STUDIES ON THE FOSSIL FLORA OF NIPANIA (RAJMAHAL SERIES), BIHAR — *CONIFERALES*

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ABSTRACT

Besides adding additional information about the morphology of the already known silicified remains from Nipania, viz. *Nipaniostrobus sahnii* Rao, *Masculostrobus rajmahalensis* Rao, *Nipanioruha granthia* Rao, new material described includes *Masculostrobus podocarpoides* sp. nov., *M.* sp., *Nipaniostrobus pagiophylloides* sp. nov., *N. aciculifolia* sp. nov., *Nipanioruha lanceolata* sp. nov. and *N. curvifolia* sp. nov.; *Mehtaia rajmahalensis* gen. et sp. nov., *M. nipaniensis* sp. nov., *M. santalensis* sp. nov.; *Sitholeya rajmahalensis* gen. et sp. nov.; *Indophyllum sahnii* gen. et sp. nov., *I. raoi* sp. nov., *I. nipanica* sp. nov.; *Elatocladus sahnii* sp. nov., *Brachyphyllum florini* sp. nov.; *Pagiophyllum araucaroides* sp. nov. Fossil history of Podocarpaceae is also discussed.

INTRODUCTION

A PRELIMINARY report of fossil conifers from Nipania was first made by Rao in 1935. In 1936 Rao reported winged pollen grains from Nipania which were later described under three new names, *Alisporites jurassicus* Rao, *A. auriculiformis* Rao and *Pityosporites nipanica*, and three-winged pollen grains under the name *Podosporites tripakshi* Rao (Rao, 1943b). Petrified conifer strobili, both male and female, were reported by Rao in 1938; the male were later described under the name *Masculostrobus rajmahalensis* Rao and the female as *Nipaniostrobus sahnii* Rao (Rao, 1943). A petrified conifer shoot under the name *Nipanioruha granthia* Rao was described by Rao in 1946. He also mentioned the probability that the male cones *M. rajmahalensis* and the female cone *Nipaniostrobus sahnii* belonged to the shoots of *Nipanioruha granthia*, although a little later he (Rao, 1949) reported a megastrobilus of *N. granthia* which was shown to be somewhat different from the seed-cones of *Nipaniostrobus sahnii*. The occurrence of the shoots of *Brachyphyllum* in the Nipania chert was reported by Rao in 1949. Further contribution to our knowledge of the winged pollen grains from Nipania was made by me (Vishnu-Mittre, 1953, 1954a). In 1956 I described under the name *Masculostrobus sahnii* Vishnu-Mittre petrified male cones from Nipania producing three-, one- and four-winged abnormal pollen grains (Vishnu-Mittre, 1956). Recently an araucarian cone-scale under the name *Araucarites nipaniensis* Singh has been described from Nipania (Singh, 1956).

Since the publication of the revisions of the Indian fossil conifers by Sahni in 1928 and 1931, contributions to the silicified conifer remains from the Rajmahal series in addition to those mentioned above have been made by Bhardwaj (1952, 1953), Bose (1952), Bose & Hsü (1953), Vishnu-Mittre (1954) and Sah (1956, unpublished) and from the other Jurassic localities in India by Suryanarayana (1953).

The present paper describes several new conifer remains from Nipania in addition to the already known ones towards the knowledge of which more information has been added. In the following pages are described two new species of *Masculostrobus*, *M. podocarpoides*. and *M.* sp.; two new species of *Nipaniostrobus*, *N. pagiophylloides* and *N. aciculifolia*; two new species of *Nipanioruha*, *N. lanceolata* and *N. curvifolia*; and a species of *Brachyphyllum*, *B. florini*.

The paper advances our knowledge of the seed-cones of *Nipaniostrobus sahnii* with respect to the form and size of the cone, the attachment, vascular supply and the exact nature of the cone-scales, and also the epidermal characters of the bract-scales. The fructifications of *Nipanioruha granthia* are also described. In the light of the new information now available emended diagnosis is given for the genus *Nipanioruha* and the species *N. granthia* Rao.

Besides the already known conifer remains, the new material is described under the following names:

1. *Mehtaia* gen. nov., a genus of *Pherosphaera*-like seed-cones comprising three new species, *M. rajmahalensis*, *M. nipaniensis* and *M. santalensis*.

2. *Sitholeya* gen. nov., a genus of *Podocarpus* or *Dacrydium*-like single-seeded fructifications, comprising a single species, *S. rajmahalensis* sp. nov.

3. *Indophyllum* gen. nov., a genus of *Brachyphyllum-Pagiophyllum*-like shoots possessing podocarpinean type of stomata, comprising three new species, *I. sahnii*, *I. raoi* and *I. nipanica*.

Two new species, one each of the genera *Pagiophyllum*, *P. araucaroides*, and *Elatocladus*, *E. sahnii*, are also described.

