greater extent, except in the size of verrucae.

Genus—*Cooksonites* Pocock emend. Dettmann 1963

Cooksonites rajmahalensis sp. nov.
Pl. 5, figs 14, 18

Holotype—Pl. 5, fig. 14; size 66 μm; Slide no. BSIP 8468.

Isotype—Pl. 5, fig. 18; size 67 μm; Slide no. BSIP 9545.

Type locality—Bore-hole RJR-2 (Sample no. 9, depth 94-102.76 m) near Kazigaon, Rajmahal Basin.

Horizon & age—Dubrajpur Formation, Late Jurassic/Early Cretaceous.

Diagnosis—Spores roundly triangular, hilate and cingulate. Cingulum with small holes on surface appearing to be short canals, also sculptured with sparsely disposed low verrucae. Central body ornamented with verrucae.

Description—Size 66-104 μm. Hilum or ruptured area present on one face, subcircular, up to 20 μm; central body convexly triangular with rounded angles, size 60-80 μm, ornamented with low 0.5-2 μm verrucae. Cingulum 9-12 μm wide, darker near the central body equator, small hole-like structures present in cingulum simulating as short channels radiating towards the peripheral region; 1-2 μm high and 1-2 μm wide verrucae present on the cingulum projecting out from the equatorial outline.

Comparison—*Cooksonites variabilis* Pocock 1962 is different from the present species in having narrower, smooth or finely scabrate cingulum without any canals and showing polygonal process arranged in reticulate pattern on the polar region. *Cooksonites* sp. recorded by Bose, Kutty and Maheshwari (1982) from Gangapur Formation differs from *C. rajmahalensis* sp. nov. in having coni which extend on to the cingulum. *C. minor* Venkatachala 1969 is smaller in size (50-60 μm) having narrower and smooth cingulum.

Type A
Pl. 2, fig. 19

Description—Subcircular, oval to squarish bodies, light brown in colour, measuring 54-58.5 μm; on equator 3-5 μm wide zona-like structure present; finely laminated, bar-like thickenings run across the width of the equatorial zone; these thickenings being 3-5 μm apart from each other, sometimes shorter than the width of zona with nail-shaped organisation at their loose ends. No haptotypic mark seen on the surface; 2-4 μm long sparse bacula with round or blunt broader heads present all over the body on both the surfaces, no process projecting beyond the equator. Exine smooth, folds prominent.

Type B
Pl. 1, fig. 15

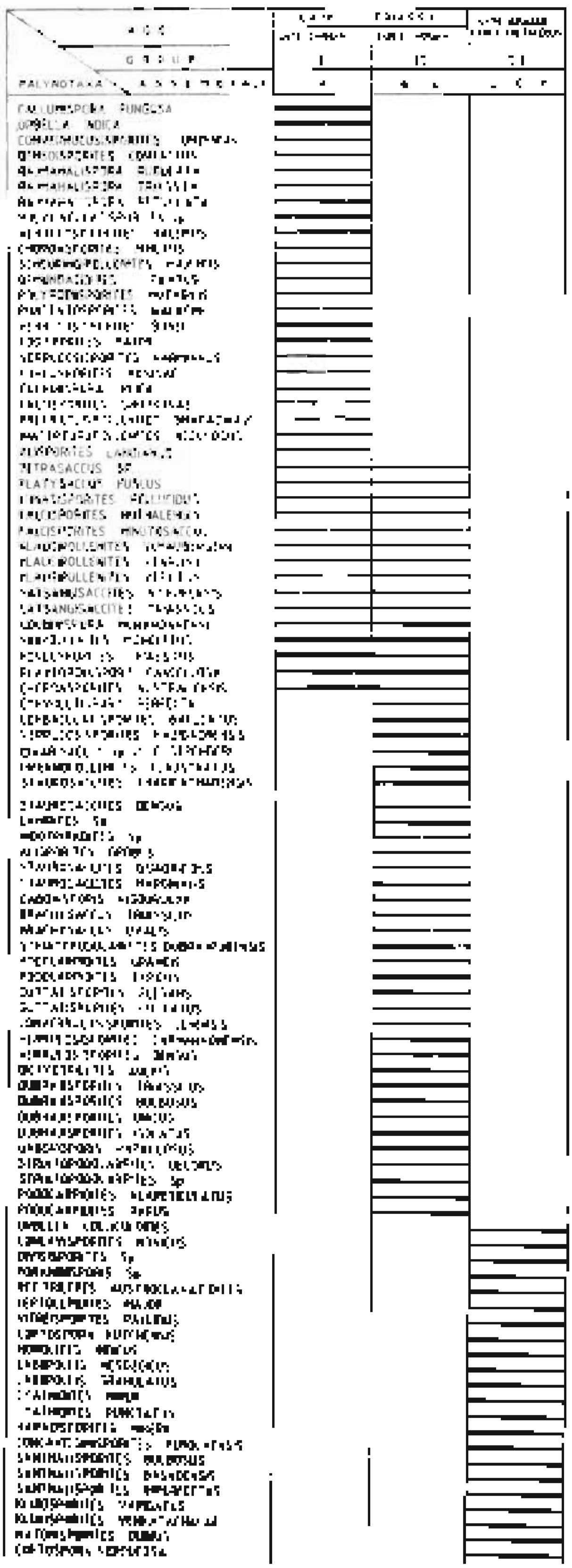
Description—Alete, subcircular to oval, light brown bodies with many folds on the equatorial region, measuring 92.5-105 μm; exine 1 μm thick, intrapunctate, puncta uniformly distributed; a weak zone present.

