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PACHYPTERIS HABURENSIS N. SP. AND OTHER PLANT FOSSILS FROM THE PARIWAR FORMATION

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ABSTRACT

Fossil plant remains collected from the Pariwar Formation, exposed about 1 km east of Habur Village, are described here. The floral assemblage at Habur is dominated by a new species of *Pachypteris* (*P. haburensis*). Besides, the assemblage comprises a fertile species of *Gleichenia*, *Pachypteris* sp., *Taeniopteris spatulata* McClelland, *Ginkgo* sp., *Elatocladus tenerrima* (Feistmantel) Sahni, *Pagiophyllum* spp., *Araucarites* sp. cf. *A. cutchensis* Feistmantel, *Coniferocaulon rajmahalense* Gupta and a 'flower'-like organ.

Key-words — *Pachypteris*, Megafossils, Pariwar Formation, ?Upper Jurassic-Lower Cretaceous (India).

सारांश

परिवार शैल-समूह से पेकिप्टेरिस हाबुरेन्सिस नव जाति एवं अन्य पादपाश्म – महेन्द्रनाथ बोस, के० पी० नवनीथ कुमारन एवं जयश्री बैनर्जी

हाबुर गाँव के पूर्व में लगभग एक किलोमीटर की दूरी पर विगोपित परिवार शैल-समूह से पादपाश्मों का वर्णन किया गया है। हाबुर में वनस्पति जातीय समुच्चय पेकिप्टेरिस की एक नई जाति (पे० हाबुरेन्सिस) से प्रभावी है। इसके अतिरिक्त इस समुच्चय में ग्लाइकीनिया की जनन जातियाँ, पेकिप्टेरिस जा०, टीनियॉप्टेरिस स्पेचुलेटा मैक्क्लीलैंड, गिन्कगो जा०, इलेटोक्लेडस टेनेरिमा (फाइस्टमेन्टेल) साहनी, पेजियोफिल्लम् जा०, ऑरोकेराइटिस जा० सजातीय अ० कच्छेन्सिस फाइस्टमेन्टेल, कोनिफेरोकोलोन राजमहलेन्से गुप्ता तथा एक 'पुष्प'-सदृश अवयव है।

INTRODUCTION

THE exposed Mesozoic sediments in the Jaisalmer basin are mostly of post-Triassic age and have been classified into Lathi, Jaisalmer, Baisakhi, Bedesar, Pariwar and Abur formations. According to Das Gupta (1974) they range in age from Liassic to Aptian. Out of these formations, until recently, plant fossils (petrified woods) were known to occur only in the Lathi Formation. Das Gupta *et al*. for the first time discovered plant impressions from the Pariwar Formation in 1975. Later a part of this collection was described in detail by Maheshwari and Singh (1976). During our recent trips (1978 and 1979) to Jaisalmer we have also collected plant remains from the same locality. Besides, we have collected fossil wood pieces from Lathi, Baisakhi, Bedesar and Pariwar formations. The wood pieces are rather badly preserved so in the present paper only the plant impressions have been described.

The fossiliferous bed, having plant impressions, is situated approximately 1 km east of Habur Village (27°10′: 70°33′) which is about 60 km from Jaisalmer. The exposures are seen along the eastern fringe of a water reservoir ("*Seraliya ka toba*" — except for the rainy season, lying dry throughout the year). The succession at this place from bottom to top is as follows:

ROCK TYPES	FROM TO	THICKNESS	FOSSIL OCCURRENCE
Variegated shales	—	A thin layer	Indeterminable fragmentary plant remains.
Dirty white, yellowish or brownish cross bedded, fine grained, highly friable sandstone with ferruginous shale partings.	00 m-0·90 m	0·90 m (P_1)*	Ferruginous fossil woods.
Yellowish shale (commonly arenaceous), seems to be marly in nature with remains of rich plant fossils. At places ferruginous partings visible.	0·90-1·40 m	0·50 m (P_2)	Fossiliferous bed with fairly well preserved plant impressions, dominated by *Pachypteris haburensis* n. sp.
Yellowish to brownish coloured. At places thinly laminated, fine to medium grained micaceous soft sandstones (?feldspathic in nature) also containing thin ferruginous intercalations.	1·40-2·10 m	0·70 m (P_3)	Fragments of fossil woods, rare occurrence of *Pagiophyllum* sp. and *Taeniopteris spatulata* McClelland.
Silty to sandy white laminated shales with fine grained sandstone intercalations. Shale calcareous in nature; in upper part at places, light purplish in colour showing rain prints-like markings.	2·10-3·50 m	1·40 m (P_4)	Rarely with indeterminable fragmentary plant remains.
Dirty brown, slightly micaceous, ferruginous, soft, somewhat fine grained sandstone with thin ferruginous partings particularly in the upper part, also at places concretionary.	3·50-4·30 m	0·80 m (P_5)	Fossil wood fragments.

*P_1 — P_5 indicate the different beds from where rock samples have been collected.

DESCRIPTION

Gleichenia sp.

Pl. 1, figs 5,6; Text-fig. 1C-D

1976 *?Gleichenites* sp.: Maheshwari & Singh, p. 116, pl. 1, fig. 2.

A detached fragmentary pinna of *?Gleichenites* sp. was described by Maheshwari and Singh (1976). The present collection includes a few detached pinnae with both sterile and fertile pinnules.

Description — Pinnae 0.4-1.1 cm long and 0.2-0.3 cm wide. Pinna rachis 0.5 mm wide, striated or with a median ridge. Pinnules alternate, attached at 40°-45°, deltoid in shape, rarely somewhat falcate, 1-1.5 mm long and 0.5-1.5 mm broad at base, margin entire, slightly revolute; apex obtuse, acroscopic margin straight; basiscopic margin slightly decurrent, touching acroscopic margin of the pinnule lying below. Substance of lamina thick. Veins obscure, only in some mid-vein visible, secondaries not preserved. Fertile pinnule with a single sorus placed near upper margin but closer to base. Sorus circular or oval with a central oval or circular depression. The number of sporangia not discernible.

Collection — Nos. 21/2095 and 28/2095 of the Birbal Sahni Institute of Palaeobotany Museum, Lucknow.

Comparison — The fertile pinnules of *Gleichenia* sp. are more like the fertile pinnules of *G. gleichenoides* (Oldham & Morris) Bose & Sah (1968, pl. 4, fig. 26). In both the species the shape of pinnules is more or less similar and each pinnule has a single sorus which is placed closer to the upper margin. *G. gleichenoides* has 12-15 sporangia. In the present specimens sporangia are not preserved. In *G. bosahii* Pant & Srivastava (1977), too, each fertile pinnule has a single sorus which is placed near base. *G. bosahii* differs in having closely set pinnules which have more obtuse apices. In *G. yuasensis* Kimura & Kansha (1978) the sterile pinnules are more like the pinnules of the present species but the pinnules in the former species have acuminate apex.

Pachypteris haburensis n. sp.

Pl. 1, figs 11, 12; Text-figs 1A-B, 2A-C

1972 *Onychiopsis* sp. cf. *O. psilotoides* (Stokes & Webb) Ward: Mathur, p. 488, fig. 19.

1975 *Cladophlebis* sp. (?): Das Gupta *et al.*, p. 236, fig. 3.

1976 Frond Type-I: Maheshwari & Singh, p. 117, pl. 1, fig. 8.

Diagnosis — Frond bipinnate, shape as a whole broadly lanceolate, up to 13 cm long and 7 cm wide. Main rachis 2-5 mm wide, with faint longitudinal striations, at times with a prominent median ridge. Pinnae closely set, alternate, rarely near apex sub-opposite, touching each other or at places even overlapping, arising at 30°-35°. Pinna rachis 0.5 mm wide, extremely delicate and slightly raised. Pinnules arising near base at 25°-30°, near apex at 15°-20°; crowded, touching each other or overlapping adjacent pinnules, lanceolate, apical pinnules sometimes pinnatifid, 2-4 mm long and about 1 mm broad, basal pinnules 5-7 mm long, 1-1.5 mm broad, apex acute-subacute; margin entire; acroscopic margin constricted or slightly decurrent; basiscopic margin decurrent, decurrent base of the lowermost pinnule running almost parallel to main rachis and touching the basiscopic margin of the pinnule belonging to pinnae lying below. Veins obscure, only at places principal vein visible, secondary veins few, rarely preserved, making narrow angle with the primary vein.

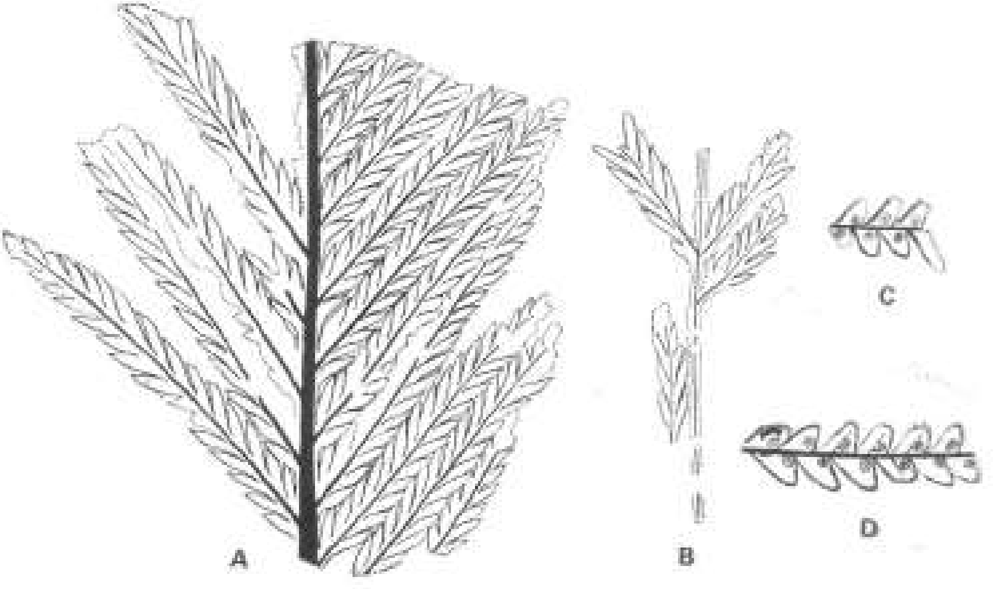
Holotype — Specimen no. 18/2011 of the Birbal Sahni Institute of Palaeobotany Museum, Lucknow.

Locality — 1 km east of Habur Village.

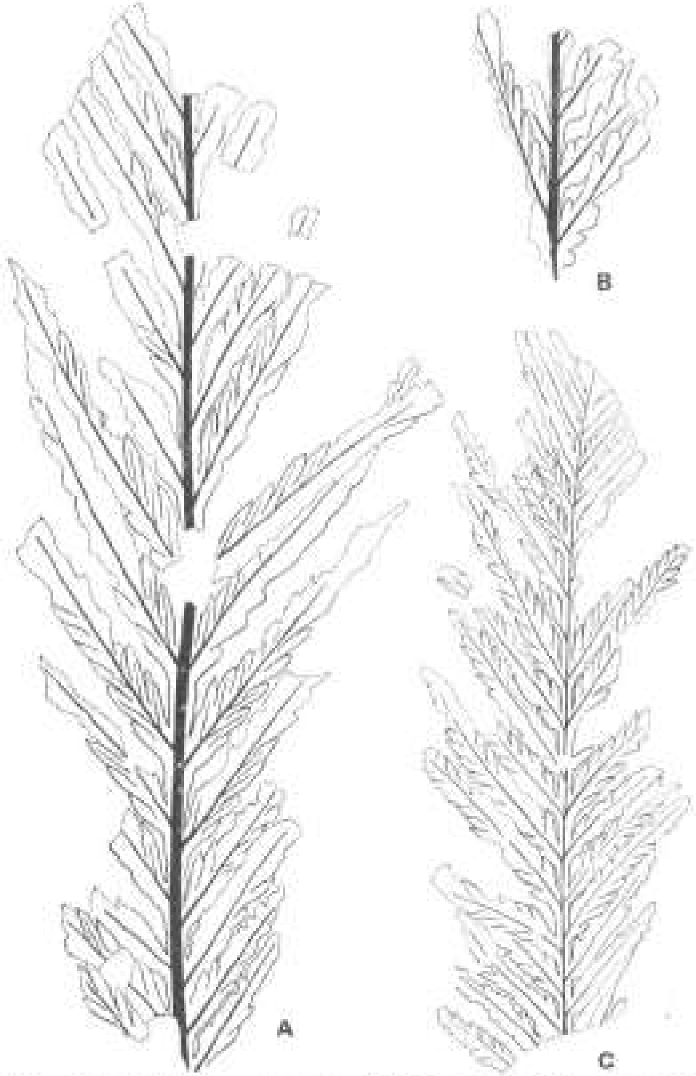
Horizon & Age — Pariwar Formation; ?Upper Jurassic-Lower Cretaceous.

Comparison — At Habur *Pachypteris haburensis* is the commonest species. Associated with these leaves quite a few branched specimens (Text-fig. 3F) have been collected. They seem to be the basal parts of main rachis of large fronds (probably of *P. haburensis*). The branches are 4-6.4 cm long.

The smaller fronds of *P. haburensis* resemble *Scleropteris coassa* Halle (1913, pl. 4, fig. 4a) described from Graham Land.



TEXT-FIG. 1 — **A-B,** *Pachypteris haburensis* n. sp., B.S.I.P. nos. 12/2011, 21/2011, × 1; **C-D,** *Gleichenia* sp., B.S.I.P. nos. 21/2095 and 28/2095, × 3.



TEXT-FIG. 2 — A-C, *Pachypteris haburensis* n. sp., B.S.I.P. nos. 26/2011, × 2, 1/2011 and 28/2011, × 1.

The Graham Land specimens have smaller pinnae and pinnules, also the pinnae are slightly more distantly placed. In general habit of fronds *P. haburensis* resembles *S. pomelii* Saporta (1873, pl. 46, fig. 1; pl. 47, fig. 1). *P. haburensis* differs in having pinnatifid apical pinnules. The basal pinnules of *P. haburensis* are like the smaller pinnules of *Pachypteris indica* (Oldham & Morris) Bose & Roy (1968). In the latter species pinnae are much more distantly placed and the majority of pinnules is bigger in size. *P. holdenii* Bose & Roy (1968) is based on a detached pinna with well-preserved cuticle. The pinnules of this species are bigger in size than those of *P. haburensis*. *P. lanceolata* Brongniart described by Harris (1964) from Yorkshire has larger and broader pinnules. However, a small leaf, figured by Harris (1964, fig. 56c), somewhat resembles the apical part of leaves of *P. haburensis*. The former specimen has distantly placed pinnae and broader pinnules.

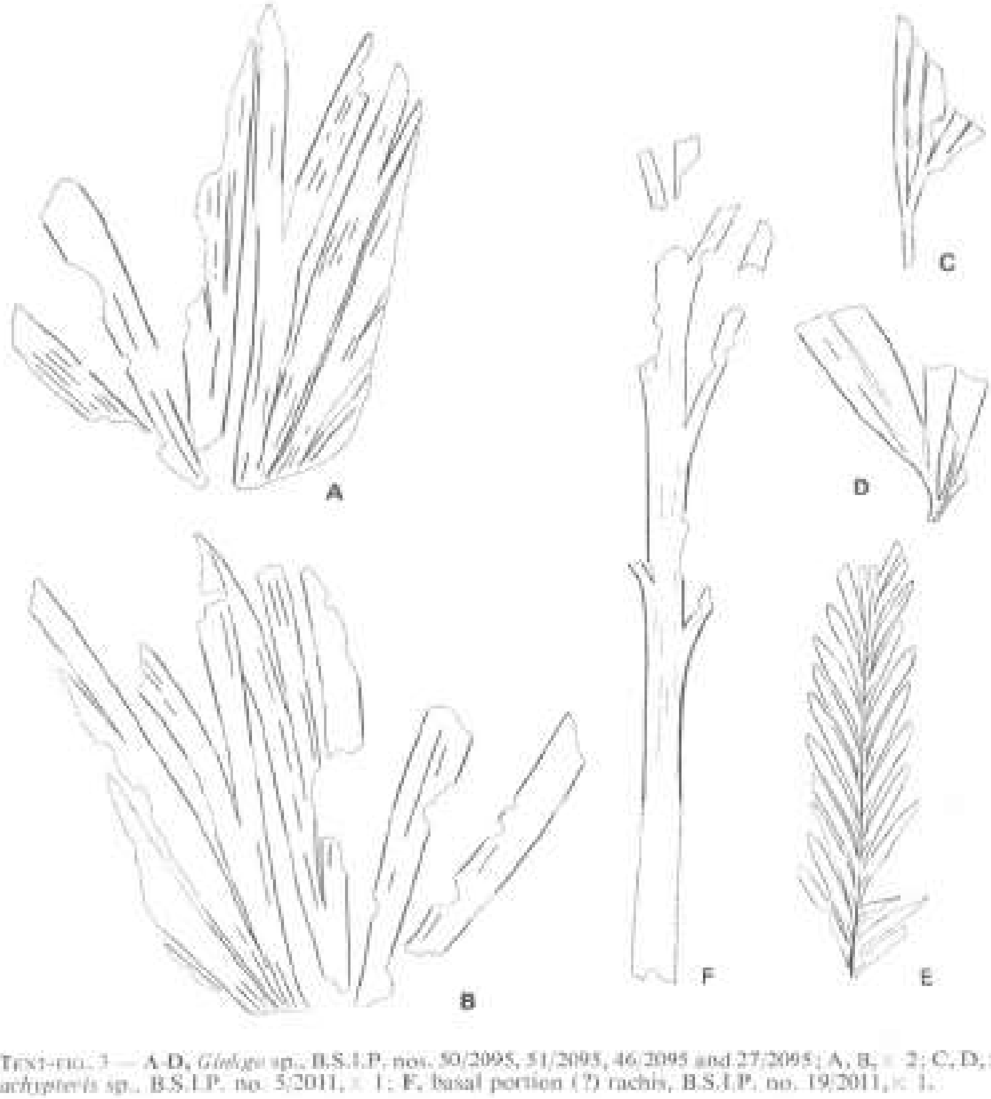
Pachypteris sp.

Pl. 1, fig. 9; Text-fig. 3E

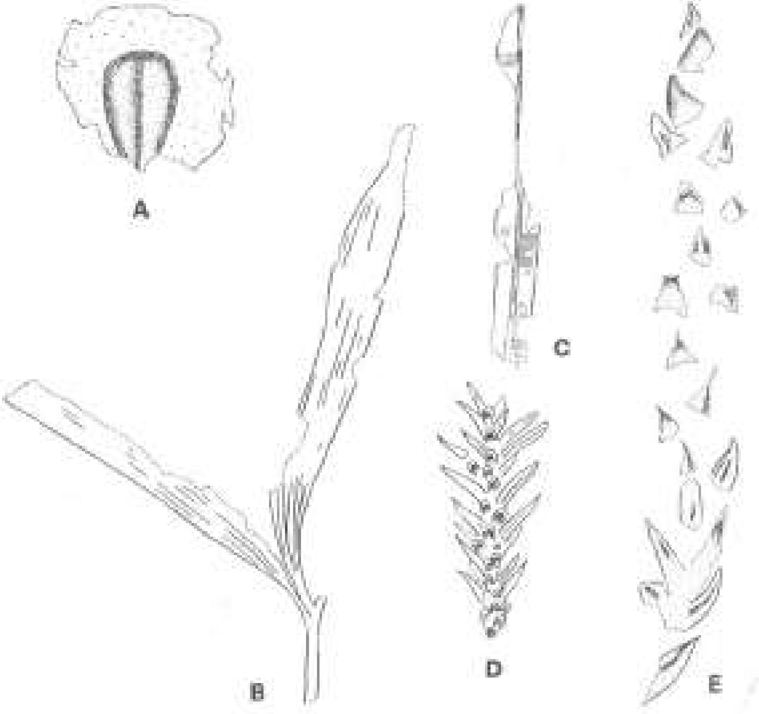
Description — Detached pinna, 6 × 1.8 cm; rachis prominent, about 1 mm wide, showing a median ridge. Pinnules alternate or subopposite, arising at 25°-30°, lanceolate, 1-1.6 cm long, 0.2 cm broad; margin entire; apex acute, rarely sub-acute; acroscopic margin gradually curving down; basiscopic margin distinctly decurrent. In some, midvein faintly marked, secondary veins not visible.

Collection — No. 5/2011 of the Birbal Sahni Institute of Palaeobotany Museum, Lucknow.

Comparison — The specimen resembles both *Pachypteris holdenii* Bose & Roy (1968, pl. 1, fig. 1) and *P. indica* (Oldham & Morris) Bose & Roy (1968, pl. 2, fig. 13). However, the pinnules of the present specimen are more like the ones in *P. holdenii*. Since cuticular details are not available so the specimen has not been referred to any of these species.



TEXT-FIG. 3 — A-D, *Ginkgo* sp., B.S.I.P. nos. 50/2095, 51/2095, 46/2095 and 27/2095; A, B, × 2; C, D, × 1; E, *Pachypteris* sp., B.S.I.P. no. 5/2011, × 1; F, basal portion (?) rachis, B.S.I.P. no. 19/2011, × 1.



TEXT-FIG. 4 — A, *Araucarites* sp. cf. *A. cutchensis* Feistmantel B.S.I.P. no. 15/2011, × 2; B, *Ginkgo* sp. B.S.I.P. no. 9/2011, × 2; C, *Taeniopteris spatulata* McClelland, B.S.I.P. no. 25/2011, × 1; D, *Pagiophyllum* sp. B, B.S.I.P. no. 25/2011, × 2; E, *Pagiophyllum* sp. A, B.S.I.P. no. 17/2011, × 2.

**Taeniopteris haburensis* Bose & Banerji

Remarks — The new collections include a large number of leaves of *Taeniopteris haburensis*. At Habur, after *Pachypteris haburensis* they are next in abundance. The largest specimen so far collected measures 23.8 cm in length and 2.4 cm in breadth. The specimen is incomplete both at base and apex. It seems that the length must have exceeded more than 25 cm. The largest specimen of Maheshwari and Singh (1976) did not exceed 14 cm in length.

Taeniopteris spatulata McClelland

Pl. 1, fig. 4; Text-fig. 4C

This species has already been described by Maheshwari and Singh (1976). In addition to new specimens from the main fossiliferous bed (P_2) we have also collected a specimen from the ferruginous shale partings from the underlying bed (P_3). The description of the specimen is given below.

Description — Leaf fragmentary, simple, narrow, strap-shaped, 4 × 0.5 cm; margin entire, base and apex not preserved. Midvein prominent, about 0.5 mm wide; lateral veins arising almost at right angle, simple or forked.

Collection — No. 25/2011 of the Birbal Sahni Institute of Palaeobotany Museum, Lucknow.

Comparison — In general shape and venation pattern the present specimen resembles most the specimen of *T. spatulata*

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*This species was originally described by us as *Taeniopteris vittata* Brongniart, which was expected to have been published in 1980. However, due to unavoidable circumstances the publication of this paper was delayed. In the meantime Bose & Banerji (1981) assigned our specimens of *T. vittata* to a new species, *Taeniopteris haburensis* and referred them under the synonymy of this new species.

described by Maheshwari & Singh (1976, pl. 2, fig. 13; text-fig. 5). It may also be compared with the specimens of *T. spatulata* figured by Feistmantel (1879, pl. 1, figs 8, 9), from Vemavaram. In the Vemavaram specimens the secondary veins bifurcate just after emergence. Here the secondary veins are mostly not well-preserved near the point of emergence, so their exact nature is not clear.

Ginkgo sp.

Pl. 1, fig. 10; Text-figs 3A-D, 4B

Description — Leaf petiolate, maximum available length of petiole 0.9 cm, finely striated. Lamina as a whole obcuneate, deeply divided into segments. Central division reaching almost up to apical part of petiole. Segments simple or forked, when forked segment dividing once, more than 9 in number. Unforked segments somewhat lanceolate in shape, with obtuse apices. Near base veins about 2-3 per segment, higher up due to forking approximately 4-6, parallel.

Collection — Nos. 51/2095, 50/2095, 46/2045 and 27/2095 of the Birbal Sahni Institute of Palaeobotany Museum, Lucknow.

Comparison — *Ginkgo* sp. resembles most the smaller leaves of *Ginkgo* sp. cf. *sibrica* Heer described by Harris and Millington (in Harris, Millington & Miller 1974, text-fig. 5E, F) from Petrad Point, Yorkshire. *Ginkgo* sp., however, differs in having lobes which are much closely set or even overlapping at places. *G. rajmahalensis* (Sah & Jain) Zeba-Bano *et al.* (1979) has mostly broader lobes and they are not so deeply dissected. Das Gupta *et al.* (1975) had described a specimen as *Actinopteris* sp. It is quite likely that this specimen is same as *Ginkgo* sp. described here. The specimen seems to be more complete than the ones present in our collection.

Elatocladus tenerrima (Feistmantel) Sahni

Pl. 1, fig. 9

1976 ?*Elatocladus* sp.: Maheshwari & Singh, p. 121, pl. 2, figs 16a, 17.

Amongst the several specimens of *Elatocladus conferta* (Oldham & Morris) Halle collected from Habur one specimen proved to be *E. tenerrima* (Feistmantel) Sahni (Pl. 1, fig. 7). The specimen is rather fragmentary and it matches exactly the specimens of *E. tenerrima* earlier described by Sahni (1928, pl. 1, figs 10-12) and *E. sehoraensis* Maheshwari & Kumaran (1976).

Description — Leafy twig, 2.2 cm long and 0.9 cm broad; leaves biseriately arranged, linear, rarely slightly falcate, 9 mm in length and 6 mm in width, margin entire, apex rounded; acroscopic margin constricted; basiscopic margin markedly decurrent. Midvein clearly marked.

Collection — No. 37/2095 of the Birbal Sahni Institute of Palaeobotany Museum, Lucknow.

Pagiophyllum sp. A

Pl. 1, fig. 13; Text-fig. 4E

Description — Shoot about 5.4 cm long, with spirally arranged leaves, leaves at base more divergent than apical leaves. Basal leaves narrower and longer than apical leaves, about 4 mm long and 2 mm broad; apical leaves triangular, about 3 mm long and 2 mm broad. Apex acute, margin entire.

Collection — No. 17/2011 of the Birbal Sahni Institute of Palaeobotany Museum, Lucknow.

Comparison — The apical leaves are somewhat like *Pagiophyllum bansaensis* Bose & Sukh-Dev (1972, pl. 2, fig. 10) and the apical leaves of *P. marwarensis* Bose & Sukh-Dev (1972, pl. 1, fig. 3). *Pagiophyllum* sp. A also resembles, to some extent, some of the twigs of *P. connivens* Kendall (1948) in general shape of leaves.

Pagiophyllum sp. B

Pl. 1, figs 1, 2; Text-fig. 4D

Description — Unbranched leafy twig, approximately 2 cm long. Leaves crowded, spirally arranged, diverging, 2-3 mm long and 0.5 mm broad, falcate, lower surface keeled; margin entire; apex acute; base decurrent, concealed by leaves below.

Collection — No. 25/2011 of the Birbal Sahni Institute of Palaeobotany Museum, Lucknow.

Comparison — The specimen described above was collected from the ferruginous shale partings of the bed (P_5) which is overlain by the main fossiliferous plant bed (P_6). *Pagiophyllum* sp. described by Maheshwari and Singh (1976, pl. 2, fig. 16b) from Habur matches with the present specimen. In general form of leaves *Pagiophyllum* sp. B resembles *P. rewaensis* Bose & Sukh-Dev (1972, pl. 1, fig. 6). However, the present specimen has smaller leaves. In leaf size *Pagiophyllum* sp. B is more like *P. marwarensis* Bose & Sukh Dev (1972) but the latter has more broader and divergent leaves. *Pagiophyllum* sp. B also resembles one of the shoots of *Elatocladus heterophylla* Halle (1913, pl. 8, fig. 20). However, *E. heterophylla* differs in having more spreading leaves.

Araucarites sp. cf. *A. cutchensis* Feistmantel

Pl. 1, fig. 3; Text-fig. 4A

Description — Detached seed-scale, both base and apex missing, approximately 1.1 cm long and 1.4 cm broad at broadest region. Seed obovate, 0.7 cm long and 0.5 cm broad, showing a prominent median ridge.

Collection — No. 15/2011 of the Birbal Sahni Institute of Palaeobotany Museum, Lucknow.

Comparison — The specimen is too fragmentary and bigger in size than *Araucarites minutus* Bose & Maheshwari (1973). In general shape and size it is more like *A. cutchensis* Feistmantel described by Bose & Maheshwari (1973, pl. 1, figs 3, 4; text-fig. 1C). But in the absence of base and apex it is difficult to assign the present specimen to any of the known species with certainty.

Coniferocaulon rajmahalense Gupta

Pl. 1, fig. 14

Description — The collection includes three specimens resembling *Coniferocaulon rajmahalense* Gupta (1954). They are 3.3 cm to 11 cm in width and are characterized by narrow transverse grooves. Within the grooves lense-shaped protuberances are present, these range in size from 4-5 mm in length and 1-1.5 mm in breadth.

Collection — No. 11/2011 of the Birbal Sahni Institute of Palaeobotany Museum, Lucknow.

Comparison — The genus *Coniferocaulon* was previously described from India by Bancroft (1913), Sahni (1931), Gupta (1954), Bose (1959), and Bose *et al.* (1979). Amongst these, the present specimens resemble most the specimen described by Bose *et al.* (1979) from Gardeshwar.

SPECIMEN TYPE A

Pl. 1, fig. 8

Description — A small " flower " like organ, about 1.1 cm long and 0.9 cm broad at broadest region, more or less inverted bell-shaped. Bracts spirally arranged; 1.1 cm in length and 1-1.5 mm in width, near apex bracts slightly spreading and curving downwards; margin entire.

Collection — No. 35/2095 of the Birbal Sahni Institute of Palaeobotany Museum, Lucknow.

Remarks — The specimen is rather small in size. It could be a small Bennettitalean " flower ".

DISCUSSION

From the Pariwar Formation, exposed near Habur, Maheshwari and Singh (1976) had described ?*Gleichenites* sp., *Phlebopteris* sp., Frond Type-1, *Taeniopteris vittata* Brongniart, *T. densinervis* Feistmantel, *T. spatulata* McClelland, *Pterophyllum* sp., *Otozamites imbricatus* Feistmantel, *Ptilophyllum acutifolium* Morris, *Elatocladus conferta* (Oldham & Morris) Halle, ?*Elatocladus* sp. and *Pagiophyllum* sp. Except *Otozamites imbricatus* and *Ptilophyllum acutifolium* the present collection includes all these species. In addition, it has *Pachypteris* sp., *Ginkgo* sp., *Elatocladus tenerrima* (Feistmantel) Sahni, *Pagiophyllum* sp. A, *Araucarites* sp. cf. *A. cutchensis* Feistmantel and *Coniferocaulon rajmahalense* Gupta.

The mega-plant assemblage at Habur is dominated by the presence of *Pachypteris haburensis* n. sp. The next in abundance are *Taeniopteris haburensis* Bose & Banerji, *Elatocladus conferta* (Oldham & Morris) Halle and *Pterophyllum* sp. respectively. The species belonging to *Pagiophyllum* is extremely rare and so far the genus *Brachyphyllum* has not been found at Habur. So the mega-plant assemblage at Habur really does not fit in the sub-zone *Pagiophyllum*-

Brachyphyllum of Sah, Singh and Sastry (1971, table III) as was suggested by Maheshwari and Singh (1976). The assemblage is more like the one known from Kakadbhit in Kachchh. At Kakadbhit the flora has a fair representation of *Pachypteris*, *Taeniopteris* (*T. haburensis*) and *Otozamites*. The Habur assemblage differs in having *Gleichenia* which is more common in the Lower Cretaceous though it is also known from the Upper Jurassic. So far the genus *Gleichenia* has not been found anywhere in Kachchh. In the presence of *Gleichenia* and in having *Pachypteris*, *Taeniopteris spatulata* and *Ptilophyllum* the assemblage from Parsapani, Satpura basin is somewhat like the one met with at Habur. However, at Habur *T. spatulata* and *Ptilophyllum* are rare, whereas, both these are quite common at Parsapani. Because of the presence of *Gleichenia* it is likely that the fossiliferous bed exposed near Habur is somewhat younger in age than the fossiliferous plant bearing beds of Kachchh.

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EXPLANATION OF PLATE

1, 2. *Pagiophyllum* sp. B., B.S.I.P. No. 25/2011, fig. 1 (× 1), fig. 2 (× 2).

3. *Araucarites* sp. cf. *A. cutchensis* Feistmantel, B.S.I.P. No. 15/2011. × 1.

4. *Taeniopteris spatulata* McClelland, B.S.I.P. No. 25/2011. × 1.

5, 6. *Gleichenia* sp. showing fertile pinnules, B.S.I.P. Nos. 21/2095 and 28/1095. × 2.

7. *Elatocladus tenerrima* (Feistmantel) Sahni, B.S.I.P. No. 37/2095. × 1.

8. Specimen Type-A, B.S.I.P. No. 35/2095. × 2.

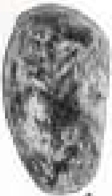
9. *Pachypteris* sp., B.S.I.P. No. 5/2011. × 1.

10. *Ginkgo* sp., B.S.I.P. No. 51/2095. × 1.

11, 12. *Pachypteris baburensis* n. sp., B.S.I.P. Nos. 18/2011 (Holotype) and 20/2011. × 1.

13. *Pagiophyllum* sp. A., B.S.I.P. No. 17/2011. × 1.

14. *Coniferocaulon rajmahalense* Gupta, B.S.I.P. No. 11/2011. × 1.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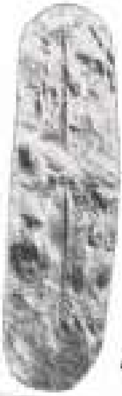
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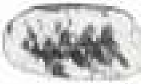
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PLATE 1

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TWO NEW FOSSIL WOODS OF SAPINDACEAE FROM THE TERTIARY OF INDIA

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ABSTRACT

The present paper deals with two sapindaceous woods, viz., *Euphorioxylon indicum* gen. et sp. nov. and *Schleicheroxylon kachchhensis* gen. et sp. nov. These show closest resemblance with the woods of *Euphoria* and *Schleichera* respectively. The former is being reported from both the Kankawati Series of Kachchh and the Cuddalore Series near Pondicherry while the latter is from the Kankawati Series of Kachchh only.

Key-words — Xylotomy, *Euphorioxylon*, *Schleicheroxylon*, Kankawati Series, Cuddalore Series, Mio-Pliocene (India).

सारांश

भारत के तृतीयक युग से सैपिन्डेसी कुल की दो नवीन काष्ठाश्म – नीलाम्बर अवस्थी, जसवन्तसिंह गुलेरिया एवं राजेन्द्रनाथ लखनपाल

प्रस्तुत शोध-पत्र सैपिन्डेसी कुल की दो काष्ठाश्मों अर्थात् यूफ़ोरिऑक्सीलॉन् इन्डिकम् नव प्रजाति व नव जाति तथा श्लीचेरॉक्सीलॉन् कच्छेन्सिस नव प्रजाति व नव जाति से सम्बन्धित है। ये यूफ़ोरिया एवं श्लीचेरा की काष्ठों से क्रमशः घनिष्ठतम् समानता प्रदर्शित करती हैं। इनमें से पहली काष्ठ कच्छ की कनकावती एवं पाण्डिचेरी के समीपस्थ कुड्डलोर दोनों ही श्रेणियों से अभिलिखित की गई है जबकि दूसरी काष्ठ केवल कच्छ की कनकावती श्रेणी से अभिलिखित की गई है।

INTRODUCTION

THE family Sapindaceae is known from the Tertiary of India by three species of petrified woods. Two of them are described from the Deccan Intertrappean beds of Central India, viz., *Sapindoxylon schleicheroides* Dayal (1965) and *S. chhindwarensis* Chitaley & Shallom (1969), and the third, *Pometioxylon tomentosum*, is described by Prakash and Tripathi (1970) from the Tipam Series near Hailakandi, Assam. There is one more record known as *Sapindoxylon indicum* Navale (1957) from the Cuddalore Series near Pondicherry, but it has recently been found to be a wood of *Duabanga* of the family Sonneratiaceae and consequently renamed as *Duabangoxylon indicum* by Awasthi (1981).

In the present study of petrified woods from (i) the base of Kankawati Series of Mothala and Dhaneti in Kachchh, and (ii) the Cuddalore Series near Pondicherry, we have been able to recognize two more types of sapindaceous woods, one showing closest resemblance with that of *Euphoria* and the other with that of *Schleichera*. The former has been found both in Kachchh and Pondicherry while the latter in Kachchh alone. They are described here in detail.

The fossils were compared with the living woods at the Xylarium of the Forest Research Institute, Dehradun, for which we are thankful to the authorities of the Institute for all facilities received.

DESCRIPTION

Genus — *Euphorioxylon* gen. nov.

1. *Euphorioxylon indicum* sp. nov.

Pl. 1, figs 1-4

This species is represented by five small pieces, one from the Cuddalore Series near

Pondicherry and four from the Kankawati Series of Kachchh. They show fairly good preservation.

Topography — *Wood* diffuse-porous. *Growth rings* not seen. *Vessels* small to medium, solitary or in radial multiples of 2-5 (Pl. 1, figs 1, 2), rarely up to 10-12, evenly distributed, 9-14 per sq mm; tyloses absent; vessels sometimes filled with dark contents. *Parenchyma* paratracheal, sparse, limited to a few cells, forming at the most an incomplete or narrow sheath round the vessels (Pl. 1, fig. 2). *Rays* uniseriate, rarely biseriate mainly due to pairing of cells through the median portion (Pl. 1, fig. 3), 12-24 μm wide, 4-60 cells or 60-720 μm high, closely placed (Pl. 1, figs 2, 3), 12-18 per mm in cross section; ray tissue homogeneous; rays homocellular, consisting of procumbent cells only (Pl. 1, figs 3, 4). *Fibres* aligned in radial rows between the two consecutive rays (Pl. 1, fig. 2).

Elements — *Vessels* circular to oval in cross section (Pl. 1, fig. 2), t.d. 50-140 μm, r.d. 60-180 μm, thick-walled, common wall 8-20 μm in thickness; vessel members 120-600 μm in length with truncated ends; perforations simple; intervessel pits small, alternate, bordered, about 4-5 μm in diameter. *Parenchyma cells* round to oval in cross section, t.d. 20-32 μm. *Ray cells* round to oval in shape (Pl. 1, fig. 3), 10-20 μm in tangential height, 20-160 μm in radial length, infiltration dark. *Fibres* round to oval in cross section, 12-20 μm in diameter, thick-walled, wall about 3-6 μm, nonseptate to rarely septate.

AFFINITIES

Comparison with the modern woods — The important features of the present fossil are (i) vessels small to medium, (ii) parenchyma scanty paratracheal, (iii) xylem rays uniseriate to rarely biseriate due to paired cells, homocellular, and (iv) fibres thick-walled, nonseptate to rarely septate. Among various dicotyledonous families, the members of Sapindaceae and Sonneratiaceae (Metcalfe & Chalk, 1950) exhibit the above important characters.

The genus *Sonneratia* L. of the family Sonneratiaceae shows similarity with the fossil in gross features. However, the presence of tyloses, vestured intervessel pits and the absence of parenchyma differentiates it from the fossil.

The Indian sapindaceous woods have broadly been classified into two groups (Anonymous, 1963, p. 212) on the basis of the nature and distribution of parenchyma as given below:

Group I. Parenchyma (apart from that delimiting growth rings) abundant, distinctly visible to the eye and predominantly banded, e.g. *Allophylus*, *Erioglossum*, *Lepisanthes*, *Paranephelium* and *Sapindus*.

Group II. Parenchyma (apart from that delimiting growth rings) not abundant, indistinct to eye, usually scanty, vasicentric to aliform, e.g. *Arytera*, *Dodonea*, *Filicium*, *Harpullia*, *Mischocarpus*, *Nephelium**, *Pometia*, *Schleichera and Xerospermum*.

Since the parenchyma in the present fossil is scanty paratracheal, it should be compared with the genera included in Group II. After examining the available thin sections as well as the published descriptions and figures of the above genera, it was found that the fossil shows closest resemblance with the woods of *Euphoria* Comm. ex. Juss., particularly that of *E. longana* Lamk (Syn. *Nephelium longana* Camb.). The other woods of this group although quite similar to the fossil, differ in a few important characters.

In *Arytera*, *Filicium*, *Pometia*, *Schleichera* and *Xerospermum glabratum* (Wall.) Radlk. the growth rings are distinct, whereas in the present fossil they are not seen. *Mischocarpus* and *Arytera* also differ in having diffuse parenchyma while *Pometia* differs in having bigger vessels and apotracheal parenchyma lines. Similarly, *Otonephelium* can be differentiated from the present fossil in having mostly medium sized vessels. The parenchyma in *Harpullia* is predominantly aliform to aliform-confluent, and in *Dodonea* it varies from scanty paratracheal to aliform or locally confluent. The latter further differs in the frequency of vessels which are 10-50 per sq mm as compared to 9-14 in the present fossil. *Filicium* also differs in having greater

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*Includes *Euphoria* Comm., *Litchi* Sonner., and *Otonephelium* Radlk (Anonymous, 1963, p. 224).

number of vessels, i.e. 12-31 per sq mm. *Blighia* (an African genus) and *Xerospermum ferrugineum* can also be differentiated from the present fossil in having comparatively lesser number of vessels. Similarly *Nephelium* (inclusive *Litchi*) also shows close similarity with our fossil. However, the species of *Nephelium* having aliform to confluent parenchyma and relatively bigger vessels can be distinguished easily from the present fossil.

Comparison with the fossil species — From outside India also the family Sapindaceae is known by a large number of woods, viz., *Frassia sapindoides* Unger (1850) from the Tertiary of Hungary, *Schmiedeliopsis zirkelii* Felix (1882) from the Tertiary of *Antigua*, *Sapindoxylon janssonii* Kräusel (1922) from the Miocene of Sumatra, *Sapindopsoxylon klitzingi* Pfeiffer & Heurn (1928, also see Edwards, 1931) from the Tertiary of Java, *Sapindoxylon stromeri* Kräusel (1939) from the Lower Oligocene of Egypt, *S. antioquiense* Schönfeld (1947) from the Tertiary of Columbia, *S. pleikuense* Boureau (1950) from the Neogene of Indochina (South Annam), *Sapindoxylon* sp. Hofmann (1952) from the Oligocene of Prambachkirchen (Austria), *Sapindoxylon lamegoi* Mussa (1959) from the Neogene or Quaternary of Brazil, *S. elattostachyoides* Grambast-Fessard (1966) from the Miocene of south-east France, *S. almelai* Koeniguer (1967) from the Miocene of Rio de Oro, West Africa, *S.* (?) *lapparenti* Koeniguer (1968) from the Mio-Pliocene of Tchad, Africa and *S. mbaense* Koeniguer (1973) from the Eocene of Senegal. Among the fossil woods of Sapindaceae described from India, only *Sapindoxylon schleicheroides* shows gross similarity with our fossil. However, a careful examination shows that they differ from each other in the nature and width of xylem rays. In *Sapindoxylon schleicheroides*, the rays are 1-3 seriate and weakly heterogeneous, while in the present fossil they are 1-2 seriate and homocellular.

Pometioxylon tomentosum needs no comparison since it belongs to the genus *Pometia* which is quite different from *Euphoria* especially in having 1-3 seriate heterocellular rays and apotracheal parenchyma lines.

Sapindoxylon chhindwarense is also quite different in having xylem rays 2-9 cells high, consisting of erect (upright) cells only. But in our fossil the rays are 4-60 cells high and composed of procumbent cells only. It is important to point out here that the affinities of *Sapindoxylon chhindwarense* with the woods of Sapindaceae are doubtful since it possesses such features which are not characteristic of Sapindaceae. The xylem rays in this fossil are uniseriate, 2-9 cells high and composed wholly of upright (erect) cells, and the fibres are short, thin-walled with wide lumen, as seen in the tangential longitudinal section (Chitaley & Shallom, 1969, p. 39, fig. 2). On the other hand, in Sapindaceous woods the homocellular rays are always composed wholly of procumbent cells but not of upright cells and the fibres are long, moderately thick to thick-walled with narrow lumen.

Of the foreign species, *Sapindoxylon almelai*, *S. antioquiense*, *S. lamegoi*, *S.* (?) *lapparenti*, *S. mbaense* and *S. stromeri* show some similarity with our fossil. However, they differ in one or more important characters. *S.* (?)*lapparenti*, *S. mbaense*, *S. stromeri*, *S. antioquiense* and *S. lamegoi* differ from the present fossil in the frequency of vessels. In the first three species the frequency of vessels per sq mm varies from 13-50 as compared to the present fossil in which they are 9-14. The last two species can also be differentiated in having lesser number of vessels, i.e. 4-7 per sq mm. *S. stromeri* and *S. antioquiense* further differ in having shorter rays (1-10 cells in height) as against up to 50 cells in the present fossil. Further, in *S. mbaense* and *S. lamegoi* the xylem rays are homo- to weakly heterocellular. The latter further differs in the presence of diffuse parenchyma. In *S. almelai* the vessels are relatively more frequent (11-20 per sq mm), bigger in size (80-240 μm) and the rays are shorter (2-20 cells high).

From the above comparison with the living and fossil species it is evident that the present fossil wood is very similar to that of *Euphoria* and is quite different from all the known species of *Sapindoxylon*. Hence, it is placed under a new genus *Euphorioxylon*. This genus represents the fossil woods resembling *Euphoria* as well as those species of *Nephelium* (inclusive *Litchi*) which are anatomically similar to *Euphoria longana*. Specifically, it is being named as *Euphorioxylon indicum* sp. nov.

The genus *Euphoria* consists of about 15 species (Santapau & Henry, 1973, p. 66) of shrubs and trees, distributed from Burma to Indochina and western Malaysia. In India, it is represented by a single species, viz., *Euphoria longana* Lamk. (syn. *Nephelium longana*) with which the present fossil resembles most. It is found throughout the Western Ghats from the Konkan southwards extending to Sri Lanka up to 900 m. In north-east India, it is found in the hills of Assam. It also occurs in South China, Burma and Malaya (Anonymous, 1963, p. 225).

GENERIC DIAGNOSIS

Euphorioxylon gen. nov.

Wood — Diffuse-porous. *Growth rings* indistinct or absent. *Vessels* small to medium, solitary or in radial multiples of 2-5 or more, uniformly distributed; perforations simple; intervessel pits small, alternate, bordered; tyloses absent. *Parenchyma* scanty paratracheal to vasicentric, forming at the most an incomplete or narrow sheath round the vessels. *Rays* fine, uniseriate, rarely biseriate mainly due to pairing of procumbent cells through the median portion, usually up to 60 cells or 720 μm high; ray tissue homogeneous; rays homocellular, consisting of procumbent cells. *Fibres* thick-walled, nonseptate to septate.

Genotype — *Euphorioxylon indicum* gen. nov.

SPECIFIC DIAGNOSIS

Euphorioxylon indicum sp. nov.

Wood — Diffuse-porous. *Growth rings* not seen. *Vessels* small to medium, t.d. 50-140 μm, r.d. 60-180 μm, solitary or in radial multiples of 2-5, rarely up to 10-12, 9-14 per sq mm; intervessel pits simple, nearly horizontal to oblique, alternate, bordered; tyloses absent. *Parenchyma* paratracheal, sparse, limited to a few cells, forming at the most an incomplete or narrow sheath round the vessels. *Rays* predominantly uniseriate, rarely biseriate due to mainly pairing of procumbent cells through the median portion, 4-60 cells or 60-720 μm high, homocellular, consisting of procumbent cells only. *Fibres* thick-walled, nonseptate to septate.

Holotype — B.S.I.P. Museum Specimen no. 35359.

Localities — Murattandichavadi near Pondicherry; Mothala, about 66 km SW of Bhuj, on the Bhuj-Naliya Road and Dhaneti, about 24 km east of Bhuj, on the Bhuj Bhachau Road, district Kachchh, Gujarat.

Horizon & Age — Cuddalore Series, Mio-Pliocene; Kankawati Series, ?Pliocene.

Genus — *Schleicheroxylon* gen. nov.

2. *Schleicheroxylon kachchhensis* sp. nov.

Pl. 2, figs 5-7; Pl. 3, figs 9, 11, 12

This species is represented by two pieces of fairly well-preserved petrified woods, measuring 12·5 × 4·0 cm and 10·0 × 4·0 cm.

Topography — *Wood* diffuse-porous (Pl. 2, fig. 5). *Growth rings* present, undulating delimited by dark and dense fibre cells (Pl. 2, figs 5, 7). *Vessels* small to medium, solitary or in radial multiples of 2-5, frequently solitary (Pl. 2, fig. 7), some crossing the boundary of rings, rarely forming clusters, more or less evenly distributed, 11-14 per sq mm; tyloses wanting; vessels filled with dark contents. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma sparse, usually confined to the tangential walls of the vessels due to contiguous xylem rays, occasionally forming incomplete to complete 1-celled sheath round the vessels (Pl. 2, figs 6, 7); apotracheal parenchyma scanty, diffuse, concentrated only towards the inner part of the ring. *Rays* fine, 1-2(3) seriate, mostly 1-seriate or 12-32 μm wide, 2-30 (mostly 8-16) cells or 40-600 μm high (Pl. 3, fig. 9); 11-16 rays per mm; ray tissue homogeneous; rays homocellular, consisting of procumbent cells only (Pl. 3, figs 9, 12). *Fibres* aligned in radial rows between the two consecutive rays.

Elements — *Vessels* circular to oval in cross section (Pl. 2, figs 6, 7), t.d. 60-152 μm, r.d. 60-200 μm; thick-walled, common wall 8-20 μm in thickness; vessel members 160-300 μm in length with truncated ends; perforations simple; intervessel pits small, alternate, bordered (Pl. 3, fig. 11), about 4 μm in diameter; vessels filled with dark gum plugs. *Parenchyma cells* round to oval in cross section, t.d. 12-24 μm. *Ray cells* round to oval in shape, 12-24 μm in tangential height, 48-80 μm in radial length; infiltration dark. *Fibres* round to oval in cross section, t.d. 6-12 μm, wall thickness 3-6 μm, septa not clearly seen.

AFFINITIES

Comparison with the modern woods — The important features of the fossil are (i) vessels small to medium, (ii) growth rings present, (iii) parenchyma scanty, paratracheal and diffuse, (iv) xylem rays 1-2(3) seriate, mostly 1-seriate, homocellular, and (v) fibres thick-walled and probably septate. These features are characteristic of certain woods of the family Sapindaceae. Since in the present fossil the paratracheal parenchyma is scanty vasicentric, its modern equivalent can be searched among the genera included in Group II of this family (see p. 13).

Considering all the characters collectively, it was found that the present fossil wood shows closest resemblance with that of *Schleichera oleosa* (Lour.) Oken (Syn. *Schleichera trijuga* Willd). The other genera of this group which also show similarity with the present fossil can be differentiated in one or more important characters. *Dodonea* and *Harpullia* differ from the present fossil in having aliform to aliform-confluent parenchyma. Further, the vessels in *Dodonea* are small to very small and their frequency is also very high (10-50 per sq mm) as compared to the present fossil in which the vessels are 11-14 per sq mm. Similarly, *Arytera*, *Filicium* and *Pometia* differ from the present fossil either in the frequency or the size of vessels. The frequency of vessels in *Arytera* and *Filicium* is 8-24 and 12-31 per sq cm respectively. *Pometia* differs in having bigger and lesser vessels, i.e. the frequency of vessels is 3-7 per sq mm. The presence of pith flecks (which are very common and often large) in *Mischocarpus* differentiates it from the fossil. The anatomical data of two Indian species of *Xerospermum*, viz., *X. ferrugineum* Fisher and *X. glabratum* (Wall.) Radlk. are available. Of these, the former differs in the absence of distinct growth rings and lesser number of vessels, i.e. the vessels being 4-9 per sq mm. The latter though being closer to the fossil differs in having small to very small vessels. *Nephelium* (sensu lato) no doubt shows close similarity. However, those species of *Nephelium* in which growth rings are indistinct, vessels are bigger in size and parenchyma relatively more (i.e. aliform to confluent), can easily be differentiated from the fossil. The remaining species can be separated only on the basis of rays which are 1-2 seriate in *Nephelium* and 1-3 seriate in the fossil.

Comparison with the fossil woods — Out of a large number of fossil woods described under the genus *Sapindoxylon* Kräusel (1922), *S. almelai* Koeniguer (1967), *S. antioquiense* Schönfeld (1947), *S. lamegoi* Mussa (1959) and *S. schleicheroides* Dayal (1965) show resemblance with the present fossil. However, it can be separated from them in having some significant differences.

The vessels in *S. almelai* are 80-240 μm in diameter and the rays are 4-7 per mm as compared to the present fossil in which vessels are 60-152 μm in diameter and the rays 11-16 per mm. In *S. antioquiense* the vessels are 4-7 per sq mm and the rays are 2-10 cells in height while in the present fossil the vessels are 11-14 per sq mm and the rays are 2-30 cells in height. Similarly, *S. lamegoi* also differs in having lesser number of vessels (4-6 per sq mm).

Sapindoxylon schleicheroides, although exhibiting general similarity with the present fossil differs in having indistinct growth ring, absence of apotracheal diffuse parenchyma and the presence of weakly heterogeneous rays. On the contrary, the growth rings in our fossil are distinctly marked, the apotracheal or diffuse parenchyma is concentrated towards the inner part of the growth ring and the rays are homogeneous.

Regarding the affinities of *Sapinodoxylon schleicheroides*, Dayal (1965) considered it similar to *Schleichera oleosa* in shape, size and distribution of vessels, the type of intervascular pitting, vasicentric parenchyma, 1-3 seriate xylem rays and septate fibres. At the same time he differentiated it from *Schleichera oleosa* in the absence of distinct growth rings, diffuse parenchyma and relatively thin-walled fibres. We have also checked and found that in *Schleichera* (*S. oleosa*, the only species) the growth rings are fairly distinct, regular, undulating, delimited by dark and denser fibres and diffuse parenchyma cells. Such growth rings are lacking in *Sapindoxylon schleicheroides*. Besides, the rays are homogeneous to weakly heterogeneous in this fossil whereas they are exclusively homogeneous in *Schleichera*. Hence, it cannot be regarded as *Schleichera* although its apparent similarity with this genus perhaps led Dayal to name it as *S. schleicheroides*.

Since the present fossil wood shows closest resemblance with that of *Schleichera* and differs from all the known fossil woods of Sapindaceae, it is placed under a new genus, *Schleicheroxylon*, and named as *Schleicheroxylon kachchhensis* sp. nov., after the district Kachchh from where it was collected.

The genus *Schleichera* consists of a single species, *S. oleosa* (Lour.) Oken, found in the Indomalayan region (Willis, 1973, p. 1042). In India, it occurs in the sub-Himalayan tract up to 900 m, from the Sutlej eastward (except perhaps Assam, Bengal and the Andamans), Central India and western Peninsula in the deciduous forests.

GENERIC DIAGNOSIS

Schleicheroxylon gen. nov.

Wood diffuse-porous. *Growth rings* distinct, undulating, delimited by denser fibres and diffuse parenchyma cells. *Vessels* small to medium, solitary or in radial multiples of 2-5, more or less evenly distributed; perforations simple; intervessel pits small, alternate, bordered; tyloses absent. *Parenchyma* paratracheal, vasicentric, sparse, forming incomplete to complete, 1-celled sheath round the vessels; apotracheal parenchyma scanty, diffuse, cells concentrated towards the inner part of the ring. *Rays* fine, 1-2(3) seriate, homocellular, consisting of procumbent cells, up to 30 (mostly 8-16) cells or 600 μm high. *Fibres* thick-walled, probably septate.

Genotype — *Schleicheroxylon kachchhensis* gen. nov.

SPECIFIC DIAGNOSIS

Schleicheroxylon kachchhensis sp. nov.

Growth rings distinct, undulating, delimited by denser fibres and diffuse parenchyma cells. *Vessels* small to medium, solitary and in radial multiples of 2-5, frequently solitary, t.d. 60-152 μm, r.d. 60-200 μm, about 11-14 vessels per sq mm, intervessel pits simple, alternate, bordered, small; tyloses absent; vessels filled with dark contents. *Parenchyma* paratracheal, sparse, usually confined to the tangential wall of the vessels, occasionally forming incomplete to complete, 1-celled sheath round the vessels; apotracheal parenchyma scanty, diffuse cells concentrated towards the inner part of the ring. *Xylem rays* fine, 1-2(3) seriate, mostly 1-seriate or 12-32 μm wide, 2-30 (mostly 8-16) cells or 40-600 μm high, 11-16 rays per mm, homocellular, consisting of procumbent cells. *Fibres* thick-walled, probably septate.

Holotype — B.S.I.P. Museum Specimen no. 35358.

Locality — Dhaneti, about 24 km east of Bhuj, on the Bhuj-Bhachau Road, district Kachchh, Gujarat.

Horizon & Age — Kankawati Series, ?Pliocene.

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EXPLANATION OF PLATES

PLATE 1

Euphorioxylon indicum gen. et sp. nov.

1. Cross section showing gross features. × 30. B.S.I.P. Museum slide no. 6101.
2. Cross section magnified to show the nature and distribution of vessels, parenchyma (scanty paratracheal). × 90. B.S.I.P. Museum slide no. 6101.
3. Tangential longitudinal section showing xylem rays. × 120. B.S.I.P. Museum slide no. 6102.
4. Radial longitudinal section showing homocellular rays. × 120. B.S.I.P. Museum slide no. 6103.

PLATE 2

Schleicheroxylon kachchhensis gen. et sp. nov.

5. Cross section showing gross features. × 7. B.S.I.P. Museum slide no. 6104.
6. Cross section magnified to show the vessels and scanty paratracheal parenchyma. × 80. B.S.I.P. Museum slide no. 6104.
7. Another cross section showing the nature and distribution of vessels, parenchyma and growth rings. × 30. B.S.I.P. Museum slide no. 6104.

Schleichera oleosa

8. Cross section showing the vessels, scanty paratracheal parenchyma and growth rings similar to those in the fossil as shown in fig. 7. × 30.

PLATE 3

Schleicheroxylon kachchhensis gen. et sp. nov.

9. Tangential longitudinal section showing xylem rays. × 120. B.S.I.P. Museum slide no. 6105.

Schleichera oleosa

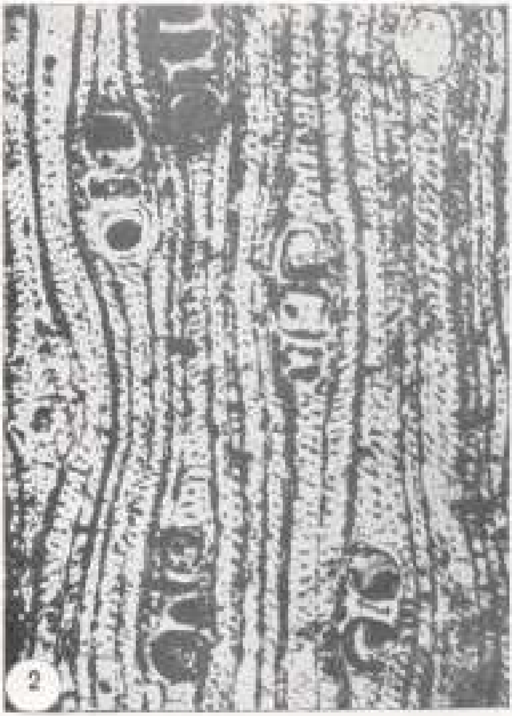
10. Tangential longitudinal section showing xylem rays similar to those in the fossil shown in fig. 9. × 120.

Schleicheroxylon kachchhensis gen. et sp. nov.

11. Intervessel pits. × 550. B.S.I.P. Museum slide no. 6105.
12. Radial longitudinal section showing homocellular rays. × 120. B.S.I.P. Museum slide no. 6106.

Schleichera oleosa

13. Radial longitudinal section showing xylem rays similar in the fossil as shown in fig. 12. × 120.



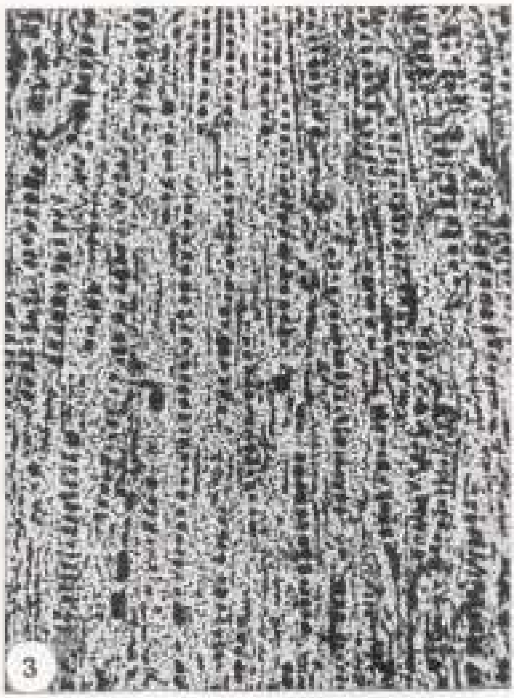
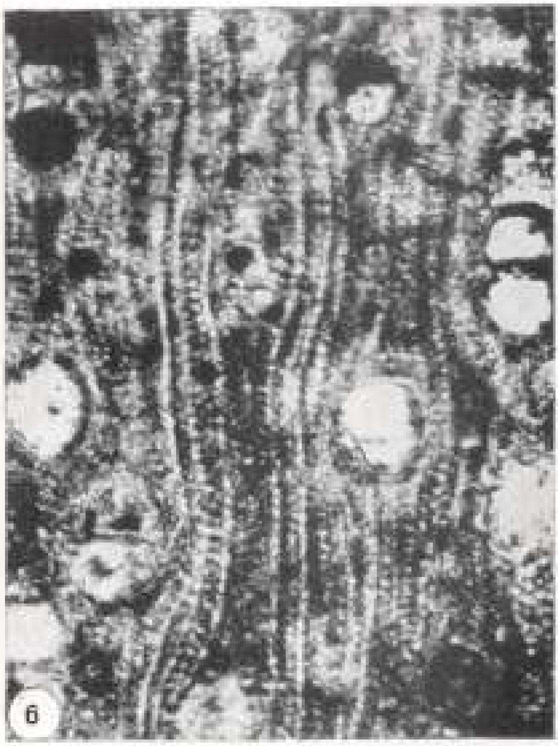
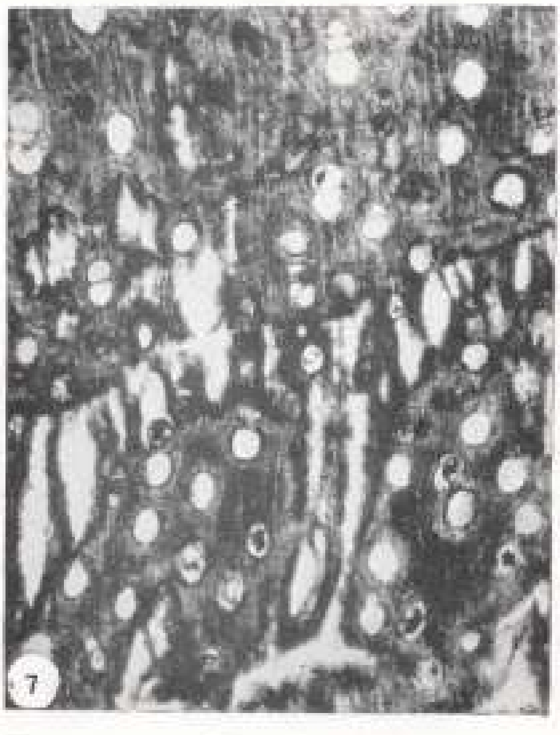


PLATE 1





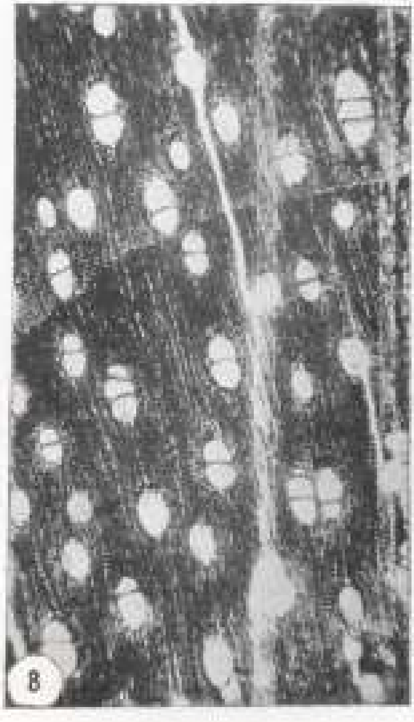
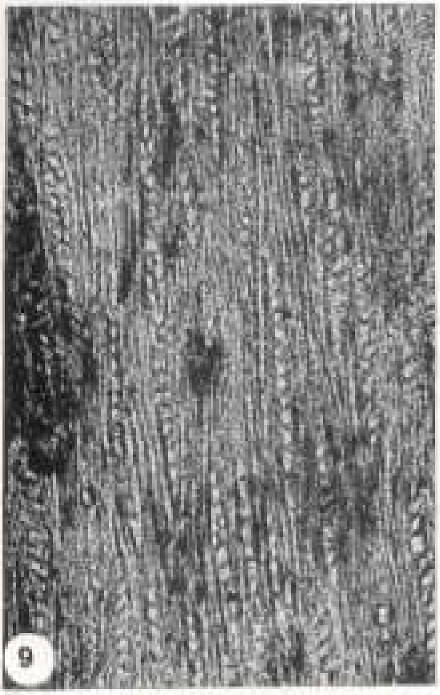


PLATE 2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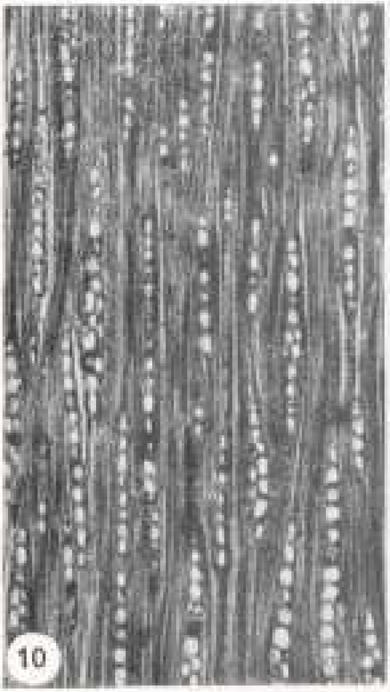
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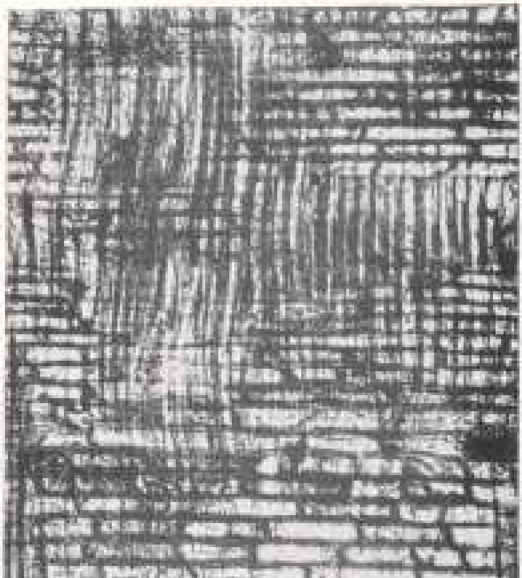
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PLATE 3

The Palaeobotanist, 30(1): 22-27, 1982.

DINOFLAGELLATE CYSTS FROM 'NON-MARINE' SEDIMENTS OF JABALPUR GROUP AT MORGHAT, MADHYA PRADESH

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ABSTRACT

The Jabalpur Group sediments are so far believed to be of non-marine origin. These sediments have yielded a rich flora comprising both mega- and microfossils. Recently, while working out the palynostratigraphy of the group, some dinoflagellate cysts were found in one of the samples from Morghat, Hoshangabad District, Madhya Pradesh. The dinoflagellate cysts are referable to three genera, *viz.*, *Kalyptea*, *Sentusidinium* and *Cannosphaeropsis*. One species, i.e. *Kalyptea indica*, is new.

Key-words — Dinoflagellate cysts, ?Upper Jurassic, Jabalpur Group (India).

सारांश

मोरघाट (मध्य प्रदेश) से जबलपुर के 'असमुद्री' अवसादों में घूर्णीकशाभ पुटियाँ – कृष्ण प्रसाद जैन, प्रमोद कुमार एवं हरिकृष्ण माहेश्वरी

जबलपुर समूह के अवसादों की उत्पत्ति अभी तक असमुद्री मानी जाती है। इन अवसादों से गुरु एवं सूक्ष्म-पादपाश्मों वाला प्रचुर वनस्पतिजात प्राप्त हुआ है। हाल ही में इस समूह का परागाणुस्तरिकीय अध्ययन करते समय मध्य प्रदेश के होशंगाबाद जनपद में मोरघाट से एकत्रित नमूनों में एक नमूने से कुछ घूर्णीकशाभ पुटियाँ उपलब्ध हुईं। ये घूर्णीकशाभ पुटियाँ तीन प्रजातियों, कैलिप्टिया, सेन्टुसीडीनियम् एवं कैमिन्जिया से निरूपणीय हैं। एक जाति, कैलिप्टिया इन्डिका, नई है।

INTRODUCTION

THE Jabalpur Group typically comprises massive sandstones alternating with white clays. At places earthy hematite, red clay, carbonaceous shale and coal are also found. The soft white clay is very characteristic of the Jabalpur Group as a similar lithology is not found in any other Gondwana formation in India. The coaly and carbonaceous facies are especially well-developed near Sehora, Marhpiparia, Hathnapur, Parsapani, Kotri, Ranidhar (Dongarkhoh), Ranikamar and Morghat.

On the basis of plant fossil distribution, Crookshank (1936, p. 250) proposed division of the Jabalpurs of Satpura Gondwana Basin into two 'stages', viz., Chaugan and Jabalpur. However, the rocks of both the stages are lithologically very similar. The age of the Jabalpur Group is believed to be Upper Jurassic.

While the megaflora of the Jabalpur Group has rather been extensively studied, it is only during the last decade or so that detailed studies on the mioflora of the group have been undertaken (Bharadwaj, Kumar & Singh, 1972; Maheshwari, 1973, 1974). Recently Maheshwari and Kumar (1979) while working out the Jabalpur mioflora of the Lokhartalai area noted the presence of microplankton-like bodies in one of the samples from Morghat.

As the sample and the section from which it was obtained are apparently of non-marine origin, the presence of dinoflagellates therein is of great interest, and these form the subject of this paper.

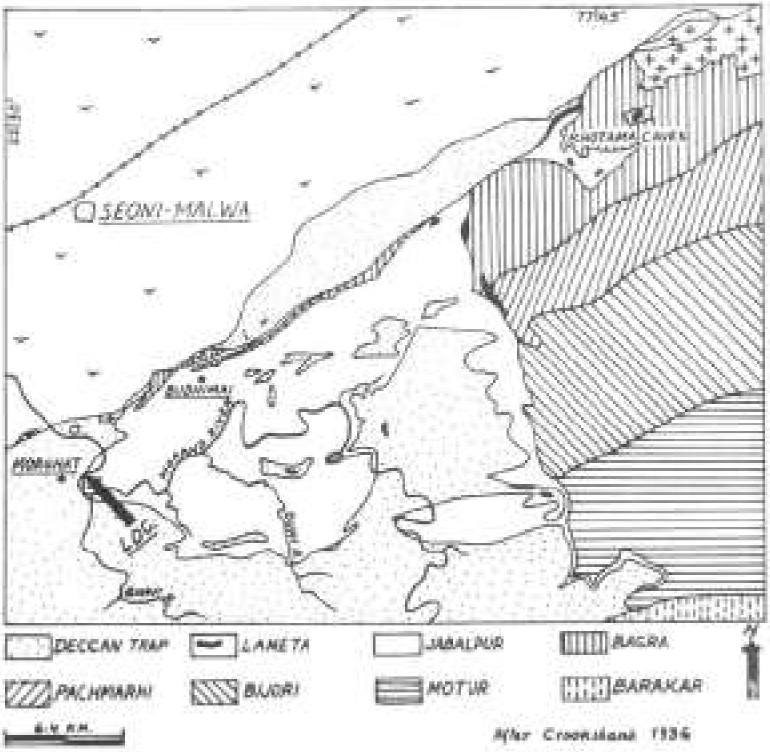
Fossil dinoflagellates are not entirely unknown from non-marine deposits. Traverse (1955) recorded *Peridinium* (*Sarp-*

todinium) *hansonianum* from the Brandon Lignite (Oligocene) of Vermont. Macko (1957) reported a modern species, *Glenodinium smrecyniense* Woloszynska, 1928, from the Miocene of Silesia. Species of *Geiselodinium* are known from the Miocene of Hungary (Nagy, 1965), Miocene of Alaska (Engelhardt, 1976) and Eocene of Germany (Krutzsh, 1962). Harris (1973) described an assemblage of non-marine dinoflagellate cysts from the Tertiary sediments of Australia. Non-marine dinoflagellates are also known from the Quaternary deposits (Churchill & Sarjeant, 1963; Sarjeant & Strachan, 1968; Harland & Sarjeant, 1970; Norris & McAndrews, 1970). Morgan (1975) reported a dinoflagellate cyst from the Early Cretaceous fluvial lithofacies of the Great Australian Basin.

The sample from which present dinoflagellate cysts were recovered is very rich in gymnosperm pollen. Only a few pteridophytic spores are present. The dinoflagellates, too, are meagrely represented and form less than 2 per cent of the total microflora. The diversity of the dinoflagellate cysts is also very low. The cysts possess well-developed horns or archaeopyle, and belong to the non-capsulate peridinioid forms. All the genera represented in the present assemblage are known from the Jurassic and younger marine sediments. To the best of our knowledge the present report happens to be the first record of 'non-marine' dinoflagellates from strata older than the Cretaceous.

MATERIAL AND METHOD

The dinoflagellate yielding sample is a carbonaceous shale collected by one of us (HKM) from the Morand River Section, east-north-east of Morghat, Hoshangabad District, Madhya Pradesh (see Map 1). The details of the palynological samples collected from the area and methodology followed are given in the earlier paper by Maheshwari and Kumar (1979). However, for dinoflagellates, the potassium hydroxide



MAP 1 — Geological map of the area showing the location of sample.

treatment was omitted and the macerate was stained with Safranin.

Photomicrographs were taken on ORWO NP 15 35 mm negative film with a Carl Zeiss Amplival microscope and automatic Camera attachment. Prints were made on AGFA Brovira paper.

The slides containing figured specimens are housed at the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

The co-ordinates of the figured specimens are from Carl Zeiss Jena "Amplival" microscope no. 535765 of Birbal Sahni Institute of Palaeobotany.

SYSTEMATIC DESCRIPTION

Class — Dinophyceae Pascher
Order — Peridiniales Schutt, 1896
Family — Pareodiniaceae Gocht emend. Sarjeant & Downie, 1974

Genus — *Kalyptea* Cookson & Eisenack emend. Wiggins, 1975

Type Species — *Kalyptea diceras* Cookson & Eisenack, 1960.

Kalyptea indica Jain & Maheshwari sp. nov.

Pl. 1, figs 7-12; Text-fig. 1A-C

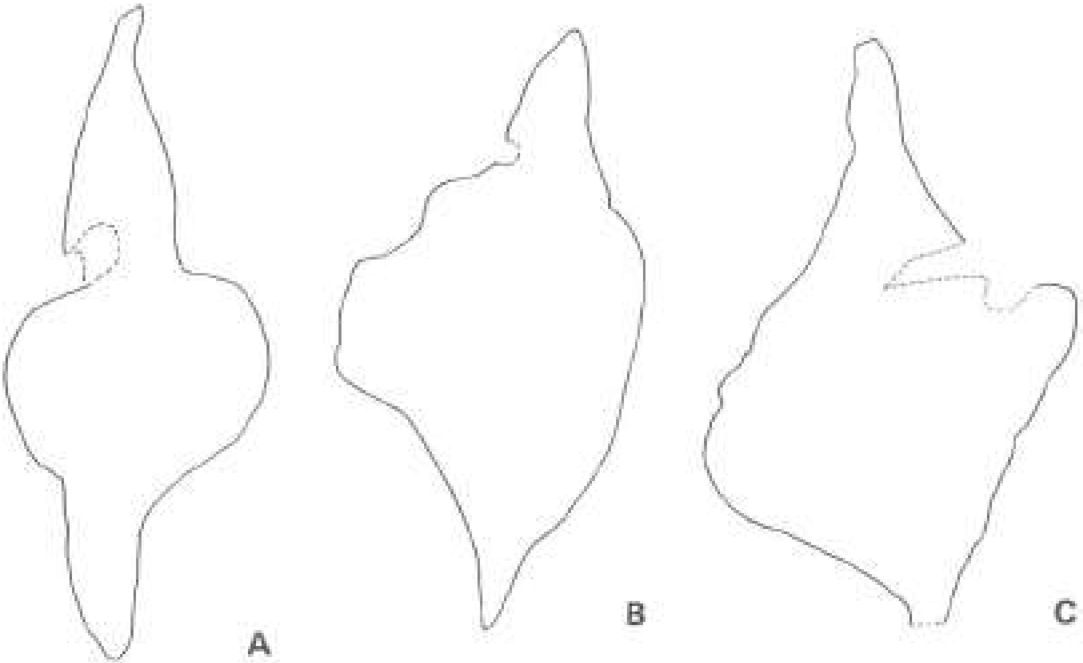
Holotype — Pl. 1, figs 8, 9; slide no. BSIP 5726/101 × 101 6·0.

Type Locality — Morand River Section, E.N.E. of Morghat, Hoshangabad District, Madhya Pradesh

Age — ?Upper Jurassic (Jabalpur Group).

Diagnosis — Cyst ellipsoidal, thin-walled, single-layered, folds frequent, surface finely granulate, apical and antapical horns well-developed; apical horn longer and broader than antapical horn, gradually tapering, tip rounded; antapical horn usually short, narrow, pointed. Central part of cyst inflated-elongate. Kalyptra and apical structures totally absent. Archaeopyle intercalary, probably made up of types 2I to 3I.

Measurements	*Holotype* µm	*Range* µm
Cyst size	125 × 65	78-125 × 50-70
Apical horn size	40 × 16	30-50 × 13-20
Antapical horn size	20 × 8	13-20 × 8-10



TEXT-FIG. 1A-C — *Kalyptea indica* Jain & Maheshwari sp. nov; cyst outline showing inflated central part with well-developed apical and antapical horns. Archaeopyle margin broken (× 500).

Comparison — Twenty-five specimens belonging to *Kalyptea indica* Jain & Maheshwari sp. nov. have been studied. The preservation of the forms is not very satisfactory, damaged specimens are frequently recovered. The species compares best with *K. diceras* Cookson & Eisenack, 1960 in having unequal horns and thin and finely granulate cyst wall but differs in having inflated elongate central part and no kalyptra. The rhombic shape of *K. glabra* (Cookson & Eisenack) Wiggins, 1975 easily distinguishes it from *K. indica*.

Remarks — Morgan (1975) has reported similar single-layered cysts as *Fusiformacysta* from the Lower Cretaceous of Australia, having precingular archaeopyle. The species *F. salasii* is believed by Morgan (1975, p. 164) to be a non-marine dinoflagellate cyst.

Genus — *Canningia* Cookson & Eisenack, 1960

Type Species — *Canningia reticulata* Cookson & Eisenack, 1960.

Canningia sp.

Pl. 1, figs 5, 6

Description — Cyst spheroidal, 50 × 40 µm in size, wall thin, granular, slight apical projection seen, antapical end broadly rounded, archaeopyle apical, margin deeply notched.

Remarks — It shows close resemblance with *Batiacasphaera macrogranulata* Morgan, 1975 but differs in the sufrace ornamentation.

Genus — *Sentusidinium* Sarjeant & Stover, 1978

Type Species — *Sentusidinium rioultii* (Sarjeant) Sarjeant & Stover, 1978.

Sentusidinium sp. A

Pl. 1, figs 1, 4

Description — Cyst ovoid, 70 × 65 µm in size, cingulum absent, surface granular, tabulation lacking. Archaeopyle apical, suture zigzag.

Remarks — The preservation of recovered specimens is not satisfactory to give a clear idea of surface ornamentation.

Sentusidinium sp. B

Pl. 1 figs 2, 3

Description — Cysts ovoid, 70 × 65 µm in size, autophragm imperfectly ornamented, appears to be coarsely granulate or tuberculate; sometimes cingulum is indicated by the arrangement of granules or tubercles. Archaeopyle apical.

FORMA A

Pl. 1, fig. 13

Description — Cyst distorted, 110 × 50 µm in size, elongate, single-layered, granulate, an apical and two antapical horns well-developed. Archaeopyle not seen.

Remarks — Only a few specimens have been recovered. The presence of an apical and two antapical horns with autophragm suggests their placement either under the genus *Batioladinium* or *Broomea*. Since the archaeopyle is not discernible, no definite placement is possible.

ACKNOWLEDGEMENTS

We thank Mrs Asha Guleria and Mr D. C. Joshi for processing the samples and Mr Rahul Garg for photographic assistance.

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EXPLANATION OF PLATE

(*All figures, unless mentioned otherwise, are* × 500)

1. *Sentusidinium* sp. A: Slide no. BSIP 5727; coordinates 102·8 × 0·5.
2. *Sentusidinium* sp. B: Slide no. BSIP 5727; coordinates 103·7 × 11·3.
3. *Sentusidinium* sp. B: Slide no. BSIP 5729; coordinates 120·7 × 12·0.
4. *Sentusidinium* sp. A: Slide no. BSIP 5726; coordinates 95·5 × 0·9.
5. *Cunningia* sp.: Slide no. BSIP 5726; coordinates 127 × 13·8.
6. *Cunningia* sp.: Slide no. BSIP 5725; coordinates 125 × 20·0.
7. *Kalyptea indica* Jain & Maheshwari sp. nov.: Slide no. BSIP 5728; coordinates 100·9 × 11·1.
8. *Kalyptea indica* Jain & Maheshwari sp. nov. magnified apical part showing archaeopyle: Slide no. BSIP 5726; coordinates 101·0 × 6·0 (× 1000). Holotype.
9. *Kalyptea indica* Jain & Maheshwari sp. nov.: Slide no. BSIP 5726; coordinates 101·0 × 6·0. Holotype. Same specimen as in fig. 8.
10. *Kalyptea indica* Jain & Maheshwari sp. nov.: Slide no. BSIP 5726; coordinates 108·0 × 19·8.
11. *Kalyptea indica* Jain & Maheshwari sp. nov.: Slide no. BSIP 5728; coordinates 138·4 × 8·8.
12. *Kalyptea indica* Jain & Maheshwari sp. nov.: Slide no. BSIP 5730; coordinates 109·5 × 14·7.
13. Forma A: Slide no. BSIP 5726; coordinates 117·6 × 12·5.

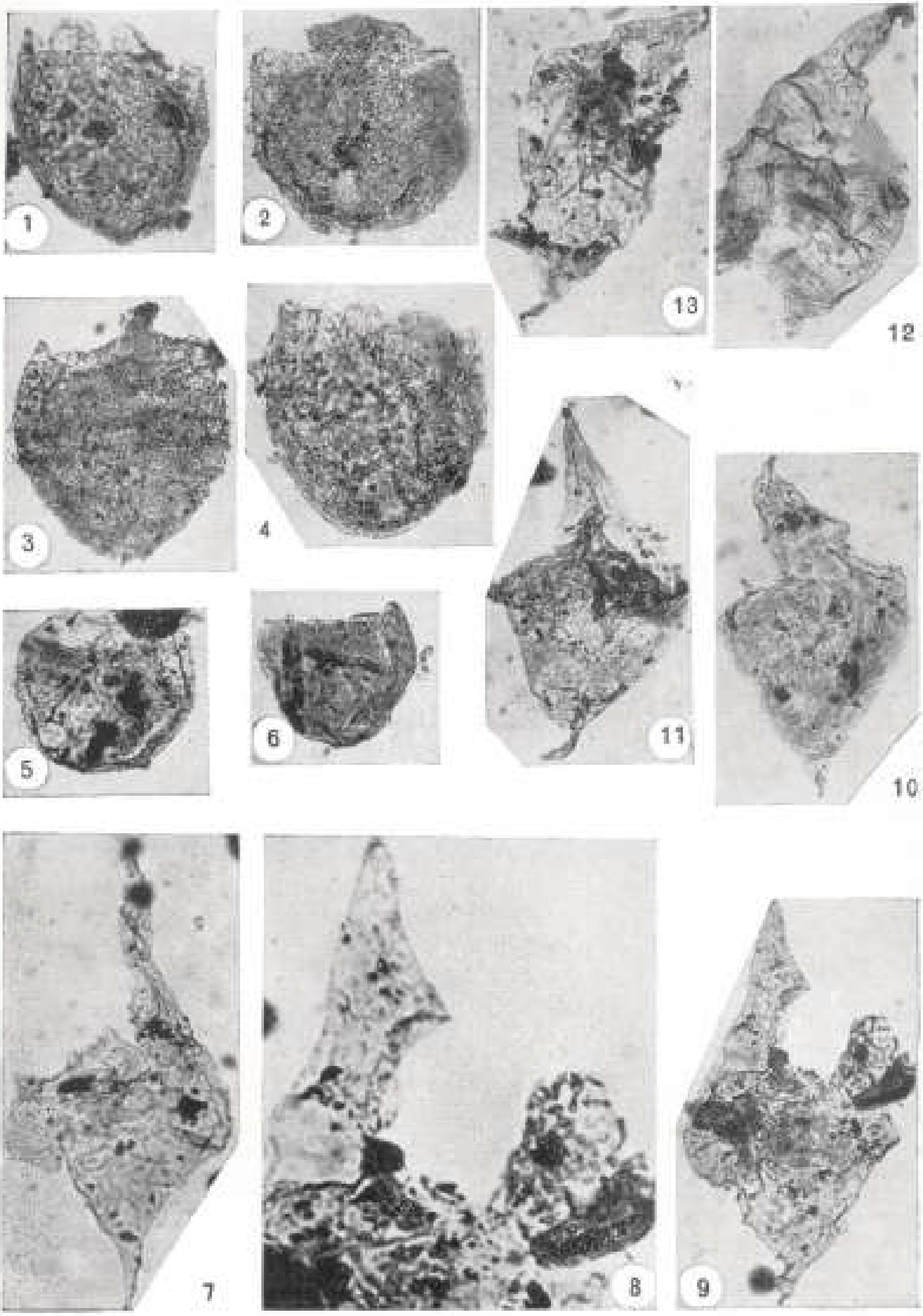

PLATE 1

The Palaeobotanist, **30**(1): 28-33, 1982.

PALYNOLOGY OF THE DECCAN INTERTRAPPEAN BEDS OF RAJAHMUNDRY DISTRICT, ANDHRA PRADESH

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ABSTRACT

Palynological studies of the Deccan Intertrappean beds from the village Kotta-Bommuru, Rajahmundry District have yielded some fungal spores and angiospermous pollen. These are represented by 7 genera belonging to 12 species. Three new species of fungal spores have been described.

Key-words — Palynology, Fungal spores, Deccan-Intertrappean beds, Early Eocene (India).

सारांश

राजाहमुंद्री जनपद (आंध्र प्रदेश) की दक्खन अन्तर्ट्रेपी संस्तरों का परागाणविक अध्ययन – कृष्ण अम्बवानी

राजाहमुंद्री जनपद में कोट्टा-बोम्मारु गाँव की दक्खन अन्तर्ट्रेपी संस्तरों के परागाणविक अध्ययन से कुछ कवकीय बीजाणु एवं आवृतबीजी परागकण उपलब्ध हुए हैं। ये सात प्रजातियों की 12 जातियों से निरूपित हैं। कवकीय बीजाणुओं की तीन नई जातियाँ भी वर्णित की गई हैं।

INTRODUCTION

LITTLE work has so far been done on the study of the mioflora from the Deccan Intertrappean Series of India. Earlier workers have carried out studies on the Deccan Intertrappean mioflora mostly found within the infected parts of the plants embedded in the chert. Sahni and Rao (1943) reported perithecia attached to septate mycelium by preparing thin sections. Rare attempts have been made to study the mioflora by maceration. Shukla and Chitaley (1948) recovered fungal zygospores resembling Mucorales. Chitaley (1950, 1951, 1957) recorded some fungal and pteridophytic spores as well as gymnospermous and angiospermous pollen grains from the Deccan Intertrappean cherts of Mohgaon Kalan, Chhindwara District, Madhya Pradesh. The fungal spores mainly belong to Mucoraceae, Microthyriaceae and Pleosporaceae, whereas the pteridophytic spores show affinities with Gleicheniaceae, Lycopodiaceae and Polypodiaceae. The gymnospermous pollen comprise monosaccates and disaccates, while the angiospermous pollen are represented by the families Gramineae, Ericaceae and Betulaceae.

Dwivedi (1959) described fossil rust spores infecting the fruit of *Enigmocarpon parijai*. Lakhanpal, Dayal and Jain (1967) discovered fungal sporangia belonging to Lagenidiales from the Deccan Intertrappean beds of Mohgaon Kalan. In 1968, Mahabale described some well-preserved two-celled fossil fungal spores as *Diploidia* from the cherts of the Deccan Intertrappean Series. Chitaley and Sheikh (1969, 1971) reported the fungal fructifications from the Deccan Intertrappean Series of Mohgaon Kalan and a fossil fungus resembling *Helminthosporium*. Chitaley and Patil (1972) described Deuteromycetous fungus in association with a dicotyledonous wood from the Deccan Intertrappean beds of Mohgaon Kalan. Trivedi and Verma (1973) described a fossil fungus *Stagonospora intertrappea* and Paradkar (1974) recovered fungal spores consisting of conidia and monosulcate grains in an infected leaf from the same beds.

The present paper deals with the palynological investigations of the Deccan Intertrappean calcareous clay. Thirty palynological samples were collected from the roadside section exposed about 2·5 km south-east of Rajahmundry near the village Kotta-Bommuru (81°48'O"N; 10°58" 5"E). The section is about 6 m thick and its base is made up of a 1·5 m thick gravel bed which is followed by thin pink-brown clay bands. Though all the samples were processed but only 5 samples yielded a poor assemblage of spores and pollen. The systematic description of the recovered assemblage is as follows.

SYSTEMATIC DESCRIPTION

FUNGAL SPORES

Genus — *Inapertisporites* (van der Hammen) Sheffy & Dilcher, 1971

Inapertisporites trivedii sp. nov.

Pl. 1, figs 1, 2

Holotype — Pl. 1, fig. 1, size 125×65 μm, slide no. 6068/3.

Type Locality — Kotta-Bommuru Village, Rajahmundry District, Andhra Pradesh.

Horizon & Age — Deccan Intertrappean Series; Early Eocene.

Diagnosis — Grains non-aperturate, golden yellow in colour; shape oval to elongated size 125×65-64×55 μm; spore wall folded, punctate, discontinuous striations present.

Description — Fungal spores subcircular to subtriangular, oval to elongated in shape, size varies from 125×65-64×55 μm. Spore wall with many irregular folds, punctate and striated, striations discontinuous on the surface of the grain, ±1 μm thick and 2-3 μm long.

Comparison — The present species differs from the following species of *Inapertisporites*, *I. minutus* van der Hammen (1954), *I. elongatus* Rouse (1962), *I. vulgaris*, *I. circularis*, *I. ovalis*, *I. subcapsularis*, *I. reticulatus*, *I. longissimus*, *I. subovoideus*, *I. obscurus*, *I. nodulus*, *I. disciformis*, *I. irregularis*, *I. obpyriformis*, *I. subcurvatus*, *I. scabridus* and *I. pulvinatus* Sheffy & Dilcher (1971) in having larger size as well as striations on the spore wall.

The species is named in honour of Prof. B. S. Trivedi.

Inapertisporites cystoides sp. nov.

Pl. 1, figs 3, 4

Holotype — Pl. 1, fig. 3, size 60 μm, slide no. 6070/3.

Type Locality — Kotta-Bommuru Village, Rajahmundry District, Andhra Pradesh.

Horizon & Age — Deccan Intertrappean Series; Early Eocene.

Diagnosis — Fungal body/cyst dark brown, non-aperturate, circular to oval in shape, size 66-60 μm in diameter, spore wall very thick ±4·5 μm, laevigate or punctate.

Description — Fungal body with cyst-like covering, dark brown in colour; circular to slightly oval in shape; size varies from 66-60 μm diameter. Spore wall very thick ±4·5 μm, laevigate to punctate.

Comparison — The present species resembles *Inapertisporites circularis* Sheffy & Dilcher (1971) but differs in having larger size and a very thick spore wall.

Inapertisporites sp. 1

Pl. 1, figs 5, 6

Description — Fungal spores dark borwn in colour, body mostly circular and thick-walled, size varies from 48-52 μm in diameter, spore wall more or less papillate or pseudoreticulate in surface view, mesh size ±2·5 μm wide, papillae thin ±2 μm long.

Remarks — The present species differs from *Inapertisporites cystoides* in having thin papillate out growth on the spore wall.

Inapertisporites sp. 2

Pl. 1, figs 7, 8

Description — Fungal spore with folded spore wall; subtriangular in shape, size about 48×36 μm, spore wall thin about 1 μm, punctate, puncta small less than 1 μm.

Remarks — The present species resembles with *Inapertisporites kedvesii* Elsik (1968) except in the spore wall thickness and having larger size.

Inapertisporites sp. 3

Pl. 1, fig. 9

Description — Fungal spore inaperturate, oval in shape, size 96×72 μm, spore wall slightly thicker about 1·5 μm, laevigate/punctate, folds present.

Comparison — The present species differs from the other known species of laevigate *Inapertisporites* in considerably larger size.

Genus — *Dicellaesporites* (Elsik) Sheffy & Dilcher, 1971

Dicellaesporites popovii Elsik, 1968

Pl. 1, fig. 10

Description — Fungal spore dark brown in colour, spore appears to be 3-celled, 30 × 16 μm in size, the basal cell larger 15 μm, middle cell 10 μm and the apical cell 5 μm in size. Spore wall mediumly thick about 1 μm, laevigate. The basal cell shows attachment scar.

Genus — *Multicellaesporites* (Elsik) Sheffy & Dilcher 1971

Multicellaesporites prakashii sp. nov.

Pl. 1, fig. 11

Holotype — Pl. 1, fig. 11, size 80 × 20 μm, slide no. 6075/1.

Type Locality — Kotta-Bommuru Village, Rajahmundry District, Andhra Pradesh.

Horizon & Age — Deccan Intertrappean Series; Early Eocene.

Diagnosis — Tetracellate spore 80 × 20 μm, individual cells spherical ± 20 μm diameter, arranged along the longer axis with 3 dark septa, spore wall laevigate ± 1·5 μm thick. Spores dark brown in colour.

Description — Tetracellate spore, size varies up to 80 × 20 μm, cells arranged along the longer axis (with 3 dark septa) individual spore spherical in shape, ± 20 μm in size, exine laevigate and 1·5 μm thick. Spores dark brown in colour.

Comparison — Among the large number of species of *Multicellaesporites*, the present species resembles *M. allomorphus* Sheffy & Dilcher, 1971 in shape and 4-celled body but differs from it in being bigger in size and having thicker spore wall with spherical cells.

The specific name is given in the honour of Dr U. Prakash.

Genus — *Monoporisporites* (van der Hammen) Sheffy & Dilcher, 1971

Monoporisporites ovalis Sheffy & Dilcher, 1971

Pl. 1, fig. 12

Description — Fungal spore dark brown/black in colour; oval in shape, 18 × 12 μm size with a faint longitudinal slit-like opening.

Monoporisporites stoverii Elsik, 1968

Pl. 1, fig. 13

Description — Fungal spore black in colour, opaque with a single aperture, circular in shape, 18 μm in size; spore wall laevigate to finely pitted, ± 0·5 μm thick.

FUNGAL REMAIN TYPE-1

Pl. 1, fig. 14

Description — Germinating spore, hypha coming out from the main body, 16 × 10 μm in size, oval in shape, swollen at both the ends, about 180 μm long. The hypha produces a small branch at the apical end.

FUNGAL REMAIN TYPE-2

Pl. 1, fig. 15

Description — Hyphae with circular to oval spores, brown in colour, non-aperturate; each spore measures about 13 × 15 μm in size; spore wall laevigate.

ANGIOSPERMOUS POLLEN

Anteturma — *Variegerminantes* Potonié, 1970
Turma — *Aletes* Ibrahim, 1933
Subturma — *Azonaletes* (Luber) Potonié & Kremp, 1954
Infraturma — *Tuberini* Pant, 1954

Genus — *Nonaperturipites* Biswas, 1962

Nonaperturipites sp.

Pl. 1, figs 16, 17

Description — Pollen grains oval to subcircular in shape, size 142-112 μm, inaperturate, exine thick about 3 μm, verrucate or gammate forming pseudoreticulum in surface view, gammae evenly distributed, verrucae/gammae ±2-4 µm high.

Remarks — The present species resembles with *Nonaperturipites berryi* Biswas (1962) except having larger size and bigger varrucae/gammae.

Turma — *Plicates* (Naumova) Potonié, 1960
Subturma — *Tryptches* (Naumova) Potonié, 1960

Genus — *Tricolpopollenites* (Pflug & Thomson) in Thomson & Pflug, 1953

Tricolpopollenites microhenrici Thomson & Pflug, 1953

Pl. 1, fig. 19

Description — Pollen grains more or less triangular in polar view, polar axis equal or slightly longer than equatorial axis, tricolpate, isocolpate, size of the grain ±20 µm; exine ±1 µm thick, laevigate.

Subturma—*Polyptyches* (Naumova) Potonié 1960
Infraturma — *Stephenocolpati* (van der Hammen) Potonié 1970

Genus — *Psilastephanocolpites* Leidelmeyer, 1966

Psilastephanocolpites maia Leidelmeyer, 1966

Pl. 1, fig. 18

Description — Pollen grains oval in equatorial view, 80×52 µm in size, tetracolpate, colpi running up to 3/4 of the longer axis, exine about 1 µm thick, laevigate/scabrate and thin.

Remarks — The present species is comparable with *Psilastephanocolpites maia* almost in all characters except slight variation in size.

DISCUSSION

The palynological assemblage recovered from the Deccan Intertrappean beds of Kotta-Bommuru is poor. The fungal spores are represented by nine species belonging to four genera, while the angiospermous pollen are represented by three species belonging to three genera.

Earlier, the palynological studies on the Deccan Intertrappean beds of Mohgaon Kalan, Chhindwara District carried out by Chitaley (1950, 1951, 1957) show the presence of some fungal fruiting bodies and fungal hyphae, as well as some thallophytic spores. Later in (1951), she recovered a good assemblage of pteridophytic spores, and gymnospermous as well as angiospermous pollen grains. Among them the pteridophytic spores constituted aletes, monoletes and triletes; gymnospermous pollen are represented by monosaccates and disaccates whereas the angiospermous pollen grains are shared by *Monoporites* (Graminidites), *Monoporites* (Typhidites), *Monosulcites* (Palmidites), *Tricolpidites* (Rhamnacidites) and *Tricolporites* (Myrtacidites). Chitaley (1957) recovered some microthyriaceous fruiting bodies and spores of Pleosporaceae and Mucoraceae. Pteridophytic spores of the families Gleicheniaceae and Lycopodiaceae were also frequent in this assemblage. Monocotyledonous as well as dicotyledonous pollen grains belonging to the families Gramineae, Ericaceae, Tiliaceae and Betulaceae were also recorded.

The present palynological assemblage does not compare with the above assemblages and the differences between these assemblages may be due to (i) the disparity in the stratigraphical horizons, and the difference in the lithology, (ii) the difference in the depositional environment and floral composition at that time, and (iii) considerable distance between the two areas.

In the present palynological assemblage it has been observed that the miospores mainly belong to inaperturate type of fungal spores, whereas the angiospermous pollen grains are scanty. Absence of bryophytic and pteridophytic spores as well as gymnospermous pollen with a poor percentage of angiospermous pollen grains in the present assemblage leads to presume a poor vegetational growth in this area. However, presence of *Nonaperturipites*-type of pollen grains indicate that there might have been some localised water logged areas at places to justify its growth.

The present palynological assemblage is poor to be employed in the palynostratigraphical studies and more data are necessary to build up a complete palynological succession of this area.

ACKNOWLEDGEMENTS

The author is grateful to Dr U. Prakash for constant encouragement throughout the progress of this work. Thanks are also due to Dr R. K. Saxena of the Oil Palynology Department of the Institute for his valuable suggestions and constructive criticism.

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EXPLANATION OF PLATE

1, 2. *Inapertisporites trivedii* sp. nov., slide nos. 6068/3 (Holotype) & 6069/1.
3, 4. *Inapertisporites cystoides* sp. nov., slide nos. 6069/2 & 6070/3 (Holotype).
5, 6. *Inapertisporites* sp. at different foci, slide no. 6071/1.
7, 8. *Inapertisporites* sp. 2, slide nos. 6069/1 & 6072/2.
9. *Inapertisporites* sp. 3, slide no. 6073/1.
10. *Dicellaesporites popovii* Elsik, slide no. 6074/3.
11. *Multicellaesporites prakashii* sp. nov., slide no. 6075/1 (Holotype).
12. *Monoporisporites ovalis* Sheffy & Dilcher, slide no. 6078/1.
13. *Monoporisporites stoverii* Elsik, slide no. 6076/1.
14. Fungal remain Type-1, slide no. 6077/3.
15. Fungal remain Type-2, slide no. 6078/1.
16, 17. *Nonaperturipites* sp., slide no. 6079/1.
18. *Psilastephanocolpites maia* Leidelmeyer, slide no. 6070/1.
19. *Tricolpopollenites microhenrici* Thomson & Pflug, slide no. 6080/1.

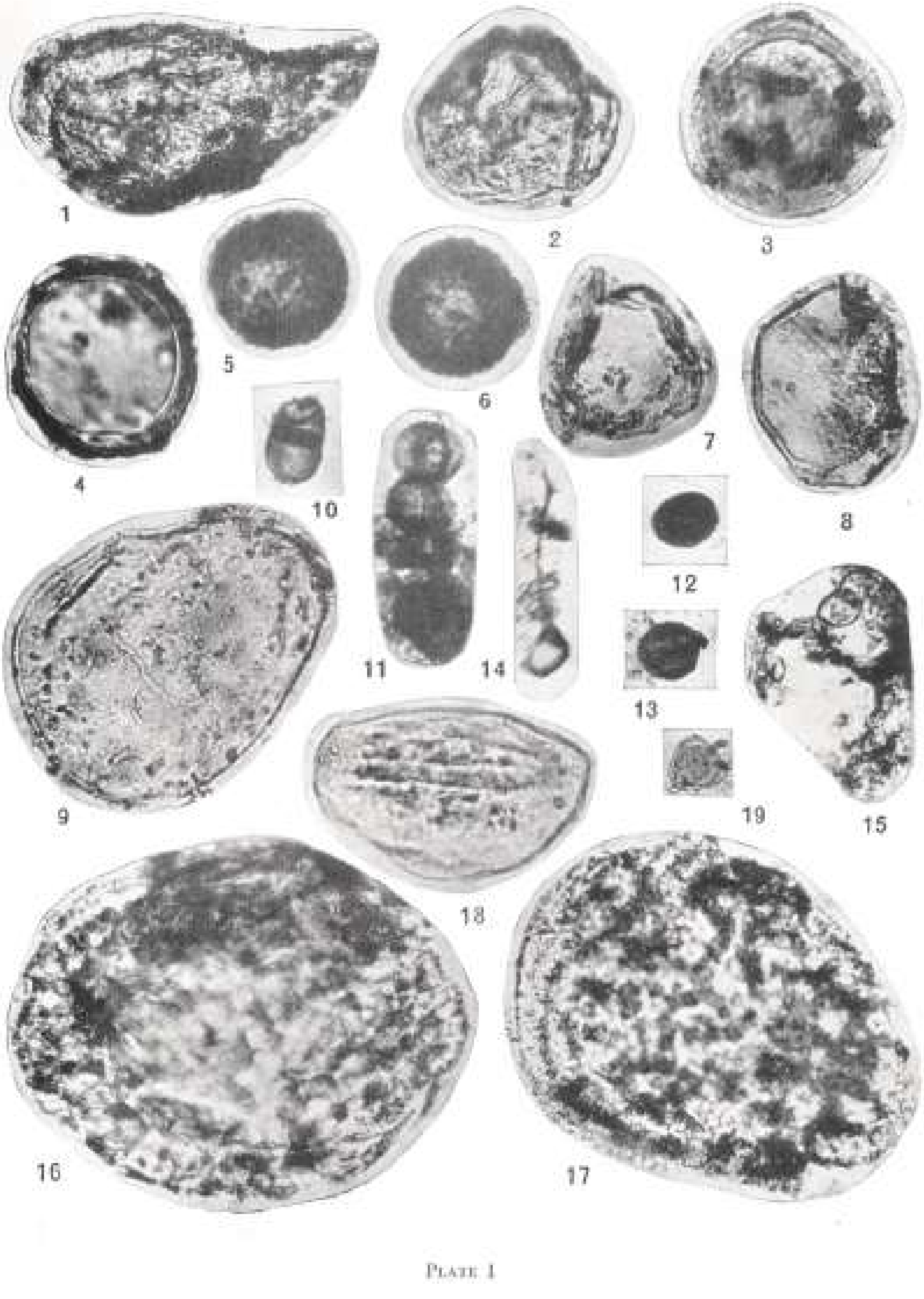

PLATE 1

The Palaeobotanist, **30**(1): 34-42, 1982.

LITHOSTRATIGRAPHY OF THE TERTIARY SEDIMENTS EXPOSED ALONG JOWAI-BADARPUR ROAD IN JAINTIA HILLS (MEGHALAYA) AND CACHAR (ASSAM)

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ABSTRACT

The paper includes the field observations on the sediments along Jowai-Badarpur Road section in Jaintia Hills and Cachar, depicting their lithostratigraphy. Starting from Jowai towards Badarpur various Tertiary sediments were observed. In ascending order, these are: Therria, Sylhet Limestone, Kopili, Laisong, Jenam, Renji, Bhuban, Bokabil, Tipam Sandstone and Recent alluvia. The lithology, nature and location of contacts and fossil contents of each of these formations are discussed.

At Sonapur, 76 km from Jowai, the section is crossed by Dauki Tear Fault, which separates the Palaeocene-Eocene rocks of the shelf facies to the north from Oligocene-Miocene rocks of the geosynclinal facies to the south.

Key-words — Lithostratigraphy, Tertiary sediments, Jaintia Hills, Cachar (India).

सारांश

जयन्तिया पहाड़ियों (मेघालय) एवं कछार (असम) में जोवई-बदरपुर मार्ग के साथ-साथ विगोपित तृतीयक अवसादों का शैल-स्तरिकीय अध्ययन – रमेश कुमार सक्सेना एवं सूर्यकांत मणि त्रिपाठी

इस शोध-पत्र में जयन्तिया पहाड़ियों एवं कछार में जोवई-बदरपुर मार्ग खंड के साथ-साथ स्थित अवसादों की शैल-स्तरिकी व्यक्त करते हुए क्षेत्रीय प्रेक्षणों का विवेचन किया गया है। जोवई से लगाकर बदरपुर की ओर को विभिन्न तृतीयक युगीन अवसाद प्रेक्षित किये गये। आरोही क्रम में ये थेरिया, सिल्हट चूना-पत्थर, कोपिली, लाइसोंग, जेनाम, रेन्जी, भुबन, बोकाबिल, टिपम बालुकाश्म एवं अर्वाचीन जलोढ़ मिट्टी हैं। इन शैल-समूहों में प्रत्येक की शैलिकी, संस्पर्श का स्थान एवं प्रकृति तथा उपलब्ध जीवाश्म भी विवेचित किये गये हैं।

जोवई से 76 किलोमीटर दूर सोनापुर में यह खंड डौकी-टियर-भ्रंश द्वारा काटा गया है। यही भ्रंश उत्तर में उपतट संलक्षणी की पुरानूतन-आदिनूतन चट्टानों को दक्षिण में भू-अभिनत संलक्षणी की अल्पनूतन-मध्यनूतन युगीन चट्टानों से अलग करता है।

INTRODUCTION

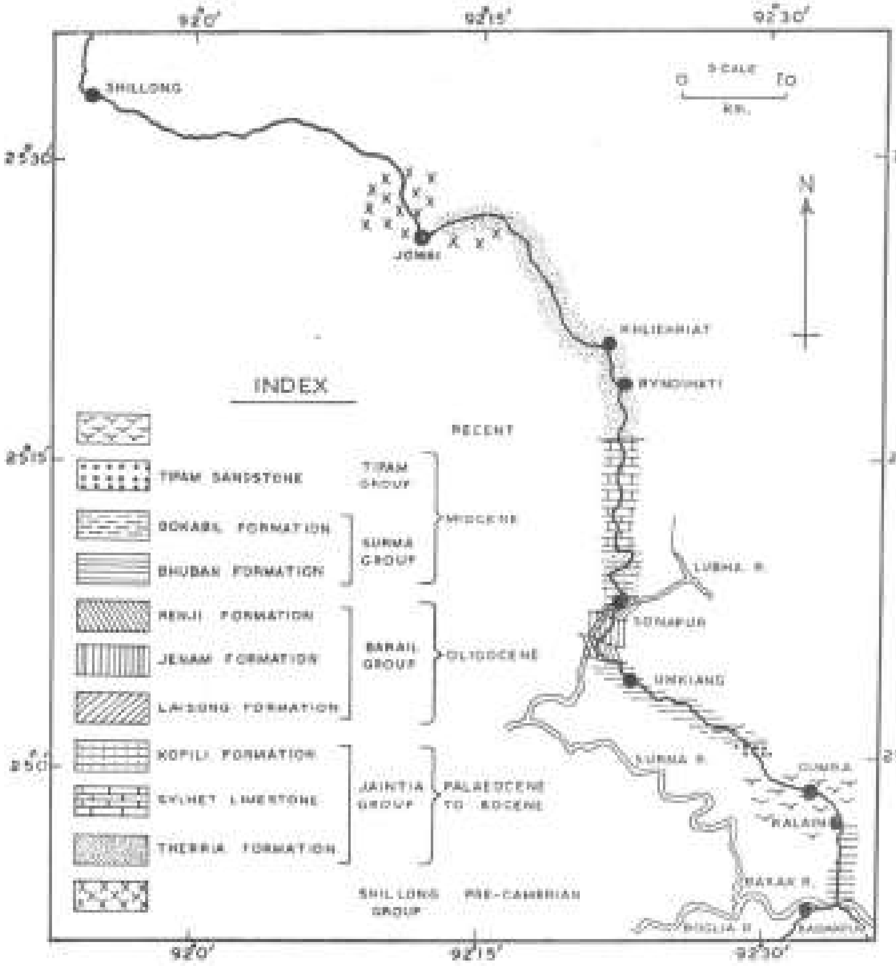
THE Jowai-Badarpur Road section, located in the south-east of Shillong, represents one of the classical sections exposing the Tertiary sediments in north-eastern India and constitutes part of Shillong-Badarpur highway (National Highway-44). The section is 136 km long and is shared by Jaintia Hills District of Meghalaya and Cachar District of Assam.

Dasgupta *et al.* (1964) published the geological map of the area along Jowai-Badarpur Road with a summarized description. Sein and Sah (1974) published a paper dealing with the palynological demarcation of the Eocene-Oligocene sediments exposed along a part of Jowai-Badarpur Road, between Lumshnong and Sonapur. Dutta and Jain (1980) described 17 genera and 31 species of dinoflagellate cysts and acritarchs from the Sylhet Limestone and Kopili formations exposed in Lumshnong area near this road section and elucidated the biostratigraphic potential of the assemblage. However, more elaborated studies are required to fully understand the stratigraphy and palynology of the area and to build up standard palynostratigraphic controls for the demarcation of various stratigraphic levels and their correlation with the isochronous sediments of the other parts of north-eastern India. With this objective, the authors undertook a geological excursion of the area in January-February, 1978. A geological map of this road section was prepared on a base map of 1:363640 scale (Text-fig. 1). Besides, over 600 stratigraphically located samples were collected for palynological studies from all the rock formations exposed along the road, which include various lithic types, viz., grey sandy shale, carbonaceous shale, coaly shale, coal, clay, limestone, etc. The lithostratigraphy of the area, based on our own field observations, is discussed in this paper.

Distances given in this paper represent the distance of a locality from Shillong along Shillong-Badarpur Highway, unless mentioned otherwise. The distances are taken from roadside kilometrestones and not from the toposheets.

LITHOSTRATIGRAPHY

The basin for the deposition of the Tertiary sediments of the Jowai-Badarpur Road section is provided by the Shillong Group, which is continuously exposed along the road from Shillong to Jowai except at 54 km from Shillong where an exposure of brown, coarse to very coarse grained, ferru-



TEXT-FIG. 1 — Geological map of the area along Jowai-Badarpur Road in Jaintia Hills (Meghalaya) and Cachar (Assam) districts.

ginous sandstone of Therria Formation was observed. Near Jowai, the Shillong Group is unconformably overlain by the Therria Formation. Further southward, the Therria Formation is overlain by Sylhet Limestone, which is followed by the Kopili Formation. The Jaintia Group comprising Therria, Sylhet Limestone and Kopili formations is overlain by the Barail Group which is represented by Laisong, Jenam and Renji formations. The Barail Group is overlain by the Surma Group which is divisible into lower Bhuban Formation and upper Bokabil Formation. Near Sonapur, the road is crossed by the Dauki Tear Fault separating Jaintia Group of shelf facies to the north from Barail and Surma groups of geosynclinal facies to the south. The Surma Group is overlain by the Tipam Sandstone, which constitutes the lower part of the Tipam Group. The other formations of Tipam Group, viz., Girujan Clay and Dupi Tila, are not exposed along the road and therefore could not be studied. The stratigraphic succession along the Jowai-Badarpur Road is summarized in Table 1. The description of various stratigraphic units is also given.

SHILLONG GROUP

This group, occupying the major portion of Shillong Plateau, is constituted by quartzite with subordinate phyllite, slate and schist. It rests over an Archaean gneissic basement complex and near Jowai it is directly overlain by Jaintia Group (Palaeocene-Eocene).

JAINTIA GROUP

It represents the Palaeocene-Eocene sequence of the shelf facies and is continuously exposed in road cutting between Jowai (64 km) and Sonapur (140 km). This group is divided into 3 formations, viz., Therria, Sylhet Limestone and Kopili.

THERRIA FORMATION

The Therria Formation constitutes the oldest stratigraphic unit of the Tertiary sequence in Jowai-Badarpur Road section and also the oldest among the 3 rock formations of the Jaintia Group. The exposures of this formation were observed in the form of outliers near Jowai (64 km) alongwith the inliers of Shillong Group. Continuous exposures of Therria Formation were observed up to 46 km from Jowai (110 km), except near 83 km where an inlier of steeply dipping quartzite of Shillong Group was observed. The rocks of this formation show low rolling dips ranging between 3 to 10 degrees and averaging 4-5 degrees.

Lithology — This formation is made up of 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. At places, the sandstone is highly weathered and lateritic. Many coal seams are also observed in this formation. Their location and thickness are: (i) at 81.5 km, 0.80 m; (ii) at 85 km, 0.90 m; (iii) near 86 km, 2 seams, 0.90 m and 0.15 m respectively; (iv) near 88.5 km, 0.20 m; (v) near 92.7 km, 4 seams, 1.10 m, 1.15 m, 0.15 m and 0.25 m respectively; (vi) near 93.5 km, 0.30 m; (vii) near 94.5 km, 0.75 m; (viii) near 100.25 km, 2 seams, each 0.15 m; (ix) near 105 km, 0.25 m; (x) near 106.5 km, 0.60 m; and (xi) near 109.5 km, 0.65 m.

Nature of Contacts — The Therria Formation unconformably overlies the Pre-Cambrian Shillong Group. This contact can be observed near Jowai (64 km). The upper contact of the Therria Formation with the overlying Sylhet Limestone is conformable. This contact is marked at the base of the grey limestone bed of Lakadong Limestone Member and is exposed near 110 km.

Fossil Contents — This formation is devoid of animal fossils or plant megafossils. However, an extensive collection of rock samples made by the authors has yielded a rich palynoflora.

SYLHET LIMESTONE

The Sylhet Limestone is the next unit in the sequence after Therria Formation and constitutes the middle part of the Jaintia Group. It appears at 110.0 km and

TABLE 1 LITHOSTRATIGRAPHIC SEQUENCE OF THE TERTIARY SEDIMENTS EXPOSED ALONG JOWAI-BADARPUR ROAD

AGE	GROUP	FORMATION	MEMBER	LITHOLOGY	REMARKS
Recent	Recent			Alluvium	Exposed between 182 and 194 km
Plio-Pleistocene	Dihing Group			—	Not exposed along the road.
	Tipam Group	Dupi Tila Formation			Not exposed along the road.
		Girujan Clay			Not exposed
		Tipam Sandstone		Medium to coarse grained, ferruginous sandstone with subordinate shale bands and streaks of lignitic coal	Poorly exposed between 180 and 182 km.
Miocene	Surma Group	Bokabil Formation		Alternations of thick shales and very fine grained laminated sandstone. Coarser grained sandstone absent.	Poorly exposed between 177.5 and 180 km
		Bhuban Formation	Upper Member	Fine grained sandstone alternated with thin grey and carbonaceous shale	Good continuous exposures between 147.5 and 177.5 km and between 194 km and Badarpur (290 km)
			Middle Member	Predominantly argillaceous sediments	
			Lower Member	Hard, fine to very fine grained sandstone alternating with thin shale bands	
		Renji Formation		Mainly arenaceous sediments. Fine to medium grained, thick massive sandstone alternated by shale bands	Continuously exposed between 145.6 km and 147.5 km
Oligocene	Barail Group	Jenam Formation		Thick carbonaceous shale with fine to medium grained sandstone	Exposed between 143.2 and 145.6 km
		Laisong Formation		Very fine grained and fine grained sandstones with subordinate shale and intraformational conglomerate	Well exposed between 140 and 143.2 km
		Kopili Formation		Alternations of fine to very fine grained grey sandstone and splintery shales of the same colour with occasional bands of ironstone, carbonaceous shale, coal and limestone	Excellent exposures between 128.5 and 140 km
Palaeocene to Eocene	Jaintia Group	Sylhet Limestone	Prang Limestone	Grey fossiliferous limestone	Exposed between 110 and 128.5 km
			Narpuh Sandstone	Medium to coarse grained sandstone with calcareous bands	
			Umlatdoh Limestone	Grey fossiliferous limestone with thin sandstone bands	
			Lakadong Sandstone	Fine to coarse grained sandstone with coal seams	
			Lakadong Limestone	Hard grey limestones with thin sandstone bands	
		Therria Formation		Medium to very coarse grained quartz sandstone alternated by carbonaceous shales. A few coal seams also occur	Exposed between Jowai (64 km) and 110 km.
Pre-Cambrian	Shillong Group	—		Quartzite with subordinate phyllite, slate and schist	Exposed between Shillong (0 km) and Jowai (64 km)

continues up to 128.5 km, where it is overlain by Kopili Formation.

Lithology — This formation is made up mainly of limestone with thin alternations of sandstones. On lithological ground, this formation is divisible into 5 members.

Lakadong Limestone Member — It is made up of grey, fossiliferous limestones and conformably overlies the sandstone of Therria Formation.

Lakadong Sandstone Member — It consists of fine to coarse grained, brown-grey sandstone. This sandstone is very much similar with the sandstone of the Therria Formation. Near 111 km, a 1.10 m thick coal seam, overlain and underlain by sandstone was observed within this member.

Umlatodoh Limestone Member — It includes hard, compact, grey and brown, fossiliferous, limestone with thin sandstone bands.

Narpuh Sandstone Member — It consists of pinkish-white, grey and black, medium to coarse grained, sandstone with calcareous bands.

Prang Limestone Member — This is the youngest member of Sylhet Limestone and consists of grey fossiliferous limestone.

Nature of Contact — The uppermost member of Sylhet Limestone, i.e. Prang Limestone Member, is overlain by the Kopili Formation at 128.5 km. This contact is conformable.

Fossil Contents — A rich foraminiferal assemblage is recorded in the limestone beds of this formation including *Nummulites* spp., *Alveolina* sp., *Lockhartia* sp., *Ranikothalia* sp., *Discocyclina* sp., *Assilina* sp., etc.

Plant megafossils from this formation are not known. During the present field excursion the authors collected a large number of rock samples from this formation for palynological investigation. The analysis of these samples has proved the presence of a palynoflora.

Kopili Formation

Kopili Formation is the youngest stratigraphic unit of the Jaintia Group. The exposures of this formation were observed between 128.5 km and 140 km.

Lithology — This formation is made up of grey, fine to very fine grained, massive to laminated, compact, sandstone alternating with shales. Lenticular bands of limestones and calcareous splintery shales occur at the base of this formation. The shale presents ellipsoidal laminated, concretionary structures. These structures do not disturb the original bedding and therefore appear to be post-depositional.

Nature of Contact — On its upper limit, this formation is conformably overlain by the arenaceous Laisong Formation of Barail Group. This contact, exposed near Sonapur (140 km), is gradational. The criteria for distinguishing the Laisong Formation from the underlying Kopili Formation are: (i) the sandstone in Laisong Formation is coarser and thicker than that of Kopili Formation; and (ii) the amount of shale is much less in Laisong Formation while in Kopili Formation shale occurs almost as well in amount as sandstone.

Fossil Contents — This formation is devoid of animal and plant megafossils. Sein and Sah 1974) reported the occurrence of 20 spore-pollen species from this formation. Of these, pteridophytic spores (63%) show dominance over angiospermous pollen (37%). Many more species of spores-pollen have been recorded by the present authors.

BARAIL GROUP

The geosynclinal facies in the section begins with the Barail Group south of the Dauki Tear Fault. The nearest exposures of the Eocene Disang Group of geosynclinal facies are 3 km from the road and, therefore, they could not be studied. The Barail Group is represented by Laisong, Jenam and Renji formations. The rocks of this group are very thick and steeply dipping and are exposed in road cutting between 140 and 147.5 km.

Laisong Formation

The Laisong Formation constitutes the lower, mainly arenaceous, part of Barail Group and is exposed between 140 to 143.2 km. The rocks are steeply dipping to almost vertical.

Lithology — The formation is made up of grey, very hard, thinly bedded, very fine to medium grained, sandstone alternating with subordinate hard, sandy shale and intraformational conglomerate. Massive and moderately thick-bedded sandstones are also common. The shales are generally carbonaceous.

Nature of Contact — The upper contact of Laisong Formation with the overlying, mainly argillaceous, Jenam Formation is conformable. This contact is exposed at 143.2 km, where thick shales were observed overlying the sandstone.

Fossil Contents — Megafossils — animals or plants — are not found in this formation in the present area. Sein and Sah (1974) recorded the occurrence of 10 spore-pollen species from the entire sequence of Barail Group. However, they did not give the assemblages of the different formations of Barail Group separately. We have also recovered a very rich palynoflora from this formation.

JENAM FORMATION

It constitutes the middle part of the Barail Group and is exposed between 143.2 and 145.6 km. The formation is conspicuous being argillaceous between arenaceous underlying Laisong and overlying Renji formations. The shale beds of this formation are thick and steeply bedded.

Lithology — The formation is mainly argillaceous and is made up of shales and sandy shales with fine to medium grained, massive to flaggy sandstones. The shale is generally carbonaceous and leached with iron. The proportion of shale is much more than that in Laisong Formation while sandstone beds similar to those in Laisong are thinly bedded. Streaks of coal occur along the base of a few sandstone bands.

Nature of Contact — The Jenam Formation passes up into the Renji Formation near 145.6 km. This contact is also conformable. The contact was marked where thickly bedded or massive, ferruginous sandstone of Renji Formation first appears.

Fossil Contents — During field work, no plant or animal megafossil could be observed in this formation. A palynoflora from this formation has been recovered by us.

RENJI FORMATION

The Renji Formation forms the upper, mainly arenaceous part of the Barail Group and is exposed between 145.6 and 147.5 km. It shows steep dips ranging between 56 to 87 degrees in south-west direction.

Lithology — This formation is characterized by thickly bedded or massive, fine to medium grained, hard, ferruginous, occasionally cross-bedded, sandstone with alternation of thin shales. The shale is mostly carbonaceous.

Nature of Contact — On its upper limit, the Renji Formation is unconformably overlain by the Bhuban Formation of Surma Group. This contact was marked near 147.5 km, between Sonapur and Umkiang.

Fossil Contents — No plant or animal megafossil could be traced in this formation. However, the palynofloral studies on this formation, being carried out by the authors, have proved these sediments rich in palynofossils.

SURMA GROUP

Near 147.5 km, the Renji Formation, the upper part of Barail Group, is overlain by the Bhuban Formation of Surma Group. The Surma Group appears at 147.5 km and continues up to 180 km. This group is divisible into two formations.

BHUBAN FORMATION

This formation constitutes the lower part of the Surma Group. It is, in general, mainly arenaceous except in the middle part where it is made up of thick shales. This formation is continuously exposed between 147.5 and 177.5 km. The rocks of this formation exhibit steep southerly dips.

Lithology — The formation consists of hard, very fine to medium grained, sandstone alternating with shales. The middle part of the formation is more argillaceous. On lithological grounds, Saxena (1981) divided it into following 3 members.

Lubha Member — It is made up of thin to fairly thick beds of fine to very fine grained, fawn, grey or brown sandstone with subordinate shales. The shales are at places carbonaceous. This member is continuously exposed between 147.5 and 151.1 km.

Umkiang Member — It is made up of thick shale beds with brown, fine to medium and occasionally coarse grained, thinly bedded, lenticular sandstones and a few thin intraformational conglomerates.

Umkiang Member is continuously exposed between 151.1 and 155 km.

Dona Member — It consists of grey and brown, very fine to medium grained, often argillaceous, fairly hard, sandstone, alternating with thin, sandy and carbonaceous shales and is excellently exposed between 155 and 177.5 km.

Nature of Contact — The Bhuban Formation passes into argillaceous Bokabil Formation near 177.5 km. This contact is conformable.

Fossil Contents — No megafossil could be recovered from this formation of the present section. Study on palynoflora from these sediments is being done by the authors.

BOKABIL FORMATION

This formation constitutes the upper part of Surma Group. In contrast to the underlying Bhuban Formation and overlying Tipam Sandstone, this formation is mainly an argillaceous one. The formation is poorly exposed between 177.5 and 180 km.

Lithology — This formation is made up of thick sandy shales with alternations of very fine grained laminated sandstone. Coarse sandstone is occasional. Alternating laminae are at times very thin. Coarse ferruginous sandstone reported elsewhere from this formation was not observed in the section.

Nature of Contact — The Bokabil Formation is overlain by Tipam Sandstone. The contact between the two seems to be conformable and can be observed near 180 km.

Fossil Contents — The fossils from this formation of the present section are not known. Fresh samples collected from these sediments by the authors have proved to be rich in palynoflora.

TIPAM GROUP

Near 180 km the Tipam Group overlies the Surma Group and continues to be poorly exposed up to 182 km where Recent alluvia covers it. The Tipam Group is divisible into 3 formations: (i) Tipam Sandstone, (ii) Girujan Clay, and (iii) Dupi Tila Formation. In the present section only Tipam Sandstone is exposed.

TIPAM SANDSTONE

The Tipam Sandstone constitutes the lower part of the group. Poorly exposed sediments of this formation were observed between 180 and 182 km.

Lithology — Tipam Sandstone consists of brown, medium to fairly coarse, occasionally gritty, ferruginous, sandstone with numerous thin partings of shale and occasionally of moderately thick shale and sandy shale. Thin bands and streaks of lignitic coal also occur in this formation.

Nature of Contact — The upper part is covered by Recent alluvia near 182 km and, therefore, the nature of the upper contact could not be studied.

Fossil Contents — Although elsewhere, the Tipam Sandstone is reported to yield a good amount of fossil woods, but in the present section not a single fossil specimen could be recovered. The formation is devoid of animal fossils too.

It has already been stated that the upper part of the Tipam Sandstone is not exposed along the road. The other formations of the Tipam Group, viz., Girujan Clay and Dupi Tila, being covered by Recent alluvia, could not be observed.

RECENT

The Tipam Sandstone is directly overlain by Recent alluvia near 182 km, which continues up to 194 km, where the Bhuban Formation is again exposed.

Lithology — The Recent deposits consist of alluvia mainly deposited by Barak River. It includes sandy soil, kankars and occasional pebble beds.

Organic Matter — The alluvia contain Recent organic remains, like root, stem and leaves of plants, smaller invertebrates and bones of vertebrates.

CONCLUSIONS

The preliminary observations, made on the Tertiary sediments exposed along Jowai-Badarpur Road Section, lead to conclude the following:

1. The shelf (Palaeocene-Eocene) and geosynclinal (Post-Eocene) sediments are separated by Dauki Tear Fault. This fault crosses the section at Sonapur and is responsible for bringing out the sediments

of shelf and geosynclinal facies in juxtaposition without any transitional zone.

2. The Therria Formation shows low rolling dips towards south-east and consists of many coal seams ranging in thickness from few centimetres to as thick as 1·30 m. It indicates that these sediments were deposited under shallow water coastal environment which was receiving sufficient vegetable matter for the formation of coal seams. The palynoflora recovered from these sediments also supports this contention.

3. The Sylhet Limestone consists alternate limestone and sandstone beds (the limestone being thicker and more dominant). It seems to represent the calcareous shelf facies being deposited in a transgressive phase. The presence of foraminifera and hystrichosphaerids (authors' unpublished data) are the supporting evidences.

4. The Kopili Formation is made up of typical sandstone and shale alternations and for this reason it is sometimes referred as 'Kopili Alternation Stage'. These beds frequently contain ellipsoidal structures, as long as 1 m. Since these structures do not disturb the original bedding, they may be inferred to be post-depositional.

5. Barail and Surma groups represent the geosynclinal facies, being much thicker than the shelf sediments and show steep dip southwards.

6. The Tipam Group is represented only by Tipam Sandstone while other formations of this group are probably covered by Recent alluvia. Tipam Sandstone is poorly exposed and consists of ferruginous, friable sandstones indicating a regressive phase of depositional environment and a dry climate.

7. The Dauki Tear Fault is the main structural feature in the present area. It produced a smash zone, mainly north of the fault, and effecting Kopili Formation, making them difficult to distinguish from overlying Barail Group of geosynclinal facies. While traversing along the road, a few minor faults were also observed but they were local and did not disturb much the stratigraphical setting of the area.

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FOSSIL DICOTYLEDONOUS WOODS FROM THE TERTIARY OF BLUE NILE VALLEY, ETHIOPIA

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ABSTRACT

Six species belonging to five dicotyledonous families have been described here from a collection of petrified woods made from the Tertiary (Mio-Pliocene) pyroclastic deposits of the basalt on the southern side of Canon in Blue Nile Valley. They are *Mammeoxylon lanneoides* Lemoigne emend. of Guttiferae, *Cassinium ethiopicum* sp. nov. of Leguminosae, *Sapotoxylon multiporosum* sp. nov. of Sapotaceae, *Stereospermoxylon eoacuminatissimum* gen. et sp. nov., *S. grambasti* sp. nov. of Bignoniaceae and *Vitexoxylon africanum* sp. nov. of Verbenaceae.

Key-words—Xylotomy, Dicotyledonous fossil woods, Blue Nile Valley, Mio-Pliocene, Ethiopia.

सारांश

इथोपिया में ब्लू नाइल घाटी के तृतीयक युग से द्विबीजपत्री काष्ठाश्म – उत्तम प्रकाश, नीलाम्बर अवस्थी एवं
वाई० लेमॉयने

ब्लू नाइल घाटी में कैनन के दक्षिणी भाग से तृतीयक युगीन (मध्यनूतन-अतिनूतन) बासाल्ट के ज्वालाश्मी निक्षेपों से एकत्रित अश्मीभूत काष्ठों के एक संग्रह से पाँच द्विबीजपत्री कुलों की छः जातियों का वर्णन किया गया है। ये गट्टीफ़ेरी की मेमिआक्सीलॉन् लेनिआयडिस लेमॉयने संशोधित, लेगुमिनोसी की केसीनियम् इथियोपिकम् नव जाति, सेपोटेसी की सेपोटॉक्सीलॉन् मल्टीपोरोसम् नव जाति, बिग्नोनिएसी की स्टीरियोस्पर्मोक्सीलॉन् इओ-एक्यूमिनेटिसिमम् नव प्रजाति व नव जाति, स्टी० ग्रामबस्टाई नव जाति तथा वर्बीनेसी कुल की वाइटेक्सोक्सीलॉन् अफ्रीकेनम् नव जाति है।

INTRODUCTION

A FEW years ago, one of us (Y. Lemoigne) made a large collection of fossil angiopsermic woods from the pyroclastic deposits of the basalt on the southern side of Canon between the village Goha-Tsion and the bridge over the Blue Nile River in Ethiopia. This locality is about 200 km north-west of Addis-Abéba along the road to Debré-Marcos in the province of Shoa (Map 1). The stratigraphical sequence (Text-fig. 1) of the rocks seen in a section of the Canon overlooking the bridge on the Blue Nile River is described below:

11 — Basalt and pyroclastic deposits - - - - 250 m.
  a — Prismatic basalt - - - - 70 m.
  b — Pyroclastic deposits: Yellow ashes with angiospermic fossil woods - - - - 35 m.
  c — Vesiculous basalt, with pyroclastic intercalations containing angiosperm fossil woods and leaf-impressions - - - - 140 m.
10 — Sandstones and shales (Upper Sandstone Formation) - - - - 15 m.
  a — Yellow sandstones.
  b — Red and green shales.
9 — Limestone and marls (Antalo Formation) - - - - 300-350 m.