Material and methods are the same as reported earlier (VISHNU-MITTRE, 1956).

DESCRIPTION

Podocarpaceae

1. GENUS *Masculostrobus* SEWARD

The literature on the genus *Masculostrobus* Seward has recently been reviewed by Vishnu-Mittre (1956). Two species, *Masculostrobus rajmahalensis* Rao (RAO, 1943) and *M. sahnii* Vishnu-Mittre, are known from Nipania.

The cones and the cone-bearing shoots described under the names *M. podocarpoides* sp. nov. and *M.* sp. are fairly small in size. The cones are oblong or cylindrical in shape. The spirally arranged sporophylls are hypopeltate, hyposporangiate and bisporangiate. The pollen grains are two-winged.

(i) *Masculostrobus rajmahalensis* Rao

Amongst about a dozen cones, one (TEXT-FIGS. 1, 2) shows a peculiar swollen region towards its base. The swollen region consists of two large sac-like bodies in which some pollen grains are also seen. The tracheids are not noted in this region. The tissue of this swollen region compares very much with that of the intercalary swellings of *Nipanioruha granthia* Rao (RAO, 1946) and the swollen region of the cone-axis is, therefore, believed to be a similar swelling.

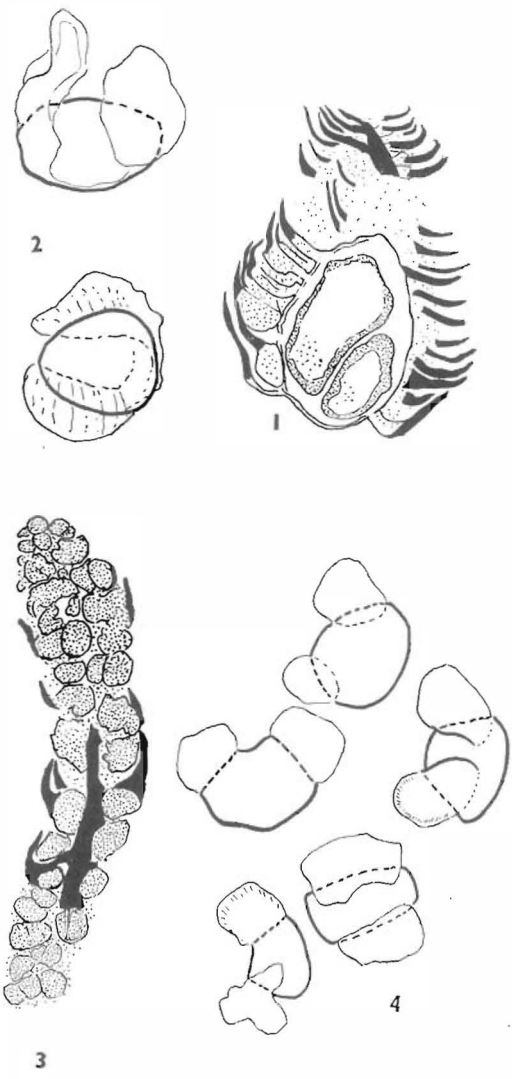
(ii) *M. podocarpoides* sp. nov.

Pl. 1, Figs. 1, 2; Text-figs. 3, 4

Diagnosis — The male cones, about 13 × 1·5 mm., are long and slender. The thick cone-axis bears short, triangular, densely and spirally arranged cone-scales. The free ends of the cone-scales, about 1 mm. long, are acuminate, acute, upturned and overlapping those above. The scales with even margins are hypopeltate and bisporangiate. The microsporangia, 550-750 × 400-500 μ, are broadly ovoid and thin-walled.

The pollen grains (TEXT-FIG. 4), 48-51 × 27-30 μ (including wings) and 18-21 × 27-30 μ without wings, are two-winged. Wings are large, bladdery with faintly reticulate meshes and are attached on the ventral surface of the body. A distinct furrow between the wings is noted. Body is oval.

Comparison — The cones differ from those of the other species of *Masculostrobus* in



TEXT-FIGS. 1-4 — 1, 2, *Masculostrobus rajmahalensis* Rao. 1, a male cone with a probably swollen axis. × 9. 2, two-winged pollen grains from above. × 500. 3, 4 — *Masculostrobus podocarpoides* sp. nov. 3, the type specimen. × 8. 4, pollen grains from above. × 470.

cylindrical form, slender nature and the large size.

Cylindrical male cones in the living conifers are produced by the Araucariaceae and Podocarpaceae. In their slender nature, short bisporangiate scales and the winged pollen grains the fossil cones resemble cones of the Podocarpaceae rather than those of the Araucariaceae.