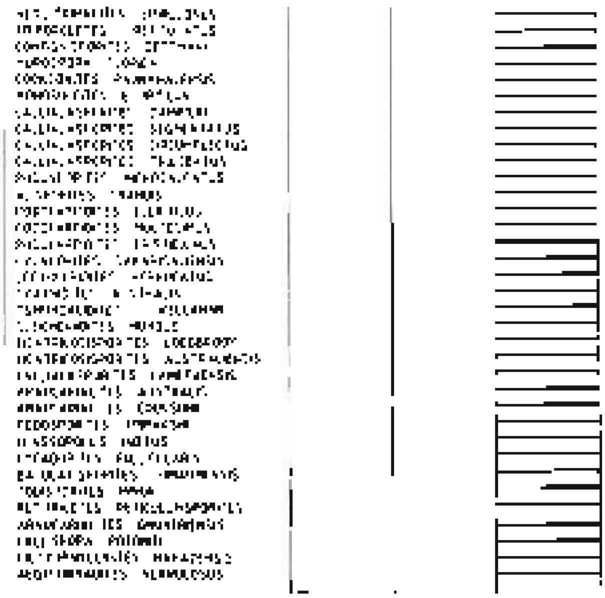
Remarks—It is observed that these bodies split along the weak zone.

DISTRIBUTION PATTERN OF VARIOUS PALYNOTAXA

The distribution pattern of various palynotaxa recorded in the sequential samples of Bore-hole RJR-2 is plotted in Table 1 which shows the presence of three distinct Groups, viz., Group I, II and III. Group I includes Assemblage A indicating Late Triassic (Late Carnian) age; Group II includes Assemblages B and C deciphering Late Triassic (Early Norian) age, and Group III having Assemblages D, E and F denotes Late Jurassic/Early Cretaceous age (Tiwari *et al.*, 1984). The older two groups (i.e. Assemblages A,

Table 6 — Distribution pattern of palynofossils in Dubrajpur and Intertrappean sediments from bore hole RJR-2, Rajmahal Basin





II & III) although have palynomorphs with restricted distribution, show the presence of 24 species in common suggesting a qualitative continuity of the flora. Thus the distribution pattern indicates a continuous process of sedimentation, without a time gap during Late Carnian and Early Norian times in this region. On the other hand, distinct break has been marked between Group II and III. Group III is represented by 59 species and none of its elements are recorded in Groups I and II. This sudden change can not be attributed to a real break in the palynoflora because very rare and mostly unidentifiable palynofossils are recovered from the sediments of 102.76 to 398.50 m depth (i.e. 295.74 m thickness). This barren zone of about 300 m thickness lies between Group II and Group III.

The continuation of palynoflora from the upper part of Dubrajpur sediments into the Intertrappean sediments indicates a floral continuity even after the volcanic activity in this region. The occurrence of palynoassemblages of different age within the sequence of Dubrajpur Formation suggests that the Dubrajpur Formation transgresses the time limits.

CONCLUSION

Palynological analysis of sediments in Bore hole RJR-2 from Rajmahal Hills has revealed the presence of a qualitatively rich palynoflora (76 genera and 136 species with 1 new genus and 11 new species) in the sediments of Dubrajpur Formation and the overlying intertrappean beds. The distribution of species shows distinct pattern of assembly which are identified as three groups, qualifying Late Triassic (including Group I and II) and Late Jurassic/Early

Cretaceous (including Group III). The marked continuity in the distribution pattern of Groups I and II is suggestive of continuous sedimentation during Late Carnian and Early Norian times. The pattern of species distribution in the uppermost part of infratrappean and second intertrappean bed is indicative of continuation of similar vegetation inspite of the first flow which demarcates the upper limit of Dubrajpur Formation.

The barren zone of 300 m thickness contains ferruginous, green, grey, red coloured shales, clay and sandstone. This zone, lithologically, is bracketed within the Dubrajpur Formation. Palynologically the base of this barren zone is marked by the Early Norian flora, while its top is delimited by a Late Jurassic/Early Cretaceous assemblage. Therefore, in all probability, this thickness of sediment represents an intervening time slot during which period the 300 m thick sediments were deposited.