TEXT-FIG. 1 — Map of Ethiopia showing the location of Goha-Tsion Village and the nearby Blue Nile River.

a — Recifal limestones - - - - 20 m.
b — Alternating limestone and grey marl beds - - - 120 m.
c — Calcareous marls - - - - 80 m.
d — Marls and yellow and red shales with interbedded calcareous sandstones - - - - 100 m.

8 — Shales with interbedded sandstones and gypsum beds in the lower part - - - - 190 m.

7 — Brown gypsum with intercalation of dolomitic limestone beds in the upper part, and of marl or sandstone beds in the lower part - - - - 220 m.

6 — Variegated shales and sandstones - - - - - - - - 100 m.
a — Red and green shales containing crystals of gypsum.
b — Red and pink sandstone beds.
c — Green shales.
d — Shale and sandstone beds.

5 — Fine-grained sandstones (siltstone) - - - - 40 m (upper part of Oldigrat Sandstone Formation).

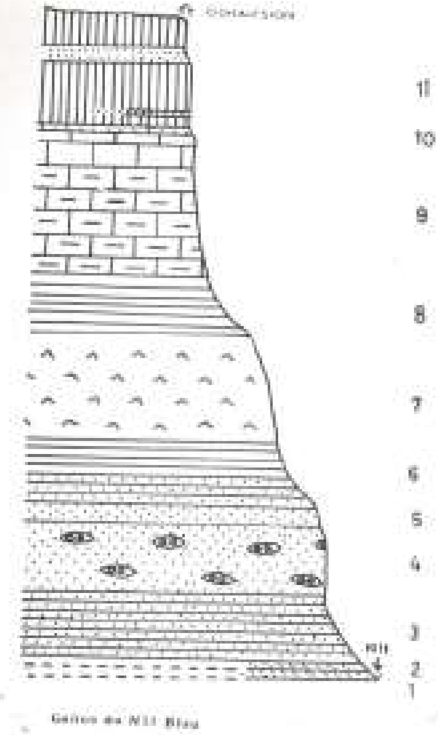
4 — Sandstones and conglomerates (middle part of Oldigrat Sandstone Formation). Red or pink sandstones often with cross beddings; silicified woods in conglomerates showing Araucarian structure - - - - 150 m.

3 — Sandstones and shales - - - - 120 m.

2 — White sandstone (with plant impressions) - - - - more than 40 m.

1 — Precambrian rocks (not visible near the bridge, but visible near the confluence between Mugher and Blue Nile).

The volcanic deposits (Bed no. 11), which represent the upper part of the Blue Nile rock sequence, contain the angiospermic leaf-impressions and silicified woods. The leaf-impressions are confined to the lower part of this deposit and are preserved in the pyroclastic intercalations, while fossil woods occur abundantly in different pyroclastic beds of the basalt (Bed nos. 11 b & c). Although more than 200 specimens of fossil woods were collected, only a few



TEXT-FIG. 2 — A section of the Canon near the bridge on the Blue Nile River.

are well-preserved and could be worked out. The ones included in this paper show resemblance with the modern woods of *Mammea* of Guttiferae, *Cassia* of Leguminosae, *Stereospermum, Kigelia* and *Markhamia* of Bignoniaceae, *Vitex* of Verbenaceae and those of the family Sapotaceae. These are described here as *Mammeoxylon lanneoides* Lemoigne (1978), *Cassinium ethiopicum* sp. nov., *Sapotoxylon multiporosum* sp. nov., *Stereospermoxylon coacuminatissimum* gen. et sp. nov., *S. grambasti* sp. nov. and *Vitexoxylon africanum* sp. nov.

Although a rich assemblage of plants has recently been worked out from the Tertiary volcanic deposits of Welkite (Lemoigne & Beauchamp, 1972), Dire Dawa (Beauchamp & Lemoigne, 1973), Debre-Libanos (Beauchamp, Lemoigne & Petrescu, 1973), Mush Valley, Molale, Debre-Sina, and Wendo (Lemoigne, Beauchamp & Samuel, 1974) and Omo Valley (Dechamps, 1976; Lemoigne, 1978), the present study on the fossil woods of Blue Nile Valley forms the first record of the Tertiary plant remains from this region of Ethiopia. The age of the pyroclastic deposits embedding the petrified woods is most porbably Mio-Pliocene as is also evident from the close resemblance of fossil forms with those of the living taxa.

SYSTEMATIC DESCRIPTION

FAMILY — GUTTIFERAE

Genus — *Mammeoxylon* Lemoigne, 1978 emend.

1. *Mammeoxylon lanneoides* Lemoigne, 1978

Pl. 1, figs 1, 3, 5, 6

In 1978, Lemoigne described *Mammeoxylon lanneoides* from the Tertiary of Omo Basin in Ethiopia showing its affinity with the extant genus *Mammea* of the family Guttiferae. In the present collection of woods we found another wood which shows closest resemblance with *Mammea*, especially with an African species, *M. africana*. From its detailed anatomical features it is apparent that our specimen belongs to *Mammeoxylon lanneoides*, although there is no mention about the presence of vasicentric tracheids and bordered pits in the fibres of fossil wood described by Lemoigne (1978) which are characteristics of *Mammea*. Besides, the gum canals have not been illustrated by its author. Therefore, it is deemed necessary to give here a well-illustrated account and emended diagnosis of *Mammeoxylon lanneoides* based on the present specimen.

Topography — *Wood* diffuse-porous. *Growth rings* indistinct. *Vessels* exclusively solitary, medium to large, showing slight tendency towards oblique arrangement along radial lines (Pl. 1, fig. 1), about 6-15 vessels per sq mm; tyloses present. *Vasicentric tracheids* present, intermingled with paratracheal parenchyma. *Parenchyma* paratracheal and apotracheal (Pl. 1, fig. 1); paratracheal parenchyma scanty, only a few cells associated with the vessels, occasionally forming incomplete sheath round the vessels, intermingled with vasicentric tracheids; apotracheal parenchyma diffuse to diffuse-in-aggregate (Pl. 1, fig. 1), occasionally forming short, uniseriate lines. *Xylem rays* fine, 1-3 (mostly 1-2) seriate, those containing horizontal gum canals 4-5 seriate (Pl. 1, fig. 3), about 4-42 cells in height and 6-12 per mm; ray tissue heterogeneous; uniseriate rays quite frequent, mostly composed wholly of upright cells; biseriate and triseriate rays heterocellular, consisting of one to several marginal rows of upright cells at both the ends and procumbent cells through the median portion (Pl. 1, figs 3, 5); end to end ray fusion often seen. *Tracheids* aligned in radial rows between the two consecutive xylem rays. *Gum canals* horizontal, occurring in broader rays (Pl. 1, fig. 3).

Elements — *Vessels* circular to oval (Pl. 1, fig. 1), t.d. 105-280 μm, r.d. 105-300 μm, walls 8-12 μm thick; perforations simple, nearly horizontal to oblique; vessel members up to 400 μm in length. *Vasicentric tracheids* 16-34 μm in diameter, length almost same as of fibres; pits arranged in two rows, 2-4 μm in diameter, with circular or slit-like orifices. *Parenchyma cells* circular to tangentially elongated, 24-52 μm in diameter. *Ray cells* both upright and procumbent; upright cells (Pl. 1, fig. 5), 40-120 μm in tangential height and 28-60 μm in radial length; procumbent cells 16-32 μm in tangential height and 40-160 μm in radial length. *Fibre-tracheids* thick-walled, angular, mostly hexagonal, 12-32 μm in diameter, nonseptate; pits bordered (Pl. 1, fig. 6), about 2-4 μm in diameter, with slit-like orifices. *Gum canals* oval (Pl. 1, fig. 3), 80-240 μm in diameter.

The genus *Mammea* is distributed in the tropical regions of the world. One species is found in tropical America, West Indies; one in Africa, 20 in Madagascar, and 27 species in Indo-Malayan and Pacific regions (Willis, 1973, p. 709). *Mammea africana* Sabine, the nearest modern equivalent of the present fossil, is found in tropical Africa, in Sierra Leone, Angola and Belgian Congo.

EMENDED GENERIC DIAGNOSIS

Mammeoxylon Lemoigne, 1978 emend.

Wood diffuse porous. *Growth rings* indistinct. *Vessels* small to large, exclusively solitary, showing slight tendency towards oblique arrangement in radial lines, tylosed; perforations simple, plates nearly horizontal to oblique. *Vasicentric tracheids* forming sheath around the vessels; pits bordered, arranged in vertical rows. *Parenchyma* mostly apotracheal, diffuse or diffuse-in-aggregate, sometimes forming short uniseriate lines, occasionally paratracheal, intermingled with vasicentric tracheids. *Xylem rays* 1-5 seriate, broader rays with horizontal gum canals; ray tissue heterogeneous. *Fibre-tracheids* angular or hexagonal, thick-walled, nonseptate; pits bordered. *Gum canals* horizontal, occurring in multiseriate rays.

EMENDED SPECIFIC DIAGNOSIS

Mammeoxylon lanneoides Lemoigne, 1978

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* medium to large, exclusively solitary, rarely tending to arrange in oblique radial lines, t.d. 105-280 μm, r.d. 105-300 μm, 6-15 vessels per sq mm; tyloses present; perforations simple, nearly horizontal to oblique. *Vasicentric tracheids* forming a sheath of 1-2 cells around the vessels; pits leading to vessels bordered, arranged in vertical rows, 2-4 μm in diameter with slit-like orifices. *Parenchyma* apotracheal, diffuse or diffuse-in-aggregate, occasionally forming uniseriate lines, 9-12 lines per mm; paratracheal parenchyma occasionally present, intermingled with vasicentric tracheids. *Xylem rays* 1-3 (mostly 1-2) seriate, those containing horizontal gum canals 4-5 seriate, 4-42 cells in height; ray tissue heterogeneous; uniseriate rays frequent, mostly homocellular, composed wholly of upright cells; multiseriate rays heterocellular, consisting of one to several marginal rows of upright cells and rest procumbent cells. *Fibre tracheids* angular or hexagonal, thick-walled, nonseptate; pits bordered, 2-4 μm in diameter with slit-like orifices. *Gum canals* horizontal, occurring in broader rays, oval, 80-240 μm in diameter.

Specimen — NB6/2, Palaeobotany Laboratory, Lyon University, France.

FAMILY — LEGUMINOSAE

Genus — *Cassinium* Prakash, 1975

2. *Cassinium ethiopicum* sp. nov.

Pl. 1, figs 7-9; Pl. 2, fig. 10

Topography — *Wood* diffuse-porous. *Growth rings* not seen. *Vessels* small to medium-sized, solitary and in radial multiples of 2-5 (mostly 2-3), evenly distributed (Pl. 1, fig. 7), about 15-30 vessels per sq mm; tyloses absent. *Parenchyma* paratracheal, banded, bands regular and somewhat wavy, completely enclosing the vessels, sometimes anastomosing or bifurcating and joining with those of adjacent vessels (Pl. 1, fig. 7), 3-6 (mostly 3-4) seriate, about 4-6 bands per mm. *Xylem rays* 1-4 seriate (Pl. 1, fig. 8), 5-27 cells in height and 7-12 per mm; ray tissue homogeneous, rays homocellular, consisting of procumbent cells (Pl. 1, fig. 9). *Fibres* aligned nearly in radial lines between the two consecutive rays.

Elements — *Vessels* circular or oval (Pl. 1, fig. 7), those of radial multiples slightly flattened at places of contact, t.d. 30-160 μm, r.d. 25-155 μm, walls 6-10 μm; perforations simple, nearly horizontal to oblique; vessel members 100-375 μm in length; intervessel pits medium to large, 6-10 μm in diameter, alternate, bordered, vestured, with lenticular apertures (Pl. 2, fig. 10); vessel-parenchyma and vessel-ray pits slightly bigger than intervessel pits. *Parenchyma cells* circular, 20-40 μm in diameter; crystalliferous strands abundant, divided into several locules containing solitary crystals. *Ray cells* procumbent, 12-20 μm in tangential height, 24-100 μm in radial length. *Fibres* semi-libriform, thick-walled, nonseptate, nearly circular, 8-20 μm in diameter.

Affinities — The most important features of the fossil wood are: vessels small to mostly medium, solitary and in radial multiples, intervessel pits vestured; parenchyma paratracheal, banded; rays 1-4 seriate, homocellular and fibres nonseptate. These features collectively show its resemblance with the modern woods of *Cynometra* and *Cassia* of the family Leguminosae. However, considering all other anatomical details *Cynometra* can be differentiated from it. One of the important differences is that in *Cynometra* the xylem rays are heterocellular, consisting of 1-2 marginal rows of upright cells, whereas in the present fossil the xylem rays are homocellular consisting only of procumbent cells.

Detailed comparative study of the fossil was made with the thin sections of a number of species of *Cassia*, viz., *Cassia alata* L., *C. aubrevillei* Pellegr., *C. auriculata* L., *C. fistula* L., *C. grandis* L., *C. javanica* L., *C. laevigata* Willd., *C. marginata* Roxb., *C. montana* Heyne, *C. nodosa* Buch-Ham. ex Roxb., *C. siamea* Lam. and *S. timoriensis* D. C. Besides examining the thin sections, it was also compared with the published description and figures of a few other species of *Cassia*. Of these, *Cassia aubrevillei* shows similarity with our fossil. However, the present fossil slightly differs from it in having comparatively thinner parenchyma bands and smaller vessels.

Fossil woods resembling the modern woods of *Cassia* are placed under the genus *Cassinium* Prakash (1975). So far six species of *Cassinium* are known from the Neogene rocks of India (see Awasthi, 1979, p. 160). Of these, *Cassinium borooahii* (Prakash) Prakash (= *Cassioxylon borooahii* Prakash, 1966) shows gross resemblance with the present fossil particularly in having banded parenchyma. However, there are some significant differences in their anatomical features which differentiate them from one another. In *Cassinium borooahii* the vessels are medium to large (t.d. 150-320 μm; r.d. 180-405 μm) and 2-4 per sq mm, and the parenchyma bands are relatively broader, i.e. more than 4-8 cells in width, whereas in the present fossil the vessels are small to medium-sized (t.d. 30-160 μm; r.d. 25-155 μm) and about 15-30 per sq mm, and the parenchyma bands are about 3-6 (mostly 3-4) cells in width.

In view of its closest similarity with the woods of *Cassia*, the present fossil is placed under the genus *Cassinium* Prakash. Since it is different from all the species of *Cassinium*, it is named as *Cassinium ethiopicum* sp. nov.

The genus *Cassia* consists of 500-600 species distributed in tropical and warm temperate regions excluding Europe (Willis, 1973, p. 211). About 26 species are found in tropical Africa. *Cassia aubrevillei* Pellegr., with which the present fossil shows closest resemblance, grows in patches in the dense forests of Ivory Coast and Central Congo (Normand, 1950, p. 125).

Specific Diagnosis

Cassinium ethiopicum sp. nov.

Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to medium, solitary and in radial multiples of 2-5 (mostly 2-3), about 15-30 vessels per sq mm.; vessel-members about 100-375 μm in height; intervessel pits medium to large, 6-10 μm in diameter, vestured, alternate with lenticular apertures. *Parenchyma* paratracheal, banded, bands regular and somewhat wavy, seldom bifurcating and joining with those of adjacent vessels, 3-6 (mostly 3-4) seriate, about 4-6 bands per mm; parenchyma strands crystalliferous. *Xylem rays* 1-4 seriate, about 4-27 cells in height, 7-12 per mm; ray tissue homogeneous, rays homocellular, consisting of procumbent cells. *Fibres* semilibriform, thick-walled, nonseptate, small, about 8-20 μm in diameter.

Holotype — NB5, Palaeobotany Laboratory, Lyon University, France.

FAMILY — SAPOTACEAE

Genus — *Sapotoxylon* Felix, 1882

3. *Sapotoxylon multiporosum* sp. nov.

Pl. 2, figs 11-15

Topography — *Wood* diffuse-porous. *Growth rings* not clearly seen. *Vessels* small to medium-sized, mostly small, solitary and mostly in radial multiples of 2-10, occasionally up to 18, exhibiting short chain-like structures, characteristically grouped together in oblique radial lines (Pl. 2, figs 12, 13) forming zig zag flame-like pattern, about 60-120 vessels per sq mm; tyloses present, thick-walled, vessels also filled with whitish crystalliferous contents. *Vasicentric tracheids* occurring in the immediate vicinity of vessels and vessel groups (Pl. 2, fig. 13). *Parenchyma* paratracheal and apotracheal, the former scanty, only a few cells associated with the vessels, intermingled with vasicentric tracheids, while the latter forming more or less loose, wavy as well as straight, regular lines, 1-3 (mostly 1-2) seriate in width (Pl. 2, fig. 13), about 8-12 lines per mm. *Xylem rays* fine, 1-2 seriate (Pl. 2, fig. 14), 7-45 cells in height and 18-22 rays per mm; ray tissue heterogeneous, rays heterocellular, consisting of procumbent cells through the median portion and one-several uniseriate marginal rows of upright cells at both the ends (Pl. 2, figs 14, 15). *Fibres* aligned in radial rows between two consecutive rays.

Elements — *Vessels* circular to oval, those in multiples flattened at places of contact, t.d. 48-100 μm, r.d. 32-120 μm; perforations simple; vessel members truncate or attenuately tailed, usually short, 60-440 μm in length; intervessel pits small to medium, 4-6 μm in diameter, crowded, alternate with small, circular apertures (Pl. 2, fig. 11); pits leading to contiguous vasicentric tracheids almost similar to intervessel pits; pit leading to ray cells slightly bigger than intervessel pits. *Vasicentric tracheids* slightly bigger than fibres, usually with 2 rows of bordered pits. *Parenchyma cells* angular or rounded in cross section, 20-28 μm in diameter, infiltration dark. *Ray cells* upright and procumbent; upright cells 64-100 μm in tangential height, 24-40 μm in radial length; procumbent cells 8-24 μm in tangential height, 40-160 μm in radial length. *Fibres* libriform, thick-walled, nonseptate, angular in cross section, small with narrow constricted lumen, about 8-12 μm in diameter; pits not seen.

Affinities — The above features of the fossil clearly show that it is a sapotaceous wood. The family Sapotaceae, on the whole, is quite homogeneous in wood structure. There is hardly any characteristic feature in the woods which can be of diagnostic value in the generic distinction. However, they can be distinguished only in certain cases when all the characters of the woods are taken into consideration collectively. After examining the available thin sections of modern woods as well as published description and illustrations of quite a number of woods of this family (Desch, 1954, pp. 538-558; Kribs, 1959, pp. 146-151, figs 309-314, 458-464; Lecomte, 1926, pls 63-64; Metcalfe & Chalk, 1950, pp. 875-877, fig. 201; Moll & Janssonius, 1920, pp. 353-412, figs 259-262; Normand, 1960, pp. 305-320, pls 131-142; Pearson & Brown, 1932, pp. 663-688, figs 217-225), it was found that the fossil shows general resemblance with some species of *Mimusops*, *Manilkara*, *Payena*, *Bequaertiodendron* (= *Neoboivinella*) and *Pachystela*.

Manilkara and *Mimusops* exhibit some significant variations with regard to the size and arrangement of the vessels, the type of parenchyma and rays. The size of vessels varies from small to large, arranged in loose to compact groups along oblique radial lines; the parenchyma lines are 1-3 seriate, close or slightly widely spaced; the rays are 1-2 or up to 4-seriate. In the present fossil the vessels are mostly small, with majority of vessels being less than 100 µm in diameter, arranged in groups as well as along oblique radial lines; the parenchyma lines are 1-3 seriate and closely spaced, and the rays are only 1-2 seriate. From this it is evident that the possibility of being either *Manilkara* or *Mimusops* as its modern equivalent can not be ruled out. In the nature and distribution of vessels and parenchyma and in the width of rays, it is also somewhat similar to those of *Payena*. However, the vessels in *Payena* are slightly bigger than those of the fossil. In the type and distribution of vessels and parenchyma, the fossil also shows resemblance with *Bequartiodendron glomeruliflora* Aubr. (= *Neoboivinella glomeruliflora* Aubr.) and *Pachystela brevipes* Baill. (Normand, 1960, p. 309, pls 136, 137). However, the former differs from the fossil in having slightly smaller vessels (i.e. the diameter being less than 100 µm), while the latter differs in having rays up to 4-seriate. Since the fossil exhibits all the anatomical characters of the family Sapotaceae, it is assigned to the genus *Sapotoxylon* Felix (1882).

So far eight species of fossil woods of the family Sapotaceae are known. These are *Sapotoxylon taeniatum* (Felix, 1882) from Bavaria in south-east Germany, *Manilkaroxylon diluviale* (Hofmann, 1948) from the Quaternary deposits of South America, *Manilkaroxylon crystallophora* and *Palaeosideroxylon flammula* (Grambast-Fessard, 1968) from the Upper Miocene of Castellane in south-east France, *Siderinium deomaliense* Prakash & Awasthi (1970) from the Mio-Pliocene of Deomali, Arunachal Pradesh, *Manilkaroxylon bohemicum* and *Sapotoxylon pacltovae* (Prakash, Brezinova & Awasthi, 1974) from the Tertiary of South Bohemia, Czechoslovaka, *Chrysophylloxylon indicum* Awasthi (1977) from the Mio-Pliocene beds, near Pondicherry, India and *Madhucoxylon cacharense* Prakash & Tripathi (1977) from the Tipam Series, near Hailakandi, Assam. All these species are quite different from the present fossil wood.

In *Sapotoxylon taeniatum* the vessels are slightly bigger (diameter 180 µm), rays 2-3 seriate and parenchyma lines 3-celled or even broader. The vessels in *Palaeosideroxylon flammula* are very much crowded and grouped forming dendritic pattern, and the parenchyma lines are 2-3 seriate and widely spaced. In *Manilkara crystallophora* the rays are 1-4 seriate with swollen and crystalliferous upright cells, and the vessels are arranged in distinct radial lines without forming zig-zag or flame-like pattern. Similarly, in *Siderinium deomaliense* and *Madhucoxylon cacharense*, the vessels are in radial lines without forming zig-zag pattern and the parenchyma is diffuse or in uniseriate lines. In *Manilkaroxylon bohemicum* the vessels are mostly large (t.d. 50-290 µm, r.d. 50-310 µm) and the rays are 1-3 seriate. The frequency of the vessels in *Sapotoxylon pacltovae* is very less (2-4 vessels per sq mm) and their size ranges between 75 to 200 µm in diameter, and the apotracheal parenchyma lines are uniseriate only. In *Chrysophylloxylon indicum* the vessels are large and the xylem rays are 1-4 seriate, whereas in the present Ethiopian fossil wood the vessels are mostly smaller (t.d. 48-100 µm, r.d. 32-120 µm), arranged in long radial multiples forming zig-zag pattern, the xylem rays are 1-2 seriate and the parenchyma is scanty paratracheal and in regular lines of 1-3 (mostly 1-2) cells in width. Thus it is seen that the present fossil is quite different from all the above species. It is, therefore, described as a new species of *Sapotoxylon* Felix, *Sapotoxylon multiporosum* sp. nov.

SPECIFIC DIAGNOSIS

Sapotoxylon multiporosum sp. nov.

Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to medium, mostly small, t.d. 48-100 µm, r.d. 32-120 µm, solitary and mostly in radial multiples of 2-10, occasionally up to 18, characteristically grouped in oblique radial lines, 60-120 vessels per sq mm; perforations simple; intervessel pits alternate, crowded, small to medium, 4-6 µm in diameter, with circular apertures; tyloses present, thick-walled. *Vasicentric tracheids* few, associated with vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma having only a few cells associated with vessels; apotracheal parenchyma forming 1-3 (mostly 1-2) seriate, almost regular, straight or wavy lines, about 8-12 lines per mm. *Xylem rays* fine, 1-2 seriate, about 7-45 cells in height and 18-22 per mm; ray tissue heterogeneous, rays heterocellular, consisting of procumbent cells through the median portion and one to several marginal rows of upright cells at both the ends. *Fibres* libriform, thick-walled with narrow constricted lumen, non-septate, angular, small, 8-20 μm in diameter.

Holotype — NB9-Palaeobotany Laboratory, Lyon University, France.

FAMILY — BIGNONIACEAE

Genus — *Stereospermoxylon* gen. nov.

4. *Stereospermoxylon eoacuminatissimum* sp. nov.

Pl. 2, figs 16, 17; Pl. 3, figs 18-20

Topography — *Wood* diffuse-porous to semi-ring porous (Pl. 2, fig. 16). *Growth rings* present, delineated by relatively bigger vessels at the beginning of annual rings (Pl. 2, figs 16, 17). *Vessels* medium to large, a few small, those occurring at the beginning of annual rings bigger in size (Pl. 2, figs 16, 17), arranged in a tangential rows and gradually grading into smaller vessels towards the close of rings, solitary and in radial multiples of 2-4 (mostly 3), rarely up to 6, sometimes in double rows, evenly distributed, about 6-10 vessels per sq mm; tyloses not seen. *Parenchyma* paratracheal, vasicentric to aliform and confluent, enclosing vessels and vessel groups laterally and obliquely, or joining with those of neighbouring vessels (Pl. 2, fig. 17); parenchyma encircling bigger vessels of early wood forming undulating lines or narrow confluent bands (Pl. 2, figs 16, 17). *Xylem rays* 1-4 seriate (Pl. 3, fig. 18), about 5-30 cells in height and 5-7 per mm; ray tissue homogeneous, rays homocellular, consisting of procumbent cells (Pl. 3, fig. 19). *Fibres* arranged in radial rows between two consecutive rays.

Elements — *Vessels* circular to oval (Pl. 2, fig. 17), t.d. 50-320 μm, walls 8-12 μm; perforations simple, horizontal to oblique; vessel members short, 60-375 μm in lenght; intervessel pits medium, 6-8 μm in diameter, alternate, bordered with circular to lenticular apertures (Pl. 3, fig. 20); vessel parenchyma and vessel-ray pits slightly bigger than intervessel pits; yellowish infiltration present. *Parenchyma cells* 3-4 per strand, angular, mostly hexagonal, radially elongated in cross section. *Ray cells* procumbent, 16-24 μm in tangential height, 40-180 μm in radial length. *Fibres* semilibriform, thick-walled, small, angular and 8-24 μm in diameter.

Affinities — The important features of the present fossil are: wood diffuse-porous to nearly semi-ring porous; vessels mostly medium to large, solitary as well as in radial multiples; parenchyma paratracheal, aliform to confluent; rays 1-4 seriate, homocellular, composed of procumbent cells and fibres moderately thick-walled and nonseptate. These features obviously suggest its affinities with the modern woods of Bignoniaceae. In the family Bignoniaceae, *Stereospermum*, *Kigelia* and *Markhamia* exhibit almost similar xylotomical features as present in our fossil wood. A number of thin sections of the woods of these genera were examined and the description and figures of *Stereospermum suaveolens* DC., *S. xylocarpum* Benth. et Hook. f. (Pearson & Brown, 1932, pp. 770-780, figs 246-248), *S. fimbriatum* DC. (Desch, 1957, pp. 50, 51, pl. 9, fig. 1), *S. neuranthemum* Kurz (Metcalfe & Chalk, 1950, pp. 1005-1009, fig. 236H), *S. acuminatissimum* K. Schum. *Kigelia africana* Benth. and *Markhamia lutea* K. Schum. (Normand, 1960, pp. 300-354, pls 156, 157) were consulted. Although it is difficult to find out the exact modern equivalent of the present fossil, but considering the nature and distribution of vessels, parenchyma and rays, the fossil appears to be more closer to *Stereospermum*, particularly with an African species — *Stereospermum acuminatissimum*. It has also been found that in most of the cases the woods of some of the species of *Stereospermum*, *Kigelia* and *Markhamia* are so similar that they cannot be differentiated anatomically. Therefore, for naming the fossil woods resembling woods of *Stereospermum*, *Kigelia* and *Markhamia* which cannot be differentiated easily from each other, a new genus *Stereospermoxylon* is created. Since the present fossil shows similarity with those of *Stereospermum*, *Markhamia* and *Kigelia* in general and comes somewhat closer to *Stereospermum acuminatissimum*, it is placed under the genus *Stereospermoxylon* and named as *Stereospermoxylon eoacuminatissimum* sp. nov.

The genus *Stereospermum* Cham. consists of 24 species, distributed in tropical Africa and Asia (Willis, 1973, p. 1103). About 11 species are found in tropical Africa, (Thiselton-Dyer, 1906, pp. 517-570). *Stereospermum acuminatissimum* K. Schum. is found in East Africa, Lagos and Cameroons.

GENERIC DIAGNOSIS

Stereospermoxylon gen. nov.

Wood diffuse-porous to occasionally semi-ring porous. *Growth rings* present, delineated by bigger vessels, parenchyma lines and thick-walled fibres. *Vessels* small to large, solitary as well as in radial multiples; tyloses absent; perforations simple; vessel members short to medium in length; intervessel pits medium to large, bordered, alternate, with lenticular apertures. *Parenchyma* paratracheal, vasicentric, aliform to confluent, extending laterally joining with those of adjacent vessels; lines of parenchyma also present at the growth rings. *Xylem rays* fine to moderately broad, mostly 1-4 seriate; ray tissue homogeneous; rays mostly homocellular, consisting of procumbent cells. *Fibres* semi-libriform, moderately thick-walled, nonseptate.

Genotype — *Stereospermoxylon eoacuminatissimum* sp. nov.

SPECIFIC DIAGNOSIS

Stereospermoxylon eoacuminatissimum sp. nov.

Wood diffuse-porous to semi-ring porous. *Growth rings* present, delineated by bigger vessels at the beginning and grading into smaller vessels at the close of the annual rings, t.d. 50-250 µm, r.d. 50-320 µm, solitary and in radial multiples of 2-4, about 6-10 vessels per sq mm; vessel members short to medium in length; intervessel pits medium to large, about 6-8 µm, alternate, bordered with lenticular apertures. *Parenchyma* paratracheal, aliform to confluent, extending laterally and obliquely joining with those of the adjacent vessels; narrow lines or bands of parenchyma present at the inception of growth rings encircling the bigger vessels. *Xylem rays* 1-4 seriate, up to 50 cells in height, and 5-7 rays per mm; ray tissue homogeneous, rays homocellular, consisting of procumbent cells only. *Fibres* semilibriform, moderately thick-walled, nonseptate, angular, small, 8-24 µm in diameter.

Holotype — NB 11, Palaeobotany Laboratory, Lyon University, France.

5. *Stereospermoxylon grambasti* sp. nov.

Pl. 3, figs 21, 23, 24

Topography — *Wood* diffuse - porous. *Growth rings* present, delineated by slightly bigger vessels, thin apotracheal parenchyma lines which merge with confluent bands and thick-walled fibres (Pl. 3, fig. 24). *Vessels* small to large, solitary and in radial multiples of 2-8 (mostly 2-3), seldom in double rows, sometimes very small and in clusters associated with bigger vessels, evenly distributed, about 10-20 vessels per sq mm; tyloses not seen. *Parenchyma* paratracheal and apotracheal, paratracheal vasicentric, aliform to confluent, extending side ways and joining with those of adjacent vessels, sometimes showing tendency to form somewhat longer, straight, interrupted, tangential, anastomosing bands joining several vessels (Pl. 3, fig. 24); apotracheal parenchyma in fine lines of 2-3 cells wide, occurring at the inception of annual rings merging with aliform confluent lines or bands. *Xylem rays* 3-4 seriate (Pl. 3, fig. 21), 6-40 cells in height and 5-7 rays per mm; ray tissue homogeneous; rays homocellular, consisting of procumbent cells only. *Fibres* aligned in radial rows between two consecutive rays.

Elements — *Vessels* circular to oval (Pl. 3, fig. 24), t.d. and r.d. about 30-3000 µm, mostly 160-250 µm, thin-walled, walls 4-8 µm; perforations simple, nearly horizontal; vessel members short, 90-450 µm in length; intervessel pits small to medium, 6-8 µm in diameter, circular, alternate, bordered with lenticular to circular apertures; vessel-parenchyma and vessel-ray pits almost similar to intervessel pits. *Parenchyma cells* 3-4 per strand, oval to angular and radially elongated in cross section, those occurring in the immediate vicinity of vessels peripherally flattened, 20-48 µm in diameter. *Ray cells* procumbent, 16-24 µm in tangential height and 40-200 µm in radial length.

Fibres nonlibriform to semilibriform, moderately thick-walled, nonseptate, small, circular to angular in cross section and 8-20 µm in diameter.

Affinities — The anatomical characters of this fossil wood indicate its resemblance with *Markhamia lutea* (Normand, 1960, p. 353, pl. 157) and *Stereospermum* spp. in the nature and distribution of vessels, parenchyma and rays. The characteristic features of the fossil, viz., the presence of distinct parenchyma lines and clusters of small vessels often associated with bigger vessels, are also seen in *Markhamia lutea* and a few species of *Stereospermum*. Hence the present fossil is placed in the genus *Stereospermoxylon*.

In spite of a close resemblance between *Stereospermoxylon eoacuminatissimum* and the present fossil specimen, particularly in the nature and distribution of vessels, parenchyma fibres and length and width of rays, there is a marked difference between the two. The former is a distinctly semiring porous while the latter is diffuse-porous. Another difference is that in the latter clusters of small vessels associated with bigger vessels are commonly present which are very rarely seen in the former. Such differences have also been noticed among the various species of *Stereospermum* and other Bignoniaceous woods. In view of this the present fossil wood is named as *Stereospermoxylon grambasti* sp. nov., after the late Professor L. Grambast of the University of Montepellier, France.

SPECIFIC DIAGNOSIS

Stereospermoxylon grambasti sp. nov.

Wood diffuse-porous. *Growth rings* present, delineated by slightly bigger vessels and thin apotracheal parenchyma lines which merge with aliform-confluent bands, and thick-walled fibres. *Vessels* small to large, solitary and in radial multiples of 2-8, mostly 2-3, sometimes in double rows or in small clusters associated with bigger vessels, circular to oval in cross section, t.d. and r.d. 30-300 µm; vessel members short 90-450 µm in length; intervessel pits bordered, alternate, 6-8 µm in diameter with lenticular to circular apertures. *Parenchyma* both paratracheal and apotracheal; paratracheal parenchyma vasicentric, aliform to confluent, extending laterally joining with those of adjacent vessels or vessel groups; apotracheal parenchyma terminal or initial, occurring at the inception of annual rings merging with aliform-confluent lines or bands, about 2-3 cells wide. *Xylem rays* 3-4 seriate and about 6-40 cells in height; ray tissue homogeneous, rays homocellular, consisting of procumbent cells. *Fibres* non-libriform to semilibriform, moderately thick-walled, nonseptate, small, circular or angular and 8-20 µm in diameter.

Holotype — NB12, Palaeobotany Laboratory, Lyon University, France.

FAMILY — VERBENACEAE

Genus — *Vitexoxylon* Ingle emend. Prakash & Tripathi, 1974 — (Syn. *Vitexoxylon* Lemoigne, 1978)

6. *Vitexoxylon africanum* sp. nov.

Pl. 4, figs 26-30

Topography — *Wood* diffuse-porous. *Growth rings* present, delimited by thin lines of apotracheal parenchyma (Pl. 4, figs 26, 28). *Vessels* mostly medium to large, solitary and in radial multiples of 2-5, mostly 2-3 (Pl. 4, figs 26, 27), rarely up to 9, sometimes in double rows, about 5-7 vessels per sq mm; tyloses and whitish infiltration present (Pl. 4, fig. 27). *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric, forming narrow, uniseriate or incomplete sheath around the vessels (Pl. 4, fig. 27); apotracheal parenchyma in narrow 1-2 seriate lines at the beginning of growth rings (Pl. 4, figs 26, 27). *Xylem rays* 1-3 (mostly 2-3) seriate (Pl. 4, fig 29), 6-40 cells in height, about 7-10 rays per mm; ray tissue heterogeneous; rays homocellular to heterocellular (Pl. 4, fig. 30), the former consisting of procumbent cells only while the latter composed of procumbent cells in the middle and 1-2 marginal rows of upright cells at one or both the ends. *Fibres* aligned in radial rows between two consecutive rays.

Elements — *Vessels* circular to oval (Pl. 4, fig. 27), t.d. 120-360 µm, r.d. 60-400 µm, walls 8-10 µm in thickness; perforations simple, nearly horizontal to oblique; vessel members usually short, about 300-600 µm in length, intervessel pits 6-8 µm in diameter, alternate, with lenticular to circular apertures (Pl. 4, fig. 22); vessel-parenchyma and vessel-ray pits slightly bigger than intervessel pits. *Parenchyma cells* circular or angular, those occurring in the immediate vicinity of vessels peripherally flattened, about 24-40 μm in diameter. *Ray cells* upright and procumbent (Pl. 4, fig. 30); upright cells 40-72 μm in tangential height, 24-40 μm in radial length; procumbent cells 1-28 μm in tangential height, 40-80 μm in radial length; cells occasionally crystalliferous. *Fibres* nonlibriform, moderately thick-walled, septate, angular to squarish in shape and 8-24 μm in diameter.

Affinities — The important features of this fossil wood are: vessels medium to large, solitary and in radial multiples, parenchyma vasicentric and apotracheal delimiting the growth rings; rays 1-3 seriate and heterogeneous; fibres septate and moderately thick-walled. These features collectively indicate the affinities of the fossil with the modern woods of the family Verbenaceae. Among the woods of various genera of this family consulted for comparison, *Vitex limonifolia* Wall. shows close resemblance with the present fossil. This study included the examination of thin sections of modern woods of *Vitex altissima* L., *V. canescens* Kurz, *V. glabrata* R. Br., *V. gaumeri* Greenman, *V. heterophylla* Roxb., *V. leucoxylon* L., *V. limonifolia* Wall., *V. negundo* L., *V. pachyphylla* Baker, *V. parviflora* A. Juss., *V. peduncularis* Wall. and *V. pubescens* Vahl. The fossil wood was also compared with the published description and figures of most of the above species as well as a few others (Desch, 1954, p. 628; Kanehira, 1924, pp. 44, 45; Kribs, 1959, pp. 161, 162, figs 473-475; Lecomte, 1926, pl. 65; Metcalfe & Chalk, 1950, pp. 1036, 1037, fig 248B, H; Normand, 1960, pl. 154; Pearson & Brown, 1932, pp. 805-811 figs 253-255).

So far only two species of fossil woods of *Vitex* are known from India and abroad. These are *Vitexoxylon miocenicum* Prakash & Tripathi (1974) from the Tipam sandstones near Hailakandi, Assam and *Vitecoxylon aethiopicum* Lemoigne (1978) from the region of Welkite in Ethiopia. Besides, Ingle (1972) described a fossil wood as *Vitexoxylon indicum* from the Deccan Intertrappean beds of Madhya Pradesh. But according to Prakash and Tripathi (1974, p. 310) it does not appear to belong to the genus *Vitex*.

Although the above species resemble the present fossil wood in gross structures, they also differ from it particularly in the absence of apotracheal parenchyma lines at the growth rings. Such parenchyma is not necessarily present in all the species of modern *Vitex*. When it is absent, the growth rings are delimited by thick-walled fibres and bigger vessels. *Vitexoxylon* (= *Vitecoxylon*) *aethiopicum* further differs from our fossil wood in having diffuse parenchyma, nonseptate fibres and smaller vessels (solitary pores 175 μm in diameter). Similarly, *Vitexoxylon miocenicum* is also distinct from this fossil in having broader, 1-6 seriate xylem rays and in the absence of terminal parenchyma. Thus, it is evident that the present fossil wood is quite different from the above species. It is, therefore, named as *Vitexoxylon africanum* sp. nov.

The genus *Vitex* consists of 250 species, distributed in tropical and temperate regions (Willis, 1973, p. 1214). About 58 species are known to occur in tropical Africa (Thiselton-Dyer, 1900, pp. 315-331).

SPECIFIC DIAGNOSIS

Vitexoxylon africanum sp. nov.

Wood diffuse-porous. *Growth rings* delimited by thin lines of apotracheal parenchyma. *Vessels* medium to large, solitary and in radial multiples of 2-5, rarely up to 9, sometimes in double rows, t.d. 120-360 μm, r.d. 60-400 μm, about 5-7 vessels per sq mm; perforations simple; vessel members medium to short, about 300-500 μm in length and tylosed; intervessel pits 6-8 μm in diameter, alternate, with lenticular to circular orifices. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric, forming narrow, usually 1-seriate, complete or incomplete sheath round the vessels; apotracheal parenchyma 1-2 seriate lines at the beginning of growth rings. *Xylem rays* 1-3 (mostly 2-3) seriate, about 6-40 cells in height; ray tissue heterogeneous, rays homocellular to heterocellular, consisting either of procumbent cells only or procumbent cells in the centre with 1-3 marginal rows of upright cells at one or both the ends. *Fibres* angular to squarish in cross section, nonlibriform, moderately thick-walled, septate, about 8-24 μm in diameter.

Holotype — NB 15, Palaeobotany Laboratory, Lyon University, France.

ACKNOWLEDGEMENTS

The authors are indebted to Dr K. R. Surange, ex-Director, Birbal Sahni Institute of Palaeobotany, Lucknow for providing facilities and for permission to work on this material. We are also grateful to the authorities of the Forest Research Institute, Dehradun for facilities to consult the Xylarium.

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EXPLANATION OF PLATES

PLATE 1

Mammeoxylon lanneoides Lemoigne emend.

1. Cross section showing nature and distribution of vessels and parenchyma. × 30.

Mammea africana

2. Cross section showing vessels and parenchyma similar to that of the fossil shown in fig. 2. × 30.

Mammeoxylon lanneoides Lemoigne emend.

3. Tangential longitudinal section showing xylem rays and horizontal gum canal. × 90.

Mammea africana

4. Tangential longitudinal section showing xylem rays and horizontal gum canal as in fossil shown in fig. 4. × 90.

Mammeoxylon lanneoides Lemoigne emend.

5. Radial longitudinal section showing heterocellular xylem rays. × 90.
6. Fibre-tracheids. × 400.

Cassinium ethiopicum sp. nov.

7. Cross section showing nature and distribution of vessels and parenchyma. × 30.
8. Tangential longitudinal section showing xylem rays. × 60.
9. Radial longitudinal section showing homocellular xylem rays. × 90.

PLATE 2

Cassinium ethiopicum sp. nov.

10. Intervessel pitting. × 400.

Sapotoxylon multiporosum sp. nov.

11. Intervessel pitting. × 400.

Sapotoxylon multiporosum sp. nov.

12. Cross section showing nature and distribution of vessels. × 30.
13. Cross section magnified to show the apotracheal parenchyma bands and the arrangement of vessels. × 90.
14. Tangential longitudinal section showing xylem rays. × 90.
15. Radial longitudinal section showing heterocellular xylem rays. × 90.

Stereospermoxylon eoacuminatissimum gen. et. sp. nov.

16. Cross section under low magnification showing nature and distribution of vessels and growth rings. × 7.
17. Cross section magnified to show vessels and parenchyma. × 30.

PLATE 3

Stereospermoxylon eoacuminatissimum gen. et sp. nov.

18. Tangential longitudinal section showing rays. × 90.
19. Radial longitudinal section showing homocellular rays. × 90.
20. Intervessel pitting. × 400.

Stereospermoxylon grambasti sp. nov.

21. Tangential longitudinal section showing rays. × 90.

Stereospermum sp.

22. Tangential longitudinal section showing rays similar to fossil as shown in fig. 25. × 90.

Stereospermoxylon grambasti sp. nov.

23. Cross section showing vessel and parenchyma distribution. × 7.
24. Cross section magnified showing distribution of vessels and parenchyma. × 30.

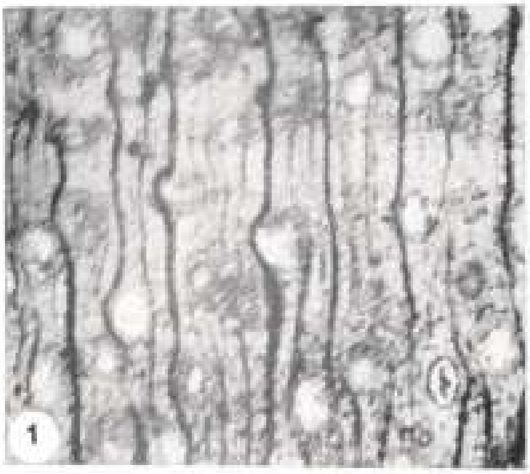
Stereospermum sp.

25. Cross section showing vessels and parenchyma similar in nature and distribution to fossil shown in fig. 23. × 90.

PLATE 4

Vitexoxylon africanum sp. nov.

26. Cross section showing nature and distribution of vessels. × 7.
27. Cross section magnified to show vessels and paratracheal and terminal parenchyma. × 30.
28. Intervessel pitting. × 400.
29. Tangential longitudinal section showing xylem rays. × 90.
30. Radial longitudinal section showing heterocellular rays. × 90.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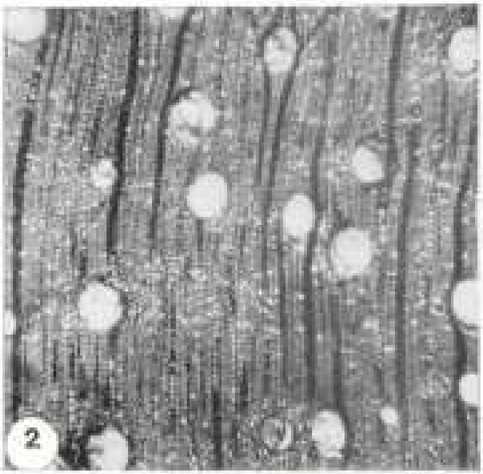
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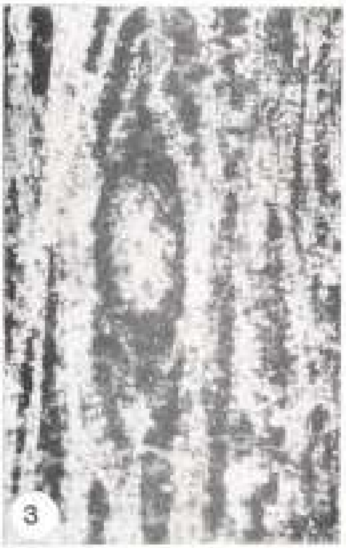
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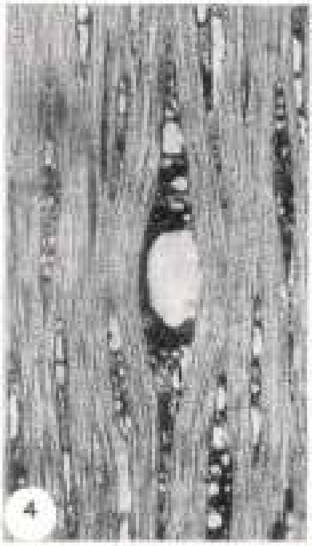
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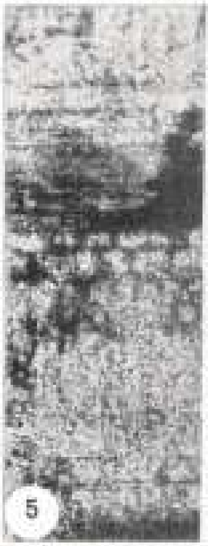
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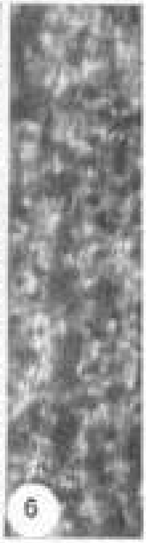
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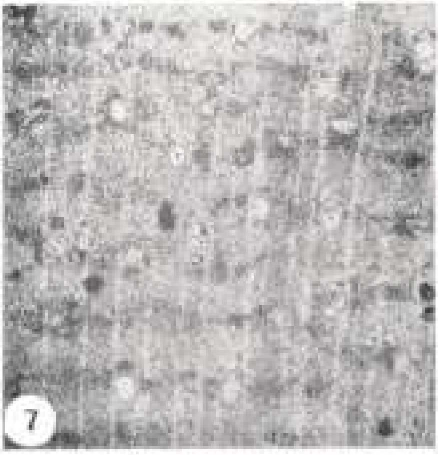
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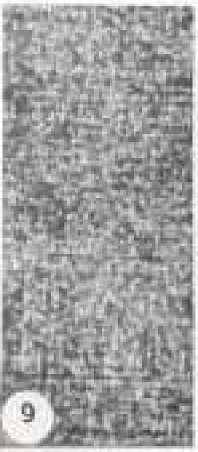
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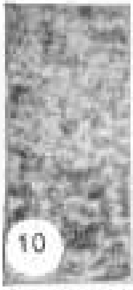
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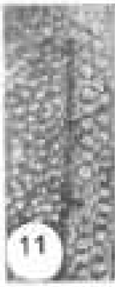
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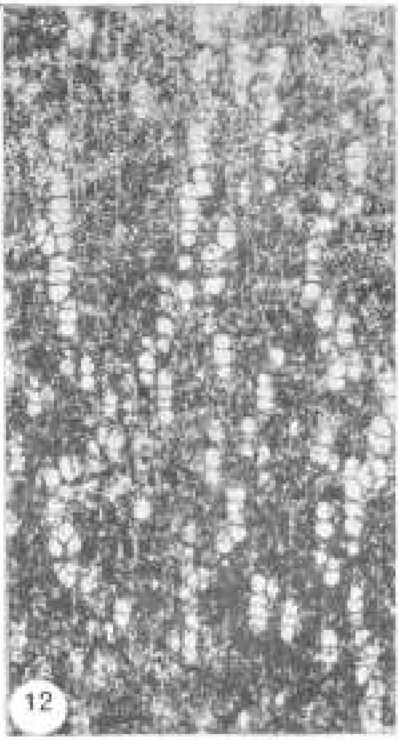
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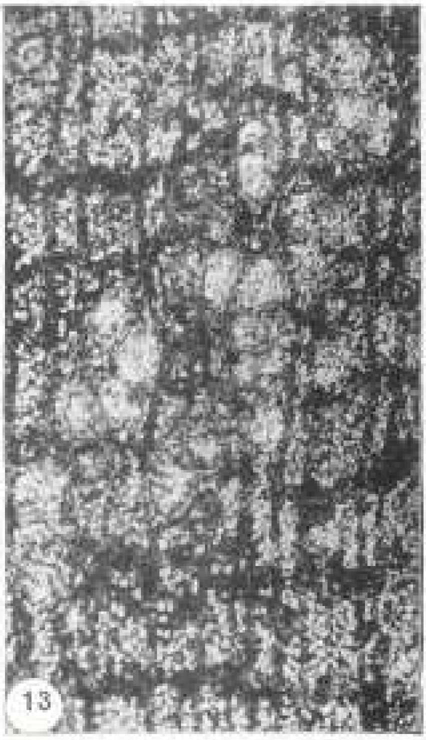
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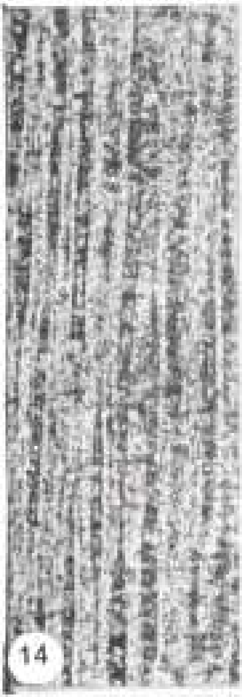
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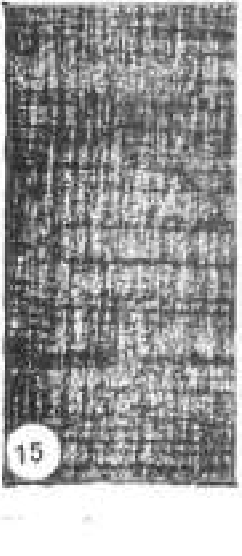
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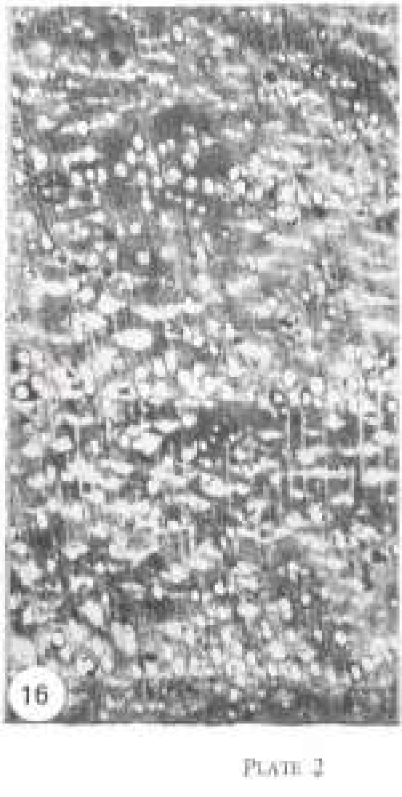
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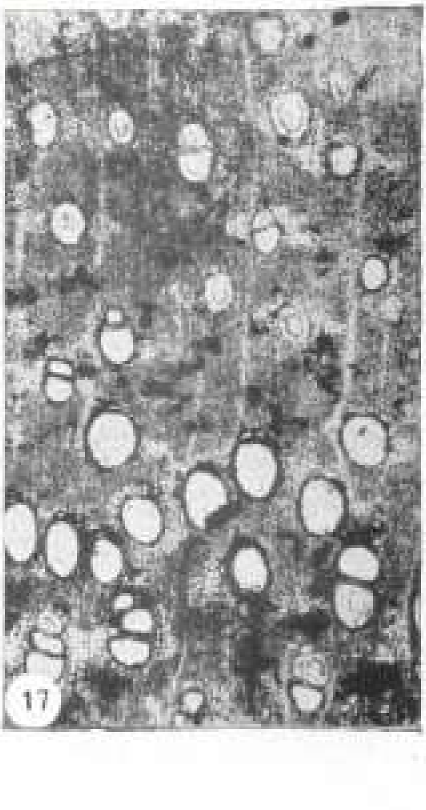
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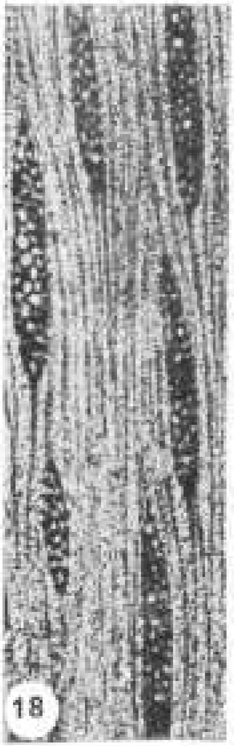
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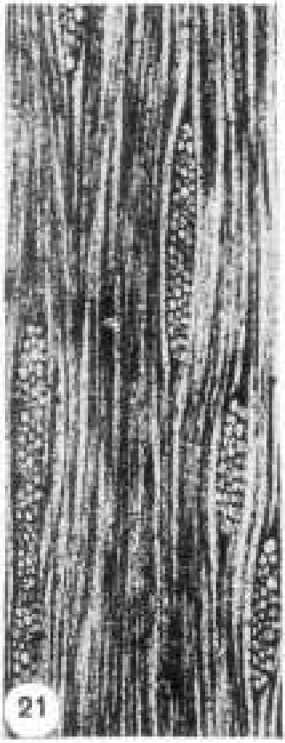
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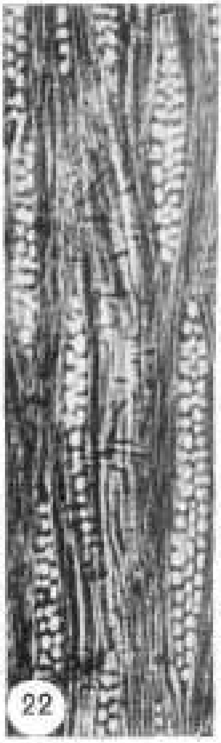
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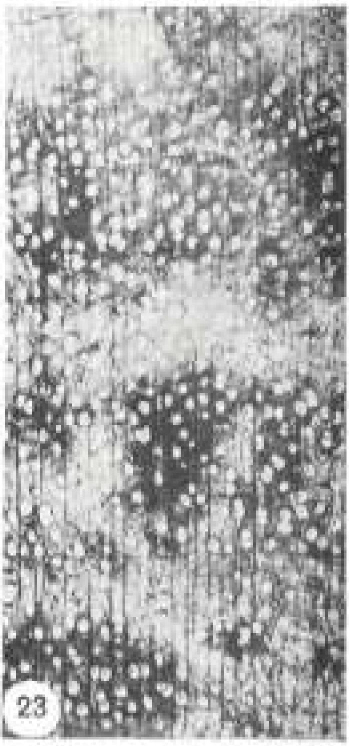
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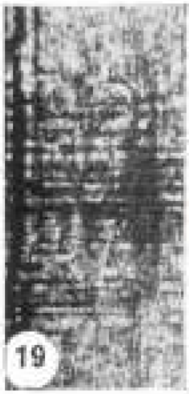
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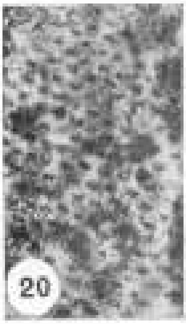
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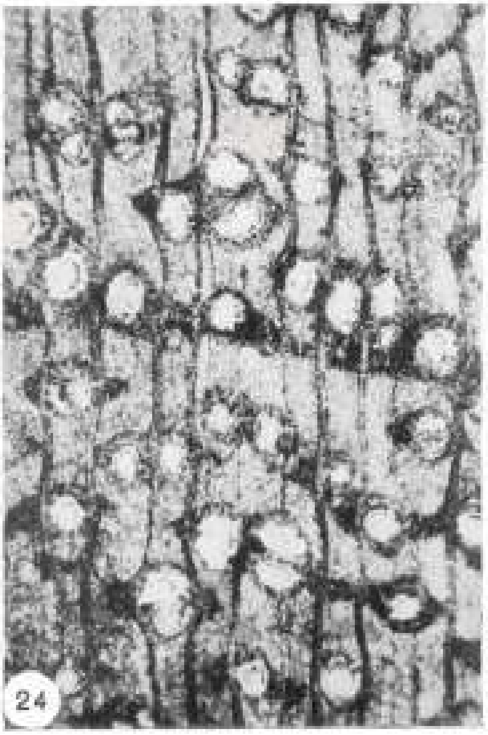
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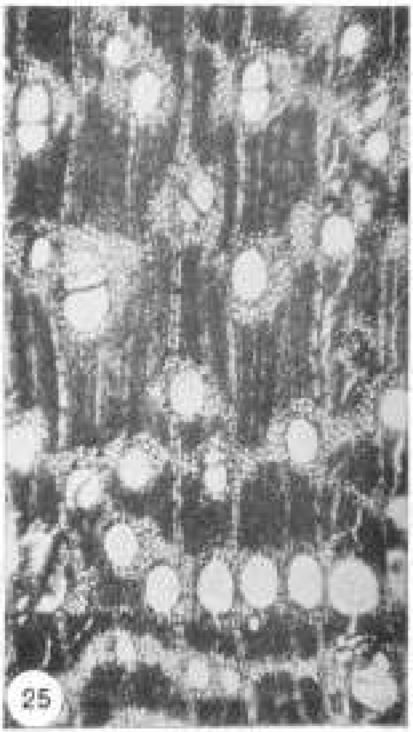
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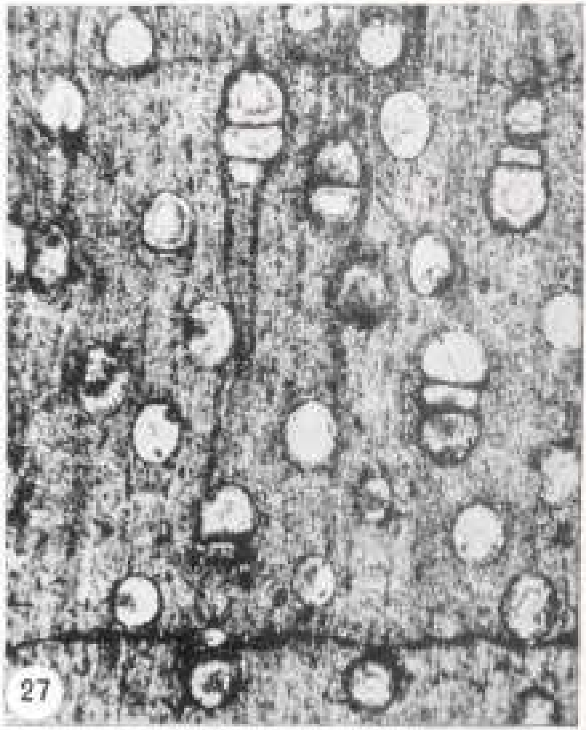

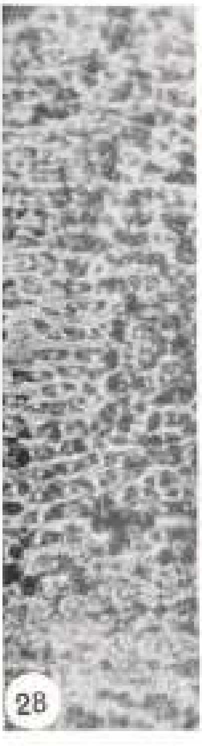

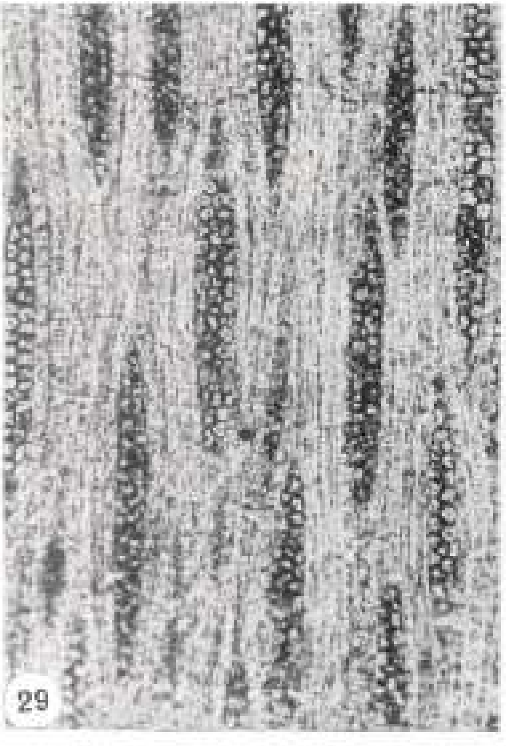

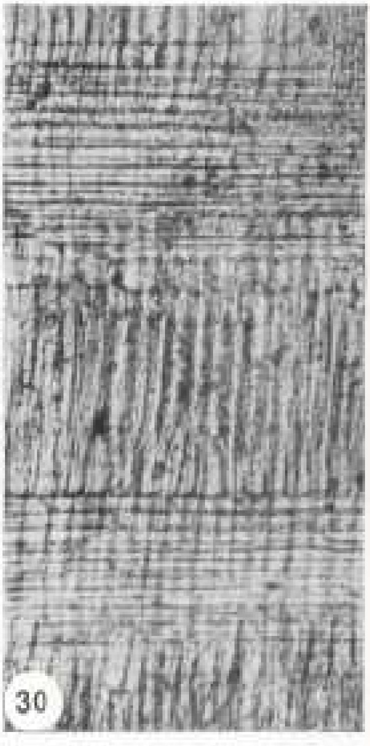

PLATE 4

The Palaeobotanist, 30(1): 60-62, 1982.

SCLEROCOCCUS: A NEW TYPE OF FOSSIL ALGA FROM THE JUTOGH 'E', SIMLA HILLS

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ABSTRACT

A new type of fossil alga, *Sclerococcus* gen. nov., is recorded from the Jutogh 'E' Member of the Simla area. The alga is characterised by the presence of sclerotic thickenings on the cells.

Key-words — *Sclerococcus*, Chroococcaceae, Jutogh Group, ?Cambrian (India).

सारांश

शिमला पहाड़ियों में जटोघ 'ई' से एक नवीन प्रकार का शैवालाश्म : स्क्लेरोकोक्कस – प्रभात कुमार माइती एवं ओंकार नाथ भार्गव

शिमला क्षेत्र के जटोघ 'ई' सदस्य से एक नवीन प्रकार का शैवालाश्म, स्क्लेरोकोक्कस नव प्रजाति, अभिलेखित किया गया है। यह शैवालाश्म कोशिकाओं पर दृढ़ स्थूलनों की उपस्थिति से अभिलक्षणित है।

INTRODUCTION

SAH, Maithy and Bhargava (1977) reported for the first time the presence of microbiota (palynomorphs) from the 'B' Member of Jutogh Group. On the basis of the microbiota Vendian age was assigned to this bed. Recently, a new characteristic form showing algal organisation has been recorded from the Jutogh 'E' Member.

The Jutogh Group of the Simla area is divisible into five mappable formations.

MEMBER	LITHOLOGY
E Formation	Carbonaceous schists, staurolite and garnet schists, marble and garnetiferous amphibolite (450 m).
D Formation	Cross-bedded pale, white to grey quartzite, with interstratified carbonaceous graphitic schist in upper part (500 m).
C Formation	Chlorite-sericite phyllite, minor quartzite, rare garnetiferous schist (1100 m).
B Formation	Pale grey to white ripple marked quartzite with carbonaceous phyllite in upper part (300 m).
A Formation	Carbonaceous phyllite/schist, limestone, little quartzite.

..............Jutogh Thrust..............

The material yielding the microbiota was collected by one of us (O.N.B.) from the Jutogh 'E' Formation about 16 m above its contact with 'D' Member, approximately 800 m WNW of Dhenda along the Simla (Jutogh)-Mandi Highway. The material is fine grained marble, dirty-white to greenish in colour. Preparations and studies were made according to the methods suggested by Pflug and Maithy (1977) to avoid contaminations.

DESCRIPTION

Division — Cyanophyta
Class — Cyanophyceae
Order — Chroococcales
Family — Chroococcaceae

Genus — *Sclerococcus* gen. nov.

Diagnosis — Cells spherical, with radial scleroid-like thickenings radiating from the centre of cell to the margin on one surface and the other with varied sculpture; solitary or in the form of irregular flat colony, enveloping sheath for individual cell or colony absent.

Genotype — *Sclerococcus jutoghensis* sp. nov.

Comparison — In its flat irregular colonial organisation and without enveloping sheath *Sclerococcus* gen. nov. compares with several known Precambrian and Cambrian forms, viz., *Aphanocapsa* Maithy & Shukla (1977), *Nanococcus* Oehler (1977), *Sphaerophycus* Schopf (1968) and *Corymbococcus* Awramik & Barghoorn (1977). But all these forms differ in the absence of thick sclerotid thickenings on cell walls. The closely comparable form *Palaeoglaucocystis* Maithy & Mandal (1982), recorded from the Upper Bhanders of Rajasthan, differs in having rugulate type of thickenings. Moreover, the cells are enveloped all round by non-lamellated sheath. On the other hand, in *Sclerococcus* the scleroid thickenings project out beyond the boundary of the cells giving fimbriate appearance to cell margin. Moreover, the encrusting sheaths around the cells are also missing.

Sclerococcus jutoghensis sp. nov.

Pl. 1, figs 1-9

Diagnosis — Cell spherical or oval in outline, either solitary or in groups of 2-10 cells, arranged in chain or irregular patterns, 10-20 μm; one surface with branched or unbranched scleroid thickenings radiating from the centre of cells to margin, margin fimbriate; other surface smooth.

Holotype — Slide no. 6062 of the Birbal Sahni Institute of Palaeobotany Museum, Lucknow.

Locality — 800 m WNW of Dhenda along Simla-Mandi Highway.

Horizon — Jutogh 'E' Member (?Cambrian).

Description — Cells are commonly spherical, occasionally oval. Mostly they are solitary. Frequently they form colony of of 2-10 cells. In colonies, the cells are arranged in a single row or form irregular pattern. Scleroid thickenings of cells are branched and closely adpressed, giving rough appearance to cells. Scleroid thickenings also project beyond the cell margin. Hence, the outline shows fimbriate appearance. The other surface of cell is smooth.

Remarks — Although biota plays a significant role in biostratigraphy, but no conclusion on the age of Jutogh 'E' can be drawn on the basis of present record of *Sclerococcus* as its vertical and horizontal distributions are not known. However, similar comparable form has been recorded by Eisenack (1960, pl. 1, fig 3a, b, c) from the lime surface on *Estnonus* shale from the Silurian of Baltic Island.

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EXPLANATION OF PLATE

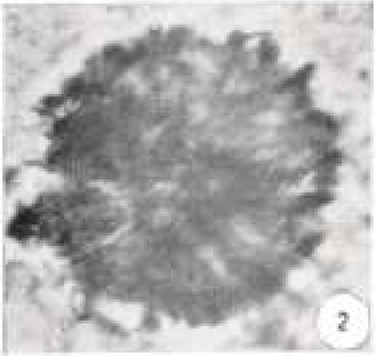
Plate 1

Sclerococcus jutoghensis gen. et sp. nov.

1. Solitary cells or 3-5 cells arranged in groups. × 1000.

2-9. Solitary cells enlarged to show the structures (in figs 5 and 6, the sclerotic thickenings are shown).


1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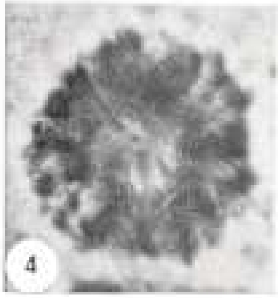
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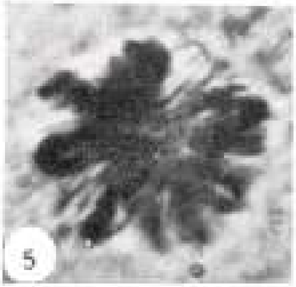
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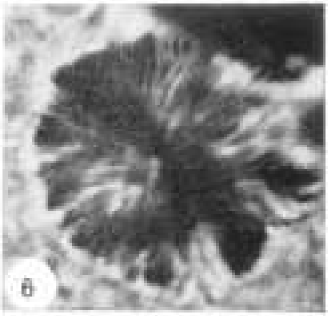
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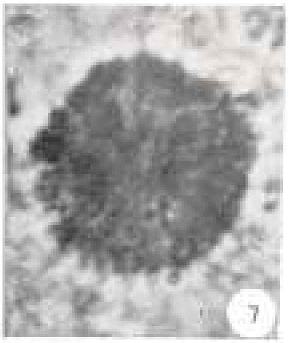
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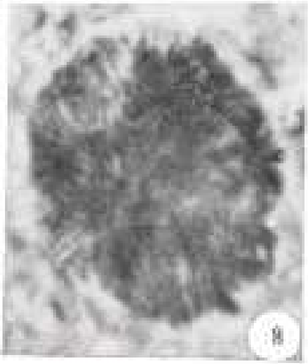
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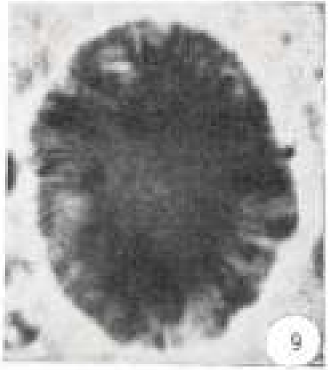
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PLATE 1

The Palaeobotanist, 30(1): 63-67, 1982.

SCLEROSPERMA-TYPE POLLEN GRAINS FROM THE NEYVELI LIGNITE OF INDIA

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ABSTRACT

Pollen grains similar to those of African palm, *Sclerosperma manii* Wendl., have been described from the Neyveli lignite. The occurrence of this African palm in the Early to Middle Tertiary of India is significant from the view point of palaeoclimate of the Indian subcontinent and the palaeogeographical distribution of *Sclerosperma*.

Key-words — *Sclerosperma*, African palm, Monocot pollen, Neyveli Lignite (India).

सारांश

भारत के निवेली मृदांगार में स्क्लेरोस्पर्मा-सदृश परागकण – मोहन बलवंत बांदे एवं कृष्ण अम्बवानी

निवेली मृदांगार से अफ्रीकी ताड़, स्क्लेरोस्पर्मा मैनाई वैन्डलैंड, के अनुरूप परागकणों का वर्णन किया गया है। प्रारम्भिक से मध्य तृतीयक युग में इस अफ्रीकी ताड़ की उपस्थिति भारतीय उपमहाद्वीप की पुराजलवायु एवं स्क्लेरोस्पर्मा के पुराभौगोलिक वितरण की दृष्टि से उल्लेखनीय है।

INTRODUCTION

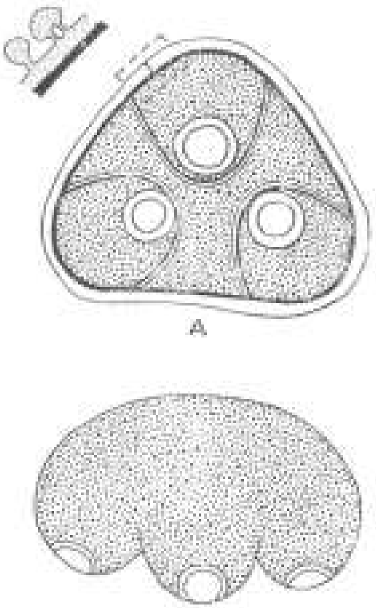
TERTIARY palynology constitutes an important part of Palaeobotany. It is from the Tertiary onwards that the vegetation started acquiring its present-day structure. Our knowledge regarding past vegetation, palaeoclimate and palaeogeography is far from complete without a clear understanding of the vegetation pattern of this period. Although a lot of morphotaxonomic work has been done on the Tertiary megafossils of India and their affinities traced to modern taxa, the microfossils which constitute an important constituent of the Indian Tertiary flora have been mostly studied and classified only artificially for stratigraphic purposes. The authors are well aware of the problems, one has to face in tracing the affinities of fossil spores and pollen to the modern genera and species, the main difficulty being lack of a detailed knowledge of the morphology of modern pollen and spores. However, it is emphasized that sincere attempts should be made in this direction whenever the related information is available for comparison. With this idea in mind, pollen grains showing affinities with the extant genus *Ctenolophon* (Ctenolophonaceae) have been recently described from the Neyveli lignite of India (Ambwani, Bande & Prakash, 1981) and in this paper the pollen grains closely comparable with those of African palm, *Sclerosperma manii* Wendl., are described. Earlier work on this lignite deposit has yielded a rich assemblage of pollen and spores belonging to angiosperms and pteridophytes (Rao, 1955; Thiergart & Frantz, 1963; Ramanujam, 1966, 1966-67; Navale, 1967; Deb, 1972).

FAMILY—PALMAE

Pollen grains cf. *Sclerosperma manii* Wendl.

Pl. 1, figs 1-6; Text-fig. 1

Description — Pollen grains heteropolar, radiosymmetrical, triangular to subcircular in polar view, convexo-concave and give the appearance of a tripod-like structure in lateral view due to the presence of three exinous projections, one at each angle on the convex side (this particular character is very clear in unmounted grains), size



TEXT-FIG. 1 — A, pollen grain in polar view; B, pollen grain in lateral view showing three exinous projections with submarginal pores (not to the scale).

31-50 µm in diameter in polar view, interpolar distance 30-36 µm. Pollen grains triporate, one pore at each angle, pores submarginal, each pore situated on an exinous projection on the convex side, ±6 µm wide, circular in shape, pores surrounded by a smooth ring-like thickening. The exinous projections are only on the convex side and become superimposed on the three angles of the grain when mounted under a cover glass. Exine 2-3 µm thick; sexine reticulate, reticulum uneven, brochi ±2 µm thick, baculae with small tegilla, simple or compound, tegillum smooth, nexine thinner than sexine, smooth.

Comparison — The above morphological characters of the pollen grains indicate their close affinities with those of *Sclerosperma manii* of Palmae. Pollen morphology of *Sclerosperma manii* has been described in detail by Erdtman and Singh (1957, pp. 217-220, fig. 24) and Thanikaimoni (1970, p. 69, pl. 9, figs 147-154). The fossil pollen grains show a very close structural similarity with the pollen grains of *S. manii* in their shape, size, nature and orientation of the apertures as well as the exine ornamentation. Pollen grains of the modern species and those under discussion are about 40 µm in diameter, triangular to rounded in shape, triporate, pores submarginal, in one hemisphere only, situated on the exinous projections on the convex side and the exine reticulate.

From the Tertiary of India pollen grains showing similar morphological characters have previously been described as *Dorreenipites* from the Tura Formation of Assam by Biswas (1962) and from the Middle to Upper Eocene of Bengal by Baksi (1972). Ramanujam (1966) described similar grains under the generic name *Trilatiporites* from the Neyveli lignite and placed them under four different species. Later on Venkatachala and Kar (1969) and Sah and Kar (1970) described two more species of *Trilatiporites* Ramanujam from the Laki Series of Kachchh. Recently, Ramanujam and Rao (1977) have reported one species of *Trilatiporites* from the Warkalli lignite deposits of South India. According to Deb, Baksi and Ghosh (1973, p. 28), "the grains described from Tura and Neyveli assemblages under two separate genera are morphologically same, i.e. anisopolar pollen, triporate, rounded to rounded triangular amb, pores surrounded by a thicker rim, prominent thickening of the exine at the base of the pores —, pores prominently non-equatorial, situated all in one hemisphere, thick exine, columellae distinct, surface mostly microreticulate and also granular, eq. diam. 29-48 µm." From these characters it is obvious that the pollen grains so far described under *Dorreenipites* and *Trilatiporites* as well as the grains described in this paper are of the same morphological type. However, as the purpose of this study is to know the botanical affinity of these fossil grains, they are described here without assigning them to any of the above two genera. Moreover, as it is also not desirable to assign the fossil pollen grains to a living genus, there being always some minor morphological differences, the present grains have been described simply as the pollen grains cf. *Sclerosperma*. Further studies on the variations in the pollen morphology in *Sclerosperma manii* and on the pollen grains described under *Dorreenipites* and *Trilatiporites* are necessary to resolve the problems of synonymy and speciation in these two genera.

DISCUSSION

The modern species, *Sclerosperma manii* Wendl., with which the pollen grains described here show a very close similarity, is a slender palm growing in swampy places on the river banks in tropical West Africa (Thiselton-Dyer, 1902, p. 100). While Willis (1973) mentions this genus with 2-3 species restricted to West Africa; Thiselton-Dyer (1902) considers this genus as monotypic with only one species, *Sclerosperma manii* Wendl., endemic to tropical West Africa. The occurrence of this African genus in the Neyveli lignite of India raises a number of interesting points. As discussed earlier, besides Neyveli such type of pollen grains are known from the Laki Series of Kachchh, Tura Formation in Assam, the Eocene of Bengal and the Warkalli lignite deposits of Kerala. The age of the Laki Series and the Tura Formation is accepted as Lower Eocene and Palaeocene to Eocene respectively and that of Warkalli lignite as Miocene. But there appears to be a controversy regarding the age of the Neyveli lignite. This issue has been discussed in detail by Deb, Baksi and Ghosh (1973) and although the age of the Neyveli lignite is usually considered as Miocene, however, these authors have suggested an Eocene age for this lignite on the basis of its palynological assemblage. Without going into the details of merits and demerits of these two different viewpoints it can be said that the presence of *Sclerosperma*-type of pollen grains in the various Early to Middle Tertiary localities of India carries special significance. If the age of the Neyveli lignite is considered to be Eocene, then it appears that during the Palaeogene of India the genus *Sclerosperma* was widely distributed throughout the Indian Subcontinent which is clear from its occurrence in the wide spread localities like Kachchh in the West, Assam and Bengal in north-east and east, and Neyveli in the south. On the other hand if the age of the Neyveli lignite is considered as Miocene, then the present finding along with the record of *Trilatiporites* in the Warkalli extends the upper limit of this genus at least up to Miocene in India before its extinction from this area. Nevertheless it is interesting to note that the modern species *Ctenolophon engleri*, pollen grains comparable to which have recently been described from Neyveli lignite by Ambwani, Bande and Prakash (1981), is also a species confined to tropical West Africa. The present finding thus strongly indicates the presence of at least some common genera in India and tropical West Africa during Early to Middle Tertiary period. It can also be deduced that by the Palaeogene although the west coast of India had separated from the east coast of Africa (Dietz & Holden, 1973, p. 827), the Indian subcontinent was situated almost in the same latitudes as the tropical West Africa. Both these regions thus might have enjoyed a similar climate permitting the growth of common genera on two widely separated lands. The extinction of these forms from the Indian subcontinent in the later part of Tertiary might be attributed to changes in the climate of this region resulting from the northward drift of India.

Locality — Neyveli, South Arcot District, Tamil Nadu.

Specimen — Birbal Sahni Institute of Palaeobotany Museum slide nos. 6048, 6049 and 6050.

ACKNOWLEDGEMENTS

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EXPLANATION OF PLATE

(Figs 1-6. Pollen grains cf. *Sclerosperma manii*, × 1500)

1-3. Pollen grain in polar view at different focii showing reticulate exine pattern and the exinous projections with pores. B.S.I.P. slide no. 6048.

4-6. Pollen grains in polar view showing variations in size and shape. 4. B.S.I.P. slide no. 6048. 5. B.S.I.P. slide no. 6050. 6. B.S.I.P. slide no. 6049.

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PLATE 1

The Palaeobotanist, 30(1): 68-100, 1982.

PALYNOLOGY OF THE QUILON BEDS OF KERALA STATE IN SOUTH INDIA II — POLLEN OF DICOTYLEDONS AND DISCUSSION

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ABSTRACT

This contribution deals with a systematic account of the dicotyledonous pollen recovered from the carbonaceous and calcareous clays of the Quilon Formation of Kerala and a critical analysis of the entire palynological data of this formation. In all, 54 genera encompassing 62 species have been recorded in this paper; of these 7 genera and 44 species are new. The genera abundantly represented are *Verrucosisporites*, *Polypodiisporites*, *Retipilonapites*, *Couperipollis*, *Clavapalmaedites*, *Paravuripollis*, *Longapertites*, *Quilonipollenites*, *Palmaepollenites*, *Dicolpopollis*, *Retitricolpites*, *Retitrescolpites*, *Foveotricolpites*, *Ctenolophonidites*, *Zonocostites*, *Heterocolpites*, *Marginipollis*, *Hippocrateaceaedites*, *Margocolporites*, *Sapotaceoidaepollenites*, *Talisiipites*, *Verrutriporites*, *Maculoporites*, *Myrcipites*, *Anacolosidites*, *Clavaperiporites* and *Ornatetradites*.

Abundant occurrence of *Polypodiisporites*, coupled with *Pteridacidites*, *Intrabaculisporis* and *Eximospora* and in conjunction with *Dicolpopollis* (abundant), *Couperipollis*, *Maculoporites*, *Compositoipollenites*, *Hippocrateaceaedites*, pollen-types of Caesalpiniaceae, Sapotaceae and Droseraceae supports Lower to Middle Miocene age assigned to these beds on faunal evidence.

The palynoassemblage indicates a tropical humid type climate with plenty of rain fall. The presence of pollen-types related to *Barringtonia*, *Rhizophora*, *Lumnitzera*, *Nipa*, *Iriartea*, *Calamus*, *Metroxylon*, Araliaceae, Sapindaceae, Meliaceae and Droseraceae and the spores of Polypodiaceae and Schizaeaceae testifies to the prevalence of brackish water mangrove swamps along the coastal belt of Kerala.

Key-words — Palynology, Dicotyledonous pollen, Quilon beds, Lower to Middle Miocene (India).

सारांश

दक्षिण भारत में केरल प्रदेश के क्वीलॉन संस्तरों की परागाणुस्तरिकी – भाग २। द्विबीजपत्रीयों के परागकण तथा विवेचन – के॰ पी॰ राव एवं सी॰ जी॰ के॰ रामानुजम्

यह शोध-पत्र केरल के क्वीलॉन शैल-समूह की कार्बनमय एवं चूनामय मृत्तिकाओं से उपलब्ध द्विबीजपत्रीय परागकणों के वर्गीकृत वर्णन तथा इस शैल-समूह के समस्त परागाणविक आँकड़ों के समीक्षात्मक विश्लेषण से सम्बन्धित है। कुल मिलाकर इसमें 62 जातियों सहित 54 प्रजातियों का वर्णन किया गया है। जिनमें से 7 प्रजातियाँ एवं 44 जातियाँ नई हैं। वेरूकोसिस्पोराइटिस, पॉलिपोडाइस्पोराइटिस, रेटिपाइलोनेपाइटिस, काउवेरीपॉलिस, क्लेवापाल्मीडाइटिस, पैरावूरीपॉलिस, लौंगापर्टाइटिस, क्वीलॉनिपोलिनाइटिस, पाल्मीपोलिनाइटिस, डाइकोल्पोपॉलिस, रेटिट्राइकोल्पाइटिस, रेटिट्रेस्कोल्पाइटिस, फोविओट्राइकोल्पाइटिस, टीनोलोफोनिडाइटिस, ज़ोनोकोस्टाइटिस, हेट्रोकोल्पाइटिस, मार्जिनीपॉलिस, हिप्पोक्रेटियासीइडाइटिस, मार्जोकोल्पोराइटिस, सैपोटेसिआइडीपोलिनाइटिस, टालीसिपाइटिस, वेरूट्राइपोराइटिस, मैक्यूलोपोराइटिस, मिरसिपाइटिस, ऐनाकोलोसिडाइटिस, क्लेवापेरिपोराइटिस एवं ओर्नाटेट्राडाइटिस बाहुल्यता में मिलने वाली प्रजातियाँ हैं।

टेरिसीसीराइटिस, इन्डुबेक्युलिस्पोराइटिस एवं ऐक्रिसमोस्पोरा से संलग्न तथा साइकैडोपाइटिस (प्रभावी), बाकेरीपोलिस, ट्राइकोल्पोराइटिस, कम्पोजिटोइपोलेनाइटिस, डिप्टेरोकार्पोइडाइटिस, [illegible], सैपो-टेसी एवं इबेनेसी कुलों के परागकण-प्रकारों से संबन्धित पोलिकोलपोराइटिस की बाहुल्यता जीवजातीय प्रमाणों पर आधारित इन संस्तरों की आयु के मध्य मायोसीन आयु का समर्थन करती है।

परागाणविक समुच्चय अधिक वर्षा वाली उष्णकटिबंधीय आर्द्र-सदृश जलवायु प्रदर्शित करती है। बैरिंग्टो-निया, राइज़ोफोरा, लुम्निट्ज़ेरा, सोनेरेशिया, कैलेमस, [illegible], बर्सेरेसी, क्लूसिएसी, ओलिएसी एवं इबेनेसी से सम्बद्ध परागकण-प्रकारों तथा पोलिपोडिएसी एवं साइज़िएसी कुलों के बीजाणुओं की उपस्थिति केरल के तटीय कटिबंध के साथ-साथ नमकीन जलयुक्त मैंग्रोव दलदल का होना इंगित करती है।

INTRODUCTION

In the first part under this title, the authors described the spores of pteridophytes and the pollen of monocotyledons (Rao & Ramanujam, 1978). The present contribution deals with dicotyledonous pollen grains recorded from the calcareous and carbonaceous clays of the Quilon beds. It also includes the floristic analysis, comparison of the microflora with a few selected Neogene microfloras, palynological evidence for the age of the Quilon sediments and the palaeoenvironmental set up during the period of deposition of the Quilon sediments. The geological set up of the area and the localities which yielded the palynological samples were reported in the previous part.

SYSTEMATIC PALYNOLOGY

Anteturma — *Pollenites* Potonié, 1931
Turma — *Aletes* Ibrahim, 1933
Subturma — *Azonoletes* (Luber) Potonié & Kremp, 1954
Infraturma — *Subpilonapiti* (Erdtman) Vimal, 1952

Genus — *Crotonoidaepollenites* gen. nov.

Type Species — *Crotonoidaepollenites euphorbioides* sp. nov.

Diagnosis — Pollen grains isopolar, spheroidal to subspheroidal, inaperturate, but generally with a central thin area towards one hemisphere. Exine 2-layered, sexine thicker than nexine, tectate, columella clear, surface pilate, pila heads free, usually triangular in surface view, aligned in a crotonoid pattern.

Remarks — The genera *Spinainaperturites* and *Verrainaperturites* instituted by Pierce (1961) differ from our new genus in the sculptural elements. *Retipilonapites* Ramanujam (1966) possesses a retipilate sculpturing without any crotonoid pattern.

Crotonoidaepollenites euphorbioides sp. nov.

Pl. 1, figs 1, 2

Diagnosis — Pollen grains isopolar, amb spheroidal to subspheroidal, polar diameter 33-45 μm; inaperturate, but usually with a small to fairly large (up to 20 μm in diameter) thin area in the centre towards one hemisphere. Exine 4-6·5 μm thick, sexine much thicker than nexine, tectate, supratectal processes pilate, pila conspicuous, 2·5-5·5 μm high, densely placed all over, pila heads 1·5-2·5 μm broad, triangular, and aligned in a reticulate manner in surface view (crotonoid pattern).

Comments — Pollen of this type are common in all the samples investigated. Similar grains were previously recovered by Traverse (1955) from the Oligocene Brandon lignite of Vermont.

Affinity — The pollen grains are particularly comparable with those of *Jatropha* and *Croton* (cf. Euphorbiaceae) but are slightly smaller (Erdtman, 1952; Guinet, 1962; Bonnefille, 1971).

Type Locality — Padappakkara.

Holotype — Pl. 1, fig. 1; Pad. II-1: 12·6 × 85·5 μm (39·5 μm).

Subturma — *Triptyches* (Naumova) Potonié, 1960

Genus — *Retitricolpites* (Hammen) Hammen & Wymstra, 1964

Genotype — *Retitricolpites ovalis* Hammen & Wymstra, 1964.

Retitricolpites dipterocarpoides sp. nov.

Pl. 1, fig. 3

Diagnosis — Pollen grains isopolar, amb rounded, polar diameter 45-60 μm; zonaperturate, tricolpate, longicolpate, colpae narrow, streak-like, margins thin, ends pointed. Exine 1·5 μm thick, stratification indistinct, tectate, surface reticulate-rugulate, reticulum rather fine, homobrochate, brochi hexagonal, small, locally irregular, muri fine, often wavy, lumina angular or irregular.

Comments — This species forms an important element of the Quilon microflora. It differs from the known species of *Retitricolpites* in the sculptural pattern (Hammen & Wymstra, 1964; Wymstra, 1971; Lang & Meon-Vilain, 1976). Further, the rounded amb and the narrow streak-like colpae also constitute the important features of the Quilon species.

Affinity — It shows strong resemblance with the pollen of *Dipterocarpus* and *Dryobalanops* of family the Dipterocarpaceae, particularly with that of the former (Anderson & Muller, 1975; Maury, Muller & Lugardan, 1975).

Type Locality — Padappakkara.

Holotype — Pl. 1, fig. 3; Pad. III-3: 13·8 × 84·1 μm (53·5 μm).

Retitricolpites microreticulatus (Hammen) Hammen & Wymstra, 1964

Pl. 1, fig. 4

Description — Pollen grains isopolar, amb rounded, polar diameter 21-25 μm; zonaperturate, tricolpate, colpae fairly long, ends pointed to blunt. Exine 2·2 μm thick, tectate, sexine thicker than nexine, reticulate, reticulum with small meshes, lumina angular, smooth; meshes towards colpae extremely small.

Occurrence — Padappakkara.

Retitricolpites marginatus Hoeken-Klinkenberg, 1966

Pl. 1, fig. 5

Description — Pollen grains isopolar, amb rounded to subcircular, polar diameter 24-29 μm; zonaperturate, tricolpate, medicolpate, colpae often obscured by heavy sculpturing, margins thin, ends pointed. Exine 2·5 μm thick, sexine thicker than nexine, surface reticulate, heterobrochate, brochi larger at poles, smaller along a margin around colpae, polygonal, muri simplibaculate, lumina angular with 1-5 free bacules.

Comments — The photomicrographs of this species provided by Hoeken-Klinkenberg show free bacules in the lumina of the reticulum, although no mention of these was made in the description (Hoeken-Klinkenberg, 1966).

Affinity — Oleaceae.

Occurrence — Edavai.

Genus — *Retitrescolpites* Sah, 1967

Genotype — *Retitrescolpites typicus* Sah, 1967.

Retitrescolpites indicus sp. nov.

Pl. 1, fig. 6

Diagnosis — Pollen grains isopolar, spheroidal equatorially and prominently 3-lobed in polar view, 48-65·5 μm; zonaperturate, tricolpate, longicolpate, colpae 15-22 μm wide, gaping at equator, margins thin, ends pointed. Exine 3·5-4·5 μm thick, sexine much thicker than nexine, surface retipilate, pila up to 3·5 μm high, reticulum homobrochate, brochi hexa to polygonal, large 4-6·5 μm, muri thick, simpli to duplipilate, lumina angular and smooth.

Comments — The species resembles *R. typicus* Sah (1967) in its spheroidal amb but differs in the possession of wide gaping colpae. *R. decipiens* Sah (1967) can be distinguished in its retipilariate exine with angustimurate nature. *R. crassimuratus* Sah (1967) is brevicolpate. *Retitrescolpites indicus* is fairly common in the samples from Padappakkara.

Affinity — Caesalpiniaceae.

Type Locality — Padappakkara.

Holotype — Pl. 1, fig. 6; Pad. III-3: 20·8 × 71·0 μm (59 μm).

Retitrescolpites singularis sp. nov.

Pl. 1, figs 7, 8

Diagnosis — Pollen grains isopolar, amb subspheroidal to rounded triangular, lobes prominent, polar diameter 20-28 μm, zonaperturate, tricolpate, longicolpate, colpae reaching poles but not uniting, colpal surface finely granular. Exine up to 4 μm thick, sexine much thicker than nexine, surface irregularly retipilate, heterobrochate, brochi hexa to polygonal, 3-5 μm in diameter, curvimuroid, lumina irregular with free baculoid processes.

Comments— The prominently longicolpate nature and the finely granular surface of the colpae are the distinguishing features of *Retitrescolpites singularis*.

Affinity — Oleaceae.

Type Locality — Padappakkara.

Holotype — Pl. 1, fig. 8; Pad. IV-ii; 17·5 ×95·7 µm (22·5 µm).

Genus — *Retibrevitricolpites* Hoeken-Klinkenberg, 1966

Genotype — *Retibrevitricolpites triangulatus* Hoeken-Klinkenberg, 1966.

Retibrevitricolpites simplex sp. nov.

Pl. 1, fig. 9

Diagnosis — Pollen grains isopolar, amb triangular to rounded triangular, sides convex, polar diameter 25-42 µm; zonaperturate, tricolpate, brevicolpate, margins thin, ends pointed. Exine 1·8 µm thick, sexine as thick as nexine, surface reticulate, brochi small ±1 µm in diameter, finer at mesocolpia.

Comments — Pollen grains of this type are occasionally found in the microflora. *Retibrevitricolpites simplex* differs from *R. triangulatus* Hoeken-Klinkenberg (1966) in its larger size and colpal margins.

Type Locality — Padappakkara.

Holotype — Pl. 1, fig. 9; Pad. II-2; 12·3 ×87·7 µm (31·5 µm).

Genus — *Foveotricolpites* Pierce, 1961

Genotype — *Foveotricolpites sphaeroides* Pierce, 1961.

Foveotricolpites piercei sp. nov.

Pl. 1, fig. 10

Diagnosis — Pollen grains isopolar, amb rounded, lobes distinct, polar diameter 16-33 µm; zonaperturate, tricolpate, brevicolpate (colpoidate), colpal margins thin, ends rounded or blunt. Exine 1·8 µm thick, sexine thicker than nexine, tectate, tectum perforated, surface foveolate, foveolae of uniform size all over, locally coalescing, up to 3 µm in diameter.

Comments — Pollen grains of the genus *Foveotricolpites* constitute a common element in the microflora. *F. sphaeroides* Pierce (1961) differs from *F. piercei* in its longer colpae with conspicuously thickened margins and smaller foveolae. *F. pomarius* Hammen & Garcia (1966) while generally agreeing with the Indian species, is microfoveolate.

Type Locality — Padappakkara.

Holotype — Pl. 1, fig. 10; Pad. II-9; 6·1×78·6 µm (29·5 µm).

Foveotricolpites prolatus sp. nov.

Pl. 1, figs 11, 12

Diagnosis — Pollen grains isopolar, amb triangular to rounded triangular, lobes distinct, prolate equatorially, 26-38×17·5-32 µm; zonaperturate, tricolpate, longicolpate, colpae gaping wide at equator, margins uneven, thin, ends pointed. Exine 1·8 µm thick, sexine slightly thicker than nexine, tectate, columella distinct, surface foveoreticulate, foveolae small, closely placed.

Comments — Pollen grains of this type are quite common and have been recorded from almost all the samples investigated. *Foveotricolpites sphaeroides* Pierce (1961) differs from the present species in its conspicuously thickened apertural margins. *F. perforatus* and *F. pomarius* (Hammen & Garcia, 1966) possess short colpae and a larger apocolpal area.

Type Locality — Paravur.

Holotype — Pl. 1, fig. 11; Par. 5; 18·5 ×96·3 µm (32 µm).

Genus — *Crototricolpites* Leidelmeyer, 1966

Genotype — *Crototricolpites annemariae* Leidelmeyer, 1966.

Crototricolpites densus Salard-Cheboldaeff, 1978

Pl. 1, fig. 13

Description — Pollen grains isopolar, amb rounded, polar diameter 26-35 µm, zonaperturate, tricolpate (colpoidate), colpae somewhat obscured by heavy ornamentation, broad at equator and tapering towards poles, margins densely beset with sculptural elements. Exine 2·5-3·5 µm thick, sexine much thicker than nexine, clavate-baculate, clava of different sizes, mostly up to 3 µm high, densely distributed, claval heads angular (± triangular), 1·5-2·5 µm broad, aligned in a crotonoid pattern.

Comments—*Crototricolpites crotonisculptus* Hoeken-Klinkenberg (1964) is larger and with longer colpae constricted at the equator.

Affinity — Euphorbiaceae; particularly the pollen of *Klaineanthus* (see Salard-Chebol-daeff, 1978).

Occurrence — Frequent at Padappakkara.

Genus — *Punctatricolpites* Pierce, 1961

Genotype — *Punctatricolpites brevis* Pierce, 1961.

Punctatricolpites sp.

Pl. 1, fig. 14

Description — Pollen grains isopolar, amb rounded triangular, sides convex, polar diameter 18-25 µm, zonaperturate, tricolpate, brevicolpate, colpae narrow, margins thin, ends pointed to blunt. Exine 1·8 µm thick, punctitectate, columella distinct, surface finely punctate.

Comments — *Punctitricolpites brevis* Pierce (1961) differs from the present pollen in its larger size and subtriangular amb. Only a few grains of this type are encountered.

Affinity — Symplocaceae.

Occurrence — Edavai.

Genus — *Bacubrevitricolpites* gen. nov.

Type Species — *B. rotundus* sp. nov.

Diagnosis— Pollen grains subprolate equatorially, amb rounded, tricolpate, brevicolpate, colpae narrow, exine intectate, beset with numerous prominent bacules, heads of bacules generally rounded in surface view.

Comments — *Baculatricolporites* Boltenhagen (1976) is a tricolporate pollen with simplibaculate or intectate exine.

Bacubrevitricolpites rotundus sp. nov.

Pl. 2, figs 15, 16

Diagnosis — Pollen grains isopolar, amb rounded, subprolate equatorially, polar diameter 21-26·5 µm; zonaperturate, tricolpate, brevicolpate, colpae narrow, margins thin, ends blunt. Exine 2-3 µm thick, intectate, baculate, bacules fine, densely distributed all over, up to 2·2 µm high, heads of bacules usually rounded in surface view.

Comments — This taxon is found occasionally in the Edavai and Padappakkara samples.

Type Locality — Edavai.

Holotype — Pl. 2, fig. 15; Edv. C_4: 23·7 × 73·1 µm (22·5 µm).

Genus — *Loranthipites* gen. nov.

Type Species — *Loranthipites elegans* sp. nov.

Diagnosis— Pollen grains with a triangular amb, distinctly 3-armed, sides concave, angles flatly arched or flared up, tricolpate, longicolpate, colpae almost extending up to poles on one side; exine tectate, smoothly or finely patterned.

Comments— *Loranthacites* Samoilovitch & Mtchedlishvili (1961) is tridiplodemicolpate and triangular with smoothly rounded apices.

Loranthipites elegans sp. nov

Pl. 2, figs 17, 18

Diagnosis — Pollen grains isopolar, amb triangular, distinctly 3-armed, prominently concave with slightly wavy margin, angles flatly arched, polar diameter 25·5-34 µm; zonaperturate, tricolpate, longicolpate, becoming almost syncolpate on one side, colpal margins thin to slightly thickened, ends pointed. Exine 1·8 µm thick, tectate, sexine only slightly thicker than or almost as thick as nexine, columella distinct, polar area thinner and smooth, rest of the surface psilate to finely patterned.

Comments — Pollen grains of this species have been found frequently in the microflora, but always in the polar compressions.

Affinity — Loranthaceae; pollen show striking resemblance with the pollen of *Elytranthe* (*Loranthus*) and *Dendrophthoe* of Loranthaceae (Erdtman, 1952; Nair, 1965).

Type Locality — Padappakkara.

Holotype — Pl. 2, fig. 17; Pad. II-9: 9·0 × 85·5 µm (29 µm).

Genus — *Marginipollis* Clarke & Frederiksen, 1968

Genotype— *Marginipollis concinnus* Clarke & Frederiksen, 1968.

Marginipollis kutchensis (Venkatachala & Kar) comb. nov.

Pl. 2, fig. 19

1968 *Rostriapollenites kutchensis* Venkatachala & Kar

Description — Pollen grains isopolar, ellipsoidal (prolate) equatorially, 37·5-42 × 23-27·5 µm, zonaperturate, tricolpate, syncolplate, colpal margins incrassate, bordered by areolate areas, colpae terminating at poles in beaked or knob-like processes. Exine 1·8 μm thick, sexine thicker than nexine, beaked projections of colpae with nexinous thickenings, surface smooth to finely granular.

Comments — Occasionally found in the Padappakkara and Paravur samples. The pollen from Quilon beds are smaller than the specimens from Kachchh.

Affinity — Lecythidaceae; *Planchonia* type of Planchonioideae (Erdtman, 1952). The fossil pollen is referable to the *Barringtonia asiatica* type of pollen and is particularly related to the pollen forms of *Barringtonia* (Muller, 1972).

Marginipollis quilonensis sp. nov.

Pl. 2, figs 20, 21

Diagnosis — Pollen grains isopolar, ellipsoidal (prolate) equatorially, 36-43 × 23-29 μm; zonaperturate, tricolpate, syncolpate, colpae ending in beaked (knob-like) processes at poles, margins incrassate. Exine 1·8 μm thick, sexine thicker than nexine, colpal beaks provided with nexinous thickenings, surface of mesocolpia punctate to foveolate.

Comments — Pollen grains of this type are common in the Padappakkara and Paravur samples and rare in Edavai samples. *Marginipollis grandis* Salujha, Kindra & Rehman (1972) although apparently comparable with *M. quilonensis* is distinguishable in its large and coarse foveolae which often coalesce to impart a reticulate look to the pollen. *M. quilonensis* is characterized by the absence of areolate areas bordering the colpae and its punctate to foveolate mesocolpia, in which respect it is distinguishable from the other species of the genus.

Affinity — Lecythidaceae (*Barringtonia*)

Type Locality — Padappakkara.

Holotype — Pl. 2, fig. 20; Pad. III-3; 12·0 × 90·5 μm (41 × 27 μm).

Genus — *Clavasyncolpites* gen. nov.

Type Species — *Clavasyncolpites gracilis* sp. nov.

Diagnosis — Pollen grains with triangular-rounded triangular amb, tricolpate, syncolpate. Exine intectate, clavate, clava locally seen in a reticuloid alignment.

Clavasyncolpites gracilis sp. nov.

Pl. 2, fig. 22

Diagnosis — Pollen grains isopolar, amb triangular to rounded triangular, sides convex, polar diameter 22-31 μm; zonaperturate, tricolpate, syncolpate, colpae wide and gaping at equatorial region, margins slightly thickened and beset with clavate-baculate processes. Exine 2·5-3·5 μm thick, sexine thicker than nexine, intectate, clavate, clava 1·5-2 μm high, locally mixed with bacules, densely and uniformly distributed all over, here and there seen in reticuloid alignment.

Comments — Occasionally found in almost all the samples investigated.

Type Locality — Padappakkara.

Holotype — Pl. 2, fig. 22; Pad. II-10; 10·1 × 95·9 μm (27·5 μm).

Genus — *Meyeripollis* Baksi & Venkatachala, 1970

Genotype — *Meyeripollis naharkotensis* Baksi & Venkatachala, 1970.

Meyeripollis baksii sp. nov.

Pl. 2, fig. 23

Diagnosis — Pollen grains isopolar, amb rounded triangular to subspherical, polar diameter 25-32 μm; zonaperturate, tricolpate, syncolpate, colpae usually obscured by heavy sculpturing, narrow at equator but widening towards poles where they meet, colpal margins densely beset with gemmae. Exine up to 4·5 μm thick, sexine much thicker than nexine, tectate, densely studded with supratectal gemmate-tuberculate processes; gemmae of different sizes, up to 3·5 μm high, rounded in surface view; apices surrounded by 2-4 gemmae only slightly larger or almost of same size as the other processes.

Comments—*Gemmatricolpites* Pierce (1961) includes only gemmate tricolpate pollen grains and hence is easily distinguishable from *Meyeripollis*. *Pistillipollenites macgregori* is a circular to broadly subtriangular triporate pollen studded with gemmate processes (Rouse & Srivastava, 1970). Gemmate trisyncolpate pollen grains were first recorded from the Tertiary subsurface sediments of Naharkatia oilfields, Assam (Meyer, 1958). Subsequently, Baksi (1962) reported similar grains from the Simsang River Section of the

South Shillong Plateau. These grains were formally described and designated as *Meyeripollis naharkotensis* by Baksi and Venkatachala (1970). *M. naharkotensis* is distinguishable from *M. baksii* in its more clearly triangular amb and in the possession of consistently two large, prominent tubercles of gemmae on either side of each angle.

The pollen is named in honour of Dr S. K. Baksi of Jadavpur University, Calcutta. *Meyeripollis baksii* represents an occasional element of the Padappakkara samples.

Type Locality — Padappakkara.

Holotype — Pl. 2, fig. 23; Pad. II-2; 10·1 × 78·0 μm (16·5 μm).

Subturma — *Polyptyches* (Naumova) Potonié, 1960

Genus — *Retistephanocolpites* Leidelmeyer, 1966

Genotype — *Retistephanocolpites angelii* Leidelmeyer, 1966.

Retistephanocolpites crassimuratus sp. nov.

Pl. 2, fig. 24

Diagnosis — Pollen grains isopolar, amb subspheroidal, polar diameter 29·5-38 μm; zonaperturate, stephanocolpate, hexacolpate, colpae fairly long, wide at equator, margins thin, ends pointed to blunt. Exine 3 μm thick, sexine much thicker than nexine, surface reticulate, reticulum homobrochate, brochi hexa to polygonal, 2-3 μm in diameter crassimurate, muri up to 2·5 μm high, lumina irregular and psilate.

Comments — *Retistephanocolpites crassimuratus* sp. nov. is characterized by its apertural features and the crassimurate reticulum. *R. williamsi* Germeraad *et al.* (1968) possesses short colpae and a reticulate-foveolate exine. *R. coramandalensis* Venkatachala & Rawat (1972) also possesses foveolate-reticulate exine.

Affinity — Labiatae.

Type Locality — Paravur.

Holotype — Pl. 2, fig. 24; Par. 2; 22·5 × 81·0 μm (33·5 μm).

Genus — *Ctenolophonidites* Hoeken-Klinkenberg, 1966

Genotype — *Ctenolophonidites costatus* Hoeken-Klinkenberg, 1966.

Ctenolophonidites costatus Hoeken-Klinkenberg, 1966

Pl. 2, figs 25, 26

Description — Pollen grains isopolar, amb stellate-spheroidal, barrel-shaped (sub-oblate to oblate) equatorially, polar diameter 35-45 μm; zonaperturate, stephanocolpate, colpae 6-8, medicolpate, margins incrassate, ends pointed to blunt, each apocolpium showing a ring-like nexinous thickening and the rings of the two poles interconnected by thick mesocolpial costae extending across the equator. Polar area inside each apocolpial ring smooth; nexinous thickenings up to 3·5 μm thick and about 2 μm high.

Comments — A considerable degree of variation was noticed with regard to the size of the amb and the number of colpae. Similar grains were reported previously from the Warkalli lignites as *Hexacolpites* and *Septacolpites* pollen types by Rao and Vimal (1952) and Vimal (1953). Recently, Ramanujam and Purnachandra Rao (1973) made a detailed study of the genus.

Affinity — Possibly with *Ctenolophon engleri* of Ctenolophonaceae (Erdtman, 1952; Saad, 1962).

Occurrence — Common at Edavai, Padappakkara and Paravur.

Genus — *Polycolpites* Couper, 1953

Genotype — *Polycolpites clavatus* Couper, 1953.

Polycolpites granulatus Sah & Kar, 1970

Pl. 2, figs 27, 28

Description — Pollen grains isopolar, amb circular to subcircular, polar diameter 26·5-38 μm, zonaperturate, stephanocolpate, colpae 7 or 8, short, margins thin, ends pointed to blunt. Exine 1·8 μm thick, thinner at polar areas, tectate, sexine as thick as nexine, columella indistinct, surface finely granular.

Comments — The Quilon specimens have a thinner exine as compared to Kachchh specimens of *Polycolpites granulatus* Sah & Kar (1970).

Affinity — Labiatae.

Occurrence — Frequent at Edavai and Padappakkara.

Subturma — *Ptychotriporines* (Naumova) Potonié, 1960
Infraturma — *Prolati* Erdtman, 1943

Genus — *Psilatricolporites* Hammen & Wymstra, 1964

Genotype — *Psilatricolporites operculatus* Hammen & Wymstra, 1964.

Psilatricolporites ebenoides sp. nov.

Pl. 2, fig. 29

Diagnosis — Pollen grains isopolar, oblong equatorially with flatly rounded or truncated poles, subtriangular in polar view, 22-29×11-16 µm; zonaperturate, tricolporate, longicolpate, colpae straight, margins thin, ends pointed, ora lalongate. Exine 1·8 µm thick, sexine slightly thicker than nexine, surface smooth.

Comments — The truncated polar areas constitute the important feature of this taxon.

Affinity — With *Diospyros* of Ebenaceae.

Type Locality — Padappakkara.

Holotype — Pl. 2, fig. 29; Pad. 11-2; 17·2×86·3 µm (26·5×13·5 µm).

Genus — *Heterocolpites* Hammen, 1956

Genotype — *Heterocolpites palaeocenica* Hammen & Garcia, 1966.

Emended Diagnosis — Pollen grains isopolar, prolate to subprolate equatorially, six-lobed in polar view with 3 major and 3 minor lobes, zonaperturate, 3 oroid colpae alternating with 3 colpoid streaks (pseudocolpae), margins of pseudocolpae fold inwards, colpal margins generally incressate, ora distinct, rounded to lalongate. Exine tectate, surface psilate to coarsely granular.

Comments — The genus *Heterocolpites* is distinguishable from the other tricolporate genera in possessing three oroid colpae which obviously represent functional colpae, alternating with three non-oroid colpoid streaks (pseudocolpae). The inward folding of the pseudocolpae is a characteristic feature. Similar pollen grains are encountered in the families Combretaceae and Melastomataceae (Hammen, 1963; Hammen & Garcia, 1966; Leopold, 1969; Blasco & Caratini, 1973).

Heterocolpites combretoides sp. nov.

Pl. 2, figs 30, 31

Diagnosis — Pollen grains isopolar, prolate equatorially, poles rounded, 6-lobate in polar view, 3 major lobes and 3 minor lobes, 20-28×15-18 µm; zonaperturate, tricolporate, longicolpate, colpae ± straight and of uniform width, crassimarginate, ora faint to distinct, lalongate, three oroid colpae alternating with three colpoid streaks (pseudocolpae), pseudocolpal margins tend to fold inward. Exine 1·5 µm thick, sexine only slightly thicker than nexine, tectate, columella distinct, surface psilate.

Comments — Pollen grains of this species are of common occurrence and constitute a characteristic element of the Quilon microflora. Somewhat similar pollen grains were recorded from the Miocene of Marshall islands by Leopold (1969). *Heterocolpites palaeocenica* (cf. Melastomataceae) is subspheroidal with flattened poles (Hammen & Garcia, 1966). *H. laevigatus* Salard-Cheboldaeff (1978) is smaller and infragranulate to scabrate.

Affinity — Combretaceae; pollen shows close resemblance with the pollen of *Lumnitzera* (Blasco & Caratini, 1973).

Type Locality — Paravur.

Holotype — Pl. 2, figs 30, 31; Par. 4; 10·5×76·6 µm (21·5×15·5 µm).

Heterocolpites granulatus sp. nov.

Pl. 2, fig. 32

Diagnosis — Pollen grains isopolar, prolate equatorially, 28-33×18-23 µm; zonaperturate, tricolporate, colpae extending more than 2/3 distance to poles; three oriferous colpae alternating with three pseudocolpal streaks, margins of pseudocolpae tend to fold inward; ora of true colpae prominent, rounded to lalongate with slightly incrassate margins. Exine 1·5 µm thick, sexine slightly thicker than nexine, tectate, columella fairly distinct, surface coarsely granular to almost finely reticulate locally.

Comments — In its coarsely granular sculpture and slightly larger size this species is distinguishable from *Heterocolpites palaeocenica* Hammen & Garcia (1966) and *H. combretoides*. *H. pseudostriatus* and *H. verrucatus* (Salard-Cheboldaeff, 1978) are distinguishable by their finely striate and verrucate sculpture respectively.

Affinity — Combretaceae.

Type Locality — Edavai.

Holotype — Pl. 2, fig. 32; Edv. c_1-1; 20·1 ×85·0 μm (22·5×16 μm).

Genus — *Retitricolporites* (Hammen) Hammen & Wymstra, 1964

Genotype — *Retitricolporites guianensis* Hammen & Wymstra, 1964.

Retitricolporites crassioratus sp. nov.

Pl. 3, fig. 33

Diagnosis — Pollen grains isopolar, amb subtriangular, polar diameter 28-35 μm; zonaperturate, tricolporate, longicolpate, colpal margins thin, ends pointed, colpae gap open at equator, ora distinct ± rounded with thickened margin, slightly protruding equatorially. Exine 1·8 μm thick, tectate, sexine thicker than nexine, thickened around ora, columella distinct, surface reticulate, brochi polygonal, small, up to 1·5 μm in diameter, lumina polygonal, smooth.

Comments — This is occasionally found. *Retitricolporites crassioratus* differs from *R. guianensis* Hammen & Wymstra (1964) in its smaller size, thickened ora and smaller-meshed reticulum. *R. annulatus* Salard-Cheboldaeff (1978) is distinguishable by its much smaller size (16-22 μm). Similar pollen were also reported by Leopold (1979).

Affinity — Rubiaceae; pollen shows particular resemblance with the pollen of *Morinda* and *Mitragyna*.

Type Locality — Padappakkara.

Holotype — Pl. 3, fig. 33; Pad. II-11; 14·2×70·1 μm (29·5 μm).

Genus — *Cauveripollis* Venkatachala & Rawat, 1973

Genotype — *Cauveripollis superbus* Venkatachala & Rawat, 1973.

Cauveripollis superbus Venkatachala & Rawat, 1973

Pl. 3, fig. 34

Description — Pollen grains isopolar, amb subtriangular, polar diameter 25-32 μm, zonaperturate, tricolporate, brevissimicolpate, colpae narrow, margins thin, ends blunt, ora distinct and lalongate. Exine 2·5 μm thick, sexine much thicker than nexine, tectate, columella clear, surface reticulate, heterobrochate, brochi smaller towards colpae, hexagonal to polygonal, muri thick, lumina angular to irregular, smooth.

Affinity — Caprifoliaceae (Venkatachala & Rawat, 1973).

Occurrence — Occasional at Edavai.

Genus — *Araliaceoipollenites* Potonié, 1951

Genotype — *Araliaceoipollenites euphorii* Potonié, 1951.

Araliaceoipollenites quilonensis sp. nov.

Pl. 3, fig. 35

Diagnosis — Pollen grains isopolar, prolate and somewhat rhomboidal equatorially, poles smoothly arched, 18-22·5× 15-17 μm; zonaperturate, tricolporate, longicolpate, colpae almost reaching poles, wide and often bent at equator, gradually tapering towards poles, ora prominently lalongate, up to 8 μm across. Exine 2·5 μm thick, thicker at poles than elsewhere, sexine thicker than nexine, columella distinct, particularly at polar regions, surface psilate to locally finely punctate.

Comments — This species is quite common in the microflora. But for its smaller size and locally punctate surface, the species compares very favourably with *Araliaceoipollenites potoniei* Ramanujam (1966). The species of *Araliaceoipollenites* described by Venkatachala and Rawat (1972, 1973) are all different in their size, shape and sculpturing.

Affinity — Araliaceae; related to *Aralia*.

Type Locality — Paravur.

Holotype — Pl. 3, fig. 35; Par. 2; 9·3× 80·4 μm (20·5×15·5 μm).

Genus — *Zonocostites* Germeraad, Hopping & Muller, 1968

Genotype — *Zonocostites ramonae* Germeraad, Hopping & Muller, 1968.

Zonocostites indicus sp. nov.

Pl. 3, fig. 36

Diagnosis — Pollen grains isopolar, subprolate equatorially, poles rounded, 12-16 ×10·5-13 μm; zonaperturate, tricolporate, colpae long, narrow ± straight, margins thin, ends pointed to blunt, ora prominent, lalongate, up to 10 μm across, ora of adjacent colpae touching each other to give a synorate look. Exine 1·5 μm thick, tectate, sexine as thick as nexine, columella distinct near poles, surface psilate to finely granular.

Comments — Occurrence common. *Z. ramonae* Germeraad *et al.* (1968) differs from the present species in its densely perforated tectum with coarseness at poles and fine to almost smooth at the equator. Similar but slightly larger pollen grains have been described from the Miocene of Eniwetok Atoll by Leopold (1969).

Affinity — The fossil grains are related to *Rhizophora*, *Bruguiera* and *Carallia* of Rhizophoraceae. A striking resemblance is seen with the pollen of *Rhizophora mucronata* (Blasco & Caratini, 1973; Muller & Caratini, 1977).

Type Locality — Edavai.

Holotype — Pl. 3, fig. 36; Edv. C_3-6; 21·8×86·6 μm (14×12·5 μm).

Infraturma — *Sphaeroidati* Erdtman, 1953

Genus — *Compositoipollenites* Potonié, 1951

Genotype — *Compositoipollenites rhizophorus* Potonié, 1951.

Compositoipollenites argutus Sah, 1967

Pl. 3, fig. 37

Description — Pollen grains isopolar, amb rounded to subtriangular, polar diameter 24-32 μm (including sculpture), zonaperturate, tricolporate, brevi to medicolpate, colpae obscured generally by heavy ornamentation, margins thickened, ends ± pointed, ora indistinct. Exine up to 5 μm thick, sexine much thicker than nexine, tectate, surface ruggedly echinate, spines robust, 2·5-4 μm high, densely placed, supratectal, base broad, tips pointed.

Comments — This is a stratigraphically important pollen.

Affinity — Compositae, Tubiflorae (Erdtman, 1952; Huang, 1972).

Occurrence — Occasional at Padappakkara and Edavai.

Genus — *Bombacacidites* Couper, 1960

Genotype — *Bombacacidites bombaxoides* Couper, 1960.

Bombacacidites minutus sp. nov.

Pl. 3, fig. 38

Diagnosis — Pollen grains isopolar, amb subtriangular, spheroidal equatorially, polar diameter 18·5-23 μm, planaperturate, tricolporate, brevicolpate, colpae narrow, margins thin, ends blunt, ora slightly lalongate. Exine 1·5 μm thick, sexine as thick as nexine, columella fine, surface finely reticulate.

Comments — Pollen grains of this type are met with occasionally in the Quilon beds. *Bombacacidites minutus* is distinguishable from the other species of this genus in its much smaller size and finely reticulate sculpture. *B. africanus* Sah (1967) and *B. inanus* Venkatachala & Rawat (1973) are much larger.

Affinity — The pollen shows a striking similarity with the pollen of *Bombax* and *Spirotheca* of Bombacaceae (Tsukada, 1964; Fuchs, 1967).

Type Locality — Edavai.

Holotype — Pl. 3, fig. 38; Edv. C_1-21; 17·0×82·6 μm (21·5 μm).

Infraturma — *Oblati* Erdtman, 1943

Genus — *Hippocrateaceaedites* Ramanujam, 1966 emend

Genotype — *Hippocrateaceaedites vancampoae* Ramanujam, 1966.

Emended Diagnosis — Pollen grains oblate to suboblate, amb triangular to subtriangular, tricolporate, longicolpate, in polar view sexine seen prolonged into characteristic knob-like processes on either side of colpus. Colpal margins thickened, ora prominent, rounded to lalongate with a thickened rim interrupted at equator. Exine punctitectate to finely reticulate.

Hippocrateaceaedites quilonensis sp. nov.

Pl. 3, fig. 39

Diagnosis — Pollen grains isopolar, amb triangular, sides convex, polar diameter 18-31 µm, zonaperturate, tricolporate, longicolpate, colpae provided with characteristic prolongation of sexine on either side at its equatorial zone in polar view, ora prominent, lalongate with a distinctly thickened rim. Exine up to 2·5 µm thick, sexine thicker than nexine, tectate, columella distinct, surface finely reticulate (microreticulate), meshes less than 1 µm in diameter.

Comments — *Hippocrateaceaedites vancampoae* Ramanujam (1966) is much larger and has punctitectate exine. *Retitricolporites* (*Favitricolporites*) *ornatus* (Salard-Cheboldaeff, 1974) compared with Hippocrateaceae pollen grains is subprolate and reticulate.

Affinity — The present species shows striking resemblance with the pollen grains of *Loeseneriella* and *Hippocratea* of Hippocrateaceae in size, apertural and sculptural features (van Campo & Halle, 1959, pl. 70, figs 2-4).

Occurrence — Common at Edavai, Padappakkara and Paravur.

Type Locality — Edavai.

Holotype — Pl. 3, fig. 39; Edv. C$_3$-1: 16·4 × 74·6 µm (22·5 µm).

Genus — *Palaeocoprosmadites* Ramanujam, 1966

Genotype — *Palaeocoprosmadites arcotense* Ramanujam, 1966.

Palaeocoprosmadites keralaensis sp. nov.

Pl. 3, fig. 40

Diagnosis — Pollen grains isopolar, amb subtriangular, suboblate equatorially, polar diameter 11-15 µm; zonaperturate, tricolporate, brevissimicolpate, colpae as long as or shorter than ora, ora prominently lalongate, with thickened margin. Exine 1·8 µm thick, sexine as thick as nexine, surface smooth to locally finely granular.

Comments — *Palaeocoprosmadites keralaensis* can be differentiated from *P. arcotense* Ramanujam (1966) in its smaller size and locally finely granular exine.

Affinity — Rubiaceae; pollen shows particular resemblance with the pollen of *Coprosma*.

Type Locality — Edavai.

Holotype — Pl. 3, fig. 40; Edv. CII: 24·3 × 95·6 µm (13 µm).

Genus — *Symplocoipollenites* Potonié, 1951

Genotype — *Symplocoipollenites vestibulum* Potonié, 1951.

Symplocoipollenites crassioratus sp. nov.

Pl. 3, fig. 41

Diagnosis — Pollen grains isopolar, amb triangular, sides ± flat, zonaperturate, polar diameter 24-30 µm, tricolporate, colpae long, slit-like, ora prominent, lalongate and thickened. Exine 1·5 µm thick, sexine as thick as nexine, surface verrucate tuberculate, verrucae small and low at mesocolpia and prominent around apertures.

Comments — Occurrence rare. The triangular amb, narrow slit-like colpae with lalongate thickened ora and the verrucate exine are the important features of this species. Pollen grains similar to *Symplocoipollenites crassioratus* were recorded previously by Stuchlik (1964).

Affinity — Symplocaceae; pollen shows close similarity with the pollen of *Symplocos* (Meijden, 1970; Gupta & Sharma, 1977).

Type Locality — Padappakkara.

Holotype — Pl. 3, fig. 41; Pad. II-8; 14·7 × 92·7 µm (25 µm).

Symplocoipollenites punctatus sp. nov.

Pl. 3, fig. 42

Diagnosis — Pollen grains isopolar, amb triangular, sides convex, polar diameter 16-24 µm, zonaperturate, tricolporate, colpae short, narrow and slit-like with blunt ends, ora prominently thickened and lalongate. Exine 1·5 µm thick, sexine as thick as nexine, surface finely punctate.

Comments — *Symplocoipollenites punctatus* is a common element of the Paravur beds. The triangular amb, short narrow colpae with prominently thickened lalongate ora and finely punctate exine are the characteristic features of this taxon.

Affinity — The pollen resembles the pollen of some species of *Symplocos* (Erdtman, 1952; Meijden, 1970; Gupta & Sharma, 1977).

Type Locality — Paravur.

Holotype — Pl. 3, fig. 42; Par-3; 12·7 ×85·6 μm (18·5 μm).

Genus — *Costatipollenites* Venkatachala & Rawat, 1973

Genotype — *Costatipollenites pauciornatus* Venkatachala & Rawat, 1973.

Costatipollenites pauciornatus Venkatachala & Rawat, 1973

Pl. 3, fig. 43

Description — Pollen grains isopolar, rounded to subtrianglar in polar view, 12-18 μm in diameter; zonaperturate, tricolporate, brevicolpate, ora prominent, margins incrassate. Exine 2 μm thick, sexine thicker than nexine, surface scabrate, scabrae locally vermiculate.

Comments — The genus *Costatipollenites* differs from *Symplocoipollenites* in its rounded to subtriangular amb. This taxon has been previously recorded from the Neogene of the Cauvery basin (Venkatachala & Rawat, 1973).

Affinity — Symplocaceae; pollen comparable with some species of *Symplocos*, viz., *S. cococinea*, *S. costata*, etc. (Meijden, 1970).

Occurrence — Paravur.

Genus — *Margocolporites* Ramanujam, 1966

Genotype — *Margocolporites tsukadai* Ramanujam, 1966.

Margocolporites tsukadai Ramanujam, 1966

Pl. 3, fig. 44

Description — Pollen grains isopolar, amb prominently 3-lobed, lobes widely spaced because of large margocolpae, oblate to sub-oblate equatorially, polar diameter 53·5-57 μm; zonaperturate, tricolporate, longicolpate, margocolpate, colpae 20-22·5 μm across and gaping at equator and tapering towards poles, margo area granular, ora large, lalongate to almost rounded, pouting in polar view at the equator. Exine 3-4, 5 μm thick, sexine much thicker than nexine, surface heavily reticulate, homobrochate, crassimurate, simpli to duplibaculate, brochi large up to 3·5 μm in diameter, hexagonal, lumina smooth.

Affinity — Caesalpiniaceae; pollen shows striking resemblance with the pollen of *Caesalpinia* and *Mezoneuron*.

Occurrence — Common at Padappakkara and Paravur.

Margocolporites oligobrochatus Ramanujam, 1966

Pl. 3, fig. 45

Description — Pollen grains isopolar, amb-rounded triangular, 3-lobed, suboblate equatorially, polar diameter 46-51 μm; zonaperturate, tricolporate, longicolpate, margocolpae 17·5 μm wide and gaping at equator, margo area granular, ora rounded to lalongate, distinctly pouting at equator in polar view, about 7 μm in diameter. Exine up to 4 μm thick, sexine much thicker than nexine, surface ruggedly reticulate, reticulum oligobrochate; homobrochate, brochi large, hexa to polygonal, crassimurate, muri duplibaculate, locally multibaculate, beaded in surface view, lumina angular with a few free baculoid processes.

Comments — *M. vanwijhei* Germeraad *et al.* (1968) is fairly similar to *M. oligobrochatus* but has wider and longer colpae (almost becoming syncolpate) with baculate margin.

Affinity — The fossil taxon shows striking resemblance with the pollen of *Peltophorum* and *Caesalpinia* (Mittre & Sharma 1962; Tsukada, 1964).

Occurrence — Common.

Genus — *Talisiipites* Wodehouse, 1933

Genotype — *Talisiipites fisheri* Wodehouse, 1933.

Talisiipites elegans sp. nov.

Pl. 3, fig. 46

Diagnosis — pollen grains isopolar, oblate equatorially, amb triangular, sides flat, polar diameter 13-20 μm, zonaperturate, tricolporate, medicolpate, colpae narrow, margins thin, ends blunt, ora slightly lalongate, thickened. Exine 1·5 μm thick, sexine as thick as nexine, surface finely granular.

Comments — *Talisiipites wodehousei* Dutta & Sah (1970) is larger and with concave sides, long colpae and finely scabrate surface. *T. retipilatus* Venkatachala & Rawat (1972) is comparable in size and shape but is distinguishable in its finely reticulate exine.

Affinity — Sapindaceae.

Type Locality — Padappakkara.

Holotype — Pl. 3, fig. 46; Pad. II-9; 26·8 × 83·0 μm (17·5 μm).

Occurrence — Common at Edavai and Padappakkara.

Infraturma — *Syncolporiti* Ramanujam, 1966

Genus — *Gothanipollis* Krutzsch, 1959

Genotype — *Gothanipollis gothanii* Krutzsch, 1959.

Gothanipollis indicus sp. nov.

Pl. 3, fig. 47

Diagnosis — Pollen grains isopolar, amb prominently triangular with deeply concave sides, distinctly 3-armed look in polar view, angles truncated and recurved, equatorial view lens-shaped, polar diameter 25-42·5 μm; zonaperturate, tricolporate, syncolporate, ora not prominent, vestibulated, located at truncated apices as seen in polar view. Exine 1·8 μm thick, sexine as thick as nexine, structure indistinct, surface psilate.

Comments — *Gothanipollis gothanii* is smaller. *G. cockfieldensis* Engelhardt (1964) is also much smaller and with granulose exine.

Affinity — The pollen resembles that of *Taxillus* of Loranthaceae.

Type Locality — Padappakkara.

Holotype — Pl. 3, fig. 47; Pad. II-11; 16·0 × 86·1 μm (31 μm).

Occurrence — Frequent at Padappakkara.

Genus — *Cupanieidites* Cookson & Pike, 1954

Genotype — *Cupanieidites orthoteichus* Cookson & Pike, 1954.

Cupanieidites punctatus sp. nov.

Pl. 3, fig. 48

Diagnosis — Pollen grains isopolar, amb triangular, sides convex, polar diameter 19·5-27 μm; zonaperturate, tricolporate, syncolpate, apocolpal area triangular, colpal margins thin, ora slightly incrassate, lalongate. Exine up to 2 μm thick, sexine as thick as nexine, punctitectate, columella indistinct, surface finely punctate.

Comments — *Cupanieidites punctatus* differs from the other species of the genus in its triangular shape with convex sides, possessing a large triangular polar island, and its punctitectate sculpture. *C. major* Cookson & Pike (1954) differs in its reticulate sculpturing and in lacking a polar island. *C. decorus* Venkatachala & Rawat (1973) is again distinctly reticulate. Pollen grains similar to *Cupanieidites* were also previously recorded by Ramanujam (1967).

Affinity — Sapindaceae.

Type Locality — Paravur.

Holotype — Pl. 3, fig. 48; Par. 4: 21·3 × 66·1 μm (23·5 μm).

Occurrence — Common.

Subturma — *Ptychopolyporines* Naumova) Potonié, 1960

Genus — *Sapotaceoidaepollenites* Potonié, Thomson & Thiergart, 1950

Genotype — *Sapotaceoidaepollenites manifestus* Potonié, Thomson & Thiergart, 1950.

Sapotaceoidaepollenites keralaensis sp. nov.

Pl. 3, fig. 49

Diagnosis — Pollen grains isopolar, prolate to subprolate equatorially, polar area smoothly arching, 24-29 × 16-20 μm; zonaperturate, tetracolporate, colpae fairly long, margins thin, ora lalongate. Exine 2·5-3·5 μm thick, sexine as thick as nexine, surface smooth to finely scabrate.

Comments — *S. dakshinii* Venkatachala & Rawat (1973) is smaller and only with three colpae. In the presence of thick exine *S. keralaensis* is distinguishable from the other species of this genus.

Affinity — Sapotaceae; particularly comparable with the pollen of *Manilkara* (Bonnefille, 1971).

Type Locality — Padappakkara.

Holotype — Pl. 3, fig. 49; Pad. II-11; 16·2 × 82·0 μm (26·5 × 10·5 μm).

Occurrence — Abundant.

Sapotaceoidaepollenites africanus Sah, 1967

Pl. 3, fig. 50

Description — Pollen grains isopolar, subprolate to broadly elliptical in equatorial view, poles smoothly rounded, 30-34 × 22-25 μm; zonaperturate, tetracolporate, longicolpate, colpal margins slightly thickened, ora lalongate to slightly lalongate. Exine up to 2 μm thick, sexine thicker than nexine, columella faint, surface smooth to finely granular.