Amongst the Podocarpaceae the male cones of the genus *Podocarpus* and certain species of *Dacrydium* are comparatively much longer than those of the other genera. In the bladdery wings on the pollen the fossil cones are comparable with the cones of *Podocarpus* than those of *Dacrydium*, the grains of which have flaccid wings. A cursory comparison of the specimen with some of the male cones of *Podocarpus* figured by Wilde (1944, pp. 14-16) further points to the podocarpinean affinities of the male cones.

(iii) *Masculostrobus* sp.

Pl. 1, Fig. 3

Fertile shoots, about 3 × 1·5 mm., with a partly preserved and crushed apical male cone, bearing short scale-like, closely overlapping leaves; margin of the leaf entire, apex acute. Leaves more or less triangular in cross-section, sharply keeled, upper surface concave with a central raised area abutting on the vascular bundle. Leaves traversed by a single vascular bundle overlying a resin cell and accompanied by a patch of transfusion tissue on either side.

Male cone, about 2 mm. long, sporophylls short, closely overlapping, with upturned apices. Microsporangia crushed, two per scale. Pollen grains, 54 × 36 μ, two-winged. Wings collapsed, faintly reticulate. Body spheroidal.

Description and Comparison — M. sp. is represented by two fragmentary shoots. In general morphology of the leaves the shoots approach those of *Indophyllum sahnii* described on p. 101 in this paper, but their epidermal characters are not known. The occurrence of two-winged pollen grains, short scale-like overlapping leaves and the transfusion tissue with a single resin cell in the specimens points to podocarpinean affinities.

2. Genus *Nipaniostrobus* (Rao) emend.

Under the genus *Nipaniostrobus* Rao (1943b) are included petrified megastrobili bearing single-seeded, spirally arranged scales, each with a slightly dorsiventral seed partly enclosed within the scale. The micropylar region of the ovule is strongly curved towards the cone-axis and the integument is two-layered but not fleshy.

The genotype *Nipaniostrobus sahnii* (Rao, 1943b) was based on an obliquely cut cross-section of a solitary fossil strobilus and a detached seed-scale. *N. sahnii* Rao was described as a lax strobilus (size and form unknown) with loosely arranged ovuliferous scales (attachment of scales unknown); ovules borne on the adaxial side of the scale, free except at the point of attachment, the posterior part of the ovule enclosed in the scale filling its entire thickness. The scale in *N. sahnii* was assumed to be double and an epimatium-like organ was believed to be present as in modern *Dacrydium*. The vascular supply in this species was unknown.

The present study of the genus *Nipaniostrobus* is based upon more than a dozen seed-cones and two cone-bearing shoots. Some of the seed-cones are lax, while several others are compact. Three layers in the integument are distinguished instead of the two as described by Rao (1943b).

The nature of the cone-scale is interpreted in accordance with Florin's (1951) recent conception of the conifer cone-scales. The seed-scale complex in *Nipaniostrobus* is very much reduced. The megasporophyll, bearing the ovule terminally, is extremely reduced with a rudimentary axis. The distal sterile part of the flower is seated immediately above the ovule and is folded back over it forming a special covering enclosing about one-third of the ovule. According to Florin (1951, pp. 364, 365) this sterile part of the flowers of Podocarpaceae is epimatium. According to Rao the sterile part of the ovule is the ovuliferous scale or the apical knob and the thin flap-like structure passing over the ovule to some distance is the epimatium (Rao, 1943b, p. 116). This thin flap is, in fact, the extension of the sterile part of the ovule and is not a distinct structure to deserve a different name.

Under the genus *Nipaniostrobus*, Rao also described certain seed-cones bearing single-seeded scales each with an erect ovule. The morphology of these seed-cones, as studied in the light of new and more material now discovered and described elsewhere in these studies, does not support their retention in the genus *Nipaniostrobus*. These seed-cones

are, therefore, segregated from the genus *Nipaniostrobus* and have now been described under a new genus *Mehtaia* (*see* pp. 88-95).

There is no other fossil on record with which these seed-cones may be compared. The comparisons of *Nipaniostrobus* with the living conifers were dealt with in detail by Rao (1943b, pp. 125-127). The seed-scale complex of *Nipaniostrobus* can be compared with that of *Dacrydium*, *Podocarpus spicatus* and *P. andinus*, though in *Dacrydium* well-defined megastrobili are not met with today. In *Dacrydium* the whole megastrobilus is reduced to a single-seeded scale.

Genus *Nipaniostrobus* (Rao) emend.

Emended Diagnosis — Shoots with short to linear, decurrent leaves slightly spreading or loosely overlapping. Each leaf single-veined with transfusion tracheids. Mesophyll loose and spongy. The epidermal cells rectangular to cubicular, straight-walled to slightly sinuous. Stomata vertical to oblique, regular or irregular, in short or long rows, orientated along the length of the leaf.