Palynologically, Dubrajpur Formation encompasses the sedimentary deposits of Late Permian to Late Jurassic/Early Cretaceous age—obviously a time transgressive phenomenon.

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An early archaeological evidence of Plane tree (*Platanus orientalis* L.) in Kashmir Valley

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An evidence of *Platanus orientalis* L. (Chinar) in charcoal samples from an archaeological site at Semthan in Kashmir Valley has brought to light the earliest record of this European tree dating back to early historic period from 500 to 1,000 A.D. The archaeological significance pertaining to its much earlier introduction in Kashmir Valley has been discussed.

Key-words—Archaeobotany, *Platanus*, Exotic tree, Kashmir Valley (India).

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सारांश

काश्मीर घाटी में प्लेन वृक्ष (प्लेटेनस ओरियेन्टेलिस एँल०) का प्रारम्भिक पुरातात्विक प्रमाण

फ़ारूक ए० लोन, गुलाम मोहम्मद बठ एवं मकसूदा खान

काश्मीर घाटी में सेमथान नामक गाँव में एक पुरातात्विक स्थान से उपलब्ध काष्ठ-चारकोल के नमूनों से प्लेटेनस ओरियेन्टेलिस एँल० (चिनार) की लकड़ी के अवशेष मिले हैं। इस प्रमाण के आधार पर पाँचवीं से दसवीं शताब्दी के मध्य काश्मीर घाटी में इस यूरोपीय वृक्ष की उपस्थिति इंगित होती है। इस शोध-पत्र में काश्मीर घाटी में इस वृक्ष के और अधिक पहले समावेशन पर एक पुरातात्विक विवेचना भी की गई है।

THE study of wood remains recovered from the archaeological excavations has revealed not only the type of vegetation growing and the way of exploitation of forest trees by the ancient inhabitants but also provided important information on the introduction of exotics in the Kashmir Valley (Lone, 1987). The oriental plane (*Platanus orientalis* L.) is a large, graceful deciduous tree cultivated in Kashmir and north-west Himalaya. In Kashmir, the tree is known as "Chinar" or "Buin" and is very closely associated with the culture and folklore. Its introduction usually has so far been ascribed to the Moghul emperor Jehangir (1605-1627 A.D.) and Shahjahan (1627-1658), who brought it from Central Asia (Lawrence, 1967). But our recent investigations on the charcoal remains from an archaeological site at Semthan in Kashmir Valley (Lat. 33°48′ N: Long. 75°9′E) have revealed that this tree was in existence centuries before the advent of Moghuls.

DESCRIPTION

Pl. 1, figs 1-4

Wood diffuse to semi-ring-porous. *Growth rings* marked by a band of fibres. *Vessels* small, 30-80 μm in tangential diameter, comparatively larger and more clustered in early-wood and smaller, solitary or in small files in latewood. Intervascular pits small, crowded and aligned in horizontal rows. *Parenchyma* apotracheal-diffuse and sparsely paratracheal. *Fibres* thin to moderately thick-walled, libriform, angular to oval in cross-view, 8-15 μm thick and not aligned in rows. *Rays* commonly larger and occasionally short and fine, more or less equidistant, homogeneous. Large rays 4 cells wide and fine rays 2-3 cells wide; height varies from 200-450 μm and width 47-103 μm.

The above combination of characters leads us to refer the ancient wood to *Platanus orientalis* L. of