Comments — *Sapotaceoidaepollenites africanus* is an abundant element of the Quilon beds. Exine structure is clearer in the South Indian grains than in the Barundi grains (Sah, 1967).

Affinity — With the pollen of *Pouteria* and *Mimusops* of Sapotaceae (Bonnefille, 1971; Gupta & Sharma, 1977).

Sapotaceoidaepollenites neyveliensis Ramanujam, 1966

Pl. 3, fig. 51

Description — Pollen grains isopolar, prolate equatorially, poles flatly arched, 26-28·5 × 17-21 μm; zonaperturate, tertracolporate, longicolpate, colpae almost extending up to poles, margins slightly thickened, ends pointed to blunt, ora lalongate. Exine 1·8 μm thick, sexine slightly thicker than nexine, surface smooth to locally faintly punctate.

Comments — Ramanujam (1966) described this species as *Sapotaceoidaepollenites neyvelii*. As the specific name is after the locality Neyveli, the specific epithet should be *neyveliensis* and not *neyvelii*.

Affinity — Sapotaceae.

Occurrence — Abundant.

Genus — *Meliapollis* Sah & Kar, 1970

Genotype — *Meliapollis ramanujamii* Sah & Kar, 1970.

Meliapollis quilonensis sp. nov.

Pl. 4, fig. 52

Diagnosis — Pollen grains isopolar, amb rounded to ± squarish, polar diameter 12-17 μm, zonaperturate, tetracolporate, colpae considerably short with thin margins, ends pointed to blunt; ora faint, rounded. Exine 1·5 μm thick, sexine as thick as nexine, columella distinct, surface smooth to locally flecked.

Comments — *Meliapollis* is one of the common elements of the Quilon beds. The present species is smaller than most of the other members of this genus. *Meliapollis minutus* Singh (1977) is larger, squarish to oval and with thickened ora.

Affinity — Melioidae of Meliaceae.

Type Locality — Paravur.

Holotype — Pl. 4, fig. 52; Par-4; 15·2 ×64·0 μm (13·5 μm).

Genus — *Foveostephanocolporites* Leidelmeyer, 1966

Genotype — *Foveostephanocolporites liracostatus* Leidelmeyer, 1966.

Foveostephanocolporites leidelmeyerii

Pl. 4, fig. 53

Diagnosis — Pollen grains isopolar, amb rounded to squarish, polar diameter 20-26 μm, zonaperturate, tetracolporate, colpae of medium length, tenuimarginate, mesocolpal exine extends and arches over colpae, ends blunt, ora prominent, incrassate, slightly lalongate. Exine up to 2 μm thick, sexine as thick as nexine, columella clear, surface foveolate, foveolae closely placed to impart a foveoreticulate look.

Comments — Occurrence occasional. The incrassate ora and the extensions of the mesocolpial exine overarching the colpae are the important features of this taxon. The species is named in honour of Dr P. Leidelmeyer.

Affinity — Labiatae.

Type Locality — Paravur.

Holotype — Pl. 4, fig. 53; Par. 1; 22·9 ×76·7 μm (23·5 μm).

Foveostephanocolporites indicus sp. nov.

Pl. 4, fig. 54

Diagnosis — Pollen grains isopolar, amb spheroidal, polar diameter 25-38 μm; zonaperturate, pentacolporate, brevicolpate, margins thin, ends blunt, ora rounded. Exine up to 2 μm thick, sexine thicker than nexine, surface foveoreticulate, imparting a spongy look to exine.

Comments — *Foveostephanocolporites liracostatus* Leidelmeyer (1966) is distinguishable in its apertural features. Similar is the case with the species described above.

Affinity — Labiatae.

Type Locality — Edavai.

Holotype — Pl. 4, fig. 54; Edv. C_1-6; 7·0 × 87·6 μm (28·5 μm).

Genus — *Padappakkarapollis* gen. nov.

Type Species — *Padappakkarapollis venkatachalae* sp. nov.

Diagnosis — Pollen grains isopolar, amb spheroidal to stellate-spheroidal; stephanocolporate, brevicolpate, colpae 6-8, ora lalongate. Exine differentially sculptured, nexine with undulating or vermiform thickenings, sexine finely pitted.

Comments — *Polybrevicolporites* Venkatachala & Kar (1969) shows general similarities with the present taxon, but lacks the characteristic vermiculate nexinous thickenings.

Padappakkarapollis venkatachalae sp. nov.

Pl. 4, figs 55, 56

Diagnosis — Pollen grains isopolar, amb spheroidal to stellate-spheroidal, polar diameter 38-50 μm; zonaperturate, septacolporate, brevicolpate, colpal margins thin, ends blunt. Ora lalongate with thickened margins. Exine up to 3 μm thick, sexine thicker than nexine, surface differentially sculptured, nexine showing characteristic vermiculate thickenings and sexine finely pitted, pits coalescing at many places to form short canals.

Comments — This is a common pollen type of the Padappakkara samples and is characteristic in its overall morphology. The species is named in honour of Dr B. S. Venkatachala, Oil and Natural Gas Commission, Dehradun.

Affinity — ?Ctenolophonaceae. Irregular nexinous thickenings are seen in the pollen of some recent and fossil members of this family (Saad, 1962; Ramanujam & Purnachandra Rao, 1973).

Type Locality — Padappakkara.

Holotype — Pl. 4, figs 55, 56; Pad. II-10; 22·8 × 72·7 (43·5 μm).

Genus — *Polybrevicolporites* Venkatachala & Kar, 1969

Genotype — *Polybrevicolporites cephalus* Venkatachala & Kar, 1969.

Polybrevicolporites karii sp. nov.

Pl. 4, figs 57, 58

Diagnosis — Pollen grains isopolar, spheroidal and distinctly lobed in polar view, ± rhomboidal in equatorial view, 21-27 × 23-29 μm, zonaperturate, pentacolporate, colpae constricted and arching at equator, tenuimarginate, ends blunt, ora prominent, lalongate, 7·5 μm across, ora of adjacent colpae almost touching each other. Exine up to 3·5 μm thick, thicker at poles than elsewhere, sexine thicker than nexine, tectate, columella distinct, surface intrareticulate with columella below tectum aligned in a reticuloid manner. Mesocolpia with 2-4 prominent thickenings.

Comments — These are occasional elements of the Edavai samples. The species is easily distinguishable from *Polybrevicolporites cephalus* Venkatachala & Kar (1969) in its shape, prominent ora and intra-reticulate exine.

Affinity — Polygalaceae. The species is named in honour of Dr R. K. Kar, Birbal Sahni Institute of Palaeobotany, Lucknow.

Type Locality — Edavai.

Holotype — Pl. 4, figs 57, 58; Edv. L-23; 9·0 × 24·7 μm (26 × 23·5 μm).

Genus — *Polygalacidites* Sah & Dutta, 1966

Genotype — *Polygalacidites clarus* Sah & Dutta, 1966.

Polygalacidites singularis Sah, 1967

Pl. 4, fig. 59

Description — Pollen grains isopolar, prolate, poles somewhat flattened to smoothly arched, 20-28 × 17-22 μm; zonaperturate, longicolpate, pentacolporate, colpae narrow, margins thin, ora prominently lalongate almost becoming synorate. Exine 1·5 μm thick, surface smooth.

Affinity — Polygalaceae.

Occurrence — Rare.

Subturma — *Triporines* (Naumova) Potonié, 1960

Genus — *Triporopollenites* (Pflug) Thomson & Pflug, 1953

Genotype — *Triporopollenites coryloides* Thomson & Pflug, 1953.

Triporopollenites minutus sp. nov.

Pl. 4, fig. 60

Diagnosis — Pollen grains isopolar, amb triangular, sides convex, polar diameter 12-16·5 μm; zonaperturate, triporate, pores ± circular, small (up to 2 μm) with annulus. Exine 1·8 μm thick, sexine as thick as nexine, slightly thickened around pores to form annulus, surface smooth to finely granular.

Comments — *Triporopollenites simplex* and *T. plicata* (Ramanujam, 1966) from the Neyveli lignite are larger. *T. triangularis* Sah (1967) is with prominently aspidote pores and finely reticulate sculpture. The present species has been encountered only occasionally in Padappakkara samples.

Affinity — Moraceae; closely resembles the pollen of *Ficus* and *Artocarpus*.

Type Locality — Padappakkara.

Holotype — Pl. 4, fig. 60; Pad. II-3; 19·5 × 89·0 μm (13·5 μm).

Genus — *Triorites* (Erdtman & Cookson) ex Couper, 1953

Genotype — *Triorites magnificus* Cookson, 1950.

Triorites microreticulatus sp. nov.

Pl. 4, fig. 61

Diagnosis — Pollen grains isopolar, amb subtriangular, sides convex, 13-18 μm; zonaperturate, triporate, pores 2-3 μm, pouting at equator, prominently aspidote. Exine 1·5 μm thick, surface microreticulate.

Comments — The above pollen type is a rare element of the microflora. *Triorites magnificus* Cookson (1950) is considerably larger. Similar is the case with *T. communis* Sah & Dutta (1966) and *T. inferius* Dutta & Sah (1970). *T. tubiferus* Venkatachala & Rawat (1972) is more distinctly triangular and larger.

Affinity — The apertural features of the fossil pollen suggest a possible affinity with the members of Onagraceae. But for their smaller size, the fossil pollen resembles the pollen of *Jussieua*.

Type Locality — Padappakkara.

Holotype — Pl. 4, fig. 61; Pad. II-10; 16·4 × 71·9 μm (15·5 μm).

Genus — *Myricipites* Wodehouse, 1933

Genotype — *Myricipites dubius* Wodehouse, 1933.

Myricipites harrisii (Couper) Venkatachala & Rawat, 1973

Pl. 4, fig. 62

Description — Pollen grains isopolar, amb triangular to subtriangular, sides flat to slightly convex, polar diameter 22-26 μm; zonaperturate, triporate, pores up to 3 μm, pore margin slightly incrassate, pores aspidote. Exine 1·5 μm thick, sexine as thick as nexine, surface smooth to finely scabrate.

Comments — *Myricaceoipollenites* Potonié (1951) is distinguishable from *Myricipites* Wodehouse (1933) in its apertural features only. In *Myricipites*, the pores are aspidote and protruding beyond the equatorial margin when compared to the former taxon. *M. harrisii* pollen grains have been encountered commonly in the Quilon beds.

Affinity — Myricaceae; closely resembles the pollen of *Myrica nagi* and *M. farquhariana*.

Genus — *Casuarinidites* Cookson & Pike, 1954

Genotype — *Casuarinidites cainozoicus* Cookson & Pike, 1954.

Casuarinidites sp.

Pl. 4, fig. 63

Description — Pollen grains isopolar, amb rounded triangular, sides convex, polar diameter 26-30 μm; zonaperturate, triporate, pores circular to ellipsoidal, 3-4 μm, aspidote, pore rim slightly thickened. Exine 1·5 μm thick, surface granular to flecked.

Comments — The genus *Casuarinidites* is triporate, oblate pollen with a subcircular amb and convex sides, and aspidote circular to slightly ellipsoidal pores; the surface is finely and indistinctly patterned. Only a few grains of this were encountered in the Quilon beds.

Affinity — Casuarinaceae.

Genus — *Maculoporites* Venkatachala & Rawat, 1973

Genotype — *Maculoporites reticulatus* Venkatachala & Rawat, 1973.

Maculoporites quilonensis sp. nov.

Pl. 4, figs 64-66

Diagnosis — Pollen grains isopolar, amb rounded triangular, sides convex, polar diameter 20-28 µm; zonaperturate, triporate, pores up to 3 µm, with conspicuous annuli. Exine 1·5 µm thick, sexine as thick as nexine, surface finely reticulate, meshes polygonal, fine, up to 1·5 µm across, lumina smooth.

Comments — *M. reticulatus* Venkatachala & Rawat (1973) is much larger and more rounded in polar view.

Type Locality — Padappakkara.

Holotype — Pl. 4, fig. 64; Pad. II-10; 18·8×104·9 µm (21 µm).

Occurrence — Common to abundant.

Genus — *Verrutriporites* Muller, 1968

Genotype — *Verrutriporites lunduensis* Muller, 1968.

Verrutriporites perverrucatus sp. nov.

Pl. 4, figs 67, 68

Diagnosis — Pollen grains isopolar, amb subtriangular, sides convex, polar diameter 16-23 µm; zonaperturate, triporate, pores aspidote, 2-3 µm, pore margin bearing verrucae. Exine 1·5 µm thick, sexine slightly thicker than nexine, surface verrucate, verrucae sparse, of low height.

Comments — This is one of the dominant elements of the Quilon sediments. *Verrutriporites lunduensis* is spherical with closely placed verrucae.

Affinity — The fossil grains show remarkable resemblance with the pollen of *Duabanga moluccana* of Sonneratiaceae (Thanikaimoni & Jayaweera, 1966).

Type Locality — Padappakkara.

Holotype — Pl. 4, fig. 67; Pad. II-8; 15·0×90·4 µm (19·5 µm).

Verrutriporites vermiculatus sp. nov.

Pl. 4, figs 69, 70

Diagnosis — Pollen grains isopolar, amb subtriangular, 20-28 µm; zonaperturate, triporate, pore margins beset with small verrucae. Exine 1·5 µm thick, finely verrucate-vermiculate, verrucae low, placed closely and irregularly in vermiculate pattern; verrucae in vermiculate rows coalesce locally.

Comments — This is a common element of the Padappakkara samples and has a characteristically verrucate-vermiculate exine.

Type Locality — Padappakkara.

Holotype — Pl. 4, fig. 69; Pad. IV-11; 14·0×90·4 µm (20 µm).

Genus — *Echitriporites* Hoeken-Klinkenberg, 1964

Genotype — *Echitriporites trianguliformis* Hoeken-Klinkenberg, 1964.

Echitriporites sp.

Pl. 4, fig. 71

Description — Pollen grains isopolar, amb subspheroidal to rounded triangular, polar diameter 16-22 µm; zonaperturate, triporate, pores up to 3 µm, prominently annulate, annulus up to 2 µm thick. Exine 1·5 µm thick, surface densely spinulose, spinules sharply pointed.

Comments — The specimens differ from *E. trianguliformis* Hoeken-Klinkenberg (1964) in smaller size, more rounded amb and prominently annulate pores. *E. irregularis* Muller (1968) is larger and with more scattered spines.

Occurrence — Rare at Edavai.

Genus — *Ornatriporites* gen. nov.

Type Species — *Ornatriporites elegans* sp. nov.

Diagnosis — Pollen grains isopolar, subtriangular to rounded triangular, triporate, pore margin ornate, beset with prominent gemmae or tubercles. Exine intectate, surface gemmate-tuberculate; locally confluent to form vermiform to cribellate structures.

Comments — *Verrutriporites* Muller (1968) is triporate with verrucate exine. *Echitriporites* Hoeken-Klinkenberg (1964) is triporate and echinate. *Pistillipollenites* (see

Rouse & Srivastava, 1970) is a circular to broadly subtriangular triporate pollen studded with gemmae, each pore being bordered by two prominent gemmae or tubercles.

Ornatriporites elegans sp. nov.

Pl. 4, figs 72, 73

Diagnosis — Pollen grains isopolar, amb subtriangular, sides convex, polar diameter 18-24 μm; zonaperturate, triporate, pores up to 3 μm, pore margin incrassate, ornate, studded with 4-6 prominent gemmae or tubercles. Exine up to 3·5 μm thick, intectate, surface gemmate-tuberculate, processes up to 2·5 μm high, densely placed all over, locally anastomosing to form vermiform or cribellate structures.

Comments — Pollen grains of this type are common elements in the Quilon beds, particularly near Edavai.

Holotype — Pl. 4, fig. 72; Edv. C_1-3; 16·7×77·4 μm (20 μm).

Genus — *Proteacidites* Cookson ex Couper, 1953

Genotype — *Proteacidites adenanthoides* Cookson, 1950.

Proteacidites retusus Anderson, 1960

Pl. 4, fig. 74

Description — Pollen grains isopolar, amb triangular, sides flat to convex, polar diameter 18-25 μm, zonaperturate, triporate, pores 2·5-3·5 μm, slightly protruding, pore margin incrassate. Exine 1·8 μm thick, sexine thicker than nexine, tectate, surface finely reticulate-foveolate.

Comments — This is an occasional element. *Proteacidites cooksonii* Salard-Cheboldaeff (1978) while resembling the present taxon, has larger pores and finely perforate exine.

Affinity — Proteaceae.

Proteacidites truncatus Cookson, 1950

Pl. 5, fig. 75

Description — Pollen grains isopolar, amb triangular, sides flat, angles truncated, polar diameter 45-55 μm; zonaperturate, triporate, pores equatorially extended, up to 7·5 μm across, pore margin thin. Exine 3-3·8 μm thick, sexine much thicker than nexine, tectate, columella distinct, surface coarsely reticulate, reticulum homobrochate, brochi polygonal to irregular, muri up to 2·5 μm high, meshes occasionally discontinuous, lumina irregular.

Comments — This has been encountered rarely in the Quilon beds. *Proteacidites adenanthoides* Cookson (1950) is slightly smaller, indistinctly and delicately reticalate and with convex sides. *P. protrudus* Sah & Kar (1970) is comparable with the present species in the nature of its apertures, but differs in having finely scrobiculate exine. *P. granulosus* Venkatachala & Rawat (1973) is smaller with granulose exine.

Genus — *Thomsonipollis* Pflug & Thomson ex Krutzsch, 1968

Genotype — *Thomsonipollis magnificus* Pflug & Thomson, 1953.

Thomsonipollis sp.

Pl. 5, fig. 76

Diagnosis — Pollen grains isopolar or subisopolar, amb rounded, polar diameter 30-38 μm; triporate, pores rounded, equatorial, occasionally subequatorial, 6-10 μm with prominent annuli. Exine up to 2·2 μm thick, surface finely granular to smooth.

Comments — These are fairly common in the Padappakkara samples. *Thomsonipollis paleocenicus* Elsik (1968) differs from the present species in its smaller size, subtriangular amb and prominently invaginated pores. *T. variornatus* from the Neogene of Cauvery basin (Venkatachala & Rawat, 1973) has a coarsely granulate exine. This is a rare element of the Quilon beds.

Affinity — The fossil pollen shows resemblance with the pollen of *Palaquium ellipticum* of Sapotaceae (Gupta & Sharma, 1977). The pollen grains of *P. ellipticum* are, however, smaller than the fossil taxon.

Occurrence — Fairly common at Padappakkara.

Subturma — *Polyporines* (Naumova) Potonié, 1960

Infraturma — *Stephanoporites* (Hammen) Potonié, 1960

Genus — *Tetrapollis* Pflug, 1953

Genotype — *Tetrapolis validus* Pflug (in Thomson & Pflug) 1953.

Tetrapolis sp.

Pl. 5, fig. 77

Description — Pollen grains isopolar, amb roundly squarish, polar diameter 18-22 μm; zonaperturate, tetraporate, pores up to 2 μm with knob-like thickenings near pore margin. Exine 1·5 μm thick, tectate, surface psilate.

Comments — Only two specimens of this pollen type were encountered in the Padappakkara samples. *Tetrapollis* sp. of Venkatachala and Rawat (1972) does not possess any knob-like thickenings around the pores.

Tetrapollis rotundus sp. nov.

Pl. 5, fig. 78

Diagnosis — Pollen grains isopolar, amb spheroidal, polar diameter 18-22 μm; zonaperturate, tetraporate, pores up to 2·5 μm, pore margin provided with nexinous thickenings. Exine 1·5 μm thick, sexine as thick as nexine, surface psilate.

Comments — Rounded amb and the nexinous thickenings around the pores are the characteristic features of this taxon.

Type Locality — Padappakkara.

Holotype — Pl. 5, fig. 78; Pad. II-3; 22·8 × 90·1 μm (22 μm).

Occurrence — Occasional at Padappakkara.

Genus — *Haloragacidites* Couper, 1953

Genotype — *Haloragacidites trioratus* Couper, 1953.

Haloragacidites verrucatus sp. nov.

Pl. 5, fig. 79

Diagnosis — Pollen grains isopolar, amb spheroidal, mesoporia flat to slightly convex, polar diameter 16-22 μm; zonaperturate, tetraporate, pores ellipsoidal to rounded, aspidote, pouting, up to 4·5 μm across including aspis. Exine 1·8 μm thick, tectate, sexine thicker than nexine, surface verrucate, verrucae small, fine and closely placed.

Comments — *Haloragacidites myriophylloides* Cookson & Pike (1954), which is faintly verrucate, is larger and with 3-5 pores.

Affinity — Haloragaceae (*Myriophyllum*).

Type Locality — Edavai.

Holotype — Pl. 5, fig. 79; Edv. C_1-1; 23·8 × 88·0 μm (19 μm).

Genus — *Clavaperiporites* Ramanujam, 1966

Genotype — *Clavaperiporites jacobi* Ramanujam, 1966.

Clavaperiporites jacobi Ramanujam, 1966

Pl. 5, figs 80, 81

Description — Pollen grains spheroidal, polar diameter 45-50 μm; pantoporate, pores circular, many, 2-4 μm, usually obscured by heavy ornamentation. Exine 4·5 μm thick, tectate, sexine much thicker than nexine, densely clavate, clava 3·5-4 μm high, heads mostly triangular, clava aligned in a reticuloid manner (crotonoid pattern).

Comments — *Buxaceaepollenites* (Sah, 1967) and *Thymelaepollis* (Sah & Kar, 1970) are strikingly similar in their generic circumscriptions with *Clavaperiporites* and may be junior synonyms of the latter. *Erdtmanipollis* which also seems to be similar to *Clavaperiporites* is, however, intectate and baculate (Krutzsch, 1962).

Affinity — Crotonoid pattern of sculpture as exhibited by the above fossil pollen is seen in the families Euphorbiaceae, Buxaceae and Thymeliaceae. In the Crotonoidae of Euphorbiaceae, where crotonoid pattern of sculpture is seen, the pollen grains are inaperturate. The pollen grains of Buxaceae and Thymeliaceae are, however, similar to the fossil pollen. The Padappakkara grains show particular resemblance with the pollen of Thymeliaceae and appear to be related to *Wikstromia* (Selling, 1947).

Occurrence — Common at Padappakkara.

Genus — *Anacolosidites* Cookson & Pike, 1954

Genotype — *Anacolosidites luteoides* Cookson & Pike, 1954.

Anacolosidites luteoides Cookson & Pike, 1954

Pl. 5, figs 82, 83

Description — Pollen grains isopolar, amb subtriangular, angles rounded, sides slightly concave, polar diameter 16-25 μm, 6-porate, (3-diploporate), three pores in each hemisphere and aligned in a triangle, pores subequatorial, circular to broadly elliptical, 3-4 μm across, margins slightly thickened. Exine 1·5 μm thick, slightly thicker at sides, surface smooth.

Comments — The Indian specimens are generally smaller as compared to the Australian ones.

Affinity — The fossil pollen shows striking resemblance with the pollen of *Anacolosa* of Olacaceae.

Occurrence — Common at Edavai, Padappakkara and Paravur.

Turma — *Jugates* Erdtman, 1960
Subturma — *Tetradites* Cookson, 1947

Genus — *Inaperturotetradites* Hoeken-Klinkenberg, 1964

Genotype — *Inaperturotetradites lacunosus* Hoeken-Klinkenberg, 1964.

Inaperturotetradites psilatus sp. nov.

Pl. 5, fig. 84

Diagnosis — Pollen grain in rhomboidal tetrads, 37-49 × 42 μm; individual grains oblate equatorially, 18-21·5 × 17-26 μm; inaperturate. Exine 1·8 μm thick, surface psilate to finely scabrate.

Comments — The rhomboidal nature of the tetrads and the psilate exine are the important features of this pollen type. *Inaperturotetradites lacunosus* shows distinct reticulate sculpture (Hoeken-Klinkenberg, 1964; Salard-Cheboldaeff, 1978).

Type Locality — Padappakkara.

Holotype — Pl. 5, fig. 84; Pad. II-10; 22·6 × 77·4 μm (48 × 35·5 μm).

Genus — *Ornatetradites* gen. nov.

Type Species — *Ornatetradites droseroides* sp. nov.

Diagnosis — Pollen grains in tetrahedral tetrads, individual grains rounded to suboblate, porate; pores 4-8 or more, usually indistinct and masked by heavy ornamentation; confined more towards proximal facets. Exine tectate, clavate, gemmate or verrucate, surface between sculptural elements punctate.

Comments — *Dicotetradites* Couper (1953) includes tetrads of tricolporate pollen grains with clavate-baculate elements and a reticulate sculpture. In *Droseridites* Cookson (1947) the pollen grains are apparently nonaperturate and bear spines or spinules. *Triporotetradites* Hoeken-Klinkenberg (1964) contains tetrads of psilate triporate pollen grains. *Polyporotetradites* Salard-Cheboldaeff (1978) incorporates tetrads of polyporate, psilate pollen grains.

Ornatetradites droseroides sp. nov.

Pl. 5, figs 85, 86

Diagnosis — Pollen grains in tetrahedral tetrads, tetrads 34-45 μm, individual grains rounded to suboblate equatorially, 15-25 × 20-27 μm; porate, pores up to 8, somewhat obscured by closely placed sculptural process, confined more towards proximal facets, circular to flattened, 2·5 to 3 μm across, with thin margins. Exine up to 3·5 μm thick, sexine thicker than nexine, tectate, columella distinct, appearing as radial striae at the periphery of the pollen; supratectal ornamentation gemmate-tuberculate; gemmae up to 2·5 μm high, rather densely placed all over, surface in between gemmae rugulate-punctate.

Comments — Tetrads of *Ornatetradites droseroides* were abundantly found in some Padappakkara samples and constitute a characteristic element of the Quilon microflora.

Affinity — Droseraceae (Chanda, 1965; Raj, 1970; Huang, 1972). The tetrahedral tetrads, presence of pores with faint margins masked by sculpture towards proximal facets and the overall sculptural pattern of the fossil pollen indicate its affinities with certain species of *Drosera*.

Type Locality — Padappakkara.

Holotype — Pl. 5, fig. 85; Pad. II-12; 16·2 × 83·6 μm (42·5 μm).

Ornatetradites chandae sp. nov.

Pl. 5, figs 87, 88

Diagnosis — Pollen grains in tetrahedral tetrads, occasional with a tendency towards rhomboidal nature, 35-43 μm; individual grains rounded, 16-23·5 × 18·5-25 μm; porate, pores 4-6, rounded to ellipsoidal, confined more towards proximal facets, tenuimarginate, obscured by heavy sculptural elements. Exine up to 3 µm thick, tectate, columella distinct, surface verrucate, verrucae up to 2 µm high, surface between verrucae psilate to finely punctate.

Comments — This has been found in Padappakkara and Edavai samples. The species is named in honour of Dr Sunirmal Chanda, Bose Institute, Calcutta.

Affinity — Droseraceae.

Type Locality — Padappakkara.

Holotype — Pl. 5, fig. 87; Pad. II-11; 14·3×76·2 µm (41·5 µm).

Genus — *Droseridites* Cookson emend. Potonié, 1960

Genotype — *Droseridites spinosa* Cookson, 1947.

Droseridites sp.

Pl. 5, fig. 89

Description — Pollen grains in loose tetrahedral tetrads, 20-25 µm, individual grains rounded, 10-13×15-17 µm; apparently inaperturate, but faint indication of few pores confined towards proximal facets in some specimens. Exine up to 2·5 µm thick, sexine thicker than nexine, tectate, surface with spinose-baculate processes, 1·5 µm high, uniformly distributed all over.

Comments — This is an occasional element of the Edavai samples.

Affinity — ?Droseraceae; in Droseraceae, however, the pollen grain are generally porate, although the pores are marked by the heavy sculptural elements.

DISCUSSION

The Quilon beds of Kerala, consisting of limestones, calcareous clays, carbonaceous clays and sands, exhibit a variety of spores of pteridophytes and pollen grains of angiosperms. In addition to these, a sizeable number of fungal spores and fruiting bodies and hystrichosphaerids have also been recorded from these beds (Jain & Gupta, 1970; Ramanujam & Rao, 1976; Rao & Ramanujam, 1975, 1976). No recognizable gymnospermous pollen grains (saccate or nonsaccate) are, however, encountered by the authors in any of the samples studied. This discussion is based upon the information contained in both parts of the investigation.

Floristic Analysis — The pteridophytes in the Quilon microflora are represented by 14 genera and 20 species, belonging to Lycopodiaceae, Gleicheniaceae, Ophioglossaceae, Schizaeaceae, Dicksoniaceae and Polypodiaceae. Of these, polypodiaceous spores are the abundant ones, followed by the schizaeaceous types. *Polypodiisporites* constitutes qualitatively and quantitatively the predominant taxon. The bulk of the Quilon microflora consists of angiospermous pollen. The monocotyledons are represented by 17 genera and 27 species, and the dicotyledons by 54 genera and 62 species.

The pollen of the monocotyledons are referable to Potamogetonaceae, Aroidae, Palmae, Liliaceae, Lemnaceae and Graminae. The predominant taxon among these is Palmae.

The spinascent and reticulate monosulcate pollen types, such as *Couperipollis*, *Spinizonocolpites*, *Longapertites*, *Quilonipollenites* and *Proxapertites* are abundantly represented; these are followed by the reticulate, inaperturate *Retipilonapites*.

The dicotyledonous pollen types are referable to the families, viz., Euphorbiaceae, Dipterocarpaceae, Caesalpiniaceae, Oleaceae, Ebenaceae, Combretaceae, Loranthaceae, Lecythidaceae, Rubiaceae, Araliaceae, Symplocoaceae, Rhizophoraceae, Caprifoliaceae, Compositae, Ctenolophonaceae, Labiatae, Sapindaceae, Meliaceae, Hippocrateaceae, Sapotaceae, Polygalaceae, Moraceae, Sonneratiaceae, Onagraceae, Proteaceae, Casuarinaceae, Myricaceae, Haloragaceae, Olacaceae, Thymeliaceae and Droseraceae. Of these, the more commonly represented families are, viz., Euphorbiaceae, Caesalpiniaceae, Sapotaceae, Combretaceae, Rhizophoraceae, Sapindaceae, Lecythidaceae, Hippocrateaceae, Olacaceae, Ctenolophonaceae, Myricaceae and Droseraceae.

Among the dicotyledonous pollen types, 3- or 4-colporate and 3-porate ones constitute the predominant elements. The polycolpate (colporate) grains too represent a fair proportion of this palynoassemblage.

The following is the break up of the known botanical affinities of the various spore and pollen taxa recovered from the Quilon beds.

PTERIDOPHYTES

Lycopodiaceae (*Lycopodium*)	*Verrucosisporites*
Ophioglossaceae (*Ophioglossum*)	*Foveosporites*
Dicksoniaceae	*Cibotiidites*
Schizaeaceae	*Lygodiumsporites, Schizaeoisporites, Crassoretitriletes*
Gleicheniaceae (*Gleichenia*)	*Gleicheniidites*
Polypodiaceae (*Pteris, Adiantum* and other taxa)	*Pteridacidites, Laevigatosporites, Polypodiisporites*

ANGIOSPERMS

Monocotyledons

Potamogetonaceae (*Potamogeton*)	*Retipilonapites, Clavainaperturites*
Liliaceae (*Lilium, Nomocharis*)	*Liliacidites, Crotonisulcites*
Palmae (*Cocos, Areca, Hyphene, Nipa, Calamus, Metroxylon, Iriartea,* etc.)	*Palmaepollenites, Arecipites, Couperipollis* (some spp.) *Clavapalmaedites, Spinizonocolpites, Verrumonocolpites, Paravuripollis, Longapertites, Quilonipollenites, Dicolpopollis*
Aroidae	*Spinainaperturites*
Lemnaceae (*Lemna*)	*Spinamonoporites*
Gramineae	*Monoporopollenites*

Dicotyledons

Euphorbiaceae	*Crotonoidaepollenites, Crototricolpites*
Dipterocarpaceae (*Dipterocarpus*)	*Retitrescolpites, Dipterocarpoides*
Oleaceae	*Retitrescolpites* (some spp.) *Retitricolpites* (some spp.)
Combretaceae (*Lumnitzera*)	*Heterocolpites*
Ebenaceae (*Diospyros*)	*Psilatricolpites ebenoides*
Loranthaceae (*Loranthus, Dendrophthoe*)	*Loranthipites, Gothanipollis*
Rubiaceae (*Randia, Coprosma*)	*Retitricolporites crassioratus, Palaeocoprosmadites*
Caesalpiniaceae (*Caesalpinia, Peltophorum, Mezoneuron*)	*Retitrescolpites* (some spp.), *Margocolporites*
Sapindaceae	*Talisiipites, Cupanieidites*
Araliaceae (*Aralia*)	*Araliaceoipollenites*
Symplocaceae (*Symplocos*)	*Symplocoipollenites, Costatipollenites*
Rhizophoraceae (*Rhizophora*)	*Zonocostites*
Bombacaceae (*Bombax*)	*Bombacacidites*
Hippocrateaceae (*Hippocratea*)	*Hippocrateaceaedites*
Caprifoliaceae	*Cauveripollis*
Compositae (Tubiflorae)	*Compositoipollenites*
Ctenolophonaceae (*Ctenolophon*)	*Ctenolophonidites*
Labiatae	*Polycolpites, Retistephanocolpites*
Meliaceae	*Meliapollis*
Sapotaceae (*Manilkara, Mimusops, Pouteria*)	*Sapotaceoidaepollenites*
Myricaceae (*Myrica*)	*Myricipites*
Casuarinaceae (*Casuarina*)	*Casuarinidites*
Sonneratiaceae (*Duabanga*)	*Verrutriporites perverrucatus*
Proteaceae	*Proteacidites*
Haloragaceae (*Myriophyllum*)	*Haloragacidites*
Onagraceae (*Jussieua*)	*Triorites microreticuloides*
Olacaceae (*Anacolosa*)	*Anacolosidites*
Thymelaeaceae (*Wikstroemia*)	*Clavaperiporites*
Droseraceae (*Drosera*)	*Ornatetradites, Droseridites*

The following spore and pollen genera have been found to be commonly to abundantly represented in the Quilon beds: *Verrucosisporites, Polypodiisporites* (abundant), *Retipilonapites* (abundant), *Couperipollis* (abundant), *Clavapalmaedites* (abundant), *Paravuripollis* (abundant), *Longapertites* (abundant), *Quilonipollenites, Palmaepollenites, Dicolpopollis* (abundant), *Retitricolpites* (abundant), *Retitrescolpites* (abundant), *Foveotricolpites, Ctenolophonidites* (abundant), *Zonocostites*(abundant), *Heterocolpites, Marginipollis, Hippocrateaceaedites* (abundant), *Margocolporites* (abundant), *Sapotaceoidaepollenites* (abundant), *Talisiipites, Verrutriporites* (abundant), *Maculoporites* (abundant), *Myricipites, Anacolosidites, Clavaperiporites,* and *Ornatetradites* (abundant).

COMPARISON OF QUILON MICROFLORA WITH OTHER NEOGENE MICROFLORAS

Neyveli Microflora — A rich assemblage of spores, pollen grains and diverse fungal remains has been recorded from the Neyveli lignite of the South Arcot District of Tamil Nadu in South India (Thiergart & Frantz, 1962; Ramanujam, 1963a, 1963b, 1966, 1966-67, 1974; Ramanujam & Ramachar, 1963; Navale, 1961, 1973; Urmila Deb, 1972; Kalavathi, 1977). The diversity and richness of the pteridophytic spores, the predominance of the angiospermous pollen and the general absence of the gymnospermous pollen are common in the Quilon and Neyveli assemblages. The following genera are common to both the assemblages: *Laevigatosporites*, *Verrucosisporites*, *Crassoretitriletes*, *Polypodiisporites* (= *Polypodiidites*), *Schizaeoisporites*, *Retipilonapites*, *Spinainaperturites*, *Arecipites*, *Palmaepollenites*, *Liliacidites*, *Dicolpopollis* (= *Disulcites*), *Quilonipollenites*, *Longapertites*, *Polycolpites*, *Psilatricolporites*, *Araliaceoipollenites*, *Hippocrateaceaedites*, *Zonocostites**, *Symplocopollenites*, *Palaeocoprosmadites*, *Retitricolpites*, *Polygalacidites**, *Margocolporites*, *Sapotaceoidaepollenites*, *Padappakkarapollis**, *Ctenolophonidites**, *Marginipollis**, *Polygonacidites**, *Maculoporites**, *Proteacidites*, *Anacolosidites**, *Meliapollis* = *Tetracolporites*), *Polycolpites*, *Retistephanocolpites**, *Monoporopollenites*, *Triporopollenites*, *Haloragacidites*, *Clavaperiporites* and *Inaperturotetradites* (* — information from Dr G. K. B. Navale and the work in progress in our own lab.) The Quilon microflora on the whole appears to be more varied and richer than that of the Neyveli lignite.

Microflora of the Cauvery Basin — The Neogene microflora of the Cauvery basin has been studied recently by Venkatachala and Rawat (1973). The Quilon microflora shows significant similarities with that of the Cauvery basin. *Verrucatosporites* (= *Polypodiisporites*), *Cauveripollis*, *Maculoporites*, *Costatipollenites*, *Sapotaceoidaepollenites*, *Bombacacidites*, *Foveotricolpites*, *Palaeocoprosmadites*, *Proteacidites*, *Talisiipites*, seen commonly in Lower to Middle Miocene of the Cauvery basin, are also known from the Quilon beds. Further, a number of taxa common to both Palaeogene and Neogene of the Cauvery basin have also been recorded from the Quilon beds. The hystrichosphaerids recorded from the Quilon beds are known from the Oligocene-Lower Miocene sediments of the Cauvery basin.

Despite the close similarity between the microfloral assemblages of the Quilon beds and the Lower to Middle Miocene of the Cauvery basin, one difference looms, i.e. the presence of a number of polycolpate (or colporate) pollen types and the absence of the saccate coniferous pollen in the former. *Magnastriatites* spores and *Malvacearumpollis* pollen known from the Neogene of the Cauvery basin are also not found in the Quilon sediments.

Neogene Microfloras of Assam and Bengal — The microfloral complexes of the Miocene and Pliocene (Surma, Tipam & Dihing series) of Assam have been studied by Baksi (1962), Banerjee (1964), Sah and Dutta (1968), Sah and Singh (1977), and Salujha, Kindra and Rehman (1977). The beginning of the Miocene in Assam is recognized by an abundance of bisaccate coniferous pollen, and the frequent occurrence of Parkeriaceae spores and *Polygonacidites*. But for the Parkeriaceae spores and the coniferous pollen most of the other palynotaxa known from the Lower Miocene of Assam are also known from the Quilon beds.

A comparison of the microfloral assemblages of palynological zones of the Bengal Basin (Baksi, 1972, 1974) with that of the Quilon beds indicates a general similarity of the palynological Zone V (representing the Miocene age) of the former with the spore and pollen complex of the latter, in the following criteria, viz. (i) presence of *Barringtonia* (= *Marginipollis*) pollen, (ii) great abundance of the tricolpate (colporate) and triporate pollen, (iii) fairly abundant occurrence of the spinose monosulcate pollen, and (iv) the presence of hystrichosphaerids.

Microflora of Barundi (*Africa*) — The Miocene-Pliocene microflora of the Rusizi Valley, Barundi (Sah, 1967) shows a close agreement with that of the Quilon sediments. The pteridophytic spores such as *Pteridacidites*, *Cibotidites*, *Cingulatisporites*, *Foveasporites*, and *Polypodiisporites* are common to both these microfloras. Among the angiospermic pollen types, the following are common to both the Quilon and Barundi palynoassemblages, viz., *Palmaepollenites*, *Arecipites*, *Retipilonapites*, *Retitrescolpites*, *Compositoipollenites*, *Bombacacidites*, *Sapotaceoidaepollenites*, *Proteacidites*, *Meliapollis* (= *Tetracolporites*), *Polycolpites*, *Spinamonoporites*, *Anacolosidites* and *Triporopollenites*. Saccate coniferous grains recorded from the Neogene of Barundi, however, have not been recorded from the Quilon beds.

Thus, on the whole, the spore and pollen complex of the Quilon beds exhibits a significant resemblance with the Neogene microfloras of the Neyveli lignite, Cauvery basin and Rusizi Valley of Barundi. At the same time, a number of taxa are rather peculiar to Quilon beds, viz., *Crotonoidae-*

pollenites, *Clavapalmaedites*, *Crotonisulcites*, *Paravuripollis*, *Quilonipollenites*, *Heterocolpites*, *Loranthipites*, *Ornatriporites* and *Ornatetradites*.

PALYNOLOGY AND GEOLOGICAL AGE OF THE QUILON BEDS

Jacob and Sastry (1952) on foraminiferal evidence assigned a Burdigalian (Lower Miocene) age to the Quilon limestones. Dey (1962) assigned a Vindobanian age (Middle Miocene) to the Quilon limestones on the basis of molluscs. Poulose and Narayana Swamy (1968) opined that the Burdigalian age assigned by Jacob and Sastry (1952) for the bore-hole cores and the Vindobanian age assigned by Dey (1962) for the topmost limestone beds (outcrops) at Padappakkara, probably constitutes the lower and upper age limits for the Quilon beds. Rao and Dutta (1976) support the Burdigalian age of the Quilon beds on the basis of foraminifers and ostracods.

The spore and pollen complex of the Quilon beds, as has been pointed out in previous pages, agrees significantly with the Neogene microfloral assemblages of India and Africa. The profusion of *Polypodiisporites*, coupled with the occurrence of *Crassoretitriletes*, *Pteridacidites*, *Intrabaculisporis* and *Eximospora* among the pteridophytes when taken in conjunction with the presence of *Dicolpopollis* (abundant), *Cauveripollis*, *Maculoporites*, *Compositoipollenites*, *Hippocrateaceaedites*, *Retitricolpites dipterocarpoides* and the abundance of the pollen types of Caesalpiniaceae, Sapotaceae and Droseraceae also point unequivocally towards the Miocene age for these beds. The abundance of *Dicolpopollis* and pollen grain of Caesalpiniaceae and Sapotaceae is characteristic of the Miocene floras of south-east Asia (Muller, 1974). The palynoassemblage thus supports the Lower to Middle Miocene age assigned to the Quilon beds on faunal evidence.

Palaeoclimate and Depositional Environment — An overwhelming majority of the fossil spores and pollen grains with recognizable botanical affinities indicates the presence of either exclusively or chiefly tropical families in the Quilon microflora. The abundance of ferns (Polypodiaceae, Schizaeaceae and Dicksoniaceae) and the presence of Dipterocarpaceae, Ctenolophonaceae, Olacaceae and *Duabanga* of Sonneratiaceae points toward heavy precipitation. It may then safely be concluded that the climate of Kerala during the Miocene was of the tropical humid type with plenty of rain fall. As the present day climate of Kerala is of the same kind, one is tempted to visualize that perhaps there has not been much change in the climate of this region since the Miocene epoch.

On the whole, among the angiosperms the pollen of arborescent plants predominate over that of the herbaceous ones. The rarity of the graminaceous pollen indicates the paucity of grass cover in the region. The majority of the pollen grains exhibit diverse types of exine sculpturing, often of a very ornate type, which incidentally indicates that they were produced by entomophilous plants and that there was not much of long distance transport of palynomorphs either by wind or water as most of them originated from plants growing in and around the vicinity of the depositional site. A few pollen types referable to the subtropical or temperate taxa (Myricaceae, Thymeliaceae, Symplocaceae, etc.) may have had their source in the mountainous region nearby.

The microfloral investigation of the Quilon sediments has brought to light the following data that could suitably be utilized in assessing and evaluating the nature of their depositional environment.

(a) Occurrence of hystrichosphaerids.
(b) Occurrence of Polypodiaceae and Schizaeaceae spores
c) Occurrence of pollen comparable to *Barringtonia*, *Rhizophora*, *Lumnitzera*, *Nipa*, *Metroxylon*, *Calamus*, *Iriartea* and pollen referable to Araliaceae, Sapindaceae, Meliaceae and Droseraceae
(d) Occurrence of pollen types related to *Potamogeton*, *Lemna* and *Myriophyllum*.

The faunal evidence indicated neritic and shallow marine conditions at the time of deposition of the Quilon beds (Poulose & Narayana Swamy, 1968). The record of hystrichosphaerids such as *Achomosphaera*, *Cleistosphaeridium*, *Spiniferites*, etc. and acritarchs represented by *Baltisphaeridium* from clays and calcareous clays of the Quilon Formation fully substantiates this contention. The presence of pollen types related to

Barringtonia, *Rhizophora*, *Lumnitzera*, *Nipa*, *Iriartea*, *Calamus*, *Metroxylon*, Araliaceae, Sapindaceae, Meliaceae and Droseraceae and the spores of Polypodiaceae and Schizaeaceae clearly testifies to the prevalence of brackish water mangrove swamps all along the coast line. The mangrove forests encompass extensive areas typically between the low and high tide regions. Depending upon the degree of salinity and tidal influences, the mangrove swamps in tropics are found in the littoral regions, at the river estuarines, along the creeks and lagoons and on low mud flats along the sea coast.

The non-mangrove members of Palmae may have occupied a position away from the storm tide. The occurrence of pollen types referable to Potamogetonaceae (*Potamogeton*), Lemnaceae (*Lemna*) and Haloragaceae (*Myriophyllum*) highlights the presence of freshwater lakes or ponds dotting the landscape, away from the mangrove belt towards inland.

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EXPLANATION OF PLATES

(All figs × 1000 unless otherwise mentioned)

Plate 1

1, 2. *Crotonoidaepollenites euphorbioides* gen. et sp. nov., fig. 1 — holotype.
3. *Retitricolpites dipterocarpoides* sp. nov., holotype.
4. *Retitricolpites microreticulatus*.
5. *R. marginatus*.
6. *Retitrescolpites indicus* sp. nov., holotype.
7, 8. *R. singularis* sp. nov., holotype.
9. *Retibrevitricolpites simplex* sp. nov., holotype.
10. *Foveotricolpites piercei* sp. nov., holotype.
11, 12. *F. prolatus* sp. nov., fig. 11 — holotype.
13. *Crototricolpites densus*.
14. *Punctatricolpites* sp.

Plate 2

15, 16. *Bacubrevitricolpites rotundus* gen. et sp. nov., fig. 15 — holotype. × 800.
17, 18. *Loranthipites elegans* gen. et sp. nov., fig. 17 — holotype.
19. *Marginipollis kutchensis* comb. nov.
20, 21. *M. quilonensis* sp. nov., fig. 20 — holotype.
22. *Clavasyncolpites gracilis* gen. et sp. nov., holotype.
23. *Meyeripollis baksii* sp. nov., holotype.
24. *Retistephanocolpites crassimuratus* sp. nov., holotype.
25, 26. *Ctenolophonidites costatus*.
27, 28. *Polycolpites granulatus*.

29. *Psilatricolporites ebenoides* sp. nov., holotype.
30, 31. *Heterocolpites combretoides* sp. nov., fig. 31 — holotype.
32. *H. granulatus* sp. nov., holotype.

PLATE 3

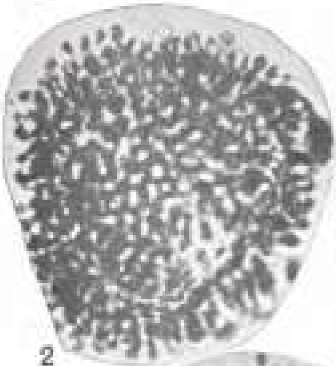
33. *Retitricolporites crassioratus* sp. nov., holotype. × 750.
34. *Cauveripollis superbus.* × 800.
35. *Araliaceoipollenites quilonensis* sp. nov., holotype.
36. *Zonocostites indicus* sp. nov., holotype.
37. *Compositoipollenites argutus.*
38. *Bombacacidites minutus* sp. nov., holotype.
39. *Hippocrateaceaedites quilonensis* sp. nov., holotype.
40. *Palaeocoprosmadites keralaensis* sp. nov., holotype.
41. *Symplocoipollenites crassioratus* sp. nov., holotype.
42. *S. punctatus* sp. nov., holotype.
43. *Costatipollenites paucioratus.*
44. *Margocolporites tsukadai.*
45. *M. oligobrochatus.*
46. *Talisiipites elegans* sp. nov., holotype.
47. *Gothanipollis indicus* sp. nov., holotype.
48. *Cupanieidites punctatus* sp. nov., holotype.
49. *Sapotaceoidaepollenites keralaensis* sp. nov., holotype.
50. *S. africanus.*
51. *S. neyveliensis.*

PLATE 4

52. *Meliapollis quilonensis* sp. nov., holotype.
53. *Foveostephanocolporites leidelmeyerii* sp. nov., holotype.
54. *F. indicus* sp. nov., holotype.
55, 56. *Padappakkarapollis venkatachalae* gen. et sp. nov., holotype.
57, 58. *Polybrevicolporites karii* sp. nov., holotype.
59. *Polygalacidites singularis* sp. nov., holotype.
60. *Triporopollenites minutus* sp. nov., holotype.
61. *Triorites microreticulatus* sp. nov., holotype.
62. *Myricipites harrisii.*
63. *Casuarinidites* sp.
64-66. *Maculoporites quilonensis* sp. nov., fig. 64 — holotype.
67, 68. *Verrutriporites perverrucatus* sp. nov., holotype.
69, 70. *Verrutriporites vermiculatus* sp. nov., fig. 69, holotype.
71. *Echitriporites* sp.
72, 73. *Ornatriporites elegans* gen. et sp. nov., fig. 72 — holotype.
74. *Proteacidites retusus.*

PLATE 5

75. *Proteacidites truncatus.*
76. *Thomsonipollis* sp.
77. *Tetrapollis* sp.
78. *T. rotundus* sp. nov., holotype.
79. *Haloragacidites verrucatus* sp. nov., holotype.
80, 81. *Clavaperiporites jacobi.*
82, 83. *Anacolosidites luteoides.*
84. *Inaperturotetradites psilatus* sp. nov., holotype.
85, 86. *Ornatetradites droseroides* gen. et sp. nov., fig. 85 — holotype.
87, 88. *O. chandar* sp. nov., fig. 87 — holotype.
89. *Droseridites* sp. × 800.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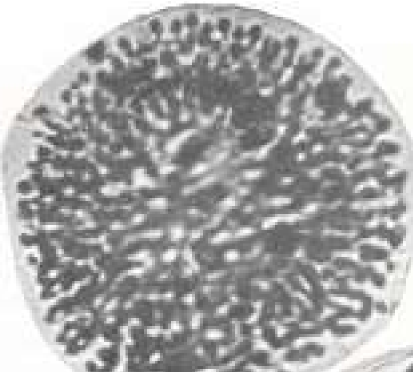
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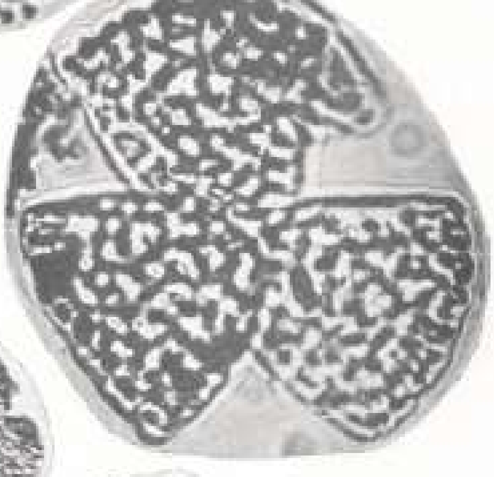
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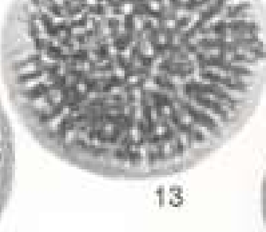
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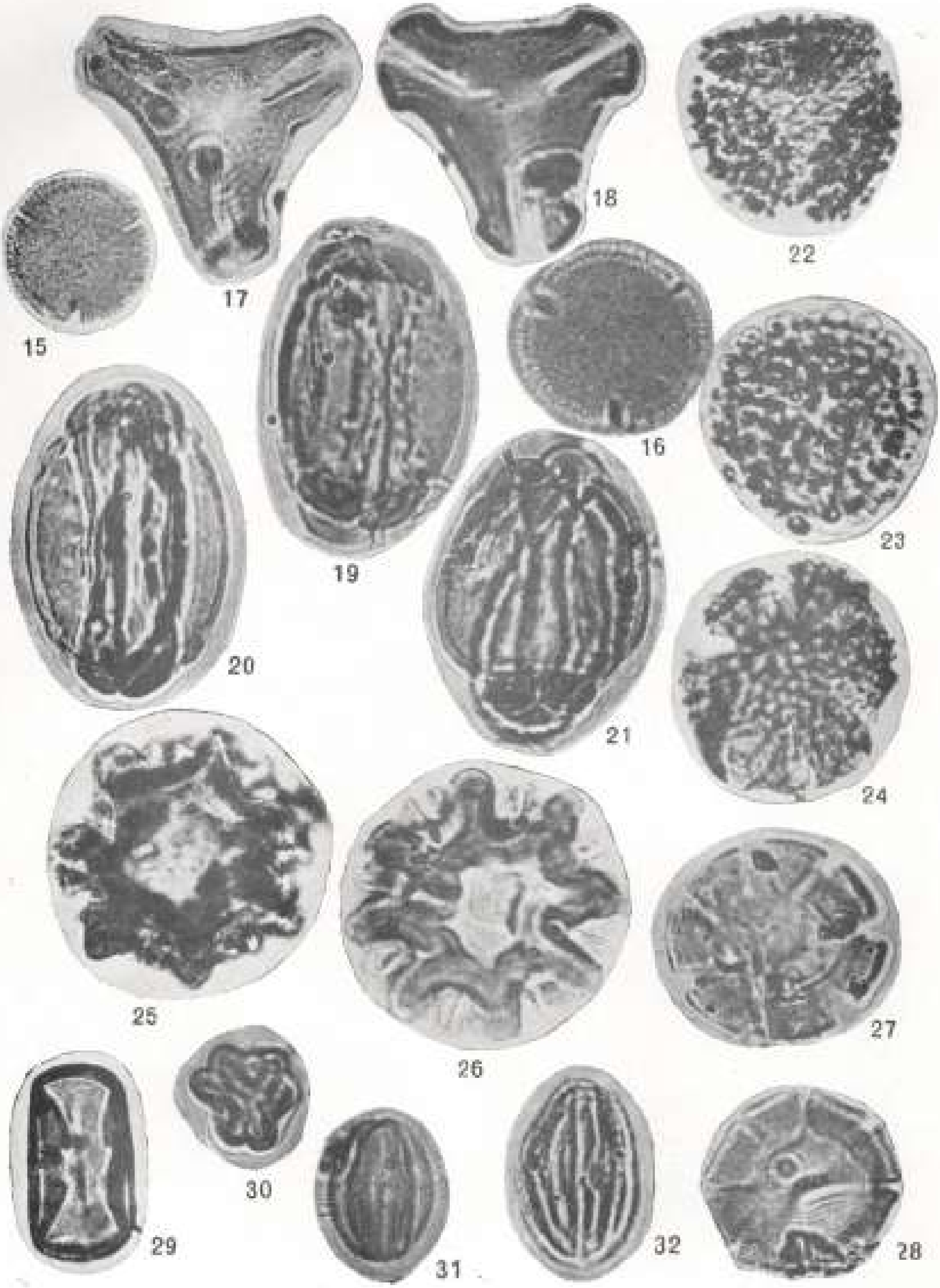
PLATE 1



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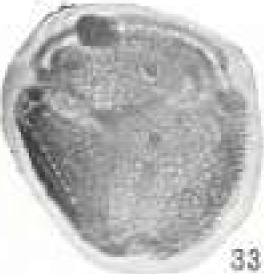
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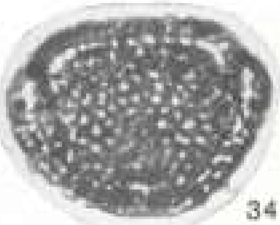
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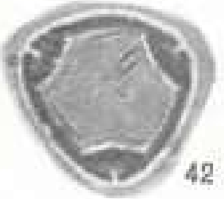
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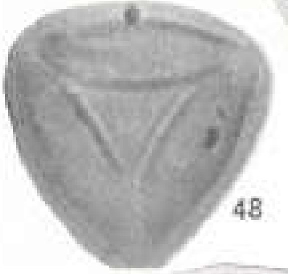
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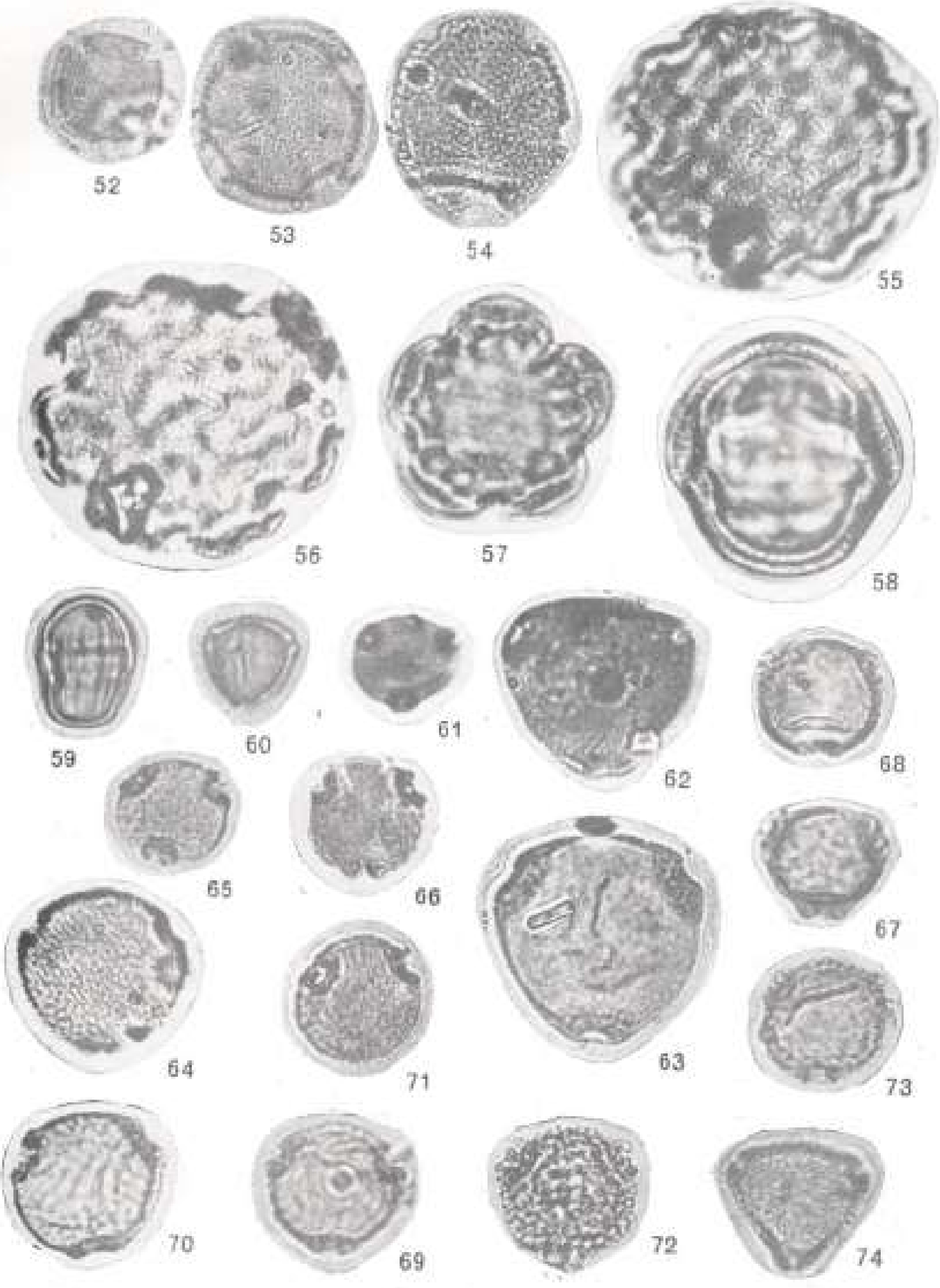
PLATE 3



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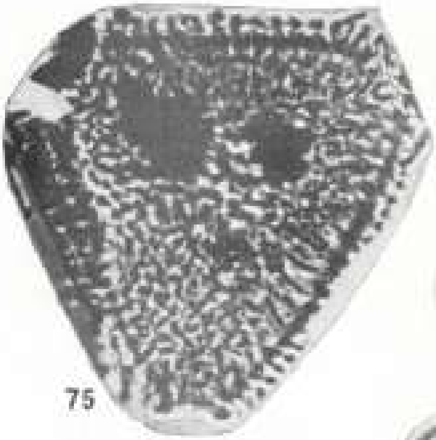

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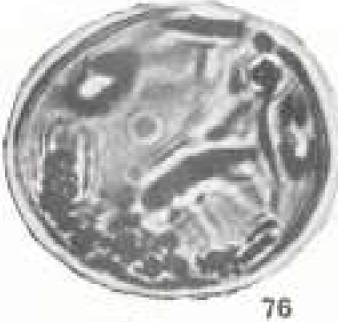

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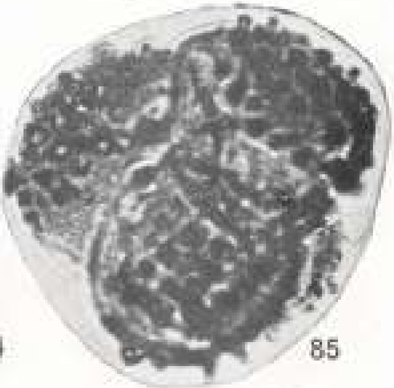

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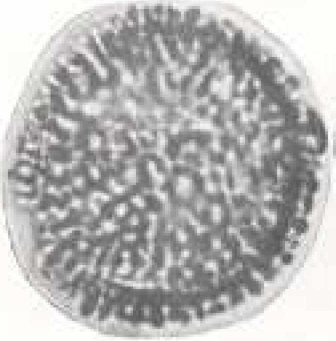

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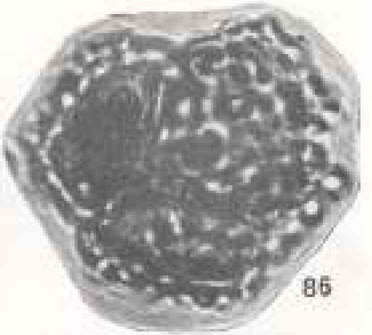

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PLATE 5

The Palaeobotanist, 30(1): 101-119, 1982.

TENTH SILVER JUBILEE COMMEMORATION LECTURE

PALYNOLOGY IN OIL EXPLORATION

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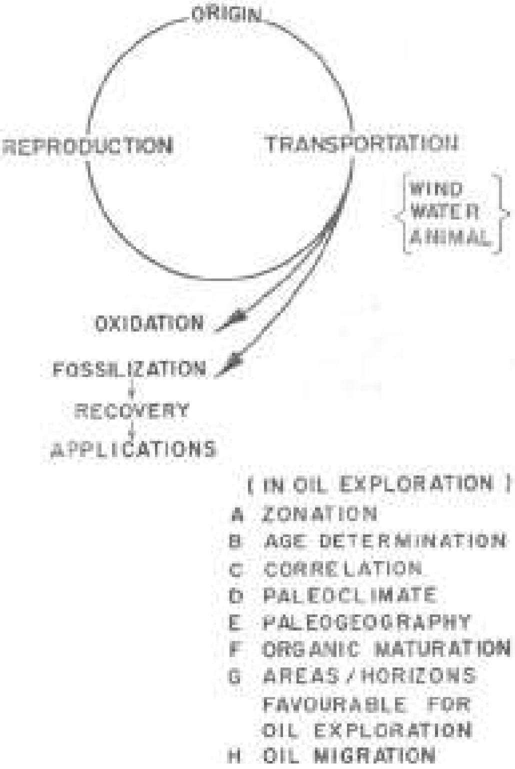
INTRODUCTION

THE Birbal Sahni Institute of Palaeobotany is the premier research organization of its kind in India. A great scientist, whose name the institute bears, was its founder, and it was to him that an oil company turned thirty-four years' ago, to solve problems of stratigraphy in oil-bearing strata of Upper Assam, which had no diagnostic marine fossils. The association between palaeobotany and oil exploration in India, which began then, has broadened in subsequent years. Therefore, when the present Director of Birbal Sahni Institute of Palaeobotany approached me, earlier in the year, to deliver the Tenth Silver Jubilee Commemoration Lecture here, it was a debt the discharge of which could not be refused, however, unworthy I may be to represent petroleum exploration in this distinguished gathering, and undeserving of the honour of delivering this lecture.

I think that it will be appropriate for me to speak about the role of palynology in oil exploration, for this is the topic which provides the connecting link between the Birbal Sahni Institute of Palaeobotany and the Institute of Petroleum Exploration.

There are four main areas in oil exploration, where the role of palynology is very significant (Text-fig. 1). These are : (i) stratigraphy, (ii) palaeogeographic reconstruction, (iii) study of oil source rocks, and (iv) maturation.



TEXT-FIG. 1 — Role of palynology in oil exploration (modified after Gutjahr, 1960).

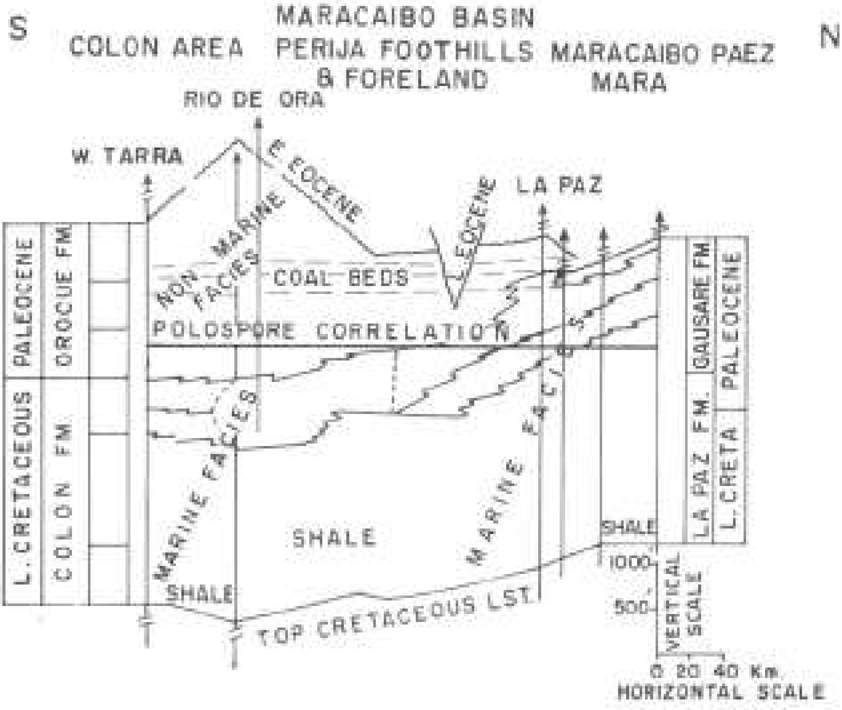
ROLE OF PALYNOLOGY IN STRATIGRAPHY

In oil exploration, the main application of geology is in the domain of sediments, because oil is formed and accumulated in sedimentary rocks. Such rocks are deposited in finite negative areas of the earth's surface, which are the sedimentary basins. Most sedimentary basins tend to remain as negative areas over most of their aereal extents, through most of subsequent geologic time. This means that their stratigraphic details can only be obtained from the subsurface, principally by drilling wells for oil and gas exploration — you cannot send a geologist to collect samples from the subcrop for stratigraphic studies. The volume of rock obtained as a sample in a drill hole is small, therefore that sample must contain the indicative fossil or mineral which can be used in stratigraphic correlation.

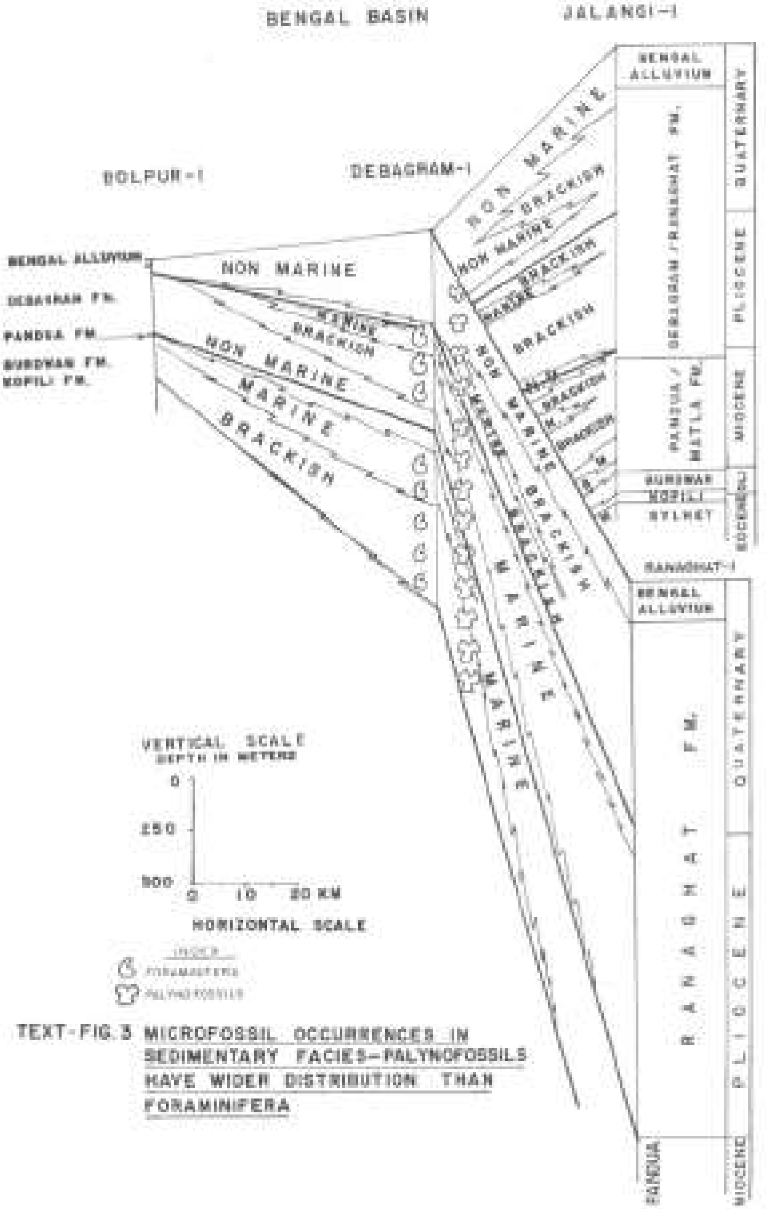
Thus, *Gangamopteris cyclopteroides* var. *major* may be the index fossil for the Karharbari Stage of the Damuda Group of the Lower Gondwana " Series ", but if the drill hole passes at 2000 m depth through a patch of Karharbari shale without *Gangamopteris cyclopteroides* var. *major* leaf impression, we shall not know its stratigraphic position to be Karharbari. Nor will it be possible to drill a large number of wells, each costing more than one crore of rupees, in the hope that one of them will supply us with a diagnostic megafossil when passing through Karharbari shales. The form or population with the identifiable stratigraphic attribute must be ubiquitous enough to be present in a drill hole sample.

It is in this respect that palynology has become increasingly important in oil exploration, because the content of polospores in rocks is much higher than other populations of chronologic significance. This is why palynology attracted the attention of oil exploring organisations, ever since 1936, when the Royal-Dutch/Shell Group studied polospore successions to solve the problem of correlation of Tertiary lignites and lignitic clays in Mexico. In India, Burmah Oil Company encountered similar problems in Assam, and in 1947, they requested Prof. Birbal Sahni to study core samples of Barail, Surma, Tipam and Dhekiajuli formations for establishing palynofossil successions, which could be used for stratigraphic analysis of these immensely thick clastic sequences.

Palynology has a definite advantage over other subsurface correlation methods, and this is the only practical method known so far by which non-marine sediments can be correlated with marine sediments (Text-figs 2, 3). Much has been made of the triumphs of micropalaeontology in stratigraphy. A great deal of information has been accumulated on these very small marine animals found in sediments, and a lot of standard chrono- and bio-zones have been erected on the basis of sequences of microforaminifera. Nevertheless, it should be remembered that, of the different types of foraminifera, it is only the calcareous forams, and among these, only those of



TEXT-FIG. 2 — Section showing facies relations and time stratigraphic correlations by polospores (after Kuyl, Muller & Waterbolk, 1955).



TEXT-FIG. 3 — Microfossil occurrence in sedimentary facies — Palynofossils have wider distribution than *foraminifera*.

planktonic habit, which are widely distributed and have evolved rapidly enough in certain periods of Phanerozoic time, for use in correlation. They occur only in open marine conditions. With reduced salinity, they are replaced by arenaceous foraminifera, which evolved much more slowly through time, and are therefore not of much use in correlation. Even the more rapidly evolving planktonic calcareous foraminifera are really of high correlation value only when, as in the Gulf of Mexico deltaic sequences, they are associated with marine transgressions, which punctuate the general prograding, by delta out-building, that occurred in this area, from the Jurassic onwards. When these transgressive tongues, each with a particular species of foraminifera, have been followed down the palaeoslope, they have expanded and gradually merged with the sequences above and below in holo-marine areas, as we would expect them to do. Thus the zonal boundaries defined by planktonic foraminifera become less distinct in areas of holo-marine deposition than they are in areas of intertonguing of marine and non-marine sediments. From the point of view of oil exploration, areas of holo-marine deposition over extended periods of time are not the best locales for looking for substantial reserves of oil and natural gas. The occurrence of oil seems to be associated with the transition, from the marine to the non-marine environment of deposition in a sedimentary basin at any particular point of time. This is because it is at this transition that the optimum association between source rocks (largely marine) and reservoir rocks (marine to non-marine) occurs. Here detailed correlation across the facies interfaces by means of microforaminifera is not successful at all. It is because of this limitation that oil companies, who were pioneers in the use of forams in stratigraphy, have gone in for the study of spores and pollen for stratigraphic zonation. Although spores and pollen originate largely in terrestrial plants, their easy transportability ensures that they are widely distributed, both in marine as well as in non-marine depositional environments. In Oil and Natural Gas Commission, the problem of correlation of strata associated with oil reservoirs with no marine fossils in them, also made us turn very early to palynology for solution.

In palynofossils we generally include spores, pollen grains, nannoplanktons, silicoflagellates, diatoms, dinoflagellates, acritarchs, algae, and plant remains such as cuticles, exines, tissue fragments, etc. (Pl. 1, figs 1-10).

According to Talukdar (1980) the advantages of correlation by palynology are as follows:

1. The relatively indestructible nature of the pollen. Even Pre-Cambrian metamorphosed sediments contain identifiable palynofossils.

2. Their relative abundance, particularly in sub-surface samples. This allows the use of quantitative methods in their study.

3. Their susceptibility to long distance transport.

4. Their occurrence in both fresh water and marine environments enables us to correlate standard marine sequences with non-marine sequences.

5. Their colouration indicates the highest temperature to which the host rock was subjected subsequent to its formation.

6. They are good indicators of the ecological habitat of source, and are thus of great importance in the study of periods of rapid climatic change, such as the Pleistocene and Holocene.

The disadvantages are:

1. Small size of spores and pollen make them particularly susceptible to the removal by waters circulating through strata. An outcrop may be barren, whilst subcrops have prolific spores and pollen content. A buried unconformity may, for the same reason, give rise to poor yield of spores and pollen in the stratum below the unconformity.

2. For the same reason, and because of their resistance to mechanical erosion, the older forms are easily re-incorporated in younger deposits, complicating stratigraphic interpretation.

3. Disaggregation of spores and pollen from host rock is not easy, and the yield is strongly influenced by the method of separation. Spore-pollen colouration is also affected by some of the chemicals used in laboratory separation processes.

4. Since the land habitat is much more diverse as compared to the marine habitat, the separation of the source factor from the age factor of polospore populations is not easy. While this is an advantage in palaeogeographic work, it is a distinct disadvantage in stratigraphy.

5. Some of the economically most important sediments, such as evaporites and carbonates, do not contain significant amounts of spores and pollen.

6. In older strata, it is difficult to relate spores and pollen with the plants and trees which gave rise to them.

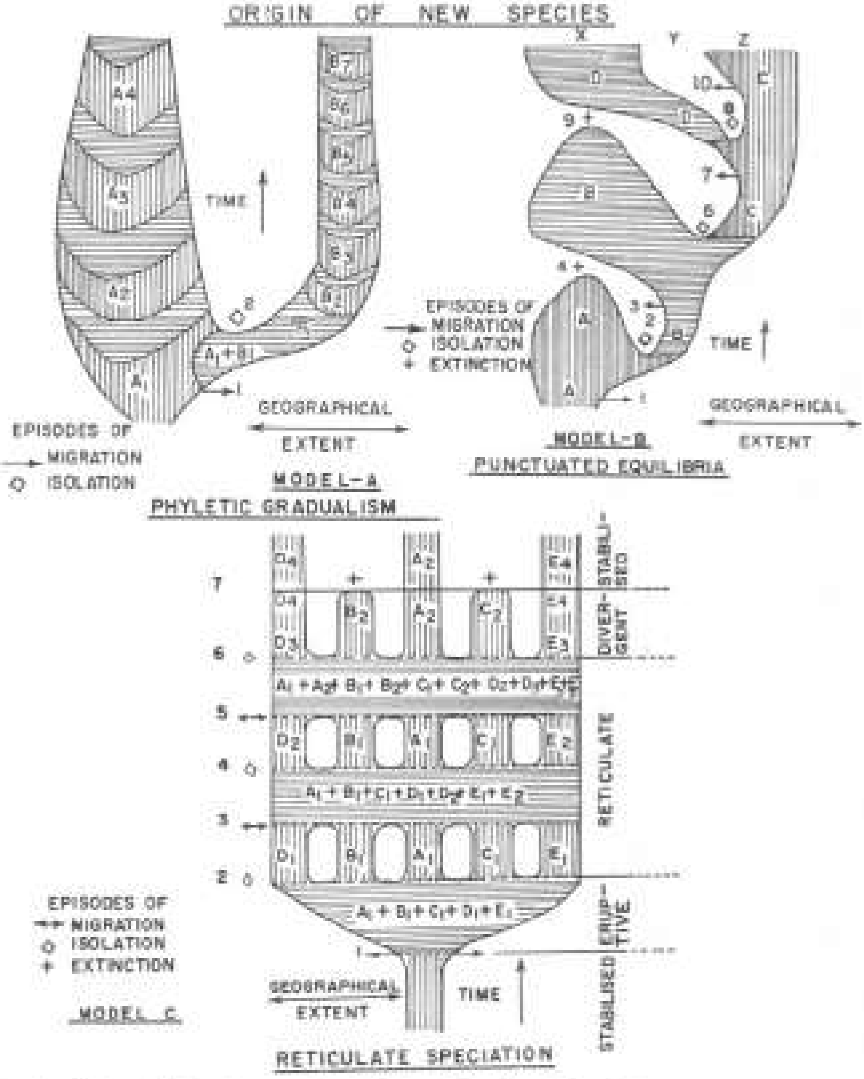
7. Taxonomy of spores and pollen is based entirely on morphology, and lineages based on genetic linkage are only inferred. Yet all stratigraphic and palaeogeographic

conclusions are based on the assumption that the evolutionary sequence of polospores can be inferred from their morphological-linkages. This is, of course, a problem which is common to all fossils.

A distinguished gathering of scientists, such as this, will be interested in the theoretical basis of palynostratigraphy, which is as follows.

The theoretical basis of palynostratigraphy is the change with time of populations and species of spores and pollen. New species may arise in a number of ways, of which the three more important are (Text-fig. 4): (i) speciation by phyletic gradualism (i.e. Darwinian classical model), (ii) by punctuated equilibria (Eldredge, 1971), and (iii) reticulate speciation (Sylvester-Bradley, 1977).

In phyletic gradualism, both phylogenesis (i.e. origin of new species, by modifications, arising in course of geological time, in a single phyletic line) and cladogenesis (origin of new species by the splitting of the phyletic line) occur. This involves the episodes of migration and isolation. In



TEXT-FIG. 4— Three different ways of evolution of species (after Sylvester-Bradley, 1977).

the punctuated equilibria model, new species arise abruptly. This involves episodes of migration, isolation and extinction. In reticulate speciation, new species arise in course of expanding migration, with hybridization between geographical races. It combines the features of phyletic gradualism and punctuated equilibria, although punctuated equilibria are antithetic to gradualism. Sylvester-Bradley (1977) claims that phyletic gradualism provides a tool that can be coupled with statistical evaluation of any population to give a precise point on a curve, correlating evolutionary modifications with stratigraphic position. The model of punctuated equilibria provides, on the other hand, a series of index fossils, each of which characterises one of a series of consecutive zones.

The three phylogenetic patterns have been described to have quite different functions in biostratigraphy :

1. There is sufficient danger of error in using a polytypic complex, with its associated geographical sub-species, and changing morphology in different directions with time and space, for correlation purposes. This danger becomes still greater if the species also exhibits ecotypic variation, where the modification is caused by the same environment at different times. Such a species can be used for stratigraphic purposes, only after studying the variations over the entire provenance of species.

2. In case of polymorphic species, discontinuous speciation showing punctuated equilibria, we get the results which are more helpful in defining the zonal boundaries. Thus, one zone is abruptly replaced by another, and is easy to recognize.

3. In phyletic gradualism, in order to determine the accurate stage of evolution in the lineage, besides the knowledge of taxonomy of the group, it is necessary to study a very large population and carry out statistical analysis of variance. Such statistical analysis of a lineage representing phyletic gradualism gives a more reliable stratigraphic picture. However, phylogeny is rarely gradual, and more often discontinuous. Therefore, one cannot assume that new species evolve in one particular manner only. Punctuation in biostratigraphy does exist and is helpful in finding the zonal limits.

Palynozones in a sedimentary sequence are generally deciphered on the basis of four criteria : (i) establishment of an evolutionary series, ii) first appearance, maximum development and extinction tops of groups, genera and species, (iii) general assemblage of palynofossils and their ratio, and (iv) increase and decrease in quantity of palynofossils.

In our own work in the Oil and Natural Gas Commission, palynology has given us information on stratigraphic position of otherwise unfossiliferous sequences when other information was lacking. Drilling in Gangetic plains had confirmed the occurrence of two sequences, an upper unfolded one thickening northwards, and a lower sequence with major folds and faults. Both are devoid of microfauna. However, spores and pollen were recovered, and it was evident that the upper sequence is of Siwalik age (Upper Miocene to Pleistocene), whereas the lower sequence is of Upper Proterozoic to Lower Cambrian age, equivalent to Vindhyans exposed to the south of Gangetic plains, in the area to the WNW of the Patna-Saharsa subsurface high. To its east, the folded sequence below the Neogene is of Gondwana age, and it is possible to establish, on the basis of polospores, the boundary between the Permian and the Triassic in the subsurface near Purnea (Venkatachala & Rawat, 1979). Similarly, it was only possible to fix the stratigraphic position of the 4000 m thick Dharmsala sequence of the foothills of north-western Himalayas on the basis of palynoflora. This thick sequence of sandstones and red clays ranges in age from Oligocene to Lower Miocene (Mathur, 1979). The overlying Siwalik sequence, known the world over for its vertebrate fossils, was examined by the ONGC in great detail in outcrops as well as in drilled wells. We found that fossil vertebrate occurrences are extremely rare, and totally absent in drilled wells. Heavy minerals did allow some correlation between blocks, but heavy mineral populations were provincial, and heavy minerals could not be used for widespread correlation. However, palynoflora does occur, not in as much abundance as we had hoped, and from the palynoflora Lower, Middle and Upper Siwalik subgroups (total thickness in excess of 6000 m) could be tied into the standard Tertiary time sequences (Mathur, 1979). Such work also showed the strong time-transgressive nature of the lithologic zones.

To the north-west of this belt, in Ladakh, the age of the youngest sedimentary sequence (the Ladakh Molasse) was established as ranging from Palaeocene to Miocene (Bhandari *et al.*, 1977). Palynoflora recorded from the tuffs associated with the Dras Volcanics suggests that the volcanic episode here is contemporaneous with that of Deccan (Mathur & Jain, 1980). This has obvious implications in regard to the tectonic history of the Indian plate in terms of the plate tectonics hypothesis.

In what is essentially a continuation of the Assam-Arakan fold belt, the Andaman and Nicobar islands, workers in the Institute of Petroleum Exploration have identified palynofossils typical of the Barails of Upper Assam and thus established a basis for long distance correlation between widely separated areas. The palynoflora of the lowermost part of Port Blair Formation of Middle Andaman Island is also similar to that found in Burdwan Formation of Bengal Basin (Mathur & Mathur, 1980).

In Bengal Basin, a large part of the sequence can only be classified on the basis of palynostratigraphy. Established palynostratigraphic zones can be recognized throughout the basin (Text-fig. 5).

At the other end of India, Muller (1974) indicated a close similarity between the Albian-Senonian palynoflora of Kachchh and that of Borneo and Australia, which provides some interesting contrasts to the affinities of the Mesozoic Cephalopod fauna of Kachchh with those of Madagascar. Subsurface material obtained by drilling of deep wells by ONGC in the Banni of Kachchh and studied in our Laboratory has clearly indicated the beginning of sedimentation in the Rhaetic-Liassic times, somewhat earlier than obtainable from surface evidence (Koshal, 1975). In the Tertiary of Kachchh, we could erect 16 palynozones and correlate them with standard planktonic foraminiferal zones.

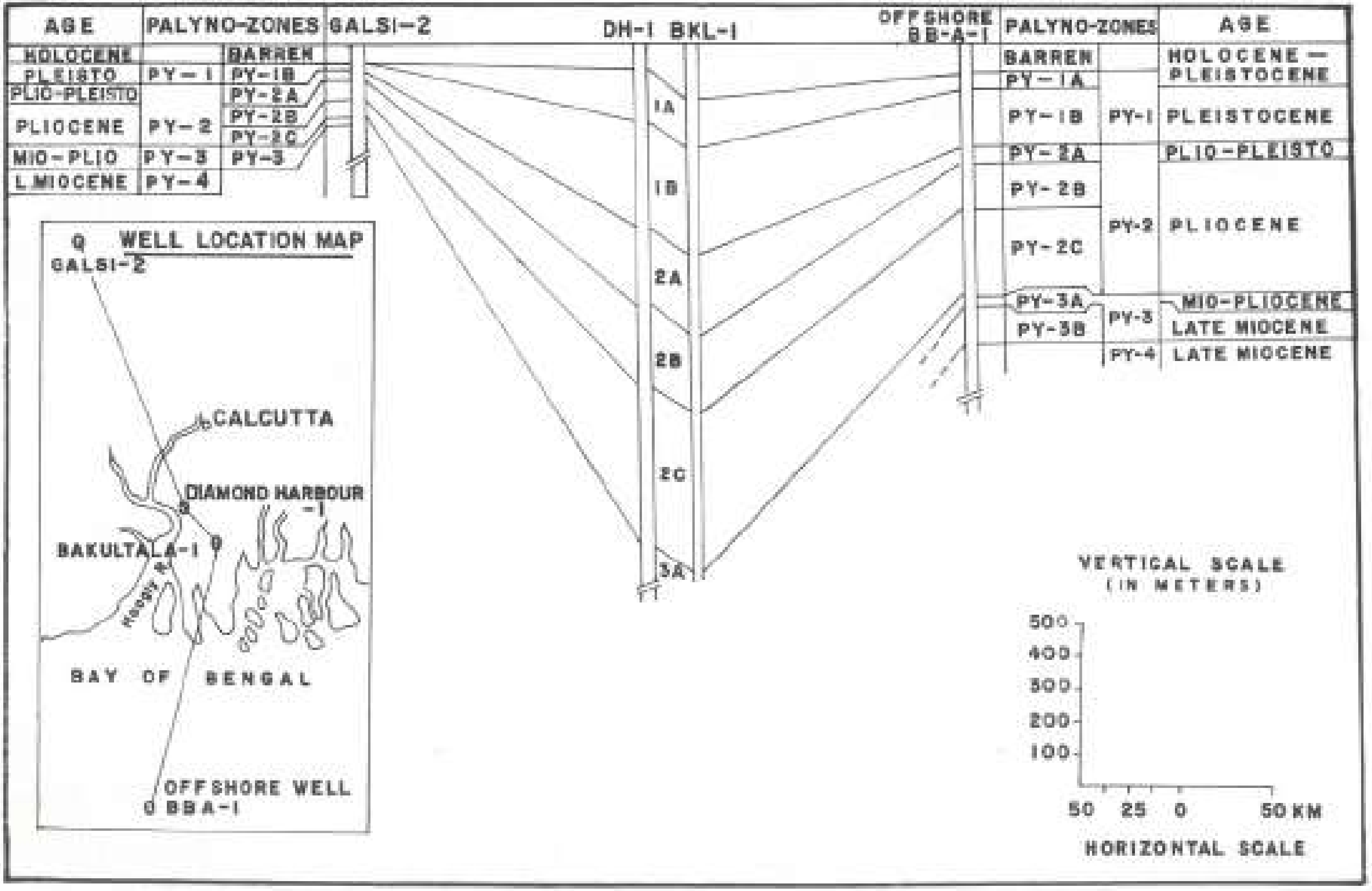
In the course of oil exploration in the other shelf of Indus Basin, Rajasthan, the ONGC found it necessary to establish a palynology laboratory at Jodhpur for solving problems of stratigraphic correlation of sequences met with during drilling. With the help of palynoflora, 18 palynozones could be established in the Mesozoic. In the Jurassic-Lower Cretaceous transition, which is totally devoid of fossil fauna, the boundary could only be obtained from polospore data (Mathur & Mathur, 1976). Permian and Triassic sediments were also recorded from palynological studies (Tikku *et al.*, 1976). All this stratigraphic information, useful for detailed analysis as well as for intra-basinal correlation, could not have been obtained by any other means.

In addition to establishing the age of a stratum or sequence, of course, palynology gives us a great deal of information on the palaeogeography.

PALYNOLOGY IN PALAEOGEOGRAPHIC RECONSTRUCTION

The geologist who is engaged in oil exploration very soon realises that where the volume of rocks in a sedimentary basin containing commercial deposits of oil and gas is very large, measurable in hundr d of thousands or millions of cubic kilometres, the fraction of interest for oil exploration is a very small percentage of the total rock volume. For example, the Gujarat petroliferous basin has about 100,000 cubic kilometers of sediments. The total oil reserves of this basin, which supplies 30% of India's indigenous production, occupies a rock volume of only 5 cubic kilometer. Source rocks and reservoir rocks each, are deposited in particular physico-chemical environments, and so are cap rocks. These environments are inter-related in space and time with each other, and therefore the different source and depositional environments existing in a particular interval of time can be mapped, the areas of interest from the point of view of oil exploration in a basin where sedimentary rocks were deposited during that period of time, can be demarcated, and exploratory activities concentrated there.

Both source rocks and cap rocks share one property — they are fine grained. However, whereas all fine-grained rocks are good cap rocks; all are not good source rocks. It is necessary that source rocks should be fine grained, because only in low depositional energy environments does organic matter get preserved. However, it is also necessary that the palaeoenvironment should be such that a significant



TEXT-FIG. 5 — Palynostratigraphic correlation of Plio-Pleistocene strata in Bengal onland and offshore wells.

quantity of organic matter could form and enable itself to be transported to the depositional area, without too much destruction. Such formation and deposition is restricted to particular environments, such as silled basins, or pro-deltas and interdistributary swamps in rapidly prograding sequences.

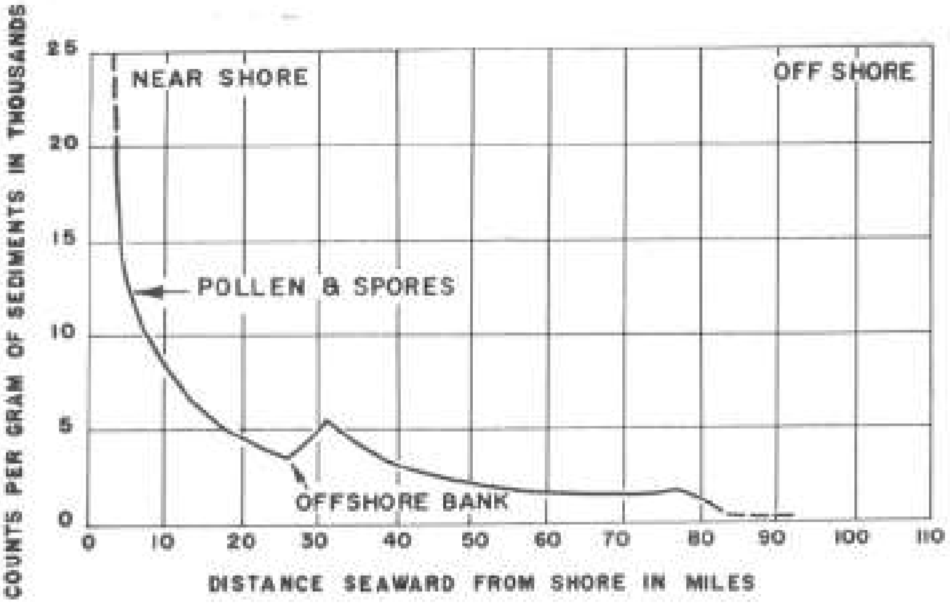
Reservoir rocks, on the other hand, should have primary and/or secondary porosity development. Primary porosity development requires a high energy depositional locale, where sorting of grains ensures that the larger and better rounded fragments are concentrated and finer fractions of the sediment winnowed out. Secondary porosity development is the result of diagenetic changes subsequent to deposition, as well as of tectonism after the sediment is consolidated. Ultimately, therefore, secondary porosity development is the result of endogenetic forces directed outwards. Source rocks maturation, on the other hand, is caused by movements in the reverse direction, i.e. towards greater depths and higher temperature associated with greater depths.

Nevertheless, for oil to concentrate into economically exploitable deposits, the source rocks, reservoir rocks and cap rocks, deposited in dissimilar palaeoenvironmental situations, must be connected up during the time of migration of the oil from the source rock. There must be a migration path or conduit between the source and reservoir, and the potential energy difference should be adequate to ensure that the oil does in fact migrate from the source to the reservoir along the conduit. After migrating to the reservoir, there must be a permeability barrier to further migration, in order to ensure the retention of the oil in the deposit. The key to understand these occurrences in a sedimentary basin is the palaeogeography during deposition and thereafter.

For these reasons, in oil exploration, geologists make a great deal of efforts on obtaining the palaeogeographic information on the sequences in a sedimentary basin. It is here that palynology is becoming increasingly important. Land plants are sensitive indicators of the environment, and it is the spores, pollen and other parts of such plants which are transported and deposited, together with the enclosing sediments in the basin. Fossilized remains of land plants should therefore indicate the climate of the source area of the sediments. Since spores and pollen are easily transported by wind, their concentration in a sedimentary sequence should also be related to the distance travelled. Remains of marine plants, on the other hand, are not transported to the same extent as those of land plants, since they occur in the depositional basin itself. Marine habitats are also not so sharply differentiated as land habitats. Temperature, salinity, amount of light available, exposure to atmosphere in inter-tidal zones, etc. are the deciding factors.

Thus, the quantity of spores and pollen of shoreline land plants in a marine sedimentary deposit indicates proximity to shore line (Text-fig. 6), as does the ratio between spores and pollen of land origin to phytoplankton of marine origin. Where the marine phytoplanktons are absent, it will be safe to conclude that the deposition was in fresh water or sub-aerial. Where the marine organisms are present, and are not, the result of redeposition, the conclusion that sedimentation was in a marine environment is inescapable.

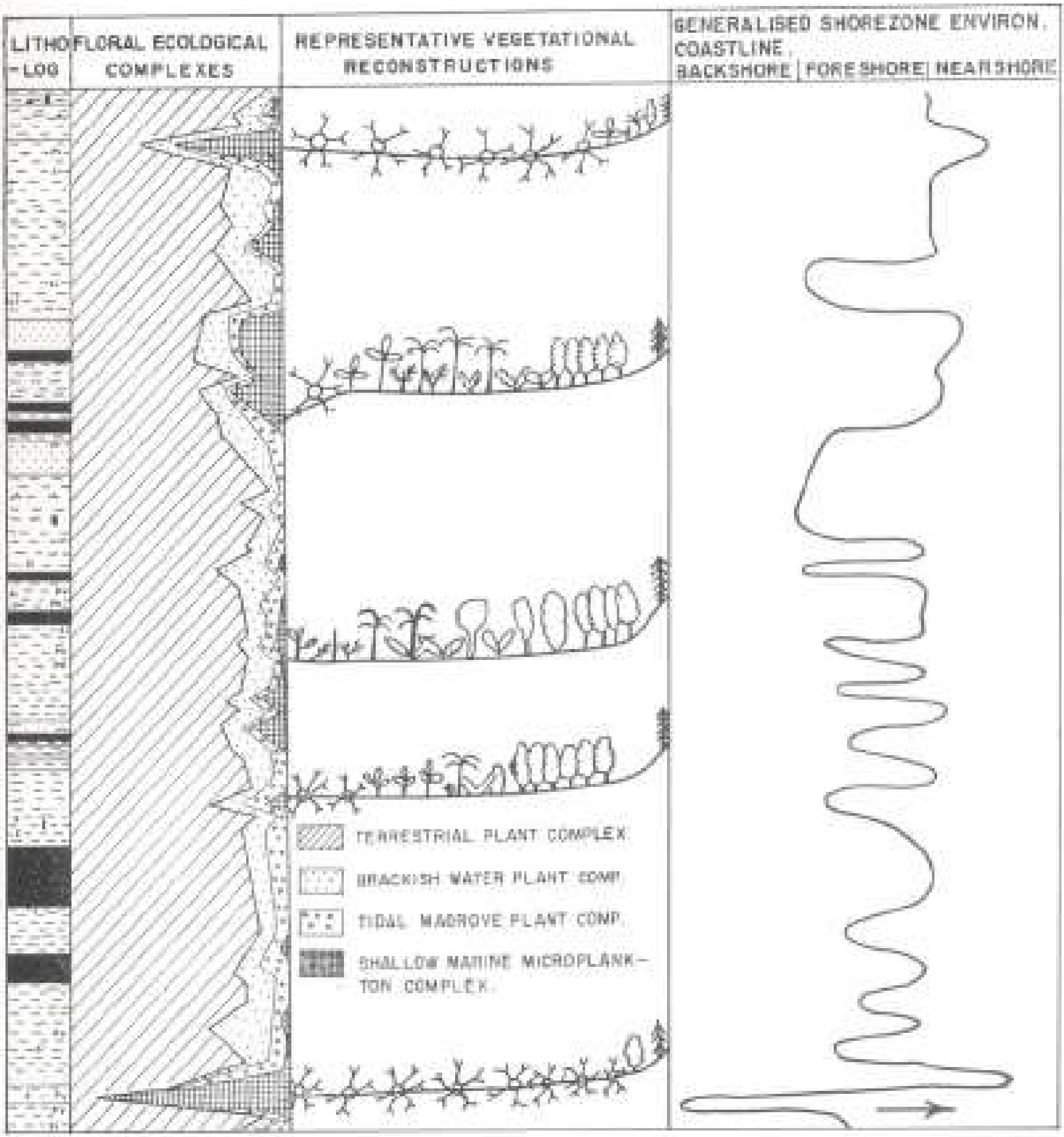
In 1958, Ghosh found spores and pollen in Lower Siwalik sediments of Jawalamukhi suggestive of warm and humid climate in close proximity to the sea. Until then, the prevailing idea was that the Lower Siwalik is entirely fresh-water in deposition, the Upper Miocene sea occurring much further to the south-west of the north-west Himalayan foot-hills area. The rich vertebrate fauna of the Kamlial and Chinji " Stages " of Potwar Plateau, 4000 km to the west of Jawalamukhi, the total absence of marine megafossils (indeed the total absence of microfauna), the red colour of Lower Siwalik clays, and the cross-bedded nature of Lower Siwalik sandstones, were all held to indicate fresh-water and sub-aerial deposition. Yet there were many saline springs in areas of outcropping Lower Siwaliks of Jammu and Kangra, and very high salinity of connate waters of Lower Siwalik sandstones in drilled wells in the plains at locations as far apart as Adampur (near Jullundur), Puranpur (in Pilibhit District, U.P.) and Raxaul (on the Nepal border of Champaran District, Bihar), suggested that the palaeogeographic conclusions from the spores and pollen in Lower Siwalik strata need not be brushed aside, although they were in opposition to the views held by such pioneer workers as Pilgrim and Wadia.



TEXT-FIG. 6 — Pollen and spore density in recent sediments from the Gulf of Mexico (after Woods, 1955).

Recently, we have obtained some microfossils of undoubted marine origin in Lower Siwalik sediments, and are trying to ascertain whether they are reworked forms, or are indigenous to the host sediments. I need hardly emphasize that possible palaeogeographic implications are tremendous. Similarly, our palynologists have recorded marine forms in the Talchir shales of the Palar basin, to the north of Madras. These are, of course, uppermost Carboniferous to Lower Permian in age.

Palaeoshoreline delineation by mapping the palynofloral density as well as by the ratio between land and marine forms, as already mentioned, is an important activity in basin studies conducted by oil exploration organizations. This is because in any one geologic interval, oil accumulation is concentrated in areas on both sides of the palaeoshoreline, where the maximum contact occurs between source and reservoir rocks. Oil fair-ways migrate with the strandline migration in time, as demonstrated many years ago by Rainwater in the deltaic sequences bordering the Gulf of Mexico. It was in shoreline delineation that palynology first proved its utility in palaeogeographic reconstruction. Hoffmeister (1954), in his classic work on the determination of ancient shorelines by means of polospores, used the technique of drawing " isobotanical lines " through points with the same microfossil population or the same type of microfossils. His opinion was that the shoreline was indicated when the density of spores and pollen decreased to below 7500 per gram of sediment. Subsequently in 1960, he utilized palaeoshoreline maps prepared on the basis of polospore density to demarcate areas favourable for oil occurrence, in the Seminole-Oklahoma City region. Mathur and Chowdhury (1977) have used palynological studies for interpreting the palaeogeography and shoreline changes in detail in the northern part of Cambay basin during the deposition of Kalol Formation (Middle Eocene). They grouped various palynofossils into 13 ecological complexes and traced their vertical and lateral distribution in time and space. Fifteen shoreline fluctuation cycles were recognized (Text-fig. 7) and generalised palaeogeographic maps for the Sertha (Text-fig. 8) and Wavel (Text-fig. 9) members of the Kalol Formation were prepared. Earlier, Mathur *et al.* (1973, 1974) interpreted certain areas and horizons of the Kalol Formation as being

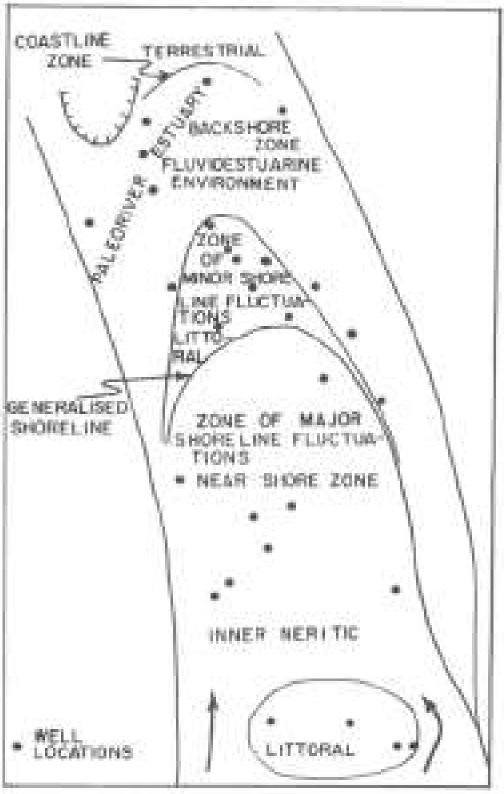


TEXT-FIG. 7 — Floral complexes distribution in Kalol Formation of Kalol Well no. 109 showing shoreline fluctuation and vegetational reconstructions (after Mathur & Chowdhury, 1977).

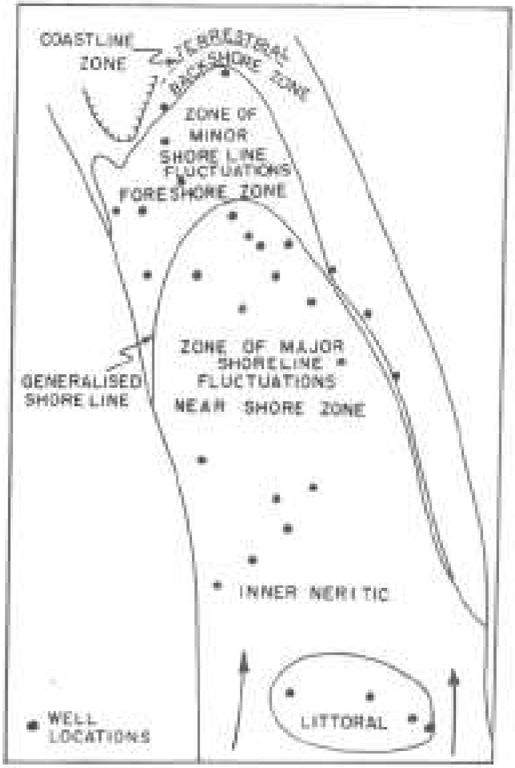
favourable for oil exploration on the basis of their study of palynoflora of the area (Text-fig. 10). Parameters taken into account were general palaeogeography of the basin during the time intervals, shoreline changes, concentration of palynoflora, polospores and dinoflagellate ratios, and distribution of lipid-rich organic matter in the sediments. In some parts of the area interpreted to be favourable, oil accumulations have subsequently been discovered.

ROLE OF PLANTS IN PROVIDING SOURCE MATERIAL FOR HYDROCARBONS

The organic origin of oil and gas is now almost universally accepted. The organic matter is incorporated in the sediments



TEXT-FIG. 8 — Palaeoecogeographic map of North Cambay Basin during the deposition of Sertha Member, Kalol Formation (after Mathur & Chowdhury, 1977).

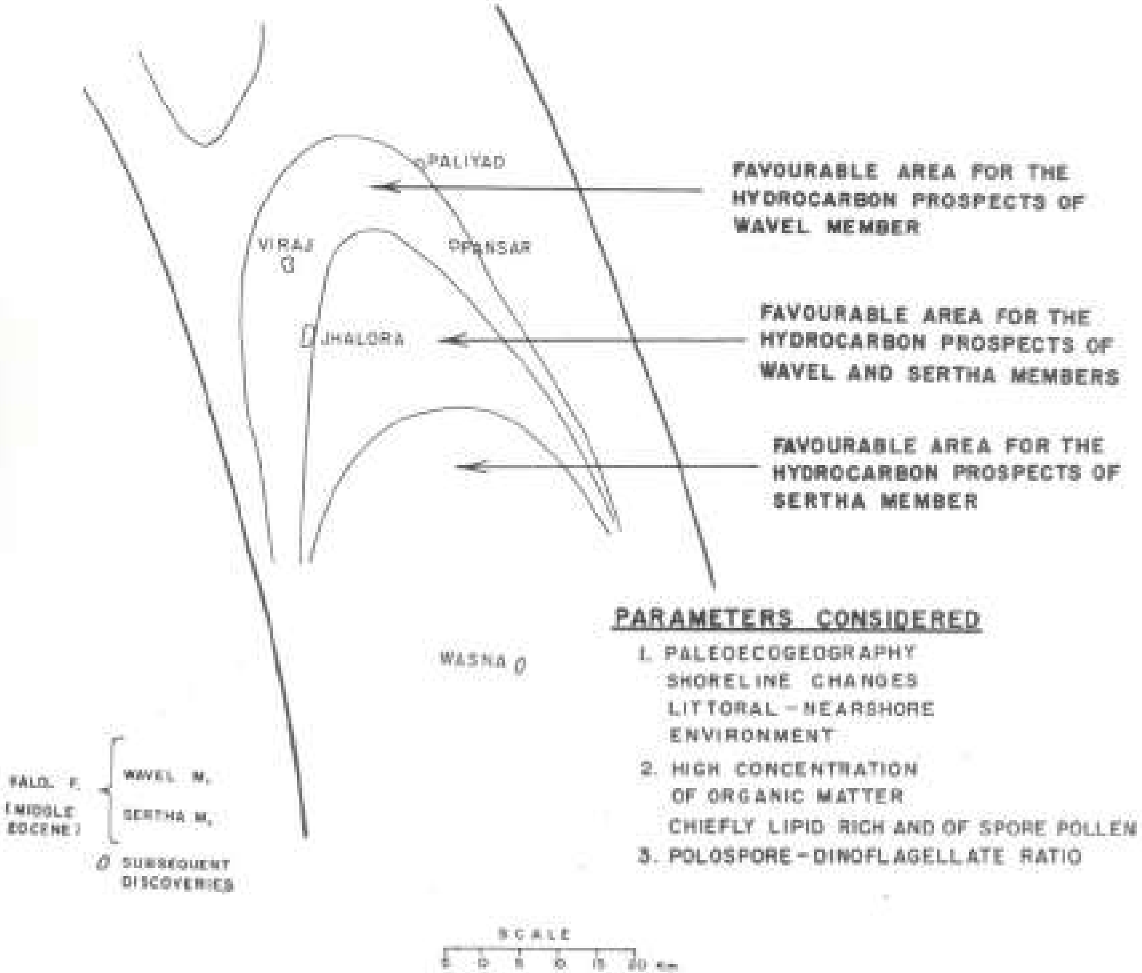


TEXT-FIG. 9 — Palaeoecogeographic map of North Cambay Basin during the deposition of Wavel Member, Kalol Formation (after Mathur & Chowdhury, 1977).

deposited and altered — at the surface by biogenic agents, and when deeply buried, in a subsiding basin receiving sediments by thermo-chemical means.

What is this organic matter ? Earlier, it was believed that only large animals contributed organic matter for transformation to oil and gas. Later on, this role was ascribed to small animals. But now it is realized from biochemistry that it is plant life, including microorganisms such as bacteria, which not only form the beginning of the food chain of the biosphere, but also contribute the largest volume of organic matter to source rocks of petroleum. This is the result of intensive work on the biological and chemical nature of the organic remains in sediments, carried out in the last decade in the laboratories of oil companies and institutes. It involves collaborative studies between petroleum geochemists and palynologists, the latter being largely concerned with the study of the alteration of plant remains by different agencies, from the time of their deposition to their complete transformation into source material, commonly known as kerogen.

Land plants and marine phytoplankton convert CO_2 by photosynthesis into cellular tissue of fatty substances, or lipids, carbohydrates and proteins. Thereafter, the plants may die and be altered, or they may provide food for animals at the beginning of the food chain. In the latter case, plants provide the material for cells of the living animal, as well as faecal matter which are enriched in lipids. On death, the animal cells are also broken down, and either returned to the atmosphere, or incorporated as organic matter in sediments. Only the

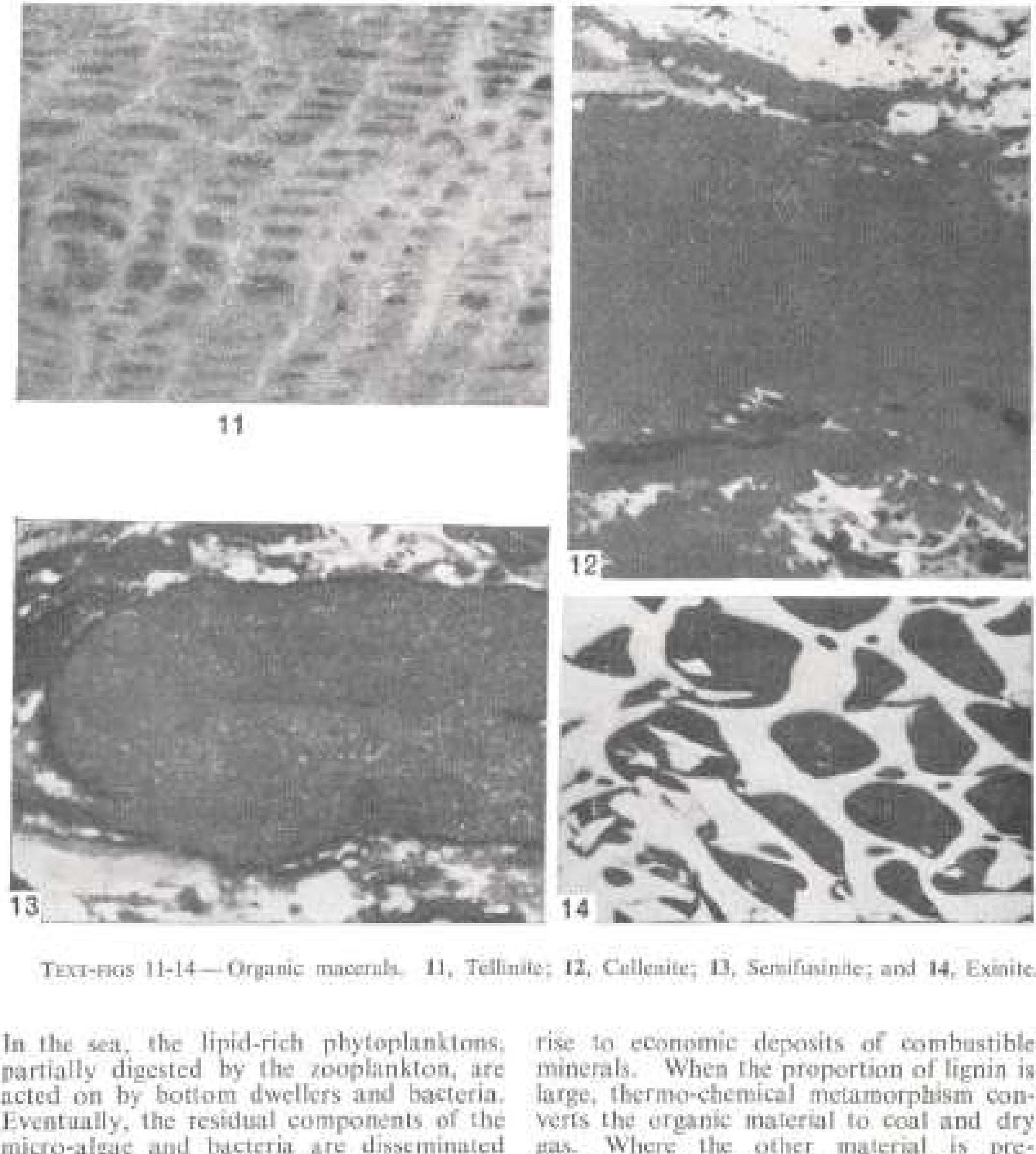


TEXT-FIG. 10 — Map of North Cambay Basin showing areas and members of the Kalol Formation predicted to be hydrocarbon bearing on palynological methods and subsequent discoveries (modified after Mathur *et al.*, 1974).

most resistant parts of organic matter remain; they consist essentially of humic and lipid matter.

Plants contain carbohydrates, such as cellulose and starch, strengthened by lignin. The leaves are protected by cuticle, which is impregnated with wax. The plants may also secrete resins, and they produce spores and pollen grains which are transported. When the plants die, they are biodegraded by means of the soil microfauna, fungi and bacteria. The carbohydrates are consumed, and humic acid is produced by the microorganisms. When plant remains are abundant and the debris water logged, oxygen supply is rapidly depleted, and the humic acid forms a gelatinous solution permeating the woody skeleton, consisting mainly of lignin. The humified wood becomes *Telinite* (Text-fig. 11) and the humic acid gel becomes *Collenite* (Text-fig. 12), two principal constituents of *Vitrinite*. With higher oxygen supply, the microbial degradation of organic matter is increased and the humic acids and humified woody skeletons become altered to mineral charcoal or *Fusinite* (Text-fig. 13). The spores, pollen, wax coated cuticle and resins together form *Exinites*.

These, then, are the components of land plants which are deposited in sediments.



TEXT-FIGS 11-14 — Organic macerals. **11**, Tellinite; **12**, Cellenite; **13**, Semifusinite; and **14**, Exinite.

In the sea, the lipid-rich phytoplanktons, partially digested by the zooplankton, are acted on by bottom dwellers and bacteria. Eventually, the residual components of the micro-algae and bacteria are disseminated through the sediment as it is buried; sometimes as actual cell walls which are termed *Alginites* and *Sporinites* (Text-fig. 14), but more often as a very fine-grained and amorphous film, clinging to inorganic particles. This organic matter is termed *Amorphous* sapropel. Where the concentration of organic matter is high enough, the enclosing rock is termed as the *source rock*. It is the thermo-chemical metamorphism which, this material undergoes due to burial, gives rise to economic deposits of combustible minerals. When the proportion of lignin is large, thermo-chemical metamorphism converts the organic material to coal and dry gas. Where the other material is preponderant, we get wet gases and oils. Historically, the insoluble organic matter remaining in a rock after extraction with solvents has been named as *Kerogen*. Kerogen on distillation yields hydrocarbons, and most authorities believe that kerogen is the source of petroleum. Most sedimentary kerogens are mixtures of organic matter derived from land plants rich in humic matter and marine plants rich in lipids.

Palynologists study the progressive alteration of plant material, from source area to mature source rock, as a part of the process of understanding how petroleum is formed. I have already mentioned the earlier stages of the process, i.e. biodegradation. The other facet of study is the *typing* of organic matter. The hydrocarbons produced by the source rock depend upon the percentages of different types of material in the kerogen, and thus we are getting near to being able to predict what kinds of oils and gas will be produced from a particular type of kerogen.

Besides the composition of the Kerogen, the other parameter in the composition of the resulting combustible mineral, i.e. coal or oil, is, of course, the degree of thermochemical alteration of the source material, due to increasing pressure and temperature, as the material is progressively buried. Here too, palynology has provided us the tools for estimating the degree of maturation of the source rock.

MATURITY OF SOURCE ROCKS FROM PALYNOLOGICAL STUDIES

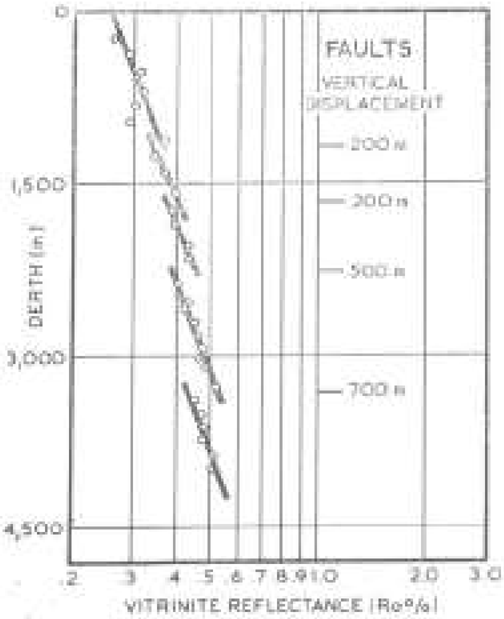
Organic matter in source rocks, as mentioned earlier, consists chiefly of remains of land and marine plants, which responds to increasing heat by physical changes, reflecting decrease in content of volatiles and concomitant enrichment in carbon. These changes are of four kinds, viz., (i) darker colouration of organic matter, (ii) increase in refractive index, (iii) increase in reflectivity, and (iv) loss of structural detail on particulate organic material and decrease in light transmission of particles.

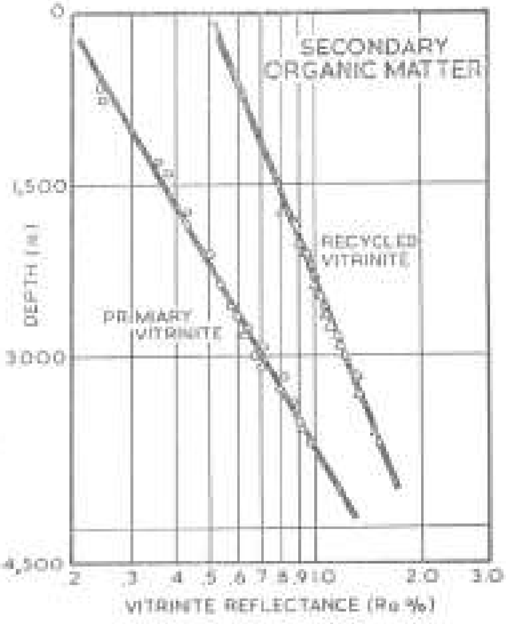
The changes can be quantified. Colour change of plant remains is the easiest to use and the least expensive method of estimating the maturity of the source rock. However, different organic material alter or mature at different rates. A scale of progressive alteration that uses colour changes must be based on similar material. It is usual to study colour change in spores and pollen which lack ornamentation as a guide to the maturity of the organic matter. Cuticles and epidermis could also be used, in the absence of spores and pollen, or as supplementary material. Care has to be taken in such work to eliminate older spores and pollen, redeposited with material appropriate to the age of the sediment being studied.

There are several scales for measuring the degree of thermal alteration. The 1-5 scale proposed by Staplin is the one which is generally used. The number assigned to a particular sample is designated as its Thermal Alteration Index or TAI. Higher numbers reflect progressively increasing temperature to which the sediments have been exposed. TAI 1 is ascribed to fresh material, and an index of 5 to thoroughly metamorphosed material. An index of 3·5 corresponds to the disappearance from both source and reservoir of all light oil producible components, except dry gas. At this index, plant cuticles and spores and pollen are dark brown in colour. The principal oil generation phase is at TAI 2·5-3·0

Of the other techniques, increase in vitrinite reflectivity is widely used, and is in many ways the most suitable, because it is quantitative, discriminatory, accounts for both time and temperature, is useful over the entire maturity range, and can be applied to most sedimentary rock types. In this type of work, too, it is necessary to identify the indigenous or autochthonous vitrinite. The results are plotted as reflectograms, i.e. histograms of frequency 1/2 V stages (0·05% vitrinite reflectivity intervals), and notes are made on organic petrography. When all the results are plotted, the indigenous vitrinite reflectance has to be selected, and the vitrinite reflectance vs. depth plot made. Vitrinite reflectivity provides a direct guide to thermal maturity of gas prone organic matter (humic material), and an indirect guide to the thermal maturity of oil prone organic matter (sapropelic material).

Discontinuities in the reflectivity — depth plot give important geological information. Normal faults are indicated by abrupt increase in reflectivity gradient, whereas reversed faults show abrupt decrease (Text-fig. 15). Reworked vitrinite may show a persistent trend (Text-fig. 16) indicating persistence through time of a particular source. Unconformities are marked by an abrupt increase in reflectivity, and often, from the change in the gradient, the thickness of the eroded strata can be calculated (Text-fig. 17). Igneous intrusions (Text-fig. 18), sills and dykes cause a rapid increase in reflectivity (Dow, 1977).



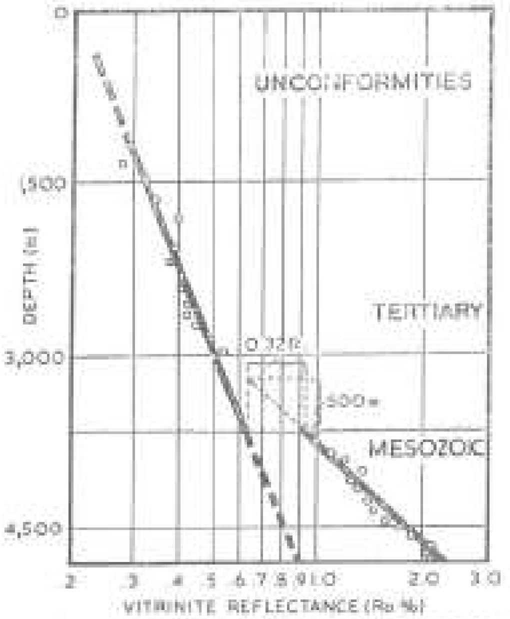


(W.G. DOW, 1977)

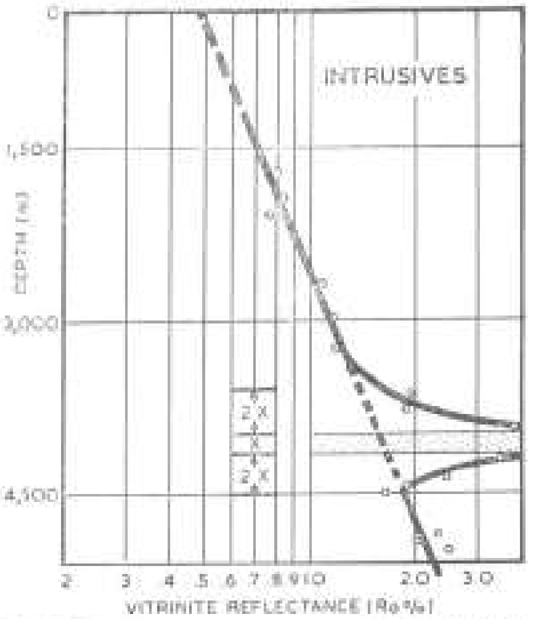
DISCONTINUITIES IN VITRINITE REFLECTIVITY DATA - I

TEXT-FIG. 15

TEXT-FIG. 16



DISCONTINUITIES IN VITRINITE REFLECTIVITY DATA - II

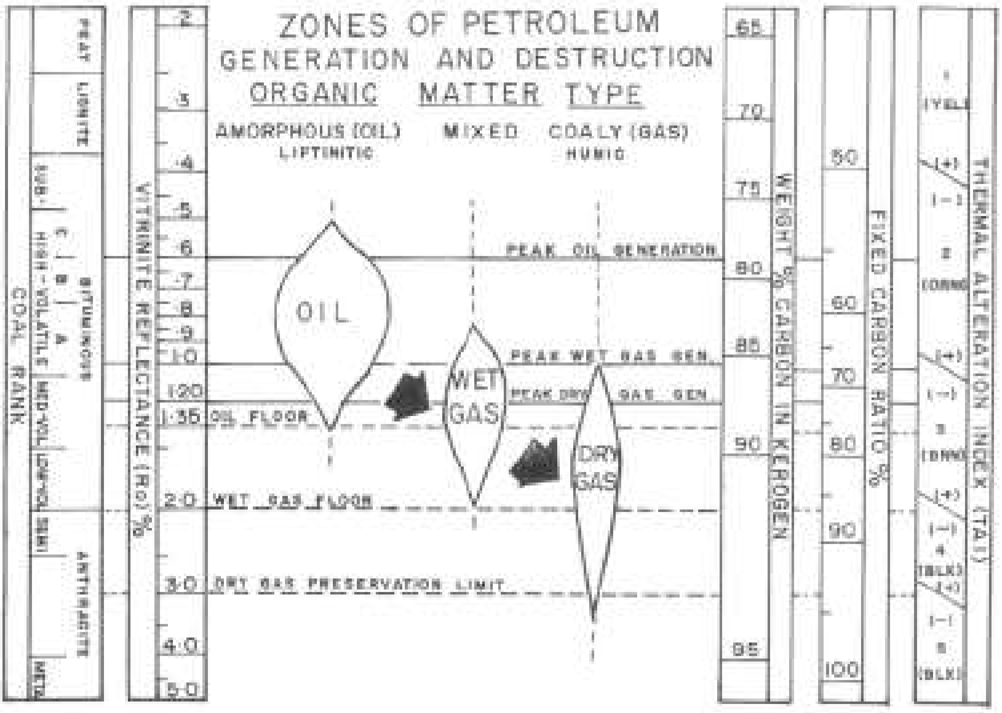


(W.G. DOW, 1977)

TEXT-FIG. 17

TEXT-FIG. 18

TEXT-FIGS 15-18 — Vitrinite reflectance maturation profiles.



TEXT-FIG. 19 — Correlation of the coal rank scale with various maturation indices and the zones of petroleum generation and destruction (Dow, 1977).

The correlation of different maturation indices and the zones of petroleum generation and destruction is shown in the Text-fig. 19 (Dow, 1977).

SUMMARY

To sum up, the special nature of the habitat of oil in sedimentary sequences is such that many of the problems connected with the geological side of oil exploration can only to tackled by palynology. In stratigraphy it is only by palynological studies that fresh-water sediments can be zoned and compared with standard marine zones down the palaeoslope from the strand line, and it is around the palaeo-shorelines that most oil occurs, being the most favourable location for the intertonguing between source and reservoir rocks. If we keep in mind the evolutionary and geological processes by which floral successions are vertically stacked in a sedimentary sequence, palynostratigraphy becomes a very important tool in oil exploration. Indian examples bear out the truth of this statement. Again, because land and marine plants occupy very specific ecological habitats, their remains are of high interpretative value in palaeogeographic studies. In particular, palaeoshorelines can be demarcated by estimating palynoflora density and ratio between land and marine palynoflora. Such studies have also been undertaken in Indian sedimentary basins. Palynology is also necessary in source rock studies, because plants contribute the largest amount of organic matter to source rocks. Different parts of plants contribute different types of organic compounds to source rocks, and form different oil and gas constituents, on the thermochemical metamorphism of the source rock. Finally, the degree of metamorphism of source rocks is best determined by studying the colouration of fossil spores and pollen and the vitrinite reflectance of plant remains. The latter study also yields other structural and stratigraphic information on a sequence, which is of importance in oil exploration.

ACKNOWLEDGEMENTS

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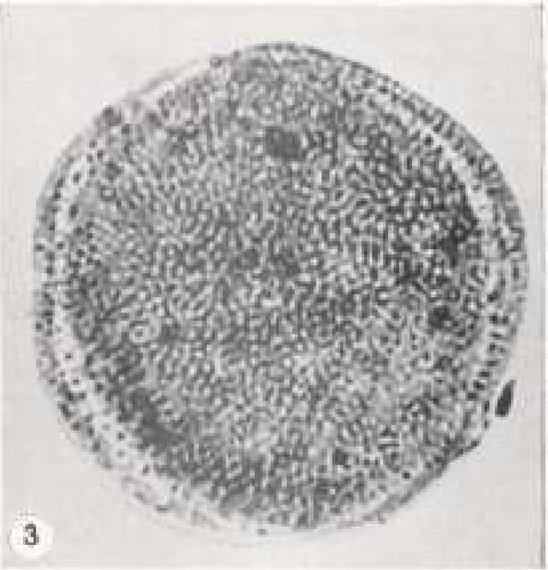

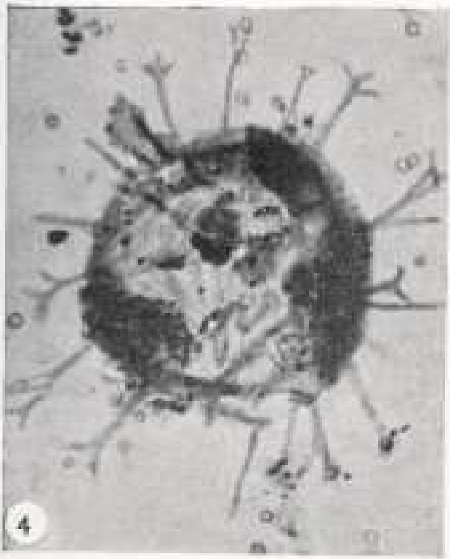

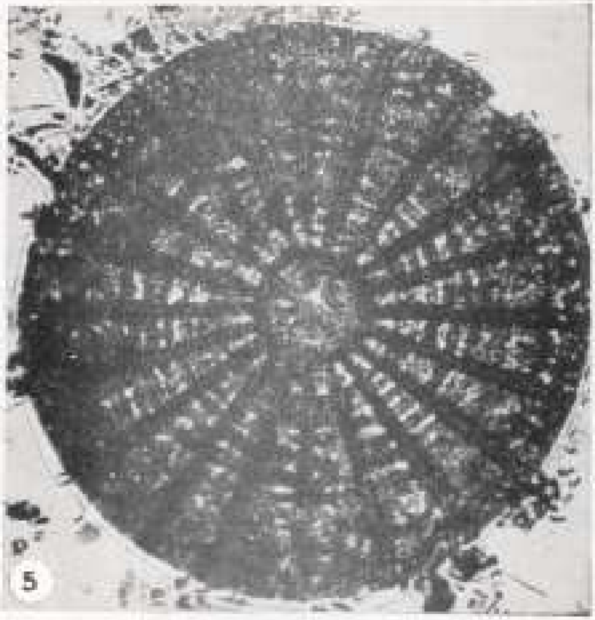

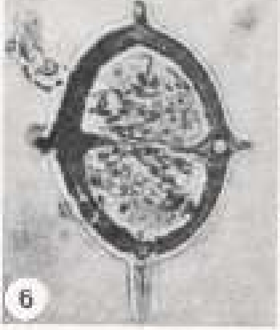

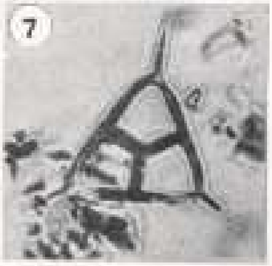

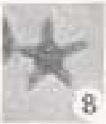

PLATE 1

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PLANT FOSSILS FROM THE GANGAPUR FORMATION

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ABSTRACT

Plant fossils have been recovered from the Gangapur Formation, originally known as 'Gangapur beds' of the Kota 'Stage'. The material was obtained from 11 localities in the vicinity of Gangapur Village, Adilabad District, Andhra Pradesh. The megafossils belong to the common Upper Gondwana forms. The commonest fossil is *Elatocladus*. A new species of the genus (*E. kingianus*) has been identified on the basis of epidermal features. Epidermal features of a species of *Pagiophyllum*, viz., *P. marwarensis*, have also been studied.