Megastrobilus loose or compact, conical, oblong or cylindrical, consisting of several spirally attached bracts each with an axillary seed-scale complex. Each seed-scale complex, single-seeded, very much reduced, seed borne on an extremely reduced megasporophyll. Seeds horizontal, inverted, dorsiventral. The sterile part of the flower seated immediately above the ovule and forming a covering enclosing about one-third of the ovule. Nucellus free to the base. Micropyle strongly curved and facing the cone-axis. Integument two- to three-layered. The epidermal cells on the cone-scale rectangular with undulating walls. Stomata vertical or oblique in longitudinal rows. The vascular supply to the cone-scale bifurcating at its base — the main supply reaching the apex of the seed-scale while the lateral branch further dichotomizing close to the point of attachment of ovule to the scale and supplying a branch each to the epimatium and ovule. The ovular supply forming a tracheidal pad at the base of the ovule.

(i) *Nipaniostrobus sahnii* (Rao) emend.

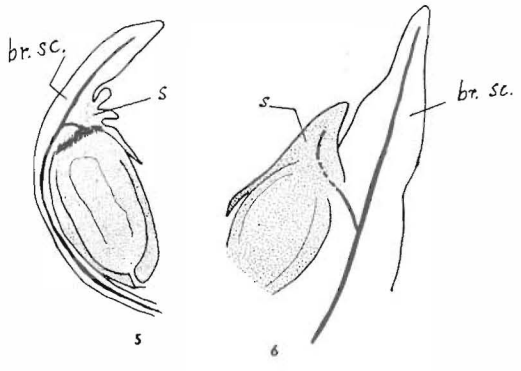
Pls. 1, 2, Figs. 4-14, Text-figs. 5-15

Size and Form — The megastrobili, 0·5-1·6 cm. long and 0·3-0·8 cm. broad, are conical, oblong (Pl. 1, Fig. 4) or cylindrical (Pl. 1, Fig. 6) in shape. The cones are fairly compact or lax (Pl. 1, Figs. 4-8).

The Peduncle — The peduncle of the cone is fairly thick, 4 × 2 mm., and bears the remains of decurrent leaf-bases. The tracheids in the peduncle possess scalariform thickening and the uniseriate, flattened bordered pits with an oval pore.

The Cone-axis — The cone-axis in cross-section shows a broad pith surrounded by a ring of vascular bundles, four to five in number, each accompanied by a resin cell (Pl. 2, Figs. 10, 11).

The Cone-scales — The bract-scales, 10-30 or more in number, and borne either at right angle to the cone-axis or obliquely forming an acute angle with the cone-axis which is generally seen in the apical region of the cone (Pl. 1, Figs. 4-8). Each scale extends horizontally to about half of its length and then bends upwards with its free end overlapping the scales above and terminates in an acute apex. The free distal part of the cone-scale nearly as broad as long measures 0·15 cm. in length and 0·1 cm. in breadth. The bract-scale is the broadest in the middle region where the proximal region of the ovule is lodged. Each seed-scale complex consists of a single ovule borne on a very much reduced megasporophyll occupying about half of its length and freely lying on the adaxial face of the horizontal part of the bract-scale and partially enclosed by it (Text-figs. 5, 6). The sterile part of the ovule is seated immediately above the ovule on its proximal side and is folded back over the ovule covering about one-third of the proximal region of the ovule. In some

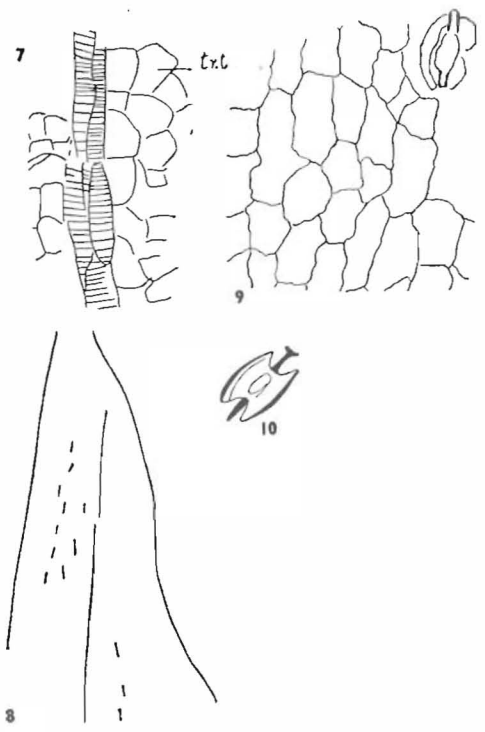


Text-figs. 5, 6 — *Nipaniostrobus sahnii* Rao emend. Two seed-scale complexes showing a bract-scale (*br. sc.*) and the sterile part (*s*). × 22.

ovules the sterile part is divided into several segments, but no vascular supply is noted in any of the segments (TEXT-FIG. 6).