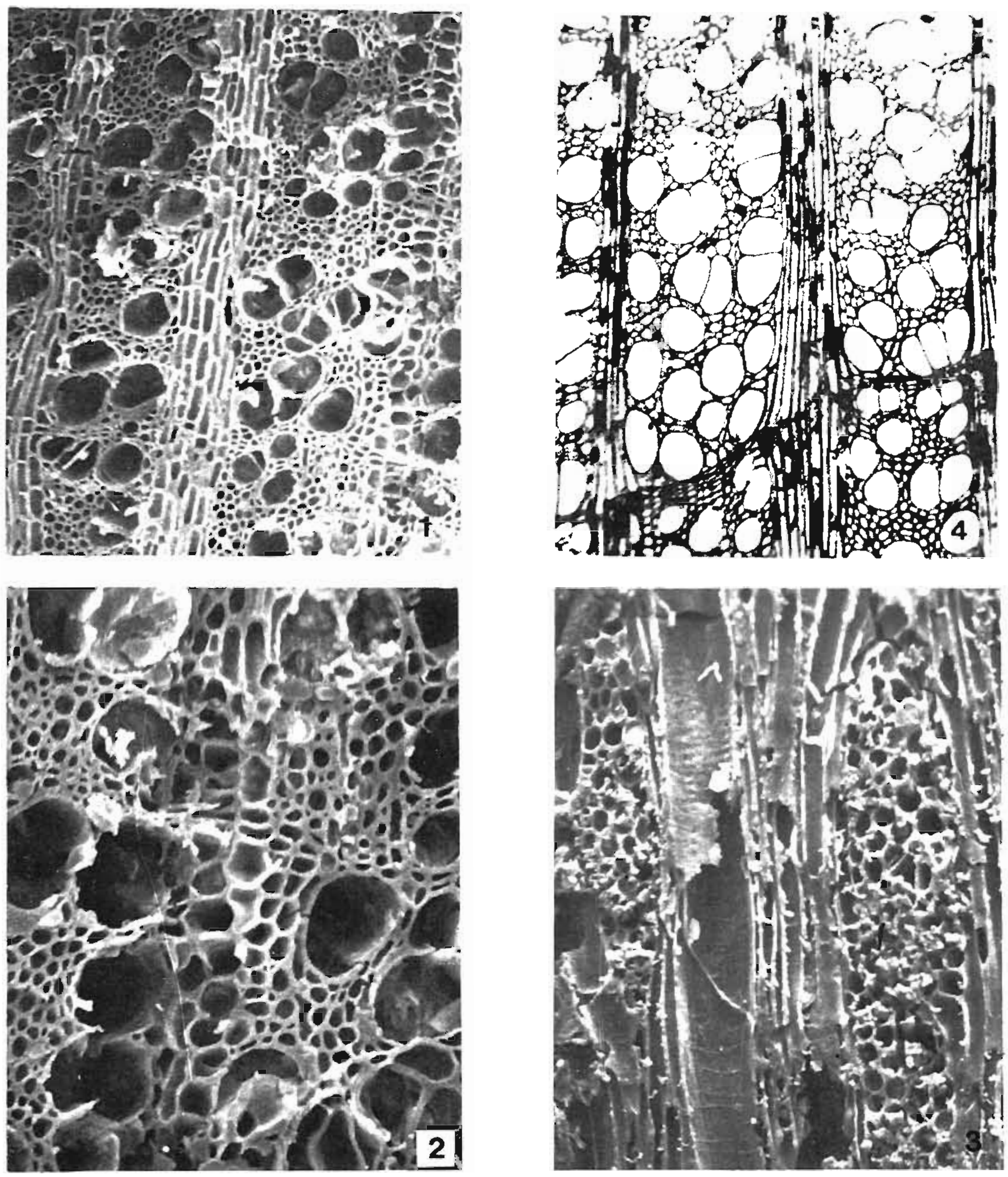

PLATE 1

1. Cross section of *Platanus orientalis* wood remain, × 100.
2. Higher magnification of the same as above, × 200.
3. Tangential longitudinal section of *Platanus orientalis* wood remain, × 200.
4. Cross section of extant *Platanus orientalis* wood for comparison with the archaeological wood, × 60.

the family Platanaceae (Schweingruber, 1978). Comparison with the extant material of the same, further supports our identification.

CONCLUSION

The beautiful tree of Oriental Plane (*Platanus orientalis*) is an old introduction in Kashmir Valley and adjoining areas. Now-a-days it has been planted for ornamental purposes. This species is indigenous in greece, *Macedonia*, Armenia and northern Persia (Gamble, 1902). At present, the plane trees have also come under extensive cultivation in Baluchistan and Afghanistan and in the western Himalaya as far as the Sutlej River ascending to 8,300 ft. In all probability, the plane tree in the north-western region of Indian subcontinent must have come from Mediterranean region (northern Persia) in the remote past.

We do not know exactly when this tree got introduced in Kashmir region. Some references in this regard could be found in the literature. Lal Ded (c. 1320-1390 A.D.), the famous mystic poetess of Kashmir, made the reference of plane tree in an epigram comparing "Virtuous and loving wife to the cool and refreshing shade on a hot summer day of Buni". In '*Akbarnama*' written by Abul Fazl (1551-1602), a scholar in the regime of Moghul emperor Akbar, it is mentioned that "the emperor took 34 persons inside the hollow trunk of an aged Chinar (plane tree)". Similarly Jehangir in his memoirs has made mention of a huge plane tree, in the hollow of which he and his seven companions could be comfortably accommodated. All the same, these references have led us to conclude that plane trees were already existing in Kashmir when the Moghul emperors visited this area. Now, the first factual evidence of plane tree from Semthan has traced back the history of its occurrence in Kashmir Valley to 1,000-500 B.C. and it is to be reckoned with. Whatsoever might have happened in the past, such an early introduction of plane, the gracious ornamental tree of Kashmir, bears ample testimony to its importance in the archaeological context.

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