The palynological assemblage comprises about 64 taxa. The dominant element is the *Araucariacites-Callialasporites* complex. The stratigraphically important forms occurring in the samples are: *Trilites tuberculiformis*, *Ischyosporites crateris*, *Cooksonites variabilis* and *Microcachryidites antarcticus*.

After analysing the available palaeobotanical and palynological data, a basal Lower Cretaceous age for the Gangapur Formation is suggested.

Key-words — Plant fossils, Sporae dispersae, Gangapur Formation, Kota Stage, Upper Gondwana, India.

सारांश

गंगापुर शैल-समूह से पादपाश्म – महेन्द्र नाथ बोस, टी॰ एस॰ कुट्टी एवं हरि कृष्ण माहेश्वरी

गंगापुर शैल-समूह, जो कि मूलतः कोटा 'चरण' के 'गंगापुर संस्तरों' के नाम से विदित थे, से पादपाश्म उपलब्ध हुए हैं। आदिलाबाद जनपद (आंध्र प्रदेश) में गंगापुर गाँव के आस-पास के क्षेत्र से 11 स्थानों से सामग्री एकत्र की गई। गुरुपादपाश्म सामान्य उपरि गोंडवाना प्ररूपों से सम्बद्ध हैं। इलेटोक्लेडस सामान्यतया मिलने वाला पादपाश्म है। अधिचर्मी लक्षणों के आधार पर प्रजाति की एक नई जाति (इ॰ किंगियानस) अभिनिर्धारित की गई है। पैजियोफिल्लम् की एक जाति, पै॰ मारवारेन्सिस, के अधिचर्मी लक्षणों का भी अध्ययन किया गया है।

परागाणविक समुच्चय में लगभग 64 वर्गक विद्यमान हैं। ऍरोकेरियासाइटिस-कैलिएलास्पोराइटिस सम्मिश्र प्रभावी तत्व है। नमूनों में स्तरिकीय दृष्टि से मुख्य प्ररूप ट्राइलाइटिस ट्यूबरक्युलिफॉर्मिस, इस्कियोस्पोराइटिस क्रेटेरिस, कुक्सोनाइटिस वेरियाबिलिस एवं माइक्रोकैक्रिडाइटिस अंटार्कटिकस हैं।

सभी उपलब्ध पुरावनस्पतिक एवं परागाणविक आंकड़ों का विश्लेषण करने के पश्चात् गंगापुर शैल-समूह के लिए आधारी-अधर क्रीटेशस आयु प्रस्तावित की गई है।

INTRODUCTION

THE Gangapur Formation is known from the Pranhita Godavari Valley outcrop and was initially recognized (Kutty, 1969) in the vicinity of the village Gangapur (19° 16′ N. lat., 79° 26′ E. long.; Adilabad District, Andhra Pradesh) to represent beds previously referred to, in this area, as the 'Gangapur beds' by King (1881).

In the type area the formation consists of coarse to very coarse and sometimes pebbly sandstones below, which tend to thin to the west but become coarser and conglomeratic eastwards. These are followed by a succession of pale grey, whitish and pinkish mudstones and siltstones interbedded with beds of sandstone. In places slightly carbonaceous shales are also found. The plant fossils and palynomorphs described here were obtained from the finer lithologies.

The recognition of the Gangapur Formation and its relationship to older beds helped to resolve an almost ninety-year-old stratigraphic controversy involving it. According to King (1881), the 'Gangapur beds' formed the lower part of his 'Kota Group' while a 'limestone series' formed the upper part. The 'limestone series' was characterized by the presence of limestones yielding a fish fauna comprising *Lepidotes*, *Paradapedium* and *Tetragonolepis*, suggesting a Lower Jurassic age to it (King, 1881; Jain, 1973). The 'Gangapur beds', however, had yielded a flora containing *Taeniopteris spatulata*, *Ptilophyllum acutifolium*, *Elatocladus confertus*, *E. jabalpurensis*, *E. tenerrimus*, *Cheirolepis muensteri* and *Araucarites cutchensis*. This flora was considered by Feistmantel (1879) and King (1881) as showing a mixture of Rajmahal and Jabalpur floras and hence of an intermediate age. The 'Kota Group' thus had "plants of the Rajmahal, Jabalpur and Umia formations in what have been claimed to be lower and not higher horizons than animals which . . . are not younger than Lias" (Pascoe, 1959, p. 988).

This stratigraphic anomaly was resolved when Kutty (1969) showed that, in the area near Gangapur, the 'Gangapur beds' did actually rest with a marked unconformity on beds of the 'limestone series' and older beds. The Kota Formation with its characteristic limestones and fish fauna was redefined and the Gangapur Formation was recognized as being characterized by the 'Gangapur beds' of this area.

While the Gangapur Formation is known in the vicinity of Gangapur and to its west, its eastward extension and therefore its relationship to the Chikiala Formation are still to be fully worked out. However, Rudra (1972) recognized the Gangapur Formation around Yamanpalli in the eastern part of the outcrop, and observed that its stratigraphic position is between the Kota Formation in its revised sense and the Chikiala Formation; except for some calcareous fossil wood, no other plant fossil was reported. Thus, the post-Triassic Upper Gondwana sequence of the Pranhita-Godavari Valley, as it stands now, is as follows:

FORMATION	ROCK TYPES	CHARACTERISTIC FOSSILS	AGE
Chikiala	Highly ferruginous sandstone and conglomerate	?	?
Gangapur	Mudstones, siltstones and sandstones with pebbly beds and conglomerates	*Gleichenia*, *Taeniopteris*, *Ptilophyllum*, *Elatocladus*, *Pagiophyllum*	Early Lower Cretaceous
		Unconformity	
Kota	Limestone, sandstone, siltstones and red clays; pebbly sandstone at the base	Fish, crocodile, sauropod dinosaur, flying reptile	Lower — ? early Middle Jurassic
		? Unconformity	
Triassic beds			

It may be pointed out that the Gangapur Formation is not strictly synonymous with the 'Gangapur beds' of King. While in the vicinity of the village Gangapur they may correspond to the same set of beds of Lower Cretaceous age, a little to the east beyond Dharmaram, what King includes in his 'Gangapur beds' are of undoubted Triassic age.

Consequent to (i) the recognition of the Gangapur Formation and its separation from the Kota Formation by a major unconformity, (ii) the recognition of the Kota Formation, and (iii) the recognition of the Gangapur Formation in eastern part of the outcrop between Kota and Chikiala formations, it becomes difficult now to place previous reports of plant fossils in the revised stratigraphic sequence with a reasonable degree of assurance; this is particularly so in the eastern part where all the three formations occur. It would seem best to build up afresh the various floras from new collections made on the basis of remapping.

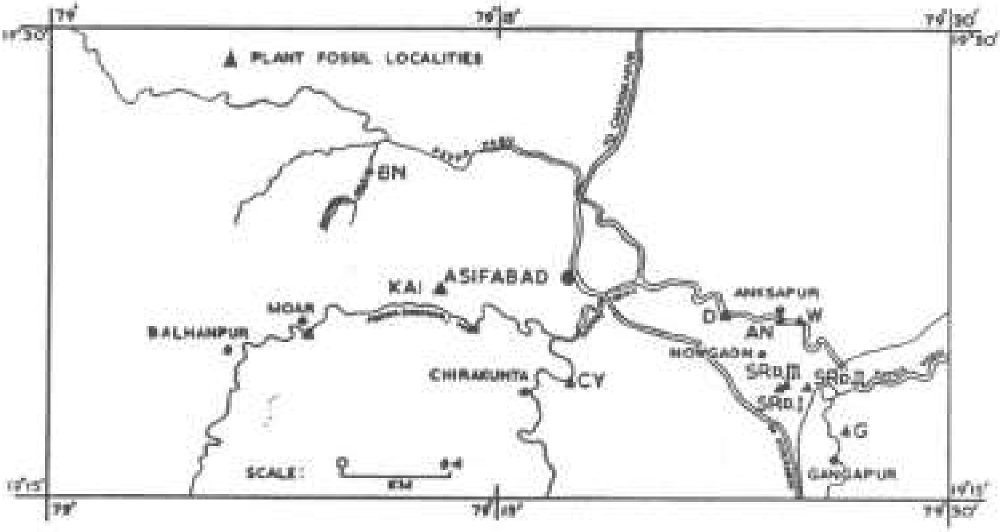
For example, Mahabale (1967) reported the following plant megafossils from the 'Kota-Maleri Stage'. The plant-bearing beds from Nowgaon and Jangaon possibly belong to the Gangapur Formation.

1. Nowgaon — *Elatocladus jabalpurensis*, *Araucarites cutchensis*.
2. Kota — *Elatocladus*, *Taxoxylon*, *Podocarpoxylon* and *Auraucarioxylon*.
3. Jangaon — *Pachypteris indica*, *Ptilophyllum acutifolium*, *Taeniopteris spatulata*, *Elatocladus confertus*, *E. jabalpurensis*, *Cheirolepis muensteri* and *Araucarites*.

His statements on the age of the 'Kota Stage' are self-contradictory. In the abstract of his work (Mahabale, 1967, p. 308) he placed Kota at par with the Upper Gondwanas or the Liassic but elsewhere in the same paper (p. 312) he says that "The age of Kota stage, could not be later than Rajmahals and earlier than Jabalpur.....". It is generally accepted that the Jabalpur flora is younger than even that of the Nipania plant bed of the Rajmahal Formation which is dated as Upper Jurassic in age. Probably he was influenced by the views of Wadia (1975, p. 67 and 188) that the Jabalpurs were older than the Rajmahals and the Kotas were still older.

Preliminary reports on the palynomorphs of the Gangapur Formation have been published by Shah and Singh (1974) and Ramanujam and Rao (1976). Palynologically a Lower Cretaceous age has been favoured.

A fresh attempt is made here to throw further light on the age of the Gangapur Formation from the palaeobotanical and palynological data obtained by the study of newly collected materials from a number of localities. For this work, T. S. K. made field observations and collected the material, M. N. B. and H. K. M. have worked out the megafossils and palynomorphs respectively. Conclusions have been arrived at jointly by the three authors whose names appear in alphabetical order.



TEXT-FIG. 1 — Map showing some of the plant fossil localities belonging to the Gangapur Formation.

MATERIAL AND METHODS

The localities from where the fossil collections were made are depicted in map (Text-fig. 1). The localities are:

1. Moar : on the stream bank near a bend SSE of the village Moar;
2. BN : on the bank of Butarmal Nala just south of the point where it crosses the road from Asifabad to Utnur 13 km W.N.W. of Asifabad;
3. CY : on a spur of the hill, east of the village Chirakunta;
4. D
5. An
6. W
{ on the banks of Pedda Vagu near Anksapur;
7. S.Rd.I
8. S.Rd.II
9. S.Rd.III
{ Quarries south-south-west of the village Nowgaon;
10. G : Quarry north of Cave Temple near Gangapur Village; and
11. KAI : Reddish mudstones and siltstones near base of hill about 7 km west of Asifabad.

Plant fossils are generally found in finer sediments, viz., mudstones, siltstones and the carbonaceous shale. A few fossils have also been found in ferruginous shales. Processing of samples for palynological study was done by the orthodox HF, HNO_3, KOH method. Slides were made in polyvinyl alcohol and canada balsam. Photography was done on ORWO NP15 35 mm film. The co-ordinates of the illustrated palynomorphs refer to Amplival microscope no. 599558 of BSIP, Lucknow.

Figured specimens and slides are housed in the Museum of Birbal Sahni Institute of Palaeobotany.

DESCRIPTION

A. MEGAFOSSILS

?*Cladophlebis* sp.

Text-fig. 2A

Detached (?) pinnule, 3.5 mm long, about 2 mm broad near base, falcate; margin thick, entire, near apex minutely denticulate; apex subacute, extreme base not well-preserved. Midrib prominant, lateral veins mostly forking once slightly away from midrib, arising at an angle of 32°-35°.

The pinnule looks like the pinnule of *Cladophlebis* sp. cf. *C. longipennis* Seward described by Roy (1968, pl. 2, fig. 17) and Kasat (1970, pl. 1, figs 3, 4).

Locality — Pedda Vagu about 3 km West of Anksapur.

Gleichenia nordenskioildii Heer

Pl. 1, figs 1-3; Text-fig. 2B, C

Detached pinnae, 0.25-1.1 cm long and 1.5-4 mm broad. Rachis slightly less than 1 mm in width. Pinnules 1-3 mm long and 0.5-1.5 mm broad, substance of lamina thick, ovate or somewhat cuneate, contiguous but margins never overlapping, occasionally sparsely set, attached at an angle of about 50°-60°. Margin thick, revolute; apex obtuse or rounded; base asymmetrical, acroscopic margin rounded and making a narrow sinus, basiscopic margin rounded, prolonged downwards, mostly covering entire width of pinna rachis. Midrib of pinnules prominent, near base forming a prominent groove; lateral veins mostly obscure.

The specimens match the specimens described by Sukh-Dev (1970, pl. 1, figs 3-5), Pant and Srivastava (1977, pl. 2, fig. 2) and Appert (1973, pl. 20, figs 9, 11).

Locality — Quarry no. S.Rd.III, S.S.E. of Nowgaon on way to Kagaznagar.

?*Gleichenia* sp.

Text-fig. 2D

The collection includes a badly preserved detached pinna whose pinnules, in gross features, resemble the pinnules of *Gleichenia rewahensis* Feistmantel described by Pant and Srivastava (1977, pl. 1, fig. 5). Its venation is not preserved.

Locality — Quarry no. S.Rd.III, S.S.E. of Nowgaon on way to Kagaznagar.

Taeniopteris sp. cf. *T. spatulata* McClelland

Pl. 2, fig. 18; Text-fig. 2E-G

Description is based on three fragmentary specimens. In all the three specimens apex and base are missing.

Leaves 1.7-4.6 cm long, 0.4-0.6 cm broad, margin entire. Midrib about 1 mm wide; lateral veins arising at an angle of 85°-90°, simple or forked, when forked mostly forking just after emergence or closer to midrib, a few forking closer to margin, about 28-32 per cm.

The specimens resemble the specimens figured by Oldham and Morris (1863, pl. 6, figs 1, 2), Feistmantel (1879, pl. 1, figs 8-10, 18) and Bose and Banerji (1980, pl. 1, figs 1, 2; pl. 5, fig. 28).

Locality — Quarry no. S.Rd.III, S.S.E. of Nowgaon on way to Kagaznagar.

?*Anomozamites* sp.

Pl. 1, fig. 5; Text-fig. 2H

Fragmentary specimen showing two incomplete segments. Frond 1 cm long and 2 cm broad; rachis about 2 mm wide, lateral veins forking once. Most complete segment measuring 1 cm in length and 0.8 cm in width, distal margin seems to be deeply notched, upper lateral margin entire, lower lateral margin not preserved.

In external feature and venation pattern the segments of the present specimen resemble the segments of *Anomozamites fissus* (Feistmantel) figured by Bose and Banerji (1980, text-fig. 8A, C).

Locality — Quarry no. S.Rd.I, S.S.E. of Nowgaon on way to Kagaznagar.

Ptilophyllum cutchense Morris

Pl. 1, fig. 4

Leaves incomplete at base and apex, 2.2-11.5 cm long, 1.1 cm broad. Rachis about 1 mm wide. Pinnae attached on upper surface of rachis by their entire base, closely set but never overlapping, 4.6 mm long, 1.5-2 mm broad; apex obtuse or sub-acute; acroscopic margin rounded, basiscopic margin straight. Veins mostly obscure, about 5-6 veins arising from base, more or less parallel, simple or forked.

The specimen matches the specimen of *Ptilophyllum cutchense* figured by Bose and Kasat (1972, pl. 2, fig. 17) from Vemavaram.

Locality — Quarry no. S.Rd.III, S.S.E. of Nowgaon on way to Kagaznagar.

Ptilophyllum sp. cf. *P. acutifolium* Morris

Text-fig. 2I-K

Leaves 9.5-10.8 cm long, 1.8-3.6 cm broad; rachis 1.5-2 mm broad. Pinnae arising at an angle of 45°-65°, closely set on upper side of rachis, 1.1-1.9 cm long and 2-2.5 mm broad near base; apex acute; margin entire, acroscopic margin curving downwards, basiscopic margin slightly decurrent. Veins parallel, 6-7 veins arising from base, simple or forked, mostly forking once, forking at all levels.

The specimens are narrower than the type specimen of *Ptilophyllum acutifolium* (Bose & Kasat, 1972, pl. 1, fig. 1). They resemble the specimen figured by Bose and Kasat (1972, pl. 1, fig. 6) from Raghavapuram which has been doubtfully referred to *P. acutifolium*. The present specimens also look like *P. acutifolium* described by Baksi (1968, pl. 1, fig. 1A, 1b) from Raghavapuram.

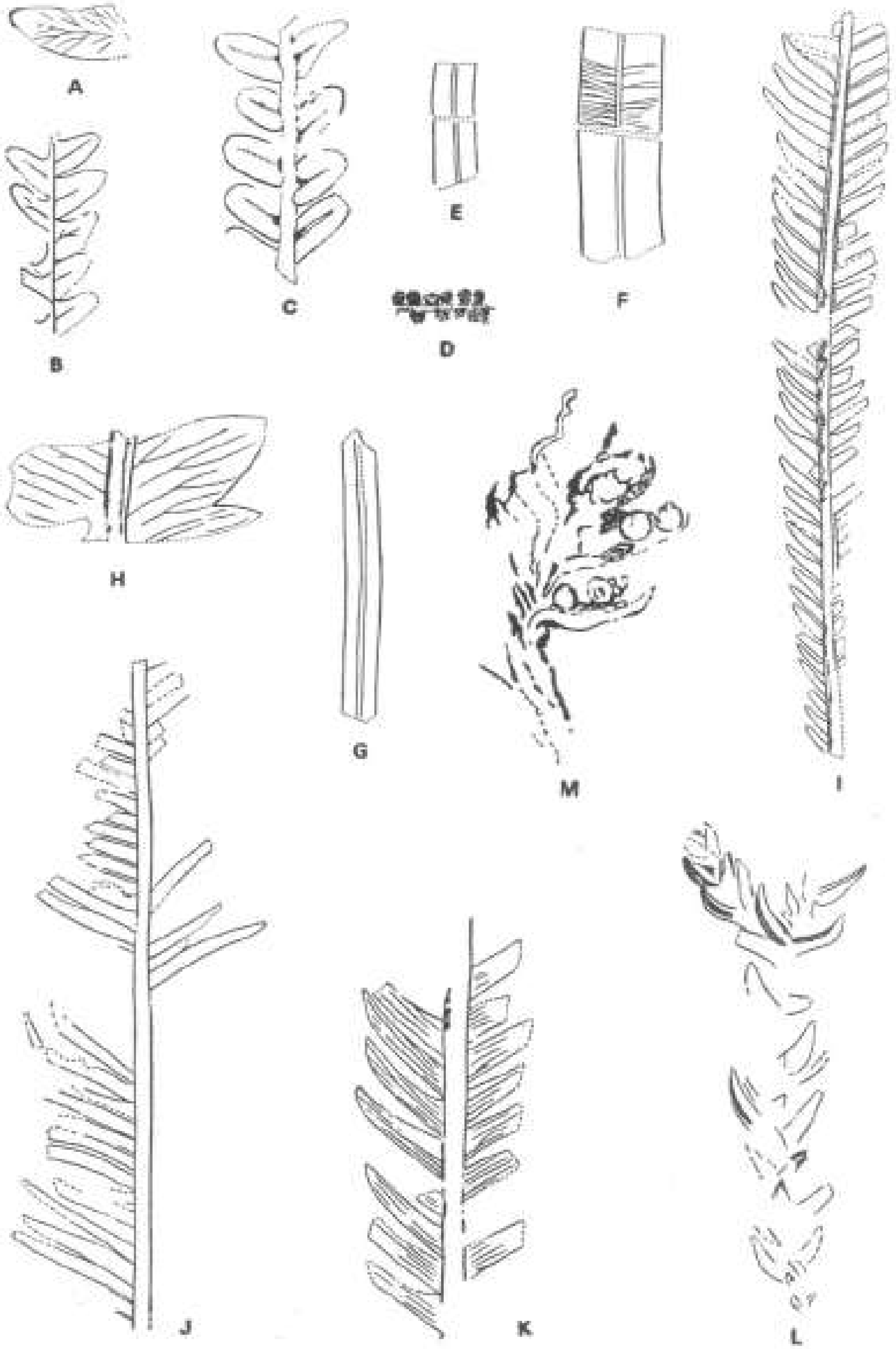
Localities — Quarry nos. S.Rd.I and III, S.S.E. of Nowgaon on way to Kagaznagar; 13 km W.N.W. of Asifabad, along the Butarmal Nala (stream); and base of hill about 7 km west of Asifabad.

Elatocladus sp.

P. 1, figs 6, 11

Shoots repeatedly branched, branchlets mostly lying in the same plane as the primary axis. Leaves helically borne, in compressed state seem to be biseriately arranged, making an angle of about 60°-90°. Leaves typically 6-8 mm long, 0.5-1 mm broad, almost uniformly broad from base to apex; margin entire; apex sub-acute or obtuse, rarely acute; acroscopic basal edge slightly constricted, basiscopic margin often slightly constricted, markedly decurrent. Midvein running from base to apex. At the point of forking branchlets covered with spirally arranged scale-like leaves which are followed by normal leaves. Scale-like leaves more or less wedge-shaped, 1.5-4 mm long, 0.5-1 mm broad near base; midvein faintly marked.

The specimens match the specimens of *Elatocladus tenerrimus* described by Feistmantel (1877) and Sahni (1928). They also



TEXT-FIG. 2

resemble the twigs of *E. pseudotenerrima* Maheshwari & Kumaran (1976), *E. sehoraensis* Maheshwari & Kumaran (1976) and *E. bosei* Maheshwari & Kumaran (1976). In the absence of cuticle the Gangapur specimens have not been referred to any of these species.

Localities — Quarry nos. S.Rd.I-III, S.S.E. of Nowgaon on way to Kagaznagar; about 13 km W.N.W. of Asifabad, along the Butarmal Nala (stream); and Pedda (Moaram) Vagu Stream, S.S.E. of Moar Village.

Elatocladus confertus (Oldham & Morris) Halle

Pl. 1, figs 7, 8, 13; Pl. 2, fig. 15; Text-fig. 2M

Branched leafy twigs, branching at different angles. Leaves spirally arranged, mostly spreading out in two rows, occasionally directed upwards or forwards, linear or linear-lanceolate, sometimes deltoid (close to base of shoot), 3-7 mm long, less than 1 mm broad. Margin entire; apex acute; base constricted or twisted, decurrent. Midrib mostly obscure, rarely visible in some.

The shoots agree with the specimens of *Elatocladus confertus* described by Halle (1913) and Sahni (1928).

Localities — Quarry no. S.Rd.III, S.S.E. of Nowgaon on way to Kagaznagar; and about 13 km N.N.W. of Asifabad, along the Butarmal Nala (stream).

Remarks — Amongst the several shoots collected, there is a branched shoot (in part and counterpart) which bears two megastrobili. The specimen (Pl. 1, figs 7, 8, 13; Text-fig. 2M) is rather badly preserved and its each branch has terminally placed megasporophylls. The megasporophylls are loosely arranged and are spirally borne. They are attached at angles of 50°-70°. In some of the megasporophylls two circular or broadly oval seeds are visible on their adaxial sides.

The specimen resembles the specimens of *Stachyotaxus sampathkumarani* Rao (1964) described from Onthea, Rajmahal Hills. The seeds in *S. sampathkumarani* Rao (1964) are pyramid-shaped, whereas, in the present specimen they are circular or broadly oval.

Elatocladus kingianus n. sp.

Pl. 1, fig. 10; Pl. 2, fig. 16; Text-fig. 3B

Diagnosis — Shoots slender and woody, irregularly or alternately branched, branches arising at angles of 40°-55°; leaves persistent, spirally borne, in compressed state seem to be biseriately arranged; attached by entire width of decurrent leaf-base. Leaves linear, 0.8-1.2 cm long, about 0.5-1 mm broad, margin entire, apex acute; leaf base contracted and twisted, acroscopic basal edge curving downwards, basiscopic basal edge markedly decurrent. Midrib mostly obscure.

Cuticle of almost same thickness on both sides of leaf, (?) upper side devoid of stomata and (?) lower side having stomata in a single band running along the midrib. Central stomatic band about 3-5 stomata wide, within the stomatic band stomata tending to form discontinuous narrow files. Stomata longitudinally orientated, distantly placed or touching each other but never sharing a common subsidiary cell. Subsidiary cells 4-6 (2 + 2 or 2 + 4), mostly 4 or 5, polar subsidiary cells smaller in size; lateral- and end-walls straight, rarely slightly undulated, surface smooth. Guard cells thinly cutinized, sunken; aperture slit-like. Encircling cells occasionally present. Cells between files and adjacent stomata mostly rectangular, rarely polygonal, smaller in size than those lying outside stomatal

←

TEXT-FIG. 2 — A, ?*Cladophlebis* sp., no. D14/67-68, × 6. B, C, *Gleichenia nordenskioldii* Heer, nos. S. Rd. III-21/67-68 and S. Rd. III-39/67-68, × 5. D, ?*Gleichenia* sp., no. S. Rd. III-29/67-68, × 2.5. E-G, *Taeniopteris* sp. cf. *T. spatulata* McClelland, nos. S. Rd. III-44/67-68 (E, F) and S. Rd. III-12/67-68 (G), E, G, × 1, F, × 2. H, ?*Anomozamites* sp., no. S. Rd. I-25/67, × 2. I-K, *Ptilophyllum* sp. cf. *P. acutifolium* Morris, nos. S. Rd. I-41b/67 (I, K) and S. Rd. III-2/67-68 (J), I, J, × 1, K, × 2. L, *Pagiophyllum marwarensis* Bose & Sukh-Dev, no. G3/4.2.71, × 3. M, *Elatocladus confertus* (Oldham & Morris) Halle showing a few megasporophylls, no. S. Rd. I-2b/67, × 4.

band; lateral- and end-walls straight, rarely slightly undulated or broken by pits. Cells outside stomatal band and cells of non-stomatic surface similar in shape and size, mostly much longer than broad, narrow, rectangular, rarely polygonal, serially arranged in longitudinal direction, lateral- and end-walls straight or rarely at places slightly undulated, or broken by pit; surface wall smooth, devoid of hair or papillae.

Holotype — No. G4/4.2.72 of Indian Statistical Institute, Calcutta, stored at B.S.I.P. Lucknow Museum.

Locality — Quarry north of Cave Temple near Gangapur Village.

Specific Name — After late Mr W. King of the Geological Survey of India, who had first worked out in detail the geology of the Gangapur region.

Comparison — In gross features *Elatocladus kingianus* resembles *E. tenerrimus* (Feistmantel) Sahni (1928), *E. pseudotenerrima* Maheshwari & Kumaran (1976), *E. sehoraensis* Maheshwari & Kumaran (1976) and *E. bosei* Maheshwari & Kumaran (1976), but it differs from all these species in having a central stomatic band on one surface only. Moreover, in the present species the ordinary epidermal cells are much longer than broad. *E. tenerrimus*, *E. sehoraensis* and *E. bosei* have stomata on both the srufaces. *E. pseudotenerrima* is hypostomatic but here the stomata are distributed within two bands leaving a central astomatic region. Most of the species of *Elatocladus* described by Harris (1935) from Greenland differ from *E. kingianus* in having two stomatal bands. Similarly the Yorkshire species of *Elatocladus* described by Harris (1979) have more than one stomatal band.

Pagiophyllum marwarensis Bose & Sukh-Dev

Pl. 1, figs 9, 12; Pl. 2, figs 14, 17, 19, 20; Text-figs 2L, 3A

Description — Unbranched, slightly curved leafy twigs, 2-8 cm long, 0.4-0.6 cm broad. Shoots bearing leaves in a spiral, spreading or directed side-ways or forwards, 3-4 mm long, 0.8-1 mm broad near base, keeled. Margin entire; apex acute; leaf base cushion rhomboidal.

Cuticle on both sides of almost equal thickness, amphistomatic. Upper side showing two broad stomatal bands leaving a central stomatic region, towards apex stomatal bands converging and joining each other. On lower side stomata confined towards lower half of leaf in two narrow, ill-defined bands. On both sides within stomatic regions stomata arranged in discontinuous files, occasionally a few lying outside files, majority transversely or obliquely orientated, rarely longitudinally placed. Guard cells thinly cutinized, not sunken, aperture slit-like. Subsidiary cells mostly 4-5, sometimes 6, slightly more cutinized than ordinary epidermal cells. Subsidiary cells surrounded by a ring of encircling cells. Ordinary epidermal cells within stomatal bands polygonal; lateral- and end-walls thick, straight, surface-wall unspecialized, rarely finely striated. Cells of non-stomatal region polygonal, more elongate.

The twigs in gross features and cuticular structure of leaves resemble *Pagiophyllum marwarensis* Bose & Sukh-Dev (1972). *P. sherensis* Maheshwari & Kumaran (1976) differs in having lesser number of stomata on upper surface. In *P. satpuraensis* Maheshwari & Kumaran (1976) on lower side, isolated stomata are found near apical region. In *P. marwarensis* such stomata are absent.

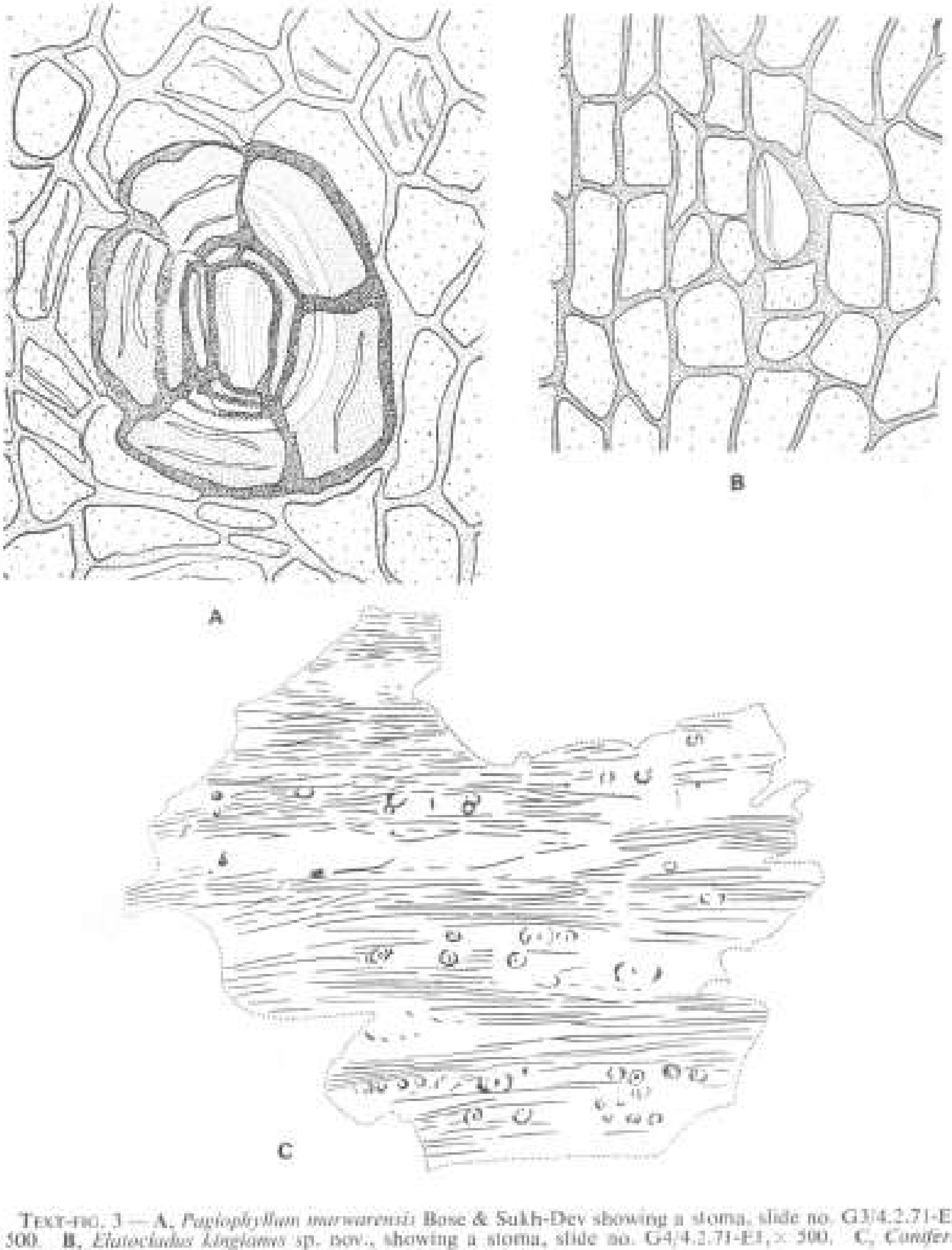
Localities — Quarry no. S.Rd.III, S.S.E. of Nowgaon on way to Kagaznagar; Quarry north of Cave Temple near Gangapur Village; Pedda (Moaram) Vagu stream, S.S.E. of Moar Village; Spur of the hill, about 2 km east of Chirakunta Village; and about 13 km W.N.W. of Asifabad, on the Butarmal Nala (stream).

Coniferocaulon sp. cf. *C. rajmahalense* Gupta

Text-fig. 3C

Description — Description is based on two fragmentary specimens measuring 6.4-7.6 cm in length and 9.7-12.1 cm in width. Surface showing discontinuous and irregularly running ridges and grooves, in transverse direction, within the ridges and grooves, at places, showing circular or elliptical protuberances.

The specimens resemble the specimens of *Coniferocaulon rajmahalense* figured by Bose *et al.* (1980) from the Pariwar Formation exposed near Habur. The specimen of *C. rajmahalense* described by Gupta (1954) and Bose (1957) from the Rajmahal Hills and Sher River respectively have ridges and grooves which are more distantly placed.



TEXT-FIG. 3 — **A**, *Pagiophyllum marwarensis* Bose & Sukh-Dev showing a stoma, slide no. G3/4.2.71-E3, × 500. **B**, *Elatocladus kingianus* sp. nov., showing a stoma, slide no. G4/4.2.71-E1, × 500. **C**, *Coniferocaulon* sp. cf. *C. rajmahalense* Gupta, no. S. Rd. I-15b/67, × 1.

B. PALYNOLOGICAL ASSEMBLAGE

Of the several samples macerated, only three, i.e. Sample D from the bank of the Pedda Vagu and samples G3/4.2.71 and G4/4.2.71 from a quarry north of the Cave Temple near Gangapur Village yielded palynomorphs. The palynomorph content of sample D is very poor and hence the following account is based upon the study of samples G3/4.2.71 and G4/4.2.71 only. The latter two samples represent the same bed. The palynological assemblage comprises 64 taxa of trilete, zonate and monolete spores and alete, monosaccate and disaccate pollen grains. Following is a systematized list of all the palynomorph taxa recorded. Some of the important taxa have been illustrated on Plates 3 and 4.

Anteturma — *Sporites* H. Potonié, 1893
Turma — *Triletes* Reinsch emend. Dettmann, 1963
Suprasubturma — *Acavatitriletes* Dettmann, 1963
Subturma — *Azonotriletes* Luber emend. Dettmann, 1963
Infraturma — *Laevigati* Bennie & Kidston emend. Potonié, 1956

Genus — *Deltoidospora*, Miner, 1953 emend. Potonié, 1956

1. *Deltoidospora* sp.

Genus — *Cyathidites* Couper, 1953

2. *Cyathidites australis* Couper, 1953
3. *Cyathidites minor* Couper, 1953
4. *Cyathidites concavus* (Bolkhovitina, 1953) Dettmann, 1963

Genus — *Stereisporites* Pflug, 1953

5. *Stereisporites psilatus* (Ross, 1949) Jain & Sah, 1966

Remarks — Specimens assigned to the genus *Stereisporites* by Kumar (1973, pl. 1, figs 16-18) do not belong here and are best placed under the genus *Deltoidospora*.

Genus — *Todisporites* Couper, 1958

6. *Todisporites* sp.

Remarks — Spore 68 μm, trilete, rays 2/3 spore radius, labra thickened; exine smooth, infolded as in *Calamospora*.

Genus — *Callispora* Dev, 1961

7. *Callispora potoniaei* Dev, 1961

Infraturma — *Apiculati* Bennie & Kidston emend. Potonié, 1956

Genus — *Leptolepidites* Couper, 1953

8. *Leptolepidites* sp.

Remarks — Spore subcircular, 64 μm, trilete mark incipient; exine ornamented with verrucate projections, verrucae 4-5 μm in diameter, clearly seen only along the equatorial margin.

Genus — *Osmundacidites* Couper, 1953

9. *Osmundacidites wellmanii* Couper, 1953

Genus — *Baculatisporites* Thomson & Pflug, 1953

10. *Baculatisporites rotundus* Kumar, 1973
11. *Baculatisporites comaumensis* (Cookson, 1953) Potonié, 1956

Remarks — Singh, Srivastava and Roy (1964, p. 287) seem to consider *Osmundacidites comaumensis* (Cookson) Balme, 1957 and *Baculatisporites comaumensis* (Cookson) Potonié as separate taxa whereas both are same being later nomenclatural changes for *Trilites comaumensis* Cookson, 1953. Stanley (1965, p. 250, pl. 31, figs 6-9) has transferred the species to the extant genus *Osmunda* L.

Genus — *Conosmundasporites* Klaus, 1960

12. *Conosmundasporites* sp.

Remarks — Spore roundly triangular, 70 μm, trilete, rays more than 3/4 spore radius long, labra raised, distinctly thickened; exine about 2 μm thick, beset with closely placed, uniformly distributed coni.

Conosmundasporites othmari Klaus, 1960 has comparatively sparse exine ornament elements. Dettmann (1963, p. 31) considers the genus to be 'almost certainly synonymous with *Osmundacidites*'.

Genus — *Neoraistrickia* Potonié, 1956

13. *Neoraistrickia* sp.

Remarks — *Lophotriletes* sp. of Kumar (1973, p. 98, pl. 1, figs 28, 29) is comparable and should be referred to the genus *Neoraistrickia*.

Genus — *Apiculatisporis* Potonié & Kremp, 1954

14. *Apiculatisporis* sp.

Remarks — Spore circular, 32 μm in diameter, trilete, rays 2/3 spore radius long; exine beset with uniformly distributed low set coni.

Genus — *Impardecispora* Venkatachala, Kar & Raza, 1969

15. *Impardecispora* sp.

Infraturma — *Murornati* Potonié & Kremp, 1954

Genus — *Foveosporites* Balme, 1957

16. *Foveosporites* sp.

Remarks — Spores subcircular, 60-78 μm in diameter, trilete, rays 1/2 to 2/3 spore radius long; exine foveopunctate, elements less than 1 μm in diameter.

One of the specimens has an apparent appearance of *Callumispora* Bharadwaj & Srivastava, 1969.

Genus — *Lycopodiumsporites* Thiergart ex Delcourt & Sprumont, 1955

17. ?*Lycopodiumsporites* sp.

Genus — *Klukisporites* Couper, 1958

18. *Klukisporites scaberis* (Cookson & Dettmann, 1958) Dettmann, 1963

Remarks — Spore subtriangular, 55 μm, sides concave, apices rounded, trilete prominent, rays 3/4 spore radius long, labra thick, accompanied by a row or two of foveolae; distal exine foveoreticulate, muri strong as if formed by coalescing warts. *K. haradensis* Kumar, 1973 is apparently similar.

Genus — *Cicatricosisporites* Potonié & Gelletich, 1933

19. *Cicatricosisporites australiensis* (Cookson, 1953) Potonié, 1956
20. *Cicatricosisporites typicus* Sah & Jain, 1956

Subturma — *Zonotriletes* Waltz, 1935
Infraturma — *Auriculati* Schopf emend. Dettmann, 1963

Genus — *Trilites* Erdtman, 1947 ex Couper, 1953 emend. Dettmann, 1963

21. *Trilites tuberculiformis* Cookson, 1947

Genus — *Ischyosporites* Balme, 1957

22. *Ischyosporites crateris* Balme, 1957

Remarks — Spore triangular, 54 μm; exine auriculate, 4 μm at apices, 2 μm elsewhere, distally reticulate, muri very thick, 2-3 μm, lumina polygonal, proximal exine smooth except at apices where distal muri encroach upon.

Infraturma — *Cingulati* Potonié & Klaus, 1954 emend. Dettmann, 1963

Genus — *Foraminisporis* Krutzsch, 1959

23. *Foraminisporis* sp.

Genus — *Contignisporites* Dettmann, 1963

24. *Contignisporites cooksonae* (Balme, 1957) Dettmann, 1963
25. *Contignisporites dettmannae* Singh & Kumar, 1969
26. *Contignisporites fornicatus* Dettmann, 1963
27. *Contignisporites glebulentus* Dettmann, 1963

Turma — *Monoletes* Ibrahim, 1933
Suprasubturma — *Acavatomonoletes* Dettmann, 1963
Subturma — *Azonomonoletes* Luber, 1935
Infraturma — *Laevigatomonoleti* Dybova & Jachowicz, 1957

Genus — *Monolites* Erdtman, 1947 emend. Potonié, 1956

28. *Monolites grandis* Dev, 1961

Remarks — *Monolites indicus* Kumar (1973, p. 111, pl. 4, figs 92, 93) represents better preserved specimens of *M. grandis* Dev and is considered here as a junior synonym of the latter species. *Monolites intragranulosus* Singh, Srivastava & Roy, 1964 also resembles *M. grandis* but for a smaller size range.

Genus — *Crassimonoletes* Singh, Srivastava & Roy, 1964

29. *Crassimonoletes minor* Singh, Srivastava & Roy, 1964

Infraturma — *Sculptatomonoleti* Dybova & Jachowicz, 1957

Genus — *Leschikisporis* Potonié emend. Bharadwaj & Singh, 1964

30. *Leschikisporis indicus* Singh, Srivastava & Roy, 1964

Remarks — There is a spore tetrad also in the collection. Spores oval, or subtriangular (probably preservation artefacts), two-layered, outer layer seemingly covering the central body on all sides, proximally forming a sort of longitudinal slit. These specimens probably do not belong to this species.

Genus — *Schizaeoisporites* Potonié, 1951 emend. Krutzsch, 1959

31. ?*Schizaeoisporites* sp.

Remarks — Spore oval-elliptical, long axis 60 µm, short axis 41 µm; exine ribbed, ribs running parallel to the longer axis, coalescing at poles, slightly criss-crossed.

Turma — *Hilates* Dettmann, 1963

Genus — *Cooksonites* Pocock, 1952 emend. Dettmann, 1963

32. *Cooksonites variabilis* Pocock, 1962
33. *Cooksonites* sp.

Remarks — Spore subtriangular, cingulate, cingulum comprising an inner thick zone and an outer thin zone; exine conate, coni extending upon cingulum, distal polar exine breaking down to form a distinct, subcircular hilum.

The specimen differs from *Cooksonites variabilis* Pocock in having a conact distal exine.

Genus — *Aequitriradites* Delcourt & Sprumont emend. Cookson & Dettmann, 1961

34. *Aequitriradites* sp. cf. *A. verrucosus* (Cookson & Dettmann, 1958) Cookson & Dettmann, 1961

Remarks — The specimen differs from the Australian specimens described by Cookson and Dettmann (1961) and Dettmann (1963) in having a comparatively narrow zona.

Anteturma — *Pollenites* Potonié, 1931
Turma — *Saccites* Erdtman, 1947
Subturma — *Monosaccites* Chitaley, 1949 emend. Potonié & Kremp, 1954
Infraturma — *Prosaccites* Maheshwari, 1974

Genus — *Callialasporites* Dev, 1961 emend. Maheshwari, 1974

35. *Callialasporites baculosus* Sukh-Dev in Maheshwari, 1974
36. *Callialasporites dampieri* (Balme, 1957) Dev, 1961
37. *Callialasporites discoidalis* (Döring, 1962) Bharadwaj & Kumar, 1972
38. *Callialasporites circumplectus* Kumar, 1973
39. *Callialasporites lametaensis* Kumar, 1973

Remarks — *Callialasporites kattarakkamense* Ramanujam & Srisailam (1974, p. 86, pl. 5, fig. 41) is a junior synonym.

40. *Callialasporites rudisaccus* Maheshwari, 1974
41. *Callialasporites rimalis* Singh, Srivastava & Roy, 1964
42. cf. *Callialasporites reticulatus* Ramanujam & Srisailam, 1974
43. *Callialasporites segmentatus* (Balme, 1957) Dev, 1961
44. *Callialasporites triletus* Singh, Srivastava & Roy, 1964
45. *Callialasporites trilobatus* (Balme, 1957) Dev, 1961

Genus — *Properinopollenites* Maheshwari, 1974

46. *Properinopollenites singhii* Maheshwari, 1974

Subturma — *Disaccites* Cookson, 1947
Infraturma — *Pinosacciti* Erdtman emend. Potonié, 1958

Genus — *Alisporites* Daugherty, 1941 emend. Jansonius, 1971

47. *Alisporites grandis* (Cookson, 1953) Dettmann, 1963

Infraturma — *Podocarpoiditi* Potonié, Thomson & Thiergart, 1950

Genus — *Platysaccus* Naumova, 1937 ex Potonié & Klaus, 1954

48. *Platysaccus indicus* Sah & Jain, 1965

Genus — *Podocarpidites* Cookson, 1947 ex Couper, 1953

49. *Podocarpidites ellipticus* Cookson, 1947
50. *Podocarpidites novus* Sah & Jain, 1965
51. *Podocarpidites vermiculatus* Kumar, 1973
52. *Podocarpidites multesimus* (Bolkhovitina, 1956) Pocock, 1962
53. cf. *Podocarpidites major* Couper, 1953

Remarks — Central body rhomboid, with two vertical infolds along distal zone of saccus attachment, sacci laterally continuous, reticulation medium coarse.

Genus — *Cedripites* Wodehouse, 1933

54. *Cedripites nudis* Kar & Sah, 1970

Infraturma — *Abietosacciti* Erdtman, 1947 ex Potonié, 1958

Genus — *Abiespollenites* Thiergart in Raatz, 1937

55. *Abiespollenites* sp.

Genus — *Microcachryidites* Cookson, 1947 ex Couper, 1953

56. *Microcachryidites antarcticus* Cookson, 1947

Genus — *Podosporites* Rao, 1943

57. *Podosporites tripakshi* Rao, 1943

Turma — *Plicates* Naumova, 1939
Subturma — *Monocolpates* Iversen & Troels-Smith, 1950

Genus — *Cycadopites* Wodehouse, 1933 ex Wilson & Webster, 1946

58. *Cycadopites gracilis* Sah & Jain, 1965

Turma — *Poroses* Naumova emend. Potonié, 1960
Subturma — *Monoporines* Naumova, 1939

Genus — *Classopollis* Pflug, 1953 emend. Pocock & Jansonius, 1961

59. *Classopollis indicus* Maheshwari, 1974
60. *Classopollis* sp. cf. *C. classoides* Pflug, 1949 emend. Pocock & Jansonius, 1961

Remarks — Pollen circular, 33 μm, trilete distinct, rays ± 3·5 μm long; exine 2 μm, infrapunctate, distally aperturate.

The specimen lacks the typical equatorial arrangement of the elements and is somewhat comparable with the specimens of Dettmann (1963, pl. 26, figs 10-12).

Genus — *Exesipollenites* Balme, 1957

61. *Exesipollenites crassimarginatus* Jain & Sah, 1966

Remarks — Pollen circular, no haptotypic mark, 32 μm, central pore about 7 μm in diameter, exine differentially thickened, pitted.

Turma — *Aletes* Ibrahim, 1933
Subturma — *Azonaletes* Luber emend. Potonié & Kremp, 1954

Genus — *Araucariacites* Cookson, 1947 ex Couper, 1953

62. *Araucariacites australis* Cookson, 1947
63. *Araucariacites ghuneriensis* Singh, Srivastava & Roy, 1964

Remarks — Pollen grains apparently of *Araucariacites* type, sometimes split into two equal halves along a median weak zone as in the case of the genus *Schizosporis*. The two hemispherical halves infold inwards along their equatorial margins and quite often become oval-elliptical in shape with a short of median pseudo-colpus. To the uninitiated eye such grains may look like those of the genus *Cycadopites*, and during frequency count one may erroneously obtain a high percentage of the genus *Cycadopites* probably at the cost of the genus *Araucariacites* (Pl. 4, figs 60-63).

Genus — *Laricoidites* Potonié, Thomson & Thiergart, 1950

64. cf. *Laricoidites communis* Sah & Jain, 1965

Sample D is very poor in number of specimens as well as that of the taxa. The important taxa identified in this sample are:

Cyathidites concavus (Bolkhovitina, 1956) Dettmann, 1963

Callialasporites dampieri (Balme, 1957) Dev, 1961

Callialasporites trilobatus (Balme, 1957) Dev, 1961, and

Araucariacites australis Cookson, 1947

ANALYSIS OF THE PALYNOLOGICAL ASSEMBLAGE

As mentioned in the earlier pages only two samples, viz., G3/4.2.71 and G4/4.2.71 have a sizable number of palynomorph taxa. There are approximately 64 species of pollen and spores, and these are referable to 39 genera. A spore-pollen count shows virtually the same quantitative representation of the genera in the two samples. This was to be expected as these represent the same bed. The minor variations in the spore-pollen content are of no significance.

The quantitative analysis shows that both the samples, viz., G3/4.2.71 and G4/4.2.71 are predominated by pollen of the genus *Araucariacites* with the percentages 57.75 and 53.00 respectively. *Callialasporites* is the next prominent genus with the respective percentages of 25.75 and 31.25. Other significantly occurring genera are *Alisporites* (3% and 3.25% respectively), *Podocarpidites* (4.75% and 3.25% respectively) and *Podosporites-Microcachryidites* (2.75% and 2% respectively). Following genera are of very rare occurrence and were not encountered in a count of 400 specimens: *Stereisporites*, *Callispora*, *Leptolepidites*, *Osmundacidites*, *Baculatisporites*, *Conosmundasporites*, *Foveosporites*, *Neoraistrickia*, *Apiculatisporis*, *Klukisporites*, *Impardecispora*, *Ischyosporites*, *Foraminisporis*, *Crassimonoletes*, *Cooksonites*, *Aequitriradites*, *Platysaccus* and *Abiespollenites*. Other genera are less than 1 per cent in occurrence.

DISCUSSION

The Gangapur Formation belongs to what is usually referred to as the Upper Gondwana or floristically as the Ptilophyllum Flora. The Upper Gondwana encompasses the time period from the Lower Jurassic to the upper part of the Lower Cretaceous. Though various authors have, from time to time, tried to palaeobotanically distinguish the Jurassic and Cretaceous parts of the Upper Gondwanas, so far no satisfactory criterion has been evolved to demarcate the Jurassic-Cretaceous boundary. For example, the Bansa Formation of South Rewa Gondwana Basin is accepted as of Lower Cretaceous age on the basis of the characteristic Wealden fern *Weichselia reticulata* Stokes & Webb (Bose & Dev, 1959) but palynologically the formation is not much different from the Jabalpur Formation (Maheshwari, 1974).

In the Jurassic-Lower Cretaceous rocks of India, two major types of megaplant assemblages are known. The older beds have mainly pteridophytic, bennettitalean and conifer remains and amongst these the Bennettitales dominate. In the younger beds the plant association is dominated by pteridophytes and conifers; the bennettitalean remains are either missing or are present only in meagre number. Here, amongst the pteridophytes the genus *Gleichenia* is common alongwith *Weichselia* and amongst the conifers *Pagiophyllum-Brachyphyllum* complex is more common. The former type of assemblage is known from most of the localities in the Rajmahal Hills (except Nipania), East Coast Gondwana, Godavari-Pranhita and Satpura basins, Pariwar Formation exposed near Habur and Kachchh. The latter type is known from Bansa, Himmatnagar, Gardeshwar and Than.

The Gangapur assemblage is characterized by the presence of *Gleichenia nordenskioldii*, *Taeniopteris spatulata*, *Ptilophyllum cutchense*, *P.* sp. cf. *P. acutifolium*, *Elatocladus confertus*, *E. kingianus*, *Elatocladus* sp. and *Pagiophyllum marwarensis*. The commonest genus amongst these is *Elatocladus*. The specimens of *Ptilophyllum* are more like the ones found at Vemavaram, Sriperumbudur and other localities in the Cauvery Basin. The overall assemblage is more like the ones occasionally found at Sivaganga and Sriperumbudur. Only *Gleichenia nordenskioldii* and *Pagiophyllum marwarensis* are not known from these localities. In India, both these species are so far known from the undoubted Lower Cretaceous beds. *G. nordenskioldii* is known from Bansa, Than and Gardeshwar, whereas, *P. marwarensis* has been reported only from Bansa. The latter species is now also known from Hard River and Parsapani in the Satpura Basin, supposed to be of Upper Jurassic age. Outside India, *G. nordenskioldii* is known mostly from Lower Cretaceous beds though recently it has been described from the Upper Jurassic of Madagascar (Appert, 1973).

The Upper Gondwana palynoflora is basically uniform and is usually dominated by the *Araucariacites-Callialasporites* complex. The palynological assemblages from eastern and central India differ little from one another (Bharadwaj, Kumar & Singh, 1972; Maheshwari, 1973, 1974, 1975). The Jurassic and Cretaceous assemblages of surface samples from Kachchh Basin have some distinctive elements but the situation is still not very clear and needs further study. Within the Lower Cretaceous of Kachchh two palynological zones have been identified. The Lower Cretaceous palynological assemblage of Section K of Venkatachala (1969) is not different from the Upper Jurassic middle palynological assemblage of the Upper Katrols (Bharadwaj, 1969). The palynological assemblages from Sections J and L of Venkatachala, on the other hand, are rich in the genus *Impardecispora*, a situation not observed so far any where else in India. In the subsurface, however, Koshal (1975) has recognized 3 distinct zones, viz. (i) *Gliscopollis-Classopollis* Zone (Lower Jurassic), (ii) *Callialasporites trilobatus* Zone (Middle-Upper Jurassic), and (iii) *Inaperturopollenites-Araucariacites*-complex Zone (Lower Cretaceous).

The Jurassic and Lower Cretaceous palynological assemblages from Rajasthan characteristically have high percentages of the genus *Classopollis* (Srivastava, 1966; Banerjee, 1972; Lukose, 1972). Such high percentages of *Classopollis* are not known so far from any other area in India.

Venkatachala and colleagues identify 3 palynological zones in the Jurassic-Cretaceous of South India. These zones are:

(i) *Callialasporites segmentatus* Zone of Upper Jurassic age, characterized by the presence of *Cicatricosisporites*, *Contignisporites*, *Callialasporites*, *Podocarpidites*, *Araucariacites* and *Classopollis* and the lack of *Trilites*, *Cooksonites*, *Aequitriradites* and *Leptolepidites*.

(ii) *Microcachrydites antarcticus* Zone of Neocomian age, characterized by the presence of *Microcachryidites*, *Podosporites*, *Trilites*, *Cooksonites*, *Leptolepidites*, *Staplinisporites* and *Aequitriradites* and by the absence of *Polypodiaceoisporites* and *Coptospora*.

(iii) *Coptospora cauveriana* Zone of Aptian-Lower Albian age, characterized by the presence of *Polypodiaceoisporites* and *Coptospora* besides other Lower Cretaceous genera.

A comparison with the various Jurassic-Cretaceous palynological assemblages reported from India shows that the Gangapur assemblage has a close affinity with the Athgarh palynological assemblage (Maheshwari, 1975) in the quantitative count of the genera *Araucariacites*, *Callialasporites*, *Alisporites* and *Podocarpidites*. But the Gangapur assemblage has certain characteristic elements, e.g. *Trilites tuberculiformis*, *Ischyosporites crateris*, *Cooksonites variabilis*, *Aequitriradites* sp. cf. *A. verrucosus* and *Microcachryidites antarcticus*. These elements characterize the Lower Cretaceous palynological assemblages of the Godavari and the Cauvery basins (Rao & Venkatachala, 1971; Venkatachala, Sharma & Jain, 1972; Ramanujam & Srisailam, 1974; Ramanujam & Varma, 1977). The Gangapur assemblage is more akin to the *Microcachryidites antarcticus* zone mioflora.

Outside India, the genera *Impardecispora*, *Foraminisporis*, *Foveosporites* and *Aequitriradites* are characteristic of the Lower Cretaceous of England and Germany (Dörhöfer & Norris, 1977). The genus *Cicatricosisporites* is believed to have appeared only at the base of Berriasian in the Siberian and Indo-European regions of the Soviet Union (Vakhrameev, Barkhatnaya, Dobrutskaya, Pavolv, Rovnina & Fokina, 1975). In Australia this genus made its appearance almost at the end of Upper Jurassic (Balme, 1964). Of course, the genus has also been reported from the Upper Jurassic of western Canada (Pocock, 1962) and England (Dörhöfer & Norris, 1977).

Thus, considering all the available plant fossil data, the age of the Gangapur Formation seems to be somewhere near the Jurassic-Cretaceous boundary probably within the basal Lower Cretaceous.

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EXPLANATION OF PLATES

Plate 1

1-3. *Gleichenia nordenskioldii* Heer, nos. Rd. III-39/67-68, D-6/67-68, S. Rd. III-42/67-68, figs 1 & 2. × 1, fig. 3. × 5.
4. *Ptilophyllum cutchense* Morris, no. S. Rd. III-3/69-70. × 1.
5. ?*Anomozamites* sp., no. S. Rd. I-25/67. × 1.
6. *Elatocladus* sp., no. S. Rd. II-2b/67. × 1.
7, 8. *Elatocladus confertus* (Oldham & Morris) Halle, showing a few megasporophylls, nos. S. Rd. I-2a, b/67, fig. 7. × 1, fig. 8. × 2.
9. *Pagiophyllum marwarensis* Bose & Sukh-Dev, no. CYI-3/67-68. × 1.
10. *Elatocladus kingianus* sp. nov., no. G4/4.2.71. × 1.
11. *Elatocladus* sp., no. S. Rd. III-2/67-68. × 1.
12. *Pagiophyllum marwarensis* Bose & Sukh-Dev, no. S. Rd. III-27/67-68. × 1.
13. *Elatocladus confertus* (Oldham & Morris) Halle, a part of the specimen shown in fig. 8 enlarged, no. S. Rd. I-2b/67. × 4.

Plate 2

14. *Pagiophyllum marwarensis* Bose & Sukh-Dev, no. G3/4.2.71. × 1.
15. *Elatocladus confertus* (Oldham & Morris) Halle, no. S. Rd. III-4/67-68. × 1.

16. *Elatocladus kingianus* sp. nov., showing a few stomata on lower surface, slide no. G4/4.2.71-E1. × 200.
17. *Pagiophyllum marwarensis* Bose & Sukh-Dev, showing epidermal cells and a few stomata on lower surface, slide no. G3/4.2.71-E3. × 200.
18. *Taeniopteris* sp. cf. *T. spatulata* McClelland, no. S. Rd. III-12/67-68. × 1.
19. *Pagiophyllum marwarensis* Bose & Sukh-Dev, showing stomata on lower surface, slide no. G3/4.2.71-E3. × 200.
20. *Pagiophyllum marwarensis* Bose & Sukh-Dev, showing epidermal cells and stomata on upper surface, slide no. G3/4.2.71-E4. × 200

PLATE 3

(All figures. × 500)

21, 22. *Stereisporites psilatus* (Ross, 1949) Jain & Sah, 1966; Slide no. 4/4.2.71-2, co-ordinates 124.2 × 22.6; Slide no. 3/4.2.71-5, co-ordinates 107 × 11.5.
23. *Cyathidites minor* Couper, 1953: Slide no. 3/4.2.71-5, co-ordinates 99.0 × 4.2.
24. *Cyathidites concavus* (Bolkhovitina, 1953) Dettmann 1963: Slide no. 3/4.2.71-1, co-ordinates 101 × 23.2.
25. *Baculatisporites comaumensis* (Cookson, 1953) Potonié, 1956: Slide no. 3/4.2.71-12, co-ordinates 107.8 × 10.3.
26. *Baculatisporites rotundus* Kumar, 1973: Slide no. 4/4.2.71-6, co-ordinates 106.9 × 12.5.
27. *Leptolepidites* sp.: Slide no. 3/4.2.71-6, co-ordinates 126.9 × 9.6.
28. *Callispora potoniaei* Dev, 1961: Slide no. 4/4.2.71-5, co-ordinates 102 × 5.
29. *Conosmundasporites* sp.: Slide no. 3/4.2.71-6, co-ordinates 108.9 × 8.2.
30. *Foveosporites* sp.: Slide no. 3/4.2.71-11, co-ordinates 122.3 × 7.8.
31. *Todisporites* sp.: Slide no. 4/4.2.71-1, co-ordinates 110.9 × 14.6.
32. *Neoraistrickia* sp.: Slide no. 3/4.2.71-6, co-ordinates 112.8 × 15.7.
33. ?*Lycopodiumsporites* sp.: Slide no. 3/4.2.71-6, co-ordinates 126.3 × 13.3.
34. *Apiculatisporis* sp.: Slide no. 3/4.2.71-8, co-ordinates 130.5 × 20.1.
35. *Trilites tuberculiformis* Cookson, 1947: Slide no. 3/4.2.71-7, co-ordinates 113 × 10.
36. *Klukisporites scaberis* (Cookson & Dettmann, 1958) Dettmann, 1963: Slide no. 4/4.2.71-4, co-ordinates 101.8 × 6.4.
37. *Ischyosporites crateris* Balme, 1957: Slide no. 4/4.2.71-3, co-ordinates 108.4 × 18.1.
38. *Contignisporites glebulentus* Dettmann, 1963: Slide no. 4/4.2.71-1, co-ordinates 112.2 × 6.8.
39. *Contignisporites cooksonae* (Balme, 1957) Dettmann, 1963: Slide no. 3/4.2.71-3, co-ordinates 121.4 × 14.8.
40. *Cicatricosisporites typicus* Sah & Jain, 1965: Slide no. 4/4.2.71-3, co-ordinates 106.4 × 12.2.
41. *Cicatricosisporites australiensis* (Cookson, 1953) Potonié, 1956: Slide no. 3/4.2.71-10, co-ordinates 120.8 × 18.
42. *Monolites grandis* Dev, 1961: Slide no. 4/4.2.71-1, co-ordinates 127.2 × 18.7.

PLATE 4

(All figures × 500)

43, 44. *Cooksonites variabilis* Pocock, 1962: Slide no. 3/4.2.71-6, co-ordinates 103.7 × 22.5; Slide no. 3/4.2.71-10, co-ordinates 104.2 × 12.
45. *Cooksonites* sp.: Slide no. 3/4.2.71-10, co-ordinates 136.4 × 18.4.
46. *Properimpollenites singhii* Maheshwari, 1974: Slide no. 3/4.2.71-1, co-ordinates 131.3 × 9.0.
47. *Aequitriradites* sp. cf. *A. verrucosus* (Cookson & Dettmann) Cookson & Dettmann, 1961: Slide no. 3/4.2.71-11, co-ordinates 122.8 × 12.
48. *Cycadopites gracilis* Sah & Jain, 1965: Slide no. 4/4.2.71-2, co-ordinates 110 × 4.7.
49. *Callialasporites discoidalis* (Döring, 1962) Bharadwaj & Kumar, 1972: Slide no. 3/4.2.71-1, co-ordinates 127.2 × 17.3.
50. *Podocarpidites novus* Sah & Jain, 1965: Slide no. 3/4.2.71-2, co-ordinates 128.2 × 20.
51. *Callialasporites segmentatus* (Balme, 1957) Dev, 1961: Slide no. 4/4.2.71-2, co-ordinates 121.9 × 19.
52. *Callialasporites trilobatus* (Balme, 1957) Dev, 1961: Slide no. 4/4.2.71-1, co-ordinates 117.8 × 11.9.
53. *Classopollis indicus* Maheshwari, 1974: Slide no. Gangapur-1, co-ordinates 108.2 × 17.6.
54. *Cedripites nudis* Kar & Sah, 1970: Slide no. 4/4.2.71-2, co-ordinates 121 × 17.8.
55. *Platysaccus indicus* Sah & Jain, 1965: Slide no. 3/4.2.71-3, co-ordinates 129.8 × 19.
56, 57. *Podosporites tripakshi* Rao, 1943: Slide no. 3/4.2.71-2, co-ordinates 107 × 15.4; Slide no. 4/4.2.71-6, co-ordinates 106 × 14.6.
58, 59. *Microcachryidites antarcticus* Cookson, 1947: Slide no. 4/4.2.71-1, co-ordinates 128.9 × 19; Slide no. 4/4.2.71-2, co-ordinates 122 × 6.0.
60-63. ?*Araucariacites* sp.— note the splitting tendency of the pollen and the incurvation at equatorial margins of the individual halves forming pseudocolpii: Slide no. 3/4.2.71-12; co-ordinates 128.8 × 20.3; Slide no. 3/4.2.71-10, co-ordinates 107.4 × 12.8; Slide no. 3/4.2.71-7, co-ordinates 122.8 × 7.7; Slide no. 3/4.2.71-11, co-ordinates 115.7 × 7.2.

Co-ordinates of lower left corner of cover-slips of figured slides:

Slide no. 3/4.2.71-1 — 132.6 × 24.0
Slide no. 3/4.2.71-2 — 133.7 × 23.8
Slide no. 3/4.2.71-3 — 132.6 × 23.9
Slide no. 3/4.2.71-4 — 133.7 × 24.3
Slide no. 3/4.2.71-6 — 134.8 × 24.4
Slide no. 3/4.2.71-7 — 133.2 × 24.9
Slide no. 3/4.2.71-8 — 133.4 × 23.5
Slide no. 3/4.2.71-10 — 136.9 × 22.9
Slide no. 3/4.2.71-11 — 137.2 × 23.8
Slide no. 3/4.2.71-12 — 137.4 × 23.4
Slide no. 4/4.2.71-1 — 134.6 × 23.9
Slide no. 4/4.2.71-2 — 134.7 × 23.8
Slide no. 4/4.2.71-3 — 133.2 × 24.1
Slide no. 4/4.2.71-4 — 134.8 × 23.8
Slide no. 4/4.2.71-5 — 137.3 × 23.2
Slide no. 4/4.2.71-6 — 139.9 × 24.0
Gangapur-1 — 140.4 × 23.7.


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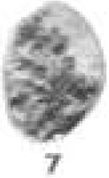
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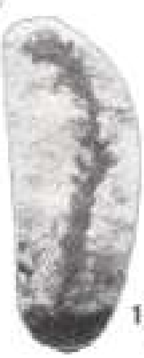
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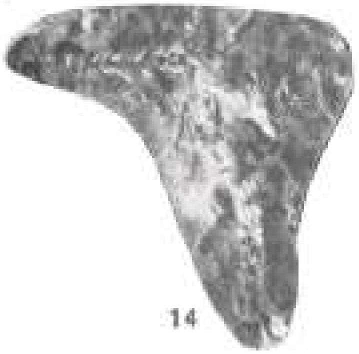
PLATE 1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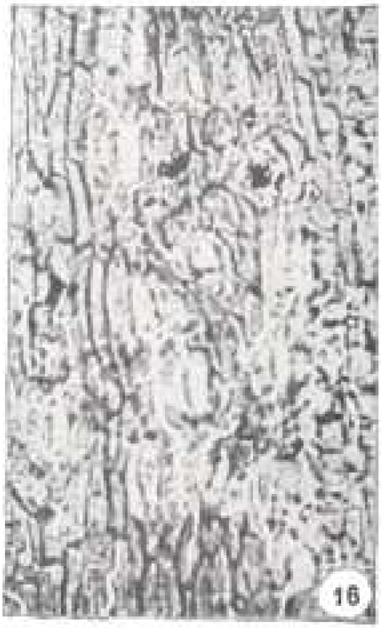
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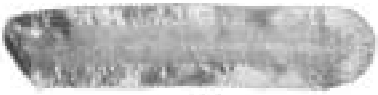
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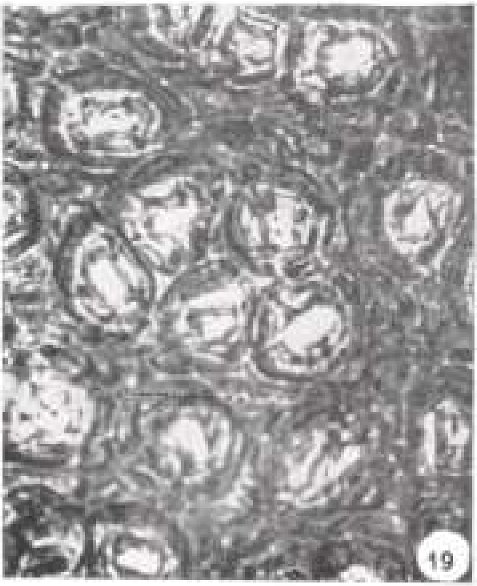
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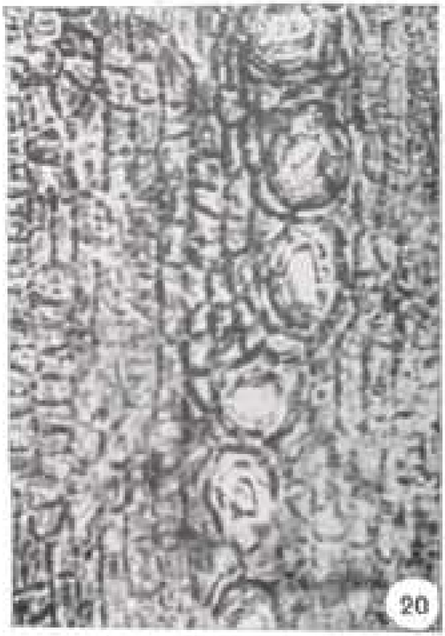
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PLATE 2

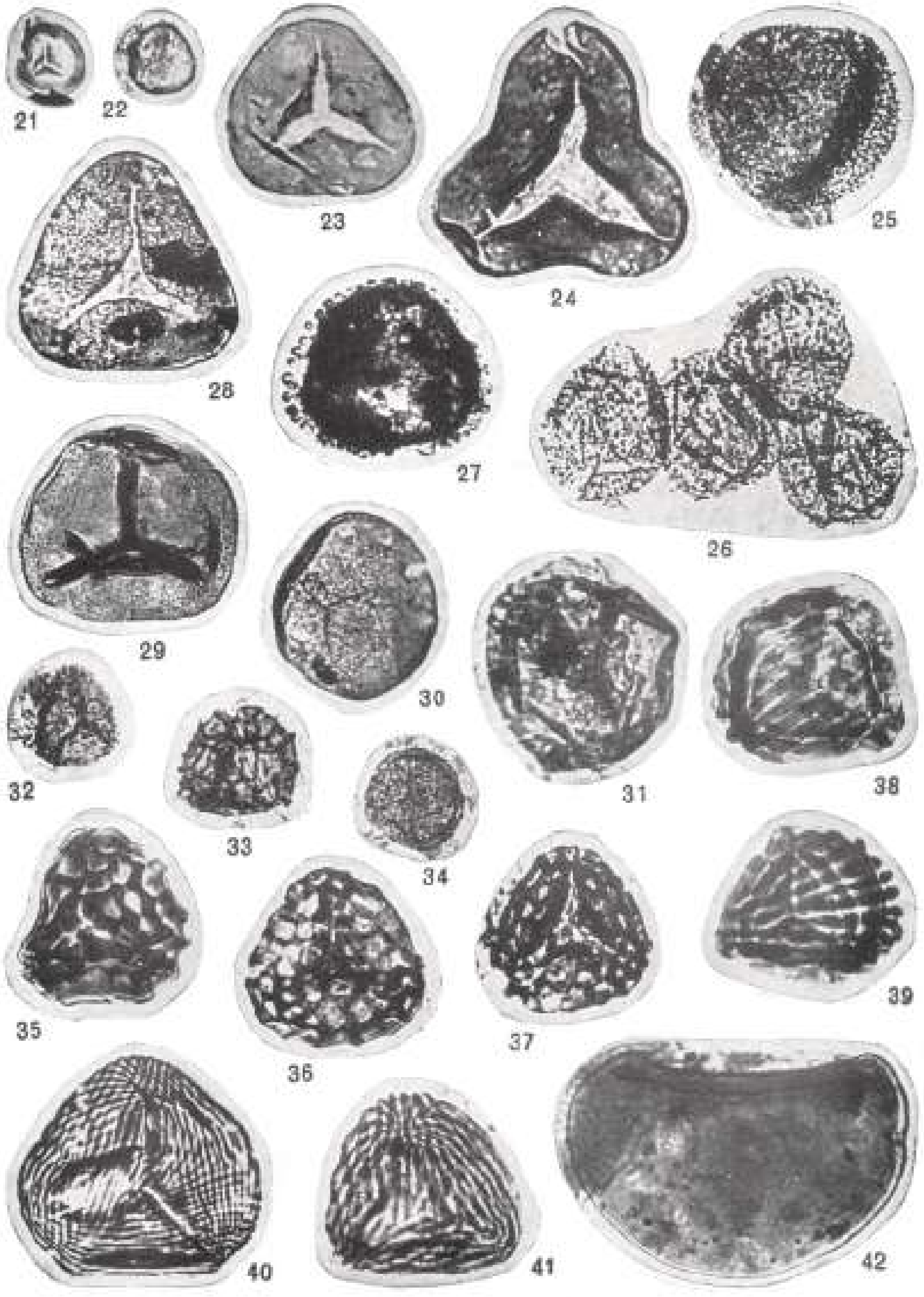

PLATE 3


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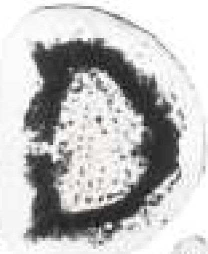
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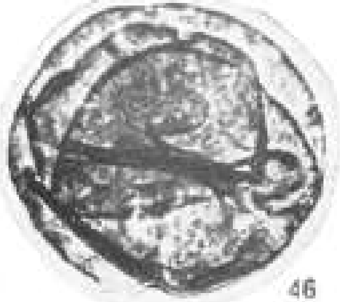
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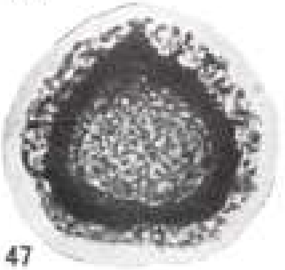
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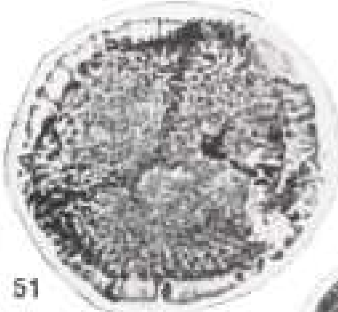
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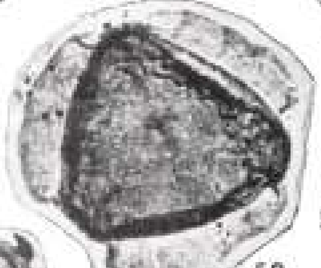
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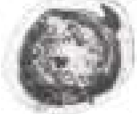
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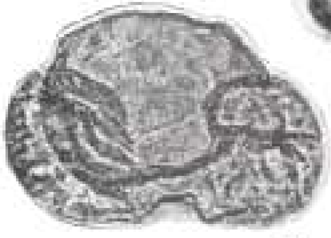
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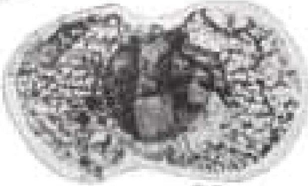
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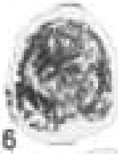
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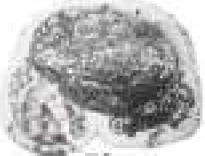
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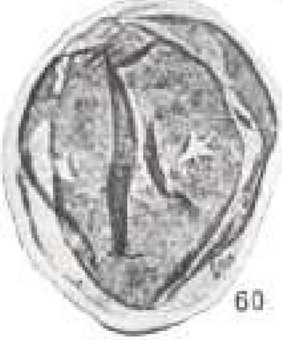
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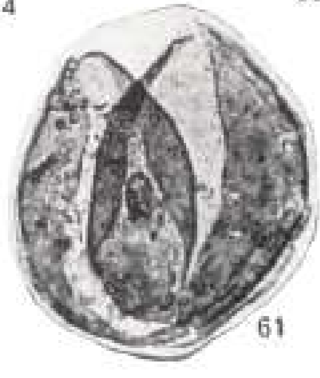
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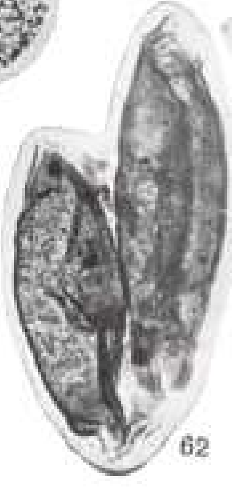
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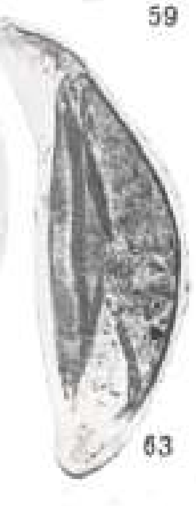
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PLATE 4

The Palaeobotanist, 30(2): 143-167, 1982.

PLANT FOSSILS FROM THE TALCHIR AND COAL-BEARING FORMATIONS OF SOUTH REWA GONDWANA BASIN, INDIA AND THEIR BIOSTRATIGRAPHICAL SIGNIFICANCE

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ABSTRACT

Plant fossils belonging to the Talchir and coal-bearing formations (Lower Permian) of four areas, namely Umaria, Birsinghpur Pali, Anuppur and Chirimiri of the South Rewa Gondwana Basin are described. The Talchir flora is represented by a few species of *Gangamopteris* and *Noeggerathiopsis*, while the megafossils from the coal-bearing formation are represented by various species of *Glossopteris*, *Gangamopteris*, *Noeggerathiopsis* and *Vertebraria*. A new species of *Noeggerathiopsis*, *N. minor*, has been recognised. It has also been observed that the flora of the coal-bearing beds in these areas are characterized by the dominance of *Gangamopteris* and *Noeggerathiopsis*. This suggests that these beds of the South Rewa Gondwana Basin are equivalent to the Karharbari 'Stage' of the Peninsular India.

Key-words — Megafossils, Biostratigraphy, South Rewa Gondwana Basin, Lower Permian (India).

सारांश

दक्षिण रीवा गोंडवाना द्रोणी (भारत) के तालचिर एवं कोयला-धारक शैल-समूहों से प्राप्त पादपाश्म तथा इनका जैवस्तरिकीय महत्व – अनिल चन्द्रा एवं अश्विनी कुमार श्रीवास्तव

दक्षिण रीवा गोंडवाना द्रोणी के तालचिर एवं कोयला-धारक (अधरि परमी) शैल-समूहों से सम्बन्धित चार क्षेत्रों – उमरिया, बीरसिंहपुर पाली, अनूपपुर तथा चिरीमिरी – से प्राप्त पादपाश्मों का वर्णन किया गया है। तालचिर वनस्पतिजात गंगामोप्टेरिस एवं नोएगेराथिऑप्सिस की कुछ जातियों से निरूपित है, जबकि कोयला-धारक शैल-समूह के गुरुपादपाश्म ग्लॉसॉप्टेरिस, गंगामोप्टेरिस, नोएगेराथिऑप्सिस एवं वर्टीब्रेरिया की विभिन्न जातियों से निरूपित हैं। नोएगेराथिऑप्सिस की एक नई जाति, नै० माइनर, अभिनिर्धारित की गई है। यह भी प्रेक्षित किया गया है कि इन क्षेत्रों के कोयला-धारक संस्तर गंगामोप्टेरिस एवं नोएगेराथिऑप्सिस की बाहुल्यता से अभिलक्षणित हैं। जिससे यह व्यक्त होता है कि ये संस्तर प्रायद्वीपीय भारत के करहरबारी चरण के समतुल्य हैं।

INTRODUCTION

In 1860, Medlicott collected plant fossils, for the first time, from the South Rewa Gondwana Basin. Hughes made further collection from this basin during 1881-1884. Feistmantel (1879, 1882) described plant fossils in detail (South Rewa) and considered the coal-bearing beds as equivalent to the Karharbari 'Stage' on the basis of floral comparison. Fermor (1914) reported *Glossopteris*, *Vertebraria* and *Schizoneura* from the Barakars of the Kurasia Coalfield. Biswas (1955) studied Fermor's collection and suggested Karharbari correlation of at least a part of the Chirimiri Coal Measures strictly on floral evidence. Surange and Lele (1956) described plant fossils from the Talchir Formation of the Johilla Coalfield (Birsinghpur-Pali). Datta (1957) studied the plant fossils and the miospores from the Barakar and the miospores from the Talchir rocks of the Jhagrakhund area. On the basis of the plant fossils he observed that the Barakar flora in this area is comparable to the lower section of the Lower Gondwana flora. Ganguly (1959) described the plant fossils from the Talchir and the coal-bearing formations of Chirimiri. Lele and Maithy (1964) described two new species of *Noeg-*

gerathiopsis from the Karharbari beds of Ganjra Nala, Birsinghpur-Pali. Pant and Varma (1964) recognized three new species of *Noeggerathiopsis* from the Lower Gondwanas of Manendragarh. Maithy (1966b) considered the coal-bearing beds at Umaria as equivalent to the Karharbari beds of Giridih. Later, he (Maithy, 1968) reported two new fossil plants from the Karharbari beds of Ganjra Nala, Birsinghpur Pali.

South Rewa Gondwana Basin was selected for palaeobotanical (including microfossils) and stratigraphical studies because of the controversy regarding the stratigraphical position of the Karharbari 'Stage'. Another important factor favouring the selection of this basin was the well-developed nature of the Talchir sediments. Detailed systematic study of both plant mega- and micro-fossils was, therefore, planned with the object of finding guide fossils which could be utilized in problems of correlation and dating. The results of the microfossil studies have been partially published (Lele & Chandra, 1967, 1969, 1972, 1973, 1974; Chandra & Lele, 1980; Srivastava & Chandra, 1982).

The present study deals only with the plant fossils collected by one of us (A. C.) during 1966, 1967 and 1968 from the Talchir and coal-bearing formations of four areas, viz., Umaria, Birsinghpur Pali, Anuppur, and Chirimiri of the South Rewa Gondwana Basin, Madhya Pradesh.

GEOLOGY

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

Surface deposits
Deccan Trap and
  Lametas
Gondwana System
    Supra-Barakars
    Barakars with
      Karharbari
    Talchirs
  Bijawars
  Metamorphics

A brief description of the geology of each area along with the account of the various traverses undertaken in the field is given below.

UMARIA

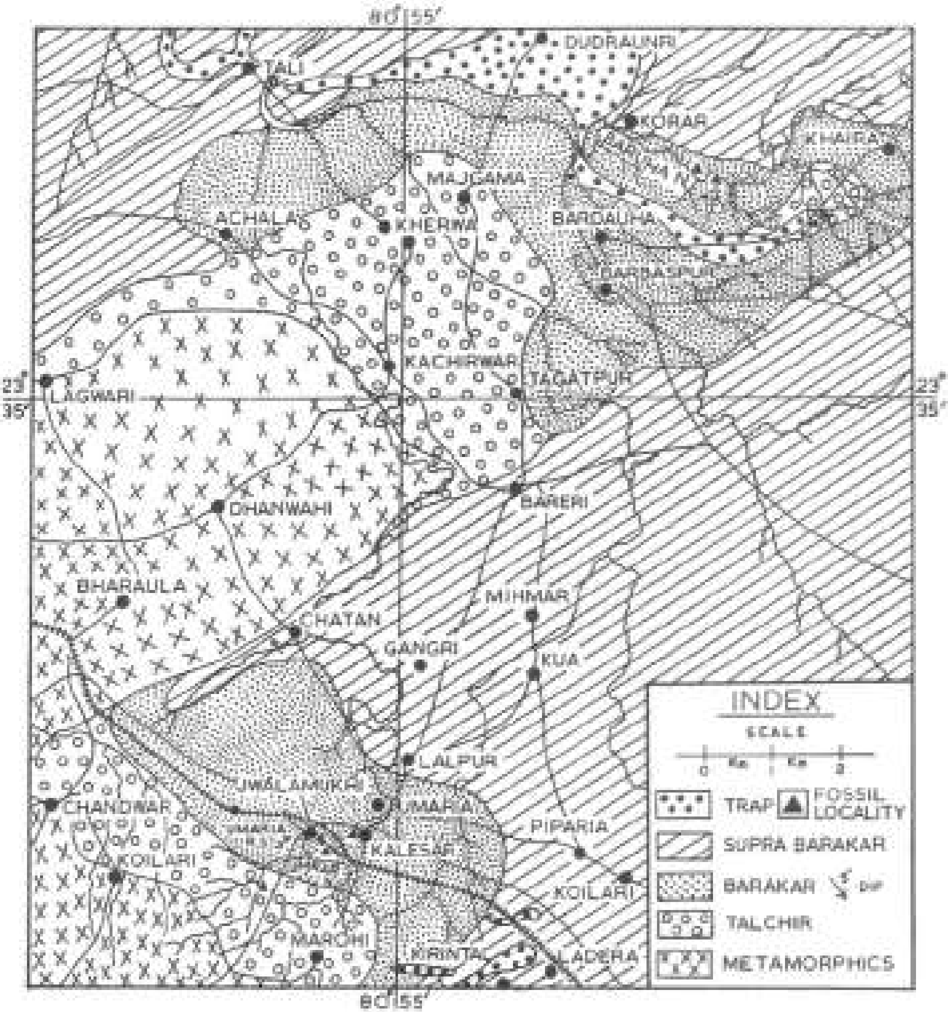
The geological formations (Ahmad, 1957) met with in the area (23° 32′: 80° 51′, Map 1) are as follows:

Supra Barakar
Barakar Coal Measures
Talchir Series
.... Unconformity ....
Metamorphics

The Archaeans, comprising the metamorphic rocks, are exposed towards west, north and south of Umaria Railway Station. The Talchir sediments occur to the south, south-west and north of Umaria. The Talchirs are generally found to rest over the Metamorphics. A fair idea of the stratigraphic sequence is obtained by taking a downstream traverse along a small stream, between Koilari and Marohi, up to its junction with the Umrar and again along this river near Kalesar, Umaria and Lalpur.

The Barakars generally seem to conformably overlie the Talchir. The lowermost bed of the Barakars is a felspathic, siliceous and slightly ferruginous sandstone which is overlain by a thin band of coaly shale followed by a series of laminated sandstones, argillaceous, blue and carbonaceous shales, and finally a zone of massive sandstones at the top. The Barakar sandstones appear to be deeply eroded near Kalesar. The lower limit of the Barakars is fairly recognisable towards south-west of Umaria. Only the sandstone facies is seen exposed from Kalesar up to the upper boundary of the Barakars which lies between Umaria and Lalpur. These Barakar sandstones are overlain by red and variously coloured clays of the supra-Barakars. A marine fossiliferous zone unconformably overlies the Talchirs and is in turn overlain by the basal members of Barakar Formation. Following traverses are described from this area.

A. *Umaria-Kalesar-Marohi Traverse* — The Barakars are exposed on both the banks of the Umrar River about 1·6 km south-west of Umaria, below the road bridge which connects Umaria with Kalesar. The Barakar sandstone attains a maximum thickness of 12.20 m.



Map 1 — Geological map of Umaria, Madhya Pradesh (from the geological map of South Rewa Gondwana Basin, Hughes, 1884).

(i) Following section is exposed just near the bridge on the north bank of Umrar river:

	LITHOLOGY	THICKNESS m	FIELD NOS.
BARAKARS	Carbonaceous shale (fossiliferous)	0.61	K8F
	Carbonaceous shale intercalated with sandstone	1.52	K7
	Greyish white massive sandstone	12.20	K1

The road running south of Kalesar up to Marohi shows no exposures as all the formations are hidden by the soil. About 3.2 km north of Marohi a 12.20 m thick sandstone member of the Barakar Formation is exposed on either side of the river; current bedding is a common feature.

(ii) Following section is exposed about 9.15 m south of the Railway bridge:

	LITHOLOGY	THICKNESS m	FIELD NOS.
	Massive sandstone	7.62	M7
	Coal	0.61	M8
BARAKARS	Carbonaceous shale (fossiliferous)	1.22	M9
	Greyish white, coarse-grained sandstone	1.83	M10

B. *Bareri-Tagatpur-Barbaspur (Baruha-Nala) Traverse* — The Supra Barakars are exposed on two hills situated west of the village Bareri which is about 6.4 km north of Umaria. Both the hills were examined. The lithological units are represented by hard pink sandstone (current-bedded), sandstone and red sandstone. The basal members of these hills are well-laminated and block-jointed sandstones and may belong to the Barakars. Weathered garnets, a constituent mineral of these sandstones, are clearly visible to the naked eye. The nala, about 1.6 km north of Bareri, was traversed up to Tagatpur. Barakar rocks are exposed in a stream, locally known as Baruha Nala, about 4.0 km north of Barbaspur. Following two sections were observed along this Nala:

(i) *North bank Section*

	LITHOLOGY	THICKNESS m	FIELD NOS.
	Shaly sandstone	1.53	BBN 3
	White sandstone	0.61	BBN 2
BARAKARS	Carbonaceous shale (fossiliferous)	1.83	BBN F
	Ash coloured sandstone	0.05	BBN 1

(ii) *Section exposed about 28 m east of Section* (i):

	LITHOLOGY	THICKNESS m	FIELD NOS.
	Sandstone and soil (mixed)	0.31	BBN 9
	Carbonaceous shale	0.92	BBN 8
BARAKARS	Sandstone	0.61	BBN 7
	Carbonaceous shale (fossiliferous)	0.92	BBNF 1
	Ash coloured sandstone	6.10	BBN 6

A coal seam measuring 0.20-0.25 m in thickness, was seen exposed at a number of places further east along the nala.

C. *Jwalamukhi* — A few fragmentary fossils of *Noeggerathiopsis hislopi* (JW 6) were collected from the Needle Shale beds of the Talchir Formation, exposed along a nala, about 1.6 km south of Jwalamukhi.

Besides, Umaria R.S.-Kirnital-Umaria and Lalpur-Gangri-Chatan-Umaria traverses were undertaken without encountering any plant fossils.

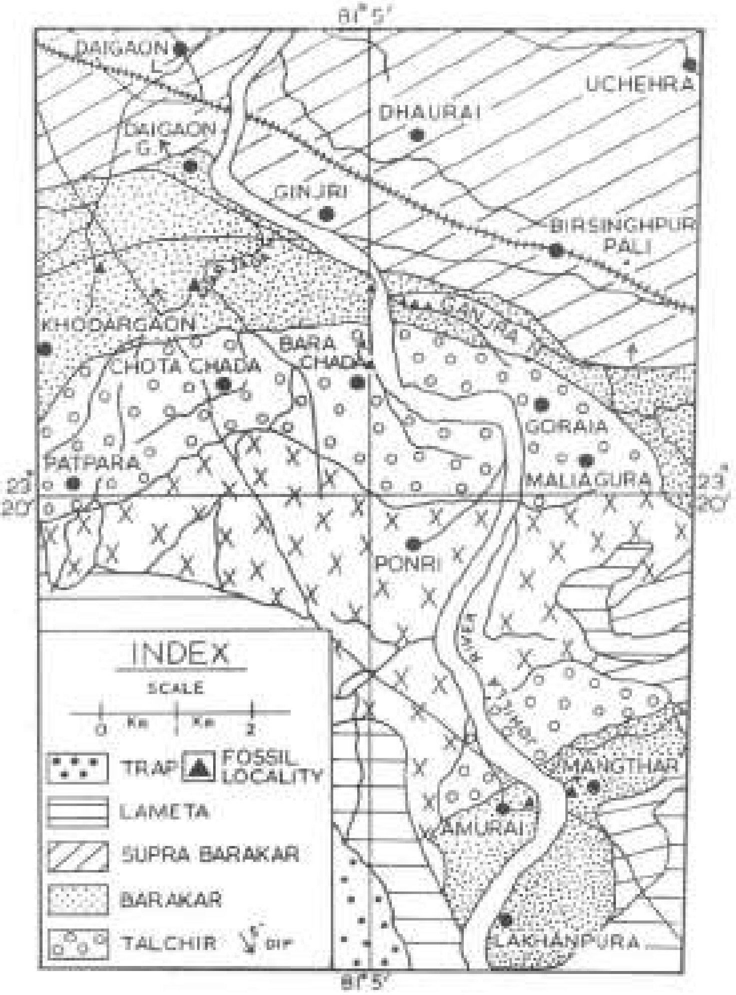
BIRSINGHPUR-PALI

The general succession of the geological formations in this area (Map 2) is as follows (after Hughes, 1884):

Traps
Lametas
Supra Barakars
Barakars
Talchirs
.... Unconformity
Metamorphics

The metamorphic inlier of the Johilla Valley covers an area of about 20.5 sq km. Good metamorphic (gneiss) exposures are seen near Ponri along the banks of Johilla River. Towards north, the metamorphic exposures are generally covered by Talchirs or by alluvium. And towards south-west, the metamorphic rocks appear to be fringed by Lametas while to the south-east and east, they are overlain by Talchirs, Supra-Barakars or alluvium.

The Talchirs occupy a belt about 9.6 km long and 2.4 km wide between Kudri and Kumurdu (Kudri is not shown in the map. It is about 1.6 km north-west of Patpara and about 1.6 km south-west of Khodargaon). Talchirs are also exposed to the north of Mangthar. Good sections of the Talchir Formation are exposed near Barachada, on both the banks of Johilla River. The bottom bed is a compact, greyish, calcareous sandstone. This is succeeded by a thick bed of greyish-green siltstone comprising fragments of quartzites, granites and schists. This siltstone in turn, is overlain by another siltstone member which is yellowish and greenish in colour. This second siltstone bed is overlain by a compact calcareous sandstone bed followed by another silt-



Map 2 — Geological map of Birsinghpur Pali, Madhya Pradesh (from the geological map of South Rewa Gondwana Basin, Hughes, 1884).

stone member at the top. These rocks along the east bank are generally covered by alluvium. On the west bank, however, they can be located at many places in small and large nalas feeding the Johilla River. The Talchirs, examined in all sections, were seen resting on the gneissic rocks of the Metamorphics. The Barakars of the Johilla Valley (Birsinghpur-Pali) are divided into two distinct areas by the Talchirs and gneissic rocks (Metamorphics). Hughes (1884) named them as the North and South areas respectively. These rocks are similar to the Barakars exposed at Umaria and include mostly the yellowish to greyish, felspathic, siliceous sandstone, shaly sandstone, carbonaceous shale and coal. The Supra Barakars of this area seem to overlap on the Talchirs and appear to be faulted against the Ponri gneiss. Only at Ponri they rest over the Metamorphics. In general they rest over the Barakars. The traverses undertaken in this area are described below:

A. *Birsinghpur Pali-Barachada-Goraia-Ponri Traverse* — The Talchirs are well exposed along both the banks of Johilla River, near the village Barachada. A traverse undertaken from Barachada to Ponri via Goraia along the Johilla River shows that the Metamorphics and the Talchir sediments are exposed near Ponri. The dip is 10° towards north. The following section was studied near Barachada Village.

	Lithology	Thickness m	Field Nos.
TALCHIR	Yellowish silty sandstone	1.83	BC 12
	Yellowish laminated sandstone (fossiliferous)	3.05	BC 11F
	Greenish silty sandstone (fossiliferous)	1.22	BC 10F
	Yellowish laminated sandstone (fossiliferous)	0.31	BC 9F
	Yellowish silty sandstone (fossiliferous)	1.22	BC 8F
	Laminated sandstone (fossiliferous)	0.92	BC 7F
	Laminated yellowish greenish sandstone	9.15	BC 6

B. *Mangthar-Amurai Traverse* — About 1.6 km west of Mangthar Village, the Talchir Boulder bed is exposed in a nala leading to Johilla River. This bad is about 1.22-3.05 m in thickness and reaches up to 9.15 m further west in the nala. The matrix mainly consists of greenish-blackish sandstones and is overlain by 3.05 m thick yellowish-whitish sandstones. The dip is 5° towards east. The Talchir Formation is exposed up to the junction of this nala with the river Johilla. About 0.45 m south of this junction and about 0.28 km west of the river Johilla the carbonaceous shales and sandstones are exposed with gentle dip towards west. The plant fossils were collected from the following two sections:

(i) About 0.40 km west of the village Mangthar and on the east bank of the river Johilla the following section was studied:

	Lithology	Thickness m	Field Nos.
BARAKAR	Yellowish white coarse grained sandstone	1.83	MA 25
	Coal	0.20	MA 24
	Bluish carbonaceous shale (fossiliferous)	1.83	MA 23
	Carbonaceous shale	0.45	MA 22
	Bluish carbonaceous shale (fossiliferous)	1.22	MA 21
	Whitish sandstone	1.53	MA 20

(ii) A few fragmentary fossils were collected from the following section exposed on the right bank (Amurai side) of the Johilla River, 0.18 km north of the road joining Amurai to Lakhanpura:

	Lithology	Thickness m	Field Nos.
BARAKARS	Pinkish sandstone	1.53	LA 9
	White yellowish sandstone	4.58	LA 8
	Carbonaceous shale	0.15	LA 7
	White sandstone	0.92	LA 6
	Carbonaceous shale (Blue)	0.92	LA 5
	Coal	0.31	LA 4
	Carbonaceous shale (fossiliferous)	0.31	LA 3
	Bluish sandstone	0.76	LA 2
	Yellowish sandstone and shale	3.05	LA 1

C. *Khodargaon-Kudri Traverse*—Following section of Supra-Barakar and Barakar members was studied along a nala approximately 1.6 km north-east of Khodargaon Village.

	Lithology	Thickness m	Field Nos.
SUPRA BARAKAR	Pinkish yellowish sandstone	1.53	KK 7
	Clay and white sandstone	0.31	KK 6
	Red sandstone	0.31	KK 5
BARAKAR	Weathered sandstone (clayey)	0.31	KK 4
	Course grained yellowish sandstone	1.22	KK 3
	Clayey shale (fossiliferous)	0.61	KK 2
	Compact clayey sandstone	0.61	KK 1

D. *Patpara-Marjada Nala Traverse* — In a section about 3.2 km east of Khodargaon Village after crossing the road bridge the succession is as follows:

	LITHOLOGY	THICKNESS m	FIELD NOS.
BARAKAR	Massive yellowish sandstone	3.05	K 7
	Carbonaceous shaly sandstone	1.22	K 6
	Yellowish sandstone	0.61	K 5
	Carbonaceous shaly sandstone	0.31	K 4
	Carbonaceous shale (fossiliferous)	0.31	K 3
	Coal	1.22	K 2

E. *Ganjra Nala-Johilla River Confluence Traverse* — Fragmentary fossil collection was made from the Ganjra Nala up to its confluence (about 2.4 km south-west of Birsinghpur-Pali Railway Station) with the river Johilla. The sections studied are described below:

(i) Section 0.27 km east of the Ganjra Nala-Johilla Confluence, along the Ganjra Nala:

	LITHOLOGY	THICKNESS m	FIELD NOS.
BARAKAR	Sandstone (fossiliferous)	—	GN 3
	Carbonaceous shale (fossiliferous)	1.83	GN 2
	Grey micaceous sandstone (fossiliferous)	1.53	GN 1F
	Carbonaceous shale (fossiliferous)	2.14	GN 1
	Coal	—	—

(ii) Section 0.18 km east of Ganjra Nala-Johilla confluence, along the Ganjra Nala:

	LITHOLOGY	THICKNESS m	FIELD NOS.
BARAKAR	Micaceous sandstone	—	GN 6
	Coaly shale	1.53	GN 6
	Carbonaceous shale (fossiliferous)	1.83	GN 5F
	Coaly shale (fossiliferous)	0.92	GN 4F

(iii) Section 0.09 km west of Ganjra Nala-Johilla confluence:

	LITHOLOGY	THICKNESS m	FIELD NOS.
BARAKAR	Micaceous sandstone	—	GN 8
	Carbonaceous shale (fossiliferous)	3.05	GN 7

(iv) Section along the other bank of Johilla River, opposite Ganjra-Johilla confluence:

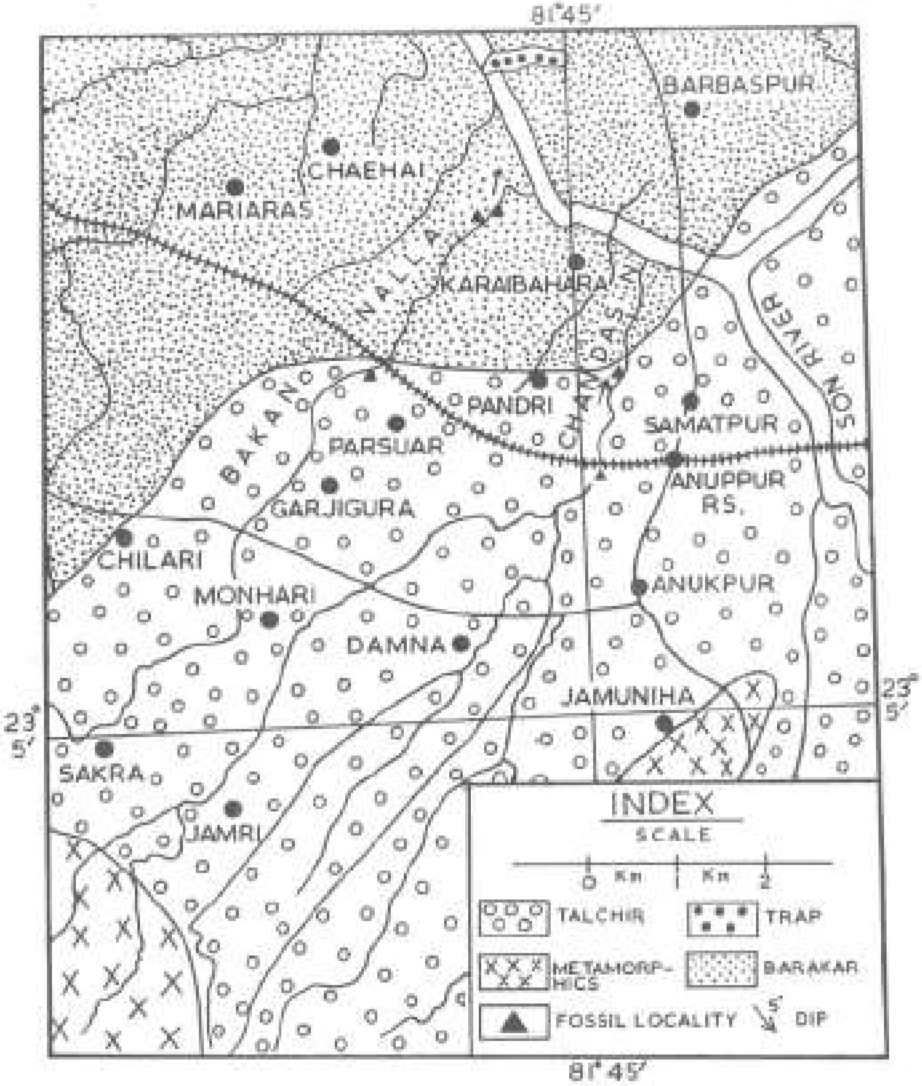
	LITHOLOGY	THICKNESS m	FIELD NOS.
BARAKAR	Micaceous sandstone (fossiliferous)	—	J1 F
	Carbonaceous shale (fossiliferous)	2.14	J1 F1
	Sandstone	2.44	J1
	Carbonaceous shale	0.92	J2
	Shale and sandstone	—	J3

ANUPPUR

The geological succession (Chandra & Lele, 1980) of this area (Map 3) is as follows:

Traps
Barakar Coal Measures
Talchir
Metamorphics

The Metamorphics (gneisses, granitic gneisses, schists, etc.) are exposed in the southern extremities of Anuppur. These rocks are overlain by the Lower Gondwana sediments, which are represented by the coal-bearing Barakar and the Talchir formations. Sandstones, shales, carbona-



Map 3—Geological map of Anuppur, Madhya Pradesh (from the geological map of South Rewa Gondwana Basin, Hughes, 1884).

ceous shales and coal form the general lithology of the coal-bearing formation. The Talchir Formation has the usual lithology of the boulder bed, needle shales, siltstone and sandstones of various shades. The Lower Gondwana formations are well exposed along the Bakan and Chandas nalas. Both these nalas have been surveyed. The areas around the villages, Sakra, Damna, Jamri and Chilari, etc. were visited and the following traverses were undertaken.

A. *Bakan Nala Railway Bridge — Son River Traverse*:

(i) Plant fossils were collected from a carbonaceous shaly bed with sandstone intercalations, exposed about 2.4 km north-east of the Bakan Nala Railway bridge (about 4.8 km north-west of Anuppur R.S.) along Bakan Nala.

This section has the following distinct beds:

	LITHOLOGY	THICKNESS m	FIELD NOS.
BARAKAR	Coarse grained sandstone	2.75	BN 21
	Carbonaceous shales with sandstone intercalations (fossiliferous)	0.95	BN 20
	Greyish white coarse-grained sandstone	2.44	BN 19

(ii) Well preserved plant megafossils have been collected from a carbonaceous shale bed exposed about 0.8 km south-west of Bakan Nala-Son River confluence along the Bakan Nala. This richly fossiliferous bed contains three species of *Noeggerathiopsis* only. The succession of different beds is as follows:

	LITHOLOGY	THICKNESS m	FIELD NOS.
BARAKAR	Coarse-grained sandstone	6.10	BN 27
	Carbonaceous shale	0.31	BN 26
	Coal	0.31	BN 25
	Carbonaceous shales (fossiliferous)	0.31	BN 24
	Coal	0.92	BN 23
	Carbonaceous shale	0.31	BN 22
	Whitish-bluish sandstone	1.22	BN 21

B. *Bakan Nala-Monhari Traverse* — In this traverse the rocks belonging to both the Talchir and coal-bearing Barakar formations were met with. In one of the sections, exposed about 0.28 km south-west of the Bakan Nala Railway bridge, some equisetaceous stems have been found. The succession of different beds is as follows:

	LITHOLOGY	THICKNESS m	FIELD NOS.
TALCHIR	Yellowish-whitish sandstone	3.05	BN 3
	Shaly sandstone (fossiliferous)	1.83	BN 2
	Whitish-yellowish sandstone	3.05	BN 1

C. *Chandas Nala Railway Bridge-Damna Traverse* — The rocks met with belong to the Talchir Formation and include the sandstone, needle shale and boulder bed. The general dip is 8°-10° due north. Equisetaceous stems have been found from the following section exposed about 45 m south of the Railway Bridge (1.6 km west of Anuppur Railway Station).

	LITHOLOGY	THICKNESS m	FIELD NOS.
TALCHIR	Massive yellowish sandstone	6.71	CN 4
	Shaly sandstone greenish-white (fossiliferous)	0.31	CN 3
	Green sandstone	1.83	CN 2
	Massive yellowish fine-grained sandstone	1.83	CN 1

D. *Chandas Nala Railway Bridge-Son River Traverse* — Both the Talchir and coal-bearing Barakar formations are exposed along the Chandas Nala. Fragmentary megafossils have been collected from a Talchir sequence exposed about 1.6 km north-east of the Chandas Nala Railway Bridge with following distinct beds:

	LITHOLOGY	THICKNESS m	FIELD NOS.
TALCHIR	Needle shales (fossiliferous)	3.05	CN 28
	Yellowish sandstone	3.05	CN 27
	Talchir Boulder Bed	3.05	CN 26

Chirimiri

According to Biswas (1955) the geological succession of the formations exposed in Chirimiri (23°11'30": 82°21'; Map 4) area is as follows:

Para-Lavas	Recent or sub-recent
Deccan Traps	Post-Barakar
Lower Barakars	(including Karharbari Stage Lower Barakar)
Talchirs	Upper most Carboniferous or Basal Permian
Archeans	Pre-Cambrian

Small patches of metamorphic rocks are exposed in the south near Akhardand Village and in the north around the village Kothari. The Talchir rocks are exposed in the southern and western extremity of the area. The Talchir Formation includes the Talchir Boulder Bed, Needle shales and sandstones of various shades. The Barakar Formation is exposed in the Kaoria Nala (known as Kararkhoh exposure), Gaemera Nala and around Chirimiri Railway Station. The rock types met within the Barakars include sandstones, shales, carbonaceous shale and coal. A belt of dolerite and basalt overlies both the Talchir and the Barakar formations. In this area the following traverses were undertaken:

A. *Chirimiri-Paradol Railway Cutting Traverse* — A number of good sections of Talchir and Barakar rocks are exposed along the railway line between Chirimiri and Paradol Railway stations. About 0.8 km north-west of the Chirimiri Railway Station, a rich collection of plant fossils was made from the following section. The beds dip 10° due north.

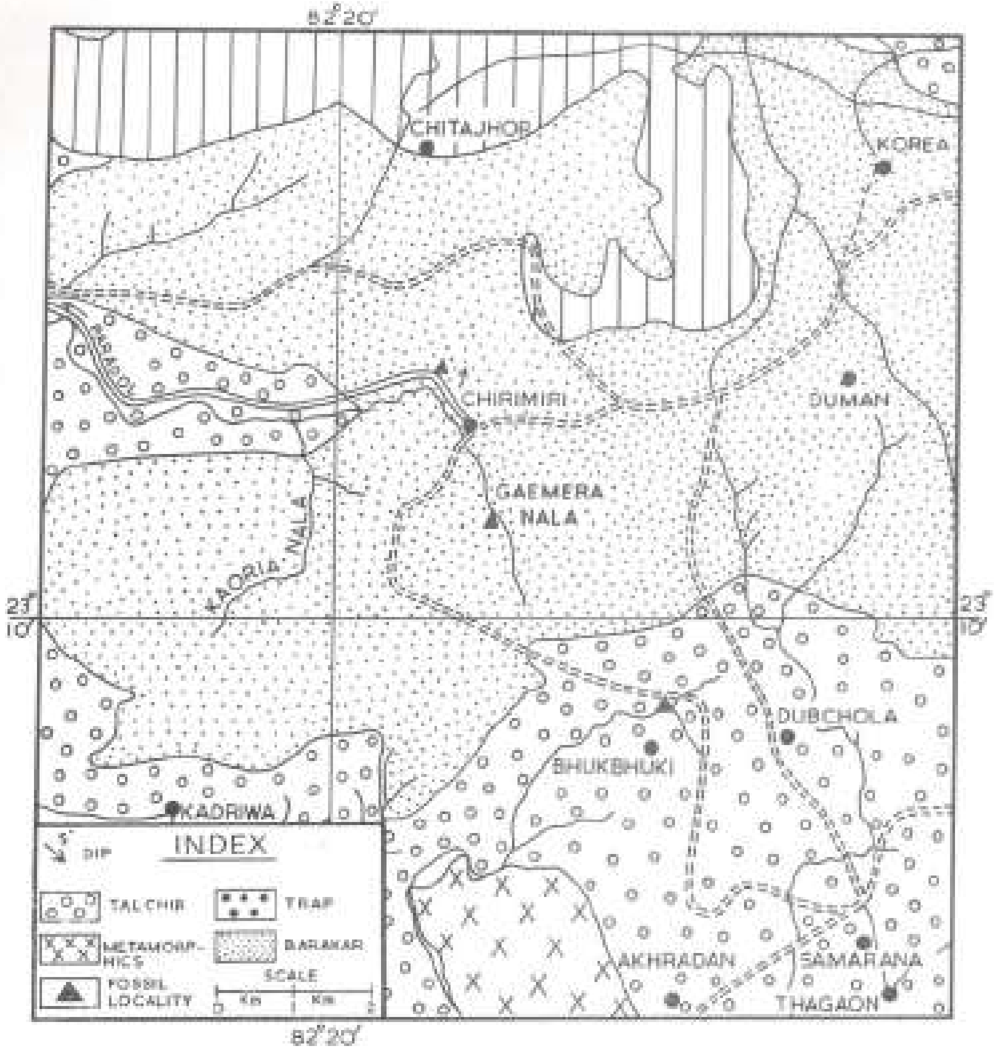
	LITHOLOGY	THICKNESS m	FIELD NOS.
BARAKAR	Yellowish-white coarse-grained sandstone (current bedded)	9.15	CP 6
	Coal	0.15	CP 5
	Carbonaceous shale and sandstone alternating (fossiliferous)	2.65	CP 4
	Carbonaceous shale	0.92	CP 3
	Sandstone	3.05	CP 2
	Carbonaceous shale	0.25	CP 2
	Fine-grained sandstone	9.15	CP 1

B. *Gaemera Nala Traverse* — From the following section, exposed 1.6 km south of Chirimiri Railway Station, a few plant fossils were collected along the bank of the Gaemera Nala:

	LITHOLOGY	THICKNESS m	FIELD NOS.
BARAKAR	Course-grained sandstone	6.10	G 1
	Coal and coaly shale	1.53	G 2
	Carbonaceous shale (fossiliferous)	2.44	G 3
	Medium grained, whitish micaceous sandstone	6.10	G 4
	Coal	7.62	G 5

C. *Duman Hill-Korea Coalfield Traverse* — This traverse was undertaken from Duman Hill to Korea Colliery along a private railway line. A rich collection of plant fossils was made from the following section exposed about 0.55 km north of Duman Colliery along the railway line:

	LITHOLOGY	THICKNESS m	FIELD NOS.
BARAKAR	Yellowish sandstone (weathered)	6.10	DK 16
	Shale	0.31	DK 15
	Weathered coal	1.22	DK 14
	Pinkish sandstone	0.92	DK 13
	Carbonaceous shale weathered (fossiliferous)	1.22	DK 12
	Bluish sandstone	0.92	DK 11



Map 4 — Geological map of Chirimiri, Madhya Pradesh (from the geological map of South Rewa Gondwana Basin, Hughes, 1884) with certain modifications.

D. *Chirimiri-Bhukbhuki Traverse* — Both the Talchir and Barakar rocks are seen exposed along this traverse from Chirimiri to Bhukbhuki. A good collection of plant fossils was made from the following section exposed north of the village Bhukbhuki and about 0.46 km west of the road turning.

	LITHOLOGY	THICKNESS m	FIELD NOS.
TALCHIR	Yellowish sandstone	?	B 5
	Needle shales	3.05	B 4
	Yellowish siltstone (fossiliferous)	1.22	B 3
	Greenish needle shales (fossiliferous)	1.53	B 2

DESCRIPTION OF PLANT FOSSILS

Genus — *Gangamopteris* McCoy, 1861

Gangamopteris cyclopteroides Feistmantel, 1876

Pl. 1, fig. 1; Pl. 3, fig. 25

Description — In all, there are 18 incomplete leaf impressions. The leaves are 9-13 cm long and 3-12.5 cm broad at maximum width. The apex is broadly rounded, base missing, and margin entire. The veins arise from the base and the median region is occupied by 5 to 6, thick, parallel running strands. The lateral veins arch out at angles of 7° to 10°. After anastomosis and dichotomization they form broad, long, polygonal meshes in the middle and linear, narrow meshes near the margin. The meshes are 8 to 12 mm long and 1.0 to 1.5 mm broad in the middle and 10 to 13 mm long and 0.8 to 1 mm broad near the margin. The density of veins is 10 to 12 per cm in the middle and 12 to 15 per cm near the margin.

Comparison — The specimens in their venation pattern and shape resemble the leaves described by Feistmantel (1879, pl. 1, figs 1, 2) and Srivastava (1977a, pl. 1, fig. 1).

Distribution — Talchir Formation — Bhukbhuki, Chirimiri (Traverse D); Coal-bearing Formation — Baruha Nala, Umaria (Traverse B), (i) and (ii), Bakan, Anuppur (Traverse A), (i). Chirimiri-Paradol Section, Chirimiri (Traverse A).

Gangamopteris clarkeana Feistmantel, 1879

Pl. 1, figs 2, 3; Pl. 2, fig. 15

Description — There are four incomplete leaf impressions in the collection. The leaves are 2.5 to 6.8 cm long and 2.5 to 3.7 cm broad at maximum width. The apex is broad obtuse, base missing and the margin is entire. The veins emerge from the base and form 5 to 7 subparallel interconnecting strands in the median region. They are thick, distant and arched. After anastomosis and dichotomization they form open, oblong, polygonal meshes. The meshes are 4 to 10 mm long and 0.5 to 1.5 mm broad in the centre and 5 to 8 mm long and 0.7 to 1 mm broad near the margin. The density of veins is 8 to 10 per cm in the middle and 10 to 20 per cm near the margin.

Comparison — The present specimens are clearly comparable in their venation pattern with *G. clarkeana* Feistmantel (1890, pl. 20, fig. 3), Maithy (1965d, pl. 4, fig. 25) and Srivastava (1977a, pl. 2, fig. 9).

Distribution — Talchir Formation — Bhukbhuki Chirimiri (Traverse D); Coal-bearing Formation — Duman Hill-Korea Section, Chirimiri (Traverse C).

Gangamopteris major Feistmantel, 1879

Pl. 1, fig. 5; Pl. 2, fig. 12

Description — There are six incomplete leaf impressions in the collection. The leaves are 5.6-9.5 cm long and 2.2-3.5 cm broad at maximum width. The leaves are narrow, elongate to spathulate in shape. The apex and base are missing and margin is entire. The median portion of the leaves is occupied by 3 to 7 parallel running strands. The secondary veins are arched and after anastomosis and dichotomization form linear, narrow meshes throughout the lamina. The meshes are 5 to 8 mm long and 0.5 mm broad. The density of veins is 15 to 22 per cm.

Comparison — The specimens resemble *Gangamopteris major* described by Feistmantel (1879, pl. 14, fig. 3) and Maithy (1965d, pl. 2, fig. 7) in its narrow, elongate shape and linear narrow mesh pattern.

Distribution — Talchir Formation — Bhukbhuki, Chirimiri (Traverse D); Coal-bearing Formation — Bakan Nala, Anuppur [Traverse A (i)].

Gangamopteris intermedia Maithy, 1965

Pl. 1, fig. 4

Description—There is only one incomplete leaf impression in the collection. The figured leaf is 6.9 cm long and 4 cm broad at its maximum width and is ovate in shape. The apex and base are missing, margin is entire. The median region of the leaf is occupied by elongate, hexagonal meshes. The secondary veins are arched and after anastomosis and dichotomization form comparatively broad and elongated, hexagonal meshes in the centre and narrow, hexagonal meshes near the margin of the leaf. The meshes are 8 to 10 mm long and 1.0 mm broad in the centre and 8 to 12 mm long and 0.6 to 1.0 mm broad near the margin. The density of veins is 10 to 12 per cm in the centre and 10 to 16 per cm near the margin.

Comparison — The present leaf is closely comparable with the holotype of *Gangamopteris intermedia* Maithy (1965d, pl. 3, fig. 22) in its shape and venation pattern.

Distribution — Talchir Formation — Bhukbhuki, Chrimiri (Traverse D).

Gangamopteris angustifolia McCoy, 1861

Pl. 2, fig. 14

Description — There are only 2 incomplete leaf impressions in our collection. The figured leaf is 6.8 cm long and 2.0 cm broad. The leaf is linear, narrow in shape. The apex is acute, base missing, margin entire. The median region is occupied by 5 to 6 subparallel running veins which give rise to secondary veins which form linear, elongate, hexagonal meshes throughout the lamina. The meshes are 6 to 8 mm long and 0.25 mm broad. The density of veins is 22 to 28 per cm near the margin.

Comparison — The present specimens resemble *G. angustifolia* described by Feistmantel (1879, pl. 9, fig. 5) and Maithy (1965d, pl. 2, figs 9, 10).

Distribution — Coal-bearing Formation — Mangthar, Birsinghpur Pali [Traverse B(i)] Baruha Nala, Umaria [Traverse B(i) and (ii)].

Gangamopteris karharbariensis Maithy, 1965

Pl. 2, fig. 13

Description — There are only two incomplete leaf specimens in the collection. The figured leaf is 10.2 cm long and 3.0 cm broad at its maximum width. Only upper part of the leaf is present. The leaf is linear to lanceolate in shape, apex pointed, base missing, margin entire. The median region of leaf is occupied by 6-7 weak subparallel veins which give rise to arched secondary veins at an acute angle. The secondary veins form narrow, elongate meshes of equal size throughout the lamina.

Comparison — The venation pattern and general shape of the specimen closely resemble *Gangamopteris karharbariensis* described by Maithy (1965d, pl. 2, figs 11-13).

Distribution — Coal-bearing Formation — Patpara-Marjada Nala Section, Birsinghpur Pali, (Traverse D).

Gangamopteris cyclopteroides var. *attenuata* Feistmantel, 1879

Pl. 2, fig. 11

Description — There are four incomplete fragmentary leaf specimens in the collection. The figured leaf is more or less complete, measuring 10.1 cm long and 3.5 cm broad at its maximum width. The apex is obtuse, base contracted and margin entire. The median region of leaf is occupied by 4 to 5 parallel running veins which form secondary veins which are thicker in the lower part. After anastomosis and dichotomization secondary veins form linear oblong, narrow meshes throughout lamina. The meshes are 4-7 mm long and 0.5 mm broad. The density of veins is 15-20 per cm near the margin of the leaf.

Comparison — The present specimens in their contracted base, i.e. attenuate base, general shape and venation pattern compare with *G. cyclopteroides* var. *attenuata* described by Feistmantel (1879, pl. 11, fig. 1; pl. 14, figs 1, 2).

Distribution — Coal-bearing Formation — Baruha Nala, Umaria (Traverse B).

Genus — *Glossopteris* Brongniart, 1882

Glossopteris sp.

Pl. 4, fig. 27

Description — Leaf is large, broad, spathulate in shape measuring 14.5 cm in length and 7.6 cm in width. The apex and base are missing, only one side of lamina is preserved. The midrib is thick, 2-3 mm broad, persistent, grooved and striated. Secondary veins arise at an acute angle, arched, after anastomosis and dichotomization form open, elongate hexagonal meshes near the midrib and linear elongate, fine meshes towards the margin. The meshes are 7 to 10 mm long and 0.75 to 1 mm broad near the midrib and 10 to 18 mm long and 0.5 mm broad near the margin. The density of veins is 9 to 10 per cm near the midrib and 20 to 22 per cm near the margin.

Comparison — The venation pattern of the present leaf is comparable with that of *G. communis* Feistmantel. However, our specimen is considerably large in size. Due to the absence of apex, base and margin of the leaf, it is difficult to assign this specimen to any known species of *Glossopteris*.

Distribution — Coal-bearing Formation — Baruha Nala, Umaria (Traverse B).

Glossopteris decipiens Feistmantel, 1879

Pl. 4, fig. 28

Description — There are seven incomplete leaf impressions in our collection. The figured leaf is 6.9 cm long and 2.8 cm broad at its maximum width. The apex is acuminate, base absent and margin is entire. The midrib is distinct, up to 3.5 cm from the basal region and then diffuses into fine secondary veins near the apex. The secondary veins arise from the midrib at an acute angle and after dichotomization and anastomosis form narrow, oblong meshes throughout the lamina. The meshes are 3 to 5 mm long and 0.25 to 0.5 mm broad. The density of veins is 10 to 12 per cm in the middle and 15-18 per cm near the margin.

Comparison — The present leaf resembles *G. decipiens* (Feistmantel, 1879, pl. 18, fig. 4).

Distribution — Coal-bearing Formation — Mangthar, Birsinghpur Pali) [Traverse B (i)].

Glossopteris communis Feistmantel, 1876

Pl. 4, fig. 29

Description — There are 10 incomplete leaves in the collection. The figured leaf is 8.1 cm long and 3.5 cm broad. The apex and base are missing, margin is entire. The midrib is 1.5 to 2.0 mm broad and striated. The secondary veins arise at an angle of 45°. They are slightly arched and after dichotomy and anastomosis form long, linear, narrow hexagonal meshes throughout the leaf. The meshes are 5 to 8 mm long and 0.15 mm broad. The density of the veins is 10 to 16 per cm near the midrib and 18 to 25 per cm near the margin.

Comparison — The present specimen closely agrees in its general shape and venation pattern with *G. communis* described by Feistmantel (1881a, pl. 36, fig. 2; pl. 32, fig. 2; 1886, pl. 2, figs 1, 2) and Maheshwari and Gyan Prakash (1965, pl. 2, fig. 14).

Distribution — Coal-bearing Formation — Baruha Nala, Umaria (Traverse B), Mangthar-Amurai Section, Traverse B(i) and (ii), Khodargaon-Kudri Section (Traverse C), Patpara-Marjada Nala Section (Traverse D), Ganjra Nala — Johilla confluence Section, Traverse E; Birsinghpur Pali, Bakan Nala, Anuppur [Traverse A(i)], Chirimiri-Paradol Railway Cutting Section (Traverse A), Duman Hill-Korea Section (Traverse C), Chirimiri.

Glossopteris karharbariensis Chandra & Surange, 1979

Pl. 2, fig. 16

Description—There are six incomplete leaf impressions in the collection. The figured leaf is 5.2 cm long, 1.8 cm broad at its maximum width. The leaf is linear, narrow in shape. Apex is acute, base missing and margin entire. Midrib distinct, striated, 1.0 to 1.5 mm broad. The secondary veins arise at an acute angle from the midrib and after 1 mm they arch and reach the margin of the leaf. They dichotomize and anastomose to form narrow, linear, polygonal meshes throughout lamina. Meshes are 3 to 4 mm long and 0.5 mm broad. The density of veins is 20 to 22 per cm throughout the lamina.

Comparison — Chandra and Surange (1979, pl. 47, fig. 3; text-figs 26A, 1a, a_{ii}, 46N) erected a new species, *Glossopteris karharbariensis* for the leaf described earlier under *Glossopteris angustifolia* by Kulkarni (1971, pl. 1, fig. 10). The present leaves are comparable to the holotype of *G. karharbariensis* (specimen no. 33072, B.S.I.P. (Museum) in their shape and venation pattern.

Distribution — Coal-bearing Formation — Baruha Nala, Umaria (Traverse B).

Glossopteris angusta Pant & Gupta, 1971

Pl. 3, fig. 22

Description — There are two incomplete leaves in the collection. The figured leaf is narrow, spathulate in shape, 9.1 cm long and 2.2 cm broad at its maximum width, only one side of the lamina is well-preserved. The apex and base is missing, margin entire. The midrib region is occupied by 5-6 parallel running strands which in due course form secondary nerves and ultimately one strand reaches the apex. The secondary veins form long narrow rectangular meshes of equal size throughout the lamina. The meshes are 2 to 4 mm long and 0.3 mm broad. The density of veins is 15 to 20 per cm near the midrib and 20 to 25 per cm near the margin.

Comparison — The specimens closely compare with the holotype of *G. angusta* Pant & Gupta (1971, pl. 21, figs 33, 34), in their shape and venation pattern.

Distribution — Coal-bearing Formation — Baruha Nala, Umaria (Traverse B).

Glossopteris indica Schimper, 1869

Pl. 3, fig. 23

Description — The specimens are fragmentary. The figured leaf is 4.6 cm long and 2.0 cm broad at its maximum width. The apex, base and margin of the leaf are not preserved. Midrib is distinct, 2·5 mm broad and persistent throughout the preserved length. The secondary veins arise at an angle of 45°. They dichotomize and anastomose to form few broad, elongate, polygonal meshes near the midrib and narrow, elongate, hexagonal meshes near the margin. The meshes are 2 to 2.5 mm and 0.75 to 1 mm broad near the midrib and 3 to 4 mm long and 0.25 to 0.5 mm broad near the margin.

Comparison — The specimens fairly resemble the basal part of *G. indica* (Schimper, 1869) which has been rephotographed by Rigby, Maheshwari and Schopf (1980), Kulkarni (1971, pl. 1, fig. 15) and Srivastava (1977b, pl. 1, fig. 1).

Distribution — Coal-bearing Formation — Duman Hill-Korea Section, Chirimiri (Traverse C), Mangthar-Amurai Section, Birsinghpur-Pali [Traverse B (i)], Khodargaon-Kudri Section, Birsinghpur-Pali (Traverse C).

Glossopteris zeilleri Pant & Gupta, 1968

Pl. 3, fig. 24

Description — Leaf fragmentary, figured leaf 4.8 cm long and 2.4 cm broad, narrow, elongate, base absent, apex acute, margin entire, midrib distinct, striated, 1·5 mm broad. Secondary veins arise at an acute angle, slightly arched, after anastomosis and dichotomization form narrow elongate, hexagonal meshes throughout lamina. Density of veins is 15-20 per cm near the midrib and 20-25 per cm near the margin.

Comparison — The present leaf compares well with the holotype of *G. zeilleri* Pant & Gupta (1968, pl. 21, fig. 20) in its shape and venation pattern.

Distribution — Coal-bearing Formation — Duman Hill-Korea Section, Chirimiri (Traverse C).

Genus—*Noeggerathiopsis* (Feistmantel) Maithy, 1965

Remarks — Rigby, Maheshwari and Schopf (1980) have not recognized the separate existence of the genus *Noeggerathiopsis* and considered it to be the Synonym of the genus *Cordaites*.

Noeggerathiopsis hislopi (Bunbury) Feistmantel, 1879

Pl. 1, figs 6-8; Pl. 2, fig. 17

Description — There are 16 specimens in the collection. The specimens from Talchir Formation are fragmentary but well preserved. The leaves are 4-10 cm long and 1.5-2.7 cm broad at maximum width. The apex is missing, base contracted but extreme base is not preserved, margin entire. The shape of leaf is probably linear-lanceolate. The veins arise from the base, dichotomize frequently during upward course. The angle of divergence between two veins is 2° and 4°. The density of veins is 16-20 per cm.

Comparison — The present specimens are comparable with *N. hislopi* described by Feistmantel (1879, pl. 20, fig. 1; pl. 29, figs 1, 2) and Maithy (1965b, pl. 1, figs 1, 2).

Distribution — Talchir Formation — Chandas Nala, Anuppur (Traverse D), Jwalamukhi, Umaria; Coal-bearing Formation — Mangthar Birsinghpur-Pali [Traverse B(i)], Bakan Nala, Anuppur [Traverse A(i)], Chrimiri-Paradol Section (Traverse A), Gaemera Nala (Traverse B), Duman Hill-Korea Section (Traverse C), Chirimiri.

Noeggerathiopsis spathulata (Dana) Maithy, Maithy, 1965

Pl. 2, fig. 18

Description — There are three specimens present in the collection. The figured leaf is 6.8 cm long and 2.8 cm broad at its maximum width. The leaf is broad, spathulate. The apex is missing, base tapering; margin is entire. The veins arise from the base, they are divergent and dichotomise frequently during upward course. The angle of divergence between two veins is 6° and 9°. Veins are not very close, the density is 14-18 per cm.

Comparison — Although the apical portion of the leaves is not preserved in the present collection but in the nature of divergent veins, the specimens are comparable with *N. spathulata* described by Maithy (1965b, pl. 1, figs 4, 5).

Distribution — Coal-bearing Formation — Bakan Nala, Anuppur [Traverse A(ii)], Mangthar-Amurai Section, Birsinghpur-Pali [Traverse B(i)], Chirimiri-Paradol Section, Chirimiri (Traverse A), Gaemera Nala, Chirimiri (Traverse B), Duman Hill-Korea Section, Chirimiri (Traverse C).

Noeggerathiopsis minor sp. nov.

Pl. 2, figs 19-21

1879 *Noeggerathiopsis hislopi* Feistmantel, pl. 19, figs 3, 4, 5.

Diagnosis — Leaf simple, symmetrical, small; spathulate in shape; apex broad, rounded, base narrow, contracted, margin entire; veins arise from base, thick, erect, dichotomize twice or thrice, open, angle of divergene 2°-4°, density of veins 11-14 per cm.

Holotype — Pl. 2, fig. 19, B.S.I.P. specimen no. 35989.

Type Locality — Bakan Nala, Anuppur [Traverse A(ii)].

Horizon — Coal-bearing Formation (Lower Permian).

Description — Six complete to incomplete leaf impressions are present in the collection. The leaves are small in size, varying from 3.5 to 6.0 cm in length and 1 to 1.5 cm in width and are spathulate in shape. The apex is always broadly rounded, base contracted, sometimes tapering, margin is entire. Veins are comparatively thick, fairly open, dichotomize only twice or thrice during upward course. The angle of divergence between two veins is 2° to 4°. The density of veins is 11 to 14 per cm.

Comparison — The present species has been instituted to accommodate the smaller leaves having open veins with distinct rounded apex. Such small leaves have earlier been described under *N. hislopi*. But it has been found that such leaves are morphologically distinct and characteristic, therefore, they have been assigned to a new species, *Noeggerathiopsis minor*.

Distribution — Coal-bearing Formation — Duman Hill-Korea Section, Chirimiri (Traverse C).

Noeggerathiopsis sp.

Pl. 1, fig. 9

Description — There are many fragmentary impressions of incomplete leaves in the collection. The apex and base are absent; margin is entire. The lamina of the leaves is occupied by erect, parallel running veins emerging from the base of the leaves. The angle of divergence of veins is 3°-7°. The density of veins is 12-15 per cm.

Comparison — The specimens are very fragmentary and it is difficult to compare them with any well known species of *Noeggerathiopsis*.

Distribution — Talchir Formation — Chandas Nala Railway bridge-Son River Section, Chandas Nala, Anuppur (Traverse D).

EQUISETACEOUS STEM

Pl. 1, fig. 10; Pl. 3, fig. 26

The collection includes a large number of well-preserved equisetaceous stems with continuous ridges and grooves.