A bract-scale is traversed by a single unbranched vascular bundle on either side of which two to four layers of the transfusion tracheids are present (TEXT-FIG. 7). The thick cuticle is followed by a single layer of epidermis which is lined by a single layer of broad, cubicular palisade-like cells. It is then followed by spongy tissue made up of shorter cells. The sterile part of the ovule is very much similar in its histology to that of the seed-scale.

Epidermal Cells and Stomata — The epidermal cells on the bract-scales are rarely preserved. Very often the epidermal cells, if at all preserved, are devoid of the cross-walls. Where preserved, the epidermal cells seem to be somewhat elongated, rectangular and with slightly undulating walls (TEXT-FIG. 9).



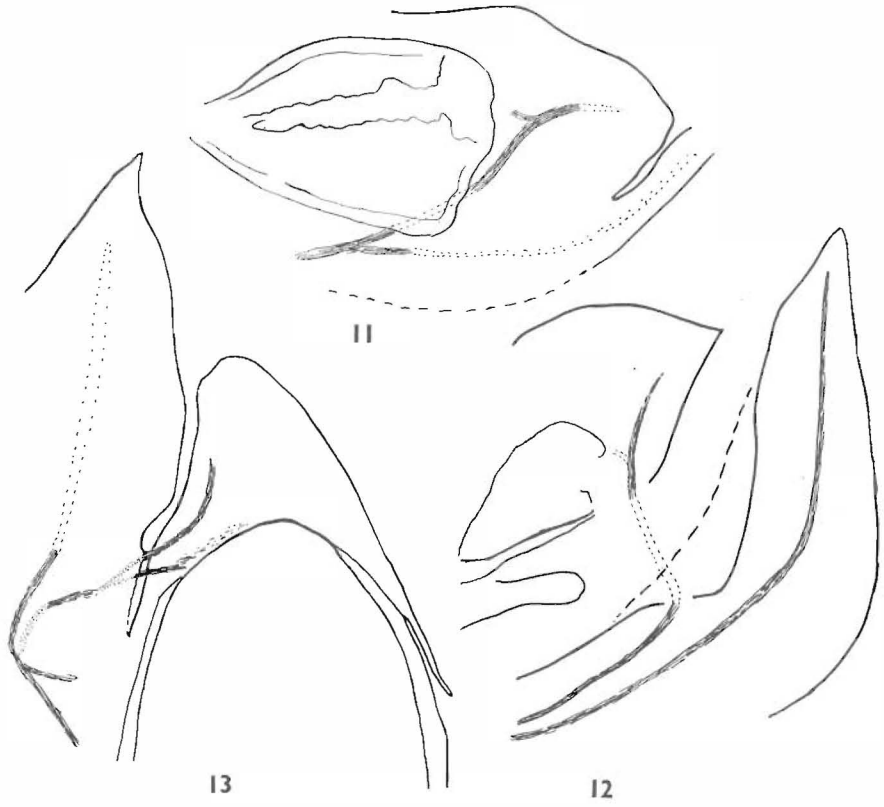
TEXT-FIGS. 7-10 — *Nipaniostrobus sahnii* Rao. 7, vertical section of a bract-scale showing tracheids surrounded by transfusion tissue. × 225. 8, showing the distribution and orientation of the stomata on the upper as well as the lower flank of a bract-scale. ×75. 9, a part of epidermis showing the epidermal cells and a stoma. × 225. 10, a stoma showing the polar and the lateral thickenings. × 375.

The stomata, the lateral thickenings and the suberized polar areas of which only are preserved, are vertically and or obliquely orientated parallel and along the length of the scales (PL. 1, FIG. 9; TEXT-FIG. 8). The transversely orientated stomata are not noted. The stomata are confined into short and long files, up to 3-4 of which are noted on the upper flank of the bract. Occasionally few stomata are also noted on the lower flank on the bract-scale. Each file is single-stoma thick. The subsidiary cells are not preserved. The stomata measure from 34 to 38 μ in breadth.

The stomata are not observed on the sterile part of the seed-scale complex.

The Ovule — The ovules, 1-1·5 × 0·50-1 mm., are horizontally placed except those in the apical region of the seed-cone where they seem to be inverted (PL. 1, FIGS. 4, 8). The micropyle and its structure are the same as described by Rao (1943b, pp. 118-120). Two layers of the integument are as previously described by Rao (1943b, pp. 118-120). In surface view the cells of the outer layer are polygonal in shape and placed end to end in regular rows (PL. 2, FIG. 12). The cells of the inner layer are thick-walled, polygonal or flattened in cross-section (PL. 2, FIG. 14) and elongated in vertical section (PL. 2, FIG. 13). In several ovules the outer layer of the integument is surrounded by a well-defined single-celled epidermal layer which is surrounded by an undifferentiated layer (PL. 1, FIGS. 13, 14). It shows that the integument was three-layered with the outermost layer probably fleshy.