Distribution — Talchir Formation — Barachada, Birsinghpur Pali (Traverse A); Coal-bearing Formation — Patpara-Marjada Nala Section (Traverse D), Mangthar-

Amurai Section [Traverse B(i)], Khodargaon-Kudri Section (Traverse C), Birsinghpur Pali, Baruha Nala, Umaria [Traverse B(i)], Bakan Nala, Anuppur [Traverse A(ii)], Chirimiri-Paradol Section, Chirimiri (Traverse A), Duman Hill-Korea Section, Chirimiri (Traverse C).

Vertebraria indica Royle, 1833

Well-preserved impressions of this species have been recorded from the Coal-bearing Formation of Birsinghpur-Pali.

COMPARISON AND DISCUSSION

Megafossils from the Talchir Formation — The Talchir plant fossils are poorly known from India. Feistmantel (1879) reported plant fossils referable to Talchir Formation from Deogarh, Karanpura, Auranga and Hutar coalfields and South Rewa Gondwana Basin. Surange and Lele (1956, 1957) reported Talchir plant fossils from the Johilla and Giridih coalfields. Lele (1966) observed a few species of *Gangamopteris* and *Samaropsis* from the Singrauli Coalfield. All the megafossil records from the Talchir Formation were synthesized by Lele (1966, table 2) and pointed that the oldest Talchir horizon is devoid of any plant fossil whereas *Gangamopteris* associated with *Noeggerathiopsis* is the common element in the younger horizons. *Glossopteris* is found in the youngest Talchirs (Rikba bed) or its presence is indicative of the overlying Karharbari flora.

The Talchir assemblage from Anuppur is represented by *Noeggerathiopsis hislopi*, *Noeggerathiopsis* sp. and equisetaceous stems. On the other hand, Chirimiri assemblage is composed of four species of *Gangamopteris*. The Chirimiri assemblage is comparable to the Singrauli flora which comprises 3 species of *Gangamopteris* and one species of *Samaropsis* (Lele, 1966). We have not found other plant fossils in Chirimiri as reported by Biswas (1955). The Anuppur flora is typical in having only *Noeggerathiopsis* and is not comparable to any known Talchir flora. It is interesting to note that the Talchir assemblage in Chirimiri is represented by *Gangamopteris* while the one from Anuppur shows only *Noeggerathiopsis*.

Megafossils from the Coal-bearing Formation — The Umaria assemblage is represented by 3 species of *Gangamopteris*, four species of *Glossopteris* and equisetaceous stems, the Birsinghpur Pali assemblage by two species of *Gangamopteris*, four species of *Glossopteris*, *Vertebraria indica*, *Arberia surangei* (Chandra & Srivastava, 1981), two species of *Noeggerathiopsis* and equisetaceous stems, the Anuppur flora by two species of *Gangamopteris*, three species of *Noeggerathiopsis*, one species of *Glossopteris* and equisetaceous stems, and the Chirimiri flora by two species of *Gangamopteris*, three species of *Noeggerathiopsis*, three species of *Glossopteris* and equisetaceous stems (Table 1).

The Karharbari plant fossils have earlier been reported from various Lower Gondwana localities such as Giridih Coalfield (Feistmantel, 1879; Maithy, 1965a-d, 1966b), Ganjra Nala bed, Birsinghpur Pali (Saksena, 1955, 1963; Maithy, 1968; Lele & Maithy, 1969), Chirimiri Coalfield (Biswas, 1955; Ganguly, 1969), South Karanpura Coalfield (Kulkarni, 1970), Jayanti Coalfield (Lele & Maithy, 1966; Lele & Makada, 1974), Auranga Coalfield (Srivastava, 1977a), etc. Recently Chandra and Surange (1979) have recognised distinct *Glossopteris* species in the different Lower Gondwana formations of India. According to them nine species of *Glossopteris* namely *G. taenoides*, *G. angusta*, *G. recurva*, *G. pandurata*, *G. giridihensis*, *G. karharbariensis*, *G. zeilleri*, *G. communis*, *G. decipiens* and *G. taeniensis* are typical of the Karharbari Stage.

The floral assemblage from the coal-bearing formations of Umaria, Birsinghpur Pali, Anuppur and Chirimiri, in general, is dominated by *Noeggerathiopsis* and *Gangamopteris*. *Glossopteris* in this assemblage is represented by seven species, of which five species namely *G. kaharbariensis*, *G. communis*, *G. angusta*, *G. decipiens* and *G. zeilleri* are common to those typical of the Karharbari Stage as listed by Chandra and Surange (1979). We have not been able to find even a single species of either *Botrychiopsis* or *Buriadia*. These palaeobotanical observations suggest that the Coal-bearing Formation in these parts of the South Rewa Gondwana Basin are equivalent to the Karharbari 'Stage' of the Peninsular India.

TABLE 1—DISTRIBUTION OF PLANT FOSSILS IN THE AREAS OF INVESTIGATION

		UMARIA	PALI	ANUPPUR	CHIRIMIRI
COAL BEARING FORMATION	GANGAMOPTERIS				
	G. cyclopteroides	—		—	—
	G. cyclopteroides var attenuata	—			
	G. major			—	
	G. angustifolia	—	—		
	G. karharbariensis		—		
	G. clarkeana				—
	GLOSSOPTERIS				
	G. karharbariensis	—			
	G. communis	—	—	—	—
	G. angusta	—			
	G. decipiens		—		
	G. indica		—		—
	G. zeilleri		—		—
	G. sp.	—			
	NOEGGERATHIOPSIS				
	N. hislopi		—	—	—
	N. spathulata		—	—	—
	N. minor sp. nov			—	—
	VERTEBRARIA				
	V. indica		—		
	EQUISETACEOUS STEM	—	—	—	—
	ARBERIA				
	A. surangei		—		
TALCHIR FORMATION	GANGAMOPTERIS				
	G. cyclopteroides				—
	G. intermedia				—
	G. clarkeana				—
	G. major				—
	NOEGGERATHIOPSIS				
	N. hislopi	—		—	
	Noeggerathiopsis sp.			—	
	EQUISETACEOUS STEM		—	—	

STRATIGRAPHICAL STATUS

Blanford (1976) for the first time recognised the Karharbari 'Stage' in the Giridih Coalfield. This stage was characterized by the presence of *Botrychiopsis validum* and *Buriadia sewardi* and by the dominance of *Gangamopteris* and *Noeggerathiopsis* to distinguish it both from the underlying Talchir and the overlying Damuda. Because of the dominance of *Noeggerathiopsis* and *Gangamopteris*, the Karharbari was accepted as the upper part of the Talchir Formation (Feistmantel, 1879; Oldham, 1893; Wadia, 1957). On the other hand, the discovery of a marine fossiliferous bed (Sinor, 1923) below the Coal-measures and unconformably overlying the Talchirs at Umaria was taken as an evidence to place the Karharbaris at the base of Damuda Group (Fox, 1931; Pascoe, 1959; Krishnan, 1960).

The lithological types constituting the Coal Measures in the South Rewa Gondwana Basin are shales, carbonaceous shales, coal and sandstones. It has been found very difficult to distinguish the Karharbari and Barakar formations on the basis of lithology. Recently Ghosh *et al.* (1964) have suggested the presence of a Boulder and/or a conglomeratic bed below the Barakars as a means of recognising the Karharbaris. The presence of a Boulder and/or conglomeratic bed below the Barakar is very uncommon feature and it is not generally possible to utilize this character in recognising the Karharbaris. A pebbly sandstone bed has been observed in a few sections in the areas of investigation. The beds overlying this zone were naturally thought to belong to the Barakar Stage. These beds overlying the pebbly zone are normally represented by thick massive sandstone or sometime carbonaceous shale. We have, however, failed to find any megafossil above this pebbly zone.

It is still disputed whether Karharbari should be recognized as a distinct formation geologically, floristically at least the plant bearing Coal-Measures (so-called Barakars) of these areas of the South Rewa Gondwana Basin are equivalent to the Karharbari Formation of the Peninsular India. These biostratigraphical studies support the views expressed earlier by Biswas (1955), Ganguly (1959), Maithy (1966, 1967, 1968, 1969) and others. The Karharbari flora is quite distinct from the typical Barakar flora and is closer to the known Talchir flora. On the other hand, the lithology of the beds having Karharbari flora is similar to that of the Barakar Formation and is distinct from that of the Talchir Formation. These facts make it apparently clear that the plant similarities between two geological horizons do not necessarily mean the lithological similarities as well and vice-versa.

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EXPLANATION OF PLATES

(All type and figured specimens are preserved at the B.S.I.P. Museum, Lucknow. Specimens shown in Plate 1 are from Talchir while those in Plates 2, 3 and 4 belong to the Coal-bearing Formation)

PLATE 1

1. *Gangamopteris cyclopteroides* Feistmantel, specimen no. 35352. × Nat. size; Bhukbhuki, Chirimiri.

2, 3. *Gangamopteris clarkeana* Feistmantel, specimen nos. 35354 and 35353. × Nat. Size; Bhukbhuki, Chirimiri.

4. *Gangamopteris intermedia* Maithy, specimen no. 35355. × Nat. size; Bhukbhuki, Chirimiri.

5. *Gangamopteris major* Feistmantel, specimen no. 35356. × Nat. size; Bhukbhuki, Chirimiri.

6-8. *Noeggerathiopsis hislopi* (Bunbury) Feistmantel, specimen nos. 35999. × 1.5; Chandas Nala, Anuppur; 36000. × 1.5; Chandas Nala, Anuppur; and 36001. × Nat. size; Jwalamukhi, Umaria.

9. *Noeggerathiopsis* sp., specimen no. 36002. × 1.5; Chandas Nala, Anuppur.

10. Equisetaceous stem, specimen no. 35357. × Nat. size; Barachada, Birsinghpur Pali.

PLATE 2

11. *Gangamopteris cyclopteroides* var. *attenuata* Feistmantel, specimen no. 35981. × Nat. size; Baruha Nala, Barbaspur, Umaria.

12. *Gangamopteris major* Feistmantel, specimen no. 35982. × Nat. size; Bakan Nala, Anuppur.

13. *Gangamopteris karharbariensis* Maithy, specimen no. 35983. × Nat. size; Patpara-Marjada Nala Traverse, Birsinghpur Pali.

14. *Gangamopteris angustifolia* McCoy, specimen no. 35984. × Nat. size; near Mangthar, Birsinghpur Pali.

15. *Gangamopteris clarkeana* Feistmantel, specimen no. 35985. × Nat. size; Duman Hill-Korea Traverse, Chirimiri.

16. *Glossopteris karharbariensis* Chandra & Surange, specimen no. 35986. × Nat. size; Baruha Nala, Barbaspur, Umaria.

17. *Noeggerathiopsis hislopi* (Bunbury) Feistmantel, specimen no. 35987. × Nat. size; near Mangthar, Birsinghpur Pali.

18. *Noeggerathiopsis spathulata* (Dana) Maithy, specimen no. 35988. × Nat. size; Bakan Nala, Anuppur.

19. *Noeggerathiopsis minor* sp. nov., specimen no. 35989. × Nat. size (Holotype); Bakan Nala, Anuppur.

20. *Noeggerathiopsis minor* sp. nov., specimen no. 35989. × 2 (enlargement of fig. 19); Bakan Nala, Anuppur.

21. *Noeggerathiopsis minor* sp. nov., specimen no. 35990. × Nat. size; Duman Hill-Korea Traverse, Chirimiri.

PLATE 3

22. *Glossopteris angusta* Pant & Gupta, specimen no. 35991. × Nat. size; Baruha Nala, Barbaspur, Umaria.

23. *Glossopteris indica* Schimper, specimen no. 35992. × Nat. size; Khodargaon-Kudri Traverse, Birsinghpur Pali.

24. *Glossopteris zeilleri* Pant & Gupta, specimen no. 35990. × Nat. size; Duman Hill — Korea Traverse, Chirimiri.

25. *Gangamopteris cyclopteroides* Feistmantel, specimen no. 35994. × Nat. size; Baruha Nala, Barbaspur, Umaria.

26. Equisetaceous stem — specimen no. 35983. × Nat. size; Patpara — Marjada Nala Traverse, Birsinghpur Pali.

PLATE 4

27. *Glossopteris* sp., specimen no. 35996. × 3/4; Baruha Nala, Barbaspur, Umaria.

28. *Glossopteris decipiens*, Feistmantel, specimen no. 35997. × Nat. size; near Mangthar, Birsinghpur Pali.

29. *Glossopteris communis* Feistmantel, specimen no. 35998. × Nat. size; near Mangthar, Birsinghpur Pali.

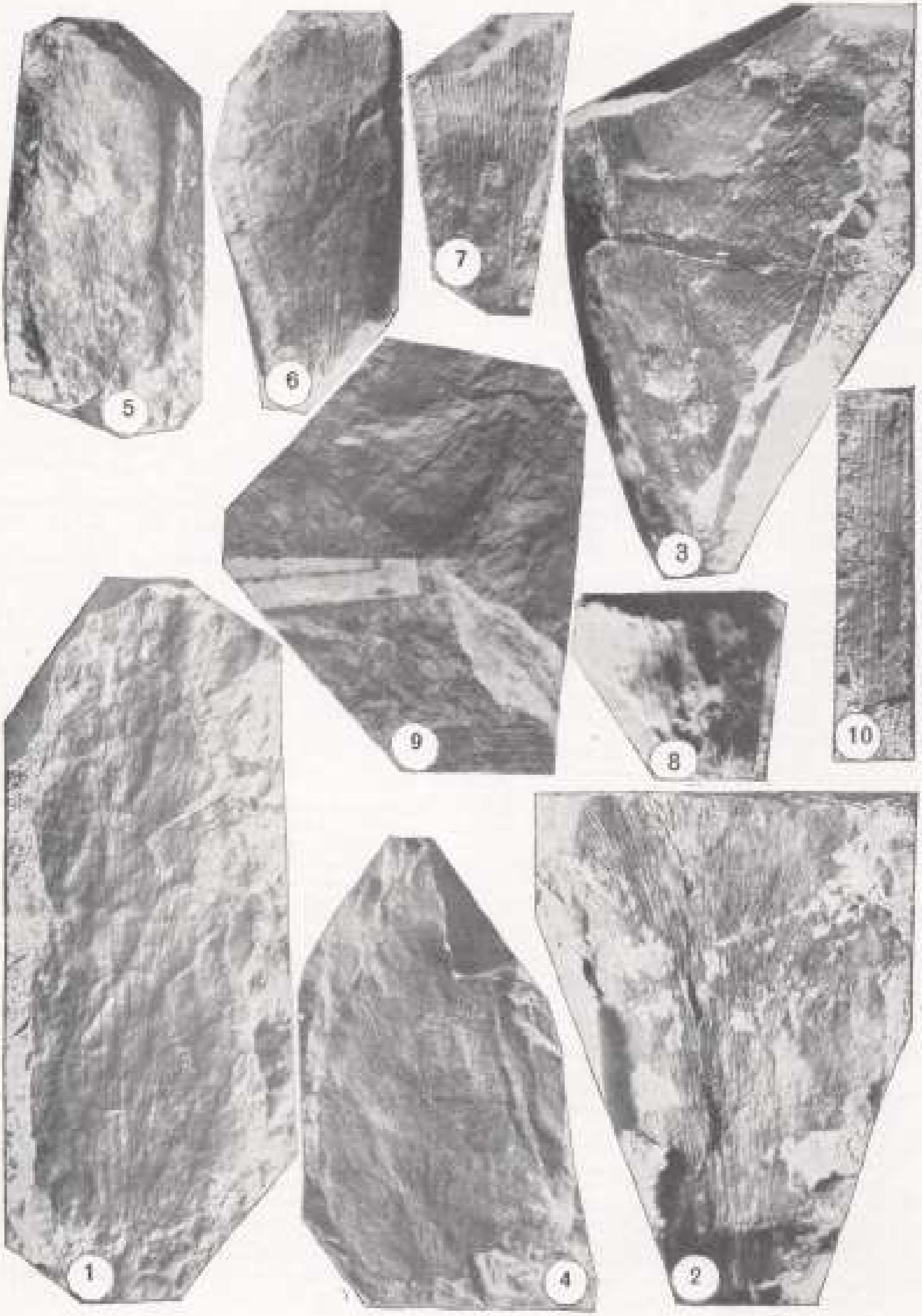

PLATE 1


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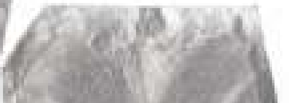
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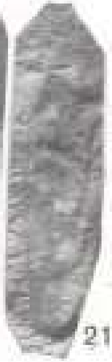
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PLATE 2

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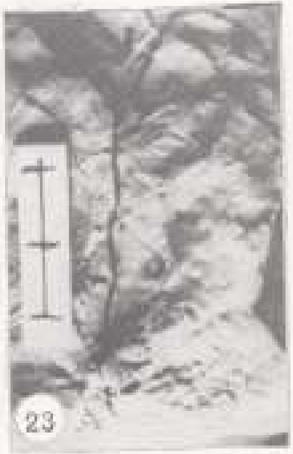

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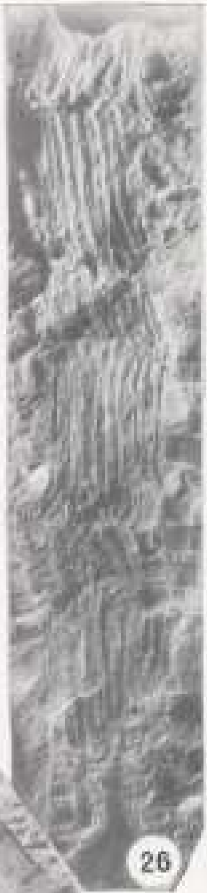

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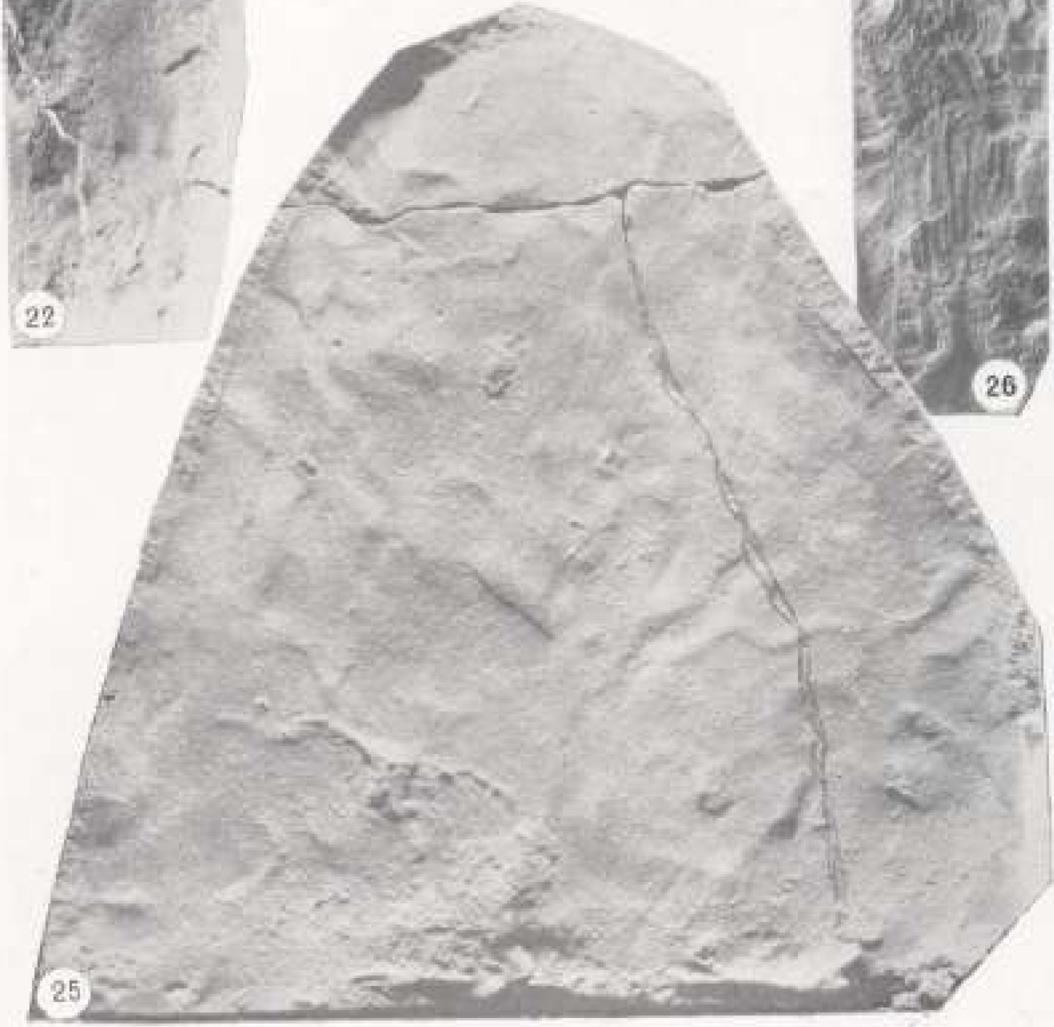

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PLATE 3

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PLATE 4

The Palaeobotanist, 30(2): 168-180, 1982.

LITHOSTRATIGRAPHY AND STRUCTURE OF THE HUTAR COALFIELD, PALAMAU DISTRICT, BIHAR

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ABSTRACT

Various traverses have been taken along the different nala and stream courses to study the Lower Gondwana sediments in the Hutar Coalfield. Details of lithology of the individual bed are presented. A generalised succession of the beds in Talchir, Karharbari and Barakar formations, present in the coalfield, has been worked out and lithological description of various members and formations is given. Besides, a general idea of the structure of the area is given. The Karharbari Formation has also been demarcated in this coalfield for the first time.

Key-words—Lithostratigraphy, Hutar Coalfield, Kurharbari Formation, Barakar Formation, Lower Gondwana (India).

सारांश

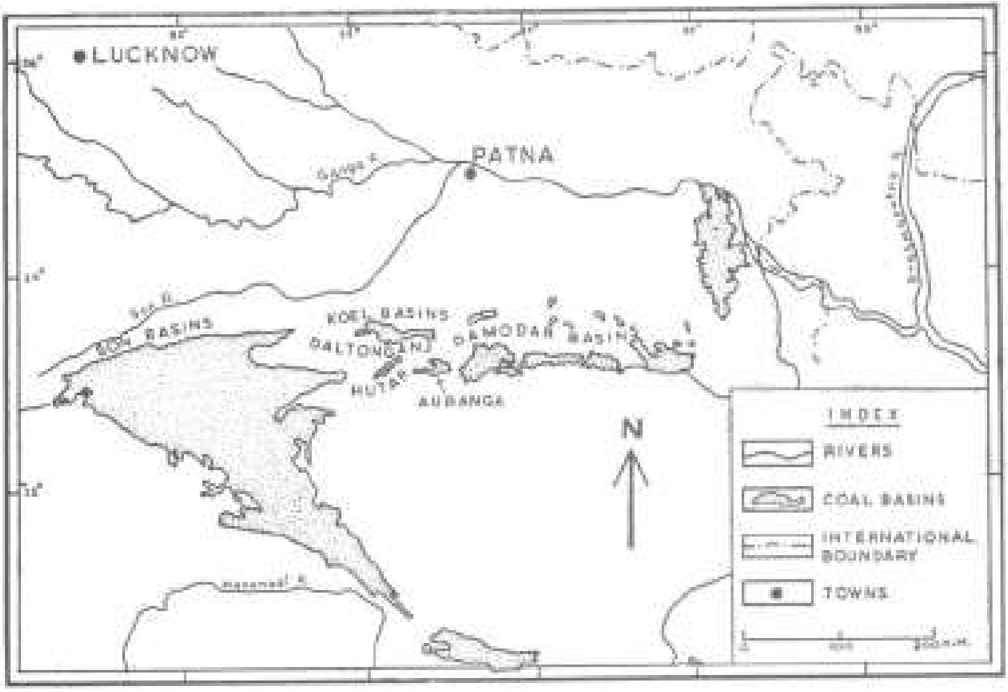
पलामऊ जनपद (बिहार) में हुटार कोयला-क्षेत्र की शैलिकी एवं संरचना – मनोज शुक्ला

हुटार कोयला-क्षेत्र में अधरि गोंडवाना अवसादों का अध्ययन करने के लिए विभिन्न नालों एवं धारा-प्रवाहों के साथ-साथ अलग-अलग चंक्रमों का उपयोग किया गया है। प्रत्येक संस्तर का शैल-विन्यास विस्तृत रूप से प्रस्तुत किया गया है। इस कोयला-क्षेत्र में विद्यमान तालचिर, करहरबारी एवं बराकार शैल-समूहों में संस्तरों का एक सामान्य अनुक्रम अन्वेषित किया गया है तथा भिन्न-भिन्न सदस्यों एवं शैल-समूहों का शैलिकीय वर्णन भी किया गया है। इसके अतिरिक्त इस क्षेत्र की संरचना पर एक सामान्य विचार प्रस्तुत किया गया है। इस कोयला-क्षेत्र में करहरबारी-शैल-समूह को भी पहली बार सीमांकित किया गया है।

INTRODUCTION

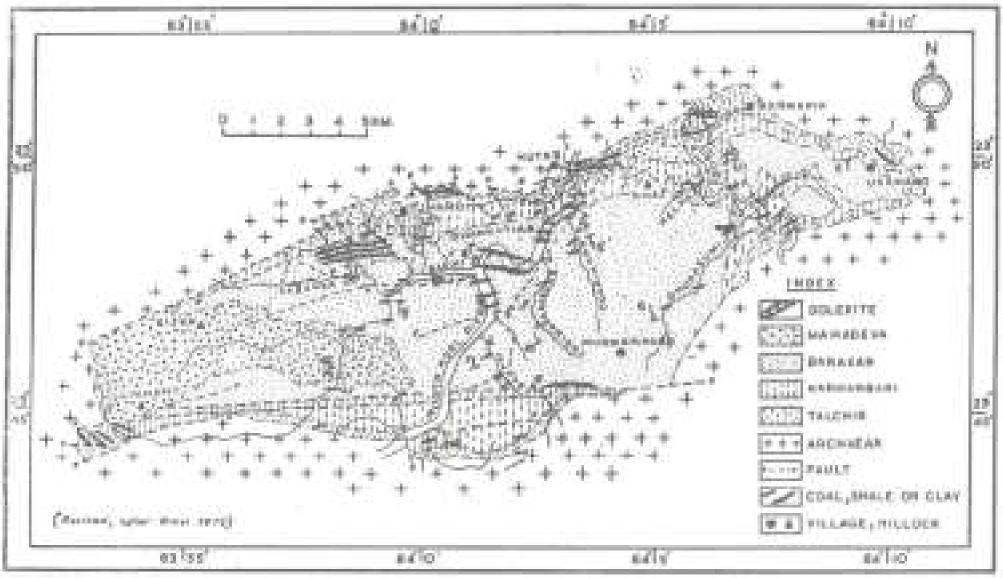
THE Hutar Coalfield (latitude, 23°44′ to 23°52′ and longitude, 83°53′ to 84°11′) lies in E-W trending Gondwana belt along Damodar, Sone, Narmada and Koel valleys. It is among those three coalfields of the Palamau District which have often been referred to as the Palamau coalfields or Koel Valley coalfields. The Hutar Coalfield with an area of about 200 sq km is situated 20 km south of the Daltonganj Coalfield and 20 km west of the Auranga Coalfield (Map 1). It extends from the Ukamnar Village in east to Mangra Pahar in west and Hutar Village in north to Parro Village in South. The Talchir, Karharbari, Barakar and Mahadeva formations are exposed in this area.

Ball (1880) named this coalfield after the village Hutar. He was the first who studied and mapped it systematically and divided the sediments into Talchir Group, Barakar Group and Mahadeva Series in ascending order. In 1886, Feistmantel reported the presence of *Glossopteris indica*, *G. damudica*, *Gangamopteris cyclopteroides*, *Vertebraria indica* and equisetaceous stems, viz., cf. *Phyllotheca* (?) in this area. On the basis of this flora, he suggested the presence of Karharbari sediments near the northern margin of the coalfield. In 1928, Dunn remapped the coalfield on modern toposheets on a scale of 1:63, 360 and suggested some modifications in the stratigraphic nomenclature adopted by Ball (1880) (see Rizvi, 1972, pp. 7, 18). Later, Rizvi (1972) remapped this coalfield using aerial photographs on a scale of

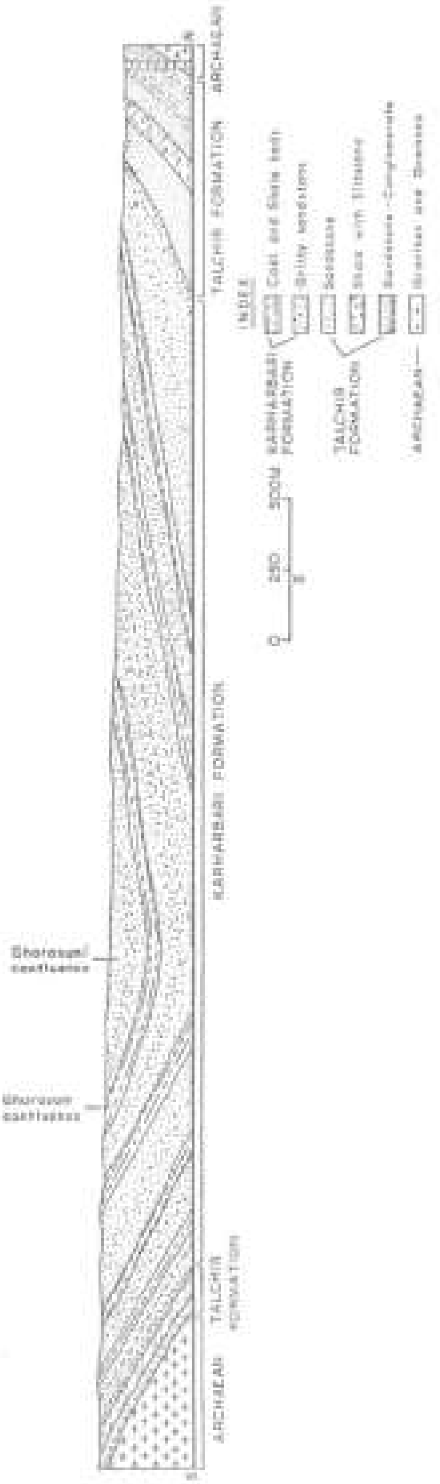


MAP 1

1:31, 680 giving more emphasis to the sedimentological aspects. He, however, agreed with the work of Ball (1880) and Dunn (1928) and also adopted the stratigraphical classification proposed by them. He traced the lithological variation in



MAP 2



Text-Fig. 1

different beds and prepared detailed sketches of the area disturbed by faults. He also gave traverse-wise description of different series of rocks and reported breaks in deposition of the Talchir, Barakar and Mahadeva series.

GEOLOGY OF THE AREA

Gondwana sediments in the Hutar Coalfield (Map 2) form a syncline (Text-fig. 1) and are surrounded on all sides by the Archeans. The Talchir Formation rests non-conformably over the Archeans, but sometimes faulted contacts have also been seen (cf. western extremity of the coalfield). The talchir sediments are successively overlain by the Karharbari Formation. A conglomerate at the base of Karharbari sediments marks the possible hiatus between the two formations. The Karharbari-Barakar boundary is mostly faulted except in the east and north-eastern parts of the coalfield. Normal contacts are marked by the ridge forming habit of chocolate brown to red colour of the lower Barakar sandstones. Dhankutia, Dhaj and Ranimai hillocks mark this contact in the eastern and north-north-eastern part of the coalfield. The Barakar sandstone is overlain by massive red sandstone of the Mahadeva Formation with an angular unconformity.

TRAVERSES

The traverses were undertaken along ten different nalas and road cuttings. It was found that no section in the field exposes all the beds. A generalized reference section is therefore, computed from 3 main traverses taken along (i) Deoria Nala, (ii) Koel River, and (iii) the Saphi Nala. Along these traverses, the thickness of beds and details of lithology were noted. Besides the main traverses, several other subsidiary traverses were also undertaken to study the lateral changes in the lighology of these beds and the structural pattern of the basins.

Main Traverse 1 — Deori Nala (South side) — This nala shows a nearly complete and best exposed succession of the Karharbari Formation. General succession of beds found in this nala is as follows:

FORMATION	MEMBER	LITHOLOGY
KARHARBARI (130·5 m)	Gritty sandstone Member (120·4 m)	Huge thickness of gritty sandstone with partition of coal and shale beds
	Basal Conglomerate Member (10.0 m)	Calcareous pebbly sandstone
	EROSIONAL BREAK	
TALCHIR (18·75 m)	Shale Member (15 m)	Rhythmite facies showing shale with siltstone alternation
	Basal sandstone conglomerate Member (3·75 m)	Coarse sandstone as matrix of a conglomerate often shows pseudo-stratification
	NONCONFORMITY	
ARCHAEAN	Schists, gneisses, granites	

Main Traverse 2 — Koel River (North side) — This river passes from the centre of the coalfield dividing it into two parts. The eastern side of the coalfield exposes older sediments and is less disturbed by tectonic activity. The western side is marked by the younger formations which are also exposed along this river. Succession of the beds along this river is given below:

FORMATION	MEMBER	LITHOLOGY
BARAKAR (224 m)	Ferruginous sandstone shale Member (48·5 m)	Coarse sandstone with partition of clay and shale beds, carbonaceous matter absent
	Gritty sandstone Member (160·5 m)	Gritty sandstone with partition of coal-shale beds
	Compact red sandstone Member (15 m)	Compact chocolate red sandstone with occasional pebble lenses
KARHARBARI (37 m)	Gritty sandstone Member (30 m)	Gritty sandstone with partition of coal-shale
	Basal conglomerate Member (7 m)	Pebbly conglomerate
	EROSIONAL BREAK	
TALCHIR (27 m)	Upper sandstone Member (9 m)	Coarse green sandstone
	Shale Member (13 m)	Splintery shale
	Basal sandstone conglomerate Member (5 m)	Conglomerate with matrix of green sandstone
	NONCONFORMITY	
ARCHAEAN		Granite, Gneiss and Schists

Main Traverse 3 — Saphi Nala (North side) — The nala flows in the western half of the coalfield. The area north of this nala is dominated by tectonically disturbed Karharbari and Barakar formations and to the south, the dominant rocks are massive sandstone of the Mahadeva Formation. The nala cuts through the youngest member of the Barakar Formation and the Mahadeva Formation. The sandstone is well-developed but the clay shale beds are generally not seen as they are covered by recent sands brought by this nala. Therefore, these beds were studied in the adjoining area.

FORMATION	MEMBER	LITHOLOGY
BARAKAR (186·5 m)	Ferruginous sandstone and shale Member (185·5 m)	Coarse gritty sandstone with partition of greenish grey shale and clay beds

Besides, several other subsidiary traverses were also taken to study the structure of the coalfield and the extension of various members (Table 1).

LITHOSTRATIGRAPHY

Generalised Reference Section — A generalised succession of the beds in the Hutar Coalfield computed on the basis of the main and subsidiary traverses is as follows:

FORMATIONS	MEMBERS
MAHADEVA	Ferruginous pebbly sandstone Member
	Angular unconformity
BARAKAR (302 m)	Ferruginous sandstone — shale Member Gritty sandstone Member Compacted sandstone Member
KARHARBARI (107 m)	Gritty sandstone Member Basal conglomerate Member
	Erosional contact
TALCHIR (27 m)	Upper Sandstone Member Shale Member Basal sandstone conglomerate Member
	Nonconformity
ARCHAEANS	Granite, gneisses and schists

ARCHAEANS

The Archeans surrounding the Hutar Coalfield belong to a series of metamorphic rocks consisting of granite gneisses with mica, hornblende and quartz veins. These rocks are uniform in nature in this region.

In south of the Hutar Coalfield the area is covered by granite gneisses, traversed by quartz veins having general trend of E 15° N-W 15° S. Some of these veins are up to 30 cm thick. Towards north-west, black synites are present. While in the west of the coalfield the area is covered with gneisses, traversed by pegmatite and quartz veins. And as regards the eastern part of the coalfield it has granite gneisses traversed by dolerite dykes which are trending east-west.

TALCHIR FORMATION

The Talchir Formation in the Hutar Coalfield forms a near continuous band surrounding the Karharbari Formation. The Talchir sediments are seen lying nonconformably over the Archaean basement. The faulted contact between the Talchir sediments and the Archaeans is also seen at certain places. Presence of sandstone-conglomerate on the border, intimate association of shale-siltstone and varves and presence of slump structure, ripple marks cross bedding, graded appearance in individual lamina of varves, and also drop stones in the shale can easily be explained by following the depositional model envisaged by Banerjee (1966) for Talchir of the Raniganj Coalfield. Rizvi (1972) also broadly agrees with this interpretation.

This formation is distinguishable by three members described below in ascending order. Each member has its own lithological characteristics. For stratigraphic classification the scheme proposed by Ghosh and Mitra (1975) has been followed.

1. *Basal Sandstone Conglomerate Member* — This member (Pl. 1, fig. 3) forms the basal part of the Talchir Formation. It is characterized by lateral and vertical variations from conglomerate to sandstone (Pl. 1, fig. 1). Towards the southern side of the coalfield the boulder bed is seen grading into sandstone and shale. Some conglomeratic lenses have also been noticed in the sandstone. Boulders and pebbles forming these beds range between 1.0 cm to 1.0 m in size and are subrounded in nature. Striations are rarely seen on boulders. The granite gneisses, vein-quartz, amphibolite schist, pegmatite, quartzite and Jespar form most of the pebbles and boulders. They are embedded in a sandy matrix. The sandstone varies from fine to medium grained and is poorly sorted. In a vertical section they show pseudostratification (Pl. 1, fig. 1) in the conglomerate.

2. *Shale Member* — This member overlies the Basal sandstone conglomerate member and shows two lithological facies as follows:

(i) *Shale facies* — It is composed of greenish-yellow fine-grained shales which break into small splintery needle-like fragments.

(ii) *Rhythmite facies* — It is represented by varves and shale siltstone alternations. The varves (Pl. 1, fig. 2) are best exposed in the Saphi Nala near the Ukamnar Village and in the Behra Nala near the Putvagarh Village. They show an alternate arrangement between darkgreen clayey and light grey silty layers. These layers invariably exhibit graded appearance within the laminae. The thickness of these layers varies vertically. The variation is more frequent in the light coloured silty layers. Laterally as well as vertically the varves

TABLE 1

FORMATION	MEMBER	DEORI NALA (SOUTH)	DEORI NALA (NORTH)	KOEL RIVER (NORTH)	SAPHI NALA (NORTH)	BEHRA NALA	SAPHI NALA (UKAMNAH AREA)	KELHA NALA	GHORASUMI NALA	DURIAKHAR	CHILHAPANIKHAR
MAHADEVA	Ferruginous pebbly sandstone										
- - - - - - - -	ANGULAR UNCONFORMITY - - - - - - - - -			(Fault)							
	Ferruginous sandstone-shale			+	+	+		+		+	+
BARAKAR	Gritty sandstone			+		+				+	+
	Compact red sandstone			+			+				
- - - - - - - -	- - - - - - - - -							(Fault)			
KARHARBARI	Gritty sandstone	+	+	+			+	+	+		
	Basal conglomerate	+		+			+				
- - - - - - - -	EROSIONAL BREAK - - - - - - - -		(Fault)								
	Upper sandstone		+	+		(Fault)	+				
	Shale	+	+	+		+	+				
	Basal sandstone conglomerate	+	+	+		+					
- - - - - - - -	NONCONFORMITY - - - - - - - -										
ARCHAEAN	Granite, gneisses, schists	+	+	+			+				

grade into shales. In the Ukamnar area they are seen affected by reverse faulting. Ripple marks, current bedding, slump structure, etc. (Pl. 2, figs 1, 3) are also observed in the sediments associated with them. The shales immediately overlying the varves show drop-stones.

As regards the shale siltstone alternation (Pl. 1, fig. 4) these beds are exposed in the Deori Nala, Ukamnar area and the Behra Nala exposures. The silty layers vary in thickness from 2 to 20 cm and can be distinguished from the shales due to differential type of weathering, massive appearance and compact nature. These beds are laterally traceable in the field for long distances.

3. *Upper Sandstone Member* — It is coarse grained and green in colour. It forms the topmost member of the Talchir Formation. It is constituted mostly of immature subrounded quartz grains and rock fragments. This sandstone is overlain by a conglomerate.

KARHARBARI FORMATION

The Karharbari Formation in the Hutar Coalfield is seen overlying the Talchir Formation without any discordance in dips, but the beds of these two formations are separated by a bed of conglomerate marking a possible hiatus. This conglomerate bed is noticeable in the Koel Section, Deori Nala Section, at the junction of the Jamtapani Nala with its tributary in the Parro River and west of the Chumna Village in a stream. Some good sections of the Karharbari Formation are exposed in deeper nala and river cuttings through the Barakar sandstones. This formation consists of thick succession of gritty ferruginous sandstones separated by thin coal-shale beds.

At the base of the Karharbari Formation conglomerate indicates an erosional lower contact. The rest of the sediments are predominantly coarse and unsorted indicating the deposition in high energy environment. The intermediate portion of the coal-shale beds indicates a low energy environment of deposition by slow moving currents. The lower contact of shale and coal beds is transitional with the result the velocity of currents gradually slowed down, while the upper contact is abrupt indicating a sudden increase in currents velocity. This formation comprises the following two members.

1. *Basal Conglomerate Member* — It is exposed at the top of the Talchir Formation and at the base of the Karharbari Formation. The pebbles are mostly of granite gneiss, hornblende-schist, mica-schist, chlorite-schist, quartzite, vein-quartz and epidiorites, which are set in a fine sandy matrix. Earlier, these conglomerates were classified alongwith the Talchir boulder beds due to the lithological similarities. In the present work, however, it is taken as the basal unit of the Karharbari Formation marking the end of the Talchir and beginning of the Karharbari cycles of sedimentation respectively.

2. *Gritty Sandstone Member* — It consists of two distinct types of sediments, viz., sandstone and coal-shale. Four coal-shale beds have been observed in the Deori Nala Section, where the Karharbari Formation is best exposed.

The sandstone is medium to coarse grained and reddish brown in colour due to high ferruginous contents. They are poorly sorted and mainly composed of subrounded quartz and feldspar grains. Occasionally, the grains become larger in size and give gritty to pebbly appearance to these sandstones. At places iron nodules are also seen in the sandstone. These nodules are often washed by water action, leaving behind rounded cavities. Frequently, the sandstones are strongly current bedded with their laminae sloping towards east (Pl. 2, fig. 4).

The thin coal beds present in the Karharbari Formation show sharp contacts with sandstone on the upper side, while the lower contact is transitional passing through coaly shale-shale-sandy shale to sandstone. The coal is dull, hard, compact, non-banded, generally of poor quality and durain-type in appearance. Lenses of vitrain are rare. The shales occurring near the sandstones are rich in sandy material and show transitional contact with sandstones, whereas the shales present near the coal-seams are rich in carbonaceous material. The shales are generally grey in colour but due to variable percentage of carbonaceous matter, they show various shades of black colour.

BARAKAR FORMATION

The beds overlying the Karharbari Formation and underlying the Mahadeva Formation in this area have been placed in the

Barakar Formation. The upper contact with the Mahadeva Formation is unconformable. These beds can be divided into lower, middle and upper units on the lithological grounds. The middle unit has alternation of coal-shale beds with compact gritty ferruginous sandstone. The upper unit consists of clay and shale beds alternating with gritty ferruginous sandstone. The shales and sandstones of this horizon are greenish in colour. A thick sandstone bed of chocolate-brown to red colour with occasional conglomeratic lenses which is the lower most unit separates Karharbari and Barakar formations at normal contacts. However, in the Hutar Coalfield the Karharbari Formation has generally a faulted contact with the Barakar Formation.

Coarser clastics of the Barakar Formation are also deposited under high energy environment. But the shale and clay beds forming a partition in this sandstone must have been deposited in low energy environment. This transitional contact on both upper and lower sides indicates a gradual decrease and then increase in currents velocity. This formation has the following three members.

1. *Compact red sandstone Member* — It is a characteristic member of this formation and can be taken as marker horizon to separate the Barakar and Karharbari formations. But due to hard and compact nature of this member it stands out in the form of a number of hillocks which marks the Karharbari-Barakar boundary. It is red to chocolate brown, coarse grained and poorly sorted in nature. Occasionally, the lenses of conglomerate are also present. The pebbles are mostly of quartz. The member is sometimes about 100 m thick.

2. *Gritty sandstone Member* — This member is composed of two distinct lithologies, viz., gritty sandstone and coal shale. The sandstone shale is coarse grained, contains ferruginous matter and occasionally becomes gritty. The grains are subrounded. Lenses of conglomerate, made up of immature quartz pebbles, are also present. It is less ferruginous than the underlying Karharbari sandstones. The iron nodules are rare. At few places the carbonaceous grits are also present which are associated with shale beds.

In coal-shale bed the lower Barakar sediments of this coalfield are characterized by thick and frequent coal seams. The coal is generally shaly and dull in nature. The coal seams show gradational contact with sandstones passing through shale and sandy shale beds. Sometimes thin streaks of coaly matter are also seen in the sandstones associated with these beds.

3. *Ferruginous sandstone-shale Member* — It consists of two types of lithologies, viz., the sandstones and clay-shale beds. The sandstones are gritty to pebbly ferruginous and mostly constituted of poorly sorted immature quartz grains. In extreme west near the Barakar-Mahadeva contact, these sandstones show a typical greenish-black colour. The sandstones, in general, have tendency to become more pebbly near the top.

The zone of clay and shale beds shows near absence of carbonaceous matter. The shales are fine grained and show various shades of green and red colours; the clays are massive and non-laminated type and yellow in colour. Occasionally, their surface is stained with iron stains. The significant feature of these shales and clay beds is their similarity with the Talchir shales. This type of lithology is not common in the Barakar Formation of other areas.

MAHADEVA FORMATION

It is represented by a thick massive sandstone which dips 10° to 12° in S 25°W and overlies the Barakar Formation with marked angular unconformity. The hills formed by these sandstones have steep escarpment with uneven top. The sandstones are feldspathic at the base with an occasional thin bed of red ferruginous shale. The extension of various members in Hutar Coalfield is given in Table 1.

DEMARCATION OF KARHARBARI FORMATION

Previous workers like Fox (1934), Ghosh *et al.* (1964), Maithy (1969), Bharadwaj (1974b), etc. have suggested the presence of the Karharbari Formation in the Hutar Coalfield on the basis of some plant remains described by Feistmantel (1886). However, field workers like Ball (1880), Dunn (1928) and Rizvi (1972) failed to demarcate this formation in this coalfield on the basis of lithological criteria. In the present work this formation is demarcated as a lithological unit for the first time in the Hutar Coalfield. As is evident from the lithological description given in previous pages, the lithology of the Karharbari Formation and the lower portion of the overlying Barakar Formation is more or less same. The only difference, which is conspicuously visible, is in the contact of the coal beds with gritty sandstone. The Karharbari coal beds show a gradational lithology near lower contact passing through coaly shale—shale—sandy shale-sandstone, while the upper contact with sandstone is abrupt. The Barakar coal beds show gradational lithology both near upper and lower contacts. These two sets of beds are separated by a compact red sandstone with occasional lenses of conglomerate. This sandstone is devoid of any carbonaceous facies and has a ridge forming habit. These ridges (Dhankutia Pahar, Dhaj Pahar, Ranimai Pahar, etc.) can easily be traced in the field. Therefore, the compact red sandstone has been taken here as the marker horizon to demarcate the Karharbari Formation from the Barakar Formation. Boundary of the Barakar Formation towards the southern side is marked by two big faults. They start from near Binda and extend up to Murwai Kalan where they join to form the boundary fault. Towards north a fault near Tiharo and the Dhankutia and Dhaj hillocks mark the upper limit of the Karharbari Formation. The lower boundary of the Karharbari Formation coincides with the lower limit of the Barakar Group of Rizvi (1972). This limit is marked by a conglomerate bed.

STRUCTURE OF THE AREA

The Gondwana sediments in the Hutar Coalfield are folded, forming a syncline with its axis tending east-west in the western portion and northeast-southwest in the eastern portion of the area. The eastern half of the coalfield is characterized by hillocks of the Lower Barakar sandstones and this area is comparatively less affected by the structural disturbances. On the contrary the western half is structurally more disturbed and is affected by many faults. Some of these faults extending up to the eastern portion of the coalfield are of regional importance.

The general dip of the beds exposed in the Deori Nala and Koel River sections and belonging to the northern limb of the syncline is 4-12 degrees due south-east. The dip direction of the beds exposed in the west of the Koel River becomes south. On the other hand with the same dip, the inclination of these beds, exposed in Deori Nala section and belonging to the southern limb of the said syncline, is north-west. Ultimately, the direction of the dip of the beds exposed in the Jamtapani and Saphi rivers (west of the Koel River) becomes north. The average dip of the Lower Gondwana Formation and Mahadeva Formation is 4°-7° and 10°-12° respectively (high dips up to 30° have been measured occasionally).

In addition to the known faults (Ball, 1880; Rizvi, 1972), the author has observed a few more faults which are marked by asterisk (*) in the text.

1. *Eastwest or Northeast-Southwest trending faults:*

A. Two major faults are seen in the Satbahni River. They extend up to Murwai Kalan where they join together to form the boundary fault. Towards west, they are traceable in the Koel and Saphi river sections; one of these extends to the Binda Village and mark the Karharbari-Barakar boundary on the southern side of the field. They are also responsible for the reduced thickness of the Barakar sediments in south of the Mahadeva Formation.

B. In the south of the Tiharo Village another fault trending nearly east-west is seen which, alongwith the Dhankutia and Dhaj hillocks, marks the Karharbari-Barakar boundary on northern side of the coalfield.

C. The third east-west trending fault cutting the Saphi River and Barenda Nala takes a northern trend and ends in the second fault.

D. North-western margin of the coalfield is marked by a fault trending north-east south-west. It is most prominent along the escarpment of the Mahadeva Formation.

E. Besides, several other smaller faults of this system are: (i) east-west trending fault affecting the Talchir sediments near the Barwadih Village in the Deori Nala; (*ii) north-east—south-west trending fault affecting the Karharbari sandstone, south of the Deori-Ghorasumi confluence; (iii) fault affecting the Karharbari sandstone, north of the Deori-Kelha confluence; (iv) east-west trending fault resulting in repetition of the Talchir sediments in the Koel River; (v) smaller faults, west of the Koel River, marking the Talchir-Archaean contact; (vi) north-east-south-west trending fault near the Binda Village marking the Talchir-Archaean contact and ending on the first fault of this system; (vii) north-east-south-west trending fault running along the axis of basin noticed in Koel River affecting the Barakar sediments; and (viii) north-east-south-west trending fault starting from the Mahadeva Formation and ending on third fault of this system affecting the Barakar sediments.

The above faults are marked by silicification in sandstone, change of dips and water seepages seen in different nala sections through which they pass.

2. *North-south trending and allied faults:*

*A. A major fault of this system runs nearly along the Koel River. The movement along this fault has resulted in the difference in strike of the Dhankutia and Dhaj hillocks, situated on both the sides of the fault. Smaller sympathetic faults, formed as a result of this major fault, are seen affecting the third coal-shale bed in the Koel River section. The area west of this major fault is the upthrow side, and the area towards east is the down throw side; thus the Upper Barakar sediments on the west come directly in contact with the Lower Barakar sandstone in the east of this fault.

B. Another fault of this system is seen to cut across the Sathahni Nala and a small, un-named nala-tributary of the Koel River. It is marked by abrupt change of dips and silicification of sandstone at both the places.

C. A few faults of smaller magnitude in the northern fringes of the field show a north-north-west: south-south-east trend and affect the Talchir and Karharbari formations.

Trends of dykes and their relationship with faults — Only two dykes have been seen in the coalfield affecting only the Talchir Formation. The first dyke is seen trending S 60°-E-N 60° W in the Deori Nala Section; the second dyke with similar trend is seen north of the Tiharo. The dyke is disturbed by a small fault trending North-north-east-south-south-west.

In general the following conclusions are surmised on the basis of these faults.

1. Faulting took place at least in two phases—(i) east-west trending faults coming first, and (ii) the oblique faults coming later, as the oblique faults are not seen to cut across the east-west trending faults.
2. Faulting is post-Barakar as it affects the Barakar sediments.
3. Faulting is also post-intrusive as the dyke is affected by these faults.
4. Most of the faults of the Hutar Coalfield are of normal gravity type with their plane of inclination between 70° and vertical. However, some strike slip fault are also seen, e.g. the fault affecting the Karharbari Formation in the Koel River.

ACKNOWLEDGEMENTS

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EXPLANATION OF PLATES

Plate 1

1. Conglomeratic lenses in Talchir sandstone; Deori Nala.
2. Varves clay; Talchir Formation, Behra Nala near Sindharwa Village.
3. Small rounded pebbles embeded in green sandstone; Talchir Formation, Deori Nala.
4. Shale-siltstone alternation; Talchir Formation, Deori Nala.

Plate 2

5. Slump structure in shales; Talchir Formation, Saphi Nala near Ukamnar Village.
6. A small fault effecting the coalshale bed; Karharbari Formation, Koel River.
7. Ripple marks; Talchir Formation, Saphi Nala near Ukamnar Village.
8. Current beddings in the sandstone; Karharbari Formation, Deori Nala.

PLATE 1


5

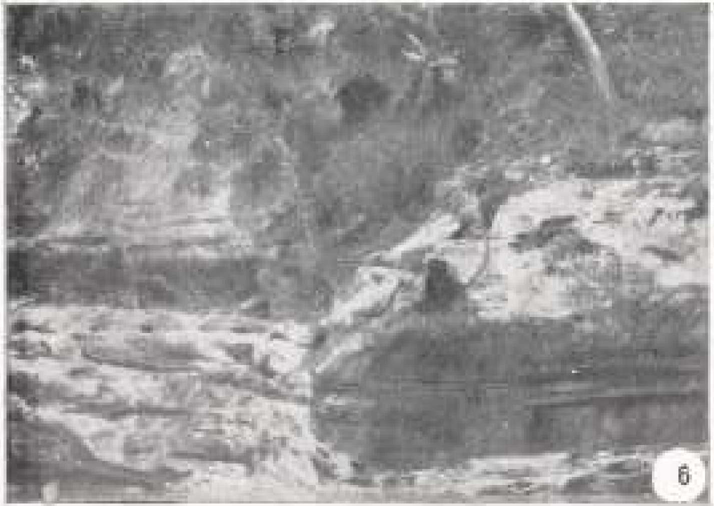
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PLATE 2

The Palaeobotanist, 30(2): 181-184, 1982.

STUDIES ON THE TRANSFUSION CELLS IN PETRIFIED LEAVES OF *PTILOPHYLLUM* AND *NIPANIOPHYLLUM* FROM THE RAJMAHAL HILLS, INDIA

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ABSTRACT

Transfusion cells have been recorded in the leaves of *Ptilophyllum* and *Nipaniophyllum*. In the former the transfusion cells are found in close association with the vascular elements, while in the latter they surround the bundle sheath. The relationship is discussed with the plants possessing allied type of arrangement of transfusion cells.

Key-words — *Ptilophyllum, Nipaniophyllum*, Transfusion cells, Rajmahal Hills, India.

सारांश

भारत की राजमहल पहाड़ियों से टाइलोफिल्लम् एवं निपानियोफिल्लम् की अश्मीभूत पत्तियों में संचरण कोशिकाओं का अध्ययन — ब्रह्मदत्त शर्मा

टाइलोफिल्लम् एवं निपानियोफिल्लम् की पत्तियों में संचरण कोशिकायें अभिलिखित की गई हैं। पहली प्रजाति में संचरण कोशिकायें संवहनी तत्वों के घनिष्ठ साहचर्य में पाई गई हैं, जबकि दूसरी में ये कोशिकायें बंडल-आच्छद को घेरे रहती हैं। संचरण कोशिकाओं के इसी प्रकार के विन्यास वाले पौधों की पारस्परिक संबंधता भी विवेचित की गई है।

INTRODUCTION

THE transfusion tissue includes three types of cells, i.e. transfusion tracheids, transfusion parenchyma and the albuminous cells. The transfusion cells occur invariably in all gymnosperms (Esau, 1965). In recent years a number of papers have been published on the structure and distribution of these cells in the stems of cycads (Greguss, 1969) and conifer leaves (Ghouse, 1973, 1974; Ghouse & Yunus, 1974, 1975; Kaushik, 1976; Kaushik & Bhattacharya, 1977). In fossil material the differentiation between transfusion parenchyma and albuminous cells is difficult. However, transfusion tracheids and the parenchyma could be recognized well in the fossil leaves.

Ptilophyllum and *Nipaniophyllum* leaves collected respectively from Amarjola and Nipania in the Rajmahal Hills, Bihar. The material of the former is soft and fragile, thus was boiled in canada balsam prior to sectioning with a wire band saw.

DESCRIPTION

Ptilophyllum — Serial sections were prepared in transverse as well as longitudinal planes through the petioles and rachises. A number of collateral, conjoint and endarch bundles are seen arranged in a double 'U'-shaped manner (Sharma, 1967). Both xylem as well as phloem are well-developed (Pl. 1, fig. 1). Xylem elements of the bundles of two rows face each other. Sclerotic cells are present in the inner portion of the cortex and adjacent to the phloem of the outer row of bundles (Pl. 1, fig. 3). These are arranged more or less in rows. The transfusion cells are present in between the two rings of bundles as well as on the lateral and outer sides of the bundles in close association with the vascular elements (Pl. 1, figs 1, 3). The transfusion tracheids are narrow, elongate, blunt end wall cells mostly having uniseriate bordered pits (Pl. 1, fig. 4). They occur in between the bundles and on the outer periphery of the phloem (Pl. 1, fig. 3). The cells of transfusion parenchyma are large, rectangular and have scalariform thickenings (Pl. 1, fig. 4) or 2-3 seriate, opposite, simple pits (Pl. 1, fig. 2). They occur in between two rings of the bundles.

Nipaniophyllum — This leaf was cut in different planes. It is a simple leaf with distinct midrib from which the lateral veins arise at right angles and divide at all levels. The midrib possesses 5-11, or so, diploxylic bundles arranged in a saucer-shaped manner (Pl. 1, fig. 5). Each bundle possesses one cell thick, sclerenchyma sheath. The transfusion cells surround the sheath (Pl. 1, figs 5-7). The transfusion tracheids occupy lateral and abaxial sides of the bundles, while the transfusion parenchyma forms a well-developed zone on the adaxial side. The former are thick-walled cells with 2-3 rows of bordered pits on the lateral walls, while the latter are rectangular cells with simple pits. The transfusion cells are distinct and different from the cells of the bundle sheath which are typical sclerenchyma with uniseriate bordered pits.

DISCUSSION

Kaushik and Bhattacharya (1977) grouped conifers and taxads into different types on the basis of distribution of transfusion cells in their leaves. The studied leaves of *Ptilophyllum* resemble the needles of Pinaceae in the absence of distinct bundle sheath and in having transfusion cells all around the bundle and closely associated with the vascular elements. The transfusion tracheids are present on the lateral sides of the bundles, while the parenchyma occur on the abaxial/adaxial sides of the vascular elements.

In *Nipaniophyllum* the transfusion cells occur outside the bundle sheath. Worsdell (1897) suggested the term "accessory transfusion tissue" for such types of cells which are found in cycads and members of Podocarpaceae. However, *Nipaniophyllum* differs from them in detail. In the presence of transfusion tracheids in between the bundles and aggregation of the parenchyma on the adaxial side, the present leaf shows resemblances with the members of Araucariaceae (Kaushik & Bhattacharya, 1977). Rao (1943) also suspected the presence of transfusion tracheids in the leaf of *Taeniopteris spatulata* (later on renamed as *Nipaniophyllum raoi* Sahni, 1948), but could not decide whether the pitted tracheid-like cells were of the surrounding sclerenchymatous bundle sheath or are really transfusion cells. The present investigation confirms the exact nature of these cells.

Further studies on the transfusion cells in the petrified fossil plants might prove helpful in better understanding of their taxonomy and relationship with allied groups of plants.

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EXPLANATION OF PLATE

1. *Ptilophyllum*: C.S. Petiole, bundles of two rows and the associated transfusion cells. × 120.
2. Same. L.S. Transfusion parenchyma with two opposite rows of simple pits. × 450.
3. Same. C.S. Outer part of phloem with associated transfusion tracheids and sclerotic cells. × 300.
4. Same. L.S. Transfusion tracheids and the parenchyma. × 450.
5. *Nipaniophyllum*. C.S. Leaf showing diploxylic bundles and associated transfusion cells. × 24.

6, 7. Same. C.S. Bundles enlarged, showing the surrounding transfusion tracheids and the parenchyma. × 120.

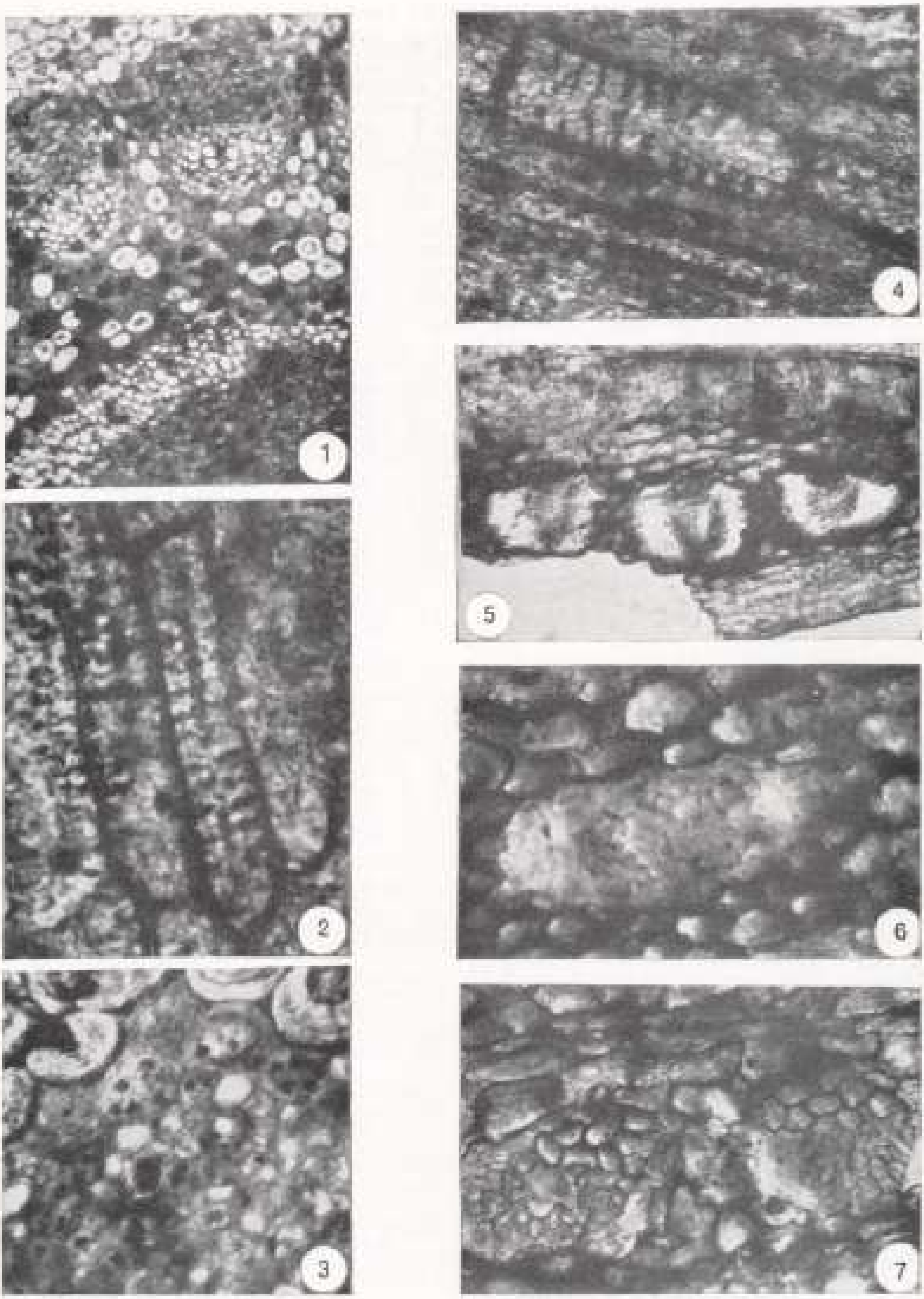

PLATE 1

The Palaeobotanist, **30**(2): 185-232, 1982.

UPPER PALAEOZOIC FLORA OF KASHMIR HIMALAYA

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ABSTRACT

The paper deals with plant fossils collected from the Upper Palaeozoic rocks of Kashmir Himalaya ranging in age from Upper Devonian to Permian. The distribution of plants, so far collected in the various formations, is as follows:

Aishmuqam Formation (Upper Devonian)—?*Taeniocrada* sp. and ?*Protolepidodendron* sp.

Syringothyris Limestone and Fenestella Shale formations (Lower Carboniferous)—*Archaeosigillaria minuta* Lejal, *Lepidosigillaria* cf. *quadrata* Danzé-Corsin, *Lepidodendropsis* cf. *peruviana* (Gothan) Jongmans, *L. fenestrata* Jongmans, *Cyclostigma* cf. *pacifica* (Steinmann) Jongmans, *Rhacopteris ovata* (McCoy) Walkom, *Triphyllopteris lescuriana* (Meek) Jongmans, *Rhodea* cf. *subpetiolata* (Potonié) Gothan and *Palmatopteris* cf. *furcata* Potonié.

Nishatbagh and Mamal formations (Lower Permian)—(a) *Nishatbagh Formation*—*Gangamopteris kashmirensis* Seward, *Glossopteris longicaulis* Feistmantel, *G. nishatbaghensis* sp. nov. and ?*Nummulospermum* sp. (b) *Mamal Formation*—*Parasphenophyllum thonii* var. *minor* (Sterzel) Asama, *Trizygia speciosa* Royle, *Lobatannularia ensifolia* Halle, *Rajahia mamalensis* sp. nov., *Glossopteris intermittens* Feistmantel, *G.* cf. *communis* Feistmantel, *G.* cf. *feistmantelii* Rigby, *G.* cf. *taeniopteroides* Feistmantel, *G. angustifolia* Brongniart, *Glossopteris* sp., ?*Cordaites* sp., *Ginkgophyllum haydenii* (Seward) Maithy, *G. sahnii* (Ganju) Maithy and a cone-like organ.

In the Upper Devonian the plant fossils are extremely rare and very badly preserved. The Lower Carboniferous flora shows a remarkable resemblance with the assemblage described from Peru and is in general agreement with the rest of the Lower Carboniferous floras known from other parts of the world. The Permian flora has two distinct elements, one present in the Nishatbagh Formation and the other in the Mamal Formation. The former is dominated by the presence of *Gangamopteris*, whereas, the latter is dominated by *Glossopteris*. Moreover, at Mamal there are two genera, viz., *Lobatannularia* and *Rajahia* which are typically Cathaysian elements. Some of the species of *Glossopteris*, too, seem to be distinct from all the species of *Glossopteris* reported from the Lower Gondwana of the Peninsular India.

Key-words—Upper Palaeozoic flora, *Glossopteris*, *Gangamopteris*, *Lobatannularia*, *Rajahia*, Permian, Upper Devonian, Kashmir Himalaya, India.

सारांश

काश्मीर हिमालय से उपरि पुराजीवी वनस्पतिजात – गोपाल सिंह, प्रभात कुमार माइती एवं महेन्द्र नाथ बोस

प्रस्तुत शोध-पत्र काश्मीर हिमालय की उपरि डिवोनी से परमी आयु तक की उपरि पुराजीवी चट्टानों के भूवैज्ञानिक एवं पुरावनस्पतिक अध्ययन से सम्बन्धित है। विभिन्न शैल-समूहों से अभी तक एकत्रित पादपाश्मों का विवरण निम्नवत् है:

ऐशमुकाम शैल-समूह (उपरि डिवोनी) – ?टीनियोक्रेडा जा० एवं ?प्रोटोलेपिडोडेन्ड्रॉन जा०।

साइरिंगोथाइरिस चूनाश्म एवं फेनेस्टेला-शैल शैल-समूह (अधरि कार्बनी) – आर्कियोसिजिलेरिया माइन्यूटा लेजल, लेपिडोसिजिलेरिया जा० सजातीय क्वाड्रेटा डान्ज़े-कॉर्सिन, लेपिडोडेन्ड्रॉप्सिस जा० सजातीय पेरूवियाना (गोथान) यौंगमैन्स, लै० फेनेस्ट्रेटा यौंगमैन्स, साइक्लोस्टिग्मा जा० सजातीय पैसिफिका (स्टाइनमैन) यौंगमैन्स, रैकॉप्टेरिस ओवेटा (मैकॉय) वाल्कम, ट्राइफिल्लॉप्टेरिस लैसकुरियाना (मीक) यौंगमैन्स, रोडिया जा० सजातीय सबपिटिओलेटा (पोटोनिये) गोथान एवं पाल्मेटॉप्टेरिस जा० सजातीय फर्केटा पोटोनिये।

निशातबाग एवं मामल शैल-समूह (अधरि परमी) – (अ) निशातबाग शैल-समूह – गंगामोप्टेरिस काश्मीरिऐन्सिस सिवर्ड, ग्लॉसोप्टेरिस नीलिकाविस फाइस्टमॅन्टेल, ग्लॉ॰ निशातबागेन्सिस न॰ जा॰ एवं गुम-मोस्पर्मम् जा॰। (आ) मामल शैल-समूह – स्फीनोफिल्लम् थोनाई उपजाति माइनर (स्टर्जेल) अयामा, ट्राइजाइजिया स्पेशिओसा रॉयल, लोबेटएनुलेरिया एन्सिफोलिया हाले, रजाहिया मामलेन्सिस न॰ जा॰, ग्लॉसोप्टेरिस इन्टरमिडिया फाइस्टमॅन्टेल, ग्लॉ॰ जा॰ सजातीय ग्लॉ॰ कम्युनिस फाइस्टमॅन्टेल, ग्लॉ॰ जा॰ सजातीय फाइस्टमॅन्टेलाई रिग्बी, ग्लॉ॰ जा॰ सजातीय टीनिऑप्टेरोइडिस फाइस्टमॅन्टेल, ग्लॉ॰ अंगस्टीफोलिया ब्रॉनिआर्ट, ग्लॉ॰ जा॰, ?कोरडाइटिस जा॰, सिग्मोफिल्लम् हेडेनाई (सिवर्ड) साहनी, ग्लॉ॰ साहनाई (सन्नू) साहनी तथा एक बीज-सदृश अवयव।

उपरि डिवोनी में पादपाश्म नितान्त दुर्लभ एवं अपूर्णतया परिरक्षित हैं। अधरि कार्बनी वनस्पतिजात पीक से वर्णित समुच्चय से उल्लेखनीय तथा विश्व के अन्य भागों से विदित शेष अधरि कार्बनी वनस्पतिजातों से सामान्य सजातीयता प्रदर्शित करता है। परमी वनस्पतिजात में दो मुख्य अवयव हैं जिन में से एक निशातबाग शैल-समूह में तथा दूसरा मामल शैल-समूह में विद्यमान है। पहली शैल-समूह गंगामोप्टेरिस से प्रभावी है, जबकि दूसरी में ग्लॉसोप्टेरिस की बाहुल्यता है। इसके अतिरिक्त मामल में दो प्रजातियाँ – लोबेटएनुलेरिया एवं रजाहिया जो कि सामान्य कैथेसी तत्व हैं – विद्यमान हैं। ग्लॉसोप्टेरिस की कुछ जातियाँ भी प्रायद्वीपीय भारत के अधर गोंडवाना में अभिलिखित ग्लॉसोप्टेरिस की सभी जातियों से भिन्न प्रतीत होती हैं।

INTRODUCTION

IN the Himalaya, Kashmir region exposes one of the best developed Palaeozoic sequences. Palaeobotanically this sequence is well known since long as it contains the Permian plant fossil bearing strata sandwiched between marine fossiliferous sequence. These Permian plant bearing horizons have been variously named as Lower Gondwana Bed, Gangamopteris Bed or Permian Gondwana in the geological literature. Recent discovery by Pal (1978) and Pal and Chaloner (1979) of plant bearing beds from the Lower Carboniferous sequence of Kashmir region has opened a new field of palaeobotanical study involving Carboniferous or Pre-Gondwana flora in Kashmir. The earlier knowledge of Pre-Gondwana flora in Indian subcontinent was negligible and restricted to Spiti in Himachal Pradesh (Gothan & Sahni, 1937; Høeg, Bose & Shukla, 1957; Dhar, Ram & Rao, 1980).

The investigation by Pal (1978) was restricted to a single horizon in the Fenestella Shale Formation (Lower Carboniferous). Since then several new plant bearing horizons in Aishmuqam Formation (Upper Devonian), Syringothyris Limestone Formation (Lower Carboniferous), and the upper part of Fenestella Shale Formation (Lower Carboniferous), have come to light in the Upper Palaeozoic succession of Liddar Valley, Kashmir.

An attempt has been made here to delineate the different plant bearing horizons developed in the Upper Palaeozoic sequence of Kashmir Himalaya. Besides, a systematic account of their floral contents has also been given. In all, six horizons (Table 1) have been recognised at distinct stratigraphic levels, out of which four show the presence of Pre-Gondwana or Devonian-Carboniferous flora and two Permian flora. The latter are somewhat similar to the Lower Gondwana flora of Peninsular India. However, within the Permian the upper horizon has also elements of Northern Hemisphere. The oldest plant bearing horizon, i.e. horizon no. 1, represents B Member of the Aishmuqam Formation (Upper Devonian); horizon no. 2 is developed in the basal part of C Member of Syringothyris Limestone (Tournasian: Lower Carboniferous); horizon no. 3 represents A Member of the Fenestella Shale Formation (Lower Carboniferous); horizon no. 4 represents C Member of the Fenestella Shale Formation (Lower Carboniferous); horizon no. 5 represents the Nishatbagh Formation (Lower Permian); and horizon no. 6 represents the Mamal Formation (Lower Permian).

Within these six horizons, five plant fossil assemblages have been recognized, in which two horizons have similar assemblages. Assemblage 1 is supposed to be of Upper Devonian age, assemblages 2 and 3 from A and C members of Fenestella Shale are

TABLE 1 — UPPER PALAEOZOIC SUCCESSION IN KASHMIR SHOWING PLANT BEARING HORIZONS

AGE		STRATIGRAPHIC UNIT		MAIN LITHOLOGY
		Formation	Member	
	UPPER	ZEWAN	D	Calcareous sandstone with bands of limestone.
			C	Arenaceous and calcareous shale.
			B	Limestone shale intercalation.
PERMIAN			A	Massive limestone with shale partings.
		////// MAMAL //////		Novaculite, limestone, tuffaceous shale, carbonaceous shale, purple and pinkish shale with arenite.
	LOWER	PANJAL VOLCANIC		Mainly basic rocks-basalt and andesitic basalt and a few intermediate and acidic rocks.
		////// NISHATBAGH //////		Black shale/slate, siltstone and bands of arenite.
			D	Ash colour tuffaceous shale with volcanic bombs lapillae, etc. Clasts rare.
			C	Dominantly quartz-arenite with lenticular conglomerates and clasts.
	UPPER	AGGLOMERATIC SLATE	B	Dominantly shale and siltstone with abundance of clasts.
CARBONIFEROUS			A	Dominantly quartz-arenite with lenticular conglomerate and clasts.
			D	Dominant shale-siltstone with bands of quartz arenite.
		FENESTELLA SHALE	///C///	Dominant quartz arenite with bands of shale and siltstone.
			B	Dominant shale/siltstone with bands of arenite.
			///A///	Dominant quartz-arenite with intercalation of shale siltstone.
	LOWER		///C///	Limestone shale/siltstone/arenite intercalations.
		SYRINGOTHYRIS LIMESTONE	B	Massive and thickly bedded limestone.
			A	Limestone and arenite.
DEVONIAN	UPPER	AISHMUQAM	///B///	Yellowish-green siltstone-shale with bands of quartz-arenite.
			A	Quartz-arenite with intercalation of blotchy siltstone.
	MUTH-QUARTZITE			Milky white orthoquartzite

////// Indicate plant bearing horizon

similar and are of Lower Carboniferous age. Assemblages 4 and 5 are of Lower Permian age (Text-fig. 1).

STRATIGRAPHY OF THE UPPER PALAEOZOIC ROCKS

The Upper Palaeozoic sequence in Kashmir is represented by several formations, namely Aishmuqam, Syringothyris Limestone, Fenestella Shale, Agglomeratic Slate, Nishatbagh, Panjal Volcanic, Mamal and Zewan in ascending order of succession. The Muth Quartzite Formation, which underlies the Aishmuqam Formation, forms a datum line in the Palaeozoic sequence and represents a distinct lithounit; as such all the post-Muth sequences are included in the Upper Palaeozoic and sequences up to Muth in the Lower Palaeozoic. The details of all the plant bearing horizons developed within the Upper Palaeozoic succession are given in Table 1.

AISHMUQAM FORMATION

Recently a distinct mappable lithounit has been delineated between orthoquartzite sequence of Muth Quartzite Formation and a calcareous-argillaceous-arenaceous sequence of Syringothyris Limestone which has been designated as Aishmuqam Formation by Kumar, Singh and Srivastava (1980). This unit was earlier grouped by Middlemiss (1910) within his Muth Quartzite Unit.

Aishmuqam Formation has been divided here into two members — A and B. A Member is represented by variegated quartz-arenite with blotchy siltstone, whereas, B Member consists of light yellowish and greenish siltstone with thinly to thickly bedded intercalations of quartz-arenite. The light coloured siltstone (B Member) has yielded plant fossils at Kotsu Hill, Diuth Spur and the Spur near Ayun and represents the oldest plant bearing horizon known so far in Kashmir. B Member is widely distributed in Liddar Valley area. No marine fauna has been reported so far from Aishmuqam Formation. The collection of fossil plants has been made mainly from Kotsu Hill and Diuth Spur.

SYRINGOTHYRIS LIMESTONE FORMATION

On the basis of dominant lithology and sedimentary sequence this formation is divisible into three distinct members — A, B and C.

A Member — It consists mainly of arenaceous limestone which is hard and compact with partings of shale and intercalations of quartz-arenite. Thus this unit essentially shows a mixed facies of arenaceous and calcareous sediments. The marine fossils are occasionally seen in the limestones and comprise brachiopod shells and crinoidal fragments. Amongst the brachiopods, most common genera are *Rhynchonella* and *Chonetes*. Possibly from this unit Savage (1976) and Tewari, Shrivastava and Gupta (1978) have described the conodont of Tournasian age.

B Member — It comprises mainly thickly bedded, hard, compact grey to black limestone. The lower part is massive while the upper part is thickly bedded. The limestone is brown on weathered surfaces and grey on fresh surfaces. This member forms the most distinctive unit of Syringothyris Limestone Formation and has the richest assemblage of marine fossils. The assemblage is dominated by brachiopods amongst which the productids are most common, followed by *Chonetes* and rhynchonellids; and differs from the underlying A Member by its richness in fossils more so because of the abundance of productids.

C Member — Intercalations of limestone, arenite and shale-siltstone sequence are characteristics of this member. Boundary between B and C Members is demarcated by the first appearance of dark carbonaceous shale and siltstone. The member is further divisible into four sub-units: (i) — The basal 35 m sequence is characterized by dominant limestone with intercalations of black shale, siltstone and arenite. Here, as compared to B Member the fauna is poorly represented, especially the productids are rare, coral and crinoid are more common alongwith fragmentary plant remains. This is further followed by a sill of basic rock (35 m). (ii) — This sill or basic rock is followed by a 50 m thick sequence of dominant arenite with intercalations of siltstone, shale and limestone. In this unit marine life is absent and plant fossils are abundant at the base and near

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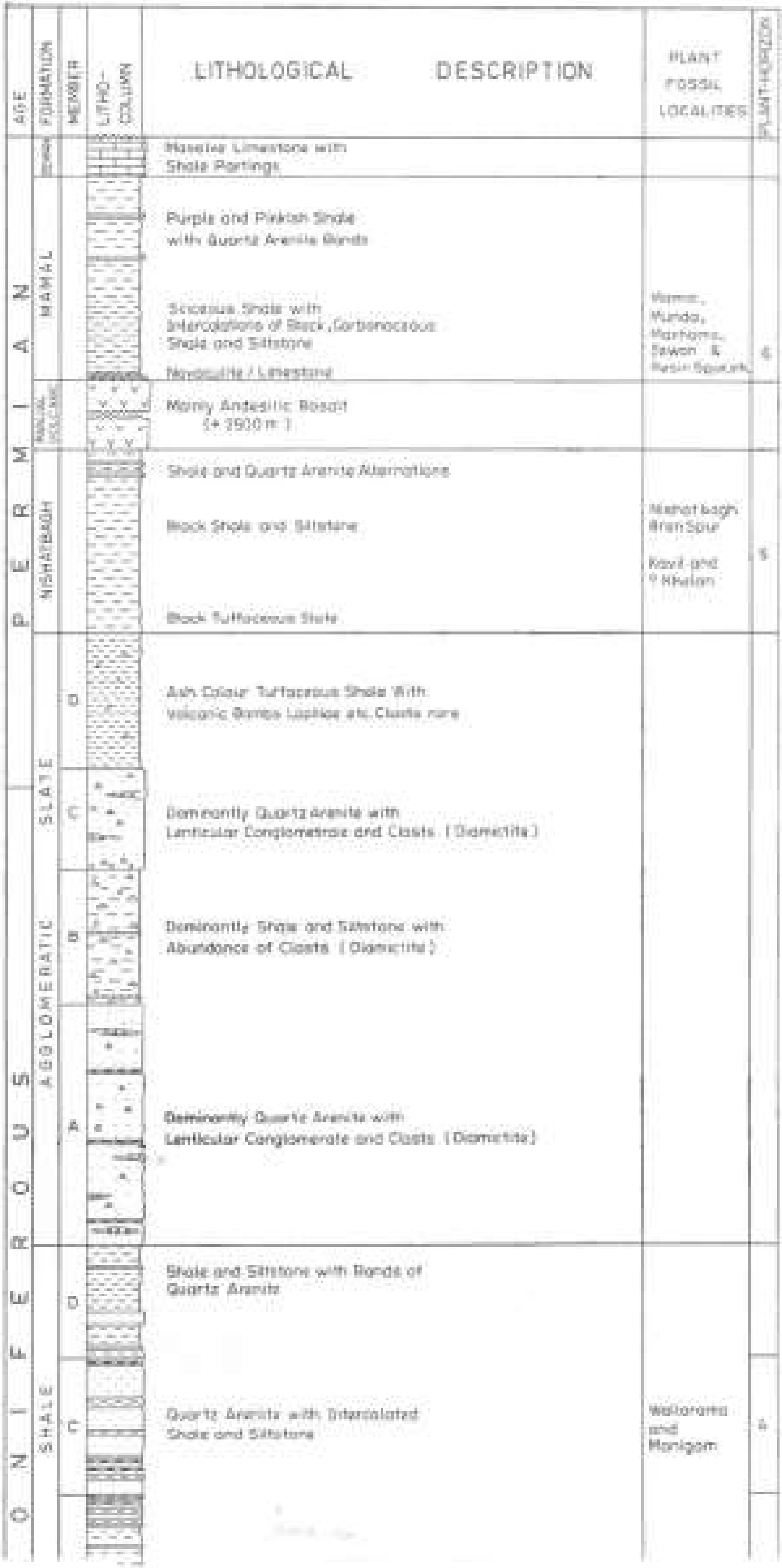


AGE	FORMATION	MEMBER	LITHO-COLUMN	LITHOLOGICAL DESCRIPTION	PLANT FOSSIL LOCALITIES	PLANT HORIZON
PERMIAN	ZEWAN			Massive Limestone with Shale Partings		
	MAMAL			Purple and Pinkish Shale with Quartz Arenite Bands		
				Siliceous Shale with Intercalations of Black, Carbonaceous Shale and Siltstone	Mamal, Munda, Marhama, Zewan & Pesin Spur,etc.	6
				Novaculite / Limestone		
	PANJAL VOLCANICS			Mainly Andesitic Basalt (+ 2500 m)		
	NISHATBAGH			Shale and Quartz Arenite Alternations		
				Black Shale and Siltstone	Nishat bagh, Brain Spur Kavit and ? Khelan	5
				Black Tuffaceous Slate		
CARBONIFEROUS	AGGLOMERATIC SLATE	D		Ash Colour Tuffaceous Shale With Volcanic Bombs Lapilae etc. Clasts rare		
		C		Dominantly Quartz Arenite with Lenticular Conglomerate and Clasts (Diamictite)		
		B		Dominantly Shale and Siltstone with Abundance of Clasts (Diamictite)		
		A		Dominantly Quartz Arenite with Lenticular Conglomerate and Clasts (Diamictite)		
	SHALE	D		Shale and Siltstone with Bands of Quartz Arenite		
		C		Quartz Arenite with Intercalated Shale and Siltstone	Wallarama and Manigam	4

the top and on the whole the entire sequence is plant bearing. This is the second plant bearing horizon which is developed in the entire Liddar Valley area, but the fossils are more common at Kotsu Hill, Gokhan gali and Ichhnar Spur. (iii) — This is represented by a 35 m thick limestone sequence with partings of shale. The limestone contains occasional remains of brachiopods and corals. (iv) — It consists of 25-30 m thick shale dominated sequence with intercalations of limestone and arenite. The limestone bands are fossiliferous in which corals are common with a few brachiopods and crinoids.

FENESTELLA SHALE FORMATION

This formation conformably overlies the Syringothyris Limestone Formation and has a sequence of quartz-arenite and shale alternations. Recently, Kumar, Singh and Srivastava (1980) have subdivided it into four members namely A, B, C and D which have been dealt below separately. Middlemiss (1910) recognized a Passage Bed between Syringothyris Limestone and Fenestella Shale comprising a sequence of quartzite and shale. However, he grouped this Passage Bed with Fenestella Shale as lithologically it resembled the latter more than the underlying formation. Pal (1978) reported a rich floral assemblage from this Passage Bed at Gund near Banihal and assigned an independent formational status, i.e. the Gund Formation. This formation was instituted because of complete absence of marine fauna and presence of profuse plant fossils. Kumar, Singh and Srivastava (1980) have indicated that similar plant bearing horizon again reappears in the upper part of Fenestella Shale. As such, there are two quartz-arenite dominant sequences, i.e. A and C Members with plant fossils and two argillite dominant sequences, namely B and D with marine fossils, thereby indicating two transgressive and two regressive phases in the sedimentary succession. The Passage Bed of Middlemiss (1910) and Gund Formation of Pal (1978) represent A Member of Kumar, Singh and Srivastava (1980). There are considerable variations in the thickness of these members and as such they are not mappable on a regional scale. However, they can be mapped in the areas where they are well-developed in Liddar Valley and Banihal. The Liddar Valley area is the type area of Fenestella Shale Formation.

A Member — This is dominated by quartz-arenite with intercalations of siltstone and shale and is characterized by the presence of plant fossils and complete absence of marine fossils. The plant fossils are present only in bands of siltstone and shale. Arenites are thickly bedded, often micaceous and light coloured and are devoid of fossils. This Member contains abundant plant fossils at Gund near Banihal while in Liddar Valley they are seen at road-section near Kotsu, Gaos and Manigam, etc.

B Member — This is dominated by shale and siltstone with bands of arenite. The shales are dark grey in colour having profuse pyrite crystals and marine fossils.

C Member — It has dominant sequence of arenite with intercalations of shale and siltstone similar to A Member at Wallarama. Shale and siltstone encompass abundant impressions and casts of stems. Marine fossils are rare or even absent.

D Member — Similar to B Member it is also dominated by argillite with the occurrence of shale, siltstone and bands of thick arenite. In some sections near the top, arenite content increases and a local E Member can be delineated. The shale and siltstone are rich in marine fossils while the plant fossils are rare.

AGGLOMERATIC SLATE FORMATION

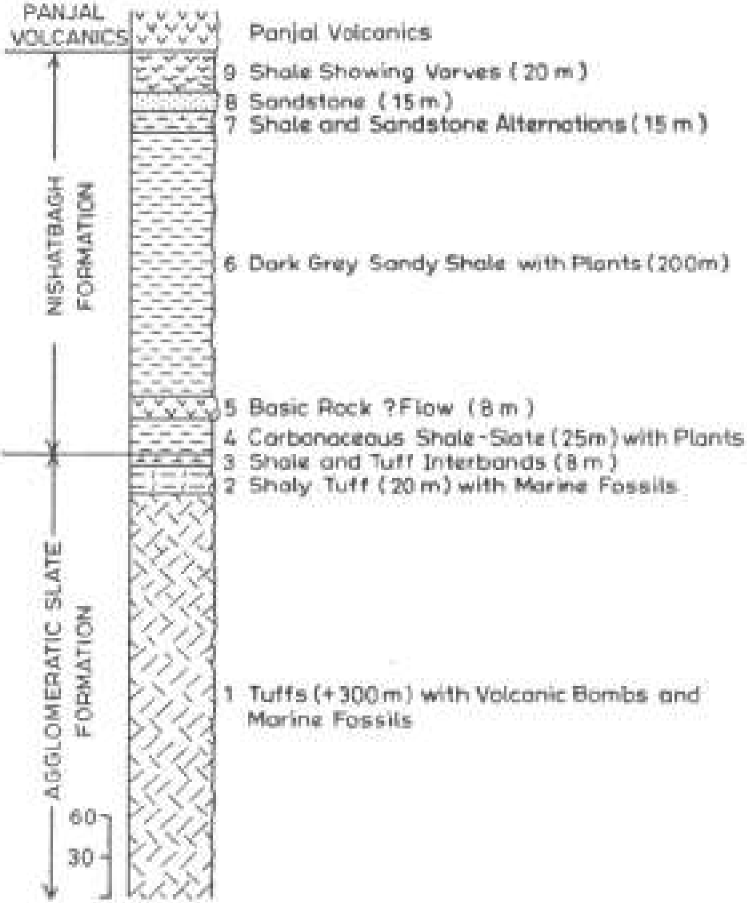
So far no plant bearing horizon is known from this formation. Earlier, lithostratigraphically the topmost part of this formation was considered to be plant bearing, but later it was separated as a distinct unit namely Nishatbagh Bed. This classification has been followed in the present work with slight modifications.

NISHATBAGH FORMATION

Lithostratigraphically this unit was mapped as a part of Agglomeratic Slate by Middlemiss (1910) and Bion and Middlemiss (1926). Then Nakazawa and Kapoor (1975) and Kapoor (1977) recognized it as a distinct plant bearing unit quite different from the underlying Agglomeratic Slate and named it as Nishatbagh Bed.

The present study in the type area has revealed that the boundary between the Nishatbagh Formation and underlying Agglomeratic Slate lies between bed nos. 3 and 4 of Kapoor (1977) and not above the volcanic flow II which is well within the Nishatbagh Formation. Bed no. 4 consisting of 25 m dark carbonaceous slate, has yielded a rich plant assemblage and is completely devoid of marine elements. Thus the lithological criteria to separate the Nishatbagh Formation from the underlying Agglomeratic Slate Formation should be according to the first appearance of dark carbonaceous slate containing plant fossils only and not as has been suggested by Kapoor (1977). This modified boundary has been shown in Text-fig. 2 and the Nishatbagh Bed has been given the status of a Formation.

The dominant lithology of Nishatbagh Formation consists of dark carbonaceous shale-slate with subordinate sandstone in the upper part. This formation shows a regional development in Kashmir region especially in the areas around Srinagar, Pir Panjal as well as in the Tral and Liddar valleys. Varma and Zutshi (1981) have reported its presence in Pir Panjal area, while Ahmed, Chib and Singh (1978) recorded its presence in Tral Valley near Kavil.



TEXT-FIG. 2.— Lithostratigraphic column at Nishatbagh Spur showing Nishatbagh Formation (modified after Kapoor, 1977).

PANJAL VOLCANIC FORMATION

This Formation is referred as the Panjal Volcanic or Panjal Trap with an estimated maximum thickness of 2,500 m. So far no plant bearing horizon has been reported from this thick succession consisting mainly of basic rocks and a few intermediate and acidic rocks.

MAMAL FORMATION

The horizons with *Glossopteris* and other Gondwana elements overlying the Panjal Volcanic were classified by Kapoor (1977) into four floral beds namely Vihi, Marhoma, Munda and Mamal in ascending stratigraphic order. Lithostratigraphically all these plant bearing beds do not occur together but occupy the same stratigraphic level, i.e. between the underlying Panjal Volcanic and overlying Zewan Formation. Their biostratigraphic distinction as given by Kapoor (1979) is also not very convincing, therefore, here it is proposed to combine the four floral beds into one formational unit. Among the sections wherefrom the plant beds were reported and earlier classified into different floral beds, Munda represents a very condensed and thin section. Marhoma and Mamal show a thick succession and amongst these, the section at Mamal is very rich in plant fossils and as such we consider it as the type section which is here being designated as Mamal Formation.

The above view is more in the lines suggested by Ahmed, Chib and Singh (1978) where they have mentioned "..Kapoor (1975) and Kapoor and Shah (1979) consider that the bed with Gondwana fossils in the Pahalgam area is the youngest Gondwana plant horizon in the Kashmir Himalaya, but its stratigraphic position above the Panjal Trap and below the well defined *Protoretepora* and *Spirifer raja* horizons of marine Zewan Formation does not seem to warrant the conclusion. Instead it may be an equivalent of Gondwana beds of the Vihi and Marhoma area".

Lithologically Mamal Formation is represented by black and glassy tuffaceous shales which weather at the surface into light grey or ash colour. This formation is characterized by the presence of siliceous and sandy shale, cherty grey limestone, arenite at times gritty and calcareous, carbonaceous shale, purple or pinkish ash bed and novaculite. The latter generally lies at the base of the formation, though more than one band has been detected in some sections. There is some regional variation in lithology, i.e. all the sequences developed in the Kashmir Valley are characterized by novaculite, limestone and tuffaceous shale at the base of the sequence, whereas, in Pir Panjal area the presence of conglomerate suggests a slightly different depositional environment.

Stratigraphic Position of Nishatbagh and Mamal Formations (Permian) — As stated earlier the plant bearing horizons having Gondwana affinities have been variously named as Gangamopteris Bed, Lower Gondwana Bed and Permian Gondwana by different workers. Earlier the Permian beds in Kashmir Himalaya were treated as a single horizon; though their different stratigraphic positions were recognized by pioneers like Middlemiss (1910), Wadia (1928, 1934), Bion and Middlemiss (1928) and Hazra and Prasad (1957). Till recently they were thought to be restricted to the Intertrappean beds in the Panjal Volcanic, i.e. the Agglomeratic Slate and Panjal Volcanic, and the earlier workers considered them as homotaxial though occurring at different horizons within the Panjal Volcanics. But recently Nakazawa and Kapoor (1975), Kapoor (1977), Ahmad, Chib and Singh (1978) and Kapoor and Shah (1979) have opined that these Gondwana plant beds occur at two distinct stratigraphic levels, i.e. one below and the other above of the Panjal Volcanic. According to Kapoor (1979) the older horizon amongst these two plant bearing beds represents single Gondwana Bed which he designated as Nishatbagh Bed while the plant bearing horizon above the Panjal Volcanic exhibits four distinct floral beds designated as Vihi, Marhoma, Munda and Mamal in ascending order. Ahmed, Chib and Singh (1978), on the contrary, observed that from the stratigraphic position and structural set up the Permian Gondwana plant beds can be considered to occur only at two stratigraphic horizons — one at the base of the Panjal Traps and the other at the top of the Trap. According to them the four floral beds proposed by Kapoor (1979) are equivalent to each other and represent a single lithounit.

Thus lithostratigraphically the Permian plant bearing horizons below and above the Panjal Volcanic are well established in the regional geology of Kashmir. The one below the Panjal Volcanic is very well developed at Nishatbagh with its characteristic *Gangamopteris* dominated assemblage appropriately designated as Nishatbagh Formation. The one above the Panjal Volcanic, though termed variably by Kapoor (1979) as Vihi, Marhoma, Munda and Mamal beds, in fact lithostratigraphically represent only one formation occupying the same stratigraphic position and having close lithological as well as floral resemblance with each other. As such all these beds have been referred here together as Mamal Formation.

ZEWAN FORMATION

Conformably overlying the Mamal Formation is a thick fossiliferous marine sequence of Zewan Formation which consists of limestone, shale and calcareous sandstone of Upper Permian age. No plant bearing horizon is so far known from this formation.

Localities — The plant remains, described here, have been collected from the following localities:

Upper Devonian — (1) Kotsu Hill (Kanjdori) — 0.5 km NE of Kotsu Village (33°51′: 75°15′).
  (2) Diuth Spur — 0.5 km North of Diuth Village (33°51′: 75°19′).
Lower Carboniferous — (1) Kotsu Hill (Kanjdori) — 0.5 km NE of Kotsu Village (33°51′: 75°15′).
  (2) Wallarama Spur — 1 km NE of Wallarama Village (33°54′: 75°15′).
  (3) Manigam Spur — 1 km SE of Manigam Village (33°47′: 75°16′).
  (4) Gund — Jammu-Srinagar road section near Gund Village (33°29′: 75°11′).
Lower Permian — (1) Nishatbagh — Spur 1 km East of Nishatbagh Garden, (34°07′: 74°54′).
  (2) Marhoma — Spur 2 km NE of Marhoma Village (33°51′: 75°07′).
  (3) Mamal — Nala Section 0.5 km West of Mamal Village (33°01′: 75°18′).

DESCRIPTION

UPPER DEVONIAN FLORA

?*Taeniocrada* sp.

Pl. 1, fig. 1; Text-fig. 3A

Description — Stems branched or unbranched, 4-13 cm long and 0.2-0.8 cm broad, ribbon-shaped, surface rugose or showing irregular polygonal markings. Each stem having a distinct median ridge or groove perhaps representing vascular strand, ±1 mm wide.

Occurrence — Kotsu Hill (Kanjdari).

Remarks — In general appearance the specimens from Kotsu resemble some of the species of *Taeniocrada* White (1903), such as *T. dubia* Kräusel & Weyland (1930) and *T. langii* Stockmans (1939), etc. However, due to lack of details in the present specimens they have been for the present doubtfully referred to the genus *Taeniocrada*.

?*Protolepidodendron* sp.

Pl. 1, figs 2, 3; Text-fig. 3B

Description — Stem measuring 7.5 cm in length and 1.2 cm in width; leaf bases spirally arranged, more or less spindle-shaped, 7 mm long and 3 mm wide, apex broadly obtuse, gradually tapering towards base. Leaf scars inconspicuous.

Occurrence — Diuth Spur.

Remarks — The above description is based on a single fragmentary stem with badly preserved leaf bases. Leaf scars are rarely visible and seem to be oval in shape and are placed in vertical direction, occupying almost the central region of leaf bases. Because of ill-preservation the specimen has been provisionally placed under the genus *Protolepidodendron*.

LOWER CARBONIFEROUS FLORA

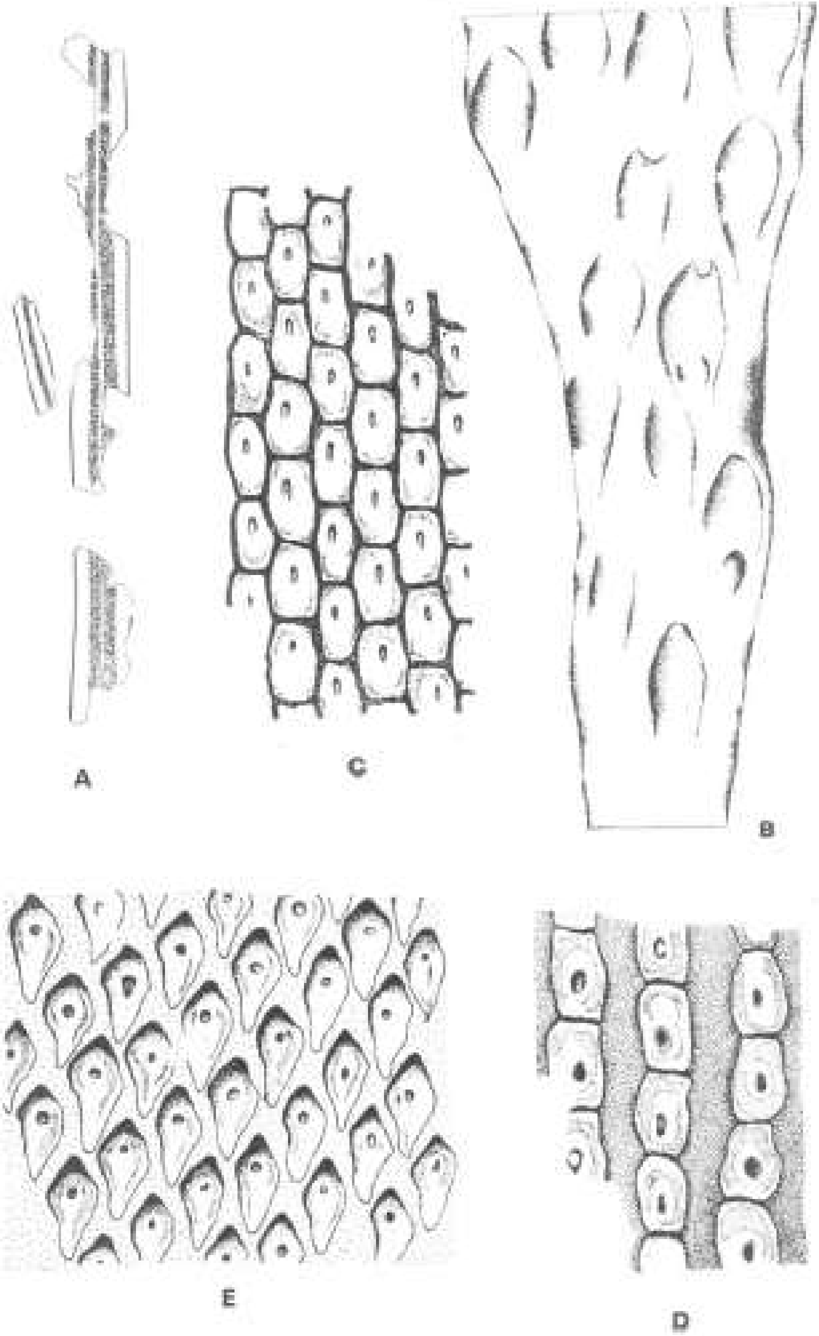
Archaeosigillaria minuta Lejal

Pl. 1, figs 4-6; Text-fig. 3C

Specimens from Kashmir:

1978 *Lepidodendropsis sigillarioides* Jongmans, Gothan & Darrah: Pal, p. 124, pl. 1, figs 2, 3; pl. 3, fig. 12.

1978 *Lepidodendropsis pranabii* Pal, p. 125, pl. 3, fig. 11.



TEXT-FIG. 3A-E — **A**, ?*Taeniocrada* sp., showing vascular strand, B.S.I.P. no. 36042/2771, from Kotsu, × 1. **B**, ?*Protolepidodendron* sp., showing spindle-shaped scars, B.S.I.P. no. 36044/2543, from Diuth Spur, × 2. **C**, *Archaeosigillaria minuta* Lejal, B.S.I.P. no. 36045/2544, from Wallarama, × 2. **D**, *Lepidosigillaria* cf. *quadrata* Danzé-Corsin, showing a few leaf scars, B.S.I.P. no. 36046/2516, from Wallarama, × 2. **E**, *Lepidodendropsis* cf. *peruviana* (Gothan) Jongmans, only a part of the specimen has been figured, B.S.I.P. No. 36048/2516, from Wallarama, × 2.

Description — Unbranched stem, measuring 3-15.5 cm in length and 1.8-3.5 cm in breadth, surface showing closely set, spirally arranged leaf cushions. Leaf cushions hexagonal in shape, sometimes oval (in ill preserved specimens), 3-8 mm long and 2-3 mm broad; lateral margins either straight or slightly curved. Leaf scars mostly placed closer to apical region of leaf cushion, vertically oval, 1-1.5 mm in length. Rarely near the centre of leaf-scar a small circular depression is visible, perhaps representing the vascular scar.

Occurrence — Manigam Spur, Wallarama Spur and Gund Village.

Remarks — *Archaeosigillaria minuta*, described here, resembles the specimens earlier figured by Lejal (1970) from the Lower Carboniferous of Sahara and the Upper Devonian of Libya by Lejal-Nicol (1975, pl. 2, fig. 10; text-fig. 15).

Lepidosigillaria cf. *quadrata* Danzé-Corsin

Pl. 1, figs 7-9; Text-fig. 3D

Specimens from Kashmir:

1978 *Lepidosigillaria quadrata* Danzé-Corsin: Pal, p. 123, pl. 2, fig. 5; pl. 3, fig. 10.

1978 *Lepidosigillaria* cf. *quadrata* Danzé-Corsin: Pal & Chaloner, p. 296, fig. 1C.

Description — Stems 2.5-12.2 cm long and 2.3-5 cm in diameter, surface covered with spirally arranged leaf cushions. Leaf cushions about 2-4 mm apart in transverse direction, intervening space more or less smooth or somewhat rugose, in vertical direction fairly closely set. Leaf cushions quadrangular in shape, lateral margins slightly convex, measuring 4-6 mm in length and 2-3 mm in breadth. Leaf scar lying closer to apical region of leaf cushions, vertically oval, measuring ±1 mm in length. Vascular scar and other details not visible.

Occurrence — Manigam Spur, Wallarama Spur and Gund Village.

Remarks — The specimens agree most with the specimens described by Lejal (1968, pl. 2, fig. 4; text-fig. 2) from the Lower Carboniferous of Sahara.

Lepidodendropsis cf. *peruviana* (Gothan) Jongmans

Pl. 2, figs 10, 11; Text-fig. 3E

Description — Stems 2-15 cm long and 2-4 cm wide, unbranched; surface showing leaf cushions arranged in steeply ascending spirals, separated from each other by a margin of about 2 mm in transverse direction, intervening region smooth. Leaf cushions vertically elongated, ±2 times longer than broad, measuring 4-6 mm in length and 2-3 mm in breadth, broadest region about 1/3 below apical end, apex broadly obtuse, base attenuate. Leaf scar oval, ±1 mm in diameter, placed closer to apical end of leaf cushion. Vascular scar not visible.

Occurrence — Manigam Spur, Wallarama Spur and Gund Village.

Remarks — The specimens from Kashmir are closest to the specimens described by Jongmans (1954, pl. 20, fig. 15) from the Lower Carboniferous of Peru.

Lepidodendropsis fenestrata Jongmans

Pl. 2, figs 12-15; Text-fig. 4A

Specimens from Kashmir:

1978 *Lepidodendropsis fenestrata* Jongmans & Koopmans: Pal, p. 123, pl. 2, figs 6, 7.

Description — Stems covered with leaf cushions which are arranged in steeply ascending spirals, in broader stems leaf cushions distantly placed, whereas in narrower stems they are closely set, 7-23 cm

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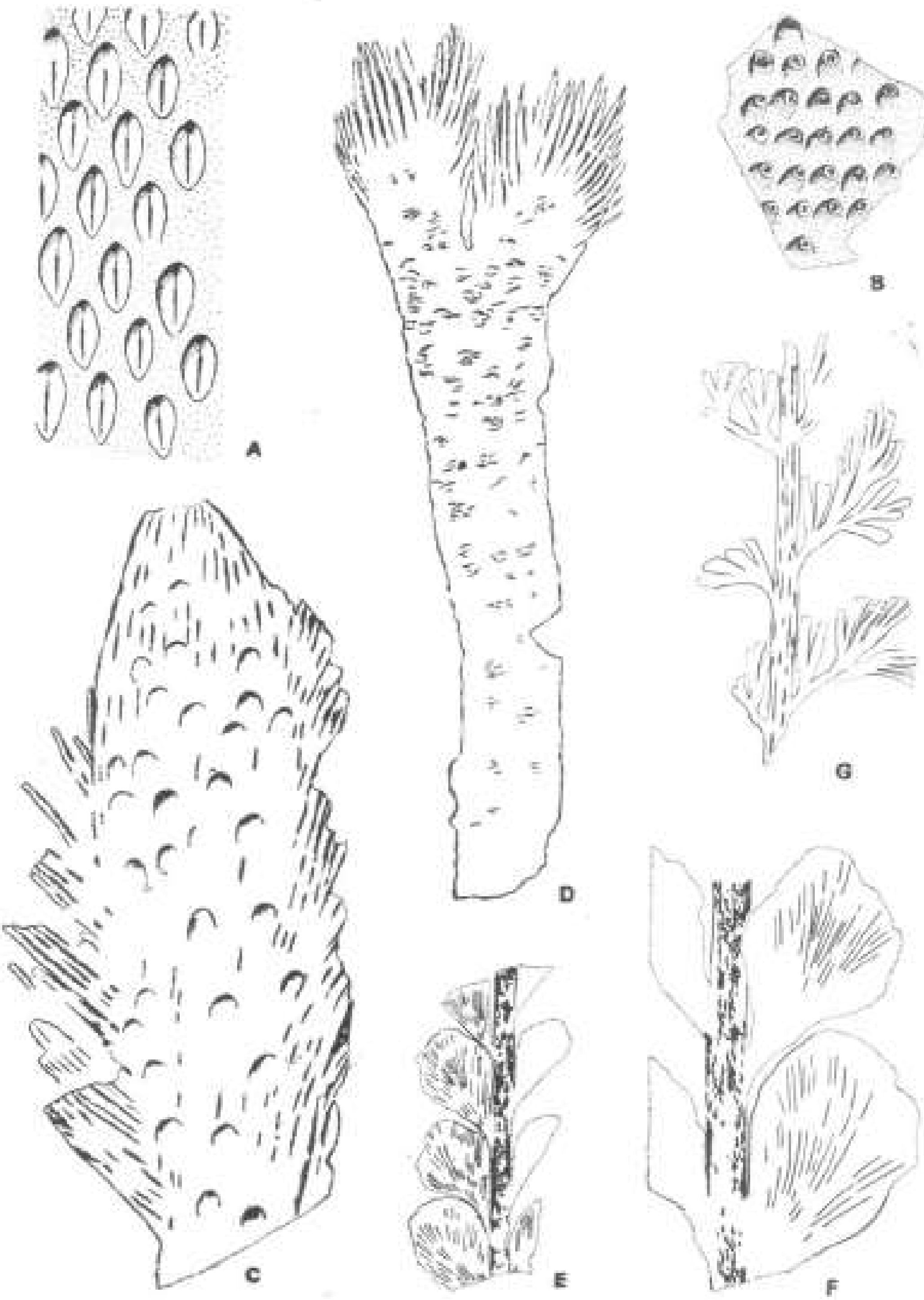
TEXT-FIG. 4A-G — **A**, *Lepidodendropsis fenestrata* Jongmans, showing part of a specimen, B.S.I.P. no. 36051/2544, from Wallarama, × 2. **B**, *Cyclostigma* cf. *pacifica* (Steinmann) Jongmans, B.S.I.P. no. 36052/2515, from Manigam, × 2. **C**, Cone-like structure, B.S.I.P. no. 36054/2515, from Manigam, × 2. **D**, showing a branched stem, B.S.I.P. no. 36055/2519, from Gund, × 1. **E**, **F**, *Rhacopteris ovata* (McCoy) Walkom, B.S.I.P. nos. 36057/2515 and 36058/2515, from Manigam; E, × 1; F, × 2. **G**, *Triphyllopteris lescuriana* (Meek) Jongmans, showing part of a specimen, B.S.I.P. no. 36091/2516, from Wallarama, × 2.



TEXT-FIG. 4A-G.

long and 2-6 cm broad. Leaf cushions elliptical, ±3 times longer than broad; in narrower stems cushions about 3 mm long and 1 mm wide, whereas, in broader stems 10 mm long and 3 mm wide; apex rounded, base attenuated. Leaf scars oval, elongated in vertical direction, about 3-5 mm long and less than 1 mm in width.

Occurrence — Kotsu Village, Manigam and Wallarama spurs.

Remarks — The specimens from Kashmir agree with most of the specimens figured by Jongmans in Jongmans and Heide (1955, pl. 7, figs 1a, 2a-d; pl. 8, fig. 3a-f, pl. 9, fig. 4a,b) from the Lower Carboniferous of Egypt.

Cyclostigma cf. *pacifica* (Steinmann) Jongmans

Pl. 2, fig. 16; Pl. 3, fig. 17; Text-fig. 4B

Specimens from Kashmir:

1978 *Cyclostigma indica* Pal, p. 128, pl. 4, figs 14, 15.

Description — Stems measuring 4.5-18 cm in length and 1.5-3.5 cm in breadth, surface showing leaf cushions arranged in steeply ascending spirals; intervening space variable. Leaf cushions mammiliform or rhomboidal, 2-6 mm long and 1-4 mm broad; apex broadly oval; base slightly tapering. Leaf scars circular, 1.2 mm in diameter, placed closer to apical end of leaf cushion.

Leaves minute, keeled, triangular in shape, about 3 mm long and 2 mm broad at base, apical end pointing outward or curving upwards; apex aristate.

Occurrence — Manigam Spur, Wallarama Spur and Gund Village.

Remarks — The collection includes about 40 specimens. Out of these, one specimen at places, shows leaves on its lateral sides. The specimens are comparable with some of the specimens described earlier by Jongmans (1954, pl. 17, figs 5-7; pl. 18, figs 8-10; pl. 19, figs 11-13; pl. 20, fig. $14b_2$, b_4) as *C. pacifica*.

LYCOPHYTA-INCERTAE SEDIS

Casts of Stems (*Pl. 4, fig. 23*) — Several specimens preserved in the form of casts have been collected from Wallarama Spur in the position of growth, i.e. in erect condition. Unfortunately, all of them have badly preserved leaf cushions and as such their generic identification is difficult.

Stem casts measuring 10-21 cm in length and 9-10 cm in diameter. Leaf cushions arranged in ascending spirals, mostly their outline is not well-marked, at places seem to be hexagonal or rhomboidal, 1.2-1.5 cm long and 0.8-1.0 cm wide. Leaf scar and other details not available.

Occurrence — Wallarama Spur.

Cone-like structure (*Pl. 3, figs 18, 19; Text-fig. 4C*) — Solitary stem terminating in a cone-like structure. Specimen as a whole measuring 5.2 cm in length and 2.2 cm in breadth. Stem surface covered by spirally arranged leaves. Leaves linear, 1-1.5 cm long and 0.2 cm broad; apex acute. (?) Cone ovoid, 2.2 cm long and 1.3 cm broad, ?bracts/sporophylls similar to the leaves covering the main stem.

Occurrence — Manigam Spur.

Remarks — The cone is too ill-preserved to be assigned to a definite genus or species.

Branched Stem (*Text-fig. 4D*) — The description is based on a single specimen preserved as impression. The main stem is about 9 cm in length and 2.1 cm in width at its broadest region. The leaf-bases are imperfectly preserved and their details are not visible. The stem at its apical end is dichotomously branched and each branch is covered with spirally arranged leaves. Leaves are linear, about 2-2.5 cm long and 1-1.5 cm broad.

Occurrence — Gund Village.

Rhacopteris ovata (McCoy) Walkom

Pl. 3, figs 20, 21; Text-fig. 4E, F

Indian specimens:

1937 *Rhacopteris ovata* (McCoy) Walkom-*Rh. inaequilatera* Feistmantel (*non* Goeppert): Gothan & Sahni, p. 196, pl. 16, figs 1, 2.

1937 *Rhacopteris ovata* (McCoy)Walkom: Gothan & Sahni, p. 198, pl. 1, figs 1-4.

1955 *Rhacopteris ovata* (McCoy)Walkom: Høeg, Bose & Shukla, p. 11, pl. 1, fig. 2.

1955 *Rhacopteris inaequilatera* Goepp. sp.: Høeg, Bose & Shukla, p. 11, pl. 1, fig. 3.

1955 *Rhacopteris ovata* (McCoy)Walkom: Høeg, Bose & Shukla, p. 11.
1955 *Rhacopteris* cf. *circularis* Walton: Høeg, Bose & Shukla, p. 11, pl. 2, figs 13-15.
1955 *Rhacopteris inaequilatera* Goepp. sp.: Høeg, Bose & Shukla, p. 12, pl. 2, figs 16, 17.
1974 *Rhacopteris* cf. *circularis* Walton: Maithy (review paper), p. 48.
1974 *Rhacopteris ovata* (McCoy)Walkom: Maithy (review paper), p. 48.
1974 *Rhacopteris inaequilatera* Goeppert: Maithy (review paper), p. 48.
1978 *Rhacopteris* cf. *circularis* Walton: Pal, p. 129, pl. 2, fig. 8.
1979 *Rhacopteris* cf. *circularis* Walton: Pal & Chaloner, p. 296, fig. 1d, e.

Description (*for description assumed to be bipinnate*) — Detached pinnae, measuring 5-10 cm in length and 2-3 cm in breadth; rachis straight, 2-3 mm wide. Pinnules alternate, closely set, sometimes apical part of pinnule (lying below) touching base of pinnule lying immediately above, attached at an angle of about 40°-48°. Pinnule 1.2-2.5 cm long and 0.8-1.4 cm wide, obovate; apex broadly rounded; base tapering below; lateral margins more or less straight, apical margin crenulate. Veins spreading from base, mostly forking once or twice; except a few veins along median region majority slightly curved downwards.

Occurrence — Manigam Spur and Gund Village.

Remarks — The new specimens agree with the earlier specimens figured by Gothan and Sahni (1937) and Høeg, Bose and Shukla (1955).

Triphyllopteris lescuriana (Meek) Jongmans

Pl. 3, fig. 22; Text-figs 4G, 5A

Indian specimens:

1937 *Sphenopteridium ?furcillatum* Ludwig sp.: Gothan & Sahni, p. 197, pl. 18, figs 1, 2.

Doubtful specimen:

1955 *Sphenopteridium* sp. b: Høeg, Bose & Shukla, p. 11 (*partim*), pl. 1, fig. 8.

Description — Fronds bipinnate, 7.5-12 cm long and 3.2-6.5 cm broad; main rachis 2-3 mm wide, surface faintly striated in longitudinal direction. Pinnae alternately arranged, attached at an angle of 30°-50°, shape as a whole lanceolate, measuring 3.5-5 cm in length and 0.8-1.5 cm in breadth. Pinnules dissected into lobes, 0.8-1.5 cm long and 0.5-0.8 cm broad, lobes of unequal size and shape, basal part constricted to form a petiole; veins mostly not discernible; 1-3 veins entering from base of each lobe radiating from base, simple or forked.

Occurrence — Manigam and Wallarama spurs.

Remarks — The present specimens match with the specimens earlier figured by Jongmans (1954, p. 26, figs 43-45) from the Lower Carboniferous of Peru.

Rhodea cf. *subpetiolata* (H. Potonié) Gothan

Pl. 5, figs 26, 27; Text-figs. 5D, 6

Indian specimens:

1937 *Sphenopteris* sp. (*Rhodea* sp.): Gothan & Sahni, p. 198, pl. 18, fig. 3.
1955 *Rhodea* sp.: Høeg, Bose & Shukla, p. 10, pl. 1, fig. 1.
1974 *Rhodea* sp.: Maithy (review paper), p. 49.
1978 *Rhodea tenuis* Gothan: Pal, p. 130, pl. 4, fig. 16.

Description — Fronds fragmentary, overall shape and size not known; main rachis 1-2 mm wide. Pinnules alternately arranged irregularly dissected into linear segments, penultimate segments uni- or bifid; apex broadly obtuse. Each segment showing a median vein.

Occurrence — Manigam and Wallarama spurs.

Remarks — The present specimens are comparable with the specimens described by Gothan (1929, pl. 1, figs 2, 3; pl. 6, fig. 4).

Palmatopteris cf. *furcata* Potonié

Pl. 4, fig. 24; Pl. 5, fig. 25; Text-fig. 5B, C

Description — Fronds tripinnate, exceeding 30 cm in length. Primary rachis 0.8-1.4 cm in breadth, longitudinally striated. Secondary rachis arising at an angle of about 40°-55°, alternate, 0.3-0.6 cm broad, surface finely striated in longitudinal direction. Pinnules alternately arranged, 1.5-2.5 cm long, lamina repeatedly dichotomously

TEXT-FIG. 5A-D.

TEXT-FIG. 6 — *Rhodea* cf. *subpetiolata* (H. Potonié) Gothan, B.S.I.P. no. 36061/2544, from Wallarama, × 1.

dissected into fine segments, apices of penultimate segments rounded. At places midvein faintly visible.

Occurrence — Kotsu Hill.

Remarks — The specimens from Kotsu Hill resemble most the specimens of *Palma-*

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TEXT-FIG. 5A-D — A, *Triphyllopteris lescuriana* (Meek) Jongmans, B.S.I.P. no. 36059/2544, from Wallarama, × 4. B, C, *Palmatopteris* cf. *furcata* Potonié, B.S.I.P. nos. 36063/2518 and 36062/2518, from Kotsu; B, × 1; C, × 1/2. D, *Rhodea* cf. *subpetiolata* (H. Potonié) Gothan, B.S.I.P. no. 36090/2544, from Wallarama, × 1.

topteris furcata described by Gothan (1931, pl. 26, fig. 2; pl. 27, fig. 1; text-fig. 4) from Westphalian B of Germany. They may also be compared with *Dactylophyllum digitatum* described by Morris (1973, pl. 1, fig. d) from New South Wales, Australia. However, our specimens of *Palmatopteris* cf. *furcata* do not show such variations of pinnules as seen in *D. digitatum*.

LOWER PERMIAN FLORA

NISHATBAGH FORMATION

Gangamopteris kashmirensis Seward

Pl. 5, figs 28-30; Text-fig. 7G

1905 *Gangamopteris kashmirensis* Seward: in Seward & Woodward, p. 3, pl. 8, figs 1-6; pl. 9, figs 1, 2.
1907 *Gangamopteris kashmirensis* Seward, p. 58, pl. 13, figs 1, 2.
1957 *Gangamopteris kashmirensis* Seward: Hazra & Prasad, p. 498, pl. 10, fig. 5.
1963 *Gangamopteris kashmirensis* Seward: Verma, p. 276.
1974 *Gangamopteris kashmirensis* Seward: Chandra (review paper), p. 131.
1977 *Gangamopteris kashmirensis* Seward: Kapoor, pp. 445, 446.

The specimens figured here were collected from Nishatbagh Spur and they exactly match with the specimens of *G. kashmirensis* earlier described by Seward (1905, 1907) from Vihi Valley and Resin Spur.

Occurrence — Banihal Pass, Tata Kuti, Apharwat, Vihi Valley (type locality), Resin and Nishatbagh spurs.

Glossopteris longicaulis Feistmantel

Pl. 5, figs 31, 32; Text-fig. 7F

Description — The collection includes a solitary specimen whose lamina is incomplete on one side of midrib and also its base and apex are missing. In venation pattern the specimen resembles the specimens of *Glossopteris longicaulis* earlier described by Feistmantel (1879-81, pl. 31, figs 1, 3), Maithy (1965, pl. 4, fig. 29), Pant and Gupta (1968, pl. 26, figs 45, 46), Banerjee (1978, pl. 7, fig. 13) and Chandra and Surange (1979, pl. 1, fig. 4; pl. 15, fig. 13).

Occurrence — Nishatbagh Spur.

Glossopteris nishathaghensis sp. nov.

Pl. 6, figs 34-37; Text-fig. 7E

Diagnosis — Leaf linear, measuring 8-14 cm in length and 0.8-1.2 cm in width at its broadest region, sometimes tortuous, apex sub-acute or obtuse; base attenuate; margins entire. Midrib distinct, persistent up to apex, ±1 mm wide. Lateral veins arising at an angle of 10°-15°, slightly away from the point of emergence bending upwards and running straight to margin so as to form an angle of 30° with margin, concentration of veins 18-22 per cm, forming short, narrow and polygonal meshes. Meshes near midrib longer than those near margins.

Holotype — No. 36067/2542 of Birbal Sahni Institute of Palaeobotany, Lucknow.

Occurrence — Nishatbagh Spur.

Comparison — In over all shape *Glossopteris nishathaghensis* resembles most some of the specimens of *G. gondwanensis* Pant & Gupta (1971, pl. 16, fig. 2; also see Chandra & Surange, 1979, pl. 23, fig. 4). In the latter, however, the apex is acute, also the vein meshes are shorter and broader than *G. nishathaghensis*. In external form *G. wilkinsonii* Feistmantel described by Banerjee (1978, pl. 10, fig. 28) and *G. taenioides* Feistmantel figured by Chandra and Surange (1979, pl. 4, fig. 6) may be compared with *G. nishathaghensis*. However, in the former two species secondary

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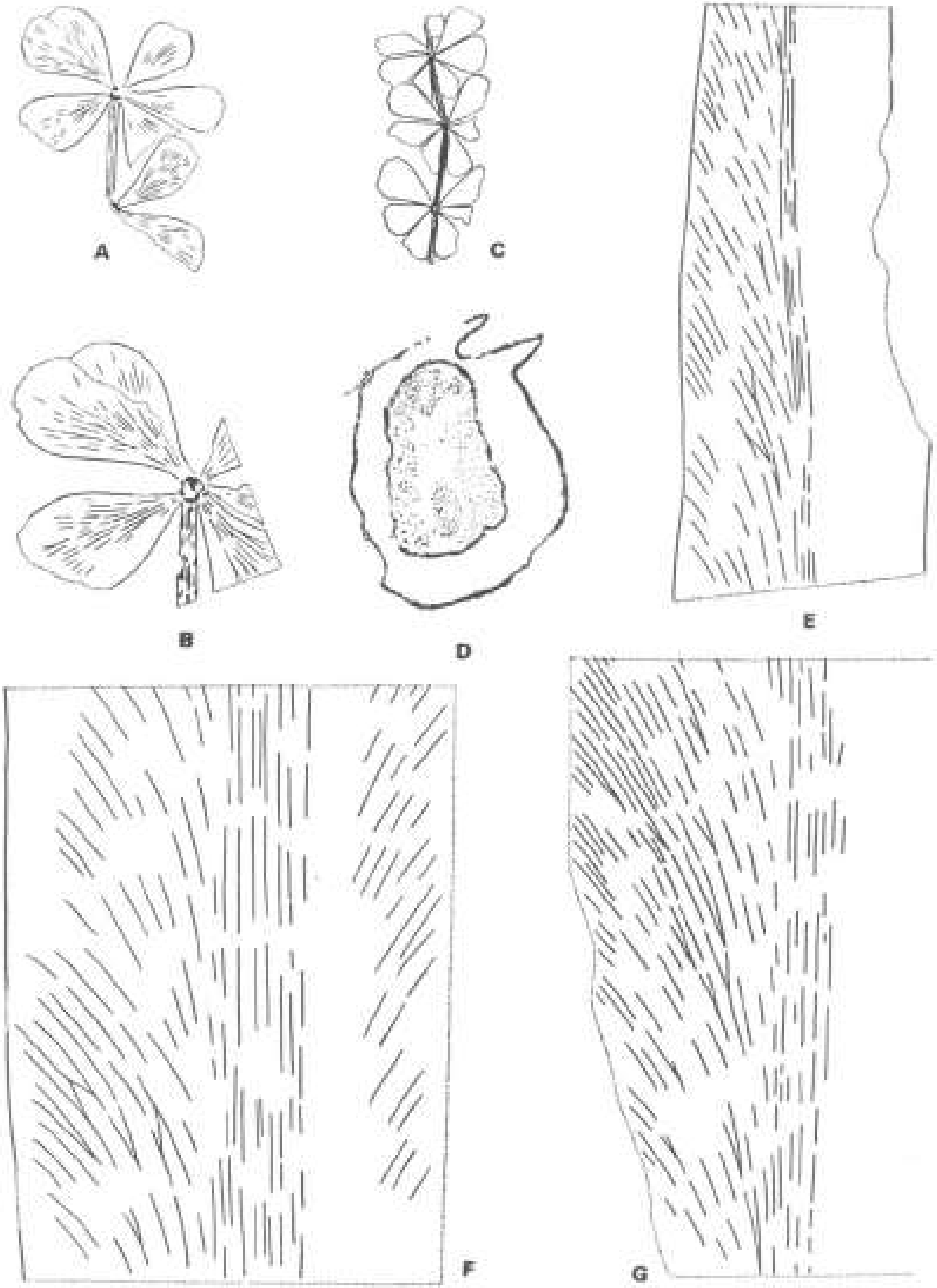
TEXT-FIG. 7A-G — A, B, *Parasphenophyllum thonii* var. *minor* (Sterzel) Asama, B.S.I.P. no. 36069/2538, from Mamal; A, × 1; B, details from A, × 2. C, *Trizygia speciosa* Royle, B.S.I.P. no. 36071/2538, from Mamal, × 2. D, ?*Nummulospermum* sp., B.S.I.P. no. 36068/2542, from Nishatbagh Spur, × 8. E, *Glossopteris nishathaghensis* sp. nov., a portion from the holotype showing veins; B.S.I.P. no. 36066/2542, from Nishatbagh Spur, × 4. F, *Glossopteris longicaulis* Feistmantel, part of a specimen showing veins, B.S.I.P. no. 36066/2542, from Nishatbagh Spur, × 4. G, *Gangamopteris kashmirensis* Seward, part of a specimen showing veins, B.S.I.P. no. 36064/2542, from Nishatbagh Spur, × 4.



TEXT-FIG. 7A-G.

veins arise at an angle of 70°-90°. *G. senii* Srivastava (1969) is much narrower and smaller in size than *G. nishatbaghensis*. In the former secondary veins arise at an angle of 60°-80°.

?*Nummulospermum* sp.

Pl. 5, fig. 33; Text-fig. 7D

Description — Platyspermic seed, 5 × 4 mm, broadly oval in shape; central body surrounded by a wing; micropylar end showing a pair of minute beak-like projections.

Occurrence — Nishatbagh Spur.

Remarks — ?*Nummulospermum* sp. resembles *N. bowense*, described by Walkom (1921) and Maithy (1965) in overall shape, however, it differs from the latter species in being much smaller in size.

MAMAL FORMATION

Parasphenophyllum thonii var. *minor* (Sterzel) Asama

Pl. 6, figs 38-40; Text-fig. 7A, B

Description — Specimens incomplete, showing one or two whorls of leaves. Stem articulate, showing a median groove or ridge, ±1 mm wide. Internodes about 1.5 cm long, each whorl having six leaves of almost similar size and shape. Leaves measuring 1-1.5 cm in length and 0.6-1.2 cm in breadth at its broadest region, obovate, apex obtuse, base cuneate, margin entire; 1-3 veins emerging from base, after emergence repeatedly dichotomising, only 2-3 veins running straight along median portion of lamina remaining arching outwards, concentration of veins 18-20 per cm.

Occurrence — Mamal.

Remarks — Unlike *Sphenophyllum* Brongniart (1828), which has straight veins, the present specimens have leaves with arched veins. As such they have been referred to *Parasphenophyllum* Asama (1970). The specimens resemble the earlier described specimens of *P. thonii* var. *minor* (Sterzel) Asama (1970) from the Permian of China, Korea, Maiya and Japan.

Trizygia speciosa Royle

Pl. 6, figs 41, 42; Text-fig. 7C

Description — Fragmentary specimens measuring 2-3.8 cm in length and 0.7-1.2 cm in breadth. Stems less than 1 mm in width, articulate with swollen nodes; internodes 4-7 mm in length, showing a median ridge. Each node consisting of a whorl of six leaves arranged in trizygoid manner, two pairs of lateral leaves (in fossilized condition) larger in size than the remaining two leaves (pointing towards base of specimen). Lateral leaves 4-8 mm long and 3-5 mm broad, the remaining two measuring 3-5 mm in length and 1.5-3 mm in breadth. Over all shape of leaves obovate, margins entire. Leaf apex broadly obtuse, base cuneate; veins obscure, seems to be straight.

Occurrence — Mamal.

Remarks — The Mamal specimens agree with those described from the Lower Gondwana beds of peninsular India by Maheshwari (1968) and Maithy (1978). They also resemble the specimens reported by Asama (1970) from the Permian of China and Korea.

Lobatannularia ensifolia Halle

Pl. 7, figs 43-46; Text-fig. 8C, D

Specimens from Kashmir:

1977 *Kashmiropteris meyenii* Kapoor, p. 446, pl. 169, figs 1, 2.

1977 *Kawizophyllum dunpathriensis* Kapoor, p. 446, pl. 170, fig. 2.

Several specimens have been collected from Mamal. Out of these, except one, the rest are either detached leaves or portions from a leaf whorl. The description is based on the specimen figured in Pl. 7, figs 43, 44.