The Vascular Supply (TEXT-FIGS. 11-15) — The seed-scale complex receives a single vascular supply which terminates at a little distance below the apex of the seed-scale. A little distance below the point of attachment of the ovule to the scale it bifurcates. The main vascular supply terminates near the apex of the seed-scale. The lateral branch enters the sterile part of the ovule where it bifurcates either soon after entering the sterile part of the ovule or after it has traversed a little distance. The lateral branch that it gives off stops short at the base of the ovule where the tracheids spread out and form a sort of a tracheidal pad (TEXT-FIGS. 14, 15). The other branch terminates in the middle of the sterile part of the ovule. The vascular supply is not noted in the integument.



TEXT-FIGS. 11-13 — *Nipaniostrobus sahnii* Rao. Showing the vascular supply to the seed-scale complexes. × *Ca.* 35.

The tracheids in the scale, sterile part of the flower or at the base of the ovule, possess scalariform pitting only.

Emended Diagnosis — Shoot or foliage unknown. Seed-cone, 0·5-1·6 × 0·3-0·8 cm., conical, oblong or cylindrical, loose or compact with the free parts of the cone-scales, 1-2 × 0·5-1 mm., overlapping each other. Ovules 1-1·5 × 0·5-1 mm. Stomata 34-38 × 18-22 μ, on the upper flank of the cone-scale, disposed in three-four short and long files, orientated vertical to oblique. Epidermal cells rectangular, longer than broad, wall slightly sinuous. Subsidiary cells not preserved.

(ii) *Nipaniostrobus pagiophylloides* sp. nov.

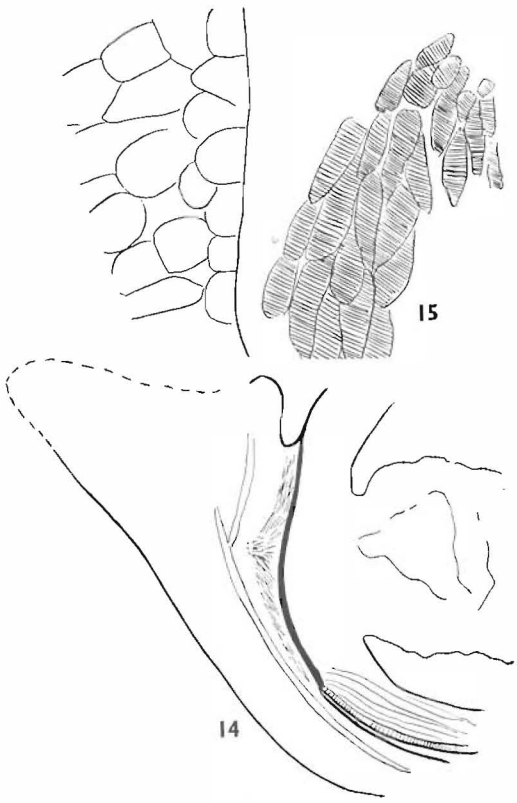
Pl. 3, Figs. 15, 16; Text-figs. 16-18

Diagnosis — Shoots bearing spirally arranged, short, spreading and loosely overlapping, decurrent leaves. Leaves linear, radial with pointed apex, 2 × 1 mm., traversed by a single unbranched vascular bundle on either side of which transfusion tracheids present. The epidermal cells are short, cubicular, with slightly wavy walls. The stomata present on the upper surface, 32 × 16 μ, vertical to oblique, arranged in rows, each single stoma wide. Subsidiary cells not preserved.

The seed-cone bearing spirally and loosely arranged cone-scales. Seeds 1 × 1·5 mm. Epidermal cells of the cone-scales preserved.

Description — The shoot (PL. 3, FIG. 15; TEXT-FIG. 16), about 3 cm. long, bears spirally attached, loosely overlapping, decurrent leaves with comparatively narrow bases. The lamina arises a little distance above the point of attachment. No cross-section of the leaf was available to ascertain the presence or absence of a resin cell along with the vascular bundle.

The mesophyll is loose with spongy tissue consisting of round cells. Palisade is made up of elongated cells.



TEXT-FIGS. 14, 15— *Nipaniostrobus sahnii* Rao. 14, a part of the seed-scale complex showing the spreading of the tracheids at the base of a seed. × 60. 15, tracheids from above. × 225.

Comparison — The specimen is referred to a new species distinct from *N. sahnii* (Rao) emend. for the reasons given below:

1. More or less similar *Nipaniostrobus* seed-cones are found to be borne on different types of shoots.

2. The seed-cone in the specimen is partly preserved and the finer details of its morphology are wanting. The isolated seed-cones are, therefore, described under the species *N. sahnii* and the *in situ* seed-cones under different names depending upon the nature and the morphology of their shoots.

(iii) *Nipaniostrobus aciculifolia* sp. nov.