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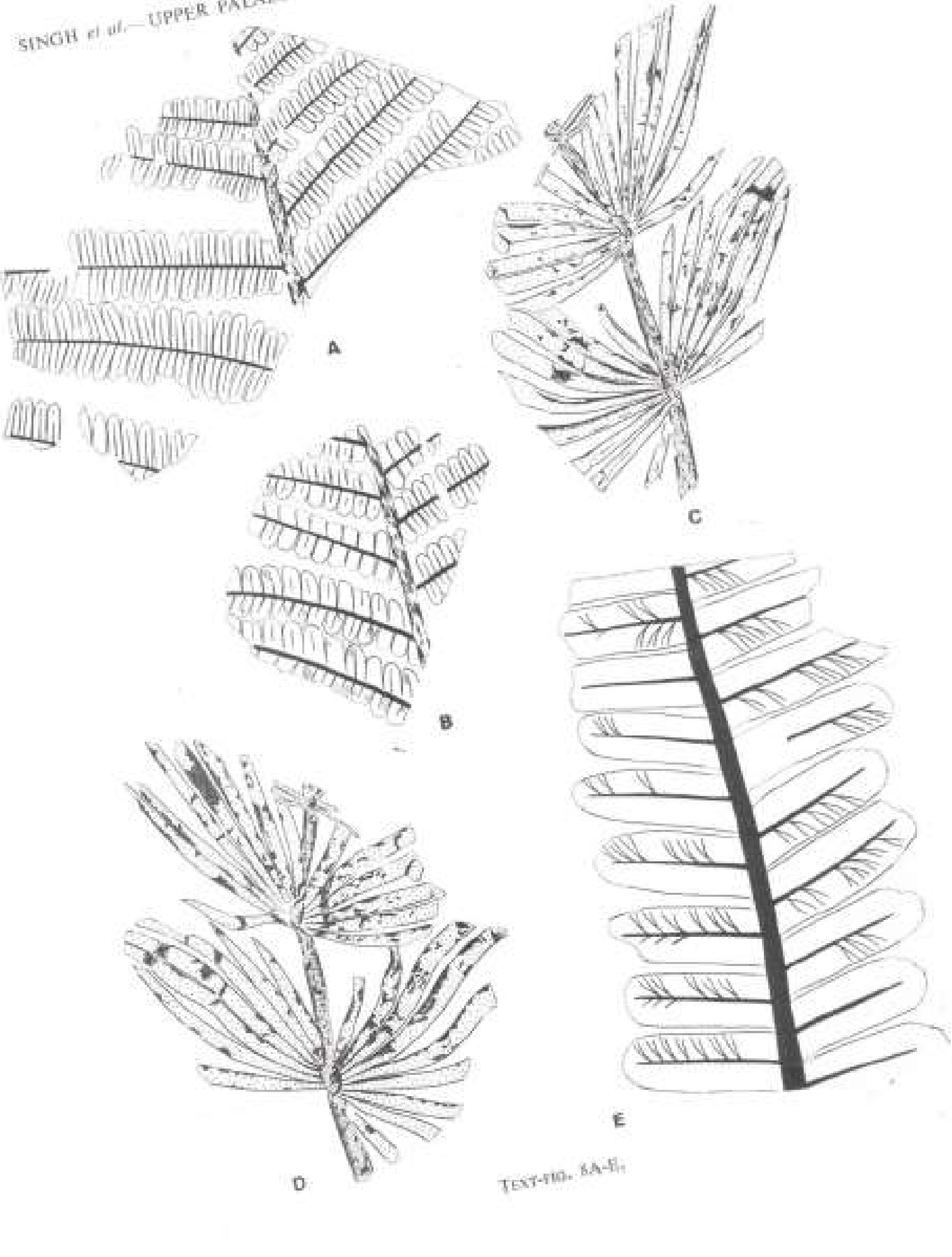
TEXT-FIG. 8A-E — **A, B,** *Rajahia mamalensis* sp. nov., B.S.I.P. nos. 36077/2538 and 36078/2538, from Mamal, × 1. **C, D,** *Lobatannularia ensifolia* Halle, showing part and counterpart, B.S.I.P. nos. 36073/2538 and 36072/2538, from Mamal, × 1. **E,** *Rajahia mamalensis* sp. nov., details from A, × 4.



TEXT-FIG. 8A-E.

Description — The largest specimen, having part and counterpart, measures 6.5 cm in length and 6 cm in breadth. Stem articulate, showing a median ridge, measuring 3 mm in breadth near basal end and 2 mm near apical end; internodes 2-3 cm long, each node with a whorl of leaves, which are divided into two groups on either side of node, each side comprising 6-9 leaves. Leaves linear with acute apex, measuring 1.5-4 cm in length and ± 0.2 cm in breadth; each leaf with a median vein; transverse thickenings absent.

Occurrence — Mamal.

Remarks — The present specimens match exactly with the specimens of *Lobatannularia ensifolia* figured by Halle (1927, pl. 11, figs 5, 6) and Boureau (1964, fig. 170).

Raniganjia qubensis Hsü (1976) from the Permian of Southern Xizang is also similar to our specimens of *L. ensifolia* and we think that they should also be referred to *Lobatannularia*. In our opinion *Kashmiropteris meyenii* Kapoor (1977) is only an apical portion of *Lobatannularia ensifolia* whereas, *Kawizophyllum dumpathriensis* Kapoor (1977) is a detached leaf of the same species.

Rajahia mamalensis sp. nov.

Pl. 7, figs 47-50; Text-fig. 8A, B, E

Diagnosis — Leaves bipinnate, sterile, estimated length and breadth more than 12 cm and 10 cm respectively, substance of lamina thick. Principal rachis straight or slightly curved near apex, 1-3 mm wide, surface showing hexagonal patterns or faint striations in longitudinal direction. Pinnae alternate, attached at an angle of 50°-80°, exceeding 5 cm in length, 0.4-1.5 cm in breadth; surface showing discontinuous, fine longitudinal striations or hexagonal patterns. Pinnules alternate, attached at an angle of 75°-90°, first pinnule arising on basiscopic side (katadromic), closely set, rarely touching each other. Pinnules somewhat oval in shape, 2-7.5 mm long and 1.5-2.5 mm broad (rarely 3 mm); margins entire; apex obtuse; acroscopic margin straight or slightly decurrent. Midrib prominent, towards apex occasionally forking and becoming fainter; lateral veins katadromic, forking once or twice (mostly once), sometimes twice (out of the first two branches only the distal forking once), emerging at an angle of 70°-85°, (rarely 90°), slightly arching.

Holotype — No. 36077/2538 of Birbal Sahni Institute of Palaeobotany, Lucknow.

Occurrence — Mamal.

Remarks — *Pecopteris* sp. figured by Kapoor (1977, pl. 170, fig. 1) resembles our specimens of *Rajahia mamalensis*. From the photograph it is not clear whether the specimen is sterile or fertile. Unfortunately none of the specimens of *Pecopteris* sp. of Kapoor (1977) were available to us, so we have not been able to include Kapoor's specimens under the synonymy of *R. mamalensis*. As our all specimens are sterile so in the diagnosis we have only included the description of sterile specimens.

Comparison — *Rajahia mamalensis* resembles, in gross features, *R. bifurcata* Koñno, *R. lingghuensis* Koñno, *R. pseudohemitelioides* Koñno, *R. rajahii* Koñno and *R. sengensis* Koñno described by Koñno in Koñno, Asama and Rajah, (1970), however, it can be readily distinguished from all of them by its venation pattern. Unlike the Chinese specimens *R. mamalensis* has twice forked veins.

R. mamalensis also resembles *Dizeugotheca qubensis* Hsü (1976, pl. 2, figs 8-12) in general shape of pinnules, however, in the latter species the lateral veins in the pinnules are unforked.

Glossopteris intermittens Feistmantel

Pl. 8, figs 52-54; Text-fig. 9

This is the first record of *Glossopteris intermittens* from Kashmir. All the specimens look similar to the ones earlier described by Feistmantel (1881), Banerjee (1978, pl. 7, fig. 12) and Chandra and Surange (1979, pl. 3, fig. 5; pl. 17, fig. 9).

Occurrence — Mamal.

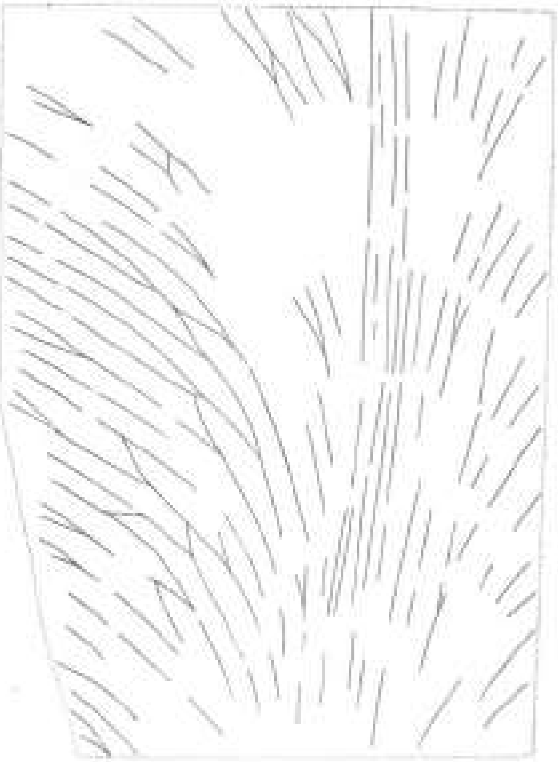
Glossopteris cf. *communis* Feistmantel

Pl. 8, fig. 51; Text-fig. 10

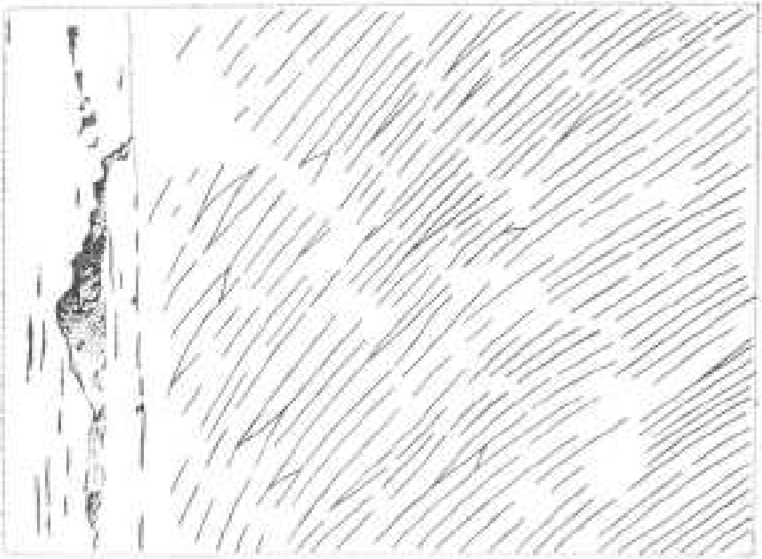
Specimens from Kashmir:

1957 *Glossopteris communis* Feistmantel: Hazra & Prasad, p. 502.

1977 *Glossopteris communis* Feistmantel: Kapoor, p. 446.



TEXT-FIG. 9 — *Glossopteris intermittens* Feistmantel, part of a specimen enlarged to show veins, B.S.I.P. no. 36081/2538, from Mamal, × 4.



TEXT-FIG. 10 — *Glossopteris* cf. *communis* Feistmantel, part of a specimen enlarged, B.S.I.P. no. 36080/2538, from Mamal, × 4.

Description — Leaves incomplete at base and apex, largest specimen 13.5 cm long and 9 cm broad, margin entire. Midrib distinct, 3-5 mm broad, showing a median groove or a ridge; lateral veins arising at an angle of 40°-45°, after emergence running forward for about 1-2 mm distance and then arching upwards, near midrib veins concentration 18 per cm and towards margin 24 per cm. Meshes narrow elongate along major part of lamina, closer to margin much narrower.

Occurrence — Mamal.

Remarks — *Glossopteris communis* Feistmantel (1876) has three lectotypes. The first (G.S.I. No. 5088) was selected by Pant and Gupta (1968) out of the specimens described by Feistmantel (1879-81, pl. 31, fig. 5) from Karharbari. This specimen is preserved in the form of incrustation and its cuticle was studied by Pant and Gupta (1968). The second (G.S.I. No. 5283) was selected by Banerjee (1978) out of Feistmantel's (1881, pl. 36A, fig. 2) specimens from Raniganj Stage. The third (G.S.I. No. 5022) was selected by Chandra and Surange (1979) out of the original collection of Feistmantel (1879-81, pl. 17, fig. 2) from Karharbari. Pant and Gupta (1968) have not mentioned any reason for selecting a lectotype for *G. communis*; nor have Banerjee (1978) and Chandra and Surange (1979) given reasons for rejecting Pant and Gupta's (1968) lectotype of *G. communis* and instituting their own. Also none of these authors have taken into consideration the original figured specimen of Feistmantel (1876, pl. 21, fig. 5).

Without adding to this confusion we have compared our specimens with some of the original specimens of *G. communis* Feistmantel (1879-81, pl. 17, figs 1, 2; pl. 31, fig. 5) and have found them to be somewhat similar. Only difference is that the angle of emergence of lateral veins in Feistmantel's (1879-81) specimen is slightly less than the specimens from Mamal. The present specimens also resemble the specimen of *G. communis* figured by Hsü (1976, pl. 4, fig. 23).

Glossopteris cf. *feistmantelii* Rigby

Pl. 9, fig. 57; Text-fig. 11

Description — Leaf size and shape unknown, largest available leaf measuring 10.5 cm in length and 4 cm in breadth; margin entire. Midrib 2-4 mm wide, showing a distinct median groove or ridge. Lateral veins emerging at an angle of 45°-50° (angle of divergence less towards apex), slightly away from the point of emergence arching upwards and then running straight up to margin, concentration of veins 8-10 per cm near midrib and 12-14 per cm near margin; meshes elongate and broad near midrib; slightly narrower and longer along major part of lamina; smaller and narrower towards margins.

Occurrence — Mamal.

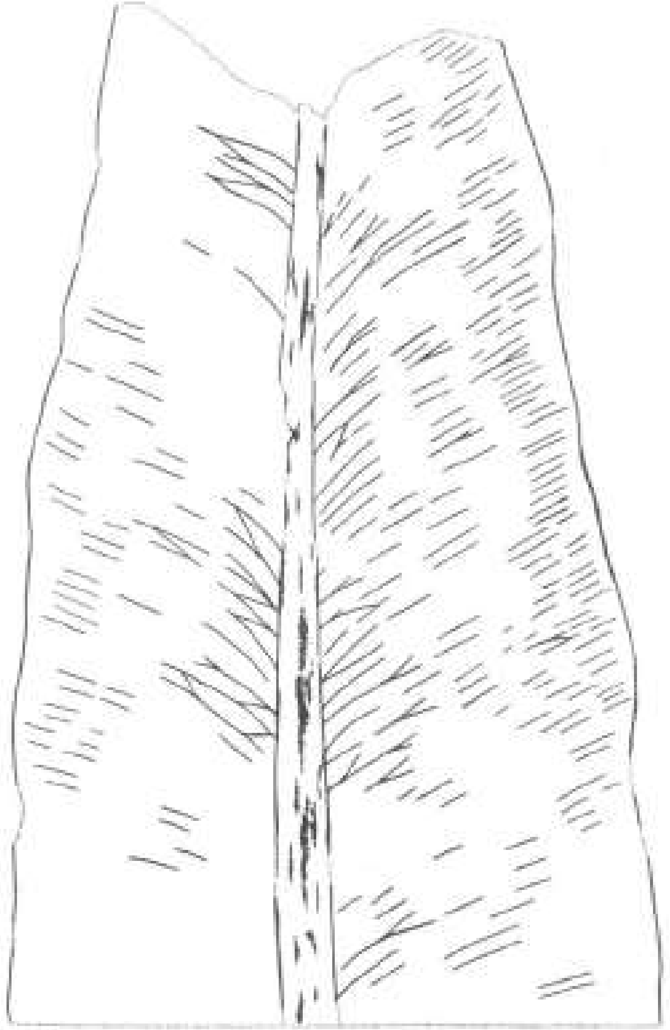
Remarks — Chandra and Surange (1979) while describing *Glossopteris feistmantelii* Rigby, kept the following specimens under its synonomy:

1882 *Glossopteris cordata* Feistmantel, *Mem. geol. Surv. India*, 4, p. 34, pl. XX, fig. 1.
1964 *Glossopteris feistmantelii* Rigby, *Proc. Linn. Soc. N.S.W.*, 89(1), p. 154.
1977 *Glossopteris fuchsii*, Srivastava, A. K., *Palaeobotanist*, 23 (3), pp. 21, 22, pl. 2, fig. 10.

However, they have figured some of these specimens as follows:

Plate 2, fig. 3 — *Glossopteris cordata* Feistmantel (= *Glossopteris fuchsii* of Srivastava, A. K.) specimen no. 37/1992, B.S.I.P.
Plate 5, fig. 3 — *Glossopteris feismantelii* Rigby, specimen no. 5478, G.S.I.
Plate 10, fig. 3 — *Glossopteris feistmantelii* Rigby (= *Glossopteris browniana* of Feistmantel), specimen no. 5252, G.S.I.
Plate 16, fig. 10 — *Glossopteris feistmantelii* Rigby (= *Glossopteris fuchsii* of *Srivastava*, A. K.), specimen no. 37/1392, B.S.I.P.

Out of the above specimens Chandra and Surange (1979, pl. 38, fig. 2) gave a restoration of *Glossopteris feistmantelii* Rigby based on the specimen figured by Feistmantel (1882, pl. 20, fig. 1). In their restoration of *G. feistmantelii*, they have shown the leaf base as cordate although in the actual specimen the base is missing. In none of our specimens the base is preserved, however, the specimens in gross



TEXT-FIG. 11 — *Glossopteris* cf. *feistmantelii* Rigby, B.S.I.P. no. 36087/2538, from Mamal, × 2.

features and venation pattern resemble most the specimen of *G. cordata* Feistmantel (= *G. fuchsii* of Srivastava, A. K.) figured by Chandra and Surange (1979, pl. 2, fig. 3).

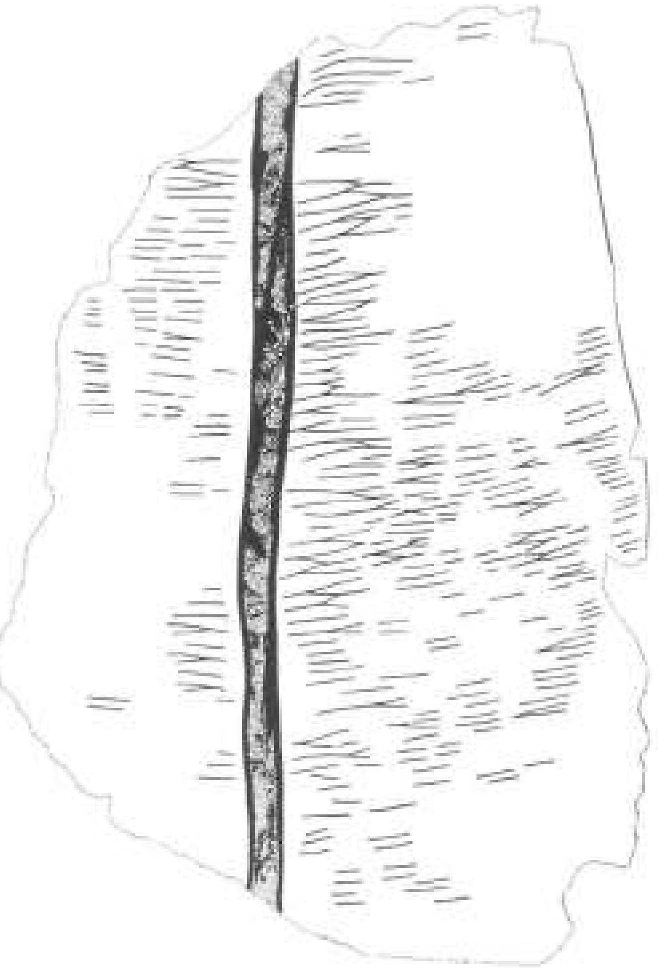
Glossopteris cf. *taeniopteroides* Feistmantel

Pl. 8, fig. 55; Pl. 9, fig. 56; Text-fig. 12

Description — Fragmentary leaves without base and apex, largest specimen measuring 8.5 cm in length and 4.4 cm in breadth; margins entire. Midrib persistent along entire length, 2 mm wide (near apex 1 mm wide); lateral veins arising at an angle of 70°-90° (near apex 60°), running straight up to margin, concentration of veins 14-16 per cm; meshes more or less hexagonal, longer towards midrib, shorter towards margin.

Occurrence — Mamal.

Remarks — The above specimens resemble in venation pattern the leaf of *Glossopteris*



TEXT-FIG. 12 — *Glossopteris* cf. *taeniopteroides* Feistmantel, B.S.I.P. no. 36084/2538, from Mamal, × 2.

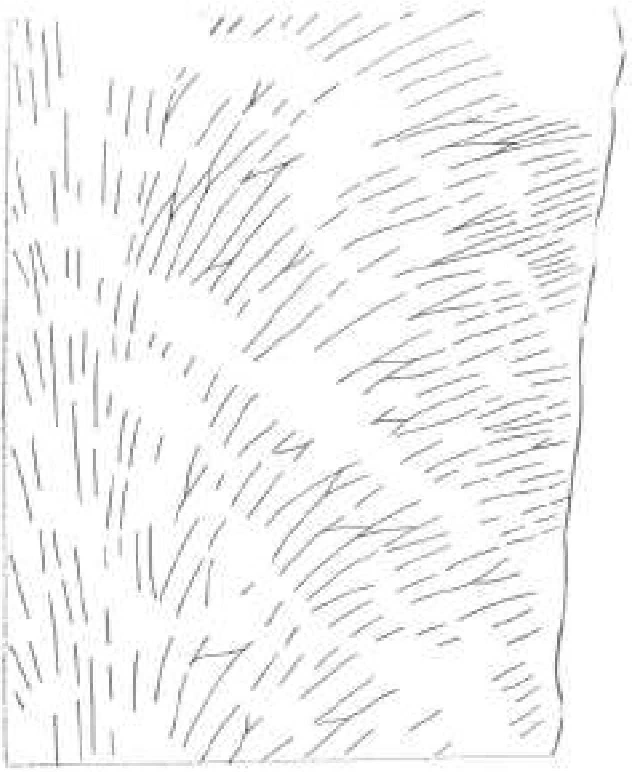
taeniopteroides Feistmantel described by Banerjee (1978, pl. 10, fig. 27). They also resemble the specimen of *G. taeniopteroides* figured by Srivastava (1956, pl. 7, fig. 48) from Raniganj Stage. This letter specimen has now been transferred under *G. srivastavae* Surange & Maheshwari by Chandra and Surange (1979). In our opinion the specimen of *G. taeniopteroides* figured by Srivastava (1956, pl. 7, fig. 48) is quite different from the type specimen of *G. srivastavae* Surange & Maheshwari (1962, pl. 1, fig. 9). In the latter specimen vein meshes are much broader and longer (nearly two times).

Glossopteris angustifolia Brongniart

Pl. 9, figs 58, 59; Text-fig. 13

At Mamal this is the commonest species. All the specimens are incomplete, but in general shape and venation pattern they are in agreement with the various specimens of *G. angustifolia* Brongniart, including the holotype figured by Banerjee (1978, pl. 1, fig. 1) and Rigby *et al.* (1980, figs 15-17). They also resemble the specimens of *G. angustifolia* described by Hsü (1976, pl. 3, figs 16, 17) from southern Xizang, Tibet.

Occurrence — Mamal.



TEXT-FIG. 13 — *Glossopteris angustifolia* Brongniart, a portion of a specimen enlarged showing veins, B.S.I.P. no. 36086/2538, from Mamal, × 4.

Glossopteris sp.

Pl. 9, fig. 62

Description — Leaf incomplete at base and apex, measuring 12.2 cm in length and 3 cm in breadth; midrib prominent throughout the entire length, ±1.5 mm wide; lateral veins emerging at an angle of 80°-90° (towards base almost at 90°), forming broad meshes near midrib, little away from midrib narrower and longer, concentration of veins 18-20 per cm.

Occurrence — Marhoma.

Remarks — *Glossopteris stricta* Bunbury (1861, pl. 9, fig. 5) has two lectotype numbers — the first, no. 10363 of British Museum (Natural History), London is mentioned by Banerjee (1978) and the second no. R 10636 of the Museum of Geological Society, London by Chandra and Surange (1979). Actually Bunbury's (1861, pl. 9, fig. 5) type specimen is now stored in the British Museum (Natural History), London and it bears the number V 19620.

Under the synonymy of *G. stricta*, Chandra and Surange (1979) have referred a specimen of *G. stricta* figured by Feistmantel (1881, pl. 38A, fig. 3). They have also figured this specimen (Chandra & Surange, 1979, pl. 5, fig. 4). We, however, consider this specimen to be quite distinct from the original specimen of *G. stricta* figured by Bunbury (1861, pl. 9, fig. 5). Bunbury's specimen shows about 1-2 mm wide infra-marginal portion which is thinner than the rest of the lamina. This infra-marginal region has much smaller and polygonal meshes as compared to the meshes over the major part of the lamina. Such infra-marginal region is not present in the specimen figured by Chandra and Surange (1979, pl. 5, fig. 4) and it is quite likely that it is different from the original specimen of Bunbury (1861, pl. 9, fig. 5). Our specimen resembles the specimens of *G. stricta* figured by Chandra and Surange (1979, pl. 5, fig. 4) in gross features as well as in venation pattern. It, however, differs from *G. stricta* of Bunbury (1861, pl. 9, fig. 5) in lacking the infra-marginal region.

?*Cordaites* sp.

Pl. 9, figs 60, 61; Text-fig. 14

Description — Fragmentary leaf devoid of base and apex, measuring 5.2 cm in length and 2 cm in breadth; veins parallel, unforked, concentration of veins 12-14 per cm; interveining spaces occupied by fibre-like structure.

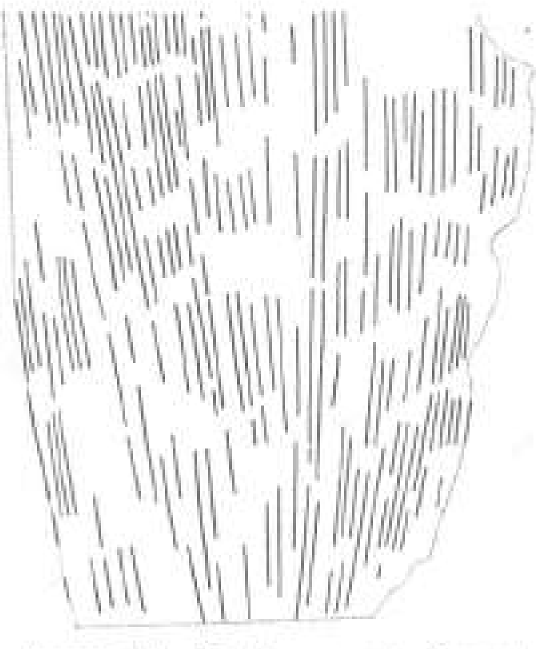
Occurrence — Mamal.

Remarks — The specimen is too incomplete; it has been doubtfully referred to ?*Cordaites* sp. because of the presence of fibre-like structure in between veins.

Ginkgophyllum haydenii (Seward) Maithy

Text-figs 15, 16

1905 *Psygmophyllum* sp.: Seward in Seward & Woodward, p. 6, pl. 9, fig. 3.



TEXT-FIG. 14 — ?*Cordaites* sp., part of a specimen showing veins, B.S.I.P. no. 36088/2538, from Mamal, × 4.

1912 *Psygmophyllum haydeni* Seward, p. 6, pl. 3, figs 8-11.

1943 *Psygmophyllum haydeni* Seward: Sitholey, p. 184, pl. 10, fig. 1; pl. 11, figs 2-8; text-figs 1-3.

1957 *Psygmophyllum haydeni* Seward: Hazra & Prasad, p. 502, pl. 10, figs 6, 7.

1960 *Ginkgophyton haydeni* (Seward) Høeg & Bose, p. 42.

1974 *Ginkgophyllum haydenii* (Seward) Maithy, p. 303.

Emended Diagnosis — Leaves flabellate, measuring up to 13 cm in length and 12 cm in width; base narrow, forming a petiole, 4-5 mm broad; apical end deeply dissected into six or more obcuneate segments, angle of division small; veins diverging from base, repeatedly dichotomising, running straight, subparallel, concentration of veins near base 10 per cm, towards apex 20-22 per cm.

Lectotype — Pl. 3, fig. 10 in Seward (1912).

Comparison — In gross features *Ginkgophyllum haydenii* somewhat resembles *G. kidstonii* Maithy (1974), but the latter differs in having a single median fissure. *G. hollandii* (Seward) Maithy (1974) differs from *G. haydenii* in having only two distinct segments in each leaf.

Ginkgophyllum sahnii (Ganju) Maithy

Text-fig. 17

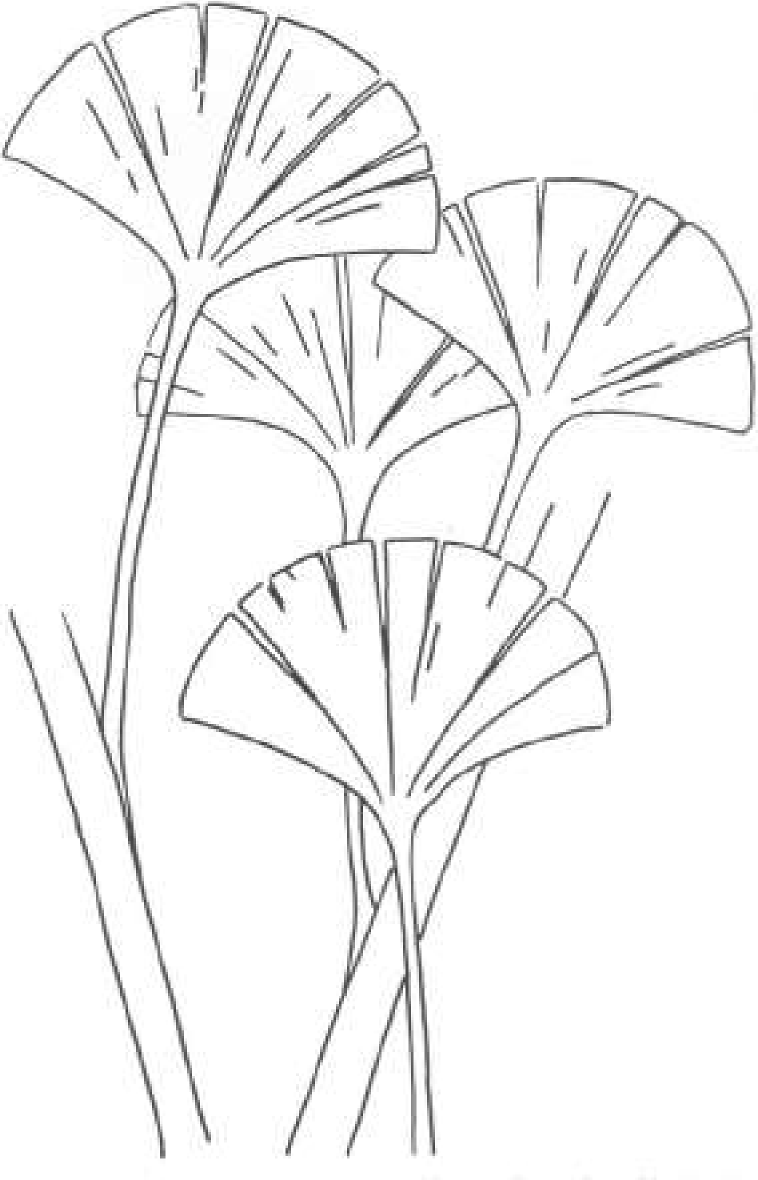
1943 *Psygmophyllum sahnii* Ganju, p. 205, pl. 14, fig. 1; text-figs 1-3

1974 *Ginkgophyllum sahnii* (Ganju) Maithy, p. 303.

1982 *Psygmophyllum sahnii* Ganju: Pant, p. 67, fig. 4F.

Emended Diagnosis — Stem measuring 21.5 cm in length and 0.8-1.2 cm in width, longitudinally striated. Leaves spirally arranged, obcuneate, base drawn into petiole-like structure, measuring 5.5-7.5 cm in length and 5-6.5 cm in width, leaf bilobed, each lobe further divided into two incomplete lobes; median fissure extending nearly 1/2 to 3/4 length of leaf, lateral fissures extending nearly up to 1/4 length of leaf. Veins emerging from base, after emergence repeatedly dichotomising, concentration of veins 10-12 per cm.

Lectotype — No. R/5 of the Department of Botany, Lucknow University, Lucknow.



TEXT-FIG. 15 — *Ginkgophyllum haydenii* (Seward) Maithy, redrawn from Sitholey (1943, text-fig. 1), ×1/2;

Comparison — *Ginkgophyllum hollandii* (Seward) Maithy (1974) differs from *G. sahnii* in having a single median fissure. Moreover, the veins in *G. hollandii* are running more or less straight, whereas, in *G. sahnii* the veins are curved. *G. kidstonii* (Seward) Maithy (1974), too, has a single median fissure. *G. haydenii* (Seward) Maithy has six or more segments.

INCERTAE SEDIS

Observations on *Lepidostrobus kashmirensis* Srivastava & Kapoor

Text-fig. 18

Srivastava and Kapoor (1967, pl. 5, figs 1-3; text-fig. 1) described *Lepidostrobus kashmirensis* from the tuffaceous shales

TEXT-FIG. 16 — *Ginkgophyllum haydenii* (Seward) Maithy, redrawn from Sitholey (1943, text-fig. 2), × 1.

of Mamal. We have also collected a few fragmentary pieces of similar cones. The description of the most complete specimen is as follows:

Cone cylindrical, uniformly broad from base to apex, measuring 18.7 cm in length and 2.4 cm in width. Exposed part of stalk about 0.5 cm long and 0.4 cm wide. Cone scales spirally arranged, rhomboidal in shape, mostly keeled.

Occurrence — Mamal.

Remarks — The figured specimen (Text-fig. 18), which is available in part and counterpart, do not show any resemblance with any of the known species of *Lepidostrobus*. It is most unlikely that it belongs to the genus *Lepidostrobus*. This has already been doubted by Surange (1971). It is quite likely that these cones may belong to one of the genera present in the Mamal assemblage.

DISCUSSION

The occurrence of various genera and species, at different localities, within the

TEXT-FIG. 17 — *Ginkgophyllum sahnii* (Ganju) Maithy, redrawn from Ganju (1943, text-fig. 1), × 1/2.

Upper Palaeozoic sequence of Kashmir Himalaya has been shown in Table 2. Within this sequence the oldest assemblage, occurring at Kotsu and Diuth spurs, has only two genera with doubtful affinities. Both *Taeniocrada* and *Protolepidodendron* are Devonian forms and their occurrence in Kashmir is important, because so far we do not have any other record of Devonian plants anywhere in Kashmir. May be further search will yield a better Devonian flora in B Member of the Aishmuqam Formation, which is overlain by a sequence having mega- and microfauna of Tournasian age.

The Lower Carboniferous flora has two distinct assemblages. Out of these, the older assemblage belongs to the basal part of C Member of the Syringothyris Limestone Formation which overlies the marine fauna of Tournasian age. Here the fossiliferous beds, exposed at Kotsu, are full of *Lepidodendropsis fenestrata* Jongmans and *Palmatopteris* cf. *furcata* Potonié. The floral assemblage and the associated marine fauna suggest a Visean age for the C Member of Syringothyris Limestone Formation. The younger assemblage, consisting of *Archaeosigillaria minuta* Lejal, *Lepidosigillaria* cf. *quadrata* Danzé-Corsin, *Lepidodendropsis* cf. *peruviana* (Gothan) Jongmans, *L. fenestrata* Jongmans, *Cyclostigma* cf. *pacifica* (Steinmann) Jongmans, *Rhacopteris ovata*, (McCoy) Walkom, *Triphyllopteris lescuriana* (Meek) Jongmans and *Rhodea* cf. *subpetiolata* (H. Potonié) Gothan, comes from A and C Members of Fenestella Shale Formation which on the faunal evidence has been dated as Middle Visean to Bashkirian in age. The overall assemblage is more like the Lower Carboniferous assemblage earlier described by Høeg, Bose and Shukla (1955) rom the Po Series of Spiti. In Spiti, Høeg, Bose and Shukla (1955) had failed to find any lycopsid remain. Their presence in Spiti has now been recorded by Dhar, Ram and Rao (1980). In its overall floral composition the Fenestella Shale assemblage resembles most the assemblage described by Jongmans (1954) from the Lower Carboniferous of Peru.

←

TEXT-FIG. 18 — Cone-like organ, redrawn from Srivastava and Kapoor (1969, text-fig. 1), × ca 1.

TABLE 2 — SHOWING DISTRIBUTION OF VARIOUS GENERA AND SPECIES DESCRIBED IN THIS PAPER

FOSSIL PLANTS	UPPER DEVONIAN		LOWER CARBONIFEROUS				LOWER PERMIAN							
	Diuth	Kotsu	Kotsu	Gund	Manigam	Wallarama	Nishatbagh	Mamal	Marhoma	Golabgarh	Dandlutar	Munda	Risin	Gunyul
?*Taeniocrada* sp.	—	+	—	—	—	—	—	—	—	—	—	—	—	—
?*Protolepidodendron* sp.	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Archaeosigillaria minuta Lejal	—	—	—	+	+	+	—	—	—	—	—	—	—	—
Lepidosigillaria cf. *quadrata* Danzé-Corsin	—	—	—	+	+	+	—	—	—	—	—	—	—	—
Lepidodendropsis cf. *peruviana* (Gothan) Jongmans	—	—	—	+	+	+	—	—	—	—	—	—	—	—
Lepidodendropsis fenestrata Jongmans	—	—	+	—	+	+	—	—	—	—	—	—	—	—
Cyclostigma cf. *pacifica* (Steinmann) Jongmans	—	—	—	+	+	+	—	—	—	—	—	—	—	—
Parasphenophyllum thonii var. *minor* (Sterzel) Asama	—	—	—	—	—	—	—	+	—	—	—	—	—	—
Trizygia speciosa Royle	—	—	—	—	—	—	—	+	—	—	—	—	—	—
Lobatannularia ensifolia Halle	—	—	—	—	—	—	—	+	—	—	—	—	—	—
Rhacopteris ovata (McCoy) Walkom	—	—	—	+	+	—	—	—	—	—	—	—	—	—
Triphyllopteris lescuriana (Meek) Jongmans	—	—	—	—	+	+	—	—	—	—	—	—	—	—
Rhodea cf. *subpetiolata* (H. Potonié) Gothan	—	—	—	—	+	+	—	—	—	—	—	—	—	—
Palmatopteris cf. *furcata* Potonié	—	—	+	—	—	—	—	—	—	—	—	—	—	—
Rajahia mamalensis sp. nov.	—	—	—	—	—	—	—	+	—	—	—	—	—	—
Gangamopteris kashmirensis Seward	—	—	—	—	—	—	+	—	—	+	—	+	+	—
Glossopteris longicaulis Feistmantel	—	—	—	—	—	—	+	—	—	—	—	—	—	—
Glossopteris nishatbaghensis sp. nov.	—	—	—	—	—	—	+	—	—	—	—	—	—	—
Glossopteris intermittens Feistmantel	—	—	—	—	—	—	—	+	—	—	—	—	—	—
Glossopteris cf. *communis* Feistmantel	—	—	—	—	—	—	—	+	—	—	—	+	—	—
Glossopteris cf. *feistmantelii* Rigby	—	—	—	—	—	—	—	+	—	—	—	—	—	—
Glossopteris cf. *taeniopteroides* Feistmantel	—	—	—	—	—	—	—	+	—	—	—	—	—	—
Glossopteris angustifolia Brongniart	—	—	—	—	—	—	—	+	—	—	—	—	—	—
Glossopteris sp.	—	—	—	—	—	—	—	—	+	—	—	—	—	—
?*Cordaites* sp.	—	—	—	—	—	—	—	+	—	—	—	—	—	—
Ginkgophyllum haydenii (Seward) Maithy	—	—	—	—	—	—	—	—	—	+	+	+	—	—
Ginkgophyllum sahnii (Ganju) Maithy	—	—	—	—	—	—	—	—	+	—	—	—	+	+
?*Nummulospermum* sp.	—	—	—	—	—	—	+	—	—	—	—	—	—	—
Cone-like organ	—	—	—	—	—	—	—	+	—	—	—	—	—	—

However, the Fenestella Shale assemblage may also be compared with most of the Lower Carboniferous floral assemblages described from Ghana (Menash & Chaloner, 1971), Shara (Lejal, 1968), Morocco (Danzé-Corsin, 1965), Libya (Lejal-Nicol, 1975), Egypt (Jongmans & Heide, 1955), Australia (Rigby, 1973; Morris, 1975), China (Szé, 1936; Chang, 1956; Asama, 1973), Western Europe (Lutz, 1933; Lacey, 1962; Wagner, 1978) and U.S.A. (Jongmans, Gothan & Darrah, 1935; Chaloner & Meyen, 1973). Thus it seems that the Lower Carboniferous flora of India was similar to those known from the other parts of the world.

Like Lower Carboniferous, the Lower Permian, too, has two distinct assemblages. The older one, i.e. the assemblage from the Nishatbagh Formation, is dominated by *Gangamopteris* and the younger assemblage from Mamal is dominated by *Glossopteris*. The Nishatbagh Formation consists of *Gangamopteris kashmirensis* Seward, *Glossopteris longicaulis* Feistmantel, *G. nishatbaghensis* sp. nov. and ?*Nummulospermum* sp. The Mamal Formation has *Parasphenophyllum thonii* var. *minor* (Sterzel) Asama, *Trizygia speciosa* Royle, *Lobatannularia ensifolia* Halle, *Rajahia mamalensis* sp. nov., *Glossopteris intermittens* Feistmantel, *G.* cf. *communis* Feistmantel, *G.* cf. *feistmantelii* Rigby, *G.* cf. *taeniopteroides* Feistmantel, *G. angustifolia* Brongniart, *Glossopteris* sp., ?*Cordaites* sp., *Ginkgophyllum haydenii* (Seward) Maithy, *G. sahnii* (Ganju) Maithy and a cone-like organ.

The fossil flora from the Nishatbagh Formation has been compared by earlier workers with the Talchir flora of Peninsular India. Recently, Kapoor (1977) opined that Nishatbagh and Vihi beds are homotaxial to the Talchir Formation rather than Karharbari Formation. In the common occurrence of *Gangamopteris* the Nishatbagh assemblage is more like the one known from the Rikba Bed of Peninsular India. However, at Nishatbagh *Glossopteris nishatbaghensis* is dominant, unlike Rikba where *Gangamopteris cyclopteroides* is dominant. The Karharbari Formation has both *Gangamopteris* as well as *Noeggerathiopsis*. At Nishatbagh so far, we have failed to collect any specimen of *Noeggerathiopsis*.

The Mamal assemblage is characterized by the dominance of several species of *Glossopteris* and by the presence of two characteristic Cathaysian genera, viz., *Lobatannularia ensifolia* Halle and *Rajahia mamalensis* sp. nov. and shows close similarity with the assemblages described by Hsü (1973, 1976) from Mt. Jolmo Lungma region and southern Xizang in Tibet. The Tibetian assemblage from southern Xizang has specimens resembling *Lobatannularia* and *Rajahia* alongwith the species of *Glossopteris* (*G. communis*, *G. angustifolia* and *G. indica*). It has also *Sphenophyllum speciosum*.

From the foregoing account it seems that the Permian flora of Kashmir is different from the Permian assemblages known from Peninsular India. The assemblage from Nishatbagh Formation differs from Talchir and Karharbari formations in having *Gangamopteris kashmirensis* and *Glossopteris nishatbaghensis*. As the fossiliferous beds belonging to Nishatbagh Formation overlie the Lower Permian beds having *Eurydesma*, the age of the Nishatbagh Formation may safely be considered as early Artinskian.

The younger assemblage from Mamal Formation is also quite distinct from all the Permian assemblages known from Peninsular India. The various species of *Glossopteris* described above resemble more the Barakar species of *Glossopteris* in gross features. However, when their cuticular structure will be known they may prove to be different. Moreover, the presence of *Lobatannularia ensifolia* Halle and *Rajahia mamalensis* sp. nov. make the assemblage different from that of the Barakar assemblage. The fossiliferous beds belonging to Mamal Formation are overlain by the Zewan Formation. The basal A Member has been dated as Abadehian because of the presence of characteristic foraminifers like *Abadehella* and *Colaniella*. As such the age of the Mamal Formation is considered as early Kungurian.

In the Himalaya, like the Mamal assemblage, recently a mixed assemblage comprising Lower Gondwana elements and northern hemisphere species like *Annularia* sp. cf. *A. stellata*(Schlothiem) has been reported by Tiwari and Singh (1981) from the Kumaun Himalaya. From Solan area, along Kalka-Simla Road, Kulshreshtha *et al.* (1982) have reported *Gangamopteris fibrosa* Maithy. These records along with the records of mixed floras occurring at Mamal and southern Xizang suggest that during Lower Permian the Himalayan region had floral assemblages which were quite distinct from the assemblages known from the Lower Gondwana of Peninsular India and the northern Cathaysian flora. This naturally raises the question whether there was a separate land mass between the Cathaysia on the north and the Gondwana Land on the south.

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EXPLANATION OF PLATES

PLATE 1

1. ? *Taeniocrada* sp. from Kotsu; B.S.I.P. no. 36043/2771. × 1.
2. ?*Protolepidodendron* sp. from Diuth Spur; B.S.I.P. no. 36044/2543. × 1.
3. Details of part of the above specimen. × 2.
4. *Archaeosigillaria minuta* Lejal from Wallarama; B.S.I.P. no. 36045/2544. × 1.
5. A portion from the above specimen enlarged. × 2.
6. *Archaeosigillaria minuta* Lejal from Gund; B.S.I.P. no. 36093/2519. × 1.
7. *Lepidosigillaria* cf. *quadrata* Danzé-Corsin from Wallarama; B.S.I.P. no. 36046/2516. × 1.
8. *L.* cf. *quadrata* Danzé-Corsin from Wallarama; B.S.I.P. no. 36047/2515. × 1.
9. Part of fig. 7, showing leaf bases and scars. × 2.

PLATE 2

10. *Lepidodendropsis* cf. *peruviana* (Gothan) Jongmans from Wallarama; B.S.I.P. no., 36048/2516. × 1.
11. Details of part of the above specimen. × 2.

12, 13. *Lepidodendropsis fenestrata* Jongmans from Wallarama; B.S.I.P. nos. 36051/2544 and 36050/2544. × 1.

14. *L. fenestrata* Jongmans from Wallarama, showing oval leaf bases; B.S.I.P. no. 36092/2544. × 1.
15. *L. fenestrata* Jongmans from Wallarama, showing a young stem; B.S.I.P. no. 36049/2544. × 1.
16. *Cyclostigma* cf. *pacifica* (Steinmann) Jongmans from Manigam, showing only a part of the specimen; B.S.I.P. no. 36052/2515. × 2.

PLATE 3

17. *Cyclostigma* cf. *pacifica* (Steinmann) Jongmans from Wallarama; B.S.I.P. no. 36053/2544. × 1.
18. Cone-like structure from Manigam; B.S.I.P. no. 36054/2515. × 1.
19. The above enlarged. × 2.

20, 21. *Rhacopteris ovata* (McCoy) Walkom from Manigam; B.S.I.P. nos. 36057/2515 and 36058/2515. × 1.

22. *Triphyllopteris lescuriana* (Meek) Jongmans from Wallarama; B.S.I.P. no. 36059/2544. × 1.

PLATE 4

23. Lycopsid stem cast from Wallarama; B.S.I.P. no. 36056/2544. × 1.
24. *Palmatopteris* cf. *furcata* Potonié from Kotsu; B.S.I.P. no. 36062/2518. *ca.* × 1/2.

PLATE 5

25. *Palmatopteris* cf. *furcata* Potonié from Kotsu; B.S.I.P. no. 36063/2518. × 1.
26, 27. *Rhodea* cf. *subpetiolata* (H. Potonié) Gothan from Wallarama; B.S.I.P. nos. 36060/2544 and 36061/2544. × 1.
28. *Gangamopteris kashmirensis* Seward from Nishatbagh Spur, showing apical part of a leaf; B.S.I.P. no. 36065/2542. × 1.
29. *G. kashmirensis* Seward from Nishatbagh Spur; B.S.I.P. no. 36064/2542. × 1.
30. A portion from the above specimen enlarged, showing veins. × 4.
31. *Glossopteris longicaulis* Feistmantel from Nishatbagh Spur; B.S.I.P. no. 36066/2542. × 1.
32. Details of veins from the above specimen. × 4.
33. ? *Nummulospermum* sp. from Nishatbagh Spur; B.S.I.P. no. 36079/2542. × 8.

PLATE 6

34-36. *Glossopteris nishatbaghensis* sp. nov. from Nishatbagh Spur; B.S.I.P. nos. 36066/2542 (holotype), 36068/2542 and 36067/2542. × 1.
37. Part of fig. 34 enlarged to show details of veins. × 4.
38, 39. *Parasphenophyllum thonii* var. *minor* (Sterzel) Asama from Mamal; B.S.I.P. nos. 36069/2538 and 36070/2538. × 1.
40. Fig. 39 enlarged to show veins. × 2.
41. *Trizygia speciosa* Royle from Mamal; B.S.I.P. no. 36071/2538. × 1.
42. The above magnified. × 2.

PLATE 7

43, 44. *Lobatannularia ensifolia* Halle from Mamal, part and counterpart; B.S.I.P. nos. 36072/2538 and 36073/2538. × 1.
45. *L. ensifolia* Halle from Mamal, a detached leaf showing median vein; B.S.I.P. no. 36075/2538. × 2.
46. *L. ensifolia* Halle from Mamal, showing a few leaves; B.S.I.P. no. 36074/2538. × 1.
47-49. *Rajahia mamalensis* sp. nov. from Mamal; B.S.I.P. nos. 36077/2538 (holotype), 36078/2538 and 36076/2538. × 1.
50. Part of fig. 47 enlarged to show veins. × 4.

PLATE 8

51. *Glossopteris* cf. *communis* Feistmantel from Mamal; B.S.I.P. no. 36080/2538. × 1.
52, 53. *G. intermittens* Feistmantel from Mamal; B.S.I.P. nos. 36081/2538 and 36082/2538. × 1.
54. A portion of fig. 52 enlarged to show veins. × 4.
55. *Glossopteris* cf. *taeniopteroides* Feistmantel from Mamal; B.S.I.P. no. 36083/2538. × 1.

PLATE 9

56. *Glossopteris* cf. *taeniopteroides* Feistmantel from Mamal; B.S.I.P. no. 36084/2538. × 1.
57. *Glossopteris* cf. *feistmantelii* Rigby from Mamal; B.S.I.P. no. 36087/2538. × 1.
58, 59. *G. angustifolia* Brongniart from Mamal; B.S.I.P. nos. 36086/2538 and 36085/2538. × 1.
60. ? *Cordaites* sp. from (Mamal; B.S.I.P. no. 36088/2538. × 1.
61. A portion from the above specimen enlarged to show details of venation pattern. × 4.
62. *Glossopteris* sp. from Marhoma; B.S.I.P. no. 36089/2540. × 1.


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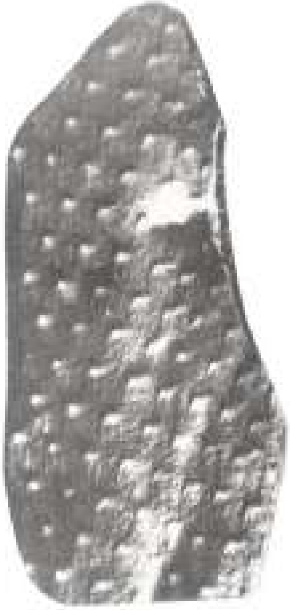
PLATE 1



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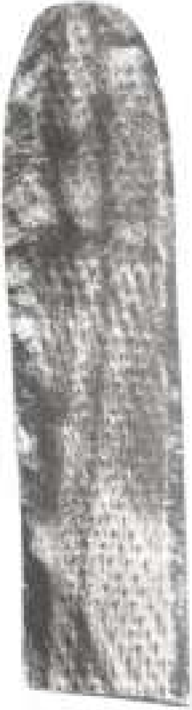

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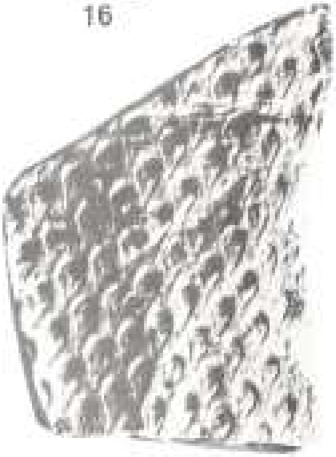

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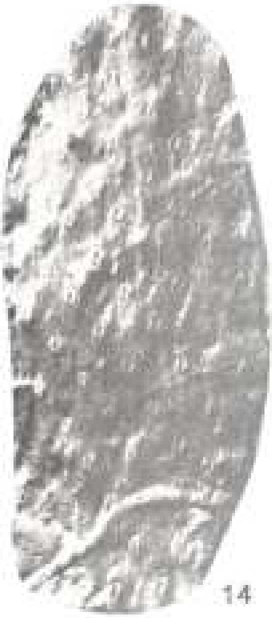

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PLATE 2


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PLATE 3

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PLATE 4

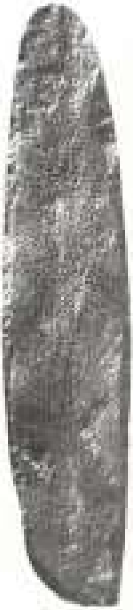

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PLATE 5


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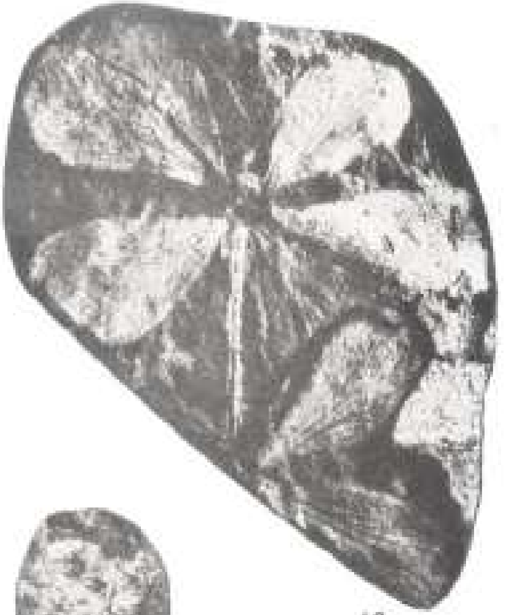
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PLATE 6

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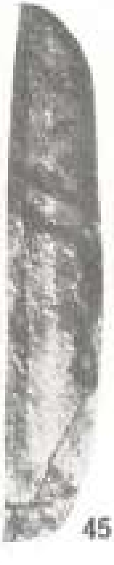

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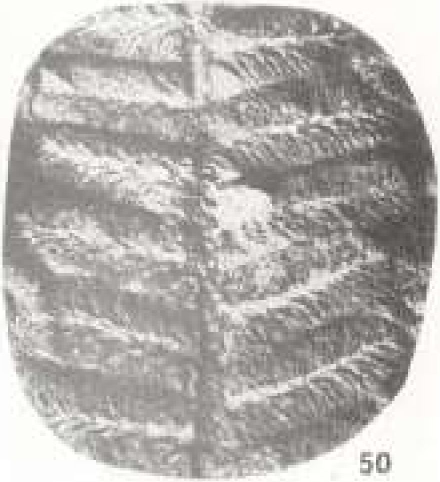

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PLATE 7


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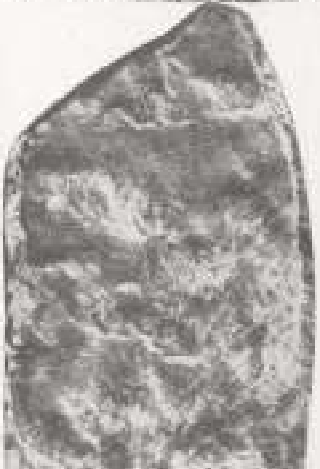
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PLATE 8

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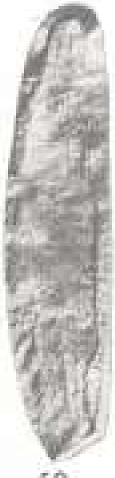

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PLATE 9

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PRECAMBRIAN AND PALAEOZOIC FLORAS FROM THE HIMALAYA: A REVIEW*

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ABSTRACT

Records of organo-sedimentary structures and microbiota from Precambrians and mega- and micro-flora from the Early and Late Palaeozoic of the Himalaya are reviewed with a brief discussion on the problems and future prospects in the area.

Key-words — Microbiota, Organo-sedimentary structures, Precambrian, Palaeozoic, India.

सारांश

हिमालय में कैम्ब्रियन-पूर्व एवं पुराजीवी वनस्पतिजात : एक समीक्षा – केशव मुकुन्द लेले एवं
प्रभात कुमार माइती

हिमालय के कैम्ब्रियन-पूर्व में कार्बनिक-अवसादीय संरचनाओं एवं सूक्ष्म-जीविता तथा प्रारम्भिक एवं उत्तर पुराजीवी से गुरु एवं सूक्ष्म-वनस्पतिजात के अभिलेखों का वर्णन किया गया है। इस क्षेत्र में भावी अन्वेषणों तथा समस्याओं पर एक संक्षिप्त विवेचन भी किया गया है।

INTRODUCTION

RECORDS of fossil floras from the Precambrian and early Palaeozoic of extra-Peninsula (Himalayas) are scanty. Nevertheless the records of early Palaeozoic are very significant as no where else in India the early Palaeozoic floras are known to occur. Thus, extra-Peninsula has a special significance for the early Palaeozoic floras. In recent years more reliable and better evidence has been obtained which raises the potential of the region for investigation of Precambrian and early Palaeozoic fossils.

Late Palaeozoic floras are also found in the extra-Peninsula which are mainly of *Glossopteris* composition. Stray records of *Glossopteris* are known from several places along the foot hills of Himalaya, i.e. from Kashmir to Arunachal Pradesh, which show the former extension of Gondwana continent up to the Tethyan coast. Sometimes the elements of possible non-Gondwana affinities have also been found. The phytogeographic and floral relationships in Permian between the Indian Gondwana and the contemporary floral provinces thus become highly interesting.

PRECAMBRIAN

Organo-sedimentary structures and microbiota have been reported from Himalayas.

STROMATOLITES

Occurrences of stromatolites in Lesser Himalayan region have been reviewed recently by Valdiya (1980), Srikantia (1980) and Kumar (1980). The entire record is considered here into six distinct geographical areas:

1. The detached belt of Raisi Group of Jammu-Himalaya.
2. Shali, Larji and Deoban belts of Himachal Himalaya.
3. Deoban-Tejam belt of Garhwal-Kumaon Himalaya.

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*Presented in the Symposium on 'Palaeontology and Biostratigraphy of the Himalaya' at the Eleventh Himalayan Geology Seminar, Dehradun, on 26th November, 1980.

4. Nawakot belt of the Nepal Himalaya.
5. Baxa belt of the Sikkim-Bhutan Himalaya.
6. Baxa belt of the Arunachal Himalaya.

JAMMU HIMALAYA

Raisi Group — In the Jammu hills of Kashmir Himalaya, within the Palaeogene zone, there is a chain of carbonate inliers variously referred as the ' Sirban Limestone ', ' Jammu Limestone ' and ' Raisi Limestone ', but now designated as the ' Raisi Group '. They are spread between Puri in Punch and Murtal in Udhampur. These carbonate inliers are characterised by prolific growth of stromatolites: *Colonella* Komar, *Conophyton cylindricus* Maslov, *Platella*, *Baicalia baicalica*, *Masloviella columnaris*, *Irregularia* Koroliuk, *Nucleela* Komar (Raha & Sastry, 1973).

HIMACHAL HIMALAYA

There are three stromatolite-bearing carbonate belts in the Himachal Himalaya. Of the three belts, the Shali occurs in the outer most zone, the Larji in the innermost zone and the Deoban in the intermediate zone. All the three belts unconformably overlie a sequence of purple and grey quartzite-shale with lava flows and are considered homotaxial.

Shali Group — The stromatolites are found in the Ropri, Khatpul, Tattapani and Parnali members of the Shali Group. *Conophyton* is seen to confine to Ropri and Khatpul members, whereas *Baicalica* is seen in Khatpul, Tattapani and Parnali members (Srikantia, 1980).

Simla Group — The Simla Group which overlies the Shali belts along a major unconformity contains *Jurusania himalayica* (Sinha, 1977).

Larji Group — It occurs within a window zone in the Kulu-Rampur area of the Himachal Pradesh. It is divisible into two formations, viz., the Hurla Formation and the Aut Formation. The Aut Formation contains profuse growth of columnar stromatolites of the type *Conophyton*, *Jurusania* and *Baicalica*. From Aut area *Conophyton*, ex. gr. *cylindricus* (Grabu) and *Colonella* sp. indet have been reported (Sinha, 1977).

Deoban Group — This group occurs in autochthonous zone in the area between Himachal and Garhwal Himalaya. The Bohar and Tioniar formations are characterised by prolific growth of stromatolites (Srikantia, 1980).

The Bohar Formation contains limestone bands, some of which are 20 m thick and are wholly made up of stromatolite reef colonies. *Colonella* and even *Conophyton* have also been seen. *Baicalica* (*Collenia baicalica*) has also been reported from this formation (Valdiya, 1969).

The Tioniar Formation has profuse growth of stromatolites, which are comparable to *Tungussia*.

GARHWAL-KUMAON HIMALAYA

Calc Zone of Pithoragarh — In this zone there are two thick carbonate sequences which show excellent preservation of stromatolites.

Valdiya (1969) reported *Collenia thalkidarensis*, *C. symmetrica* and ?*Jurasania* from the Thalkedar Dolomite. Kumar (1978) has doubted the identification of *Collenia symmetrica* and ?*Jurassiana*. According to him *C. symmetrica* is a transverse preservation of *C. thalkedarensis* and ?*Jurassiana* is perhaps a new form, which needs redescription.

Kumar and Kumar (1978) have described two stratified stromatolites *Stratifera undata* and *Gongylina differentiata* from Gurna area, Pithoragarh District alongwith *Colonella columnaris* and *Collenia clappii*.

The Gangolighat Dolomite Formation, younger carbonate horizon of the Calc zone, shows good development of stromatolites. Misra and Valdiya (1961) were first to report *Collenia* from this horizon. Dixit (1966) reported *Cryptozoon*, *Collenia columnaris*, *C. undosa*, *C. flagelliformis* from the Girichhina area. Misra and Kumar (1969) recorded *Collenia columnaris* and *C. nailensis* from the Ganai area. Valdiya (1969) reported *Collenia baicalica*, *C. columnaris*, *C. kussiensis*, *Minjaria uralica* and *Collenia symmetrica* from Pithoragarh area. Banerji (1970) described *Collenia columnaris*, *C. baicalica*, *C. frequence* var. *kandaensis*, *C. pseudocolumnaris*, *C. septentrionalis* and *C. minature* in the Gangolighat Dolomites of the Sarju Pungar Valley area, Almora District. Kumar and Tiwari (1977, 1978) recorded *Conophyton garganicus* and *C. misrai* from the Kathpuria Chhina area. Later Tewari (1979; see Kumar, 1980) recorded *Stratifera* and *Gongylina* from the same area.

Calc Zone of Tejam — Bhattacharya (1976) recorded the occurrence of *Conophyton cylindricus* from the Kapkot Formation.

NEPAL HIMALAYA

Nawakot Group — The Tejam-Pithoragarh belt continues into the Nepal Himalaya. However, the nature of extension is not clearly known. Stromatolites of *Colonella* and some lower Proterozoic types have been reported from the Formation D of the Nawakot Group. These are yet to be studied in detail.

SIKKIM-BHUTAN-ARUNACHAL HIMALAYA

Baxa Group — The Baxa Group is divisible into two formations, viz., the lower Jainti Formation and the upper Carbonate Formation. The Carbonate Formation, as the name implies, is characterised by limestone and dolomite with profuse stromatolites in the dolomite unit. Though these stromatolites have not been studied with regard to the morphological characters, yet a cursory study indicates that they are mainly of *Colonella* and *Baicalica* types.

The observations brings out the scope and utility of stromatolites in the stratigraphy of Proterozoic carbonate formations of the entire Lesser Himalaya. Considering the importance of correlation of the unfossiliferous formations in the Lesser Himalaya, there is greater need for systematic study of stromatolites with accent on the evolutionary trend in the Himalayan belt. However, one particular aspect has to be kept always in notice that the morphology of stromatolites is governed by the biota responsible for its deposition.

Oncolites — Gundu Rao (1970) and Bhattacharya (1976) have reported oncolites from Upper Krol and Kumaon Himalaya respectively.

MICROBIOTA

Prakash (1974) reported acritarchs from the Calc zone of Chamoli in the Lesser Himalaya. The identifications of the palynomorphs need rechecking. Later Sah, Maithy and Bhargava (1977) reported palynomorphs from Jutogh 'B' of Simla Hills. Recently Maithy and Bhargava (1982) have recorded an alga, *Sclerococcus* from Jutogh 'E' of Simla Hills.

The microbiota from Pithoragarh, Kumaon Himalaya belongs to cyanophytic algae (both filamentous and spheroid), Sphaeromorphitae acritarchs and *Baltisphaeridium* (Acanthomorph) (Nautiyal, 1978b, 1980). Nautiyal (1978a, 1979) also reported a few chitinozoans from the Satpuli area, Garhwal Himalaya. Some of the new genera instituted by him need revision. The possibility, however, is that they are similar to the previously recorded forms.

Singh, Tiwari and Gupta (1978) recorded acritarchs from Shali Formation near Mandi (Himachal Pradesh). Raha (1980) reported spherical and filamentous microbiota from the Great Limestone of Raisi.

CAMBRIAN-SILURIAN FLORA

Jacob *et al.* (1953) reported spores and other cutinized material from the Cambrian of Kashmir. From the study of spores, they presumed that the primitive Pteridophytes and Pteridosperms are represented in the Middle and Upper Cambrian sediments of India. Ghosh and Bose (1952) also reported spores and tracheids from the Cambrian of Kashmir.

Srivastava (1975) has recorded the following assemblage from the Cambrian-Silurian succession of Kupwara Tehsil, Baramula District, Kashmir.

Acritarchs: *Arabisphaera*, *Deunffia*, *Deusilites*, *Hemisphaeridium*, *Lacunalites*, *Leiosphaeridia*, *Leiofusa*, *Protosphaeridia*, *Quisquilites*, *Sphaeroporalites*.

Spores: *Apiculatisporites*, *Calamospora*, *Laevigatisporites*, *Leiotriletes*, *Lycospora* and wood tracheids.

Sahni (1953) reported psilophytic-like remains from the Silurian of Spiti. The fossil axes are both unforked and forked. They are either smooth or rough possibly due to minute spines. According to Sahni (1953) the straight unbranched fragments of fossils, whatever their nature, would have had a *Hostimella*-like aspect in smooth form, or *Psilophyton*-like in spiny form. He further opined that the spiny form, however, has perceptible resemblance to various marine hydroids, the suggestion of a vascular core not withstanding, because the core is not sufficiently continuous to be fully convincing. Gupta (1969) reported *Psilophyton princeps*.

Maithy (1974) doubted the psilophytic affinities of these fossils due to lack of criterion by which the fossils may indisputably be recognised as land plant, viz. (i) occurrence of a xylem element, (ii) an epidermis with cuticle and stomata, and (iii) the presence of spores in sporangia. He considered the possibility that these fossils may belong to the lower group of plants, but Pant (1978) opined that they are animal remains. Therefore, the specimens require proper reassessment to decide their nature.

CARBONIFEROUS FLORA

Till recently the only known Carboniferous flora was from the Thabo Stage (Po Series) of Spiti, Himachal Pradesh (Gothan & Sahni, 1937; Hoeg, Bose & Shukla, 1957). For about 40 years, nothing new in the plants or no new localities were found. In recent years workers have been devoting more attention to the Carboniferous sediments, with the result better preserved and more significant fossils have come to light. We are now in a position to compare our Carboniferous floras with greater certainty with the cosmopolitan Lower Carboniferous flora, known now as the 'Lepidodendropsis Flora' (Rhacopteris Flora of old times).

The Thabo Stage flora contains restricted plants, viz., *Rhodea*, *Rhacopteris*, *Sphenopteridium*, *Adiantites* and *Asterophyllites*. The faunal evidence from the Lipak Series, which underlies the Thabo Stage, indicates a Dinantian (Tournasian-Visean) age. A Lower Carboniferous age of Thabo plants as suggested by Gothan and Sahni seems to be in agreement with this.

The Gund Formation exposed in the Charil-Nawagan section, north of Banihal in Kashmir (Pal, 1978), contains a diverse floral assemblage composed of Lycopsida, Sphenopsida and Pteridopsida. The forms are *Archaeocalamites radiatus* (Brongniart) Stur (Sphenopsida), *Archaeosigillaria* sp., *Lepidosigillaria quadrata* Danzé-Corsin, *Lepidodendropsis sigillarioides* Jongmans, Gothan & Darrah, *L. pranabii* Pal, *Lepidodendron gundensis* Pal, *Cyclostigma ungeri* Jongmans, Gothan & Darrah, *C. indica* Pal (Lycopsida), and *Rhacopteris* sp. cf. *R. circularis* Walton, *Rhodea tenuis* Gothan (Pteridopsida).

The Carboniferous floras of the world are well known from U.S.A., East Germany, Czechoslovakia, U.K., Spain, Spitsbergen, Peru, Egypt, China and USSR. However, the assemblages have some local peculiarities by way of emphasis on some taxa. Thus, we have *Lepidodendropsis-Cyclostigma-Triphyllopteris* associations in some areas (Jongmans, 1954), while in others there are *Prelepidodendron-Sublepidodendron*, *Lepidosigillaria* and *Archaeosigillaria* associations (Mensah & Chaloner, 1971) or *Lepidodendron-Sphenopteridium-Rhacopteris* assemblages. It has also become apparent now that the *Lepidodendron-Sphenopteridium-Rhacopteris* assemblage is found in the younger strata (Visean) (Lacey, 1962; Pal, 1978).

The Gund Flora is characterised by the dominance of Lycopsida like *Lepidodendropsis* (2 sp.), *Archaeosigillaria* (1 sp.), *Lepidosigillaria* (1 sp.) and *Lepidodendron* (1 sp.). Pteridophytes are subordinate with one species of *Rhacopteris* and *Rhodea*, while Sphenopsida are represented only by *Archaeocalamites* (1 sp.). Pal (1978) also mentioned the occurrence of *Asterophyllites* sp. in basal part of the Gund Formation (see Litholog) but did not describe it. He compared the Gund Flora with the Lower Carboniferous assemblages of Peru (Jongmans, 1954), Pocono Flora of Pennsylvania and Virginia (Jongmans, Gothan & Darrah, 1973), Egypt (Jongmans & Heide, 1955) and the Thabo beds of Spiti (Gothan & Sahni, 1937; Hoeg, Bose & Shukla, 1957). Pal has noted that the Thabo flora is dominantly represented by Filicopsida and the absence of Lycopsida in the assemblage is striking. On the other hand in Gund Flora the lycopsids prevail over the filicopsids. The suggestion of Pal seems to point that the difference in the two floras may be due to difference in age. The Thabo flora with rich fern remains may be younger (Namurian-Westphalian) in age than Gund Flora which has the dominance of lycopsids. The Gund Formation is underlain by Syringothyris Limestone and overlain by Fenestella Shale.

The floral assemblage of Gund closely compares with the *Lepidodendropsis-Cyclostigma-Triphyllepteris* flora as defined by

Jongmans and emended by Lacey (1962) and Mensah and Chaloner (1971). Putting everything together a late Tournas to early Visean age has been assigned to the Gund Formation by Pal (1978). Pal suggested that the Gund Formation (493 m) is entirely continental and that widespread land conditions prevailed during this period. That means these beds can be traced in other parts of Himalayas which may contain floras as well. The floral evidence indicates that a moist and warm climate prevailed during this period in this region.

PERMIAN FLORA

Upper Palaeozoic beds of continental origin are found in several areas along the Tethyan Himalayan belt from Kashmir to the east. These beds are at places associated with glacial or volcanic sediments (Acharya, 1973). In some of these areas typical plants of the Glossopteris Flora, viz., *Glossopteris* and *Vertebraria* have been recorded (Jacob, 1952; Jacob & Banerji, 1954). Several new areas with Permian flora have been surveyed in recent years. The records are as follows.

KASHMIR

The earliest record of Permian floral elements from Kashmir is by Hayden (1907) and Seward (1907, 1912). In recent years our knowledge of the Permian Flora has increased due to painstaking work of Hazra and Prasad (1957) and Kapoor (1969, 1977). Kapoor (1977) recognized five distinct floras above the Carboniferous beds; one below the Panjal Trap and rest above it.

(A) *At the base of the Panjal Trap*

1. *Nishatbagh Bed* — This bed marks the beginning of Gondwana in Kashmir and occurs as isolated outcrops at various localities of which Dal Lake, Basmai, Nagmarg, Bren and Nishatbagh are important. The flora recorded is: *Gangamopteris angustifolia*, *G. kashmirensis*, *Glossopteris angustifolia*, *G. indica*, *Psygmophyllum haydeni*, *Cordaites hislopii*, *Samaropsis*, *Cordaicarpus* and stems.

(B) *On the top of the Panjal Trap*

2. *Vihi Bed* (*Gangamopteris Bed*) — Risin spur of Vihi is supposed to be type area but Hayden (1907) stressed upon the importance of Zewan spur because of its better development than Risin and also due to its position below the marine Zewan Formation. The flora recorded is cones and stems of lycopods, *Gangamopteris kashmirensis* (dominant), *Vertebraria* sp., *Psygmophyllum haydenii*, *P. hollandii* and *Cordaites hislopii*.

3. *Marhoma Bed* — Kapoor (1977) separated this bed from the Vihi Bed due to the presence of a lava flow between the two. The flora includes: *Schizoneura gondwanensis*, *Sphenophyllum*, *Sphenopteris polymorpha*, *Glossopteris*, *communis*, *G. conspicua*, *G. indica*, *Gangamopteris kashmirensis*, *Samaropsis* and *Psygmophyllum haydenii*. Ahmad, Chib and Singh (1978) did not recognize the Marhoma Bed.

4. *Munda Bed* — Hazra and Prasad (1957) studied this bed from the northern slopes of Pir Panzal. Kapoor (1977) traced the bed from Jawhar Tunnel to Ahrbal. The flora known from this bed is: *Pecopteris*, *Glossopteris communis*, *Gangamopteris kashmirensis* (rare), *Taeniopteris kashmirensis*, *T. feddeni*, *Vertebraria indica*, *Cordaites hislopii* and *Psygmophyllum haydenii*. The presence of *Pecopteris* and *Taeniopteris* is significant.

5. *Mamal Bed* — This bed is the youngest floral bed of Permian Gondwana in Kashmir. The type section is exposed on the scrap, and ravine between Mamal and Dunpathari near Pahalgam. The flora includes: *Lepidostrobus kashmirensis*, *Schizoneura*, *Phyllotheca*, ?*Sphenophyllum*, *Pecopteris* (several species including fertile), *Kashmiropteris meyenii*, *Glossopteris indica*, *G. angustifolia*, *G. communis*, *Gangamopteris* sp. (extremely rare), *Cordaites*, *Psygmophyllum* and *Kawizophyllum dunpathriensis*. Attempts have been made to correlate the Lower Gondwana sequence of peninsular region with Kashmir Permian plant beds. According to Kapoor (1977) the Nishatbagh and Vihi beds are homotaxial to Talchir, while Chakravarti (1968) suggested that the Vihi beds are closer to Rikba.

The Gondwana affinity of Permian floral beds of Kashmir is undisputable in spite of its having distinct nature. According to Kapoor (1977) the distinction can be due to its position quite far from the mainland. The fact, of its being the part of the Gondwana continents gets the support from the underlying *Eurydesma* fauna typical of the Gondwana shelf.

The presence of the floral elements of northern hemisphere in the southern and vice versa is an enigma. Besides Kashmir, such mixed floras are also known from South Africa, South America, Australia, Turkey, New Guinea, etc. A group of workers (Sahni, 1935, 1936; Wadia, 1938) believes that the intermixing of the floras is the result of migration of plants in Kashmir region. They presumed the presence of isthumus or dense archipelago in Kashmir region. Other workers oppose this view on the palaeogeographical grounds since the Kashmir region is supposed to have been thousands of kilometers away from the northern continents and separated by the 'Tethys'.

UTTAR PRADESH

Tewari and Singh (1980) recorded Permian plant fossils from Infrakrol sediments exposed along nala cuttings in Jeolikot-Bhowali section, Nainital, U.P. According to them the assemblage comprises of typical northern elements like *Lepidodendron*, *Calamites*, *Annularia*, *Sphenophyllum*, *Gondwanidium*, *Schizoneura* and *Phyllotheca* associated with *Gangamopteris* and *Glossopteris*. The assemblage needs careful examination due to extremely heterogeneous floral nature. Moreover, the author has not given any photographs of the fossils with the result it is extremely difficult to judge the authenticity of these records.

Tiwari, Tripathi, Kumar, Singh and Singh (1980) reported miospores from the Kuling Shale of the Malla Johar area, U.P. The records are *Hennellysporites*, *Callumispora*, *Lacinitriletes*, *Apiculatisporites*, *Laevigatisporites*, *Densipollenites*, *Scheuringipollenites*, *Striatopodocarpites*, *Faunipollenites* and *Crescentipollenites*.

DARJEELING

Acharya (1973) reported a flora from the Damuda Subgroup of Darjeeling foot-hills comprising *Phyllotheca* sp., *Glossopteris indica*, *G. communis* var. *stenoneura*, *G. browniana*, *G. conspicua*, *Glossopteris* sp., and *Vertebraria indica*. The predominance of *Glossopteris* and absence of *Gangamopteris* indicate a Late Permian age. This is also corroborated by the dominance of bisaccate miospore with subdominant trilete and monolete.

SIKKIM

The black laminated micaceous siltstone of the Damuda Subgroup contains plant fossils. The Damuda sandstone near Khemgon has yielded equisetaceous stems, *Glossopteris* and *Vertebraria* (Dutt, vide Sahni & Srivastava, 1956) whereas in other areas *Schizoneura* has been recorded from these beds (Dutt & Sen, vide Jaboc & Banerji, 1954).

NEPAL

Fuchs and Frank (1970) have recorded the occurrence of *Vittatina* and pitted tracheids from phyllitic slates of light green colour, which overlie the Chail Formation in the Phalbang area of Lesser Himalaya region of western Nepal. Gondwana spores have also been recorded from the Thinichu Formation of the Tethys belt of Nepal (Acharya & Sah, 1975).

ARUNACHAL PRADESH

Srivastava and Dutta (1977) have described palynomorphs from the Lower Gondwana sediments of the Diang District, Arunachal Pradesh. The spore-pollen genera recorded are: *Callumispora*, *Lycopodiumsporites*, *Brevitriletes*, *Lacinitriletes*, *Microbaculispora*, *Indotriradites*, *Jayantisporites*, *Parasaccites*, *Virkkipollenites*, *Plicatipollenites*, *Stellapollenites*, *Rugasaccites*, *Crucisaccites*, *Divarisaccus*, *Caheniasaccites*, *Potonieisporites*, *Illinites*, *Platysaccus*, *Striatites*, *Faunipollenites*, *Striatopodocarpites*, *Vesicaspora* and *Scheuringipollenites*.

Among acritarchs are *Pilasporites*, *Hemisphaerium*, *Balmella*, *Maculatisporites*, *Quadrisporites*, *Leiosphaeridia*, *Spongocystia*?, *Foveofusa* and spinose acritarchs and ?algae *Schizosporis* and *Botryococcus*.

The overall microfloral association has two distinct zones. Zone I is dominated by the radial monosaccate pollen grains. The trilete miospore, striate and nonstriate-disaccates are rare. The mioflora is comparable to the mioflora of Talchir Formation of the Lower Gondwana in Peninsular India. Miofloral Zone II is marked by the dominance of *Callumispora*; *Parasaccites* is subdominant. *Microbaculispora* and *Indotriradites* are significant, whereas *Crucisaccites* is confined to this zone. This miofloral zone has been compared to Lower Karharbari mioflora of the peninsula by Srivastava and Dutta (1977).

Singh (1979) reported Lower Permian miospores from the Garu Formation in Siang District. Two distinct miospore assemblages were recognised, viz., *Parasaccites-Plicatipollenites-Virkkipollenites*, and *Callumispora - Parasaccites - Potonieisporites*. The first assemblage was considered equivalent to the Talchir assemblage and the second to be equivalent to Lower Karharbari assemblage of the Lower Gondwana sequence of peninsular India.

Acharya, Sah, Ghosh and Ghosh (1977) recorded plant fossils from the older Khelong Formation in Kameng District. The record includes: *Phyllotheca*, *Schizoneura*, *Glossopteris indica*, *G. communis* var. *stenoneura*, *G. damudica*, *Gangamopteris cyclopteroides* and *Vertebraria*.

They also recorded *Phyllotheca griesbachii*, *Phyllotheca* sp., *Schizoneura gondwanensis*, *Glossopteris indica*, *G. communis* var. *stenoneura*, *G. angustifolia*, *G. longicaulis*, *G. formosa*, *Dictyopteridium*, *Vertebraria indica* and *Samaropsis* sp. from the Bhareli Formation in Kameng District. The assemblage is characterised by the predominance of *Glossopteris* and absence of *Gangamopteris*.

ASSAM, NAGALAND AND MEGHALAYA

Fox (1935) reported *Vertebraria indica* from Singrimari. Recently, recycled Gondwana palynomorphs have been found at some places either on subsurface or in surface (Banerji, Misra & Koshal, 1973; Datta, 1978).

GARO

Banerji, Mitra and Chakravarty (1977) reported mega- and microflora from the Lower Gondwana rocks exposed near Singrimari Bazar (Hallidayganj), western Garo Hills. The megafossil assemblage includes *Schizoneura*, *Glossopteris communis*, *G. stricta*, *G. parallela* and *Vertebraria*. The miospores are represented by *Leiotriletes*, *Calamospora*, *Punctatisporites*, *Cyclobaculisporites*, *Horriditriletes*, *Microfoveolatispora*, *Laevigatosporites*, *Scheuringipollenites*, *Platysaccus* and *Striatites*. Banerji, Mitra and Chakravarty (1977) compared the fossil records with the Lower Barakar flora of the peninsular region.

CONCLUDING REMARKS

From the foregoing review on the Precambrian and Palaeozoic floras of the Himalaya, we can infer that though the records are poor, yet painstaking search by workers will definitely bring about new information. The time is now ripe to concentrate on the following problems:

1. Evolution of floras in geological time with the morphological complexity of elements. Himalayan region suits best for this sort of investigation because here we find a continuous succession from Precambrian to younger sediments. Such a continuous succession is lacking in peninsular India.

2. Phytogeography of floras during the Palaeozoic times, particularly with reference to the claims or the presence of Angaran and Cathaysian elements in the Carboniferous and the Permian floras of Himalaya.

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MESOZOIC PLANT FOSSILS FROM THE HIMALAYAS— A CRITIQUE*

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ABSTRACT

A reconnaissance of the available literature has shown that the reports of Mesozoic plant fossils from the Himalayas are far too meagre as compared to the peninsula. Undoubted plant megafossils have been reported only from the Tethyan zone, i.e. from Lingshi in Bhutan, Kagbeni in Nepal and Loma in Ladakh. The Mesozoic microflora from the Tethyan zone comprises poorly preserved and mostly unidentifiable spores and pollen. The dinocysts from the Spiti Shale of the Malla Johar area are comparatively well-preserved. In the Lesser Himalayan zone the situation is rather complex. No definite plant megafossils are known from the Krol or the Tal, certain algae-like organisms excepted. There seems to be a good amount of controversy regarding the nature and age of these "fossils". A well-preserved palynoflora has been reported from but a single sample in the Krol A (?Infra-Krol) of the Nainital area. The other reports of microfossils (including nannofossils) from the Krol Formation are not convincing enough. Similarly the reports of recovery of palynomorphs from the Lower Tals cannot be totally relied upon as no research paper has come out on these.

Key-words—Himalayas, Krols, Tals, Tethyan zone, Palynofossils, Megaplants.

सारांश

हिमालय से मध्यजीवी कल्प के पादपाश्म : एक समालोचना — हरिकृष्ण माहेश्वरी

उपलब्ध साहित्य के अध्ययन से पता चलता है कि प्रायद्वीप की तुलना में हिमालय क्षेत्र से मध्यजीवी कल्प के पादपाश्मों का ज्ञान अल्प है। गुरु-पादपाश्म केवल टेथियन क्षेत्र में ही पाये गये हैं, उदाहरणतः भूटान में लिंगशी, नेपाल में काग्बेनी एवं लद्दाख में लोमा। सूक्ष्म-पादपाश्म उत्तर प्रदेश में मल्ला जौहर से ज्ञात हैं। यहाँ से प्राप्त बीजाणुओं एवं परागकणों की जाति एवं/अथवा प्रजाति पहचान पाना प्रायः कठिन होता है। मल्ला जौहर क्षेत्र के स्पिटी शैलों से प्राप्त डाइनोसिस्टें अपेक्षाकृत सुपरिरक्षित हैं। लघु हिमालय क्षेत्र में स्थिति वस्तुतः जटिल है। क्रोल अथवा ताल में शैवाल-सदृश अश्मों के अतिरिक्त निश्चित गुरु-पादपाश्म अभी तक भी उपलब्ध नहीं हुए हैं। इन अश्मों की प्रकृति एवं आयु को लेकर काफी मतभेद है। यहाँ से केवल सुपरिरक्षित परागाणु-वनस्पतिजात ही प्राप्त हुआ है परन्तु वह भी नैनीताल क्षेत्र के क्रोल-अ (इन्फ्रा-क्रोल) के मात्र एक नमूने से ही। क्रोल शैल-समूह से प्राप्त सूक्ष्म-जीवाश्मों तथा परासूक्ष्म-जीवाश्मों के विवरणों पर काफी कुछ निर्भर नहीं रहा जा सकता। इसी प्रकार अधर ताल से प्राप्त परागाणविकसणाओं की प्राप्ति पर भी अवलम्बित नहीं रहा जा सकता, चूँकि इन पर अभी तक कोई शोध-पत्र प्रकाशित नहीं किया गया है।

THE Himalayan mountain chain extends for about 2400 kilometres, from Nanga Parbat (9186 m) in the west to Namcha Barwa (7823 m) in the east. The Himalayan mountain system can be divided into three structural and tectonic (lithological) units which are, from north to south: (i) Tethyan Himalayan Zone, (ii) Central Crystalline Zone, and (iii) Himalayan Zone; the last one comprising

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(a) Lesser Himalaya and (b) Sub-Himalaya.

The Tethyan Himalayan Zone consists of a more or less complete stratigraphic sequence ranging from the Precambrian to the Cretaceous, except for a slight unconformity between the Upper Carboniferous and the Permian. The Central Crystalline Zone separates the Tethyan Himalayan and the Himalayan zones. The Himalayan Zone reveals a more complex geological history. The rocks are generally unfossiliferous except for the Tertiary formations and a few scattered outcrops of Permian and Cretaceous fossil bearing rocks.

The age of the Infra-Krol, the Krol and the Tal formations, sometimes regarded as representatives of the Mesozoic sediments in the Lesser Himalaya, has been a matter of raging controversy. Sporadic and ill-preserved fossil finds have been used to date these sediments. Unfortunately in most of the cases the sampling data are too meagre to be of real help in biostratigraphy and age determination. It is therefore not surprising that some of the geologists stubbornly refuse to take into account these fossil finds, though not all for the same reasons. Valdiya (1975) believes that there was no Mesozoic sedimentation in the Lesser Himalaya.

The genetic affinity of the Himalayan Mesozoic sediments is also a matter of controversy. Gansser (1964, p. 242, fig. 144) has shown extension of Gondwana characters to the north, into the Himalayas. Colchen (1975) extends the Gondwanas in the northern high Himalayas of Nepal. But Crawford (1974) maintains that the northern limit of the Gondwana is still an open question. In recent years plant fossil evidence has been used to support the extension of the Gondwana facies into the Himalayas. These will be examined in this article at the proper place.

During the last three decades a lot of geological work has been done in the Himalayas by scientists from India and abroad. The regional and local geological surveys have resulted in new palaeontological findings. The reports of plant fossils, however, are far too meagre, particularly those of the Mesozoic times.

Both plant mega- and micro-fossils have been reported from the Mesozoic and so-called Mesozoic formations in the Himalayas. Plant megafossils of higher plants are known only from the Tethyan Zone whereas the microfossils and algal remains are reported both from the Tethyan and the Lesser Himalayas.

PLANT MEGAFOSSILS FROM THE TETHYAN ZONE

Plant megafossils have so far been reported from Bhutan, Nepal and Ladakh.

The Mesozoic Era is represented in Bhutan by the Lingshi Group of Jurassic-Cretaceous age, which unconformably overlies the Permo-Carboniferous Shodug Formation. The lower horizon of the Lingshi Group — the Mochu Formation — contains a plant bed with: *Equisetites*, *Ptilophyllum*, *Elatocladus*, *Nilssonia*, *Taeniopteris* and *Desmiophyllum* (Chaturvedi *et al.*, 1980).

In Nepal, the plant bed lies in a 10 m thick grey sandstone exposed in a section on the right bank of the Thakkola River near Kagbeni (or Kag). The fossils were first reported by Bordet *et al.* (1964) as cycadophytic fronds and araucarian woods. Bordet *et al.* (1967) and Mouterde (1971) reported: *Nilssonia orientalis*, *Otozamites abbreviatus* and *Ptilophyllum* (*Williamsonia pecten*).

Barale, Bassoullet and Bose (1978) described and illustrated this flora in detail. The revised list of megafossils of the Kagbeni sandstones is: ?*Taeniopteris* sp. cf. *T. spatulata* McClelland, *Ptilophyllum acutifolium* Morris, *Ptilophyllum* sp. cf. *P. cutchense* Morris, and *Araucarioxylon nepalensis* Barale *et al.*

This assemblage is somewhat comparable with that from the lower beds of the Rajmahal Hills in peninsular India but is too poor to be of much use stratigraphically. The section has not been examined palynologically. There is a possibility that the dark grey shales or the silty black shales found intercalated both below and above the plant bed may yield palynomorphs.

In Ladakh, the megafossils have been found in a small hillock along the left bank of the Indus, about 50 km upstream of Loma (Sah & Sharma, 1980; Sharma, Gupta & Sah, 1980). It is possible that the plant fossils occur in more than one hillock as according to Sharma *et al.* (1980, p. 471) ' The sediments containing Gondwana plants are exposed as small detached hillocks'. The rock types in the area comprise dark quartzite, creamish quartzite, calcareous sandstone, conglomeratic breccia and carbonaceous shale. The plant fossils come from a 50 cm thick zone within the carbonaceous shale. Following fossils have been listed: ?Equisetalean axes, *Cladophlebis* spp., *Gleichenites* spp., *Ptilophyllum cutchense* Morris, *Ptilophyllum acutifolium* Morris, *Pterophyllum* sp., *Taeniopteris* sp., *Podozamites* sp., *Elatocladus* sp. cf. *E. plana* (Feistmantel) Seward, and *Brachyphyllum* sp.

Sharma *et al.* (1980) conclude that 'The presence of the above mentioned floral elements etc. suggests an Upper Gondwana affinity for the fossil assemblage'. Taken at its face value this conclusion makes this report as the first find of Gondwana plants from north of the Indus Suture Zone. This conclusion has resulted in the presumption that the Ladakh plant beds may be detached fragments of Gondwana sediments from the northern margin of the Gondwanaland which is supposedly represented in the Muktinath area of western Nepal (Colchen, 1975). However, neither the Ladakh nor the Nepal floral assemblage has a single genus which is restricted only to Gondwana formations. In fact, Barale *et al.* (1978) while comparing the Nepal assemblage with the Rajmahal one did not find definite Gondwanian link. Thus, while it is possible that the Kagbeni and the Loma floral assemblages may have some inter-relationship, the question of their having genetic affinity with the Gondwana flora is still wide open. In this connection it would be worthwhile to make elaborate megafossil collections from other hillocks in the Ladakh area as well as from Kagbeni. Palynological studies of the carbonaceous shales may also be undertaken.

Mesozoic sediments of Ladakh have also yielded algal fossils. Pascoe (1959, p. 1319) recorded the presence of the dasycladaceous alga *Neomeris* in a limestone in the Lingzi Thang area. Pal and Chatterji (1978) have reported a varied algal flora from two horizons of the Indus Flysch Formation, viz., *Orbitolina* limestone near Khalsi (Albian-Cenomanian) and fossiliferous limestone exposed in Raldong Nala near Samdo (Campanian-Maestrichtian). According to Pal and Chatterji (1978) 'the rocks are much disturbed and some imes recrystallized to obliterate the structural details of the fossils'. As such it is difficult to say as to how much reliance can be put on their taxonomic identifications. Following is the list of algal taxa: *Acicularia* sp. cf. *A. comanchense* Johnson, *A. khalsiensis* Pal & Chatterji, *Neomeris deterrae* Pal & Chatterji, *Cayeuxia fruticulosa* Johnson, *Cayeuxia* sp., *Lithophyllum* sp. cf. *L. antiquum* Lemoine, *Thaumatoporella* sp., *Permocalculus budaensis* Johnson, *P. ladakhensis* Pal & Chatterji, *P.* sp. cf. *P. texana* Johnson, *Gymnospora indica* Pal & Chatterji. The authors conclude that the algae were deposited in the shallower part of the continental shelf.

PALYNOMORPHS FROM THE TETHYAN ZONE

As far as palynological studies of the Mesozoic sediments of the Tethyan realm are concerned, to my knowledge there are reports from two areas only.

Lukose (1964) reported a 'striated' spore from the 'Upper Mesozoic' of Wakkachu traverse between Kargil and Pashkyum, Ladakh which he named as *Schizea kashmiriensis*. This sporomorph was later renamed as *Schizaeasporites kashmiriensis* by Ghosh and Lukose (1967) who published an illustrated account of the palynomorph assemblage for which they assumed an Upper Jurassic to Middle Cretaceous age. According to Bhandari *et al.* (1977) the palyniferous sample (D5565) originated from the Middle Member of the 'Ladakh Molasse Group' of Tewari (1964). The authors call this member as the Tarumsa Formation. A palynological re-examination of the samples carried out by Bhandari *et al.* has shown the presence of advanced angiospermic pollen associated with typical Upper Mesozoic forms such as *Neoraistrickia*, *Ceratosporites*, *Araucariacites*, *Allsporites* and *?Callialasporites*. The Mesozoic forms have been interpreted as reworked into younger sediments. On the basis of the new angiospermic finds the age of the Tarumsa Formation is taken to be Eocene-Miocene.

The other record of the Mesozoic microfossils in the Tethyan realm is from the Malla Johar area, Pithoragarh District, Uttar Pradesh (Jain *et al.*, 1978; Tiwari *et al.*, 1980). Tiwari *et al.* (1980) have reported pollen and spores from the Upper

Triassic-Upper Jurassic succession. Following is the list of genera recorded by them:

Tetraporina Naumova
Platysaccus Naumova ex Potonié & Klaus
Klausipollenites Jansonius
Callumispora Bharadwaj & Srivastava
Maculatasporites Tiwari
Alisporites Daugherty
Lundbladispora Balme emend. Playford
Parasaccites Bharadwaj & Tiwari
Lophotriletes Naumova emend. Potonié & Kremp
Lunatisporites Leschik emend. Scheuring
Striatopodocarpites. . . . ?
Callialasporites Sukh-Dev
Cycloverrutriletes Schulz
Deltoidospora Weyland & Krieger emend. Dettmann

There is an illustration of the genus *Densisporites* (pl. 1, fig. 5) but it does not find a mention in the text.

The oldest Mesozoic formation which has yielded palynomorphs is the Kuti Shale (Norian). Palynomorphs have not been nomenclaturally identified except for the genus *Klausipollenites*. Passage Formation (Norian) also has *Klausipollenites* and certain other non-striate bisaccate pollen. The Kioto Limestone (Rhaetic) has genera such as *Callumispora, Maculatasporites, Alisporites, Lundbladispora, Parasaccites, Lophotriletes, Lunatisporites* and *Striatopodocarpites*. This assemblage in a way indicates an age not younger than the Permian. Unfortunately, two genera, which could thrust the assemblage into the Triassic have not been illustrated. The Spiti Shale (Portlandian) has *Deltoidospora, Cycloverrutriletes, Callialasporites* and *Platysaccus* alongwith unidentifiable non-striate disaccate pollen. Except for '*Callialasporites*' none of the other taxa has any significance as age determiner.

Tiwari *et al.* (1980) while accepting the difficulty in working out the affinities of the Spiti Shale mioflora have presumed a Gondwanic affinity for the Upper Triassic miofloras. Now do we really have a convincing evidence for this? The Kioto Limestone mioflora has to be ruled out of this discussion as it could as well be a reworked one, particularly if the age of the Kioto Limestone is accepted to be Rhaetic on other evidences.

As far as the Kuti Shale and the Passage Formation are concerned the only worthwhile record is of the genus *Klausipollenites* which has been taken as an indicator of Gondwanic affinity. But it has a wide horizontal and vertical distribution as is also accepted by Tiwari *et al.* (1980, p. 41, para 1). They base their argument on the basis of definite occurrences of this genus in the Triassic sediments of peninsular India. But they do not tell us if the genus is absent in the Euramerican or the Angaran Triassic. I may add that our work on the Upper Triassic miofloras of South Rewa Gondwana Basin has shown the presence of typical Euramerican elements there (Maheshwari & Kumaran, 1979; Kumaran & Maheshwari, 1980). I have examined the slides and am not fully convinced of the presence of *Klausipollenites* in the Malla Johar samples. The specimen referred to *Striadopodocarpites* (pl. 1, fig. 13) does not show any apparent striations. *Cycloverrutriletes* and *Deltoidospora* are wrongly identified. Miospore A (pl. 1, fig. 24) is a foraminifer. On the other hand, specimens of modern organisms are present on some of the slides (see pl. 1, figs 15, 18, 19), e.g. pollen of *Pinus*, fungal bodies, etc. Certain peculiar structures, variously referred to as acritarchs or hystrichosphaerids are also seen. Overall, the Malla Johar spore and pollen assemblage is very poor in quantity and quality.

Dinoflagellate cysts recorded from the Spiti Shale of Malla Johar (Jain *et al.*, 1978) are also not well-preserved but are characteristic enough for age determination. Important dinocyst taxa recorded are:

Oligosphaeridium anthophorum (Cookson & Eisenack) Davey
O. pulcherrimum (Deflandre & Cookson) Davey & Williams
Lithodinia sp.
Sentusidinium spp.
Pareodinia ceratophora Deflandre
Prolixosphaeridium sp. cf. *P. torynum* (Cookson & Eisenack) Eisenack & Kjellstrom
Gonyaulacysta jurassica (Deflandre) Norris & Sarjeant
Tubotuberella apatela (Cookson & Eisenack) Ioannides *et al.*
Adnatosphaeridium aemulum (Deflandre) Williams & Downie

Oligosphaeridium dictyophorum (Cookson & Eisenack) Davey & Williams, and
Omatia montgomeryi Cookson & Eisenack

Mehrotra and Sinha (1980) have discovered dinoflagellate cysts from the Sangcha Malla Formation of Malla Johar. Some authors have raised Sangcha Malla to the rank of a group which includes a lower Jhangu Formation and an upper Balcha Dhura Formation. Mehrotra and Sinha report does not give precise information about the stratigraphic location of the samples within the Sangcha Malla Formation (or group), but possibly the samples represent both Jhangu and Balcha Dhura formations. According to Mehrotra and Sinha (1980) the microplankton found by them indicate an Upper Cretaceous age for the former and possible Eocene age for the latter. It may be of interest to recall that Jain *et al.* (1978) found no dinoflagellate cysts in the Sangcha Malla Group, but they recovered a rich radiolarian assemblage which suggests a Cretaceous 'affinity' even for the Balcha Dhura Formation. In the absence of illustrations, it is not possible to verify the dinoflagellate identifications and hence are listed below:

Odontochitina cribropoda Deflandre & Cookson
Systematophora schindewolfi Neale & Sarjeant
Oligosphaeridium complex Davey & Williams
Diphyes colligerum Davey & Williams
Cordosphaeridium inodes (Klumpp) Davey & Williams
C. exilimurum Davey & Williams
Acrosphaeridium diktoyplokus Eaton
Hystrichokolpoma Klumpp
Hystrichosphaeridium Deflandre emend. Davey & Williams
Homotryblium Davey & Williams
Cleistosphaeridium Davey *et al.*
Gonyaulacysta Deflandre

PLANT MEGAFOSSILS FROM THE HIMALAYAN ZONE (LESSER HIMALAYA)

Mesozoic plant fossils in the Lesser Himalaya were first reported by Wadia (1919) in the form of impressions on black shales of the Lower Tals. No details of this report were probably ever published.

Bhargava (1969) reported "algal pisolites" from the Krol E of Nigali Synform, Himachal Pradesh.

Raha and Gururaja (1970) found stromatolites associated with the Mussoorie Phosphorite Member, till then believed to be the basal unit of the Tal Formation. Raha (1971) designated the Phosphorite Member as the topmost unit of the Krol Formation in the Mussoorie area. Raha (1971) recognised 5 types of stromatolites which he thought "appear to have affinity with the late Palaeozoic to early Mesozoic forms". It would, however, seem that his remarks on the age were interpolated on the basis of data other than his own.

Mithal and Chaturvedi (1972) reported the occurrence of certain peculiar structures in the limestones of the upper Krols, possibly Krol C, exposed on the Rajpur-Mussoorie Mule Track south-east of Mussoorie Town. The authors compare these structures with the external form of the red algae Solenoporaceae. These structures are vaguely similar to Bird's eye structure of Pisolitic dolomite (see Singh *et al.*, 1980, pl. 1, fig. 2; pl. 2, fig. 4).

Fuchs and Sinha (1974, p. 573) reported the occurrence of high growing branching stromatolites in the Krol E near All Saint's College, Nainital. Singh and Rai (1977) have recorded the presence of stromatolite taxa *Conophyton garganicus* Koroljuk, *Colonella* sp. and *Baicalia baicalica* Krylov from the Upper Krol sediments of Nainital area. This find is considered as indicative of a middle Riphean age for the Krol Formation.

However, calcareous algae reported by Kumar (1978) from the oolitic limestone of Krol D exposed near Solan, Himachal Pradesh apparently do not indicate an age older than Permian. The taxa listed by Kumar (1978) are:

Dvinella comata Khvorova
Sphaerocodium bornemanni Rothpleitz
Atractyliopsis sp.
Girvanella sp.
Permocalculus sp.
?*Zaporella* sp.
Diplopora annulata (Schafh), and
Teubiphytes sp.

He concludes that ' on the basis of overlap of the recorded ranges of all the discussed species of algae found in Krol limestone, it can be inferred beyond doubt that the age of Krol Formation is not older than Permian. It is likely that this sequence may be Permo-Triassic although the upper limit is open to discussion'. I have a query. Is it possible to infer the age of a great thickness of sediments simply by computing the age of a part at the top ?

Patwardhan (1978) reported the discovery of fossils belonging to the problematic group 'Moravamminids' from the chert-Phosphorite horizon of the Lower Tals of Mussoorie area. Bhatia (1980, p. 81) believes that these fossils 'can, with equal certainty, be assigned to certain Jurassic-Cretaceous dasycladacean algae' — *Cylindroporella* Johnson. According to Bhatia (1980), certain animal fossils reported by Ahluwalia (1978) from the same horizon are infact algae. While *Palaeobiogerina* (?) of Ahluwalia (1978, fig. 1b) is same as the Patwardhan fossil, *Archaediscus* (?) and indeterminate *Pachyphloia* (Ahluwalia, 1978, fig. 1a, c) 'appear to be close to distorted sections through discs or primary branches of *Clypenia*, a Jurassic-Palaeocene alga'. Bhatia goes on to suggest a Lower Cretaceous age for the Lower Tal. However, the carbonaceous shales of Lower Tals have yielded the lamellibranch *Posidonia*, and were assigned a Jurassic age (Shrivastava, 1972). The genus *Posidonia* ranges in age from Lower Carboniferous to Upper Jurassic.

Tewari and Kumar (1967) recorded algal fossils (*Neomeris*) from the shell limestone at Nilkanth. This limestone constitutes the topmost unit of the Upper Tal Member of the Tal Formation and has been named as the Manikot Shell Limestone by Dhaundiyal and Kumar (1976, cited in Kumar & Dhaundiyal (1980)). Some authors have raised this limestone to the status of a formation, e.g. Nilkanth Formation of Singh (1974, in Mussoorie-Nilkanth area), Singtali Formation of Mehrotra *et al.* (1976, at Singtali). Singh (1979) believes that this limestone unit is not a part of the Tal Formation *sensu stricto* and is actually separated from the latter by a major hiatus. Bhatia (1980) sounds sceptic about Singh's hypothesis.

Kalia (1974, 1976) reported an algal assemblage from the Manikot Shell Limestone exposed in the southern limb of the Garhwal Syncline near Bansi in the Dugadda area. She identifies the presence of following taxa:

Parachaetes lamellatus Konishi
Gymnocodium bellerophontis (Rothpleitz) Accordi
Permocalculus anantii Kalia
Anthracoporella spectabilis Pia
A. mercuri Elliott
Mizzia bramkampi Rezak
Pseudoepimastopora sp. cf. *P. likana* (Kochansky & Harak) Elliott
Pseudovermiporella sodalica Elliott
P. cylindrica Kalia
Diplopora
Velebitella triplicata Kochansky-Devide
Epimastopora
Hikorocodium elegantae Endo
H. sp. cf. *H. transversum* Endo, and
Ortonella morikawae Endo

According to the author algal forms are indicative of a Permian (Guadalupian) age. Algae have also been reported from the Manikot Shell Limestone exposed in the northern limb of the Garhwal Syncline near Singtali on Rishikesh — Dev Prayag road (Mehrotra *et al.*, 1976). Following taxa are described and illustrated:

Gymnocodium bellerophontis (Rothpleitz) Pia
G. sp. cf. *G. nodosum* Ogilvie-Gordon
Permocalculus forcepianus (Johnson) Elliott
Parachaetes sp.
Anatolipora singtaliensis Mehrotra *et al.*
Clavaphysoporella elegantonmulata (Endo & Kanuma) Endo
Eogoniolina sp. cf. *E. undulata* Endo
Epimastopora sp.
Gyroporella symmetrica Johnson
Mizzia velebitana Schubert
Oligoporella nipponica Endo
Pseudoepimastopora krishnaswamyi Mehrotra *et al.*
Anchicodium sp.
Hikorocodium transversum Endo
Ortonella gracilis Johnson, and
Succodium hikorocoides Endo

Just like Kalia (1976), Mehrotra *et al.* (1976) also believe that the Manikot Limestone algae are suggestive of a Permian age. According to the latter authors the presence of *Mizzia velebitana* clearly indicates an Upper Permian Age. This created an anomalous situation as till then the age of the Tal Formation was believed to be between Triassic and Cretaceous. To counter this anomaly Mehrotra *et al.* (1976) came out with an interesting hypothesis that 'the Garhwal Thrust probably passes below the Singtali Formation and that the Singtali Formation (a part of Tal Formation of earlier workers) should be included into the Lower Binji unit of RAVI SHANKAR and GANESHAN (1973)'. However, Kumar and Dhaundiyal (1980, p. 65) consider that the limestone at Singtali is of the same age as the Manikot Shell Limestone.

Bhatia (1980) has analysed the taxonomy of algal forms reported by Kalia (1976) and Mehrotra *et al.* (1976). From his report it would seem that there are only three species of algal fossils. Rest are animal fossils. The algal species recognized by Bhatia are:

1. *Archaeolithothamnium* sp.
    - 1969 *Lithothamnium nilkanthensis* Tewari & Kumar, *nomen nudum*
    - 1974 *Misellina* sp.: Kalia, pl. 1, fig. 3.
    - 1976 *Parachaetes* sp.: Mehrotra *et al.*, pl. 1, fig. 5.
    - 1980 *Archaeolithothamnium* sp.: Bhatia, fig. 3, p. 6.
2. *Halimeda* sp.
    - 1974 *Neoschwagerina* cf. *N. craticulifera* (Schwager): Kalia, pl. 1, figs 4-6.
    - 1976 *Hikorocodium elegantae* Endo: Kalia, pl. 3, figs 3, 4.
    - 1976 *Gymnocodium bellerophontis* (Rothpleitz) Pia, 1920: Mehrotra *et al.*, pl. 1, fig. 1.
    - 1976 *Gymnocodium* cf. *nodosum* Ogilvie-Gordon: Mehrotra *et al.*, pl. 1, figs 2, 3.
    - 1976 *Clavaphysoporella elegantannulata* (Endo & Kanuma) Endo, 1961: Mehrotra *et al.*, pl. 1, fig. 8.
    - 1980 *Halimeda* sp.: Bhatia, figs 1, 4a, c.
3. *Neomeris* sp.
    - 1976 *Pseudoepimastopora* cf. *likana* (Kochansky & Herak) Elliott: Kalia, pl. 2, figs 7, ?8.
    - 1976 *Eogoniolina* cf. *E. undulata* Endo, 1957: Mehrotra *et al.*, pl. 2, fig. 14.

These algal remains alongwith animal fossils such as, *Millepora*, *Diplocava*, *Corymbopora* and echinoid spines are said to indicate a Maestrichtian-Danian age (Bhatia, 1980, p. 94).

PALYNOMORPHS FROM THE HIMALAYAN ZONE (LESSER HIMALAYA)

The first microfossils from the Lesser Himalaya were reported from the carbonaceous shale assumed to be belonging to the Krol 'Series' (Sitholey *et al.*, 1954). As the Krols were till then understood to be totally unfossiliferous, there probably was a nagging doubt in the mind of the authors about the genetic relationship of this carbonaceous shale.

The area was therefore revisited twice to ascertain the exact source of the carbonaceous shale. According to Lakhanpal *et al.* (1959) the carbonaceous shale is exposed in a gulch where the rock sequence is disturbed by local slips and displacements. 'The shale bed is intercalated with bluish limestone and purple, grey and green shales. These beds overlie quartzites and greyish slates exposed along the road cutting near the main boundary fault separating these older formations from the Tertiary Nahan sandstones'. They placed the carbonaceous shale in Krol A. However, later authors have placed the carbonaceous shale in the Infra-Krol (Fuchs & Sinha, 1974; Bhargava, 1979).

Whereas Sitholey *et al.* (1954) found only a few palynomorphs alongwith pieces of tracheids and cuticles, Lakhanpal *et al.* (1959) listed 18 species of miospores, one seed type, and 4 types each of tracheids and cuticles. Sah *et al.* (1968) reinvestigated the mioflora and recognized 13 genera of palynomorphs. Unfortunately they did not go into taxonomy at the species level. Following is a list of species identified by Lakhanpal *et al.* with nomenclatural changes and modifications by Sah *et al.*

Lakhanpal *et al.*, 1959	Sah *et al.*, 1968
Calamospora sp.	*Calamospora*
Planisporites parvus	*Apiculatisporites*
Dictyotriletes sp.	
Laevigatosporites minor	*Laevigatosporites*
Striatites sewardii	*Striatites*
S. renisaccatus	*Striatites*
S. kumaonensis	
Striatites sp.	
Lunatisporites sp.	*Striatopiceites* sp.
Striatopodocarpites fusus	*Strotersporites*
S. gondwanensis	
Pityosporites potoniei	*Cuneatisporites*
P. (*Florinites*) *ovatus*	*Sulcatisporites*
Succinctisporites ovalis	
Alisporites phaseolasaccatus	*Alisporites*
Platysaccus tenuis	
P. crassimarginatus	*Triadispora*
Platysaccus sp.	
	Platysaccus
	Voltziaceaesporites
	cf. *Schizopollis*

According to Sah *et al.* (1968) the assemblage is dominated by non-striate bisaccate pollen. This plus the presence of the genera *Voltziaceaesporites* and *Triadispora* lead them to presume a lowermost Triassic age for this mioflora. In its looks the mioflora is strikingly similar to that of the Raniganj Formation of peninsular India. I, therefore, decided to verify the taxonomic identifications. Unfortunately it would seem that the material and the slides have either been misplaced or lost and are not available for study.

In this connection it will be in order to recollect that Tewari and Singh (1980) have deduced a Permian age for the Infra-Krol on the basis of a varied megaflora collected by them from the Infra-Krol sediments of the Jeolikot-Bhowali section. This find lead them to postulate 'that the lower age limit of the Krol Formation cannot go beyond the Triassic period as the immediately underlying Infra-Krol sediments are positively of Permian age'. I do not agree. To say that the Infra-Krols are of Permian age is not sufficient to postulate on the age of the Krols. We should know which stage or which part of the Permian is represented by the Infra-Krols ? If the list of megafossils given by Tewari and Singh (1980) is taken at its face value then the assemblage may not be younger than the Lower Permian meaning thereby that the Krol sedimentation started within the Permian. But one solitary report can not be taken as a basis for assigning age to a complete unit. One does wish that Tewari and Singh had given the exact geographical and stratigraphical location of their specimens. The megaflora reported by Tewari and Singh could have come from the same bed from which Sitholey *et al.* got microfossils. In view of great importance of the megafossil find the specimens should have been described and illustrated in detail and with precision. Publication of good illustrations can not but be overemphasized because not every body gets a chance to have a look at the original specimens for verification of taxonomic identifications. For example, Shrivastava and Venkataraman (1975) have reported a mioflora from the Blainis and assigned it a Carboniferous age. However, reproduction of their photo-illustrations is such some of the forms look those of the Mesozoic *Circulina-Classopollis* complex. Had the illustrations been good there would not have been a doubt.

There are a couple of reports on the occurrence of nannofossils in the Krol sediments. Tewari (1969) reported nannofossils from the contact of Krol B and Krol C of the Solan area. Sinha (1975) reported the presence of nannofossils in the green shale of Krol B exposed in the south-eastern flank of Pachmunda Syncline near Solan, Himachal Pradesh. He identifies the following types:

Zygolithus concinnus Martini
Tetralithus sp. cf. *T. gothicus* Deflandre
Lucianorhabdus cayeuxi Deflandre
Micula staurophora Vekshina
Lithraphidites carniolensis Deflandre
Discorhabdus sp.
Deflandrius sp.
Tergestiella margereli (Noel) Reins, and
Microrhabdus orbitosus Shumenko

On the basis of the occurrence of the above nannofossils Sinha (1975, p. 75) suggests 'that the stratigraphic range of Krol B horizon extends from Oxfordian (J_3Oxf) to Danian (Cr_2dn)'. However, from the chart showing stratigraphic distribution of different species (Sinha, 1975, p. 76, fig. 5) it is clear that the age of the nannofossil assemblage under question could only be from Coniacian to Campanian. But, the Himalayan question is how many of these forms are really nannofossils ? According to Jafar (1980) "Among four forms documented under the high-power light microscope, only single one is genuine but indeterminate coccolith; the biogenic nature of other three remains doubtful. All the three forms documented under the transmission electron microscope are true coccoliths but only a single form permits specific identification with known range of upper Tithonian-Campanian".

Ghosh and Srivastava (1962) reported palynomorphs from the Infra-Krol, Krol and Tal formations. The samples came from the section along Rajpur-Mussoorie Mule Track, but they have not given the exact locations of their samples. They referred the palynomorphs to the families Schizaeaceae, Polypodiaceae, Selaginellaceae, Podocarpaceae and Pinaceae. However, from the photographs these forms seem to have a three-dimensional figure on a scale much more than I have ever observed in Palaeozoic or Mesozoic palynomorphs. By referring these palynomorphs to extant families of plants, the authors have, probably unintentionally, projected the true picture that the forms are contaminants, either from recent or sub-recent deposits.

Recently Geological Survey of India (in Roy Chowdhury, 1979) have reported plant microfossils from the Krol and the Tal. However, as no descriptions or illustrations are given the report is presented here for whatever it is worth.

The Lower Tal shales at Durmala, Mussoorie Synform, Uttar Pradesh contain mainly algal and fungal remains, hystrichospheres, some acritarchs and a few pteridophytic spores. A few tricolpate grains with faint colpi have also been found. The microflora is assigned a post-Jurassic age.

The Lower Tals at Maldeota, Mussoorie Synform contain acritarchs, spores and pollen grains, fungal spores and wood tracheids with simple as well as bordered pits. The taxa are:

Baltisphaeridium, Crossosphaera, Cymatiosphaera, Granodiscus, Leiosphaeridia, Micrhystridium, Tasmanites, Laevigatosporites, Polypodiites, Schizaeosporites, Foveomonolites, Triletes, etc.

Bisaccate pollen allied to Podocarpaceae and tricolpate grains like *Castanea* are most significant in this assemblage. An Upper Jurassic-Lower Cretaceous age is assigned.

DISCUSSION

From the foregoing it is evident that as far as Mesozoic Palaeobotany of the Himalayas is concerned, not much work has been done and whatever has been done, most of it is open to doubt or to more than one interpretation. In the Tethyan Himalaya, of course, we have the satisfaction of knowing that undoubted megaplant remains of Mesozoic age do occur. The reports of Mesozoic plant microfossils in the Tethyan Himalayan Zone are also reliable, though there definitely is some reworking. The genetic affinity of the Tethyan Himalayan sediments, however, is a different matter altogether. I agree with Barale *et al.* (1978) that there are no compulsive evidences to believe that the Kagbeni flora has a Gondwanic affinity. Similarly I find no evidence to guide me to believe that the Ladakh megaplant remains or the Malla Johar microflora has exclusive Gondwanian relationship. But all the same these finds are interesting and most encouraging. These suggest that fossils are there for one with a will to find them.

As far as the Lesser Himalayan Zone is concerned, the situation is rather complex. There is as yet no concensus as to whether Mesozoic sedimentation took place in the area or not. Usually Nagthat, Blaini and Infra-Krol were considered to be of Palaeozoic age, while Krol and Tal were taken as representing the Mesozoic sediments. Of course fossil finds have been variously interpreted to suit one's own fancy about the age of the Krol and the Tal formations. Some examples!

Lakhanpal *et al.* (1959) palynologically dated the Krol A carbonaceous shale of the Nainital area (laterly supposed to be within the Infra-Krol) as of Permian age. A restudy of the same slides suggested a lowermost Triassic age to Sah *et al.* (1968). Meanwhile Ghosh and Srivastava (1962) had earlier dated Krol A and Krol D as of Triassic age on the basis of certain pollen types, which I am afraid have been derived from recent or subrecent sediments. Sinha (1975) believes that the Krols may be even younger in age and that the Krol B red shale extends from Oxfordian to Danian. On the other hand, there are reports of the occurrence of middle Riphean columnar stromatolites in the Upper Krol (Singh & Rai, 1977) to the occurrence of Mississipian stromatolites and Precambrian algal oncolites in Krol D (Bhargava, 1979). The whole situation is confounded by the reported failure of Austrian palaeontologists to find any thing but 'primitive' forms of no stratigraphic significance in the Krols (Fuchs & Sinha, 1974). It should be remembered here that Lakhanpal *et al.* (1959) and Sah *et al.* (1968) also could not recover any microflora from the Blaini Boulder Bed, Infra-Krols and Krol of the Sirmur, Simla, Chakrata, Mussoorie and Nainital areas, except for that one lucky find, from near Brewery.

Situation is not much encouraging in the Tals too. Ghosh and Srivastava (1962) date the Lower Tal as Jurassic on the basis of a single 'schizaeaceous' spore which most probably belongs to an extant plant. Shrivastava and Mehrotra (1974) report that they have found some angiospermous pollen in the Lower Tals and hence these could be as young as Albian-Late Aptian. Kalia (1974, 1976) and Mehrotra *et al.* (1976) put up a strong case for an Upper Permian age for the overlying Upper Tal. Thus, we had a situation where the lower sediments were seemingly younger than the upper sediments. So, Bhargava (1979) came up with an original idea that may be after all the fossils reported by Kalia, and Mehrotra *et al.* did not originate in the Shell Limestone but in the allochthonous Boulder Slate of the Bijni Unit. Thus if we accept Bhargava's opinion about the Shell Limestone fossils and my own views about the Ghosh and Srivastava microspore, then the Tal become devoid of any known plant fossils. But, Bhatia (1980) would like us to believe that only if the fossils were correctly identified there would not have been an incongruity about the age of the Upper Tal which he feels is Maestrichtian-Danian. On the other hand Kumar (1980) opines that 'some part of Tal Formation may be Pre-Cambrian in age'. His opinion is based on the report of a stromatolitic limestone from the lower part of the Tal Formation at Pasi Tiba, near Mussoorie (Sharma, 1976).

From Bhatia's (1980) discourse one point emerges very distinctly that in the Lesser Himalaya the palaeontologists are having difficulty in deciding fundamental questions, such as whether a 'fossil' is actually a fossil or not, and if it is a fossil, whether it is an animal fossil or a plant fossil. Here I have in mind Mithal and Chaturvedi's Solenoporaceae, Kalia's fusilinids and algae, Mehrotra *et al.*'s algae and Patwardhan's motavamminids. Sinha's nannofossils also come within the ambit of this comment.

Seeing all these pitfalls, I feel that in a complicated area like the Himalaya, only a multidisciplinary concerted effort may take us out of the Lesser Himalayan tangle. It should involve a large scale remapping, establishment of type and reference sections, systematic collection of stratigraphically located samples in a profile, fool-proof laboratory processing and a little conservatism in arriving at conclusions. All the reported fossil finds must be verified at more than one laboratory.

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TERTIARY PLANT MEGAFOSSILS FROM THE HIMALAYA — A REVIEW*

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ABSTRACT

The paper presents a critical review of the Tertiary plant megafossils from the Himalaya falling within the Indian territory. The floral assemblages can be conveniently grouped into two: (i) the pre-Siwalik flora, and (ii) the Siwalik flora. The pre-Siwalik Tertiary plants are poorly preserved and comprise monocotyledonous leaf-impressions assigned to the genera *Sabalites* (palm or palm-like leaves) and *Poacites* (grass-like leaves), and a few dicotyledonous leaves placed under the genus *Dicotylophyllum*. The Siwalik flora, so far known, consists of both monocotyledonous and dicotyledonous leaf-impressions, petrified woods, a few seeds and some fresh water algal remains belonging to Charophyta. The physical conditions around the area of deposition of the plants have been discussed briefly in the light of the distribution of their modern equivalents. The scope and the importance of further studies of fossil plants of the Himalaya have been discussed.

Key-words — Megafloristics, Palaeoecology, Tertiary, Himalaya (India).

सारांश

हिमालय से तृतीयक युगीन गुरु-पादपाश्म : एक समीक्षा – नीलाम्बर अवस्थी

प्रस्तुत शोध-पत्र में हिमालय के भारतीय-क्षेत्र से प्राप्त तृतीयक युगीन गुरु-पादपाश्मों की समालोचना की गई है। वनस्पतिजात समुच्चयों को सरलता से दो समूहों – (अ) पूर्व-शिवालिक वनस्पतिजात, तथा (आ) शिवालिक वनस्पतिजात – में रखा जा सकता है। पूर्व-शिवालिक के तृतीयक युगीन पादपाश्म कम परिरक्षित हैं। इन पादपाश्मों में सेबेलाइटिस (ताड़ या ताड़-सदृश पत्तियाँ) एवं पोआसाइटिस (घास-सदृश पत्तियाँ) नामक प्रजातियों से नामांकित एकबीजपत्री पर्ण-छापें तथा डाइकोटिलोफ़िल्लम् प्रजाति के अन्तर्गत रखी गई कुछ द्विबीजपत्रीय पत्तियाँ सम्मिलित हैं। अभी तक ज्ञात शिवालिक वनस्पतिजात में एकबीजपत्री एवं द्विबीजपत्री पर्ण-छापें, अश्मीभूत काष्ठ, कुछ बीज तथा केरोफ़ाइटा से सम्बन्धित कुछ अलवणी शैवालीय अवशेष सम्मिलित हैं। पादपाश्मों के वर्तमान समतुल्यों का वितरण ध्यान में रखते हुए निक्षेपण के क्षेत्र के आस-पास की भौतिक परिस्थितियाँ संक्षिप्त रूप से विवेचित की गई हैं। हिमालय से प्राप्त पादपाश्मों के और अध्ययन के महत्व एवं सीमा भी विवेचित किये गये हैं।

INTRODUCTION

IN the Himalaya the Tertiary rocks of all stratigraphic units are found throughout its length, extending from Nanga Parbat in the west to Namcha Barwa Peak in the east. The early part of the sequence (Eocene) consists of marine facies, whereas the later part is characterised by estuarine, fluviatile and lacustrine deposits formed during intervals of different phases of the Himalayan upheaval.

The first information about the occurrence of plant fossils in the Tertiary sediments of

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the Himalaya dates back to 1864 when Medlicott in his memoir on "The sub-Himalayan ranges between Ganges and Ravi" mentioned the occurrence of leaf-impressions in the Kasauli Hills. In subsequent years various other geologists also pointed out the presence of petrified woods and leaf-impressions in the Siwalik beds of the foot-hills. In spite of the sufficient information available, the Tertiary plants of the Himalaya remained almost uninvestigated until quite sometime back. Perhaps this may be due to the fact that the main interest of the earlier workers had been the study of the Deccan Intertrappean flora, being the oldest and the best preserved of the Indian Tertiary.

During the last two decades detailed mapping of the Himalayan region, especially the foot-hills, done by the Oil and Natural Gas Commission for exploration of oil and gas, has provided ample information regarding the occurrence of plant fossils in the Siwalik beds. This was substantiated by various palaeontologists who, in the quest of animal fossils, happened to come across the fossiliferous outcrops from time to time. In recent years attempts have been made successfully to collect and investigate systematically the Tertiary plant megafossils of the Himalaya by various workers. A critical review of the plant megafossils, so far known, is presented in the present paper incorporating all the available information with regard to the fossil localities and plants preserved therein.

FLORISTIC COMPOSITION

The floral assemblages from the Himalayan Tertiary sediments can be conveniently grouped into two: (i) the pre-Siwalik flora, and (ii) the Siwalik flora.

Pre-Siwalik Flora

The pre-Siwalik Tertiary sediments in the Lesser Himalayan zone of the western region constitute the lower part of the Cenozoic which includes Subathu, Dagshai and Kasauli formations, ranging in age from Palaeocene to Miocene. The Kasauli Formation in the Dharamsala area of the Kangra District are classified as part of the Dharamsala Group, whereas in the Jammu area these sediments constitute part of the Murree Group. In the Tethys Himalaya they are represented by the Nummulitic Limestone and associated rocks in the Upper Ladakh corresponding to the Subathu Formation (Eocene) overlain by Ladakh Molasse belonging to Oligo-Miocene.

The Early Tertiary sediments belonging to marine facies are poorly represented by plant megafossils. The only fossil plant hitherto known is an alga, *Lithoporella melobisoides* (Foslie) Foslie belonging to the class Rhodophyta, described by Pal and Chatterjee (1978) from the Nummulitic shales and limestones of Palaeocene to Eocene horizon of the Mahe and Nida Valley, Ladakh.

The plant megafossils of the later part of the Pre-Siwalik sediments comprise dicotyledonous and monocotyledonous leaf-impressions which have been reported from the Kasauli Formation. The earliest known fossils are some leaf-impressions of palm, collected by Medlicott (1864) from the Kasauli beds of the type area Kasauli, which were briefly described by Kane (in Medlicott, 1864, pp. 97, 98) as cf. *Flabellaria raphifolia* Stbg. These were later figured and referred to *Sabal major* Heer by Feistmantel (1882, figs 3-5). In a posthumous paper, Sahni (1953) described three ill-preserved dicotyledonous leaf-impressions under the non-committal genus *Dicotylophyllum* and a parallel ribbed impression probably belonging to a fan palm which he collected from near Kasauli club. In the same paper he refigured *Sabal major* (Sahni, 1953, pl. 1, fig. 1). Again in 1964, Sahni renamed the above palm leaves as *Sabalites microphylla* and *Sabalites* sp. (see Table 1).

From Banog Grahat on the left bank of Koshalya River, another fossil locality in the Simla Hills, Chaudhri (1969) described a few badly preserved leaves which he has referred to palms and dicotyledons in general.

There are a few preliminary report on the occurrence of plant-remains in the Dharamsala beds of Himachal Pradesh. Gupta and Jiwan (1972), in a note, reported some leaf-impressions from near Namhol, about 26 km from Bilaspur on Bilaspur-Simla Road. They identified one of the leaves as *Ficus cunea*, but no description and photographs have been given. In his book, Gupta (1976, p. 36) has mentioned that the monocotyledonous leaves (*Palmophyllum* spp.) *Dicotylophyllum* and woody tissues are also

TABLE 1 — PLANT MEGAFOSSILS FROM THE PRE-SIWALIK SEDIMENTS

FOSSIL	LOCALITY	HORIZON/ FORMATION/ SERIES/STAGE	REFERENCE
ALGAE			
I. CHAROPHYTA			
1. *Grambastichara* cf. *G. cylindrica* (Madler) Horn af Rantz.	Mangunor, near Kargil, Ladakh	Wakka Formation	Tewari & Sharma, 1972b
2. *Grambastichara* cf. *G. tornata* (Reid & Groves) Horn af Rantz.	do	do	do
3. *Harrisichara* cf. *H. vasiformis* (Reid & Groves)	do	do	do
II. RHODOPHYCOPHYTA			
1. *Lithoporella melobesioides* (Foslie) Foslie	Mahe and Nida Valley, Ladakh	Nummulitic Shale and Limestones (Palaeocene-Eocene)	Pal & Chatterjee, 1978
ANGIOSPERMS			
Monocotyledons			
I. PALMAE			
1. *Sabal* sp.	Between Kargil and Leh, Ladakh	Ladakh Molasse	Drew, 1875 (in Tewari, 1964); Sahni & Bhatnagar, 1958;
2. *Sabalites microphylla* (i) Leaf cf. *Flabellaria raphifolia* Stbg. Kane in Medlicott, 1864, pp. 97-99 (ii) *Sabal major* Heer, Feistmantel, 1882, fig. 3; Sahni, 1953	Kasauli, H.P.	Kasauli	Sahni, 1964
3. *Sabalites* sp. (i) Leaves (in part) cf. *Flabellaria raphifolia* Stbg. Kane in Medlicott, 1864, pp. 97-99 (ii) *Sabal major* Feistmantel, 1882, figs 1, 2, 4, 5	Near Chakoti (Kashmir) on the river Jhelum; Kasauli, H.P.	Murree and Kasauli	Sahni, 1964
4. *Palmophyllum* sp.	Banong Grahat, Koshalya River bank, H.P.	Kasauli	Chaudhri, 1969
5. Leaf fragment cf. Palm	Kasauli, H.P.	Kasauli	Sahni, 1953
II. INCERTAE SEDIS			
6. Plicated parallel veined leaf-impressions	Rajaori, J. & K.	Murree	Sahni, 1953
7. *Poacites Rajaoriensis*	Under the Bridge at Rajaori, J. & K.	Murree	Sahni, 1964
Dicotyledons			
I. MORACEAE			
1. *Artocarpus murreeous*	Liranwali Ban, South of Thannandi, Rajaori Dist., J. & K.	Murree	Sharma & Gupta, 1972
II. INCERTAE SEDIS			
1. *Dicotylophyllum* spp. 1-3	Kasauli, H.P.	Kasauli	Sahni, 1953
2. *Dicotylophyllum* spp. 1-3	Banong Grahat, Koshalya River bank, H.P.	Kasauli	Chaudhri, 1969

found in the Upper Dharamsala Sub-group, but he has not given the locality as to where from these plants were collected.

In the Ladakh Himalaya the pre-Siwalik sediments have yielded a few megafossils. Palm leaves referred to *Sabal* sp. were described earlier by Drew in 1875 (in Tewari, 1964). Later, Sahni and Bhatnagar (1958) also reported a similar fan palm leaf referable to *Sabal* sp., along with fresh water molluscs from south-east of Leh and concluded that these fresh water deposits belong to Eocene. However, Tewari (1964) regarded the sequence of these deposits to Ladakh Molasse which are of Miocene in age. Quite recently Sah and Sharma (1980) also reported a palm leaf from Hemis conglomerate (Oligo-Miocene) of Ladakh. From the freshwater deposits of Wakka River Formation near Kargil, Tewari and Sharma (1972) described 3 species of Charophytic gyrogonites and placed them provisionally under the genera *Grambastichara* and *Harrisichara*. These were found in association of gastropods, vertebrate remains and dicot leaf-impressions. On the basis of these fossils they have suggested the age of the beds as Oligo-Miocene.

From the Jammu and Kashmir Himalaya a fragmentary palm-like leaf having several converging parallel veins undoubtedly belonging to fan palm was reported by Sahni (1964) from the Murree Formation (Lower Miocene) near Chakoti (Kashmir) on the River Jhelum, about midway between Rawalpindi and Srinagar. He (Sahni, 1964) also reported grass-like leaf-impressions of unknown affinities from Rajaori and named as *Poacites rajaoriensis* and *Poacites* sp., In 1962, Sharma and Gupta reported a leaf-impression as *Artocarpus murreecus* from the shale beds exposed near Liranwali Ban, south of Thanmandi in Rajaori District.

In the northeastern India the Tertiary rocks of the Arunachal Pradesh Himalaya were considered to be unfossiliferous until sometimes back. However, recently from the Eocene beds of Dihang Valley in Siang District, Tripathi *et al.* (1979) reported the occurrence of a leaf-impression assigned to *Apocynophyllum* sp. and a few fruits referred to *Canavalia*, *Hicoria*, *Grewiopsis* sp. and *Sophora*. Regarding the identification of these fruits nothing can be said since they are not accompanied by description and figures.

THE SIWALIK FLORA

The Siwalik Group consists of fresh water sedimentary rocks of Middle Miocene to Lower Pleistocene age, massively developed all along the Sub-Himalaya from Potwar Plateau on the north-west to Brahmaputra on the north-east, covering a distance of about 2,400 km in length and 20 to 25 km in width. The stratigraphy of the Siwalik Group has been worked out by several geologists from time to time. Pilgrim (1910) proposed the following classification of the Siwalik Group on the basis of lithology and palaeontology, which has been followed by Sahni and Mathur (1964) and other workers.