Pl. 3 , Figs. 17-21; Text-figs. 19-21

Diagnosis — Shoots with leaves spirally arranged, decurrent, needle-like radial, decurrent, up to 4 mm. long and 1 mm. thick. Leaves 3-4 × 1 mm., slightly spreading or overlapping those above, uninerved, with a patch of transfusion tracheids on either side and a resin cell below the bundle. The epidermal cells cubicular, slightly longer than broad, with slightly wavy walls. Stomata 35·2 × 27·2 μ, vertical to oblique, in rows. Subsidiary cells rarely preserved. Seed-cone 5 × 4 mm., compact.

Description — The longest shoot (PL. 3, FIGS. 17, 18) is about 1·5 cm. long. The single unbranched midrib in each leaf terminates a little below the pointed apex. As in the other species, the thick cuticle in the leaf is followed by palisade-like tissue which is followed by loose spongy tissue consisting of small spherical cells which are elongated in a vertical section. The leaves appear to be epistomatic.

The Female Cone — The female cone (PL. 3, FIGS. 17, 19) is borne on a small lateral branch which bears short, overlapping leaves. The seed-cone cut obliquely measures 5 × 4 mm. in size. Some scales at the top seem to be sterile. The seed-cone is more or less compact and its ovules, about 1 mm. across, possess sterile part and curved micropyles. The integument in cross-section consists of an outer layer of shorter cells, a middle layer of palisade-like tissue and the inner layer made up of several layers of polygonal cells.

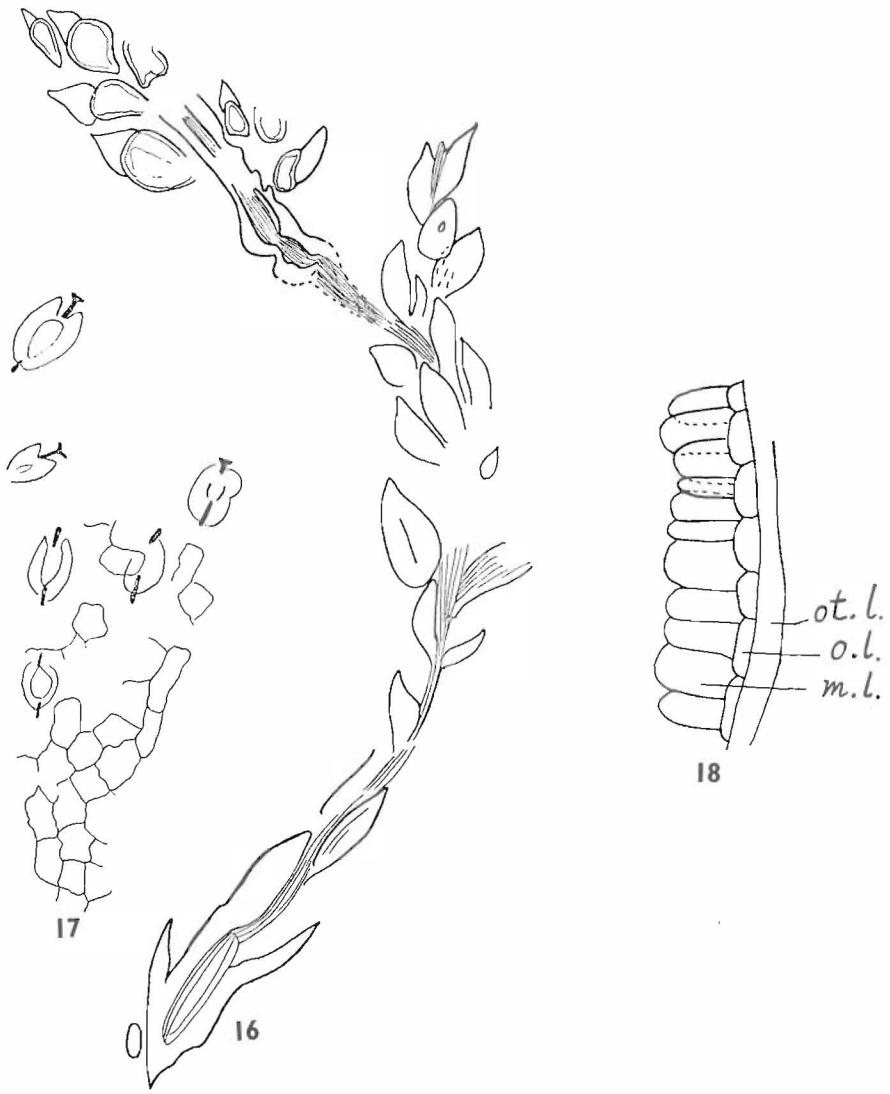
The epidermis on the cone-scales is not preserved except a few vertically orientated stomata, the thickenings of the guard cells of which only are preserved.