Upper Siwalik	Boulder conglomerate Stage Pinjor Stage	Pleistocene
Middle Siwalik	Tatrot Stage Dhok Pathan Stage Nagri Stage	Pliocene
Lower Siwalik	Chinji Stage Kamlial Stage	Middle to Upper Miocene

The rocks belonging to above stratigraphical units have been found very rich in animal as well as plant fossils.

To begin with the plant fossils of the Siwalik Group the Jammu and Kashmir Himalaya have been taken first. So far only a few taxa are known from this region. Sahni (1931, 1964) reported for the first time two petrified palm woods and placed them under the genus *Palmoxylon*. They were collected from the alluvial boulder deposits (Upper Siwalik conglomerate) near Jammu. He also described a grass-like leaf, *Poacites siwalicus*, from the Lower Siwalik (Palandri Formation = Chinji Formation) near Poonch, Jammu and Kashmir. Since then perhaps no further record of fossil plants has been made from this region.

Of the Siwalik beds extending from north-west to north-east those exposed in the foot-hills of Himachal Pradesh and Uttar Pradesh are perhaps the richest in plant fossils. During the last two decades a number of fossil localities have been explored and valuable contributions made to the knowledge of the Tertiary palaeobotany of the Himalaya by various workers.

From a small patch of Lower Siwalik beds exposed at Balugoloa near Jawalamukhi, Lakhanpal (1965, 1967, 1968, 1969) and Lakhanpal and Dayal (1966) described

TABLE 2 — PLANT MEGAFOSSILS FROM THE SIWALIK SEDIMENTS

Fossil	Locality	Horizon/ Formation/ Series/Stage	Reference
ALGAE			
CHAROPHYTA			
1. *Chara contraia* Brain ex Kuetz.	Near Chandigarh	Pinjor	Bhatia & Mathur, 1978
2. *C. rantzieni* (Tewari & Sharma) emend. Bhatia & Mathur Synonym: *Grambastichara rantzieni* Tewari & Sharma *Grambastichara bhatiai* Tewari & Sharma *Tectochara pinjorica* Tewari & Sharma *Tectochara* cf. *T. diluviana* Tewari & Sharma	do	Tatrot and Pinjor	do
3. *C. rantzieni siwalensis* sub-sp.	Near Daulatpur, Kangra Dist., H.P.	Dhok Pathan	Bhatia & Mathur, 1978
4. *C. Surajpurica* (Tewari & Sharma) Bhatia & Mathur Synonym: *Charites surajpurica* Tewari & Sharma	Near Chandigarh and Dhamala, about 6 km NW of Pinjor	Tatrot	do
5. *Chara molassica* (Straub) Horn. af Rantz.	Punyagiri, Tanakpur, U.P.	Kamlial	Lakhanpal *et al.*, 1976
6. *Chara* sp.	Near Chandigarh	Tatrot	Bhatia & Mathur, 1978
7. *Charites indica*	Near Chandigarh	Pinjor	Tewari & Sharma, 1972a
8. *Charites siwalicus*	Punyagiri, Tanakpur, U.P.	Kamlial	Lakhanpal *et al.*, 1976
9. *Hornichara maslovi*	Near Chandigarh and Dhamala, near Pinjor	Pinjor and Tatrot	Bhatia & Mathur, 1978
10. *Raskyaechara purnagiriensis*	Punyagiri, Tanakpur	Kamlial	Lakhanpal *et al.*, 1976
11. *Sphaerochara ralli* (Unger) Horn. af Rantz.	Punyagiri, Tanakpur, U.P.	Kamlial	Lakhanpal *et al.*, 1976
12. *S. tewarii*	Daulatpur, H.P.	Dhok Pathan	Bhatia & Mathur, 1978
13. *S. pecki*	do	do	do
14. *Sphaerochara* sp.	Triloknath and Bharil, H.P.	Chinji	do
15. *Tectochara meriani meriani* (Papp) Grambast	Daulatpur, Triloknath and Kotla, H.P.	Dhok Pathan and Chinji	do
16. *T. meriani huangi* (Lu) Wang	Triloknath, H.P.	do	do
17. *T. sahnii*	Triloknath, H.P.	do	do
18. *Tectochara* sp.	Triloknath, H.P.	do	do
ANGIOSPERMS			
Monocotyledons			
I. PALMAE			
1. *Palmoxylon jammuense*	Tawi River, near Jammu	Siwalik conglomerate	Sahni, 1931, 1964
2. *P. wadiai*	Turanagiri, left bank of Tawi, opposite Jammu		Sahni, 1931, 1934
II. SMILACACEAE			
3. *Smilax* sp.	Balugoloa, near Jawalamukhi, H.P.	L. Siwalik	Lakhanpal & Dayal, 1966

— *Continued*

TABLE 2 — PLANT MEGAFOSSILS FROM THE SIWALIK SEDIMENTS — *Contd.*

FOSSIL	LOCALITY	HORIZON/ FORMATION/ SERIES/STAGE	REFERENCE
III. INCERTAE SEDIS			
Poacites siwalicus	Garala-Gorah Road, Sudnatti, Poonch, J. & K.	L. Siwalik (Palandri Marl)	Sahni, 1964
Poacites spp. A-C	Near Jawalamukhi	Chinji	Mathur, 1978
Dicotyledons			
I. ANNONACEAE			
1. *Fissistigma senii*	Balugoloa, near Jawalamukhi, H.P.	L. Siwalik	Lakhanpal, 1969
2. *Polyalthioxylon indicum*	Kalagarh, U.P.	do	Prakash, 1978
II. DIPTEROCARPACEAE			
3. *Anisopteroxylon jawalamukhi*	Khundian, near Jawalamukhi, H.P.	M. Siwalik	Ghosh & Ghosh, 1958
4. *A. kalagarhensis*	Kalagarh, U.P.	L. Siwalik	Prakash, 1978
5. *Dipterocarpoxylon siwalicus*	Khokhra, near Nalagarh, H.P.	do	Prakash, 1975
6. *D. nalagarhense*	do	do	Prakash, 1975
7. *D. premacrocarpum*	do	do	Prakash, 1975
8. *D. parabaudii*	Kalagarh, U.P.	do	Prakash, 1978
9. *D. nungarensis*	Nungarh Nala (Kalagarh), U.P.	do	Trivedi & Ahuja, 1980
10. *D. surangei*	Kalagarh, U.P.	do	Prakash, 1981
11. *Dipterocarpoxylon* sp.	Mohand, near Dehradun, U.P.	M. Siwalik	Rawat, 1964
12. *Shoreoxylon ornatum* (Trivedi & Ahuja) Prakash & Bande	Kalagarh, U.P.	L. Siwalik	Prakash & Bande, 1980; Trivedi & Ahuja, 1979b
Synonym: *Pentacmeoxylon ornatum* Trivedi & Ahuja			
13. *Vaterioxylon kalagarhense*	Kalagarh, U.P.	L. Siwalik	Trivedi & Misra, 1980
14. *V. miocenicum*	Kalagarh, U.P.	L. Siwalik	Trivedi & Misra, 1980
III. STERCULIACEAE			
15. *Sterculioxylon kalagarhense*	Kalagarh, U.P.	L. Siwalik	Trivedi & Ahuja, 1978a
IV. MELIACEAE			
16. *Meliaceaephyllum mahagonites*	Bagh Rao, Hardwar, U.P.	Low.Mid. Siwalik	Verma, 1968
17. *Dysoxydendron kalagarhensis*	Kalagarh, U.P.	L. Siwalik	Trivedi & Misra, 1979
V. RHAMNACEAE			
18. *Berchemia balugoloensis*	Balugoloa, near Jawalamukhi, H.P.	L. Siwalik	Lakhanpal, 1967
19. *Zizyphus siwalicus*	do	L. Siwalik	Lakhanpal, 1967
20. *Z. champarensis*	Bhikhnathoree, W. Champaran Dist., Bihar	Probably U. Siwalik	Lakhanpal & Awasthi (in Press)
21. *Z. indicus*	5 km North of Pasighat, Siang Dist., Arunachal Pradesh	Upper Miocene	Singh & Prakash, 1980
VI. ANACARDIACEAE			
22. *Dracontomelumoxylon mangiferumoides* Ghosh & Roy	Kalagarh, U.P.	L. Siwalik	Prakash, 1979a, b
Synonym: *Dracontomeloxylon palaeomangiferum* Prakash	Kalagarh, U.P.		
23. *Glutoxylon kalagarhensis*	Kalagarh, U.P.	L. Siwalik	Trivedi & Ahuja, 1978b
24. *Mangifera someshwarica*	Bhikhnathoree, W. Champaran Dist., Bihar	Probably U. Siwalik	Lakhanpal & Awasthi (in Press)

— *Continued*

TABLE 2 — PLANT MEGAFOSSILS FROM THE SIWALIK SEDIMENTS — *Contd.*

FOSSIL	LOCALITY	HORIZON/FORMATION/SERIES/STAGE	REFERENCE
VII. LEGUMINOSAE			
25. *Albizinium eolebbekianum*	Khokhra near Nalagarh, H.P.	L. Siwalik	Prakash, 1975
26. *Bauhinioxylon indicum*	Mohand, near Dehradun, U.P.	M. Siwalik	Rawat, 1964-65
27. *Bauhinia siwalika*	Bhikhnathoree, W. Champaran Dist., Bihar	Probably U. Siwalik	Lakhanpal & Awasthi (in Press)
28. *Cassinium prefistulai*	Khokhra, near Nalagarh, U.P.	L. Siwalik	Prakash, 1975
29. *C. borooahii* (Prakash) Prakash	Kalagarh, U.P.	do	Prakash, 1978
30. *Cynometroxylon holdeni* (Gupta) Prakash & Bande Synonym: *Cynometroxylon* sp. cf. *C. indicum* Prakash, *Cynometroxylon siwalicus* Trivedi & Ahuja	Nalagarh, H.P. and Kalagarh, U.P.	do	Prakash & Bande, 1980
31. *Dalbergia sisso* (Fruit)	Balugoloa, near Jawalamukhi, H.P.	L. Siwalik	Lakhanpal & Dayal, 1966
32. *Dalbergia* sp. (Leaf)	Bhikhnathoree, W. Champaran Dist., Bihar	Probably U. Siwalik	Lakhanpal & Awasthi (in Press)
33. *Dialiumoxylon kalagarhense*	Kalagarh, U.P.	L. Siwalik	Trivedi & Misra, 1978
34. *Hopenxylon eosiamensis*	do	do	Prakash, 1981
35. *Indigofera prepulchella*	Bhikhnathoree, W. Champaran Dist., Bihar	Probably U. Siwalik	Lakhanpal & Awasthi (in Press)
36. *Millettioxylon pongamiensis*	Nalagarh, H.P.	L. Siwalik	Prakash, 1975
37. *Pahudioxylon indicum*	do	do	Prakash, 1979b
38. *Papilionid* sp. (Leaf)	Near Jawalamukhi, H.P.	Chinji	Mathur, 1978
VIII. ROSACEAE			
39. *Parinarioxylon splendidum*	Kalagarh, U.P.	L. Siwalik	Trivedi & Ahuja, 1979
IX. COMBRETACEAE			
40. *Terminalioxylon palaeomanii*	do	do	Prakash, 1981
X. LECYTHIDACEAE			
41. *Careyoxylon pondicherriense* Awasthi	Nalagarh, H.P.	do	Prakash, 1979b
XI. LYTHRACEAE			
42. *Lagerstroemia* sp. (Leaf)	Balugoloa, near Jawalamukhi, H.P.	do	Lakhanpal & Dayal, 1966
XII. APOCYNACEAE			
43. *Apocynophyllum* sp.	Dihand Valley, Siang Dist., Arunachal Pradesh	L. Eocene	Tripathi *et al.*, 1979
XIII. EBENACEAE			
44. *Diospyros embryopterisites*	Bagh Rao, near Hardwar, U.P.	Lower-Mid. Siwalik	Verma, 1968
45. *Ebenoxylon miocenicum*	Kalagarh, U.P.	L. Siwalik	Prakash, 1978
46. *E. siwalicus*	Kalagarh, U.P.	L. Siwalik	Prakash, 1981
XIV. BORAGINACEAE			
47. *Boraginocarpus lakhanpalii*	Near Chandigarh	Tatrot	Mathur, 1974
XV. RUBIACEAE			
48. *Gardenia palaeoturgida*	Bhikhnathoree, W. Champaran Dist., Bihar	Probably U. Siwalik	Lakhanpal & Awasthi (in Press)

— *Continued*

TABLE 2 — PLANT MEGAFOSSILS FROM THE SIWALIK SEDIMENTS

FOSSIL	LOCALITY	HORIZON/ FORMATION/ SERIES/STAGE	REFERENCE
XVI. LAURACEAE			
49. *Cinnamomum palaeotamala*	Bhikhnathoree, W. Champaran Dist., Bihar	Probably U. Siwalik	Lakhanpal & Awasthi (in Press)
50 *Cinnamomum tamala* Nee	Mahanadi River Section, near Darjeeling	M. Siwalik	Pathak, 1969
51. *Litsea prenitida*	Bhikhnathoree, W. Champaran Dist., Bihar	Probably U. Siwalik	Lakhanpal & Awasthi (in Press)
52. *L. polyantha* Juss.	Mahanadi River Section, near Darjeeling	M. Siwalik	Pathak, 1969
53. *L. bhatiai*	1.5 km North of Daulatpur Dist., Kangra, H.P.	Tatrot	Mathur, 1978
54. *Machilus villosa* Hook.	Mahanadi River Section, near Darjeeling	M. Siwalik	Pathak, 1969
55. *Persea punyagiriensis*	Punyagiri, Tanakpur, U.P.	L. Siwalik	Lakhanpal & Guleria, 1978
XVII. EUPHORBIACEAE			
56. *Bridelia stipularis* Bl.	Mahanadi River Section, near Darjeeling	M. Siwalik	Pathak, 1969
57. *B. verrucosa* Haines	do	do	Pathak, 1969
58. *Mallotus philippinensis*	do	do	Pathak, 1969
58a. *Mallotus* sp.	Near Jawalamukhi, H.P.		Mathur, 1978
XVIII. MORACEAE			
59. *Ficus precunia*	Balugoloa, near Jawalamukhi, H.P.	L. Siwalik	Lakhanpal, 1968
60. *F. champarense*	Bhikhnathoree, W. Champaran Dist., Bihar	Probably U. Siwalik	Lakhanpal & Awasthi (in Press)
XIX. ERICACEAE			
61. *Rhododendron lepidotum*	Mahanadi River Section, near Darjeeling	M. Siwalik	Pathak, 1969
XX. CUPULIFERAE			
62. *Castanopsis tribuloides* ADC	Mahanadi River Section, near Darjeeling	M. Siwalik	Pathak, 1969
XXI. INCERTAE SEDIS			
63. *Dicotylophyllum* spp. 1-4	Koshalya River beds, near Kalka water works, H.P.	Nahan (L. Siwalik)	Dayal & Chaudhri 1967
64. *Dicotylophyllum dioscoreoides*	5 km north of Pasighat, Siang Dist., Arunachal Pradesh	Upper Miocene	Singh & Prakash, 1980
65. *Phyllites* sp. cf. *Phyllites kamrupensis* Seward	Road Cutting, Kimin-Ziro Road, Subansiri Dist., Arunachal Pradesh	Tertiary	Chaudhry *et al.*, 1970
66. *Eucalyptophyllum raoi*	Bagh Rao, Hardwar, U.P.	M. Siwalik	Verma, 1968
67. *Croton tegilis*	do	do	Verma, 1968
68. *Dryoxylon nahanai*	Khokhra, near Nalagarh, H.P.	L. Siwalik	Prakash, 1975

some well-preserved dicotyledonous and monocotyledonous leaf-impressions belonging to the families Smilacaceae, Annonaceae, Rhamnaceae, Lythraceae, Moraceae and a fruit of *Dalbergia*.

With regard to the petrified wood from Jawalamukhi area so far only a single wood, *Anisopteroxylon jawalamukhi*, has been described by Ghosh and Ghosh (1958) from the Middle Siwalik beds near Khundian

Village. Further records of fossil woods from this area are lacking.

Rich deposits of plants comprising exclusively of petrified woods have been found in the vicinity of Nalagarh. The rocks in which these fossils occur are attributed to the Nahan beds which correspond to the Chinji Stage. Extensive studies of these petrified woods have been carried out by Prakash (1975, 1979a, 1979b) who described 11 species belonging to the dicotyledonous families, viz., Annonaceae, Dipterocarpaceae, Leguminosae, Anacardiaceae and Lecythidaceae. Similar deposits of petrified dicotyledonous woods have also been found in the Lower Siwalik beds near Dhaula Kuan in Nahan District. Although they have not yet been studied in detail, preliminary examination of the material made by Dr U. Prakash (Personal communication) has revealed that most of the woods belong to the family Dipterocarpaceae and a leguminous genus *Cynometra*. To the east of Nalagarh, near Kalka, from Nahan Formation (= Kamlial-Chinji sequence of Lower Siwaliks) Dayal and Chaudhuri (1967) in a brief note illustrated four dicotyledonous leaves and assigned to a genus *Dicotylophyllum*. These leaves are so badly preserved that they cannot be identified to the generic or family level.

Recently Mathur (1978) has described a few leaf-impressions from the Lower Siwalik (Chinji Formation) near Jawalamukhi and the Upper Siwalik (Tatrot Formation) near Daulatpur, Kangra District. One of the leaves belonging to Upper Siwaliks is complete and shows all the details of venation. He identified it with the leaves of *Litsea* and named *Litsea bhatiai*, whereas those collected from the Lower Siwalik are named as *Papilionid*, *Mallotus* sp. and *Poacites* sp. A, B and C. Since these leaves are incomplete, nothing can be definitely said about their identification. Besides leaves, from Tatrot Formation Mathur (1974) reported a seed as *Boraginocarpus lakhanpalii* of the family Boraginaceae from near Chandigarh.

It has been observed that the charophytic remains are quite commonly found in the Siwalik sediments. Bhatia and Mathur (1970, 1978) and Tewari and Sharma (1972a) have investigated extensively a large number of Charophytic gyrogonites from different localities situated near Chandigarh, Pinjore and in Kangra District. In all they have recognized 15 species belonging to the genera *Chara*, *Hornichara*, *Sphaerochara* and *Tectochara*. Bhatia and Mathur (1970) also highlighted the significance of fossil charophytes in the biostratigraphic subdivision of the Siwalik Group.

In the Himalayan foot-hills of Uttar Pradesh there are a number of fossil localities from which rich collections of plant megafossils have been made in recent years. Rawat (1964, 1964-65) described two dicotyledonous woods, viz., *Dipterocarpoxylon* sp. and *Bauhinioxylon indicum* from the Middle Siwalik beds of Mohand near Dehradun. Another fossil locality exposed at Kalagarh is also very rich in petrified woods. There are a number of streams coming down from the small hills in which the fossil woods occur quite frequently. It is believed that they have been derived from the Lower Siwalik sediments. Systematic study of these woods has been carried out by Prakash (1978, 1981), Trivedi and Ahuja (1978a, 1978b, 1978c, 1979a, 1979b, 1980) and Trivedi and Misra (1978, 1979, 1980) who identified most of them with the modern genera belonging to the families Annonaceae, Sterculiaceae, Dipterocarpaceae, Meliaceae, Anacardiaceae, Leguminosae, Rosaceae Combretaceae and Ebenaceae. As far as their identification is concerned, some of the woods described by Trivedi and Ahuja (1979a) and Trivedi and Misra (1980) do not exhibit the characters of the modern genera or species to which they have been compared. One of them is *Parinarioxylon splendidum* of the family Rosaceae which has been compared with the modern species of *Parinarium*. The anatomical features of this fossil as shown in the photograph do not conform with those of *Parinarium* but appears to be very similar to those of the wood which Prakash (1978) described as *Ebenoxylon miocenicum* of the family Ebenaceae from the same locality. Similarly, two species of *Vaterioxylon* have been created by Trivedi and Misra (1980). These seem to be either *Anisoptera* or *Dipterocarpus* which are already reported from this area. *Pentacmeoxylon ornatum* another dipterocarpaceous wood is described by Trivedi and Ahuja (1979b) showing its close resemblance with the woods of *Pentacme*. Anatomically the woods of *Parashorea*, *Shorea* and *Pentacme* are so similar that they cannot be differentiated from each other, and hence it is very difficult to decide whether the fossil wood described by Trivedi and Ahuja belongs to *Pentacme* or *Parashorea* or *Shorea*. Such fossil woods are usually placed under the genus *Shoreoxylon*. So in view of this Prakash and Bande (1980) treated the genus *Pentacmeoxylon* Trivedi & Ahuja as synonym of *Shoreoxylon* and changed the name of fossil wood from *Pentacmeoxylon ornatum* to *Shoreoxylon ornatum* (Trivedi & Ahuja) comb. nov.

The Siwalik beds near Hardwar, locally known as " Hardwar beds " also comprise plant fossils. Varma, in 1968, described some leaf-impressions belonging to four species. Two of them are *Meliaceaphyllum mohgonites* and *Diospyros embryopterisites* which have been shown to resemble Meliaceae in general and *Diospyros* of Ebenaceae respectively. Out of the remaining two, one is identified with the leaves of *Eucalyptus* and named *Eucalyptophyllum raoi*. This needs reinvestigation as the genus *Eucalyptus* is a native of Australia whose occurrence in the Indian Tertiary is beyond imagination. The leaf described as *Croton* cf. *C. tegelis* also needs critical reinvestigation.

In the foot-hills of Nainital District the Siwaliks are well-exposed along the Kathgodam-Nainital Road, Kathgodam-Bhimtal Road, Ranibagh-Amritpur Road and along the Gola River. From a small patch in front of Ranibagh, recently we collected a few leaf-impressions preserved in the dark grey micaceous shales. These are yet to be studied.

From near Tanakpur, the eastern most part of Kumaon foot-hills just bordering the Sharada River at the Nepalese frontier, Misra and Valdiya (1961) reported the occurrence of leaf-impressions in the road cutting along the river on the southern side of Punyagiri. Preliminary examination of the material collected from this area by the author in 1967, 1968 and 1972 has revealed that there is a great variety of leaves, although so far only one leaf has been described by Lakhanpal and Guleria (1978) as *Persea punyagiriensis* sp. nov. showing close resemblance with *Persea odoratissima* and *P. gamblei* of the family Lauraceae. From the same section exposed along the road cutting Lakhanpal, Jain and Kapoor (1976) described charophytic gyrogonites, recovered from a clay shale band overlain and underlain by fine grained sandstones. In all they have recognised four species belonging to *Charites*, *Chara*, *Raskyaechara* and *Sphaerochara*.

Near Jarwa in Gonda District, Uttar Pradesh from Koilabas village, about 1 km inside the Nepal Territory, recently we also collected some well-preserved angiospermous leaf-impressions. They are found in dark grey shales exposed along the upstream of a small river. The exact stratigraphical position of these fossiliferous beds within the Siwalik Group is not definitely known, though the rock matrix and the leaf-impressions appear preserved therein more or less similar to those of the Lower Siwalik of Tanakpur.

In the foot-hills of Bihar also, the Siwalik beds are exposed all along the Indo-Nepal border. One of the exposures, which lies a few meters on the Nepal side from the National boundary Post No. 35 at Bhikhnathoree, West Champaran District, has yielded about 35 distinct types of angiospermous leaf-impressions belonging to several genera of dicotyledonous families. Of these, Lakhanpal and Awasthi (in Press) have described nine species showing close resemblance with the modern species: *Ziziphus jujuba*, *Mangifera indica*, *Bauhinia corymbosa* and *B. tomentosa*, *Indigofera pulchella*, *Dalbergia* spp., *Gardenia turgida*, *Litsea nitida*, *Cinnamomum tamala* and *Ficus* spp. One of the characteristic features of this floral assemblage is that the leaves in general are smaller than the normal size of their modern equivalents.

From the Middle Siwalik beds of Darjeeling Himalayas Pathak (1969) for the first time reported some leaf-impressions from the Mahanadi section, near Darjeeling, borne on the massive compact, dark coloured carbonaceous shale. The leaves have been assigned to 8 species, viz., *Castanopsis tribuloides*, *Cinnamomum tamala*, *Machilus villosa*, *Litsea polyantha*, *Bridelia stipularis*, *B. verrucosa*, *Mallotus philippinensis* and *Rhododendron lepidotum*. Since most of the specimens are incomplete without base and apex it is difficult or rather impossible to identify such leaves with the modern species and therefore Pathak's identification should be considered as provisional.

The Upper Tertiary rocks of north-east Himalaya (Arunachal Pradesh) have been correlated with the Siwalik sediments of the western Himalaya. They are known as Lower Subansiri, Upper Subansiri and Kimin. The plant fossils have been reported only from three places. Chaudhury, Das and Ahmed (1970) have described an incomplete leaf, collected from a road cutting near 20 km Post (from Kimin) along the Kimin-Zero Road in the Subansiri District, Arunachal Pradesh. The leaf has been compared with *Phyllites kamrupensis* Seward (1912) described from the Coal Measures of Assam. They have assigned the beds to Middle to Upper Miocene. Recently Singh and Prakash (1980) have reported two well-preserved leaf-impressions resembling *Ziziphus* of Rhamnaceae and *Dioscoria* of Dioscoriaceae respectively, from a Siwalik bed exposed about 5 km north of Pasighat in Siang District.

A few years back Dr S. K. Dutta of Dibrugarh University collected some pieces of petrified woods from the Upper Subansiri of Ghogra River section in Siang District and near Kimin in Subansiri District of Arunachal Pradesh. This small collection, investigated by me, has yielded about 10 forms showing close resemblance with the modern woods of *Shorea*, *Euphoria*, *Gluta-Melanorrhoea*, *Albizia*, *Afzelia-Intsia*, *Cynometra*, *Cassia* and *Sindora*.

DISCUSSION

Plant megafossils are reliably used in deciphering the ecology and phytogeography of the fossil floras particularly those of the Cenozoic era. This is because of the fact that they are mostly entomed in the sediments not far from the place of their existence. Secondly, the megafossils can be identified in most of the cases in terms of the modern genera and species.

The floral assemblages of the pre-Siwalik Tertiary of the Himalaya are too small to surmise any definite conclusion about the climatic conditions. Most of the plants constituting the assemblages are either palm or palm-like leaves whose exact affinities with the modern species are not known.

From the foregoing review of the plant megafossils of the Siwalik Group it is evident that majority of the taxa are from the Lower Siwalik sediments. The modern species with which they have been identified are: *Smilax* spp., *Polyalthia simiarum*, *Fissitigma wallichi*, *Anisoptera scaphula*, *Dipterocarpus indicus*, *D. dyerii*, *D. macrocarpus*, *S. baudii*, *D. tuberculatus*, *Berchemia floribunda*, *Ziziphus incurva*, *Sterculia* spp., *Gluta-Melanorrhoea* spp., *Dracontomelum mangiferum*, *Dysoxylum* spp., *Albizia lebbek*, *Cassia fistula*, *Cynometra polyandra*, *Dalbergia sisso*, *Millettia prainii*, *Afzelia-Intsia* spp., *Sindora siamensis*, *Terminalia manii*, *Careya arborea*, *Lagerstroemia indica*, *Diospyros brandisiana*, *D. kurzii*, *D. embryopteris* and *Ficus cunea*. Excepting a few which still survive in the foot-hills, most of these species occur today in the tropical evergreen to semi-evergreen or deciduous forests of Western Ghats, north-east India, Bangladesh, Burma and elsewhere in south-east Asia. On the basis of these plants it has reasonably been concluded by Lakhanpal (1970), Vishnu-Mittre (1979) and Prakash (1979b) that warm humid climate with high precipitation prevailed all along the Himalayan foot-hills during the Lower Siwalik sedimentation. Now the question arises as to how and where from these tropical evergreen plants came in the Himalayan foot-hills. Close similarity of the Lower Siwalik plants with the corresponding floral assemblages of the peninsular India (Awasthi, 1974), Burma (Prakash, 1973) and south-east Asia (Schweitzer, 1958; Kramer, 1974, 1975) as well as with the present day tropical evergreeen flora of south-east Asia provides a supporting evidence to the assumption that the Lower Siwalik plants may have come from south-east Asia. During the Miocene, with the Himalayan upheaval large areas previously occupied by the Tethys sea were converted into land with numerous water basins. This major geographical change brought about significant change in the climatic conditions in this region which became more warm and humid. As a result, the south-east Asian tropical wet evergreen and semi-evergreen plants led by dipterocarps entered the Himalayan foot-hills replacing or dominating over the so-called Murree and Kasauli floras. How long and under what conditions these plants remained there is yet to be definitely ascertained through the study of fossils. But there are some indications about their continuation in the Middle Siwaliks as evidenced by the occurrence of *Dipterocarpus* in the Middle Siwalik beds near Mohand. Recent discovery of some fossil woods in the Upper Subansiri sediments of Arunachal Pradesh also confirms that warm humid conditions existed in the Himalayan foot-hills of north-east India. In this floral assemblage almost the same elements are present which are reported from the Lower Siwaliks of Uttar Pradesh and Himachal Pradesh.

Regarding the environmental conditions during the Upper Siwaliks there is a consensus of opinion among the various geologists that the fourth upheaval of the Himalaya took place at the onset of the Upper Siwalik sedimentation by which time the warm humid climate had gradually changed into distinctly colder and drier. This might have adversely affected the surviving tropical evergreen forests which eventually disappeared and were replaced by the subtropical or temperate moist deciduous or dry deciduous forests. Evidences in favour of the above view are provided by our recent studies of the leaf-impressions from the Siwalik beds (probably Upper Siwalik) of Bhikhnathoree, Bihar. In a fairly rich assemblage of leaves comprising about 35 distinct forms, there is none to represent the family Dipterocarpaceae which was so dominant at the time of its deposition in the Lower and Middle Siwaliks. Most of the modern equivalents of Bhikhnathoree leaves are found in dry deciduous forests even though some of them may have a wider distribution in moister forests also. Further, the leaves on the whole are smaller in size than their modern counterparts. All these features strongly suggest that dry or arid conditions might have prevailed in this region during the Upper Siwalik sedimentation.

The inferences made above are still considered as generalized and tentative since they are based on sporadic and insufficient records of plant megafossils. From the available information furnished in the foregoing account it is quite evident that there are rich treasures of various kinds of plants in almost all the Tertiary sediments of the Himalaya. Their extensive collection and systematic studies are needed in order to build up complete floristic successions in a chronological sequence and to throw light on the climatic changes that took place with the result of Himalayan upheaval at different intervals since the beginning of the Cenozoic era. The palaeobotanical data thus accumulated can also be successfully used in broad stratigraphical subdivisions and correlations of strata.

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TERTIARY PALYNOLOGY OF THE HIMALAYA — A REVIEW*

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ABSTRACT

Palynomorph assemblages recovered from the Tertiary rocks of Himalaya have been reviewed. Most of the Tertiary palynological information available till today has been developed from the western Himalayas. A beginning seems to have been made in regard to the development of Tertiary palynology of the eastern Himalaya, particularly from Arunachal Pradesh. On the basis of palynomorph assemblages some workers have attempted to establish palynological succession both in the Lower and Upper Tertiary rocks of western Himalaya. Palynological evidences have also been used in the interpretation of environment of deposition, dating, correlation of strata and palaeoclimates. The present paper reviews the status of Tertiary palynology of the Himalaya and evaluates some of the assemblages in regard to their applied aspects.

Key-words — Palynology, Tertiary rocks, Himalaya (India).

सारांश

हिमालय की तृतीयक युगीन परागाणुस्तरिकी : एक समीक्षा – हरिपाल सिंह

हिमालय की तृतीयक युगीन चट्टानों से उपलब्ध परागाणविकपणक समुच्चयों की समीक्षा की गई है। अभी तक उपलब्ध तृतीयक युगीन परागाणविक जानकारी में अधिकतर जानकारी पश्चिमी हिमालय से ही है। पूर्वी हिमालय, मुख्यतया अरुणाचल प्रदेश, के तृतीयक कालीन परागाणुस्तरिकीय अध्ययन की शुरुआत की जा चुकी है। परागाणविकपणक समुच्चयों के आधार पर कुछ विज्ञानियों ने पश्चिमी हिमालय, अधरि एवं उपरि दोनों तृतीयक चट्टानों में परागाणविक अनुक्रम स्थापित करने के प्रयास किये हैं। निक्षेपणीय वातावरण, कालनिर्धारण, स्तरों के सह-सम्बन्धन तथा पुराजलवायु की व्याख्या करने में परागाणविक प्रमाणों का उपयोग किया गया है। प्रस्तुत शोध-पत्र में हिमालय की तृतीयक युगीन परागाणुस्तरिकीय स्थिति की समालोचना तथा कुछ समुच्चयों के व्यावहारिक पहलुओं का मूल्यांकन किया गया है।

INTRODUCTION

DURING the last twenty years palynological studies have emerged both as an academic as well as an applied tool in solving various problems related to stratigraphy, particularly from the Tertiary rocks of the western Himalaya. The palynomorphs recovered from these sediments include spores, pollen grains, and the remains of algae, fungi or their fruiting bodies. The planktonic algae represented by the dinoflagellate cysts and also by *Pediastrum* and *Botryococcus* have been recorded by Mathur (1963, 1964, 1965; Salujha *et al.*, 1969) from the marine Lower Tertiary rocks of Simla Hills. The discipline of palynology has also been employed (Khanna, Ph.D. dissert., 1977; Singh *et al.*, 1978; Singh & Khanna, 1980) for establishing palynological succession in the Subathu Formation and in interpreting other related aspects like dating, environment of deposition, correlation of strata and relationship of biofacies with lithofacies. Singh and Khanna (1978) and Khanna and Singh (1980) studied the palaeoecological significance of *Pediastrum* and *Subathua* respectively in the Subathu Formation. The progress of Palaeogene palynology in the Simla Hills has been reviewed by Singh (1981). Spores-pollen assemblages have

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also been studied from the Upper Tertiary rocks of Punjab, Himachal Pradesh, Bihar and Arunachal Pradesh. Amongst the prominent workers who have carried out palynological study of these sediments are: Ghosh *et al.* (1963), Banerjee (1968), Lukose (1968), Nandi and Bandyopadhyay (1970), Venkatachala (1972), Nandi (1972, 1975), Mathur (1973), Singh *et al.* (1973), Ghosh (1977), Bhandari *et al.*, (1977), Jain and Dutta (1978), Saxena and Singh (1980) and Dutta and Singh (1980). Distinctive palynological forms have been recorded and utilized for the recognition of different stratigraphical levels (Nandi, 1975; Ghosh, 1977), though the recovery of spore-pollen content has been quite low, both qualitatively and quantitatively. In spite of these snags, palaeoclimate during the Siwalik sedimentation has been inferred by Ghosh (1977). The Miocene sediments of Kameng District, Arunachal Pradesh exhibit mixed type of spore-pollen assemblages. Recently Saxena and Singh (1980) have recovered a palynological assemblage from the Upper Siwaliks exposed near Chandigarh which is very rich in *Laricoidites*-complex.

GEOGRAPHY AND STRATIGRAPHY OF HIMALAYA

Geographically, the Himalaya is divided into (i) the sub-Himalaya, (ii) the Lesser Himalaya, and (iii) the Great Himalaya. The sub-Himalayan Zone includes the Neogene sediments of Siwalik ranges whereas the Lesser Himalaya consists of the Palaeogene and pre-Tertiary rocks. The Great Himalaya mainly consists of the central crystallines. To the north of Great Himalaya lies the Tethys Himalaya having Cambrian to Cretaceous rocks which normally yield fossils. It is followed by the zone of Tsangpo Suture in Kashmir Himalaya consisting of geosynclinal Cretaceous to Palaeogene sediments. The trans-Himalaya includes the Ladakh region of Kashmir.

From west to east the horizontal extent of Himalayan range has been divided into various sectors, viz., (i) the western Himalaya, (ii) the central Himalaya, and (iii) the eastern Himalaya. The western Himalaya includes Jammu and Kashmir, Himachal Pradesh, Garhwal and Kumaon sectors. The central Himalaya consists of Nepal, whereas the eastern Himalaya covers Darjeeling, Sikkim, Bhutan, Arunachal Pradesh and Lohit.

Geology and stratigraphy of the Tertiary sediments of Himalaya have been worked out by various workers. It is beyond the scope of this paper to deal in detail with this aspect of study. In the present review the stratigraphical order of Tertiary rocks as adopted by Sahni and Mathur (1964) and Chaudhuri (1968) has been followed:

After Sahni and Mathur, 1964

AGE	UPPER ASSAM	HIMALAYAN FOOT-HILLS
Lower Pleistocene to Pliocene	Dihing Series	Upper Siwalik
....	Unconformity	....
Pliocene	Tipam	Middle Siwalik
Miocene	Surma	Lower Siwalik
....	Unconformity	....
Oligocene to Upper Eocene	Barails	Dharamsala

After Chaudhri (1968)

AGE	HIMALAYAN FOOT-HILLS
Lower Miocene to Upper Oligocene	Kasauli Formation
Lower Oligocene to Upper Eocene	Dagshai Formation
Eocene to Upper Paleocene	Subathu Formation

Stratigraphical correlation of the Tertiary rocks of Himalaya has been a difficult task because most of the lithostratigraphical units exhibit similarity in lithology and structural complexity. This problem is further aggravated by the lack of animal and plant fossils in most of the lithostratigraphical units. However, recovery of plant as well as animal fossils, at some places, though quite often of local importance, has provided such cogent evidences that on the basis of which new interpretations relating to stratigraphy and structure have emerged. The present paper aims to review the palynostratigraphical information derived so far from the Tertiary sediments of Himalaya and also to throw light on such problems that have defied solutions so far.

PALYNOSTRATIGRAPHY OF THE LOWER TERTIARY ROCKS

Palynological information from the Lower Tertiary rocks is mostly available from the western Himalayas. It has been arranged in chronological order. Hence, the Palaeocene horizons have been taken up first for discussion.

In the western Himalaya Srikantia and Bhargava (1967), on the basis of palaeontological studies, established Kakara Series which is a Palaeocene horizon exposed near Kakara-Chapla Village, Simla Hills. Palynology of these sediments has not been worked out so far. In order to confirm the proposed dating of the Kakara Series by Srikantia and Bhargava (1967) it is essential to investigate these sediments palynologically.

The overlying Subathu sediments are developed along the Himalayan foot-hills belt as a narrow discontinuous strip from Jammu in the west to as far as Nepal in the south-east. They rest unconformably on the pre-Tertiary Slates (Auden, 1934; Gansser, 1964). Lithology of the Subathu Formation mainly consists of limestones and carbonaceous shales/coaly bands, calcareous red, green, pale-olive shales, siltstones with rare development of sandstones. A white orthoquartzitic zone generally delineates the top of the Subathu Formation.

A palynological beginning for the study of Subathu sediments was made by Mathur (1963) who reported the occurrence of *Pediastrum*. Subsequently she (Mathur, 1964, 1965) published two more short notes regarding the presence of *Botryococcus*, *Pediastrum* and a varied type of assemblage having hystrichosphaerids and pollen grains surmising subtropical to tropical climate for the miofloral assemblage and assigning Middle to Upper Eocene age. In 1969, Salujha *et al.* studied the palynological composition of the Subathu sediments exposed in the Simla Hills reporting a rich assemblage of spores, pollen grain, hystrichosphaerids and other algal remains. The assemblage, though poorly preserved and much less suitable for taxonomic study, is of academic interest as it brought to light some palynologically productive horizons in the Subathu sediments which were earlier known to be mostly devoid of plant microfossils. They surmised Lower Eocene age for the Subathus. A general review paper of Venkatachala (1972) lists some characteristic palynomorphs, viz., *Baltisphaeridium*, *Hystrichosphaeridium*, *Pediastrum*, *Anacolosia*, *Couperipollis*, *Trialtisporites*, *Triorites*, *Retitricolpites*, *Favitricolpites* and *Pinuspollenites*. Singh *et al.* (1973) and Salujha (1974) reviewed the then existing status of palynological knowledge both for the Lower and Upper Tertiary rocks of western Himalaya and made some general observations on various aspects of the study.

In 1971, systematic palynostratigraphical study of the Subathu sediments was initiated (Singh) at the Birbal Sahni Institute of Palaeobotany, Lucknow. The recovery of reasonably well-preserved dinoflagellates, spores and pollen grains resulted in the identification of 43 genera and 106 species (Khanna Ph.D. Thesis, 1977). Of these, some of the important taxa are: *Cyclonephelium*, *Cleistosphaeridium*, *Oligosphaeridium*, *Homotryblium*, *Hystrichokolpoma*, *Achmosphaera*, *Thalassiphora*, *Cordosphaeridium*, *Subathua* and many more along with spores and pollen grains, viz., *Todisporites*, *Lygodiumsporites*, *Lycopodiumsporites*, *Cyathidites*, *Podocarpidites*, *Laricoidites*, *Liliacidites*, *Couperipollis*, *Palmidites*, *Proxapertites*, *Verrutricolpites*, etc. The palynofloral assemblage has been recovered from several localities, viz., Koti, Jabli, Dharmpur, Dagshai and Kumarhatti. These localities lie on the Kalka-Simla Highway between Baroti and Barog. The type locality Subathu is exposed in the Kuthar Nala near the Subathu town.

Qualitative and quantitative analyses of the palynological data have been carried out by Singh *et al.* (1978) who have established palynological succession in the Subathu section proposing seven cenozones and one barren zone. They have also recognized two subzones. With the exception of the barren zone, the remaining cenozones are characterized by the abundance of a single genus with one or more species together with the occurrence of a few restricted species or with the first appearance of a taxon or taxa. In the ascending order of stratigraphy, the cenozones are as follows:

8. *Todisporites* spp. Cenozone
7. *Subathua sahnii* Cenozone
6. *Cordosphaeridium multispinosum* Cenozone
5. *Hexagonifera* spp. Cenozone

4. *Homotryblium* spp. Cenozone
3. *Cleistosphaeridium* spp. Cenozone
2. Barren Zone
1. *Cyclonephelium* spp. Cenozone

Information on the association of other palynomorphs with the above mentioned cenozones is published by Singh *et al.* (1978) and hence is not repeated here. The distributional pattern of palynoflora within the Subathu Formation exhibits some dissimilarities in its composition. Perhaps these are related to the changing environment of deposition. These dissimilarities are noticeable when a comparative account of the palynological composition is taken into consideration particularly from such sections which are located at the margin in contrast to those located in the deeper part of the epicontinental sea. The apparent effect of the variable environment on the composition of the assemblages falls in three categories: (i) fluctuation in the abundance of long ranging species, (ii) local development of a particular morphotype, and (iii) the appearance of stratigraphically insignificant forms. To examplify Khanna and Singh (1981) have reported the preponderant occurrence of *Cleistosphaeridium diversispinosum*, *Cyclonephelium exuberans* and members of the family Thalassiphoraceae from the shallow water environment particularly exhibiting mesohaline condition. The association of *Hexagonifera* spp. with the highly calcareous facies denotes their preference to hypersaline conditions. *Cleistosphaeridium disjunctum* and *Cyclonephelium compactum* inhabit mostly normal saline condition of depositions. To sum up, it can be said that the gross palynofloral character of the Subathu Formation up to the *Subathua sahnii* Cenozone (Singh *et al.*, 1978) is identified by the abundance of hystrichosphaerids along with other dinocysts. The upper part of the Subathu Formation is easily identifiable both by the development of the red facies and abundance of pteridophytic spores along with gymnospermous and angiospermous pollen grains. Different cenozones of the Subathu section have been traced laterally (Khanna *et al.*, 1981) in the other seven stratigraphically measured sections, viz., Koti, Jabli, Dharmpur, Dagshai A, B, C and Kumarhatti exposed along the Kalka-Simla Highway between Baroti and Barog. Generally the boundaries of the palynological cenozones seem to coincide with the lithological boundaries with a few exceptions. On the basis of this study, these distantly located sections have been successfully correlated by Khanna *et al.* (1981).

AGE OF THE SUBATHU FORMATION

A perusal of the literature shows that there has hardly been any unanimity in regard to the age of the Subathu Formation. Pilgrim and West (1928) opined that the basal part of the Subathus particularly consisting of limestone and carbonaceous shales belong to Upper Middle Eocene age whereas the purple sandstone and grits, characteristic of the upper part, represent Oligocene age. Later on, Cox (1931), Vokes (1937), Mandwal (1959), Pascoe (1959), Datta *et al.* (1965), Krishnan (1968), Mathur (1964, 1965), Chaudhri (1968), Salujha *et al.* (1969), Khanna and Singh (1981) have also dealt with the subject and expressed divergent views. In short, the Subathus have been shown to be varying from Palaeocene to Oligocene in age. The present palaeontological and palynological data point out that the Subathus can be assigned to Upper Palaeocene to Upper Eocene age particularly in the Simla Hills. Khanna and Singh (1981) took into consideration (i) the order of superposition of strata, (ii) palaeontology, and (iii) palynology in deciphering the age of the Subathus. They have dated the palynological succession in the type area as Upper Palaeocene to Upper Eocene. The sequence of dating as proposed by them is reproduced below:

(i) Upper Palaeocene-Lower Eocene (represented by strata from the base of the *Cyclonephelium* spp. Cenozone to the top of the *Homotryblium* spp. Cenozone).

(ii) Middle Eocene (represented by strata between the base of *Hexagonifera* spp. Cenozone to the base of *Todisporites* spp. Cenozone).

(iii) Upper Eocene (represented by the remaining part of *Todisporites* spp. Cenozone).

So far as palaeontological (Datta *et al.*, 1965) and palynological data are concerned, they are in agreement for the Upper Palaeocene to Upper Eocene dating for the Subathus. Recently Sarkar (Personal communication) has recovered *Striatriletes susannae* from the top most horizons of the Subathu Formation in the Nahan area. Its first appearance in this horizon has been considered to be age definitive thus confirming the Upper Palaeocene-Upper Eocene dating for the Subathus as proposed by Singh *et al.* (1978) and Khanna and Singh (1981).

ENVIRONMENT OF DEPOSITION

Bhandari and Aggarwal (1966) expressed the opinion that the Subathu sediments were deposited in a shallow linear epicontinental sea opening north westwards, the floor of which was marked by parallel to subparallel ridges resulting in the development of deposition in different parts of the basin. Chaudhri (1976) recognized transgressive-regressive cycles on the basis of fluctuations in the land-sea level changes. Raiverman (1964) considered the environment of deposition of the Subathu sediments as varying from marine to brackish to fresh water. Bhatia and Mathur (1965) are of the opinion that the Subathus were deposited under marine condition with their upper part indicative of fresh water condition. The results of palynological investigations of Subathu succession (Khanna & Singh, 1981) in the Simla Hills show that the rock sequence occurring between the *Cyclonephelium* spp. Cenozone and *Cordosphaeridium multispinosum* spp. Cenozone is indicative of the shallow marine environment whereas the strata between the *Subathua sahnii* Cenozone and the base of *Todisporites* spp. Cenozone represent brackish water conditions. The upper horizon of *Todisporites* spp. Cenozone which is completely devoid of microplanktons seems to have been deposited under fresh water environment. This observation, in general, agrees with the interpretation of Bhatia and Mathur (1965). The appearance of land derived elements together with the absence of microplankton has been considered to be indicative of the onsetting of fresh water environment. Singh (1978) carried out environmental analysis of the Subathu sediments and believes that they were deposited in a shallow sea having some tidal channel characteristics. He has also postulated an embayment having shelf mud zone, tidal flats together with poorly developed alluvial plains though minor part of the succession could have been a product of rivers pouring into the embayment. This observation can be correlated with the palynological findings of Singh *et al.* (1978) in regard to the occurrence of *Pediastrum* Subzone in the Jabli Section and in the upper parts of Subathu succession. Local development of a particular morphotype/morphotypes in stratigraphical sections have been indicative of the prevalence of varying environmental conditions. The utility of such morphotypes in stratigraphy is of no special significance and hence has been considered to be of local importance only though sometimes providing very useful information. The general distributional pattern of microplanktons and spore-pollen shows that the former constitute 97 per cent of the total assemblage in the lower part of the Subathus, but recording an inverse proportion towards its top. The spore-pollen and land derived elements dominate the assemblage in the Upper horizons. This palynological observation lead Singh and Khanna (1980) to recognize one transgressive phase of the sea followed by a regressive phase in the *Todisporites* spp. Cenozone.

MURREE/DHARAMSALA SEDIMENTS

The Subathu sediments are conformably overlain by the Murree Formation (Upper Eocene-Lower Miocene) in the Jammu area. To the east in the Punjab and Himachal Pradesh, the Murree equivalent rocks are known as Dharamsalas and perhaps rest unconformably over the Subathu sediments though the contact between the two has been considered as conformable by Bhandari and Agarwal (1966). Venkatachala (1972) has indicated that the Lower Dharamsala sequence is deposited both under marine and continental conditions whereas the Upper Dharamsalas have been considered to be of fluviatile origin. Further, to the east in Himachal Pradesh, particularly in the Simla Hills, the Dharamsala sediments are represented by Dagshai and Kasauli formations, the former representing perhaps coastal and the latter fresh water condition of deposition.

Murees have not been investigated palynologically so far. As regards the Dharamsala sediments (Upper Eocene-Lower Miocene of Kangra District), Ghosh *et al.* (1963) reported the occurrence of some palynomorphs referable to the genus *Ephedra*. Palynological contents of Dharamsalas are very scantily known. Venkatachala (1972) listed the palynomorphs occurring in the Lower Dharamsala (Eocene) sediments, viz., Chenopodiaceae, Tiliaceae, *Lindsaya*, *Ephedripites*, *Striainaperturites*, *Scabratriporites*, *Pinuspollenites* and *Tetracolpites*. These forms have neither been described nor illustrated. The spore-pollen assemblage of Upper Dharamsala (Venkatachala, 1972) consists of spores of Schizaeaceae, Hymenophyllaceae and Polypodiaceae together with pollen grains of Pine and Chenopodiaceae. The Upper Dharamsalas have been ascribed Upper Oligocene-Lower Miocene age (personal communication by Raiverman to Venkatachala, 1972) and considered to have been deposited under predominantly fluiviatile conditions. Thus the Dharamsala sediments have been dated ranging from Upper Eocene to Lower Miocene in age.

DAGSHAIS/KASAULIS

Palynological information of the Dagshai sediments recorded so far (Singh & Khanna, 1980) is very meagre. However, the most striking feature of the Dagshai assemblage is the absence of microplanktons and the presence of pteridophytic, gymnospermic and angiospermic spores and pollen grains. Some of the important constituents of this assemblage are: *Lygodiumsporites*, *Lycopodiumsporites*, *Todisporites*, *Inaperturopollenites*, *Laricoidites*, *Couperipollis*, *Palmidites*, *Palmaepollenites*, *Tricolpites* and *Verrutricolpites*. In addition to these forms, the occurrence of *Pediastrum* and fungal spores is also noteworthy. The presence of pollen grains of Palm affinity together with the trilete spores seems to be indicative of coastal transitional environment for the Dagshai Formation. Singh (1978) has expressed the opinion that the Dagshai sediments were deposited under marine conditions in an estuarine complex.

The palynological assemblage recorded from the Kasauli sediments near Koti (Singh & Khanna, 1980) is of academic interest only. Preservation of the spores and pollen grains is rather poor. Some of the important constituents of the assemblage are: spongy spicules (27%), angiospermic pollen grains represented by *Palmaepollenites* spp., *Couperipollis* spp., some monoporate and colporate pollen grains (24%). Additionally the representation of *Podocarpidites* spp. (17%), fungal spores (17%) and *Pediastrum* (9%) and the virtual absence of *Inaperturopollenites* is also significantly noteworthy.

SIWALIK SYSTEM

The Siwalik rocks, in general, are well-developed all along the sub-Himalayas. They are exposed from west to east and conformably rest on the Murrees. They are broadly divided into Lower, Middle and Upper Siwaliks ranging from Middle Miocene to Lower Pleistocene in age. The Lower Siwaliks usually have bright red shales and clays and brown sandstones, the matrix being well cemented. The Middle Siwaliks are identified by having coarser, micaceous grey sandstones and dull clays, the matrix being less cemented. The Upper Siwaliks usually have boulder conglomerates, grits, loose sandstones and brown clays. The Siwaliks are about 5,000 m thick and are believed to have been deposited in different environments, viz., piedmont, outwash, plains, channel and flood plains and lacustrine. The fine clastics of Siwalik sediments have yielded some palynological assemblages which have been systematically evaluated as below.

Palynology

Palynology of the Lower Siwalik rocks has been carried out by Banerjee (1968), Venkatachala (1972), Mathur (1973), Nandi (1975) and Ghosh (1977). Taxonomic study of the recovered palynofloras, in general, need a renewed effort for describing morphological details of many undescribed palynomorphs and to remove anomalies in regard to the use of invalid names of some taxa. Realizing that the Siwalik sediments mostly prove unproductive, the present palynological information developed by the above workers is, indeed, a commendable effort. Amongst the important constituents represented in the Lower Siwalik of Bhakra-Nangal area, Banerjee (1968) reported the presence of palynomorphs probably belonging to the families, viz., Compositae, Gramineae, Palmae and Abietineae. Pteridophytic spores of gleicheniaceous and polypodiaceous affinity were also recorded, besides many other palynomorphs assigned to form genera belonging to angiospermic pollen grains. Venkatachala (1972) mentioned that the Lower Siwalik sediments have the presence of pollen grains belonging to the families Palmae and Graminae together with form genera like *Quercoidites*, *Haloragacidites*, *Cupuliferoidaepollenites*, *Sapotaceoidaepollenites* and *Araceoipollenites*, whereas the Middle Siwalik assemblage contains the pollen grains of Malvaceae, Betulaceae, Anacardiaceae, Pinaceae and spores of Polypodiaceae. Contrary to this observation, Banerjee (1968) opined that the Middle Siwalik assemblage exhibits the dominance of gymnospermous pollen grains together with poor occurrence of pteridophytic spores and angiospermic pollen grains, indicating cool climate. Mathur (1973) has worked out palynology of the Lower Siwalik sediments exposed in Tharukhola-Chepang, north-east of Nepal-Gange, Nepal. The presence of *Sabalpollenites*, *Graminidites* and *Echimonocolpites* in addition to many other pteridophytic forms and gymnospermous forms seems to be quite characteristic for this assemblage. Mathur (1973) has indicated that the angiospermic pollen grains dominate the assemblage. Pteridophytic spores are relatively low in abundance whereas the occurrence of gymnospermous pollen grains is very low. The general palynofloral spectrum of this assemblage is in agreement with the one described from the Lower Siwalik of Bhakra-Nangal area by Banerjee (1968) particularly in exhibiting almost similar type of numerical distribution of various botanical groups. Mathur (1973) opined that the climate during the Lower Siwalik times was of tropical to subtropical type contrary to the opinion held by Banerjee (1968) who inferred tropical to temperate climate during the Lower Siwalik times. The palaeobotanical data based on the study of fossil woods (Prakash, 1975; *Anisopteroxylon*) is in agreement with the views expressed by Mathur (1973).

The Siwalik Group exposed near Dalhousie has been investigated palynostratigraphically by Nandi (1975) and Ghosh (1977). Nandi has recognized four palynological zones in the Siwaliks. Each zone has characteristic palynomorphs. Some of the important constituents of the general assemblage are: Polypodiaceous spores, *Verrucososporites*, *Verrucatosporites*, *Cicatricosisporites*, *Cyathidites*, *Hymenophyllumsporites*, *Cyathidites*, *Gleichenidites*, *Laevigatosporites*, *Cupuliferoidaepollenites*, *Palmaepollenites*, *Tetradomonosporites*, *Abietinaepollenites*, *Pinuspollenites*, *Piceapollenites*, *Podocarpidites*, *Polyadopollenites*, *Caryapollenites* and *Alnipollenites*. Representation of pteridophytic spores and angiospermic pollen grains is quite prominent in this assemblage. Palynological analysis of this Siwalik unit lead Nandi (1975) to believe that the climate during the Lower Siwalik times was subtropical to tropical. The Middle Siwalik exhibited subtropical to temperate climate whereas the Upper Siwaliks were identified in having a distinctly colder one. Ghosh (1977) reviewed this work and came with some more observations on the palaeoecology and palaeoclimate during the Siwalik sedimentation.

Banerjee (1968), Lukose (1969), Nandi and Bandyopadhyay (1970), Venkatachala (1972), Nandi (1972, 1975) and Ghosh (1977) have worked on the palynological assemblages of Middle Siwalik. In general, the Middle Siwalik assemblages tend to exhibit the following characteristics: (i) increase in the occurrence of the gymnospermous pollen grains, and (ii) fall in the incidence of pteridophytic spores and angiospermous pollen grains. Both these characteristic changes have been ascribed to the change in climate by various workers particularly from subtropical to temperate one although the plant megafossil records of Middle Siwalik times indicate the prevalence of mostly tropical climate with comparatively less precipitation. Palynological data, even otherwise, do not synchronize well with the megafossil record. The virtual absence of gymnospermous plant megafossils in contrast to their high incidence of pollen grains rather remains an enigma. It seems possible that the gymnospermous pollen could have come to lie in their place of burial from the surrounding high hills, but the absence of gymnospermous megafossils is quite intriguing. Some of the important constituents recorded from the Middle Siwaliks of Rexaul (Bihar) by Lukose (1968) are: *Retimonoletes*, *Foveomonoletes*, *Retitriletes*, *Monosaccites*, *Disaccites*, *Polyadites*, *Inaperturites*, *Reti-*

monocolpites, *Triporites* and *Retitriporites*. Some of the taxonomic names used here are invalid. The taxonomy of this assemblage needs to be re-done. It seems possible to concur with the interpretation of Lukose (1968) that the assemblage contains a mixture of pollen grains representing temperate to tropical climates. The former could have been derived from the north and the latter from the south. The assemblage recorded by Nandi and Bandyopadhyay (1970) is rather too poor for any comments excepting that it brings to light the presence of pollen grains probably referable to the genera *Pinuspollenites* and *Graminidites* in addition to some others.

The Mohand field assemblage (Nandi, 1972) seems to be quite typical of the Middle Siwaliks. Palynomorphs, in general, can be referred to various pteridophytic families, viz., Lycopodiaceae, Hymenophyllaceae, Schizaeaceae, Gleicheniaceae, Polypodiaceae and Cyatheaceae together with pollen grains perhaps of grasses, palms, *Pinus*, *Podocarpus*, *Abies*, *Larix*, polyporates, tricolporates, etc. Most of the important constituents recorded by Nandi (1975) have been listed earlier in the text and hence are not repeated here. The striking feature of the Middle Siwalik assemblage seems to be the predominance of pteridophytic spores and bisaccate pollen grains in contrast to the Lower Siwalik assemblages.

Palynology of the Upper Siwalik rocks is poorly known. Singh *et al.* (1973) recorded the presence of Pinus-type, monosulcate-type, and inaperturate (non-saccate) pollen grains of gymnospermous affinity from the Pinjor Formation surmising temperate to subtemperate climate during the Upper Siwalik times. This assemblage exhibits the dominance of inaperturate pollen grains. Another possible record of palynomorphs from the basal part of Upper Siwalik sediments has been given by Nandi (1975) with forms referable to the following genera, viz., *Cyathidites*, *Alsophilidites*, *Pinuspollenites*, *Podocarpidites*, *Monoporopollenites*, *Alnipollenites*, *Tetradomonoporites*, etc. Normally the Upper Siwalik sediments prove unproductive. However, Saxena and Singh (1980) have recovered a palynological assemblage from the Pinjor Formation exposed near Chandigarh in which gymnospermous pollen grains represented by *Laricoidites*-complex (including *Araucariacites*) are dominant in distribution. They constitute about 61 per cent of the total assemblage. Pollen grains of *Pinjoriapollis* (perhaps of Magnoliaceae affinity) in addition to the *Laricoidites*-complex are the most striking feature of this assemblage. Pollen grains perhaps belonging to the following families have also been reported, viz., Schizaeaceae, Parkeriaceae, Podocarpaceae, Araucariaceae, Pinaceae, Palmae, Liliaceae, Gramineae, Magnoliaceae, Proteaceae and Oleaceae. Amongst these the occurrence of Araucariaceae and Proteaceae seems to be doubtful. It is likely that some of the forms referred to *Araucariacites* may be reworked pollen grains from the Palaeogene sediments. But most of the remaining lot may belong to the *Laricoidites*-complex. Pollen grains referable to the family Proteaceae may either be reworked or need re-examination for taxonomic study. Vishnu-Mittre (1979), on the basis of high incidence of *Pinus* and possibly of *Larix* pollen grains, opined a cool and moist climate during the Upper Siwalik times.

Bhandari *et al.* (1977) have worked out the stratigraphy, palynology and palaeontology of the Ladhakh Molasse Group in the Kargil area. On the basis of palynoflora they opined a Palaeocene-Eocene age to the Kargil Formation, Oligocene-Miocene age to the Tarumsa Formation and Miocene age to the Pashykum Formation.

From the eastern Himalayas Jain and Dutta (1978) have studied dinoflagellates, spores and pollen grains from a limestone sample located near the contact of Lower Gondwana and Upper Tertiary succession in the Siang District of Arunachal Pradesh. The assemblage is rich in dinoflagellates and Palmae pollen grains. The presence of *Couperipollis*, *Lakiapollis*, *Polycolpites*, *Triorites* and *Polygonacidites* is quite striking. They have suggested a probable Eocene age for this assemblage which has been confirmed by the occurrence of Nummulitics in the Dihing Valley, Siang District (Tripathi *et al.*, 1979). Jain and Dutta (1978) have postulated near shore deposition for the material investigated.

Dutta and Singh (1980) reported a Miocene assemblage from the Siwalik rocks of Lesser Himalaya of Kameng District, Arunachal Pradesh. It consists of reworked palynomorphs characteristic of the Palaeozoic and Eocene times. Palynologically it has been categorized into 4 assemblages pertaining to four rock units D, B+C and A. Jain and Dutta (1978) have observed that the rock unit D which lies near the Lower Gondwana sediments and also contains hystrichosphaerids and some smaller foraminifera indicates marine conditions of deposition for this unit, possibly belonging to the Lower Tertiary rocks. Dutta and Singh (1980) believe that the reworked forms of Palaeozoic and Eocene from the north and south possibly show that the source rocks were of the Lower Gondwanas and Disangs respectively.

CLIMATE

Lakhanpal (1974) believes that the Subathu Formation (Upper Palaeocene-Lower Eocene) had subtropical climate which continued in the Siwalik belt of Miocene-Pliocene times. Khanna and Singh (1980) have suggested coastal transitional environment of deposition for the Dagshai Formation (Upper Eocene to Oligocene) whereas the Kasauli sediments (Lower Miocene) were deposited under fluviatile environment having subtropical elements together with gymnospermous pollen grains coming from the high hills of neighbourhood area.

According to Vishnu-Mittre (1979) megafossil and pollen assemblage evidence from the Siwaliks is rather inadequate to comment upon the past environments, plant communities and vegetational history. He further observes that the identification of spores and pollen grains from the Middle Miocene to the end of Early Pleistocene is ' improper ' and hence the assemblages as such are not useful for palaeoecological interpretations. In spite of these snags he has suggested the local occurrence of semi-evergreen tropical forests during the Lower Siwaliks on flat ground and in hilly country. During the Middle Siwaliks the climatic shift was towards less warmth and moisture. The increase in *Pinus* and possibly *Larix* during the upper part of the Upper Siwalik has been considered to be indicative of a cool and moist climate. The observations indicating these climatic trends have reasonably good support from the pollen evidence.

CONCLUSION

From the foregoing account, it can be inferred that the palynological information from the Tertiary deposits of Himalaya has been gathered mostly during the last decade though the beginning for its development was made two decades earlier. On the basis of palynological composition the Subathus, the Dharamsalas (and their equivalent rocks in Simla Hills) and the Siwaliks can be grossly distinguished. Significance of each assemblage has been discussed particularly in regard to its stratigraphical importance and other applied aspects. Various rock sequences have been dated and correlated palynologically. Palynological information, though scanty, has been utilized in the interpretation of the depositional environment and palaeoclimates during the Tertiary times. Finally, a careful analysis of the palynological data may throw light on the vegetational history of the Tertiary period of this region.

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PLANT REMAINS FROM THE MIOCENE OF KACHCHH, WESTERN INDIA

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ABSTRACT

The paper deals with a few impressions of leaves, fruits and seeds belonging to 5 families, 10 genera and 11 species collected from the Khari Series (Aida Stage — Lower Miocene) of Kachchh. They have been described here as *Murraya khariensis* sp. nov. of Rutaceae, *Millettia symmetrica* sp. nov., *M. miocenica* sp. nov., *Bauhinia kachchhensis* sp. nov., *Cassia miokachchhensis* sp. nov., *Leguminocarpon khariensis* sp. nov., *Leguminophyllum khariensis* sp. nov. and *Leguminosites khariensis* sp. nov. of Leguminosae, *Cinnamomum miokachchhensis* sp. nov. of Lauraceae, *Ficus khariensis* sp. nov. of Moraceae and *Palmacites khariensis* sp. nov. of Palmae. The assemblage suggests moist to dry deciduous vegetation in this area.

Key-words — Plant remains, Rutaceae, Leguminosae, Lauraceae, Moraceae, Palmae, Khari Series, Lower Miocene (India).

सारांश

कच्छ (पश्चिमी भारत) में मध्यनूतन युग के पादपाश्म – राजेन्द्र नाथ लखनपाल एवं जसवंत सिंह गुलेरिया

प्रस्तुत शोध-पत्र में कच्छ की खारी श्रेणी (ऐडा चरण—अधर मध्यनूतन) से एकत्रित कुछ पत्तों, फलों एवं बीजों की छापों का, जो कि पाँच कुलों, 10 प्रजातियों एवं 11 जातियों से सम्बद्ध हैं, वर्णन किया गया है। इन्हें रुटेसी कुल के मुराया खारीयेन्सिस न० जा०, लेग्यूमिनोसी कुल के मिलेटिया सिमेट्रिका न० जा०, मि० मायोसेनिका न० जा०, बौहीनिया कच्छेन्सिस न० जा०, कैसिया मायोकच्छेन्सिस न० जा०, लेग्यूमिनोकार्पोन खारीयेन्सिस न० जा०, लेग्यूमिनोफिल्लम् खारीयेन्सिस न० जा० एवं लेग्यूमिनोसाइटिस खारीयेन्सिस न० जा०, लॉरेसी कुल के सिन्नामोमम् मायोकच्छेन्सिस न० जा० मोरेसी कुल के फ़ाइकस खारीयेन्सिस न० जा० तथा पाल्मी कुल के पाल्मासाइटिस खारीयेन्सिस न० जा० से नामांकित किया गया है। यह समुच्चय इस क्षेत्र में नम से शुष्क पर्णपाती वनस्पति का होना इंगित करता है।

INTRODUCTION

LAKHANPAL and Guleria have recently (1981) summarized the work done so far on the Tertiary flora of Kachchh. Since then a few hitherto unknown impressions of leaves, seeds and fruits have been collected from the Miocene beds (Aida Stage — Aquitanian) of Kachchh (Biswas & Raju, 1973; Tewari & Singh, 1977) and described in the present paper. These beds are exposed along the Khari Nadi (23°25'30" Lat., 68°52' Long.) about 2.5 km south of the village Goyela, district Kachchh, Gujarat. The locality lies on the southern bank of Khari Nadi about 100 m east of the road where it cuts the river bed. Goyela is about 125 km north-west of Bhuj on the Matanomadh-Naliya route via Rampur. The impressions preserved in arenaceous and light fawn coloured shales are totally devoid of cuticles.

In contrast to the leaf-assemblage described from the Eocene of Kachchh by the authors (1981), the present assemblage consists of smaller leaves of which a large number belong to the family Leguminosae. They seem to indicate relatively drier conditions during the Lower-Miocene of Kachchh.

For the description of leaf-impressions the system of terminology given by Hickey (1973, 1974) and Dilcher (1974) has been followed.

The authors are thankful to the authorities of the Forest Research Institute, Dehradun for allowing them to consult their herbarium for identifying the fossils.

DESCRIPTION OF IMPRESSIONS

FAMILY — RUTACEAE

Genus — *Murraya* Koen. ex L.

Murraya khariensis sp. nov.

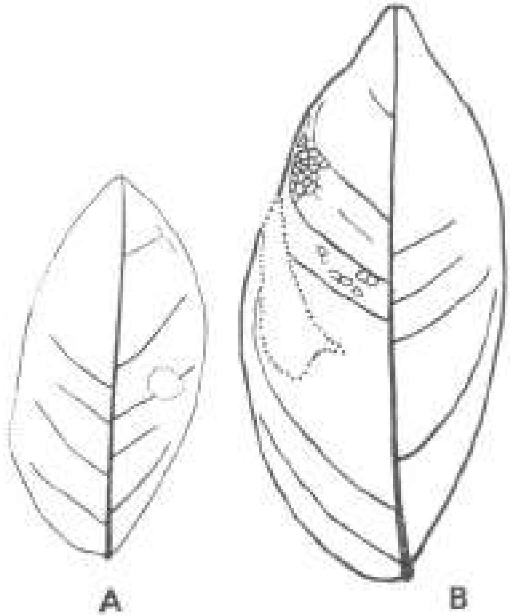
Pl. 1, figs 1, 2; Text-fig. 1A, B

The present species is based on two impressions of leaflets — 3.4 and 4.9 cm long respectively.

Description — Leaflets asymmetrical, elliptic; lamina about 3.4 to 5.0 cm in length and 1.6 to 2.4 cm in width; apex blunt acute to short acuminate; base asymmetrical; margin entire; texture thick smooth; petiolule hardly preserved; venation pinnate, eucamptodromous to brochidodromous, preservation poor; primary vein (1°) single, size moderate, slightly curved; secondary veins (2°) — angle of divergence acute, 50°-60°, fine, curved, rarely branched; tertiary veins (3°) forming fine meshes, pattern random to orthogonal reticulate; areoles well-developed, appearing triangular to pentagonal; veinlets not seen.

Discussion — The important features of the present fossil are: (i) asymmetrical shape, (ii) small size, (iii) smooth margin, (iv) blunt acute to short acuminate apex, (v) thick smooth texture, and (v) pinnate venation.

The leaves of some of the genera of the families Meliaceae, Euphorbiaceae, Salvadoraceae, Leguminosae and Rutaceae show apparent resemblance with the present fossil in having one or more of the above mentioned characters. The common feature which the leaves of Meliaceae show with the fossil is the asymmetrical shape. However, they differ in other characters. In shape the small leaves of *Drypetes roxburghii* Wall. (*Putranjiva roxburghii* Wall.) of Euphorbiaceae show similarity with the present fossil but they differ in having finely serrated margin. The leaves of *Azima tetracantha* Lamk. of Salvadoraceae show resemblance in shape and size but they differ in the pattern of venation and in having distinct mucronate apex. In Leguminosae the leaflets of *Millettia ovalifolia* Kurz show apparent resemblance with the present fossil but the leaflets of *M. ovalifolia* differ in having greater width and weakly retuse apex. Of the family Rutaceae the leaves or leaflets of some of the species of *Zanthoxylum* Linn. and *Paramignya beddomei* Tanaka, *Aegle marmelos* Correa, *Murraya koenigii* Spreng. and *M. paniculata* (Linn.) Jack (syn. *M. exotica* Linn.) show better resemblance with the present fossil. The leaflets of *Zanthoxylum* spp. and leaves of *Paramignya beddomei* differ in having longer apex than the present fossil. Further, in *P. beddomei* the petiole is longer. The leaflets of *Aegle marmelos* show resemblance with the fossil but differ in having crenate margin. Similarly, the leaflets of *Murraya koenigii* though showing general similarity with the fossil yet differ in relatively longer apex and serrated margin. Further, the leaflets in *M. koenigii* are chartaceous. The leaflets of *M. paniculata* show the nearest similarity with the present fossil in its shape, size, form, etc. However, they differ in having bigger petiolule



TEXT-FIG. 1 — A, B, *Murraya khariensis* sp. nov., leaflets, × 1.5.

Fossil Records and Comparison — The authors are unaware of any fossil record of the leaflet of *Murraya* except a doubtful species of *Murraya*, i.e. *Murraya* sp. (?), simply recorded by Puri (1948, p. 118) without any description and photograph from the Lower Karewa (Pleistocene) beds of India. Obviously, this is for the first time that fossil leaflets of *Murraya* are being described under the binomial *Murraya khariensis* sp. nov., the specific epithet indicating the locality (Khari Nadi bed) from where the fossil specimens have been collected.

Present Distribution — The genus *Murraya* consists of 12 spp. (Willis, 1973, p. 766), distributed in East Asia, Indo-Malaya and Pacific islands. In India, only two species, viz., *Murraya paniculata* and *M. koenigii* are found.

Murraya paniculata, with which the present fossil shows the nearest resemblance, is a large shrub or small evergreen tree, distributed from Ravi eastwards to Assam, ascending to 1,350 m in Uttar Pradesh, Bihar, Orissa, South and West India; usually common in the underwood in ravines and forests, throughout the hotter parts of India, Burma, the Andamans and Ceylon. It also occurs in China, Australia and the Pacific islands.

Holotype — B.S.I.P. Museum no. 35416.

Paratype — B.S.I.P. Specimen no. 35417.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

FAMILY — LEGUMINOSAE

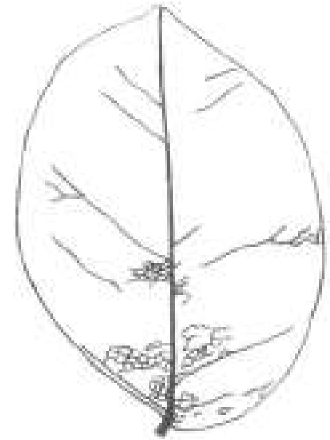
Genus — *Millettia* Wight & Arn.

Millettia asymmetrica sp. nov.

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

The present species is based on three leaflet impressions, 3.1 cm, 3.4 cm and 3.9 cm long. The impressions are fairly well-preserved.

Description — Leaflets asymmetrical, elliptic-wide elliptic; lamina length 3.0-3.9 cm, maximum width 1.6-2.7 cm; apex shortly acuminate?; base asymmetrical; margin entire; texture appearing somewhat coriaceous; petiolule short, 0.1 cm in length; venation pinnate, eucamptodromous, poorly preserved; primary vein (1°) single, size moderate slightly curved; secondary veins (2°) angle of divergence acute, 60°-90°, thickness fine, curved; smaller veins forming fine meshes; pattern random to orthogonal reticulate; areoles well-developed, shape appearing to be quadriangular; veinlets not seen.



TEXT-FIG. 2 — *Millettia asymmetrica* sp. nov., leaflet, × 1.5.

Discussion — The important features depicted by the present fossil are: (i) asymmetrical shape, (ii) small size, (iii) smooth margin, (iv) shortly acuminate? apex, (v) small petiolule, and (vi) eucamptodromous venation.

These characters can be seen in the leaves of various genera of a number of families as given on page 280. However, the present specimens show better resemblance with the members of Leguminosae, such as *Dalbergia sissoo* Roxb., *D. latifolia* Roxb., *Pongamia pinnata* (Linn.) Pierre (Syn. *P. glabra* Vent.) and *Millettia ovalifolia* Kurz. The leaflets of both the species of *Dalbergia* are broadly elliptic-orbiculate-ovate. Also the apex of the leaflet in *D. sissoo* is relatively long acuminate. The leaflets of *Pongamia pinnata* show near similarity. However, in them the angle of secondaries is relatively acute. The fossil shows close resemblance with the leaflets of *Millettia ovalifolia* in its shape, size, form and petiolule length.

Fossil Records and Comparison — The authors are aware of only 3 species of *Millettia* (based on leaflets). *Millettia impressa* Harms, was reported by Menzel (1920) from Kamerun, West Africa (Age — Uncertain, Recent to Tertiary). Other two species have been described from Japan, viz., *M. notoensis* Ishida (1970) from Eocene and *Millettia* sp. Huzioka & Takahasi (1970) from the

Mid-Eocene. As *Millettia impressa* is not accompanied by its description and photograph, it is not possible to compare this species with the present fossil. *M. notoensis* differs from the present fossil in shape and form. *M. notoensis* is ovate in form and more or less symmetrical in shape. *Millettia* sp. distinctly differs from the present fossil in form and size. It is lanceolate in form and 7 cm long as compared to present fossil which is elliptic-wide elliptic in form and 3.1-3.9 cm long.

Obviously, the present species differs from all the known fossil species of *Millettia*, based on the leaflets and hence a new name *Millettia asymmetrica* is assigned to this species, indicating the asymmetric shape of the fossil.

Millettia ovalifolia, with which the specimen shows resemblance, is a tree species found in dry forests of Burma (Kurz, 1877, p. 356; Brandis, 1906, pp. 220, 706).

Holotype — B.S.I.P. Museum no. 35418.

Paratypes — B.S.I.P. Specimen nos. 35419 and 35420.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

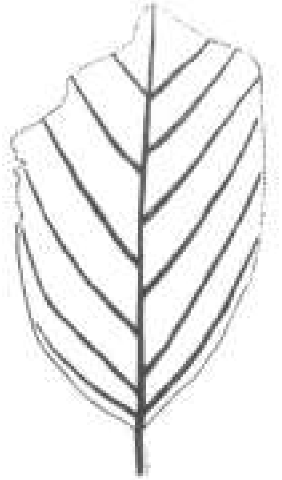
Millettia miocenica sp. nov.

Pl. 1, fig. 9; Text-fig. 3

The present description is based on a single fairly well-preserved 6.2 cm long specimen, whose apical portion is broken.

Description — Leaflet symmetrical, seemingly oblong; lamina length 5.6 cm, maximum width 3.2 cm; apex broken; base acute, normal; margin entire; texture chartaceous; petiolule short, 0.6 cm in length; venation pinnate, seemingly eucamptodromous; primary vein (1°) single, stout, slightly curved, unbranched; secondary veins (2°) — angle of divergence acute, moderate, 45°-50°, lowest pair more acute than pairs above, arrangement alternate, number of preserved secondaries six on either side of midrib, relatively less thick than the primary vein, uniformly curved, unbranched; intersecondary veins absent, tertiary veins (3°) and higher order venation not preserved.

Discussion — The important features of the fossil are: (i) symmetrical shape, (ii) oblong form, (iii) acute base, (iv) entire margin, (v) pinnate, eucamptodromous venation, and (vi) small petiolule. All these characters could be seen in the leaflets of *Desmodium* Desv., *Millettia* Wight & Arn. and *Pterocarpus* Linn. of the family Leguminosae.



TEXT-FIG. 3 — *Millettia miocenica* sp. nov., leaflet, × 1.

The frequency of secondary veins is more in those species of *Desmodium* and *Pterocarpus* which resemble the present fossil. Further, intersecondaries are present in the *Pterocarpus* spp., which are absent in the present fossil.

Among the various examined species of *Millettia* only *Millettia auriculata* Baker, *M. macrostachya* Coll. & Hemsl. and *M. pachycarpa* Benth. show similarity with the fossil. *M. pachycarpa* differs distinctly from the present fossil in the angle of divergence of the lowermost secondaries, which is more acute in the fossil as compared to *M. pachycarpa*. The leaflets of *M. auriculata* and *M. macrostachya* show very close similarity with the fossil and with each other, hence it is not possible to distinguish them on mere morphological basis. However, taking into consideration the present distribution of *M. auriculata* and *M. macrostachya*, it is presumed that the present fossil is likely to show closer affinities with *M. auriculata*, rather than with *M. macrostachya*.

Fossil Records and Comparison — The authors are aware of 4 fossil species of *Millettia*, viz., *M. impressa* Harms from West Africa, *M. notoensis* Ishida and *Millettia* sp. Huzioka & Takahasi from Japan and *M. asymmetrica* (see pp. 281-282) from India. Since *M. impressa* is unaccompanied by any description or photograph, it is not possible to compare it with the present fossil. *M. notoensis* differs in its shape and angle of divergence. The shape of *M. notoensis* is ovate, whereas it is oblong in the present fossil. *Millettia* sp. from Japan differs from the present fossil in having lanceolate shape and inequilaterally obtuse base. Similarly, *M. asymmetrica* differs from the present fossil in shape and form. As the present specimen is different from all the known species of *Millettia*, a new specific name is assigned to this, viz., *Millettia miocenica* sp. nov. The specific name indicates the age of the beds from which the fossil has been collected.

Present Distribution — The genus *Millettia* comprises 180 spp. (Willis, 1973, p. 746) of trees, shrubs and woody climbers, distributed in the warmer regions of Africa, Asia and Australia. Approximately 30 species (Ramesh Rao & Purkayastha, 1972, p. 114) are reported to occur in the Indian region, chiefly in Burma.

M. auriculata, a woody climber, is found in sub-Himalayan tract, from Sutlej eastward, Bihar, Central India, south to the Godavary, common in Sal forests. It is also common in the deciduous forests of Upper and Lower Burma. *M. macrostachya*, a tree is found in the southern Shan hills (Burma). As regards climbers, it is important to note that the same species may sometimes be described as an erect shrub. According to Brandis (1906, p. 219), " In the deep shade of the forest *Millettia auriculata*, *Derris scandens* and other climbers remain stunted shrubs, but when light is given overhead, the internodes lengthen out; the shoots seek the light, and begin to climb, attaching themselves to other shrubs and trees. Again, in the open, exposed to the sun, climbing species may remain shrubby for want of supports to lean upon ".

Holotype — B.S.I.P. Museum no. 35421.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

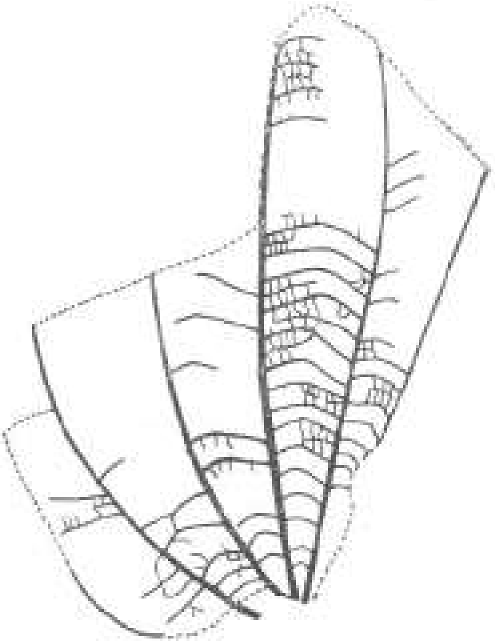
Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

Genus — *Bauhinia* Linn.

Bauhinia kachchhensis sp. nov.

Pl. 2, figs 10, 12, 13; Text-fig. 4

The present species is based on five specimens of incomplete leaf-impressions, out of which one shows very well-preserved details of venation. The specimens in all likelihood represent folded leaves.



TEXT-FIG. 4 — *Bauhinia kachchhensis* sp. nov., leaf, × 1.5.

Description — Leaf appearing symmetrical, composed of two wide obovate lobes; lamina length 5.0 cm, maximum width 4.0 cm; lobes rounded; apex not preserved; base? cordate; margin entire; texture appearing to be thick chartaceous; petiole not preserved; venation acrodromous; primary vein (1°) four to six in one half, arranged as series of veins of relatively equal thickness, weak, markedly curved; secondary veins (2°) numerous between the two primaries and joining the adjacent primaries, fine, curved to wavy; tertiary veins (3°) pattern random to reticulate, distant to closely arranged; areoles well-developed, arrangement oriented, triangular to pentagonal, size medium; veinlets not seen.

Discussion — The most important feature of the fossil is the acrodromous venation with entire margin of the leaf. That the specimen is a folded leaf or it is one half of the leaf is clearly indicated by one of the margins of the fossil leaf, which is running almost straight like an edge (thereby, abruptly marking the end of lamina on that side) whereas the other margin of the leaf is showing clear curvature, and hence indicates that the fossil leaf has got folded up from the side of sharp straight edge. This folding of the leaf provides a very strong circumstantial evidence that the leaf must have had emarginate apex, as it has been observed that the leaves normally do not get folded up unless the apex is emarginate or the leaf is incompletely or completely bilobed. This type of leaf having emarginate apex or incompletely to completely lobed lamina with entire margin and acrodromous venation is found in *Hardwickia* Roxb. and *Bauhinia* Linn.

Of the two species of *Hardwickia* found in India only the leaves of *H. binata* Roxb. show some resemblance with the fossil. However, leaves in *H. binata* are relatively smaller in size and almost completely bifoliate. Due to bilobation, both the margins of each lobe exhibit curvature, as compared to the present fossil, in which one margin shows curvature, whereas the other margin is almost straight. Further, the orientation of the secondary venation in *H. binata* also differs from the present fossil.

Leaves of a large number of *Bauhinia* species were compared with the fossil. Of them, *Bauhinia purpurea* Linn. and *B. phoenicea* Heyne show very close similarity with the fossil and it is difficult to differentiate these two species from one another on the basis of leaf morphology.

Fossil Records and Comparison — From India Lakhanpal and Awasthi (in press) have reported the fossil leaf of *Bauhinia* from the Siwalik beds of West Champaran District, Bihar. From abroad, the fossil leaves of *Bauhinia* have been described under two genera, viz., *Bauhinia* Linn. and *Bauhinites* Seward & Conway (1935). The earliest record of *Bauhinia* leaf is known from the Middle-Cretaceous of Bohemia (Velenovsky, 1885). Besides one species of *Bauhinites*, *B. groenlandica* Seward & Conway (1935), the authors are aware of 17 spp. of *Bauhinia*, viz., *B. alabamensis* Berry (listed in Berry, 1916), *B. cretacea* Newberry (1886, 1895), *B. destructa* Unger (1850), *B. ecuadorensis* Berry (1945), *B. europaea* Engelhardt (listed in Muller, 1934), *B. germanica* Heer (1859), *B.* (?) *gigantea* Newberry (1895), *B. marylandica* Berry (1908), *B. olympica* Unger (1867), *B. parschlugiana* Unger (1850), *B. pseudocotyledon* Cockerell (listed in Knowlton, 1919), *B. ripleyensis* Berry (1916), *B. siwalika* Lakhanpal & Awasthi (in press), *Bauhinia* sp. Knowlton (listed in Knowlton, 1919), *B. wadii* Berry (listed in La Motte, 1952), *B. weylandi* Chaney (1933) and *B. wyomingana* Brown (1956d). These species have been reported from Austria, Bolivia, Czechoslovakia, Equador, West Germany, Greece, Greenland, India, North Vietnam, Uganda, U.S.A. and U.S.S.R.

All the records available to the authors have been compared here. *Bauhinia siwalika* can easily be distinguished from the present fossil. The former is smaller in size (1.5-4 cm in length and 1-3 cm in width) as compared to the fossil (up to 5.0 cm in length and 4.0 cm in width). Further, the number of primaries are only 3-4 in *B. siwalika* as compared to 4-6 in the present fossil. *Bauhinia ecuadorensis* shows some resemblance. However, the angle and course of the second pair of lower primaries in *B. ecuadorensis* is entirely different from the present fossil. *B. cretacea* differs from the present fossil in having only one to two lateral primaries in each lobe of the leaf. Moreover, the inner primaries bifurcate several times. Similarly, *B. ripleyensis* differs in having only one lateral primary in each lobe. Like the present fossil, *B.* (?) *gigantea* is also based on one lobe of the leaf. Nevertheless, it differs from the fossil in its size and in the number of primaries. It possesses only one lateral primary, against four to six in the present fossil. In *B. wyomingana* primaries arise from different points, contrary to the present fossil in which primaries arise from single basal point. Berry (1945) does not regard *B. pseudocotyledon* from the Miocene of Florissant, Colorado, as representing *Bauhinia*. According to him *B. europaea* and *B. germanica* are more likely referable to the genus *Hymenaea* Linn. as they possess well defined midvein in each leaflet, unlike in the genus *Bauhinia*. The pinnate venation in *B. destructa* and *B. parschlugiana* differentiate these from the present fossil. *Bauhinites groenlandica* can also be differentiated by its relatively smaller size and in having 3 primaries in each lobe, as against 4 or more in the present fossil.

Thus the present fossil is distinct from all previously known fossil Bauhinias and is assigned to a new species, *Bauhinia kachchhensis*. Its specific name is after the area from where the material was collected.

Present Distribution — The genus *Bauhinia* comprises 300 spp. (Willis, 1973, p. 127) and is found throughout the tropics of the world. These consist of trees, shrubs, vines and gigantic lianes. Brandis (1906) has enumerated 30 spp. from India and Burma, of which 6 attain tree size.

Of the two comparable species, *B. phoenicea* Heyne is a gigantic climber and *B. purpurea* Linn. is a medium-sized tree. The former is common on the Ghats of South Kanara, Wainad and also found in the evergreen forests of Coorg and Travancore. The latter is found in sub-Himalayan tract, from the Indus eastwards, ascending to 1,600 m in Assam, Khasi Hills, Chittagong, western Peninsula, in deciduous forests.

Holotype — B.S.I.P. Museum no. 35422.

Paratypes — B.S.I.P. Specimen nos. 35423-35425.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

Genus — *Cassia* Linn.

Cassia miokachchhensis sp. nov.

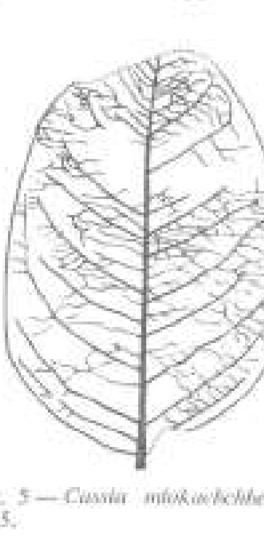
Pl. 2, fig. 11; Text-fig. 5

The present species is represented by three fairly well-preserved leaflets. However, the apices of leaflets in all the specimens are broken.

Description — Leaflet almost symmetrical, ovate; lamina length 3.5 cm, maximum width 2.6 cm; apex broken; base obtuse; margin entire; texture seemingly chartaceous; attachment of petiolule normal, petiolule 2.0 cm long; venation pinnate, eucamptodromous; primary vein (1°) simple, stout, slightly curved; secondary veins (2°) — angle of divergence acute (70°-50°), 70° near the base and gradually decreasing upwards, thickness fine, curved upwards, appears unbranched; intersecondaries present, simple; tertiary veins (3°) still finer, pattern random reticulate, simple, distant to close; quaternaries forming fine net work, course orthogonal to randomly oriented; areoles well developed, oriented, shape appears quadrangular, size small; veinlets not seen.

Discussion — The important characters of the present fossil are: (i) small size, (ii) almost symmetrical shape, (iii) ovate form, (iv) obtuse base, (v) entire margin, (vi) short petiolule, (vii) eucamptodromous venation, and (viii) chartaceous texture.

The petiolule and the small size of lamina of the present fossil suggest that it is a



TEXT-FIG. 5 — *Cassia miokachchhensis* sp. nov., leaflet, × 1.5.

leaflet of some leguminous plant, thereby ruling out all other families from consideration. In the family Leguminosae the leaflets of *Dalbergia* Linn. f., *Pterocarpus* Linn. and *Cassia* Linn. show the above noted characters. The leaflets of *Pterocarpus* spp. which show apparent resemblance with the present fossil, however, differ in the angle of divergence of secondaries. Among the large number of *Dalbergia* spp. examined, the leaflets of *D. latifolia* Roxb. and *D. sissoo* Roxb. show some resemblance. However, they differ in having broadly-elliptic-orbiculate-ovate form. Moreover, they differ in being coriaceous as compared to chartaceous texture of the present fossil. The fossil thus shows the nearest approach to *Cassia* leaflets.

Fossil Records and Comparison — Leaflets of *Cassia* have been reported under two genera, namely *Cassia* Linn. and *Cassiophyllum* Geyler (1887). The authors are aware of about 100 species of leaflets of *Cassia* and one species of *Cassiophyllum* (LaMotte, 1952; Guleria, 1978). They have been reported from different parts of the world such as Australia, Bolivia, Czechoslovakia, Germany, Greenland, Indonesia, Italy, Japan, New Zealand, Switzerland, U.S.A. and U.S.S.R.

So far there is no record of leaflets of *Cassia* from India. However, a fruit said to be comparable to *Cassia* has been described by Carter (1854) from Takli (Deccan Intertrappean Series), near Nagpur, Maharashtra. This is perhaps the earliest record of the so-called *Cassia* from India. Lately, a legume fruit comparable to Carter's (1854) specimen has been reported by Shivarudrappa (1976) from the Intertrappean beds of Burjapalli area of Gulbarga District, Karnataka.

Present Distribution — *Cassia* is a large genus of 500-600 spp. of herbs, shrubs and trees and grows in tropical and warm temperate (excluding Europe) regions of the world (Willis, 1973, p. 211). The genus includes some of the most beautiful flowering trees and shrubs, planted in avenues and gardens. Brandis (1906) enumerates 12 spp. of *Cassia* from the Indian region.

As no fossil species of leaflets of *Cassia* is known from India, the present leaflet is assigned to a new species, *Cassia miokachchhensis* sp. nov., the specific name suggesting the age and the place from where the present fossil was collected.

Holotype — B.S.I.P. Museum no. 35426.

Paratypes — B.S.I.P. Specimen nos. 35427 and 35428.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

Genus — *Leguminocarpon* Goeppert, 1855

Leguminocarpon khariensis sp. nov.

Pl. 3, figs 16-18, 20

This species is represented by a number of fragmentary impressions of pods.

Description — Pods fragmentary; dehiscent; 1.6-7.0 cm long, 1.4-2.4 cm broad, terminating into a short pointed apex; margin wavy due to shallow constrictions setting apart lobes; each lobe containing a single somewhat rounded seed; suture lines visible close to the margins; texture coriaceous.

Since the pods undoubtedly belong to the family Leguminosae and it is difficult to determine the affinity of these pods beyond family level at present, they are placed under the artificial genus *Leguminocarpon* Goeppert (1855) which is the earliest instituted genus for the fossil fruits referable to Leguminosae. The specific epithet *Leguminocarpon khariensis* sp. nov. is after the locality, Khari Nadi bed.

Holotype — B.S.I.P. Museum no. 35429.

Paratypes — B.S.I.P. Specimen nos. 35430-35433.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

Genus — *Leguminosites* Bowerbank, 1840

Leguminosites khariensis sp. nov.

Pl. 3, figs 19, 21

Description — The species is based on two leguminous seeds. One of them is split open into two parts. Both the specimens are round to circular in form, 1.0-1.9 cm in diameter.

Since these seeds have been found in close association with leaflets and pods they are therefore considered to be leguminous. Hence they are placed under the artificial genus *Leguminosites* Bowerbank (1840) which represents the fossil seeds belonging to Leguminosae. The specific name is after the locality.

Holotype — B.S.I.P. Museum no. 35434.

Paratype — B.S.I.P. Specimen no. 35435.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

Genus — *Leguminophyllum* Lemoigne, Beauchamp & Samuel, 1974

Leguminophyllum khariensis sp. nov.

Pl. 2, fig. 14; Pl. 3, fig. 22; Text-fig. 6

The present species is based on a few impressions of leaflets.

Description — Leaflets asymmetrical, oblong to narrow ovate; 1.3-1.8 cm long, 0.6 cm wide; apex appearing obtuse to mucronulate; base oblique; margin entire; texture chartaceous; petiolule absent; venation pinnate; primary vein (1°) single stout, slightly curved, unbranched; secondary veins (2°) preserved only in the basal region, angle of divergence acute, 50°, fine, curving upwards; tertiary veins and higher order venation not clear.

Discussion — The small size, asymmetric shape and the absence of petiole/petiolule doubtlessly indicate that the present specimens are the leaflets of compound leaves. The leguminous pods found in close association with these leaflets provides additional support to the fact that these are the leaflets of leguminous plant. Such leaflets are found in a large number of modern genera of Leguminosae. As the present leaflets are indubitably leguminous in their affinity they are placed under the artificial genus *Leguminophyllum* Lemoigne *et al.* (1974), which perhaps accommodate all the fossil leaflets of legumes whose affinities cannot be ascertained definitely beyond the family level. The present leaflets are assigned the specific name *Leguminophyllum khariensis* sp. nov., the specific name indicating the locality from where the material was collected.

TEXT-FIG. 6 — *Leguminophyllum khariensis* sp. nov., leaflet, × 3.

It seems that *Leguminocarpon khariensis* sp. nov., *Leguminosites khariensis* sp. nov. and *Leguminophyllum khariensis* sp. nov. may belong to one and the same plant as the leaflets, pods and seeds are preserved in close association though not in actual organic connection. Similar type of leaflets and pods are present in various species of a number of modern leguminous genera such as *Abrus*, *Acacia*, *Albizia*, *Caesalpinia*, *Dalbergia*, *Gleditsia*, *Parkia*, *Peltophorum*, *Schizolobium*, *Tamarindus*, etc. Thus it is hazardous to commit anything about the exact generic affinities of the above described leaflets, pods and seeds.

Holotype — B.S.I.P. Museum no. 35436.

Paratypes — B.S.I.P. Specimen nos. 35437 and 35438.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

FAMILY — LAURACEAE

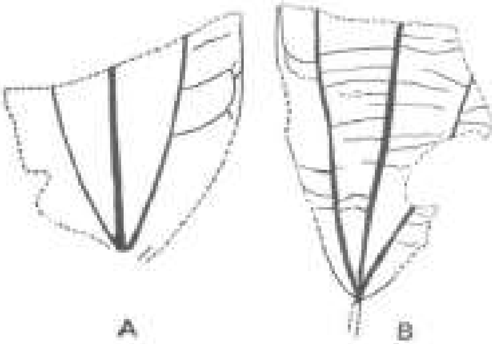
Genus — *Cinnamomum* Schaeffer

Cinnamomum miokachchhensis sp. nov.

Pl. 1, figs 3, 7, 8; Text-fig. 7A, B

The present species is based on four incompletely preserved specimens. Preservation, however, is poor.

Description — Leaves appearing symmetrical, elliptic to narrow-ovate; preserved lamina length 4.25-6.75 cm, maximum width 2.7-3.5 cm; apex broken; base acute to



TEXT-FIG. 7 — A, B, *Cinnamomum miokachchhensis* sp. nov., leaves, × 1.

sometimes obtuse, margin entire; texture seemingly chartaceous; petiole unpreserved; venation basal acrodromous, (?) perfect; primary veins (1°) three, moderate to stout, more or less straight, two lateral primaries slightly curved, unbranched; secondaries (2°) very fine, running approximately at right angles (forming ripples) to acute angles, sometimes branched, emerging from the median primary and joining the two laterals, also arising from the outer side of the two lateral primaries at acute angles moving upward and forming fine intramarginal veins, prominent secondaries (seen in specimen nos. 35440 and 35441) moving upwards at acute angles; tertiaries still finer forming numerous fine meshes; areoles imperfect; veinlets not seen.

Discussion — As discussed elsewhere by the authors (1981), the overall characters of these fossils indicate that they belong to the genus *Cinnamomum*. Hitherto, three species of *Cinnamomum*, based on their leaves, are known from India, i.e. *Cinnamomum* sp. cf. *C. tamala* Nees, described by Pathak (1969) from the Upper Tertiary (Middle Siwalik) of West Bengal, *C. palaeotamala* cf. *C. tamala* reported by Lakhanpal & Awasthi (in press) from near Bhikhnathoree (Indo-Nepal border) in West Champaran District, Bihar and *C. eokachchhensis* described by the authors (1981) from the Eocene of Kachchh. The presence of intramarginal veins and the absence of prominent secondaries at the basal region differentiate the present fossils from *Cinnamomum tamala* described by Pathak (1969). Similarly, *C. palaeotamala* can be easily differentiated from the present fossil. In the former lateral primaries are suprabasal in origin as compared to their basal origin in our specimens. Further, intramarginal vein is present in our specimens whereas it is not seen in *C. palaeotamala*. *C. eokachchhensis* differs in its bigger size, coriaceous texture, obtuse to almost round base and in the absence of prominent secondaries as compared to the smaller size, relatively thin texture, normally acute base and the presence of prominent secondaries in the present fossil.

Thus the present fossil differs from the earlier known Indian species of *Cinnamomum*. Therefore a new binomial, viz., *Cinnamomum miokachchhensis* sp. nov. is assigned to it. The present fossil in all likelihood is a variant of *Cinnamomum zeylanicum* Breyn.

Cinnamomum zeylanicum is a large tree and is found in Western Ghats and adjoining hill ranges, from Konkan southwards and also in Tenasserim (Brandis, 1906, p. 533).

Holotype — B.S.I.P. Museum no. 35439.

Paratypes — B.S.I.P. Specimen nos. 35440 and 35441.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

FAMILY — MORACEAE

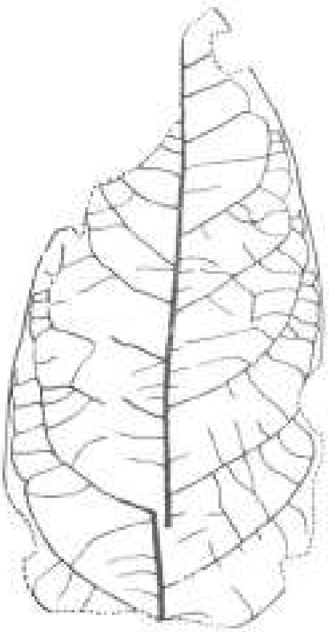
Genus — *Ficus* Linn.

Ficus khariensis sp. nov.

Pl. 2, fig. 15; Text-fig. 8

The present species is based on a single fairly well-preserved leaf-impression. The specimen is, however, incomplete.

Description — Leaf symmetrical, narrow ovate to lanceolate; preserved lamina length 7.7 cm, maximum width 4.1 cm; apex not preserved; base unpreserved (however, appearing to be symmetrical); margin entire, slightly wavy; texture seemingly thick chartaceous; petiole unpreserved; venation pinnate, brochidodromous; primary vein (1°) single, stout, slightly curved; secondary veins (2°) angle of divergence acute (75°-60°), 75° near the basal region and gradually decreasing upwards, moderately thick, curved, branched, forming loops near the margin, loop forming branches joining superadjacent



TEXT-FIG. 8 — *Ficus khariensis* sp. nov., leaf, × 1.

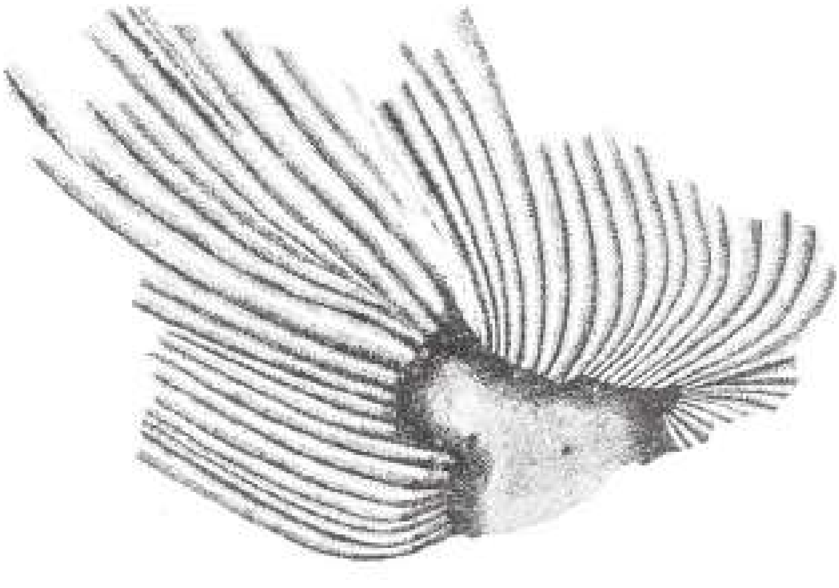
secondary at wide acute angle; intersecondary veins present, simple; tertiary veins (3°) angle of origin usually RR to OR, pattern percurrent to reticulate, sometimes joining primary, mostly obliquely arranged in relation to midvein, arrangement seems alternate, distant to close, forming arches just inside the margin enclosing loops formed by secondaries; higher order venation not seen; areoles and veinlets not preserved.

Discussion — The overall characters of the fossil indicate that it belongs to the genus *Ficus*. The leaves of *Ficus infectoria* Roxb. show apparent resemblance with the present fossil.

Among the fossil leaves of *Ficus* from India (Lakhanpal & Guleria, 1981) only *Ficus arnottiana* Miq. and *F. glomerata* Roxb. described by Mahajan and Mahabale (1973) from the Quaternary deposits of Maharashtra show some resemblance with the present fossil. *F. arnottiana* is bigger in size, moreover the angle of divergence in it is less than 60° as compared to the present fossil in which the angle of divergence varies from 60°-75°. In *F. glomerata* the secondaries bifurcate below the margin at an angle of 30° and less than 30° as compared to the present fossil where the corresponding angle is greater than 30°.

Thus, the present specimen differs from the known Indian fossil leaves of *Ficus*. Therefore, a new specific name *Ficus khariensis* sp. nov., is assigned to it. The specific epithet refers to the locality, Khari Nadi bed, from which the specimen was collected.

Ficus infectoria is a large deciduous tree found in sub-Himalayan tract and outer



TEXT-FIG. 9 — *Palmacites khariensis* sp. nov., × 1.

hills up to 1600 m, common in northern India, the Central Provinces, Berar and the western Peninsula (Brandis, 1906, p. 602.)

Holotype — B.S.I.P. Museum no. 35442.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

FAMILY — PALMAE

Genus — *Palmacites* Brongniart, 1822

Palmacites khariensis sp. nov.

Pl. 3, fig. 23; Text-fig. 9

The present species is based on about half a dozen specimens of leaf-impressions, of which two are quite big. The preservation is fairly good.

Description — Preserved lamina length 9.0 cm, maximum preserved width 9.0 cm; form palmate; petiole thick, broad, incomplete, preserved length 2.5 cm, distal end irregularly rounded with impression of a shallow ridged hastula, costa not seen; lamina consisting of a large number of plicate segments, about 45 preserved, width of segments varying from 0.1-0.5 cm, segments fused (the specimen consisting of the basal region of the leaf), each segment with a midrib in the middle; further details indistinct.

Discussion — Read and Hickey (1972) in their revised classification of fossil palm and palm-like leaves have pointed out that "numerous similarities in the form and gross external features of palm leaves make it difficult or impossible to assign them to modern genera based only on their external morphology (except *Phoenix* Linn.)....... Since it is difficult to identify specimens of modern palms accurately from their leaves alone, no attempt should be made to place fossil palm fragments in genera of modern palms unless unquestionably identifiable with them".

Keeping the above observation in view, the present specimen can only be identified in a broad sense, i.e. it belongs to a true palmate palm as is obvious by the presence of hastula in the present specimen (Tomlinson, 1961, p. 24). The true palmate leaves are confined to two subfamilies of the family-Palmae, i.e. Coryphoideae and Lepidocaryoideae (Corner, 1966, pp. 347, 349, 351). Only three genera of Lepidocaryoideae possess palmate leaves, viz., *Mauritia* L.f., *Mauritiella* Burret, and *Lepidocaryum* Mart. but these are confined to America (Corner, 1966, p. 349). Hence, the present specimen possibly belongs to subfamily Coryphoideae of the Palmae. To know whether the present fossil shows some similarity with the leaves of any Indian member of Coryphoideae, the leaves of modern Indian genera of this subfamily have been compared with the fossil.

The subfamily Coryphoideae consists of 33 genera (Corner, 1966, p. 347) of which only *Corypha* Linn., *Licuala* Thunb., *Livistona* R. Br., *Nannorhops* Wendl. and *Trachycarpus* are found in India (Brandis, 1906, p. 644). Among these 5 genera, the leaves of *Corypha*, *Livistona* and *Nannorhops* are costapalmate and hence are incomparable with the present fossil. The genera *Licuala* and *Trachycarpus* are represented by 2 spp. each, the former by *Licuala peltata* Roxb. and *L. spinosa* Wurmb. and the latter by *Trachycarpus martiana* Wendl. and *T. takil* Becc. (Blatter, 1926).

The leaves of aforesaid species of *Licuala* and *Trachycarpus* are much bigger in size (about 90-152.5 cm in diameter) as compared to the present fossil. Moreover, *Trachycarpus* spp. are confined to the Himalayan region from 1,220-2,440 m, where trees are often covered with snow. Thus, the leaves of none of the modern Indian palms show similarity with the fossil. Hence, the generic similarity of the present fossil could not be ascertained.

Indian Fossil Records and Comparison — The earliest record of palm leaves are from the Deccan Intertrappean Series. These are *Palmophyllum dakshinense* Achuthan (1968), *P. mohgaonense* Mahabale (1966), and a palm leaf described by Trivedi and Chandra (1971). In addition to these, palm leaves have also been reported from the Eocene and Miocene beds of Kashmir and Himachal Pradesh. These are *Sabalites microphylla* Sahni (1964), *Sabalites* sp. Sahni (1964), *Palmophyllum* sp. Chaudhri (1969) and a fan-palm reported by Sahni and Bhatnagar (1958). *Palmophyllum dakshinense* is based on the anatomical features of a fragment of lamina. *P. mohgaonense* is unaccompanied by its description. *Palmophyllum* sp. Chaudhari (1969) differs from the present fossil in its narrow width and the palm leaf described by Trivedi and Chandra is very big in size, besides having much broader segments. Obviously none of them is similar to the present fossil. *Sabalites microphylla* differs in its small size (3.0×2.5 cm) as compared to the bigger size (9.0×9.0 cm) of the present fossil. Moreover, the number of segments in the present fossil are many more than in *S. microphylla*. *Sabalites* sp. Sahni (1964) differs from the present fossil in having much broader segments. The fan palm of Sahni and Bhatnagar shows only the apical portion of the segments as seen in the photographs and the portion near the base is missing. Consequently, it is not comparable with the present fossil.

Following Read and Hickey's recent classification (1972) of fossil palm and palm-like leaves, the present fossil falls under the genus *Palmacites* Brongniart. Since it is quite different from the known Indian fossil species of palm leaves, a new specific name, *Palmacites khariensis* sp. nov., is assigned to it. The specific epithet indicates the locality from where the fossil was collected.

Holotype — B.S.I.P. Museum no. 35443.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

GENERAL DISCUSSION

The above data have brought to light an important point that the Neogene megaflora of Kachchh is quite rich in legumes unlike the Palaeogene megaflora of this region from where no legume has so far been recorded (Lakhanpal & Guleria, 1981).

The components of the florule, in the light of distribution of their modern comparable forms, indicate a tropical climate in which it had flourished. The modern comparable forms of this Lower Miocene assemblage are distributed in the following types of tropical forests (see Table 1).

From this distribution it is clear that the modern equivalents of the fossil forms are not confined to a particular type of tropical forests. The climatic conditions must have been moderate (neither very moist nor very dry) as indicated by the majority of elements of this florule belonging to moist deciduous to dry deciduous forests. This view is further substantiated by the smaller size of the leaves and dominance of legumes. The semi-evergreen plants might have been growing in pockets.

From the general survey of the florule, it is seen that out of the known modern comparable genera, namely *Bauhinia*, *Cassia*, *Ficus*, *Cinnamomum*, *Millettia* and *Murraya*, the first three are found in the present day flora of Kachchh. Thus it is obvious that the last three were much wider in distribution during the Tertiary period. Of these, *Cinnamomum* and *Murraya* are the important genera from the palaeophytogeographical point of view. In the modern flora both these genera are confined to East Asia and Indomalaya. The latter, however, extends to Pacific islands (Willis, 1973, pp. 255, 766). *Cinnamomum zeylanicum* Breyn, the modern comparable species, is found in India confined to Western Ghats and adjoining hill ranges from Konkan southwards (Brandis, 1906, p. 533). It is quite likely that this species might have been growing all along the western coast up to Kachchh during Eocene

TABLE 1 — TROPICAL FOREST TYPES

TAXA	WET EVER GREEN FORESTS	SEMI-EVER GREEN FORESTS	MOIST DECIDUOUS FORESTS	LITTORAL AND SWAMP FORESTS	DRY DECIDUOUS FORESTS	THORN FORESTS	DRY EVER GREEN FORESTS
Bauhinia phoenicea }	+						
Bauhinia purpurea }		+	+				
Cinnamomum zeylanicum	+	+					
Cassia sp.			+		+	+	
Ficus infectoria			+		+		
Millettia auriculata			+		+		
Millettia ovalifolia					+		
Murraya paniculata		+	+		+		

to Lower Miocene times and subsequently died out from Kachchh on appearance of unfavourable conditions there. The modern comparable ally of *Murraya khariensis*, viz., *M. paniculata* L. (syn. *M. exotica* L.) is found east of Ravi, ascending up to 1,350 m in Uttar Pradesh, Bihar, Orissa, West and South India including the Andamans, usually common in the underwood, in ravines and forests throughout the hotter parts of India. Its occurrence in the Lower Miocene of Kachchh indicates that *Murraya* perhaps had its westward extension in the past up to Kachchh.

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EXPLANATION OF PLATES

PLATE 1

1. *Murraya khariensis* sp. nov., leaflet. × Natural size.
2. Another specimen of *M. khariensis* sp. nov., leaflet. × Natural size.
3. *Cinnamomum miokachchhensis* sp. nov., leaf. × Natural size.
4-6. *Millettia asymmetrica* sp. nov., leaflets, showing variations in shape and size. × Natural size.
7. Another specimen of *Cinnamomum miokachchhensis* sp. nov., leaf. × Natural size.
8. A third specimen of *C. miokachchhensis* sp. nov., leaf × Natural size.
9. *Millettia miocenica* sp. nov., leaflet. × Natural size.

PLATE 2

10. *Bauhinia kachchhensis* sp. nov., leaf. × Natural size.
12. Another specimen of *B. kachchhensis* sp. nov., leaf × Natural size.
13. Enlarged photograph of fig. 10, showing details of venation. × 2.
11. *Cassia miokachchhensis* sp. nov., leaflet. × Natural size.
14. *Leguminophyllum khariensis* sp. nov., leaflet. × 2.
15. *Ficus khariensis* sp. nov., leaf. × Natural size.

PLATE 3

16, 18. *Leguminocarpon khariensis* sp. nov., pods. × Natural size.
17, 20. *L. khariensis* sp. nov., pods, showing enclosed seed. × Natural size and × 2 respectively.
19, 21. *Leguminosites khariensis* sp. nov. × 2.
22. *Leguminophyllum khariensis* sp. nov., leaflets. × Natural size.
23. *Palmacites khariensis* sp. nov., leaf. Natural size.

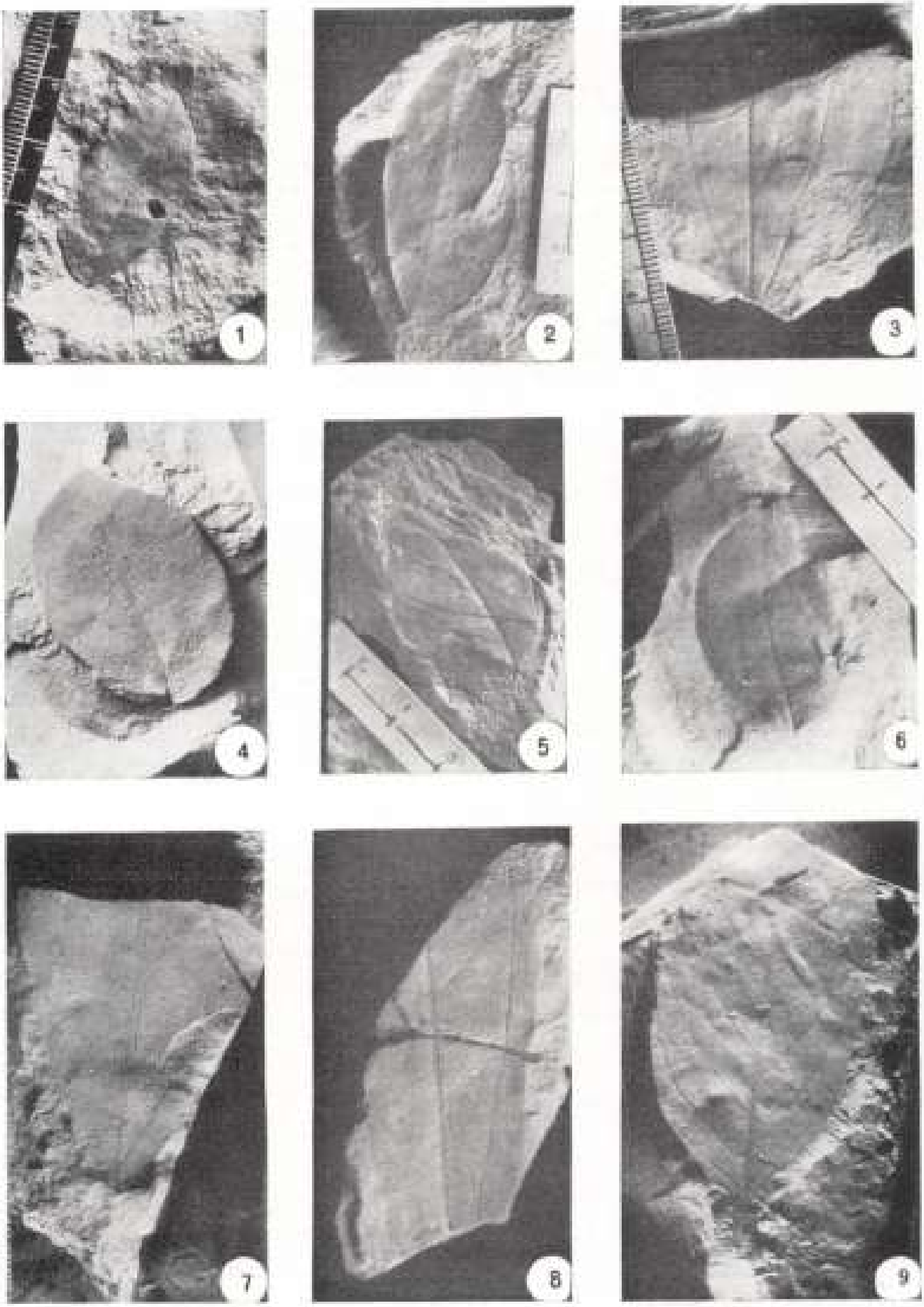

PLATE 1

PLATE 2


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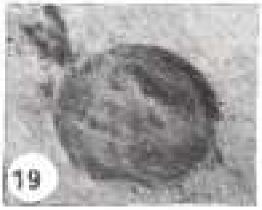
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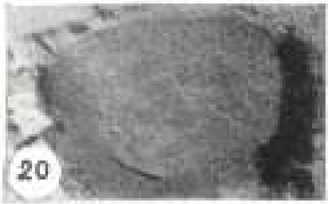
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PLATE 3

The Palaeobotanist, 30(3): 297-302, 1982.

OCCURRENCE OF THE GENUS *AQUILAPOLLENITES* IN THE UPPER CRETACEOUS KALLAMEDU FORMATION OF VRIDDHACHALAM AREA, CAUVERY BASIN, SOUTHERN INDIA

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ABSTRACT

The presence of triprojectate pollen in the Upper Cretaceous of Cauvery Basin is confirmed. The pollen belong to the species *Aquilapollenites bengalensis* Baksi & Deb. From comparative palynology it is deduced that *Aquilapollenites* yielding bed in Baksi's Bengal Palynological Zone I, i.e. Biswas' *Chara*—Ostracod Facies Zone, could not be older than Maestrichtian in age.

Key-words—Triprojectacites, *Aquilapollenites*, Upper Cretaceous, Kallamedu Formation, India.

सारांश

कावेरी द्रोणी (दक्षिणी भारत) में वृद्धाचलम् क्षेत्र के उपरि क्रीटेशस युगीन कल्लामेडु शैल-समूह से ऍक्विलापोलिनाइटिस प्रजाति – हरि कृष्ण माहेश्वरी एवं कृष्ण प्रसाद जैन

कावेरी द्रोणी के उपरि क्रीटेशस अवसादों में त्रिप्रवर्धीय (ट्राइप्रोजेक्टेट) परागकणों की उपस्थिति का समर्थन किया गया है। ये परागकण ऍक्विलापोलिनाइटिस बंगालेन्सिस बक्सी व देब जाति के हैं। तुलनात्मक परागाणविक दृष्टि से यह निष्कर्ष निकाला गया है कि बक्सी के बंगाल परागाणविक मंडल 1 में ऍक्विलापोलिनाइटिस-धारक संस्तर अर्थात् बिस्वास का चारा-ओस्ट्रेकोड संलक्षणी मंडल, आयु में मेस्ट्रिक्शियन से पुराना नहीं हो सकता।

INTRODUCTION

THE genus *Aquilapollenites* was established by Rouse (1957) to incorporate certain peculiar palynomorphs recovered from the Upper Cretaceous Brazeau and Oldman formations of Alberta, Canada. Since then more than 80 species of this genus (*sensu lato*) have been identified and described from Albian to Eocene beds. According to Srivastava (1978) while the Albian and Cenomanian records of the genus are unreliable, the Palaeocene and Eocene occurrences of the genus may mostly be due to reworking. However, *Aquilapollenites* specimens found in the Upper Palaeocene Porter Creek Clay Formation of Tennessee do not seem to be reworked as several clumps, each made up of a number of specimens, have been found (Herrick & Tschudy, 1967).

Majority of the species of *Aquilapollenites* are confined to late Campanian-early Maestrichtian of the circum-Pacific region (western United States of America, western Canada, Alaska, Japan and Siberia). Several species of the genus are also now known from the Maestrichtian of Scotland (Martin, 1968; Srivastava, 1975). Only a few species are known from other areas, e.g. Brazil (Herngreen, 1975), Africa (Jardiné & Magloire, 1963; Belsky, Boltenhagen & Potonié, 1956), India (Banerjee & Misra, 1968; Baksi & Deb, 1976) and Malaysia (Muller, 1969).

From India, so far three species of the genus *Aquilapollenites* have been reported. Banerjee and Misra (1968, p. 102, pl. 4, fig. 58) were first to report the genus in India. The solitary specimen recovered from the samples of Karaikal well-2 was placed under *A. quadrilobus* Rouse, 1957. Though the specimen was illustrated, no description was given. Baksi and Deb (1976, p. 404) have cast doubts on the identification of this specimen with *A. quadrilobus*. The specimen has since been lost (Venkatachala, 1978) and hence one can only surmise about its characters from the illustration. Venkatachala and Jain (1970) did not find any examples of *Aquilapollenites* or other angiosperm pollen in the Karaikal well sediments studied by them. The two other species known from India are *A. indicus* and *A. bengalensis* which have been reported by Baksi and Deb (1976) from the Upper Cretaceous of the Jalangi well-1 drilled in West Bengal.

In the present communication the occurrence of the genus *Aquilapollenites* in the Upper Cretaceous of southern India is confirmed. The specimens agree in toto with *Aquilapollenites bengalensis* Baksi & Deb (1976). However, no specimen even remotely resembling the illustration of Banerjee and Misra has been found.

MATERIAL AND METHOD

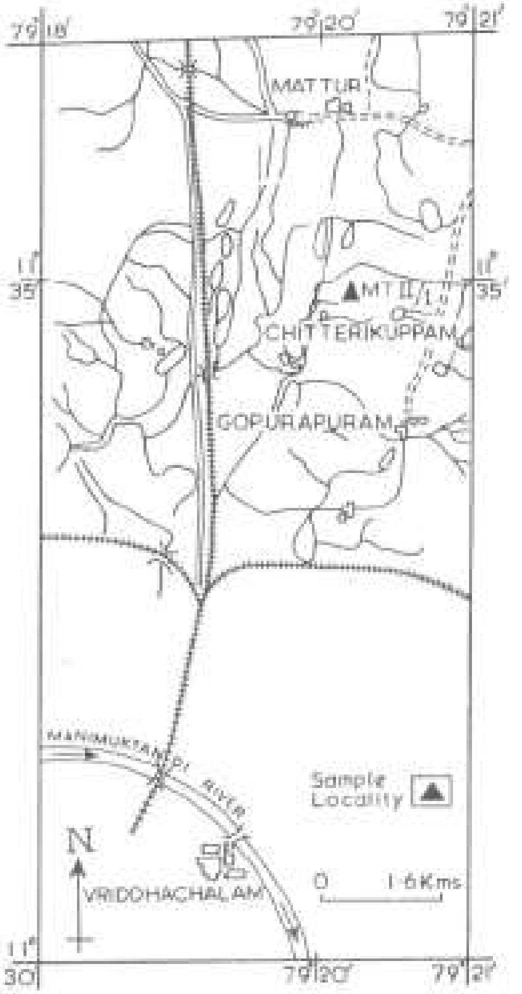
The samples were collected from a well cutting about 3 km due south of Mattur Village in Vriddhachalam area (Map 1). The lithological succession in the well (MT-II/1) is as follows:

3. Medium-to coarse-grained sandstone,
2. Sandy clays,
1. Calcareous sandstones with no apparent fossils but with carbonaceous streaks.

The *Aquilapollenites* pollen were recovered from the calcareous sandstone. The palynological assemblage of the sample comprises spores, pollen, dinoflagellates and acritarchs. Dinoflagellates and acritarchs have already been described earlier (Jain, 1978).

The lithology of the productive sample is similar to that of the Cullmoad Sandstone Member which represents the upper part of the Cullmood Formation of Srivastava and Tewari (1967). Sastry, Mamgain and Rao (1972) consider the sandstone member to represent a formation in itself, which they named as the Kallamedu Formation. However, Banerji (1973) placed the sandstone member in his Kallankurchi Formation.

The sample was first treated with dilute hydrochloric acid to remove the carbonates. It was then demineralized in hydrofluoric acid and again treated with dilute hydrochloric acid to remove the fluorides that might have formed. The palynomorphs so obtained were stained with Safranin O in water. Polyvenyl alcohol and canada balsam were used to prepare the slides.



MAP 1 — Geographic set up of Vriddhachalam area showing location of sample.

DESCRIPTION

Turma — *Projectoaperturites* Mtchedlishvili, 1961

Subturma — *Triprojectacites* Mtchedlishvili, 1961 emend. Stanley, 1970

The group Triprojectacites as emended by Stanley (1970, p. 10) includes iso- or heteropolar pollen with three equatorial projections which characteristically have meridionally oriented colpoids at the distal ends of the projections. Mtchedlishvili (1961) included six genera, viz., *Triprojectus*, *Aquilapollenites*, *Integricorpus*, *Mancicorpus*, *Parviprojectus* and *Projectoporites*, in the group Triprojectacites. Khlonova (1961) described several genera of triprojectate pollen, e.g. *Triceratopollis*, *Translucentipollis*, *Fibulapollis* and *Accuratipollis*. Stanley (1970) reviewed the above genera and found only five genera to be distinct enough for retention. Tschudy and Leopold (1971) opined that all the above genera intergrade into one another and therefore, they recognized only the genus *Aquilapollenites*. Srivastava (1978), however, retains the genera *Mancicorpus* and *Mtchedlishvilia* besides *Aquilapollenites*. Though our specimens correspond to the genus *Integricorpus* as restated by Stanley (1970), we have retained the original taxonomic assignment of Baksi and Deb (1976) because of the obvious difficulty in studying the variations due to paucity of specimens.

Genus — *Aquilapollenites* Rouse, 1957 emend. Srivastava, 1968

Type Species — *Aquilapollenites quadrilobus* Rouse, 1957.

Aquilapollenites bengalensis Baksi & Deb

Pl. 1, figs 1-5

Aquilapollenites bengalensis Baksi & Deb, 1976, *Pollen Spores*, vol. 18, no. 3, p. 402, pl. 1, figs 3-5.

Holotype — Baksi & Deb, 1976, pl. 1, fig. 3; slide no. J-I 10669/2, Palaeontological Laboratory, Department of Geological Science, Jadavpur University, Calcutta; Jalangi Well-1, West Bengal, India; Upper Cretaceous.

Description — Only three well-preserved specimens of the species have been found in the preparations. The pollen grains are isopolar, with three equatorially situated lateral projections. Polar axis is 53 to 79.6 μm long, equatorial width is 38.8 to 44.7 μm, length of equatorial projections is 7.8 to 9.3 μm, width of the equatorial projections (measured at midlength) is 3.0-6.0 μm. The equatorial projections are small, with rounded apices. Distal ends of the projections have a distinct colpoid each. Body exine is tectate, tectum is striate and the striae run concentrically round the equatorial projections, but not encroaching upon them.

REMARKS

Banerjee and Misra (1968) were the first to record the presence of the genus *Aquilapollenites* in India. The well from which they got their specimen was drilled in the same basin from where we have also recorded the genus. However, our specimens do not resemble the one illustrated by Banerjee and Misra (1968, pl. 4, fig. 58), but on the other hand are indistinguishable from *Aquilapollenites bengalensis* Baksi & Deb, 1976 reported from the Upper Cretaceous of Bengal Basin. The identification of our specimens was confirmed by Dr S. K. Srivastava of Chevron Oil in 1977.

In Bengal, *Aquilapollenites* was recorded from Palynological Zone I of Baksi (1972), at a depth of about 3554 metres. This depth is said to be the base of *Chara*-Ostracod Facies Zone of Biswas (cited in Baksi & Deb, 1976, p. 400) which is dated as of basal Upper Cretaceous age.

There seems to be some confusion about the age of Baksi's Palynological Zone I (see Table 1). According to Baksi (1972,

TABLE 1

Baksi, 1972, p. 190, table 1		Baksi, 1972, p. 192, table 2		Baksi, 1972, p. 194, text-fig. 2	Baksi & Deb 1976
Lower Eocene Palaeocene	Jalangi Formation	Palynological Zone II	Palaeocene-Lower Eocene	Palaeocene-Lower Eocene	
Middle-Upper Cretaceous	Ghatal Formation	Palynological Zone I	Middle-Upper Cretaceous	Upper Cretaceous	Upper Cretaceous Palaeocene
	Bolpur Formation				

p. 191) the zone covers Bolpur, Ghatal and lower part of Jalangi formations and is of Upper Cretaceous age. On the other hand Baksi's table 1 on page 190 denotes that Bolpur, Ghatal and Jalangi formations range from Middle Cretaceous to Lower Eocene thus implying that Palynological Zone I is probably Middle Cretaceous-Palaeocene in age. Baksi's table 2 on page 192 implies a Middle to Upper Cretaceous age, while text-figure 2 on page 194 implies an Upper Cretaceous age for Palynological Zone I. Baksi and Deb (1976, p. 405) date the Bengal Palynological Zone I as of Upper Cretaceous to Palaeocene age. We are therefore, not sure about the exact age of Baksi's Palynological Zone I.

However, in no case it could have been older than the Upper Cretaceous due to the reported occurrence of *Nypa* type pollen in association with massulae of the water fern (not algae as printed in text-figure 2 of Baksi, 1972, p. 104) *Azolla*. The Kallamedu assemblage in which we found *Aquilapollenites* lacks definite *Nypa* type pollen but has a large number of *Azolla* massulae associated with characteristic pollen such as *Cranwellia*, *Scollardia*, *Zlivisporis*, *Bullasporis*, *Proteacidites*, etc. On the basis of these occurrences it is dated to be of Maestrichtian age. The associated dinoflagellate cysts indicate a Maestrichtian-Danian transitional phase (Jain, 1978). It can, therefore, be safely assumed that the *Aquilapollenites bengalensis* yielding bed of Baksi's Bengal Palynological Zone I is not older than Maestrichtian in age. In other words, the *Chara*-Ostracod Facies Zone of Biswas must lie in the upper part of the Upper Cretaceous.

At present it is difficult to precisely indicate the route through which *Aquilapollenites* entered India. It is a characteristic and dominant element of the late Upper Cretaceous palynofloras of western North America and Siberia. In the provinces of the former Gondwanaland the genus makes extremely rare appearances. It is known only from north-eastern Brazil, Senegal, Gabon and Egypt. We do not know of any record so far from Australia and Antarctica. Srivastava (1978, p. 92) speculates that *Aquilapollenites* migrated to South America and West Africa from North America. From West Africa the genus reached Egypt and finally India. However, *Aquilapollenites bengalensis* is more akin to the *Integricorpus* group of species. It shows great resemblance with *Integricorpus* (*Parviprojectus*) *striatus* (Mtschedlishvili, 1961) Stanley, 1970 reported from the Maestrichtian-Danian of West Siberia. Another south-east Asia species, viz., *A. wilfordii* Muller, 1968 from the Senonian-Palaeocene of Sarawak, Malaysia is also pretty close to the *Integricorpus* group of species. The *Integricorpus* group of species is so far not known from South America or Africa. Therefore, an Asian route for migration of *Aquilapollenites* to India is equally plausible.

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EXPLANATION OF PLATE

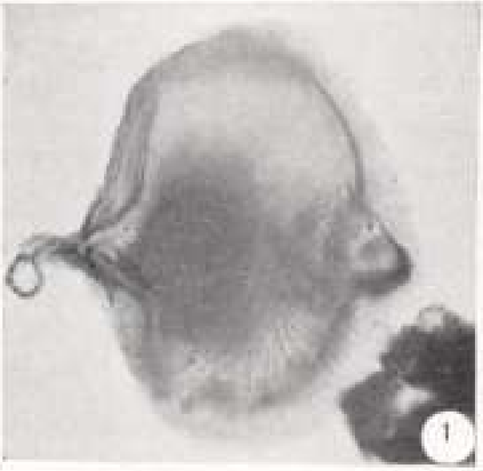
(All photomicrographs × 1200)

Aquilapollenites bengalensis Baksi & Deb, 1976

1-4. A specimen in four different foci showing small equatorial projections and tectate-striate exine. Slide no. BSIP 6186, co-ordinates: 115 × 11.3.

5. This specimen clearly shows the striate nature of the exine. Slide no. BSIP 6185, co-ordinates: 110.0 × 15.2.

6, 7. A specimen probably belonging to this species. Slide no. BSIP 6186, co-ordinates: 119.5 × 16.5.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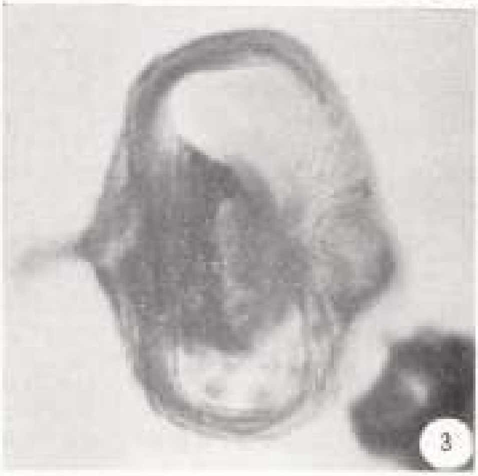
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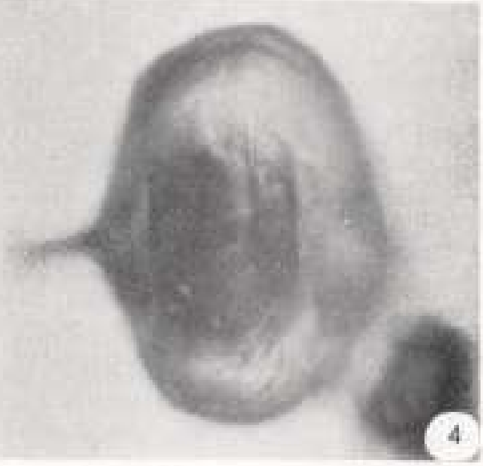
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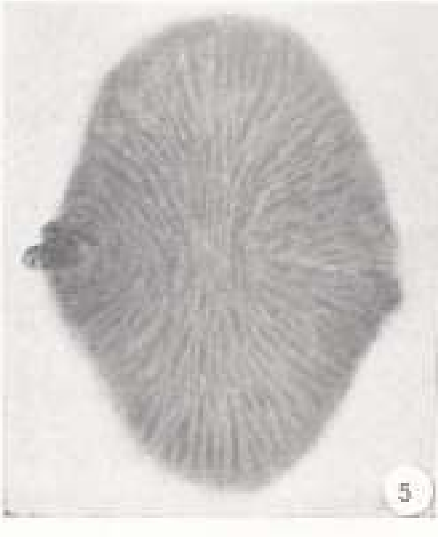
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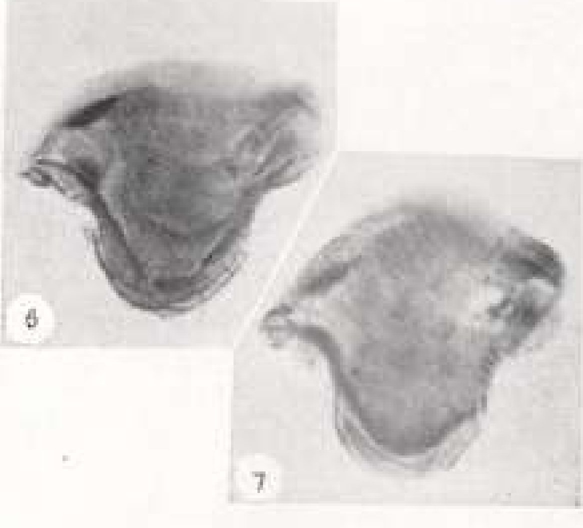
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PLATE 1

The Palaeobotanist, 30(3): 303-309, 1982.

A FOSSIL PALM FRUIT *HYPHAENEOCARPON INDICUM* GEN. ET SP. NOV. FROM THE DECCAN INTERTRAPPEAN BEDS, INDIA

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ABSTRACT

A silicified palm fruit collected from the Deccan Intertrappean beds near Shahpura in Mandla District of Madhya Pradesh has been described. It shows close resemblance with the fruits of modern *Hyphaene* Gaertn., and has been described under a new genus *Hyphaeneocarpon*, instituted to include fossil fruits belonging to the modern taxa of *Hyphaene* alliance of Borassoid group of palms.

Key-words — Silicified palm fruit, *Hyphaeneocarpon*, Palmae, Deccan Intertrappean beds, India.

सारांश

भारत के दक्षिण अन्तर्ट्रैपी संस्तरों से एक ताड़ फलाश्म – हाइफीनिओकार्पोन इन्डिकम् नव प्रजाति व जाति

– मोहन बलवंत बांदे, उत्तम प्रकाश एवं कृष्णा अम्बवानी

मध्य प्रदेश के मांडला जनपद में शाहपुरा के समीपस्थ दक्षिण अन्तर्ट्रैपी संस्तरों से एकत्रित एक सिलिकाभूत ताड़ के फल का वर्णन किया गया है। यह वर्तमान हाइफीनी गेर्टन० के फलों से समानता प्रदर्शित करता है तथा इसे एक नव प्रजाति के अन्तर्गत वर्णित किया गया है। यह नव प्रजाति ताड़ों के बोरेसॉयड समूह के हाइफीनी सहगण के वर्तमान वर्गकों से सम्बन्धित फलाश्मों को सम्मिलित करने के लिए स्थापित की गई है।

INTRODUCTION

FOSSIL palms form a major group of the Indian Palaeogene flora. Practically all the parts of a palm tree, viz., stem, roots, petioles, leaves, fruits, flowers, etc. have already been described in fossil state from the Deccan Intertrappean beds of India (Prakash, 1972; Lakhanpal, 1973; Chitaley & Kate, 1974). The petrified flower *Deccananthus savitrii* Chitaley & Kate (1974) is known from Mohgaonkalan and is said to show affinities with Palmae. Besides, a petrified inflorescence *Monocotylostrobus bracteatus* showing similarity with that of Palmae has also been recently described from the Deccan Intertrappean beds of Mohgaonkalan (Lakhanpal, Prakash & Bande, 1975, 1982).

Palm fruits occur quite commonly in the Indian Tertiaries especially in the Deccan Intertrappean beds of Mohgaonkalan. However, as in the case of fossil palm stems, the identification of these fruits with any extant taxa of Palmae is usually not possible although it can be said with certainity that a particular fossil fruit belongs to Palmae. A few forms which have been reliably identified with modern taxa from the Indian Tertiaries are *Cocos* (Kaul, 1951) and *Nipa* (Sahni & Rode, 1937; Lakhanpal, 1952). Otherwise, the palm fruits are usually placed under the artificial genus *Palmocarpon* Miquel (1853) instituted to include fossil fruits of Palmae.

A silicified palm fruit collected from the Deccan Intertrappean beds near Sahpura in Mandla District of Madhya Pradesh is being described here. Besides, a number of fossil dicotyledonous woods have also been described recently from this locality by Bande and Prakash (1980, 1982).

DESCRIPTION

FAMILY — PALMAE

Genus — *Hyphaeneocarpon* gen. nov.

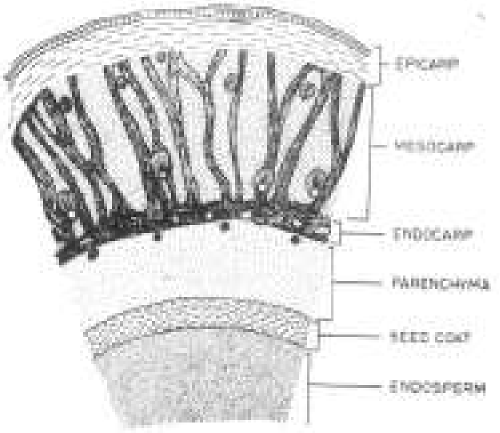
Hyphaeneocarpon indicum gen. et sp. nov.

Pl. 1, figs 1-7; Text-figs 1, 2

Material — It consists of a single specimen of silicified fruit without a stalk; oval in shape but somewhat laterally compressed due to pressure during fossilization. The fruit was first studied and photographed under reflected light and then a cross section was prepared to study its anatomical details.

MORPHOLOGY

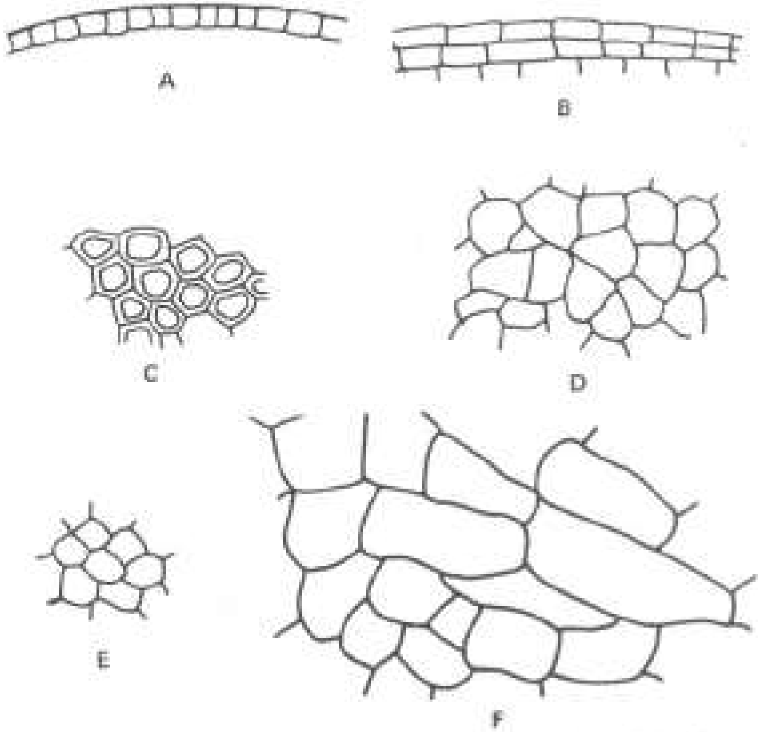
Gross Features — The fossil fruit is a typical drupe measuring 4 cm in length and about 3.2 cm in diameter (Pl. 1, fig. 1). It is unilocular and oval in cross section (Pl. 1, fig. 2). The *Pericarp* or fruit wall is well-preserved except on one side, and 0.9 cm in thickness. *Epicarp* is smooth and unevenly preserved. *Mesocarp* is massive with radially arranged fibres (Pl. 1, fig. 1; Text-fig. 1). *Endocarp* is thick and fibrous. A zone of parenchymatous cells is present in between the endocarp and the seed (Pl. 1, fig. 2; Text-fig. 1). *Seed* is solitary, more or less circular in cross section and 1.4 cm in diameter (Pl. 1, fig. 2). *Endosperm* is homogeneous and shrunken towards one side of the seed (Pl. 1, fig. 2).



TEXT-FIG. 1 — *Hyphaeneocarpon indicum* gen. et sp. nov. — A portion of the fruit wall magnified to show the distribution of various zones (semi-diagrammatic). × 16.

Anatomy — *Epicarp* 200-250 μm in radial thickness and divisible into epidermis and hypodermis. *Epidermis* single layered, preserved at places only and made up of squarish cells, 12-16 μm in diameter (Text-fig. 2A). *Hypodermis* made up of two zones; 2-3 layers of rectangular, thin-walled cork cells without intercellular spaces (Text-fig. 2B) towards the outer side. Cork cells 16-25 μm in tangential length and 8-12 μm in radial width, then followed by 8-10 layers of thick-walled, polygonal cells (Text-fig. 2C). *Mesocarp* massive, about 3 mm in radial thickness, and mostly composed of highly lignified, radially running fibrous strands distributed in the parenchymatous ground tissue (Text-fig. 1). Some of the fibre strands appear to radiate from the endocarp. A zig-zag row of fibrovascular bundles present in the inner region of the mesocarp (Text-fig. 1). Parenchyma cells forming the ground tissue thin-walled, variously shaped and 40-150 μm in size (Text-fig. 2D). *Endocarp* situated in the middle of the fruit wall measures about 700-800 μm in radial thickness. It consists of a cylinder of tangentially and vertically traversing fibrous strands which are haphazardly arranged and enclosing in between the islets of parenchyma (Pl. 1, fig. 5; Text-figs 1, 2E). Individual fibres highly lignified and polygonal in cross section. Parenchyma islets are made up of thin-walled, circular to angular cells, about 8-12 μ in size (Text-fig. 2E). Endocarp encloses, towards its inner side, a zone of parenchymatous tissue. Parenchyma cells forming this zone are thin walled, oval to circular in shape and about 30-100 μm in size (Pl. 1, fig. 4; Text-fig. 2F). A few fibrous bundles appear to be present near the periphery of this zone. *Seed coat* is about 300 μm thick, made up of compactly arranged, thick-walled cells. *Endosperm* homogeneous and consisting of thin-walled cells with brown contents (Pl. 1, fig. 6).

Affinities — The structural features of the fossil fruit indicate that it belongs to Palmae. However, the difficulty in identifying a fossil palm fruit with the extant palm taxa is tremendous. It is mainly due to lack of detailed information regarding the fruit morphology and anatomy of various genera and species of palms, their reference collec-



TEXT-FIG. 2 — *Hyphaeneocarpon indicum* gen. et sp. nov.— Cellular details of the various zones of fruit wall: **A**, a portion of single layered epidermis, × 130; **B**, cork cells of the epicarp, × 130; **C**, thick-walled polygonal cells of the epicarp, × 130; **D**, parenchymatous cells of the ground tissue of the mesocarp, × 130; **E**, thin-walled cells of the endocarp islets, × 130; **F**, parenchyma cells below the endocarp, × 320.

tion being very rare. The outstanding contributions on this subject are those of Guerin (1949) and Murray (1973). During the investigations on the fruits and seeds of palms Biradar and Mahabale (1969), Mahabale and Kulkarni (1975) and Robertson (1977) have referred to the endocarp structure in *Phoenix*, *Livistona* and *Jubaeopsis* respectively. A good contribution has recently been made by Pandey (1979) who worked out the fruit anatomy of 51 species of palms representing 32 genera from 8 out of 15 major divisions of Palmae (Moore, 1973). This detailed study has indicated that in case of palm fruits the structure of the endocarp is of great significance in dividing this large family into smaller groups on the basis of its fruit anatomy. Pandey (1979) and Kulkarni and Pandey (1980) have grouped the endocarp of palm fruits into six major types as given below:

Type 1 — Endocarp single layered, organized by the locular epidermis. This type is found in *Sabal*, *Phoenix*, *Caryota*, *Arenga*, *Wallichia* and *Hyophorbe*.

Type 2 — Endocarp many layered, solely of sclerotic cells, not including the vascular bundles and the locular epidermis. This type is restricted to Coryphoid palms.

Type 3 — Endocarp composite, consisting mostly of fibrous strands, islets of parenchyma and fibrovascular bundles, it is situated in the middle of the fruit wall, several layers away from the locular epidermis. All Borassoid palms studied have endocarp of this type.

Type 4 — Endocarp consists of sclerosed fibrous sheaths of one to many inner rows of vascular bundles of the fruit wall along with sclerotic parenchyma in between the vascular bundles extending up to and often involving sclerotic locular epidermis. All Arecoid palms studied show this type of endocarp.

Type 5 — Composition and structures as in type IV, but extremely sclerosed with 'eyes' or 'pores' where the endocarp formation is restricted to the sclerotic locular epidermis alone. Endocarp of all Coccoid palms belongs to this type.

Type 6 — Fruit wall is covered with polished and sclerified overlapping scales. The ground tissue of the entire fruit wall more or less sclerotic forming a bony cover, functionally representing the endocarp. Examples of this type are *Raphia* and *Calamus*.

It is quite clear from the above classification that the type of endocarp which occurs in the present fossil palm fruit, i.e. endocarp situated in the middle of the fruit wall, consisting mostly of fibrous strands, enclosing in between the islets of parenchyma, has been designated by Kulkarni and Pandey (1980) as Type 3. This is a characteristic type of endocarp of all the Borassoid palms. However, this type of endocarp has also been described in *Nipa* by Guerin (1949). But the fruit of *Nipa* is quite distinct from the present fossil fruit in its quadrangular shape with prominent ridges and a well-defined umbo and in possessing a distinctly grooved seed.

In 1973, Moore included 7 genera and 56 species under the Borassoid palms; these have been grouped into the following two distinct alliances including a number of palm taxa.

1. *Borassus* alliance — *Borassodendron*
Latania
Borassus
Lodoicea

2. *Hyphaene* alliance — *Hyphaene*
Medemia
Bismarckia

Studies on the fruit anatomy of all these genera (Guerin, 1949; Murray, 1973; Pandey, 1979) indicate that in the genera included under *Borassus* alliance the mesocarp is made up of vertically running fibres, while in the genera placed under *Hyphaene* alliance the mesocarp is made up of radiating strands of fibres distributed in the parenchymatous ground tissue. As the second type of mesocarp is seen in the present fossil fruit, the affinities of this fruit should be traced to *Hyphaene*, *Medemia* and *Bismarckia* which are included under *Hyphaene* alliance. In *Bismarckia nobilis* Hildeber & H. Wendl., which is the only species of this genus, Guerin (1949) has shown that the fruit is usually trilocular, while it is unilocular in the present fossil. Of the remaining two genera, fruit slides and description of two species of *Hyphaene*, viz., *Hyphaene indica* and *H. buscii* were available for comparison. A detailed comparison shows that the fruits of both these modern species resemble very closely the present fossil fruit in their anatomical details except in the size of the fruit which is slightly bigger in the extant species. The fruits of *H. indica* available for study measure about 4.8 cm in length and 3.6 cm in diameter as compared to the fossil fruit from Shahpura which measures about 4 cm in length and 3.2 cm in diameter.

As we do not have any information regarding the fruit morphology of the third genus of this alliance, viz., *Medemia* Wuert ex H. Wendl., it is not possible to compare it with the same. However, it can be said with certainty that the present fossil fruit belongs to the *Hyphaene* alliance of the Borassoid group of palms and shows a very close resemblance with the modern fruits of *Hyphaene*. *Medemia* Wuert ex H. Wendl. is a monotypic genus with only one species, *M. abiadensis* H. Wendl. restricted to Africa, Arabia and Europe. On the other hand, *Hyphaene* Gaertn. includes 41 species distributed all over tropical and subtropical Africa, Arabia and western India. Only one species, *H. indica* Becc., is found in India distributed all along the western coast up to Goa (Moore, 1973). Thus, the present day distribution of *Medemia* and *Hyphaene* suggests a greater possibility of the present fossil belonging to *Hyphaene* rather than to *Medemia*. One more evidence which indirectly supports this probability is the fact that a palm petiole showing a close resemblance with that of *Hyphaene* has been recently described from the Deccan Intertrappean beds of Wardha District in Maharashtra (Shete & Kulkarni, 1980). This indicates the presence of this genus in the Deccan Intertrappean flora of India.

Five species of fossil palm fruits assigned to *Palmocarpon* Miquel (1853) are known from the Deccan Intertrappean beds of India. These are *Palmocarpon insigne* Mahabale (1950), *P. mohgaonense* Prakash (1954), *P. indicum* Prakash (1960), *P. sulcatum* Prakash (1960), and *P. splendidum* Trivedi & Chandra (1973). As in none of these species the mesocarp is made up of radiating fibres distributed in the mass of parenchymatous tissue, this single character is sufficient to separate the present fossil fruit from these known species of *Palmocarpon*. Because the present fossil fruit forms the first record of a palm fruit of this type from all over the world and shows a close resemblance with the modern fruits of *Hyphaene*, it is described here under a new genus, *Hyphaeneocarpon* instituted to include fossil fruits belonging to *Hyphaene* alliance of the Borassoid group of palms. The specific name *Hyphaeneocarpon indicum* suggests its occurrence in the Tertiary of India.

GENERIC DIAGNOSIS

Hyphaeneocarpon gen. nov.

Drupe unilocular and single seeded. *Pericarp* massive composed of epicarp, mesocarp and endocarp. *Epicarp* thin and smooth; *mesocarp* thick made up of radiating strands of fibres distributed in the parenchymatous ground tissue; *endocarp* composite, situated in the middle of the fruit wall, consisting of tangentially and vertically running anastomosing fibrous strands with islets of parenchyma followed by a zone of parenchymatous cells. *Seed* solitary, seed coat single zoned; *endosperm* homogeneous made up of thin-walled cells.

Genotype — *Hyphaeneocarpon indicum* sp. nov.

SPECIFIC DIAGNOSIS

Hyphaeneocarpon indicum sp. nov.

A unilocular, single seeded drupe, 4 cm in length and 3.2 cm in diameter, oval in cross-section. *Pericarp* 9 mm in thickness divisible into epicarp, mesocarp and endocarp. *Epicarp* 200-250 µm in radial thickness and divisible into epidermis and hypodermis; *epidermis* single layered, made up of squarish cells, 12-16 µm in diameter; *hypodermis* made up of two zones, 2-3 layers of thin-walled cork cells towards outer side followed by 8-10 layers of thick-walled, polygonal cells. *Mesocarp* massive, about 3000 µm in radial diameter, mostly composed of highly lignified radially running fibrous strands distributed in the parenchymatous ground tissue. A zig-zag row of fibrovascular bundles is present in the inner region of this zone; parenchyma cells of the ground tissue thin-walled. *Endocarp* situated in the middle of the fruit wall, measuring 700-800 µm in radial thickness, made up of a cylinder of tangentially and vertically traversing, haphazardly arranged fibrous strands enclosing in between the islets of parenchyma; individual fibres highly lignified; parenchyma cells, forming islets thin-walled. A zone of thin-walled parenchymatous tissue is present towards the inner side of the endocarp. A few fibrous bundles appear to be present towards the periphery of this zone. *Seed* solitary, oval in shape; seed coat about 300 µm thick, made up of compactly arranged, thick-walled cells; *endosperm* homogeneous, composed of thin-walled cells.

Holotype — B.S.I.P. Museum no. 35408.

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The authors wish to express their sincere thanks to Dr A. R. Kulkarni and Dr S. B. Pandey of Ramnarain Ruia College, Matunga, Bombay for kindly making available their collection of modern palm fruits and slides to one of us (M. B. Bande) for comparison. We are specially thankful to Dr A. R. Kulkarni for going through the slides of the fossil fruit and for useful suggestions.

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EXPLANATION OF PLATES

Hyphaeneocarpon indicum gen. et sp. nov.

1. The fossil fruit in reflected light. × 2.
2. Cross section of the fruit showing the fruit wall with a single seed in the centre. × 2.5. Slide no. 6182.
3. Mesocarp of the fruit wall showing bands of radiating fibres. × 100. Slide no. 6182.
4. Cells of parenchymatous zone of fruit wall just below the endocarp. × 100. Slide no. 6182.
5. Endocarp showing haphazardly arranged fibres enclosing islets of parenchyma (P). × 100. Slide no. 6182.
6. Dark coloured seed coat enclosing endosperm(E). × 100. Slide no. 6182.
7. A fibrovascular bundle of the mesocarp. × 90. Slide no. 6182.

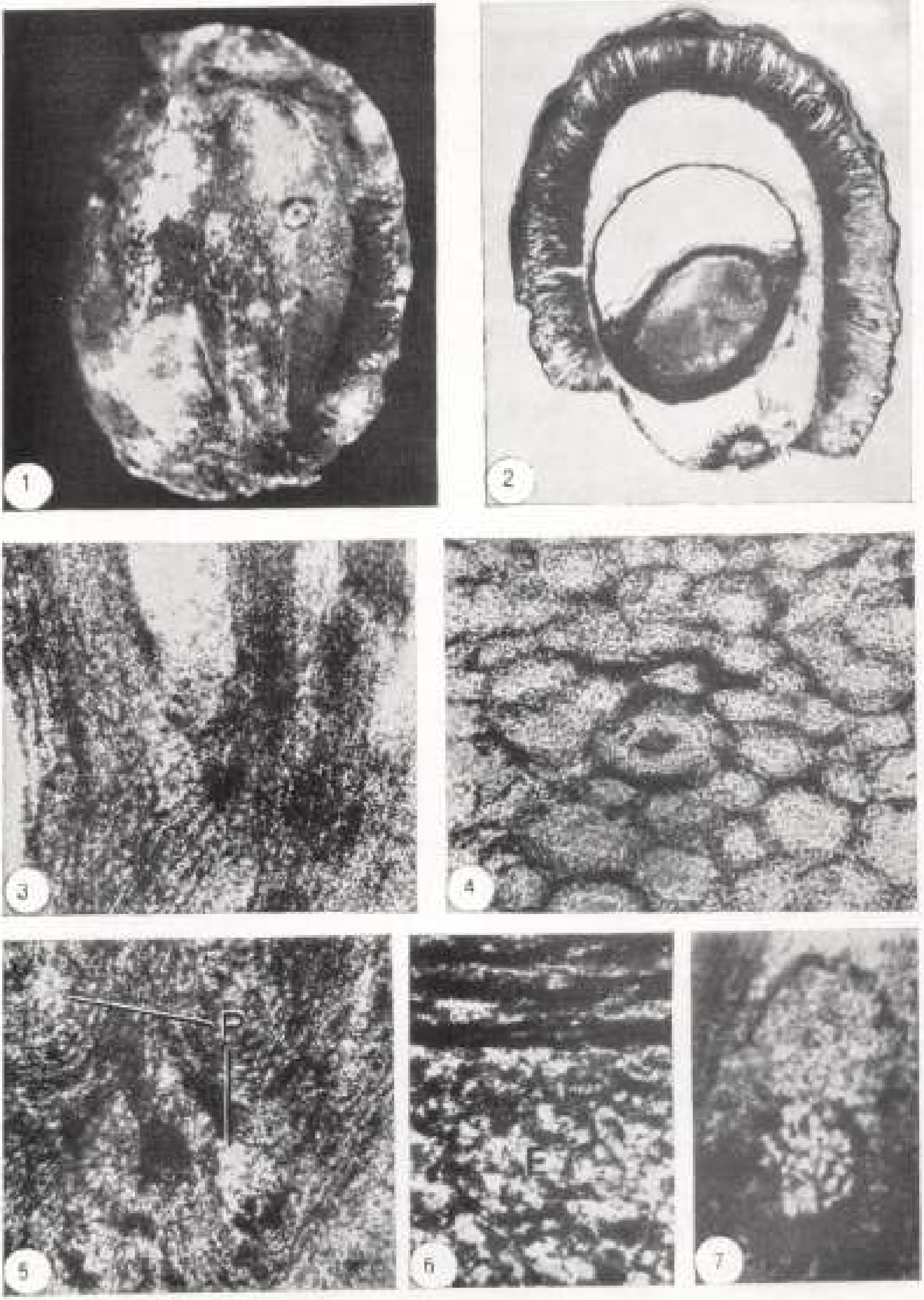

PLATE 1

The Palaeobotanist, 30(3): 310-315, 1982.

PHLEBOPTERIS MINUTIFOLIUS SP. NOV. FROM THE BHUJ FORMATION OF KACHCHH, INDIA

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ABSTRACT

A new species of the genus *Phlebopteris*, viz., *P. minutifolius* is reported from Walkamota, District Kachchh, Gujarat. Both sterile and fertile fronds have been described. The sori have yielded trilete spores having laevigate exine.

Key-words — *Phlebopteris*, Sterile and fertile fronds, Trilete spores, Bhuj Formation, Lower Cretaceous (India).

सारांश

भारत में कच्छ के भुज शैल-समूह से फ्लेबोप्टेरिस माइन्यूटिफोलियस नव जाति – जयश्री बेनर्जी

गुजरात के कच्छ जनपद में वलकामोटा से फ्लेबोप्टेरिस प्रजाति की एक नव जाति – फ्ले० माइन्यूटिफोलियस – अभिलिखित की गई है। बन्ध्य एवं अबन्ध्य दोनों ही प्रकार के पर्णों का वर्णन किया गया है। बीजाणुधानियों से चिकने बाह्यचोल वाले त्रिअरीय बीजाणु प्राप्त हुए हैं।

INTRODUCTION

ONLY a few species of the genus *Phlebopteris* have so far been reported from the Jurassic-Lower Cretaceous formations of India. These are *P. athgarhensis* Jain (1968) described from a hill about 1.6 km south-south-east of Ghantekhal Village, Cuttack District, Orissa, *P. polypodioides* Brongniart from Marwar Ghat about 0.8 km NE and about 0.4 km NNW of Bansa, Patparha and Tekan, Shahdol District, Madhya Pradesh; Songad, Surendranagar District, Gujarat (Sukh-Dev, 1970), *Phlebopteris* sp. from Chunakhal, Santhal Parganas, Bihar (Bose & Sah, 1968) and *Phlebopteris* sp. from east of Habur Village, Jaisalmer District, Rajasthan (Maheshwari & Singh, 1976). In none of those species details of sporangia and spores are known.

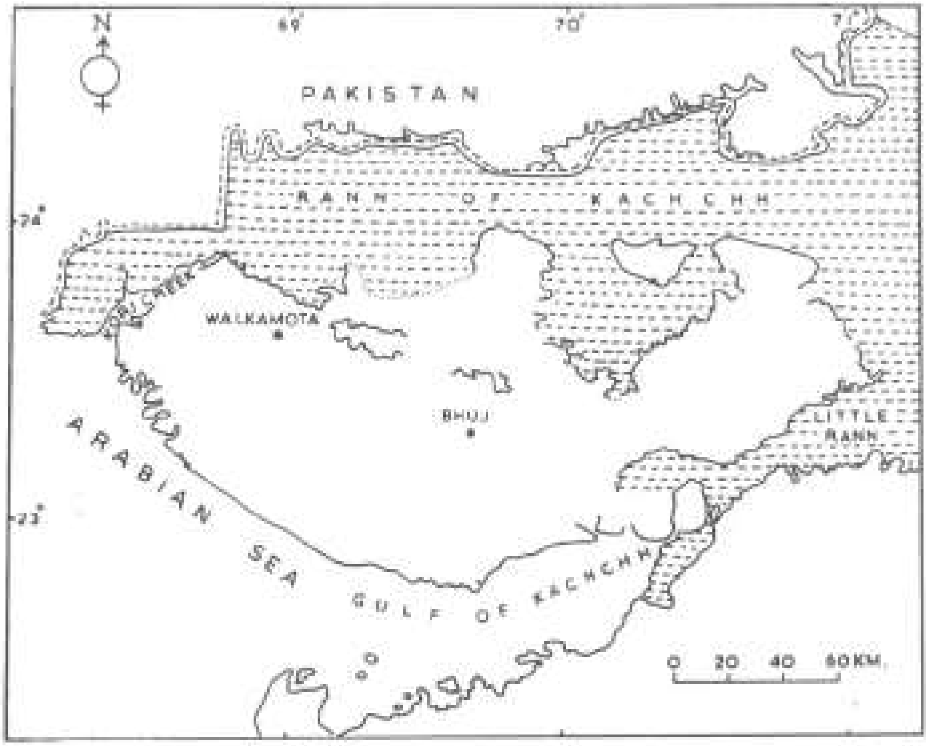
Recently a few specimens of *Phlebopteris* have been collected from shale dumps lying around a freshly dug out well, about 1 km east of the village Walkamota (Text-fig. 1), District Kachchh (formerly spelt as Cutch). In the fertile specimens both sporangia and spores are well-preserved. From one specimen small pieces of cuticle could also be obtained from the rachis.

DESCRIPTION

Phlebopteris minutifolius sp. nov.

Pl. 1, figs 1-11; Text-fig. 2A-H

Diagnosis (based on isolated pinnae) — Pinnules small, sub-opposite, falcate, attached at an angle of about 45°-50° by entire base. Margins entire. Apex acute or subacute. Midrib prominent, lateral veins arising at narrow angles and forming elongated meshes along midrib, veins from corners of these meshes further branching and occasionally joining each other. Fertile pinnules having 4 sori, 2 each on either side of midrib. Each sorus having 7 or 8 sporangia attached to central receptacle, annulus of sporangium vertical. Spores triangular or subtriangular in equatorial view, 38-50 μm, trilete; exine laevigate, about 1 μm thick, slightly more thickened around trilete rays.



TEXT-FIG. 1 — Map showing the Walkamota locality in Kachchh.

Holotype — B.S.I.P. Specimen no. 35409.

Locality — Walkamota, Kachchh District, Gujarat.

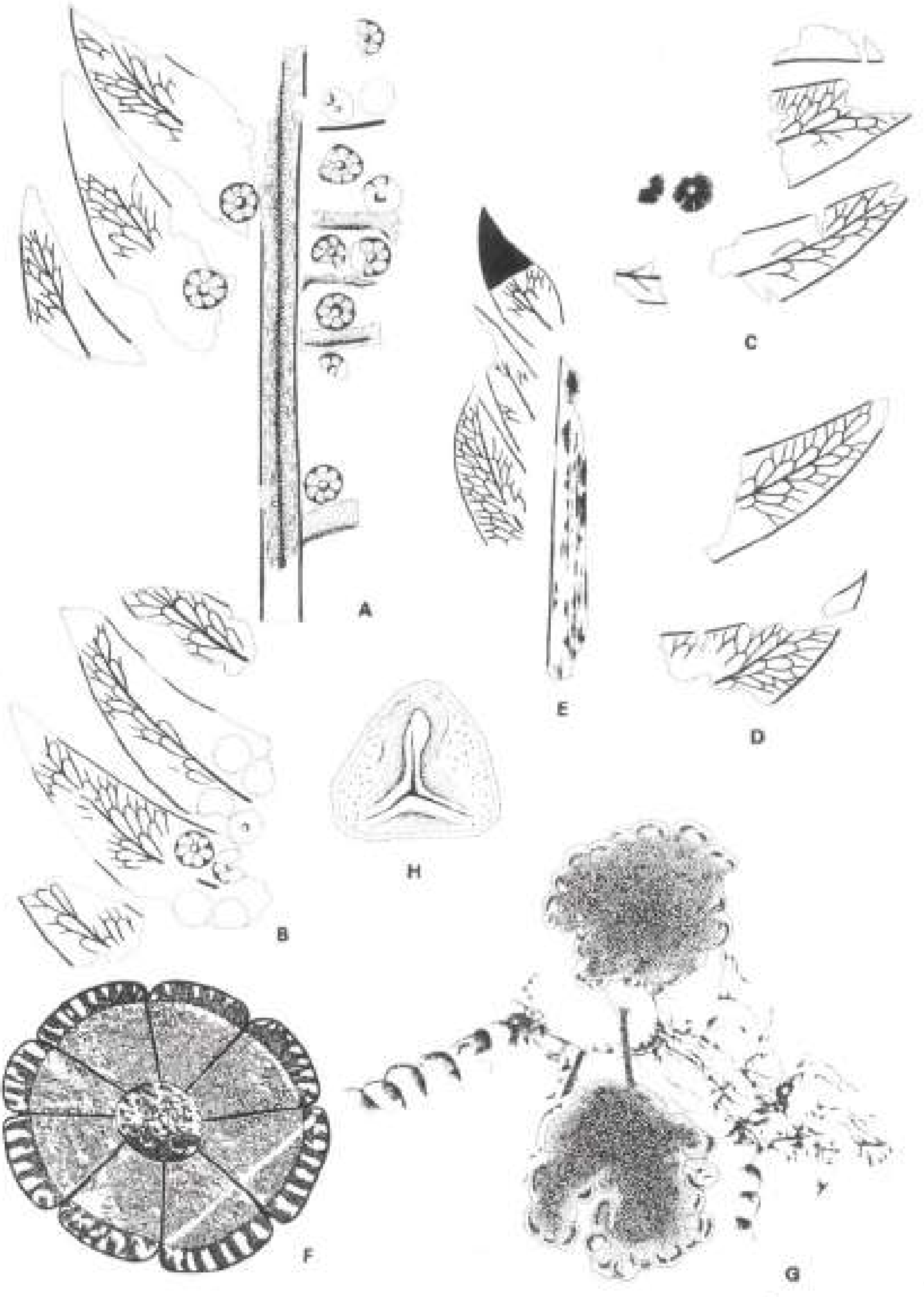
Horizon & Age — Bhuj Formation (Biswas, 1977); Lower Cretaceous.

Description — The description is based on a few incomplete pinnae. Largest available specimen 2.3 cm long and 1.5 cm broad. Rachis 1 mm wide, marked with a distinct median groove. Pinnules sub-oppositely arranged, falcate, 5-7 × 2.5-3 mm in size, broader at base, gradually tapering to an acute or subacute apex, attached to rachis by entire base at an angle of about 45°-50°. Margin entire. Midrib prominent, extending up to apex, lateral veins arising at an angle of 30°-35°, usually at a distance of 1 mm, after emergence lateral veins bifurcating and anastomosing to form large elongated meshes along the midrib, veins from these meshes again branching and joining to form few more meshes towards margin, sometimes in the apical portion of pinnules veins merely forked, 3 or 4 veins per mm occurring at the margin.

Epidermal cells of rachis rectangular, elongate, lateral walls straight or slightly wavy, end walls straight or oblique; surface smooth.

Fertile pinnules bearing a single row of two sori on either side of midrib. Sori circular, 1 mm in diameter, almost covering the entire basal portion of the lower surface of pinnules, attachment of sorus indistinct. Sporangia 7-8, radially arranged around a central receptacle, seem to be sessile, about 0.5 mm long and 0.3 mm broad with a distinct vertical annulus; receptacle in surface view, circular, 0.2 mm in diameter; indusium absent.

Each sorus on maceration released 8 spore-masses, conforming with the number of sporangia. Each sporangium has about 64 trilete spores. Spore-amb triangular to subtriangular, size 38-50 μm, trilete distinct, rays usually extending up to 3/4th of spore radius; exine laevigate, about 1 μm thick, nearer trilete rays slightly more thickened; folds also present in the interradial region.



TEXT-FIG. 2

Comparison — *Phlebopteris minutifolius* differs from all the known Indian species of the genus in having smaller pinnules, in its venation pattern and by the number of sporangia per sorus. *P. athgarhensis* Jain (1968) has falcate pinnules, but can be readily distinguished from *P. minutifolius* by its larger pinnules, narrow meshes and greater number of sori. Specimens of *P. polypodioides* Brongniart described by Harris (1961) and Sukh-Dev (1970) show similarity in falcate nature of pinnules but differ in their larger size, the presence of web connections between pinnules, the venation pattern and in having larger number of sori. The spores of *P. polypodioides* Brongniart described by Harris (1961) have laevigate exine with thickening along the trilete mark similar to *P. minutifolius*.

P. hirsuta and *P. indica* described from Salt Range by Sahni and Sitholey (1945) resemble *P. minutifolius* in size and falcate nature of the pinnules. However, *P. hirsuta* differs in having ramental hairs and spores with more thickened exine at the apices. In *P. indica*, in contrast to *P. minutifolius*, lateral veins are once forked, each sorus has fewer number of sporangia and spore wall is more thickened at the apices. *P. indica* seems to be rather closer to *Matonidium cingulatum* described by Zeba-Bano and Bose (1981) from Trambau, Kachchh District.

P. minutifolius somewhat resembles *P. woodwardi* Leckenby, described by Harris (1961), in the presence of meshes and number of sporangia per sorus, but pinnules in the former species are much smaller in size and have lesser number of sori. Spores of *P. minutifolius* resemble the dispersed spores of Matoniaceae recently described by Juhasz (1979) from Lower-Middle Cretaceous sediments of Hungary as *Phlebopterisporites equiexinus* (Couper, 1958) Juhasz and *P. harskutensis* Juhasz in having uniformly thickened laevigate exine and frequent occurrence of torus.

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TEXT-FIG. 2 — **A**, *Phlebopteris minutifolius* sp. nov., holotype showing venation pattern of pinnules and sori, B.S.I.P. specimen no. 35409, × 7. **B**, counter part of the holotype, B.S.I.P. specimen no. 35410, × 7. **C**, specimen showing venation pattern and sori with distinct annulus of sporangia, B.S.I.P. specimen no. 35411, × 7. **D**, pinnule showing apex and venation pattern, B.S.I.P. specimen no. 35412, × 7. **E**, sterile frond, B.S.I.P. specimen no. 35413, × 6. **F**, detached sorus from holotype, showing 8 sporangia attached to the central receptacle, × 50. **G**, spore masses released from sporangia on maceration, × 100. **H**, triangular trilete spore isolated from spore masses showing distinct interradial thickening, B.S.I.P. slide no. 6444, × 500.

EXPLANATION OF PLATE

Phlebopteris minutifolius sp. nov.

1, 2. 1, Holotype showing fertile frond, B.S.I.P. specimen no. 35409 × 2. 2, same specimen. × 6.

3, 4. 3, Sterile frond showing shape and venation pattern of pinnules, B.S.I.P. specimen no. 35414. × 1. 4, same specimen. × 4.

5. Pinnule showing basal sorus, B.S.I.P. specimen no. 35411. × 6.

6. Pinnule showing venation pattern, B.S.I.P. specimen no. 35412. × 6.

7. Single sorus showing 8 sporangia with distinct annulus. × 50.

8-11. Trilete spores showing laevigate exine, slide nos. 6444 and 6445. × 500.


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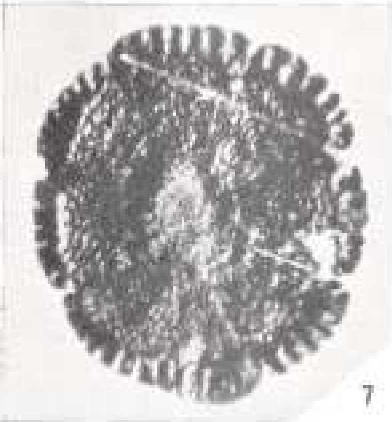
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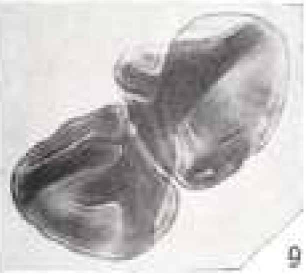
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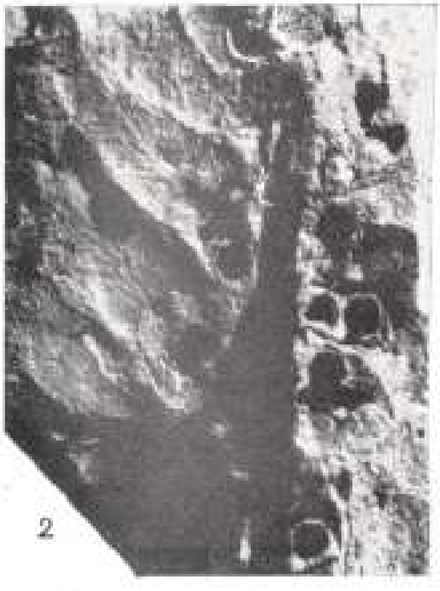
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PLATE 1

The Palaeobotanist, 30(3): 316-324, 1982.

A MONOCOTYLEDONOUS INFLORESCENCE FROM THE DECCAN INTERTRAPPEAN BEDS OF INDIA

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ABSTRACT

A monocotyledonous inflorescence, *Monocotylostrobus bracteatus* gen. et sp. nov., is described from the Deccan Intertrappean beds of Mohgaon Kalan, Chhindwara District, Madhya Pradesh. Although the exact affinities of the inflorescence could not be ascertained, close relationship with the families Palmae and Liliaceae is indicated.

Key-words — Monocotyledonous inflorescence, *Monocotylostrobus*, Palmae, Liliaceae, Deccan Intertrappean beds, Palaeocene-Eocene (India).

सारांश

भारत के दक्खिन अन्तर्ट्रैपी संस्तरों से एक एकबीजपत्रीय पुष्पक्रम – राजेन्द्र नाथ लखनपाल, उत्तम प्रकाश
एवं मोहन बलवंत बांदे

मध्य प्रदेश के छिन्दवाड़ा जनपद में मोहगाँव कलाँ के दक्खिन अन्तर्ट्रैपी संस्तरों से एक एकबीजपत्रीय पुष्पक्रम – मोनोकॉटिलोस्ट्रोबस ब्रैक्टिएटस नव प्रजाति व जाति – का वर्णन किया गया है। यद्यपि पुष्पक्रम की वास्तविक सजातीयताएं तो निश्चित नहीं की जा सकीं, परन्तु पाल्मी एवं लिलिएसी कुलों से इसका घनिष्ठ सम्बन्ध प्रदर्शित किया गया है।

INTRODUCTION

IN a short note published a few years ago (Lakhanpal *et al.*, 1975) we had reported the occurrence of an angiospermous inflorescence from the Deccan Intertrappean beds of Mohgaon Kalan, Madhya Pradesh. It was then stated that a detailed description would be published when more specimens of this interesting fossil became available. On further scanning, we have found three more specimens which have furnished sufficient information forming the basis of the present communication.

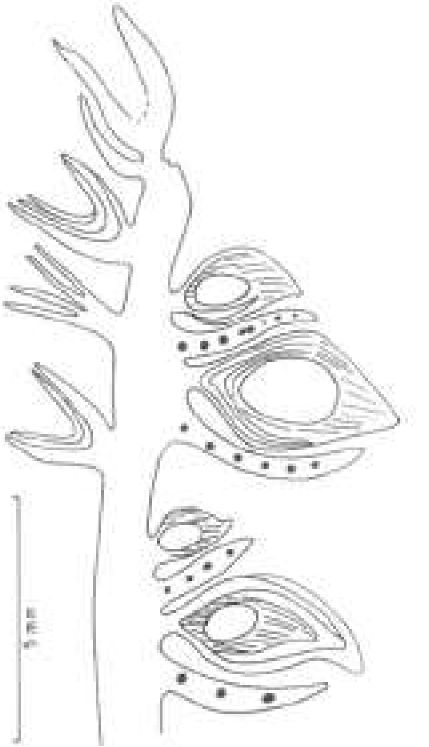
All the specimens were exposed in the longitudinal plane and none was complete. The largest of them measures about 3.5 cm in length. As the material was fragmentary and limited, the specimens were studied serially by grinding the surface and taking photographs from different regions. Ultimately, wherever considered desirable, thin longitudinal sections were prepared from each specimen.

DESCRIPTION

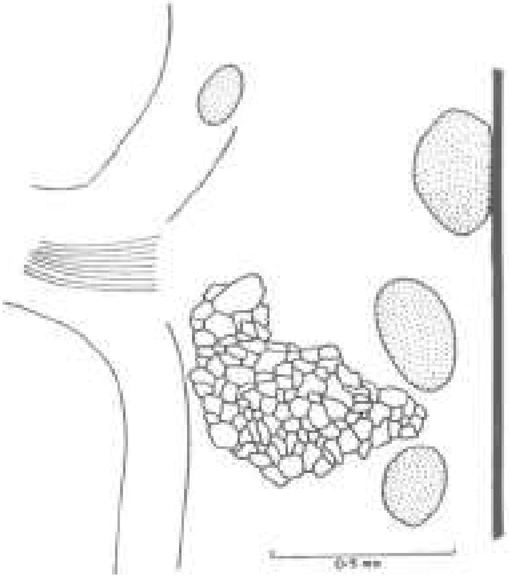
General Features — The inflorescence is a branched racemose spikelet with sessile flowers arranged spirally on the axis. They are in acropetal succession (Pl. 1, fig. 4; Pl. 2, fig. 8; Text-fig. 1) with those in the apical region still immature. A significant feature is the presence of a conspicuous bract below each flower (Pl. 1, fig. 4; Pl. 2, fig. 6; Text-figs 1, 3). At places the axis shows well-preserved anatomical details. It is made up of thin-walled cells of irregular shape (Text-fig. 2) with vascular traces going to the bract and the flowers (Text-fig. 3).

Flowers — They are small, 3-5 mm in length and 1.5-3 mm in diameter, sessile, bracteate, hypogynous and probably unisexual (Pl. 1, fig. 4; Text-fig. 1).

Bract — The bract subtending each flower is a persistent structure like the perianth and is present even in the mature flowers. It is about 3-5 mm in length and 1 mm in thickness, narrowing towards the apex



TEXT-FIG. 1 — *Monocotylostrobus bracteatus* — Inflorescence in vertical longitudinal section showing main axis with sessile, bracteate flowers arranged in acropetal succession.

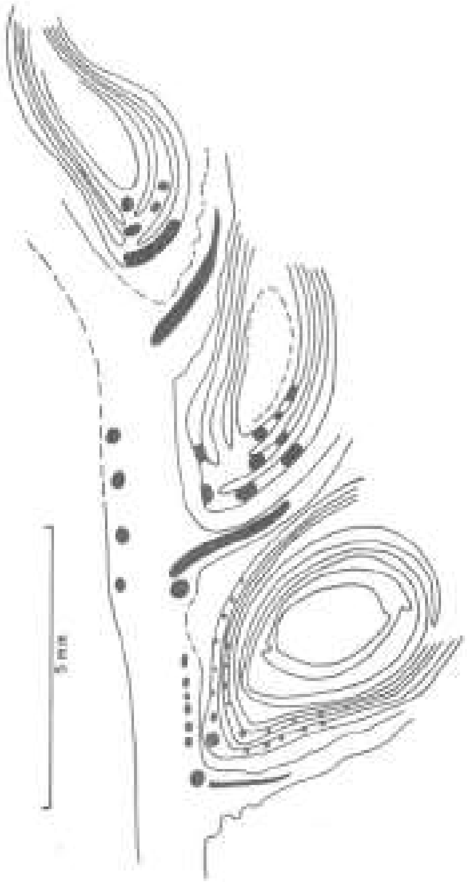


TEXT-FIG. 2 — *Monocotylostrobus bracteatus* — Main axis in vertical section showing vascular bundles and traces going to the bract.

(Pl. 2, fig. 6; Text-fig. 1). Anatomically it is well differentiated. In a vertical section, a single layered epidermis consisting of a row of horizontally elongated cells is seen on the adaxial side of the bract. Below the epidermis, there are 2-3 successive rows of fibrovascular bundles (Text-fig. 4). Each fibrovascular bundle consists of a round vascular part surrounded below by a broad fibrous sclerenchymatous sheath made up of thick-walled polygonal cells. The cells of the vascular part are polygonal, thin-walled, in which some protoxylem elements with annular or spiral thickenings can be seen. The area of the fibrous part is slightly more than that of the vascular.

The ground tissue of the bract is made up of thin-walled, oval, irregular or rod-shaped cells (Text-fig. 4). The abaxial part of the bract is badly preserved due to which it is not possible to study its details.

Perianth — The perianth is hypogynous, persistent and made up of whorls of similar perianth lobes. The number of lobes in each whorl as well as the total number of whorls could not be ascertained as no cross section of the flower was available. However, at one place where the flower is exposed in an oblique longitudinal section, three perianth whorls seem to be present as indicated by three distinct midribs with well-developed fibrovascular bundles at the middle part of each lobe (Pl. 2, fig. 7; Text-fig. 5). The cellular details of the perianth lobes are well-preserved. The oblique longitudinal section reveals an epidermal layer of squarish to vertically elongated cells with wavy outline on the outer side and a layer of horizontally elongated cells on its inner side (Text-fig. 6). However, there is no such distinction between these two layers in the young perianth lobes (Pl. 1, fig. 5). Well-developed fibrovascular and fibrous bundles are quite common and crowded near the midrib region of the perianth lobes but they are somewhat diffuse and less frequent in the region away from the midrib (Pl. 2, fig. 7; Text-fig. 5). The



TEXT-FIG. 3 — *Monocotylostrobus bracteatus* — Inflorescence in vertical longitudinal section showing bracteate flowers and the vascular supply of the bract and perianth lobes.

ground tissue of the perianth is made up of thin-walled, compact cells of variable shape and size without intercellular spaces (Text-fig. 6).

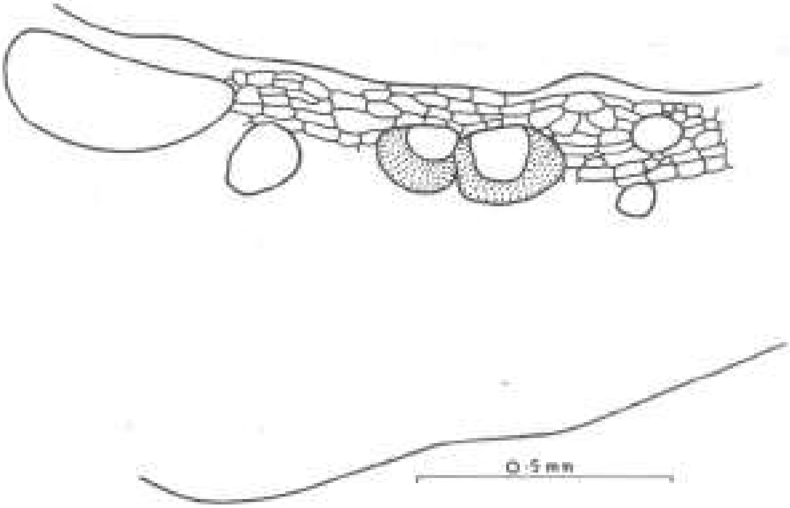
Androecium — Neither stamens nor their remnants were observed in any of the flowers studied. This most probably indicates the unisexual nature of the flowers.

Gynaecium — The gynaecium seems to be tricarpellary, of the three carpels only two being seen in the longitudinal section (Pl. 2, fig. 9; Text-fig. 7), syncarpous with a superior ovary (Text-fig. 7). A common style with a broad base and a pointed apex was seen in one of the flowers (Pl. 2, fig. 9; Text-fig. 7). The number and position of ovules in each locule could not be found out.

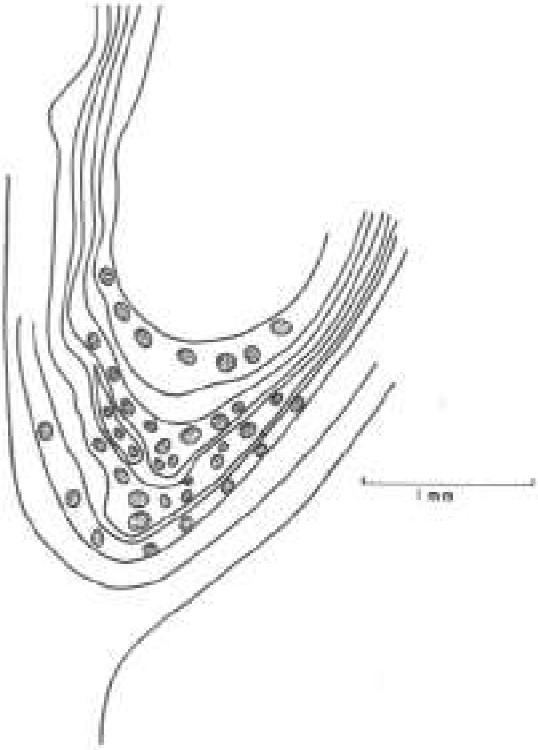
DISCUSSION

The presence of collateral and closed vascular bundles in the bract as well as in the perianth lobes of the flowers indicates that the inflorescence belongs to the monocotyledons. The other characters of diagnostic value are (a) recemose inflorescence with sessile flowers arranged in acropetal succession, (b) well-developed bract subtending each flower, (c) perianth lobes arranged in probably three whorls, and (d) a syncarpous, superior ovary.

Of all the families of monocots listed by Hutchinson (1959), there are 24 in which a syncarpous, superior ovary is present. Amongst these a racemose inflorescence is present in Bromeliaceae, Liliaceae, Pontederiaceae, Smilacaceae, Philesiaceae, Araceae, Agavaceae, Palmae, Pandanaceae, Haemodoraceae, Centrolepidaceae and Restionaceae. Further, a well-developed bract subtending each flower is present in the families Bromeliaceae, Centrolepidaceae Restionaceae, Liliaceae and Palmae. However, in Centrolepidaceae the perianth is totally absent and in Bromeliaceae the perianth is made up of two dissimilar whorls whereas in the present inflorescence the flowers appear to possess 3 similar whorls of perianth. In Restionaceae also the perianth is in two series made up of 3-6 glume-like scarious or hyaline segments. However, in the fossil under discussion the perianth lobes appear to be quite thick with well-developed vascular tissue. Liliaceae is a big family with about 250 genera (Willis, 1973) and shows a variety of characters. Practically all the morphological characters of this petrified inflorescence, viz., its racemose nature with flowers subtended by bracts, well-developed perianth lobes arranged in similar whorls, and a tricarpellary, syncarpous, superior ovary can be found in various tribes of this family. But the fossil inflorescence shows well-developed fibrous and fibrovascular tissue suggesting a woody nature which is not expected in the floral axes of the members of Liliaceae. Moreover, in Liliaceae the perianth is made up of two similar whorls while in the fossil inflorescence it appears to be made up of three whorls.

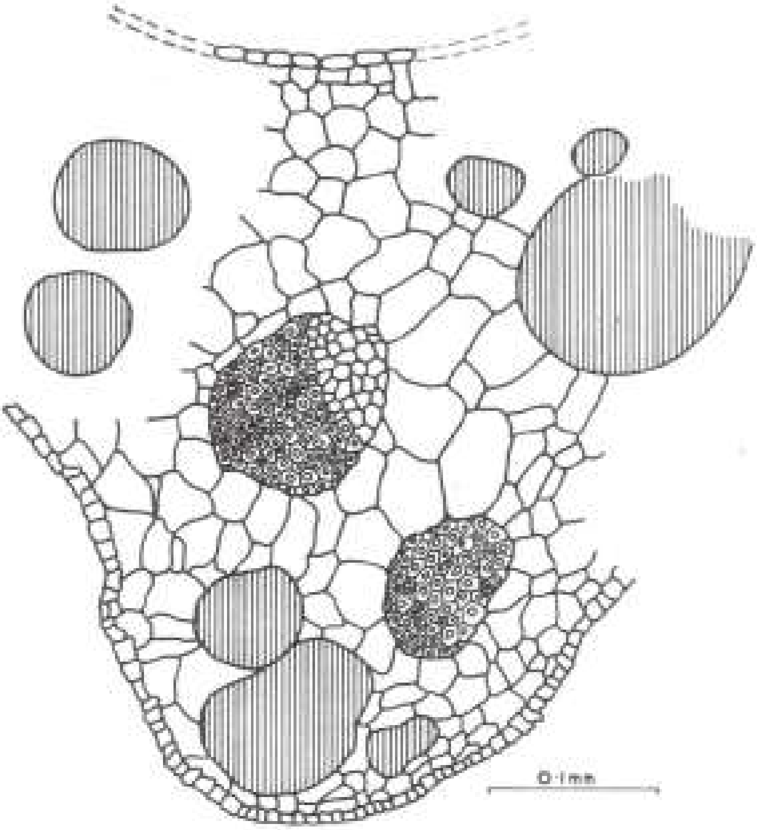


TEXT-FIG. 4 — *Monocotylostrobus bracteatus* — Bract in vertical section showing collateral and closed fibrovascular bundles.



TEXT-FIG. 5 — *Monocotylostrobus bracteatus* — A flower in oblique vertical section showing three perianth lobes.

Presence of a palm inflorescence in the Deccan Intertrappean beds of India is not at all unexpected as practically all the vegetative parts of palms as well as their fruits are abundantly known from these beds. Palm inflorescence and flower have been described in detail by Corner (1966). A palm inflorescence with unisexual and bracteate flowers is somewhat sturdy and quite commonly found in panicles or spikes and a small portion of this can be closely compared with the present fossil. The presence of well-developed fibrous and fibrovascular bundles in perianth and bracts in the fossil also strongly supports this possibility. However, the number of perianth whorls in each flower and the number of perianth lobes in each whorl in the fossil are characters which must be considered before assigning it to any modern family. Unfortunately, in the present state of our knowledge, it does not seem possible as the flowers could not be studied in cross-section. Unless this is done, the affinities of the present fossil remain an open question. For the present it is being described under a newly proposed form genus *Monocotylostrobus*, indicating its being a monocotyledonous inflorescence. The specific name *M. bracteatus* emphasizes the occurrence of prominent bracts.



TEXT-FIG. 6 — *Monocotylostrobus bracteatus* — A perianth lobe in longitudinal section showing fibrous and fibrovascular bundles, thin-walled cells of the ground tissue and upper and lower epidermis.

GENERIC DIAGNOSIS

Monocotylostrobus gen. nov.

Monocotyledonous inflorescence which cannot be assigned to any family.

Genotype — *Monocotylostrobus bracteatus* sp. nov.

SPECIFIC DIAGNOSIS

Monocotylostrobus bracteatus sp. nov.

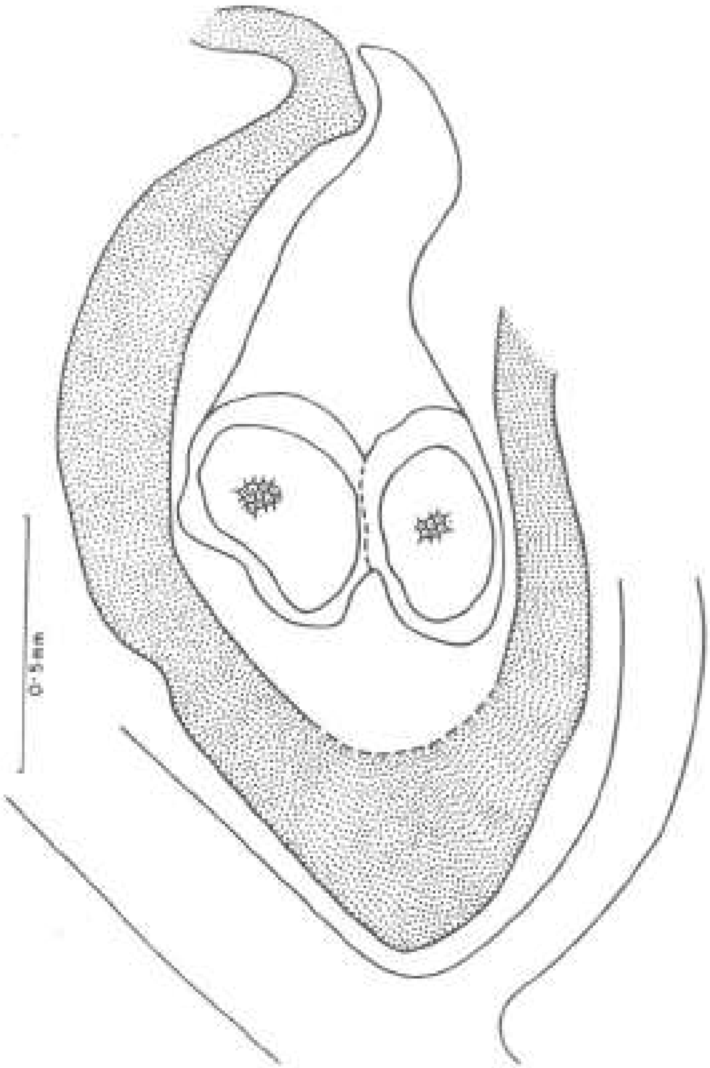
A branched, racemose spikelet with sessile flowers arranged spirally on the axis in acropetal succession. *Flowers* 3-5 mm in length and 1.5-3 mm in diameter, sessile, bracteate, hypogynous and probably unisexual. *Bract* well-developed below each flower, 3-5 mm in length and 1 mm in thickness; 2-3 successive rows of collateral and closed fibrovascular bundles present on the adaxial side of the bract. *Perianth* hypogynous, persistent, made up probably of three whorls of similar lobes; well-developed fibrous and fibrovascular bundles similar to those of bract present. *Androecium* not observed. *Gynaecium* probably tricarpellary, syncarpous, superior, style probably one.

Holotype — B.S.I.P. Museum slide no. 6267.

Paratypes — B.S.I.P. Museum slide nos. 6268, 6269 and 6270.

Locality — Mohgaon Kalan, District Chhindwara, Madhya Pradesh.

Horizon — Palaeocene-Eocene.



TEXT-FIG. 7 — *Monocotylostrobus bracteatus* — A flower in oblique vertical section showing two carpels cut vertically and a single style.

ACKNOWLEDGEMENTS

We are grateful to Prof. T. S. Mahabale and Prof. V. Puri for enlightened discussions and helpful suggestions regarding possible affinities of the present fossil. We are also sincerely thankful to Prof. R. M. Pai for examining the slides and discussing their structure and interpretation with one of us (M.B.B.).

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EXPLANATION OF PLATES

PLATE 1

Monocotylostrobus bracteatus

1. Inflorescence in reflected light. × 1.5.
2. Another specimen in reflected light. × 2.
3. Third specimen slightly enlarged, also in reflected light. × 5.
4. Inflorescence in vertical longitudinal section showing main axis with sessile, bracteate flowers arranged in acropetal succession. × 8. B.S.I.P. slide no. 6267.
5. A young perianth lobe in longitudinal section showing fibrous bundles. × 100. B.S.I.P. slide no. 6267.

PLATE 2

Monocotylostrobus bracteatus

6. A mature flower in oblique longitudinal section with a well-developed bract. × 16. B.S.I.P. slide no. 6267.
7. Base of the flower in oblique longitudinal section showing three perianth lobes with well-developed fibrous and fibrovascular bundles. × 60. B.S.I.P. slide no. 6268.
8. Inflorescence in longitudinal section with flowers arranged in acropetal succession. × 11. slide no. 6269.
9. Inflorescence in longitudinal section with a flower at the top showing two carpels and single style. × 9. C-carpel, S-style. B.S.I.P. slide no. 6270.


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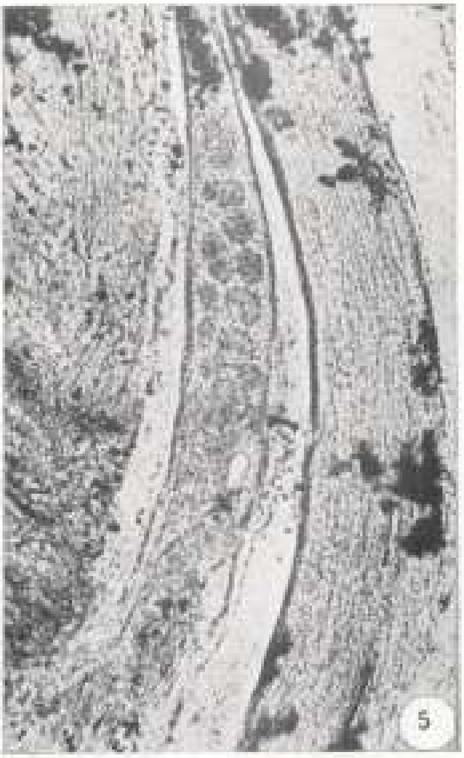
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PLATE 1


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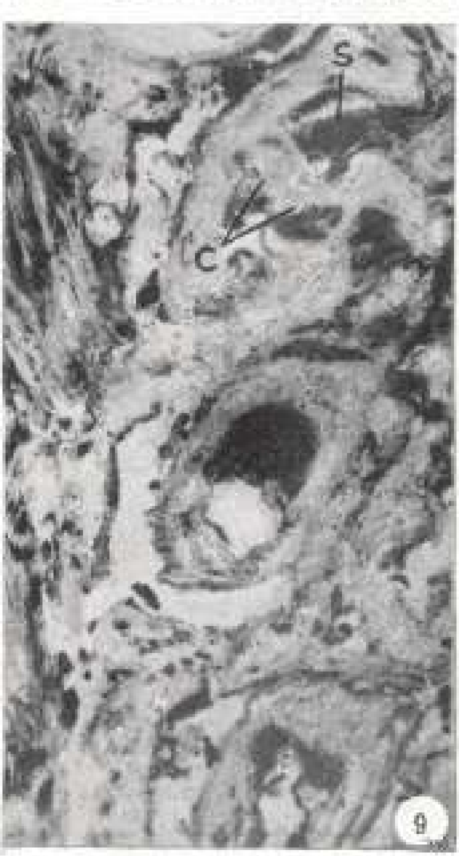
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PLATE 2

The Palaeobotanist, 30(3): 325-339, 1982.

PALYNOLOGY OF THE PINJOR FORMATION (UPPER SIWALIK) EXPOSED NEAR CHANDIGARH, INDIA

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ABSTRACT

The paper deals with the systematic description and discussion of the palynoflora recovered from the Pinjor Formation near Chandigarh. A total of 19 genera and 23 species have been recovered. Of these, two species are new.

The study of the Pinjor assemblage reveals that the spores and pollen grains may belong to 11 families, viz., Cyatheaceae, Schizaeaceae, Parkeriaceae, Podocarpaceae, Pinaceae, Palmae, Liliaceae, Gramineae, Magnoliaceae, Proteaceae and Oleaceae. The occurrence of reworked Eocene phytoplanktons has been discussed. The significance of the assemblage has also been commented upon.

Key-words — Palynology, Upper Siwalik, Pinjor Formation, Chandigarh (India).

सारांश

चन्डीगढ़ (भारत) के समीप विगोपित पिंजौर शैल-समूह (उपरि शिवालिक) का परागाणविक अध्ययन—
रमेश कुमार सक्सेना एवं हरिपाल सिंह

चन्डीगढ़ के समीपस्थ पिंजौर शैल-समूह से उपलब्ध परागाणविक वनस्पतिजात का वर्गीकृत वर्णन एवं विवेचन किया गया है। कुल मिलाकर 19 प्रजातियाँ एवं 23 जातियाँ प्राप्त हुई हैं जिनमें दो जातियाँ नई हैं।

पिंजौर समुच्चय के अध्ययन से यह व्यक्त होता है कि परागकण एवं बीजाणु 11 कुलों – स्यैथिएसी, शाइज़िएसी, पार्करिएसी, पोडोकार्पेसी, पाइनेसी, पाम्मी, लिलिएसी, ग्रेमिनी, मेग्नोलिएसी, प्रोटिएसी एवं ओलिएसी – से सम्बन्धित हैं। पुनः निक्षेपित आदिनूतन युगीन पादप-प्लवकों की उपस्थिति भी विवेचित की गई है। इस समुच्चय के महत्व पर भी टिप्पणी की गई है।

INTRODUCTION

THE progress of palynological research on the Upper Siwalik sediments has been rather slow because of the paucity of spores and pollen grains in these sediments. The possible reason for the absence or impoverished recovery of palynomorphs seems to be the prevalence of oxidizing environment of deposition in addition to secondary weathering to which these sediments have been exposed as they are mostly coarse grained, loose and friable in nature. In spite of these setbacks, palynologists have recovered assemblages which have been used to throw light on the problems like climatology and environment of deposition (Ghosh, 1977). Informal assemblage zone has also been recognized in the Upper Siwalik (Nandi, 1975). The present paper is the first attempt in which palynology of the Pinjor Formation near Chandigarh has been systematically described and compared with the known comparable assemblages.

The literature on palynology of the Siwalik Group is rather scanty. Banerjee (1968) was the first to publish a paper on the palynology of Lower and Middle Siwalik sediments of Bhakra-Nangal area, Himachal Pradesh. On the basis of the recovered palynoflora, he inferred that during the Lower Siwalik sedimentation the vegetation was coastal having tropical-temperate climate, while during the deposition of Middle Siwalik it changed to a predominantly inland type of vegetation with temperate climate. The dominance of gymnospermous elements over the angiospermous ones and rather poor representation of pteridophytes lead him to suggest a gradual cooling of the surrounding climate. Lukose (1969) described a palynoflora from the Middle Siwalik of Raxaul, Bihar and discussed about the source of sediments and probable cause of their poor fossiliferous state. Nandi and Bandyopadhyay (1970) published a short note on the microfossils and microstructures from the Middle Siwalik lignite exposed along Bhed Khad in Himachal Pradesh between Ghasoti and Badahr. They described the palynofossils under 5 types, viz., porate, inaperturate, polycolpate, saccate and fungal spores. Venkatachala (1972), while reviewing the palynological contributions to Indian stratigraphy, gave the characteristic palynomorphs of the Lower and Middle Siwalik sediments. Palynoflora from Middle Siwalik sediments of Mohand (East) Field, Uttar Pradesh has been described by Nandi (1972). Based on the palynofloral evidence, she concluded that the sediments were deposited under fresh water condition and a great climatic change occurred during their deposition, i.e. during Upper Miocene to Lower Pliocene. Mathur (1973) described Lower Siwalik palynoflora from Tharukhola-Chepang, located towards north-east of Nepalgange, Nepal, assigning a Miocene age to the sediments. She inferred the prevalence of tropical to subtropical climate during the time of deposition.

Singh, Khanna and Sah (1973) mainly reported the occurrence of *Pinus*-type, monosulcate-type and inaperturate (nonsaccate) pollen grains from the Pinjor Formation of which the later mentioned being in abundance. This fact has been confirmed by the present investigation. Singh, Khanna and Sah (1973, p. 76) surmised sub-temperate to temperate climate during the Upper Siwalik times.

Palynostratigraphical studies on the Siwalik Group exposed in Jawalamukhi area of Himachal Pradesh have been attempted for the first time by Nandi (1975). She proposed 4 palynological zones in the Siwalik, i.e. zones 1-4, giving characteristic palynomorphs and their vertical distribution for each zone and concluded the prevalence of tropical to subtropical climate during Lower Siwalik, subtropical to temperate during Middle Siwalik and a distinctly colder one during Upper Siwalik sedimentation. Ghosh (1977) reviewed the palynological work done on Siwalik sediments. He discussed the palaeoecology and palaeoclimate during the Siwalik sedimentation and gave a brief description of the palynological zones originally proposed by Nandi (1975).

From the above mentioned resume, the present authors feel that the terms like subtropical to temperate climate or vegetation have been very loosely used by various authors which need to be avoided in future work.

The material for the present study was collected from a carbonaceous shale bed of the Pinjor Formation exposed in the vicinity of Chandigarh which was kindly made available by Dr S. B. Bhatia of Punjab University, Chandigarh. The slides and unused material have been deposited in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

SYSTEMATIC PALYNOLOGY

Anteturma — *Proximegerminantes* Potonié, 1970

Turma — *Triletes* Reinsch emend. Dettmann, 1963

Suprasubturma — *Acavatitriletes* Dettmann, 1963

Subturma — *Azonotriletes* Luber emend. Dettmann, 1963

Infraturma — *Laevigati* Bennie & Kidston emend. Dettmann, 1963

Genus — *Cyathidites* Couper, 1953

Type Species — *Cyathidites australis* Couper, 1953.

Cyathidites minor Couper, 1953

Pl. 1, fig. 1

Cyathidites sp.

Pl. 1, fig. 2

Description — Spores triangular-subtriangular, 30-38 μm. Trilete rays extending almost up to the equator. Exine 2-3 μm thick, occasionally slightly thicker at apices, laevigate- ± sculptured.

Comparison — The present specimens are identical to *C. minor* Couper (1953) in shape, size and nature of trilete mark but in the former, the exine is slightly thicker and occasionally faintly sculptured.

Genus — *Lygodiumsporites* Potonié, Thomson & Thiergart ex Potonié, 1956

Type Species — *Lygodiumsporites adriennis* Potonié, Thomson & Thiergart, 1950.

Lygodiumsporites sp.

Pl. 1, fig. 3

Description — Spores subtriangular, apices broadly rounded, interapical margin convex, 46 μm. Trilete, rays extending up to the equator. Exine 2.5 μm thick, laevigate-± intrastructured.

Comparison — The present spores resemble *Lygodiumsporites pachyexinus* Saxena (1978) in shape and size but in the latter the exine is thicker. *L. lakiensis* Sah & Kar (1969) and *L. eocenicus* Dutta & Sah (1970) are bigger in size.

Genus — *Todisporites* Couper, 1958

Type Species — *Todisporites major* Couper, 1958.

Todisporites sp.

Pl. 1, fig. 4

Description — Spores circular-subcircular, 30-35 μm. Trilete, rays extending three-fourth of the radius, generally covered by exinal fold. Exine 1-1.5 μm thick, laevigate.

Remarks — The present specimens resemble *Todisporites* cf. *plicatus* Sah & Kar (1969) described by Nandi (1972, p. 376, pl. 1, fig. 7) from the Middle Siwalik sediments of Mohand (East) Field, Uttar Pradesh.

Infraturma — *Murornati* Potonié & Kremp, 1954

Genus — *Striatriletes* van der Hammen, 1956

Type Species — *Striatriletes susannae* van der Hammen, 1956.

Striatriletes sp.

Pl. 1, fig. 5

Description — Spore triangular with acute apices, 65 μm. Trilete, rays obscure. Exine 2.5 μm thick, striate, 4 ridges in each interradial region, ridges as wide as furrows, occasionally bifurcating on distal surface to form loop-like structures.

Anteturma — *Variegerminantes* Potonié, 1970
Turma — *Saccites* Erdtman, 1947
Subturma — *Disaccites* Cookson, 1947
Infraturma — *Podocarpoiditi* Potonié, Thomson & Thiergart, 1950

Genus — *Podocarpidites* Cookson emend. Potonié, 1956

Type Species — *Podocarpidites ellipticus* Cookson, 1947.

Podocarpidites ellipticus Cookson, 1947

Pl. 1, fig. 9

Podocarpidites microreticuloidatus Cookson, 1947

Pl. 1, fig. 8

Remarks — The present specimens are slightly bigger in size than those described by Cookson (1947) from Kerguelen Archipelago.

Infraturma — *Pinosacciti* Erdtman emend. Potonié, 1958

Genus — *Pinuspollenites* Raatz, 1937

Type Species — *Pinuspollenites labdacus* (Potonié) Raatz, 1937.

Pinuspollenites sp.

Pl. 1, fig. 6

Description — Pollen grains elliptical in polar view, 88-108 × 58-62 μm. Bisaccate. Central body circular-subcircular, 60-66 × 50-60 μm, very finely reticulate. Sacci equal in size, smaller than central body, reticulate, reticulum fine to coarse, muri delicate, sometimes meshes irregular and obscure. Sulcus 18-22 μm wide, longitudinally oval.

Remarks — The present specimens resemble *Disaccites* sp. 1 and *Disaccites* sp. 5 described by Lukose (1969) from the Middle Siwalik sediments of Bihar.

Infraturma — *Cedrosacciti* Erdtman, 1945

Genus — *Cedripites* Wodehouse, 1933

Type Species — *Cedripites eocenicus* Wodehouse, 1933.

Cedripites sp.

Pl. 1, fig. 7

Description — Pollen grains ± oval in polar view, 77-112 μm. Bisaccate. Central body subcircular, 66-70 μm, finely sculptured, granulose. Sacci ± equal in size, smaller than central body, very finely reticulate. Sulcus wide.

Remarks — Only two specimens assignable to *Cedripites* Wodehouse (1933) have been found in the present assemblage.

Turma — *Aletes* Ibrahim, 1933
Subturma — *Azonaletes* Luber emend. Potonié & Kremp, 1954
Infraturma — *Psilonapiti* Erdtman, 1947

Genus — *Laricoidites* Potonié, Thomson & Thiergart ex Potonié, 1956

Type Species — *Laricoidites magnus* (Potonié) Potonié, Thomson & Thiergart, 1950.

Laricoidites magnus (Potonié) Potonié, Thomson & Thiergart, 1950

Pl. 1, fig. 10

Remarks — The present species is predominant in the assemblage.

Laricoidites punctatus Saxena, 1979a

Pl. 1, fig. 11

Infraturma — *Granulonapiti* Cookson, 1947

Genus — *Araucariacites* Cookson ex Couper, 1953

Type Species — *Araucariacites australis* Cookson, 1947.

Araucariacites australis Cookson, 1947

Pl. 1, fig. 12

Remarks — The occurrence of this species is rare in the present assemblage.

Infraturma — *Reticulonapiti* (Erdtman) Bose & Kar, 1967

Genus — *Retiinaperturites* Mathur, 1966

Type Species — *Retiinaperturites depressus* Mathur, 1966.

Retiinaperturites pinjoricus sp. nov.

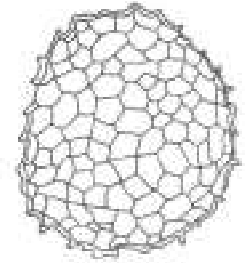
Pl. 1, figs 16-18; Text-fig. 1

Holotype — Pl. 1, fig. 16, size 118 × 100 μm; slide no. 6198/2.

Type Horizon & Locality — Pinjor Formation, Upper Siwalik, near Chandigarh, India.

Diagnosis — Pollen grains subcircular-oval, 93-120 × 68-102 μm. Germinal mark absent. Exine 1-3 μm thick, reticulate, reticulum coarse, muri fairly raised, lumina polygonal-irregular in shape.

Comparison — The present species can be differentiated from the type species, *R. depressus* Mathur (1966), in being much bigger in size and in having thicker exine and coarser reticulum.



Text-fig. 1 — *Retiinaperturites pinjoricus* sp. nov., × 250.

Turma — *Plicates* Naumova emend. Potonié, 1960
Subturma — *Monocolpates* Iversen & Troels-Smith, 1950
Infraturma — *Monoptyches* Naumova emend. Potonié, 1958

Genus — *Palmidites* Couper, 1953

Type Species — *Palmidites maximus* Couper, 1953.

Palmidites maximus Couper, 1953

Pl. 2, fig. 19

Genus — *Psilamonocolpites* van der Hammen & Garcia de Mutis, 1965

Type Species — *Psilamonocolpites medius* van der Hammen & Garcia de Mutis, 1965.

Psilamonocolpites sp.

Pl. 2, fig. 28

Description — Pollen grain elliptical, 100 × 43 μm. Monosulcate, sulcus wide, extending from one end to the other. Exine 1.5 μm thick, laevigate.

Genus — *Pinjoriapollis* Saxena & Singh, 1981

Type Species — *Pinjoriapollis magnus* Saxena & Singh, 1981.

Pinjoriapollis magnus Saxena & Singh, 1981

Pl. 2, figs 20, 21

Pinjoriapollis lanceolatus Saxena & Singh, 1981

Pl. 2, figs 27, 29

Infraturma — *Sculptati* Potonié, 1970

Genus — *Liliacidites* Couper, 1953

Type Species — *Liliacidites kaitangataensis* Couper, 1953.

Liliacidites matanomadhensis Saxena, 1979a

Pl. 2, fig. 23

Subturma — *Ptychotriporines* Naumova emend. Potonié, 1960
Infraturma — *Prolati* Erdtman, 1943

Genus — *Favitricolporites* Sah, 1967

Type Species — *Favitricolporites eminens* Sah, 1967.

Favitricolporites sp.

Pl. 2, fig. 24

Description — Pollen grain subcircular in polar view, 42 μm. Tricolporate, colpi long, well-developed, funnel-shaped, mesocolpia wide, pore margin slightly thickened. Exine 2·5 μm thick, sexine thinner than nexine, reticulate, reticulum fine, tegillate.

Remarks — Only one specimen of this species could be recovered from the present assemblage.

Turma — *Porosus* Naumova emend. Potonié, 1960
Subturma — *Monoporines* Naumova emend. Potonié, 1960

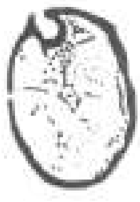
Genus — *Graminidites* Cookson, 1947

Type Species — *Graminidites media* Cookson, 1947.

Graminidites chandigarhensis sp. nov.

Pl. 2, fig. 25; Text-fig. 2

Holotype — Pl. 1, fig. 25, size 47 × 34 μm, slide no. 6192/8.



TEXT-FIG. 2 — *Graminidites chandigarhensis* sp. nov., × 500.

Type Horizon & Locality — Pinjor Formation, Upper Siwalik, near Chandigarh, India.

Diagnosis — Pollen grains oval, 30-40 × 25-30 μm. Monoporate, pore ± circular with a clearly defined annulus. Exine 0.5-1.5 μm thick, laevigate.

Comparison — The present species differs from *G. media* Cookson (1947) and *G. subreticulata* Cookson (1947) in having laevigate exine while the latter two have reticulate ornamentation of the exine. *G. assamicus* Sah & Dutta (1968) is bigger in size.

Subturma — *Triporines* Naumova emend. Potonié, 1960

Infraturma — *Zoniporiti* Ramanujam, 1966

Genus — *Triorites* Erdtman ex Couper, 1953

Type Species — *Triorites magnificus* Cookson, 1950.

Triorites sp.

Pl. 2, fig. 22

Description — Pollen grains subtriangular, 26-40 μm. Triorate, ora distinct, 7-9 μm in diameter, ora margin slightly thickened. Exine 3 μm thick ornamented by a few, very fine, conical, sparsely placed spinules, interspinal area laevigate.

Comparison — The present species differs from other species of *Triorites* Erdtman ex Couper (1953) in having very fine sparsely placed conical spinules.

Palynomorph type-1

Pl. 1, fig. 13

Description — Spore circular, 24 μm. Trilete, rays extending almost up to the equator. Exine 1 μm thick, spinulose, spinules hair-like, small, up to 2 μm in length, sparsely placed.

Palynomorph type-2

Pl. 2, fig. 30

Description — Pollen grains elliptical, 187 × 77 μm. Inaperturate. Exine 2 μm thick, intrapunctate, puncta closely placed and evenly distributed, exine irregularly folded.

Remarks — The present specimen resembles *Laricoidites* sp. described by Saxena (1979a) from the Matanomadh Formation of Kachchh.

Palynomorph type-3

Pl. 2, fig. 26

Description — Pollen grain elliptical, 49 × 26 μm. Monosulcate, sulcus oval in shape, extending half the length of longer axis. Exine 1.5 μm thick, baculate-pilate, pila/bacula small.

Remarks — The present specimen appears to have some affinity with Liliaceae.

FUNGAL SPORES

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

Type Species — *Inapertisporites pseudoreticulatus* Rouse, 1959.

Inapertisporites vulgaris Sheffy & Dilcher, 1971

Pl. 1, fig. 14

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

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

Monoporisporites minutus van der Hammen, 1954

Pl. 1, fig. 15

1954 *Monoporisporites minutus* A. & B. van der Hammen, pl. 21, figs 1, 2, p. 103.

DISCUSSION

The palynofloral assemblage from the Pinjor Formation consists of fungal and pteridophytic spores alongwith gymnospermous and angiospermous pollen grains. Altogether 19 genera and 23 species have been recovered. Of these, two species are new.

Quantitative Analysis

An analysis of the mioflora reveals the occurrence of different spores and pollen grains in the following order: gymnospermous pollen (65%), angiospermous pollen (23%), fungal spores (9%) and pteridophytic spores (3%) (Text-figs 3, 4).

Among gymnospermous pollen, *Laricoidites* Potonié, Thomson & Thiergart ex Potonié (57%) is the predominant genus, being represented by two species, viz., *L. magnus* (Potonié) Potonié, Thomson & Thiergart (52%) and *L. punctatus* Saxena (5%), while the other two alete genera, *Araucariacites* Cookson ex Couper (3%) and *Retiimaperturites* Mathur (2%) are meagre in occurrence. The bisaccate pollen are represented by three genera, viz., *Pinuspollenites* Raatz (2%), *Podocarpidites* Cookson emend. Potonié (1%) and *Cedripites* Wodehouse (less than 1%).

Among angiospermous pollen, *Pinjoriapollis* Saxena & Singh (10%), is represented by two species, viz., *P. magnus* Saxena & Singh (4%) and *P. lanceolatus* Saxena & Singh (6%). *Graminidites* Cookson (6%), *Psilamonocolpites* van der Hammen & Garcia de Mutis (3%), *Triorites* Erdtman ex Couper (2%) and *Palmidites* Couper (2%) have also been encountered.

The pteridophytic spores are very poorly represented. Out of 4 genera present in the assemblage, only two appear in the counting, viz., *Cyathidites* Couper (2%) and *Striatriletes* van der Hammen (1%).

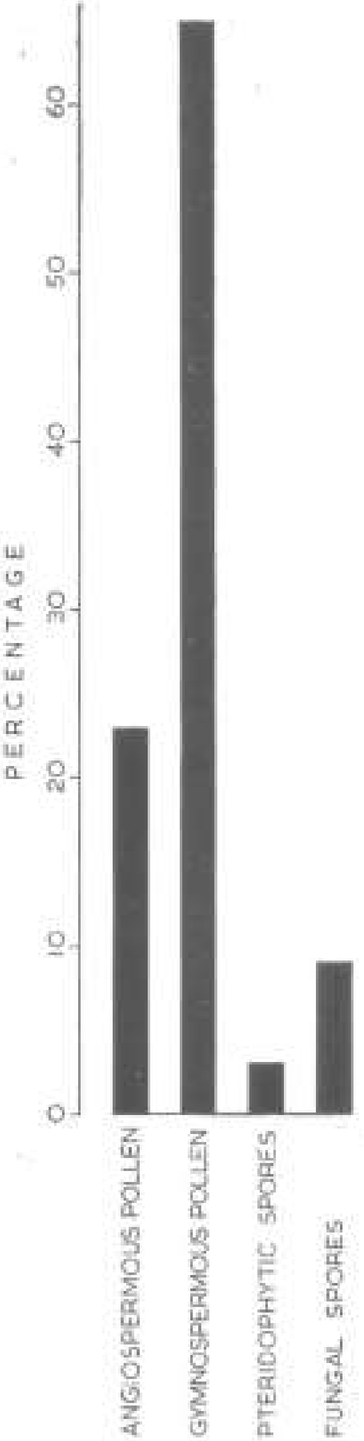
The fungal spores are represented in the assemblage by two genera, *Inapertisporites* van der Hammen emend. Sheffy & Dilcher (9%) and *Monoporisporites* van der Hammen emend. Sheffy & Dilcher. The latter does not figure in the percentage count.

Qualitative Analysis

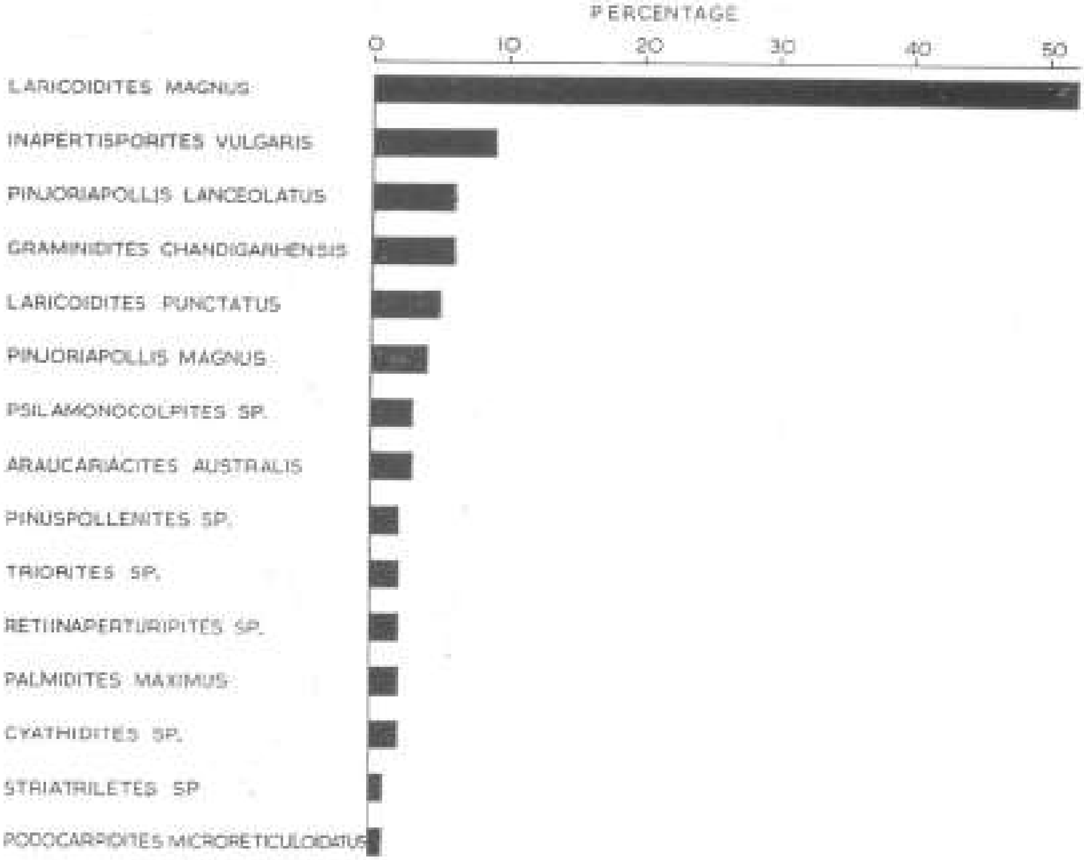
Pteridophyta

The pteridophytic spores are represented by 4 genera and 5 species and may be related to the following three families:

1. *Cyatheaceae* — The spores referred to *Cyathidites minor* Couper and *Cyathidites* sp. are comparable to those of Cyatheaceae. The present day distribution of this family is in tropical-subtropical region.



TEXT-FIG. 3 — Showing the representation of various plant groups in the Pinjor palynoflora of Chandigarh.



TEXT-FIG. 4 — Showing the representation of various palynomorph species in the Pinjor palynoflora of Chandigarh.

2. *Schizaeaceae* — The spores described under *Lygodiumsporites* sp. and *Todisporites* sp. seem to belong to this family. This family is chiefly distributed in tropical-subtropical climatic belt.

3. *Parkeriaceae* — Only a single specimen referred to *Striatriletes* sp. shows close relationship with this family and probably belongs to the living genus *Ceratopteris*.

GYMNOSPERMAE

The gymnospermous pollen are represented by six genera and eight species and may be referred to the following two families:

1. *Podocarpaceae* — The pollen grains described under *Podocarpidites ellipticus* Cookson and *P. microreticuloidatus* Cookson have close affinity with Podocarpaceae and in all probability, they represent this family. This family is distributed in both tropical and temperate region.

2. *Pinaceae* — The presence of this family in the present assemblage is evident by *Laricoidites magnus* (Potonié) Potonié, Thomson & Thiergart, *L. punctatus* Saxena, *Araucariacites australis* Cookson, *Pinuspollenites* sp. and *Cedripites* sp. The rich representation of *Laricoidites* Potonié, Thomson & Thiergart ex Potonié clearly testifies that this family constituted the principal element in the present assemblage. The family is distributed in both tropical and temperate climate.

ANGIOSPERMAE

The angiospermous pollen are represented by 7 genera and 8 species. Of these, 4 genera and 4 species belong to monocotyledons and 3 genera and 4 species belong to dicotyledons. The monocotyledonous pollen may be related to Palmae, Liliaceae and Gramineae while dicotyledonous ones may be referred to Magnoliaceae, Proteaceae and Oleaceae.

1. *Palmae* — Pollen grains referred to *Palmidites maximus* Couper and *Psilamonocolpites* sp. show close affinity with the pollen grains of Palmae. The geographical distribution of this family is exclusively tropical-subtropical.

2. *Liliaceae* — This family is represented by the pollen grains described under *Liliacidites matanomadhensis* Saxena. The present day distribution of this family is cosmopolitan.

3. *Gramineae* — Pollen grains described under *Graminidites chandigarhensis* sp. nov. prove the presence of this family in the Pinjor assemblage.

4. *Magnoliaceae* — This family is represented by the pollen grains described under *Pinjoriapollis magnus* Saxena & Singh and *P. lanceolatus* Saxena & Singh. This family is distributed primarily in temperate regions.

5. *Proteaceae* — Pollen grains referred to *Triorites* sp. show close relationship with this family. The family is ubiquitous in distribution.

6. *Oleaceae* — A single specimen referred to *Favitricolporites* sp. appears to belong to Oleaceae. The present day distribution of this family is in tropical-warm temperate zone.

PALYNOFLORAL COMPARISON

Very little has so far been published on the Siwalik palynology. Many taxa reported in the literature are either invalid, viz., *Monosaccites, Disaccites* (Lukose, 1969, p. 109) or their morphological details are not available, viz., *Siwalikisporites* (Nandi, 1975, p. 416; Ghosh, 1977, p. 15) or no generic or specific name has been assigned, viz., pollen grains having affinities to Compositae (Asteraceae), Palmae (Arecaceae), Gramineae (Poaceae), etc. (Banerjee, 1968, p. 172). As such a comparison of the present assemblage with those described earlier has been extremely difficult. However, an attempt has been made here in this regard with the help of whatever data is available.

Lower Siwalik palynoflora has so far been recorded by Banerjee (1968), Venkatachala (1972), Mathur (1973), Nandi (1975) and Ghosh (1977). Banerjee (1968) recovered palynomorphs belonging to Compositae (5·5%), Gramineae (8%), Palmae (5·5%), *Pinus* spp. (5·5%), *Disaccites* sp. (2·5%), tricolpate (2·5%), tetracolpate (13·5%), polycolpate (2·5%), inaperturate (5·5%) types alongwith a good percentage (11%) of trilete and monolete spores belonging to Gleicheniaceae, Polypodiaceae, etc. from the Lower Siwalik sediments exposed in Bhakra-Nangal area. This assemblage resembles the present Pinjor assemblage in common occurrence of inaperturate and Gramineae pollen. However, the two assemblages are distinctly different as the Bhakra-Nangal assemblage is rich in tetracolpate, polycolpate and tricolpate pollen which are completely absent in the Pinjor assemblage. On the other hand, Pinjor assemblage is loaded with inaperturate pollen (62%) and magnoliaceous pollen (10%). Of these, former is poor and the latter is totally unrepresented in Bhakra-Nangal palynoflora.

Venkatachala (1972), while reviewing the palynological contributions to Indian stratigraphy, mentioned that the Lower Siwalik sediments are characterized by pollen of Palmae and Gramineae associated with *Quercoidites, Holoragacidites, Cupuliferoipollenites, Sapotaceoidaepollenites* and *Araceopollenites*. Except for the occurrence of Gramineae (6%) and Palmae (2%) pollen, none of these genera could be recorded in the present assemblage.

Mathur (1973) described a rich assemblage from Lower Siwalik sediments exposed in Tharukhola-Chepang, northeast of Nepalgange, Nepal. It consists of *Verrucosisporites* (3 spp.), *Polypodiaceoisporites* (1 sp.), *Leiotriletes* (1 sp.), *Cyathidites* (1 sp.), *Hymenophyllumsporites* (1 sp.), *Lycopodiumsporites* (1 sp.), *Perotriletes* (1 sp.), *Cicatricosisporites* (2 spp.), *Contignisporites* (2 spp.), *Pityosporites* (1 sp.), *Sabalpollenites* (1 sp.), *Echinomonocolpites* (1 sp.) and *Graminidites* (1 sp.). It is interesting to note that none of the species described by Mathur (1973) is common to the Pinjor palynoflora. Moreover, Mathur's assemblage is dominated by angiospermous pollen followed by pteridophytic spores while gymnospermous pollen are rare, but in the Pinjor assemblage gymnospermous pollen are dominant (65%) followed by angiospermous ones while pteridophytic spores are rare (3%). It may be mentioned here that *Contignisporites* spp. A & B recorded by Mathur (1973) may be recycled Mesozoic spores.

Nandi (1975) and Ghosh (1977) proposed a palynostratigraphic zonation of the Siwalik Group. They mentioned, *Cicatricosisporites, Polypodiaceoisporites, Pteridacidites, Verrucosisporites, Monoporopollenites, Cupuliferoidaepollenites, Cyathidites, Triplanosporites, Verrucatosporites, Hymenophyllumsporites, Leptolepidites, Polypodiaceaesporites, Polypodiisporites, Palmaepollenites, Tetradomonoporites, Gleicheniidites, Alsophilidites, Siwalikisporites, Laevigatosporites, Polypodiidites, Abietineaepollenites, Pinuspollenites, Piceapollenites, Podocarpidites, Caryapollenites, Alnipollenites, Polyadopollenites*, etc. as characteristic palynomorphs of the Lower Siwalik. This assemblage is rich in pteridophytic spores and angiospermous pollen grains while the present assemblage is rich in gymnospermous (65%) pollen, hence easily distinguishable.

The Middle Siwalik assemblages have been recorded by Banerjee (1968), Lukose (1969), Nandi and Bandyopadhyay (1970), Venkatachala (1972), Nandi (1972, 1975) and Ghosh (1977). Banerjee (1968) recovered *Pinus* spp. (26·5%), angiospermous pollen of tricolpate (5·5%) and pentacolpate (2·5%) types and pteridophytic spores of monolete (2·5%) and trilobate (2·5%) types. Inaperturate and magnoliaceous pollen, which are dominant in Pinjor assemblage, are completely absent from the Middle Siwalik assemblage of Bhakra Nangal area. On the other hand, tricolpate and pentaporate pollen and monolete and trilobate spores recorded in the Bhakra Nangal assemblage are completely absent and *Pinus* sp. is poorly represented in the Pinjor assemblage.

Lukose (1969) described Middle Siwalik palynoflora from Raxaul, Bihar. He recorded *Retimonoletes* (1 sp.), *Foveomonoletes* (1 sp.), *Retitriletes* (1 sp.), *Cingutriletes* (1 sp.), *Monosaccites* (2 spp.), *Disaccites* (6 spp.), *Polyadites* (1 sp.), *Inaperturites* (1 sp.), *Retimonocolpites* (1 sp.), *Triporites* (1 sp.), *Retitriporites* (2 spp.). A perusal of this assemblage reveals that none of these genera is common to the Pinjor assemblage except probably for a few bisaccate pollen.

Nandi and Bandyopadhyay (1970) recorded some monoporate, periporate, inaperturate, polycolpate, monosaccate and bisaccate pollen types alongwith a few fungal spores. This assemblage is too scanty to be of any use in specific comparison. However, except for the probable resemblance in inaperturate, bisaccate (cf. *Pinuspollenites*) and monoporate (cf. *Graminidites*) pollen, the two assemblages are entirely different. The high frequency of *Laricoidites magnus* (52%) also makes the present assemblage distinct.

Venkatachala (1972) mentioned that Middle Siwalik assemblage contains palynomorphs belonging to Malvaceae, Betulaceae, Anacardiaceae, Pinaceae and Polypodiaceae. This assemblage shows better representation of gymnospermous pollen than angiospermous ones. In the Pinjor assemblage too, pollen of Pinaceae have been recorded associated with high frequency of inaperturate, magnoliaceous and graminoid pollen.

Nandi (1972) published Middle Siwalik assemblage from Mohand (East) field in Saharanpur District, Uttar Pradesh. This assemblage consists of many spore-pollen species related to Lycopodiaceae, Hymenophyllaceae, Schizaeaceae, Gleicheniaceae, Polypodiaceae, Cyatheaceae, monoporate (Cyperaceae), monosulcate (Palmae), polyporate, tricolporate, inaperturate types alongwith *Pinus* sp., *Podocarpus* sp., *Abies* sp. and monosaccate pollen. The present Pinjor assemblage differs from the Mohand assemblage by having rich representation of *Laricoidites* and *Pinjoriapollis* and scarcity of pteridophytic spores (monolete spores are completely absent) and *Pinus* sp. However, monoporate pollen (cf. *Graminidites*) may be common to both the assemblages. *Klukisporites, Concavissimisporites* and *Tsugaepollenites* may be recycled Mesozoic sporomorphs (Saxena, 1979b).

Nandi (1975) and Ghosh (1977) stated that *Pinuspollenites, Piceapollenites, Abietineaepollenites, Podocarpidites, Abiespollenites, Cyathidites, Gleicheniidites, Triplanosporites, Siwalikisporites, Leptolepidites, Laevigatosporites, Polypodiidites, Verrucatosporites, Polypodiisporites, Alsophilidites, Hymenophyllumsporites, Poly-*

podiaceoisporites, *Tsugaepollenites*, *Cedripites*, *Sciadopityspollenites*, *Betulaepollenites*, *Caryapollenites*, *Monoporopollenites*, *Alnipollenites*, *Polyadopollenites*, *Tetradomonoporites*, *Longapertites*, *Verrunapertarites*, *Cupuliferoidaepollenites*, *Cupuliferoipollenites* are characteristic of Middle Siwalik. This assemblage is fairly rich in pteridophytic (both trilete and monolete) spores and bisaccate pollen and very poor in inaperturate pollen while reverse is the case with Pinjor assemblage.

Nandi (1975) and Ghosh (1977) mentioned that the basal part of Upper Siwalik contains a very poor assemblage represented by *Cyathidites*, *Alsophilidites*, *Leptolepidites*, *Pinuspollenites*, *Podocarpidites*, *Monoporopollenites*, *Alnipollenites* and *Tetradomonoporites*. This assemblage comes comparatively closer to the present assemblage except for the absence of inaperturate and magnoliaceous pollen in the former and *Leptolepidites*, *Alnipollenites* and *Tetradomonoporites* in the latter. Nandi (1975) and Ghosh (1977) also stated that except for the basal part, the rest of the Upper Siwalik is unfossiliferous. The present Pinjor assemblage which represents the middle part of the Upper Siwalik has proved it to be productive now. Palynological assemblages from different horizons in other areas and even from the Boulder Conglomerate bed representing uppermost part of the Siwalik Group have been recovered by the present authors and are being studied for their botanical and stratigraphical importance. It is hoped that the Upper Siwalik palynoflora will be better understood in the coming times because of the enhanced research activity on these sediments by various workers.

OCCURRENCE OF REWORKED PALYNOMORPHS

While studying the Pinjor palynoflora, a few specimens of phytoplanktons were also recorded. Their representation in the present assemblage is very poor as only 3 such specimens could be recovered. The preservation of these specimens is poorer than that of the original Pinjor mioflora.

It is very likely that the specimens of phytoplanktons are of Subathu (Lower Eocene) origin. Normally the phytoplanktons are found in the marine sediments while the Pinjor Formation is essentially of fresh-water origin. It, therefore, appears that these phytoplanktons are not part of the original Pinjor assemblage and might have been derived from the Subathu Formation of the neighbouring area. The reworked palynomorphs must have been transported and redeposited in the Pinjor sediments along with the material eroded and transported from the Subathu Formation.

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EXPLANATION OF PLATES

(All photomicrographs are enlarged *ca.* × 500 unless otherwise mentioned)

PLATE 1

1. *Cyathidites minor* Couper, slide no. 6189/4.
2. *Cyathidites* sp., slide no. 6190/1.
3. *Lygodiumsporites* sp., slide no. 6191/1.
4. *Todisporites* sp., slide no. 6192/1.
5. *Striatriletes* sp., slide no. 6193/2.
6. *Pinuspollenites* sp., slide no. 6194/19.
7. *Cedripites* sp., slide no. 6189/6.
8. *Podocarpidites microreticuloidatus* Cookson, slide no. 6194/10.
9. *Podocarpidites ellipticus* Cookson, slide no. 6195/4.
10. *Laricoidites magnus* (Potonié) Potonié, Thomson & Thiergart, slide no. 6192/2.
11. *Laricoidites punctatus* Saxena, slide no. 6191/6.
12. *Araucariacites australis* Cookson, slide no. 6196/13.
13. Palynomorph type-1, slide no. 6189/20.
14. *Inapertisporites vulgaris* Sheffy & Dilcher, slide no. 6197/2, × 1000.
15. *Monoporisporites minutus* van der Hammen, Slide no. 6197/3, × 1000.

16-18. *Retiinaperturites pinjoricus* sp. nov., slide nos. 6198/2 (Holotype), 6189/21, 6193/5.

PLATE 2

19. *Palmidites maximus* Couper, slide no. 6192/8.
20, 21. *Pinjoriapollis magnus* Saxena & Singh, slide nos. 6196/5, 6189/5.
22. *Triorites* sp., slide no. 6199/12.
23. *Liliacidites matanomadhensis* Saxena, slide no. 6195/6.
24. *Favitricolporites* sp., slide no. 6196/19.
25. *Graminidites chandigarhensis* sp. nov., slide no. 6192/8. (Holotype).
26. Palynomorph type-3, slide no. 6199/4.
27, 29. *Pinjoriapollis lanceolatus* Saxena & Singh, slide nos. 6198/7, 6193/9.
28. *Psilamonocolpites* sp., slide no. 6199/8.
30. Palynomorph type-2, slide no. 6199/13.

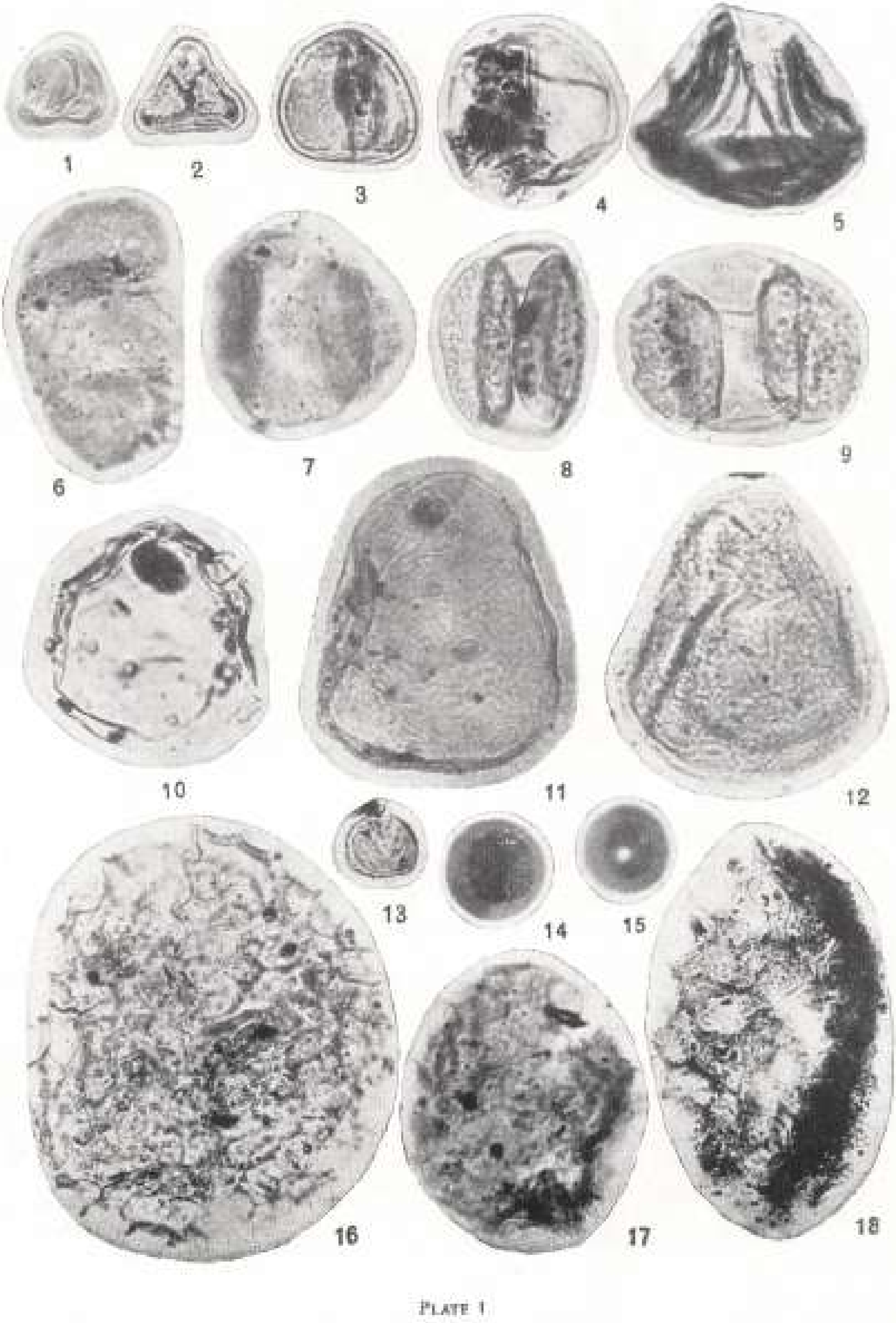

PLATE 1

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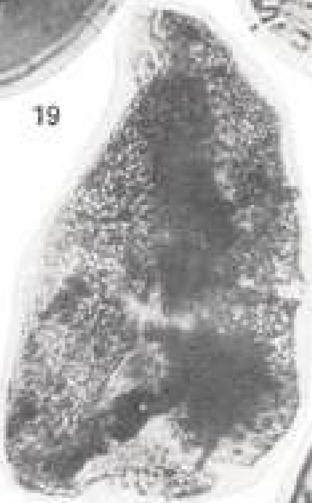

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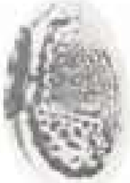

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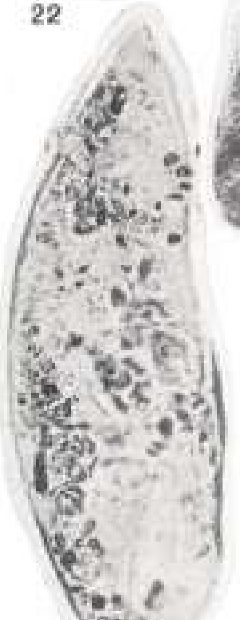

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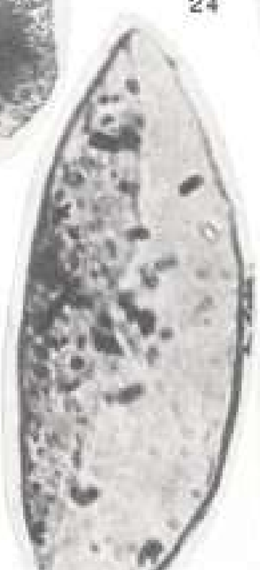

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PLATE 2

The Palaeobotanist, 30(3): 340-346, 1982.

TWELFTH BIRBAL SAHNI MEMORIAL LECTURE

WHAT IS PALAEOBOTANY FOR?

TOM M. HARRIS
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I WAS deeply honoured to be invited to give this year's Sahni lecture and touched to find my room in this building labelled "T. M. Harris, Birbal Sahni Professor", I am one of the diminishing number of his friends; he was born not many years earlier than I. I feel he might have been still alive if he had worked less hard. Well he was inspiring and a man of courage and I must give a cheerful lecture. But I am an old man and cannot tell you about new things as a young man should. Instead I look back and think and I ask myself the question "What is Palaeobotany for?". It is a question I have asked myself many times; when young I was an ardent collector of all sorts of things, beetles, shells, plants as well as fossils and I knew I would soon turn to something else. So when I asked 'why am I doing it' I thought a minute and went on, not at all discouraged by my failure as a philosopher.

I shall talk about a few pieces of work by others; they are as I consider worthwhile because they were done with courage and should give courage. But that and the tiresome state of fossil plant material is all they have in common. The state is important. It gives men who work on fossils sympathy with one another.

I begin with some fossils barely 10,000 years old from a marshy field in Yorkshire, the field is called Star Carr. All the plant species still live in Britain and 10,000 years would seem a moment at an earlier period, not more than one Ammonite zone. But it was at a time of rapid change, especially of climate for only 3000 years earlier the last glaciation was at its maximum and in Britain most of the land north of London was covered by ice. South of London we had permafrost, the land was deeply frozen in winter but the surface thawed to give mud in summer. I have lived in permafrost in Greeland for a year, life is indeed possible and there are bright flowers but trees cannot survive on land that flows down hill each year. Along with glaciation there were notable changes in sea level and Britain was widely connected to N. Europe.

The other great change was in human technology. As I understand our species long existed as a rare animal with bones indistinguishable from those of modern man and then at first very slowly and afterwards with increasing rapidity developed new tricks and remembered them, and as he added new ones became more numerous. Thus ten thousand years ago, while these animals and plants preserved at Star Carr are all essentially modern, the way the people lived had changed and would change again. This is Archaeology and is of wide interest. It was appropriate that the main work was done by the archaeologist Clark of Cambridge but he made use of Botanists, Zoologists, Geographers and others, a happy collaboration which should be normal but is rare. And there was early help from two men in jobs where you would hardly expect scholarly treatment of scientific evidence; the skipper of a trawler and a road engineer who dug ditches. And finally there was a strong smell of scientific scandal; to save disappointment I say at once the scandal proved baseless, everyone had been honest but it undoubtedly roused interest in Star Carr.

I will tell the story as a history. I had only faint concern with archaeology and I thought of Englishmen before the last glaciation, dimly seen creatures, living as hunters and called Palaeolithic man. After the glaciation I called them 'Neolithic' herdsmen but this was too simple and for a good 3000 years after the maximum they were still hunters and are called Mesolithic. The 'lithic' part of the word refers to the fact that almost the only things which survived decay were their stone tools and even these are rare and scattered. Archaeologists recognize types of stone tools and name them but stones tell very little about the people who used them, particularly as a flint, that is a chert knife, picked up in a ploughed field has no attached date.

The first relevant fossil found in England was a barbed spearhead, made not of stone but of deer antler and dug up in 1903 not far from Star Carr. It was sold to a private collector who just kept it for twenty years. Also in 1903 an able archaeologist excavated a bog at Maglemose in Denmark and he got numerous barbed spearheads and also various stone tools. He did his work well and his find became known as the Maglemose culture, now known to extend from Spain to Siberia and limited to a period of a few thousand years after the glacial maximum, the Late Glacial. When the Yorkshire collector showed his specimen in 1922 it was denounced as a forgery. Archaeology is only too open to forged evidence. In 1932 the trawler skipper brought up a great lump of peat off the Yorkshire coast (and the occurrence of peat was well known round there). Instead of just throwing it back he cut it with a spade and found a beautifully preserved barbed spearhead. He recorded the exact place where he got it and handed it to the nearest museum. Harry and Margaret Godwin got a peat core from the sea bed just there and showed that the pollen indicated early Post glacial; tree growth was at its beginning. Then in 1947 the road engineer saw a flint knife in a newly cut ditch at Star Carr, noted the place and also handed it in. The finds were duly reported and Clark realized that Star Carr might give him what he wanted. He worked there for several years with volunteer labour of undergraduates. He was digging in wet peat formed by a reed swamp at the margin of a great lake which existed there in the Late Glacial. The lake had been dammed by ice and moraine and later was to vanish. What they uncovered was the site of a tiny settlement only a few metres wide and built of tree branches laid roughly on reed swamp. Towards the lake there was a track of wood going through a water lily belt to the open water. The platform was made casually of irregularly laid birch branches and lumps of clay and stones but they seem to have had thoughts of comfort as there are local piles of moss. The platform could not have had more than about four small skin tents, a tiny settlement indeed and not a village but so was the Danish original Maglemose.

I show you a plan of the platform in relation to the lake and a picture of the platform as excavated. It seems that the site was used for quite a long time and many thousands of flints, the local form of chert, were collected and hammered there to make useful tools. The hammer and anvil stones were found. Most of the flint tools were spoilt. We know they were made there because the flakes can be fitted together. Some hundreds of finished flint tools were found and they are of a dozen kinds, little sharp arrow points, skin scrapers, augers for boring holes, saws and special tools for working deer antlers and some of unknown function. I show you a group of skin scrapers and some large mattock heads made from the antlers of the extinct giant deer, the Elk. Plenty of spoilt deer antler spearheads are available, so we know how they were made. The antler was first scratched deeply with flints, then the surface between the scratches was split off and then the splinter was filed till barbed. I show you one group of spear points. These are sometimes notches suitable for attachment to sticks.

Now for some inferences. The little platform about 20 m across was occupied only as a winter camp. We know this from the deer antlers. Deer shed their antlers every year and as the new ones grow they change and the state can be recognized even when fossil. Huge numbers of deer were slain and smaller numbers of other wild animals, cattle, horses and small ones also. The bones suggest that they collected every kind of creature for food. But unfortunately there are no human bones. Several of the Star Carr plants are eaten by people in Europe when hungry but there is no fossil evidence that they were eaten in the winter camp. It seems that the camp was used over a long period, Clark estimates more than 100 years and changes in style of tool occurred. Then though life was doubtless precarious, and Clark suggests that the wild animals of Britain could scarcely have supported more than a very few thousand people in tiny groups of families, we need not suppose they were unhappy. They did things for pleasure, they bored holes through teeth and bits of amber for necklaces (you can find amber today on the coast) and they made themselves hats out of the tops of deer heads. I show you a picture of a modern hunter from Arctic Siberia wearing just such a hat for a ceremonial dance and he plainly enjoys his life. But I must warn you, Clark was a pioneer worker and a man a century hence would find other things when he knew what to look for. We still know little about the lives of my Mesolithic ancestors who lived at Star Carr.

I have barely mentioned Godwin's work on the pollen at Star Carr and the work on the undersea peat where the earlier spearhead was found and I will not give any details. It was standard work; first the pollen of certain trees *Betula* and *Pinus* is considered, *Betula* being by far the commoner. We know that all over Britain in the late Glacial this was true. But then *Pinus* became the commoner. And after considering these trees, made to add to 100%, other kinds of pollen are considered in relation to them; the shrub *Corylus* and this briefly becomes enormously abundant just at the time of switch from *Betula* to *Pinus*. And then the herbaceous plants, mainly grasses and Cyperaceae are taken and they are more abundant than the trees at Star Carr but later on when *Pinus* established itself as forest they become few. Later still warmth loving trees *Ulmus*, *Quercus* and *Tilia* replace *Pinus* and *Betula* but not at Star Carr; that belongs to a brief phase of the late Glacial. It is a phase dated by radiocarbon to just under 10,000 years ago.

I now take a research in the early Tertiary, a thing I would not have done twenty years ago when the Tertiary gave me bad feelings; I was unconvinced but knew I had no right to judge. But I did recognize that the fossils were worthy of study and should illuminate flowering plant taxonomy. So I remained silent, but things have changed.

Tertiary plant fossils are mostly bits of dicot trees, the separate leaves, fruits or seeds, pollen grains and pieces of petrified wood and each organ is determined by comparison with organs of modern plants. But not exactly as in the Quaternary because we are becoming sure that most of the plants have changed a good deal, at least since the early Tertiary so the comparison is a general and vague one with several living species or genera and when you decide that agreement of a leaf with *Ficus* say, is impressive you cannot be sure the fossil is of this genus. I think about every known genus of Eocene mammals has vanished and most without modern descendants. Plants may be more stable and secure; but perhaps the fossil mammals are merely better understood.

The new Tertiary work I enjoy starts like the old style work that I do not. It takes the organ, say a leaf, and compares its shape and veins with various living leaves. The old style work stops there but the new goes on. It uses a second kind of evidence unrelated to leaf shape; the pattern of epidermal cells. In a family or in a genus we can recognize a basic leaf shape and veins but there are also widely divergent species. So it is with the epidermis. Then a peculiar seed may be noted in association with the leaf. Association means that the leaves and seeds were produced near one another at the same time but when they are found together repeatedly in different localities of rather different age, it is impressive and when there is no rival organ in those localities, I am deeply impressed and would say so.

The paper I select out of many is by the Americans Crepet and Daghluin who early this year described what they called ' Euphorbioid inflorescences from the Middle Eocene Clairborne Formation '. Note their restrained wording, it continues through their paper. When men of science feel they have a strong case they often write modestly. The inflorescences are branchlets bearing tiny male flowers they name *Hippomanoidea* and compare with various members of the Hippomaneae a tribe of Euphorbiaceous trees of tropical America: I had never heard of them. In particular they compare with *Gymnanthes*. They give pictures of *Gymnanthes* inflorescences and their fossil, they plainly look similar but are the tiny and very simple flowers really similar? The fossil is imperfectly seen. But the fossil gave excellent pollen grains and these are compared with various Hippomaneae, some are strikingly similar, some not and this is usual. Pollen grains evolved like every other plant organ. If I had been sent two separate papers to referee; one on the inflorescence and one on separate pollen I would have been unimpressed by either, always remembering that I am ill informed about pollen and about tropical American plants. But when I take the two together and the authors' statement that there is nothing else in the world which shows this combination of characters I am deeply impressed. I recognize that we do not have certainty. Palaeobotany is not for those who require certainty, but there is good probability on which I could build. The authors do build a little; they point out that it is odd that the Hippomaneae, regarded as an advanced tribe should occur so early.

It must be sixty years since I considered whether I would give my life to Tertiary plants and decided — no. I would have poor respect for my own determinations. But I could work happily with determination based on two different kinds of evidence. You may well say, the second kind of evidence commonly is not there; what then? I would do something else.

I next give you Krassilov's paper of 1975 on *Dirhopalostachys*, a cone from the Upper Jurassic and Lower Cretaceous of eastern Siberia. I say at once, he was not responsible for this long word and I also say that such words are one reason why lay men dislike science.

In the Mesozoic most of the pteridophytes fit into living families but most of the gymnosperms do not, or not easily, so their study is one of bringing a strange plant to light, first as separate organs and then assembling them. Krassilov attributes the leaf *Nilssonia schmidtii* to the same plant and he has a strong case; repeated association, some agreement in structure and no rival associate.

The cone is about 12 cm long and 2 cm wide. It has a slender axis bearing short horizontal stalks in a loose spiral and these fork into two capsules. The capsules are closed and each ends in a pointed beak, eventually they split open along one side and expose and then drop a single seed; careful dissection sometimes demonstrates the seed in a closed capsule. The substance of the fossil is fragile and its cuticles are delicate and Krassilov had great trouble in making out its structure though he had plenty of specimens.

A *Dirhopalostachys* cone looks like some sort of Angiosperm fructification, Krassilov compares it in particular with the Upper Cretaceous *Trochodendrocarpus* but we do not yet know anything about pollination. Surely the beak played a part, either as a stigma or opening sufficiently to admit pollen grains. The only grains found were on the capsule surface. Krassilov sees it as one of several Jurassic and Lower Cretaceous gymnosperms which were advancing on a broad front towards angiosperms, two others are *Caytonia* and *Czekanowskia* and he calls the whole varied assemblage 'Proangiosperms' in the way Devonian plants of partly gymnosperm character are called Progymnosperms. He favours the idea that angiosperms had several gymnosperm starting points. I will not follow this idea but a comparison he makes with the Jurassic cone *Beania*, also linked with *Nilssonia* leaves. *Beania* is a more robust and easily studied fossil. It is similar, but instead of the lateral branches bearing two capsules, they form a broad somewhat lobed scale with two naked ovules on the upper side. To Krassilov this is the primitive condition of *Dirhopalostachys*; the halves of a *Beania* scale have wrapped themselves round the ovules; an idea I can accept. We have more or less good knowledge of several kinds of *Beania*, always in association with a *Nilssonia* leaf, the first known and perhaps the oldest from the Rhaetic of Sweden was provided by Nathorst in 1909 though not under that name. There was one in the Greenland Lower Liassic, there are three in Yorkshire, all rather similar and I only described the two better known by name. I found them rather discouraging, they did not apparently help with the apalling problem of taxonomy of *Nilssonia* though the two better known are to be counted as among the more completely known of Jurassic gymnosperms having also their male cones and scale leaves. There are no stems but Kimura in Japan found *Nilssonia* leaves attached to a slender stem. I imagine that this stem had been torn off by violence before the time for leaf abscission.

Nilssonia is one of the most tiresome genera of N. Hemisphere Mesozoic leaves but not as far as I know in Gondwanaland; India is lucky in this. Specimens are uncommonly hard to group in species. There is great variation in each species, and a huge number of species are distinguished by differences less than between the right and left sides of a single leaf. But I do not say the apalling pile of binomials is nonsense; some of them do correspond to something real. When as often happens you get hundreds of leaves in a bed varying around a central type you feel sure they represent one taxon and this is reinforced when you can prepare the cuticles: they also range around a mean. But most *Nilssonia* leaves have delicate cuticles and they are often ill-preserved. Occasionally the cuticle gives a clear answer. Krassilov's *Nilssonia schmidtii* looks like *Nilssonia kendalliae* from Yorkshire but their cuticles do distinguish them; it seems the plants were very different, one had *Dirhopalostachys*, the other is associated with an unnamed *Beania*.

So we have a pile of *Nilssonia* names almost without stratigraphic value because similar looking leaves occur widely and over a long range. My own work in Greenland and Yorkshire has contributed about twenty species that have been of no use to anyone so far and people add more every year. Even more than with *Beania* I felt discouraged, I felt I was dealing with endless local variants of a nearly uniform plant. But Krassilov has changed this: he has demonstrated variety in the plants producing *Nilssonia* that is at least of generic value (he gives it family value) and if these are fruits of two genera why not more? If I were young I might go back to Yorkshire or Greenland and work hard in a bed rich in a *Nilssonia* and search for other organs. And in my experience with *Beania* they should turn up, occasionally, perhaps once for every thousand leaves. I would work in a bed where there were leaves in thousands. Quite apart from anything about Proangiosperms, Krassilov has made the Botany of the *Nilssonia* plants worth pursuing; he has roused courage.

My last exercise deals with plants of the morning of life on land, or if as some hold plants lived on land far earlier, they are too little known to speak about. Those I shall take are Lower Devonian. Certain Devonian plants are aristocrats among fossil plants, excellently preserved, excellently studied and described and their descriptions are written up again in reviews and textbooks. But far more are miserable specimens of what seem very simple organisms and more than with most fossils what interest they have come from the writer's mind.

I deal with some problematic gametophytes. Many feel that the simpler Devonian plants should have similar looking generations and *Rhynia gwynne-vaughani* was thought likely as the gametophyte of *R. major*, an undoubted sporophyte. *R. gwynne-vaughani* lacked sporangia but there are many little pits on the aerial axes. They were first considered to be wounds, but some in section do look like certain pteridophyte antheridia and archegonia, dead ones surrounded by brown cells. Three authors independently offered them as antheridia and archegonia but their different interpretations of the whole plant were confusing and the recent find of sporangia by Edwards seems to end the matter. But almost at once and in the last two years there were two attempts; by Schweitzer of Bonn and by W. & R. Remy of Münster and they deal with the little Rhine-land fossil *Sciadophyton*, known since 1930. *Sciadophyton* is gregarious and forms rosettes of radiating branches. Hepatics growing on mud often look like this but those who have studied *Sciadophyton* conclude that the branches were round in section and the plant was attached by a central disc from which the branches grew upwards and outwards. A peculiar feature is that some branches end in a sort of flat umbrella, rather like the antheridiophore of *Marchantia* and the umbrella certainly shows small black spots which could be antheridia but are they? Schweitzer and the Remy's think they may be, but for different reasons.

The Remy's rely on a plant they found in the Rhynie chert called *Lyonophyton*. I will refer to it soon. Schweitzer considers he has later stages in the umbrellas. He considers that the small marginal spots are antheridia, the larger inner ones archegonia and that after fertilization the umbrella flops onto the mud and several sporophyte axes grow out, looking like young *Sciadophyton* branches, from the central disc. When rather larger they are the fossil called *Drepanophycus langi* and when much larger and tall they become *Zosterophyllum rhenianum* and bear sporangia. Schweitzer who is bold and cheerful reckons that he can see the early sporophyte stages among the figures that the Remy's offer as gametophytes. He offers a life cycle diagram.

The Remys' *Lyonophyton* is like the umbrella heads of *Sciadophyton* but excellently preserved by silica impregnation. It gave me much pleasure that the old Rhynie chert, first studied just before I became a student, should still be providing new things. The heads are on rather long stalks a mm thick and their margins are lobed and raised. Again there are black spots on the upper surface but this time there is more. The best do show the characteristic structure of antheridia containing spermatocytes, and even it seems nearly mature spermatozoids. Do not worry about the preservation of nuclei in this chert, other Rhynie plants show them, even chromosomes. An unusual feature is that the wall is two cells thick.

The archegonia are less satisfactory but are held to form a small radiating group in the centre but all I can say of the few sections showing one is that while it can well be a section of an archegonium, it is not the section cut in the best possible plane. There is no young sporophyte and the fossil though remarkable leaves us asking for more. But it does fit the idea that the *Sciadophyton* umbrellas may also be bisexual gametangiophores. All this in the last two years, is too recent to have been controverted.

If the young men of Palaeobotany are like what they used to be they will be dissatisfied and will seek for new evidence and destroy or, I rather hope, confirm the ideas of these three Germans. Either way there is progress.

I now face my opening question, 'what is palaeobotany for?' using these four exercises and must not shirk answering it.

All four are, in modern phrase 'on coming', they should cause further work and the oldest, Star Carr certainly has. The palaeobotany of Star Carr stands apart in that it was usefully applied to Archaeology. It is easy to see what applied science is for. When a spore man works for an oil firm, his employers think his results worth his wages. But the other three in pure palaeobotany only lead, as far as I can see, to more pure palaeobotany. I judge that each of the four was good: vigorous, to me inspiring and palaeobotany is doing well when such work appears but still I have misgivings about our future. I think of palaeobotany as a living plant species, I do not know what *that* is for but all plants act as though *they* know what they are for, their job is to live as well as they can, and to propagate their kind so to be replaced when they die. They do this in an environment partly physical and partly biological, mostly of other plant species in competition.

We know that nearly all species of one era have vanished by the next, and I imagine that the cause is in the changing environment and the danger I fear for palaeobotany is in its environment. I limit myself to Britain where our Universities are the sole environment for recruitment and the main one for research. Just now our Universities are in financial straits, they had over expanded and there is national stringency. Staff are leaving without replacement. A plant analogy is a miserable period of widespread cold, you cannot know when it will end, may be next year or as some hold it may be the start of the next glaciation. Palaeobotany found its optimum climate in Britain early this century. The discovery of pteridosperms was still exciting and a Botany lecturer felt that in palaeobotany he had a fair chance of reward from his research labour: what he taught was what his department needed, descriptive work on various living plants, fossils would be a small fraction.

Fossil material for research is still available and with the advances in technique perhaps more promising than formerly but I fear failing demand for lecturers in general and descriptive Botany. You will find very little palaeobotany in the respected old journals today and none of the kind of descriptive morphological Botany that there used to be. I suppose there is less exciting material from living plants in this largely explored world. I cannot think of the discovery of any new genus of living gymnosperm since *Metasequoia* but only new genera by dreary splits, former sections raised to generic rank. When departments can make new appointments it is likely to be men in fields fashionable today.

If a young lecturer who proposes to work on fossils is appointed it will be because he is already inspired and the committee can see possible interest. Both will come from recent papers of the right kind, ones read by those outside palaeobotany, inspiration is all.

I tell you my history which began when palaeobotany was declining in Britain. It was not Cambridge or Seward who inspired me; Seward gave me research opportunity and help. I had taken an external degree of London University at the small college at Nottingham and there Harry Holden, of whom you may not have heard, inspired me. Holden was trained at Manchester where Weiss and Marie Stopes were working; earlier there was the great W. C. Williamson their first professor. He had been inspired as a child by his father, a gardener with interest in natural history. The thread is thin.