Comparison — In the distribution and the orientation of the stomata resemblance is noted with those of *N. pagiophylloides*, but from it the specimen differs widely in the nature of its foliage. The seed-cone is very small in size as compared to that of *N. pagiophylloides*.

3. *Mehtaia* gen. nov.

Diagnosis — Shoots bearing overlapping or spreading scale-like leaves. Megastrobili lax or compact, cone-scales spirally attached. Each cone-scale consisting of a bract-scale bearing extremely reduced, single-seeded seed-scale complex. Seed erect, borne on an extremely reduced megasporophyll; the sterile part of the flower absent. Micropylar tube facing outwards and upwards and strongly curved towards the cone-axis. Integument single and two-layered.

The genus is named after Dr. K. R. Mehta.

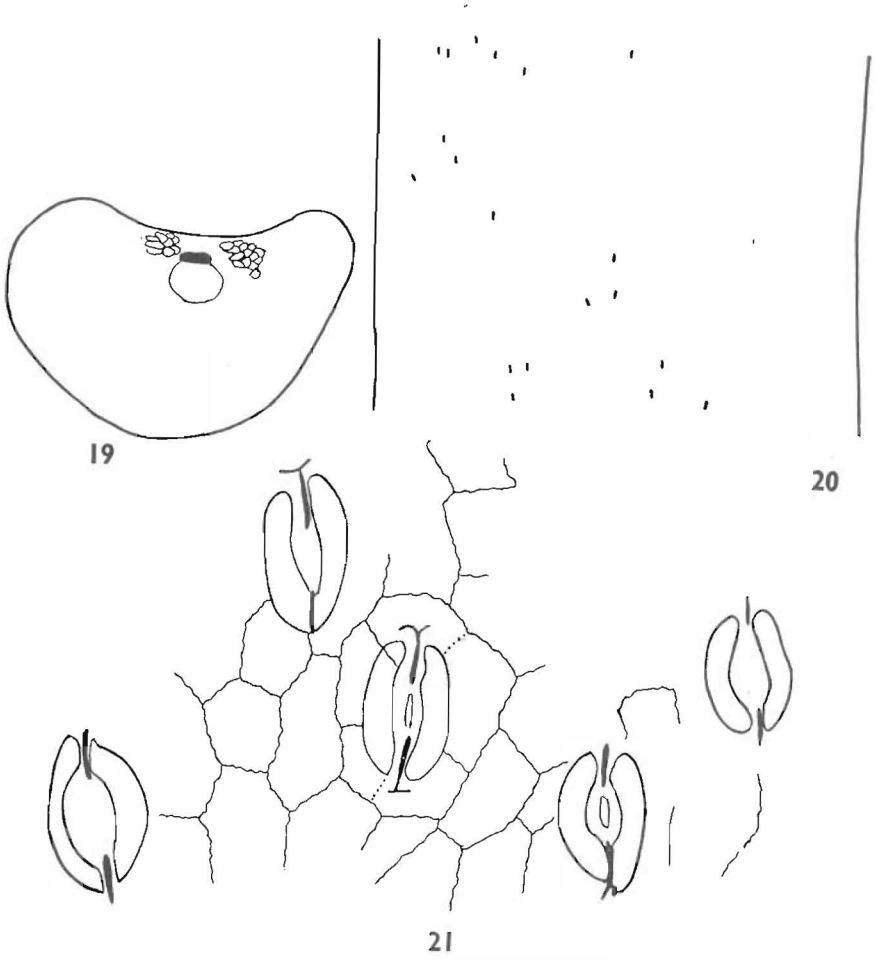


TEXT-FIGS. 16-18 — *Nipaniostrobus pagiophylloides* sp. nov. 16, the type specimen. × *Ca.* 3. 17, a part of epidermis showing epidermal cells, distribution and orientation of the stomata. × *Ca.* 250. 18, a section of a part of the integument showing the outermost undifferentiated layer (*ot. l.*), the outer layer (*o.l.*) and the middle layer (*m.l.*). × *Ca.* 200.

The characteristic features of the genus *Mehtaia* constitute the erect posture of the ovules and the absence of the sterile part of the flower and in these the seed-cones of the genus *Mehtaia* differs from those of the genus *Nipaniostrobus*.

Rao (1943b, pp. 121, 122, FIGS. 19, 20) figured and described two ill-preserved lax and slender cones identical with one of the specimens of *Mehtaia* (PL. 4, FIG. 24), and included them in *N. sahnii*, but at the same time expressed doubt if these cones belonged to *N. sahnii* or not. He found a strong contrast between these cones and the others included in *N. sahnii* particularly in the erect posture of the ovule (RAO, 1943b, p. 122), but Rao (1943b, p. 123) believes that these cones might represent a young stage of the cones of *N. sahnii*.

Discussing the affinities of the cones with erect ovules Rao (1943b, p. 125) stated that comparison could be made with *Pherosphaera*

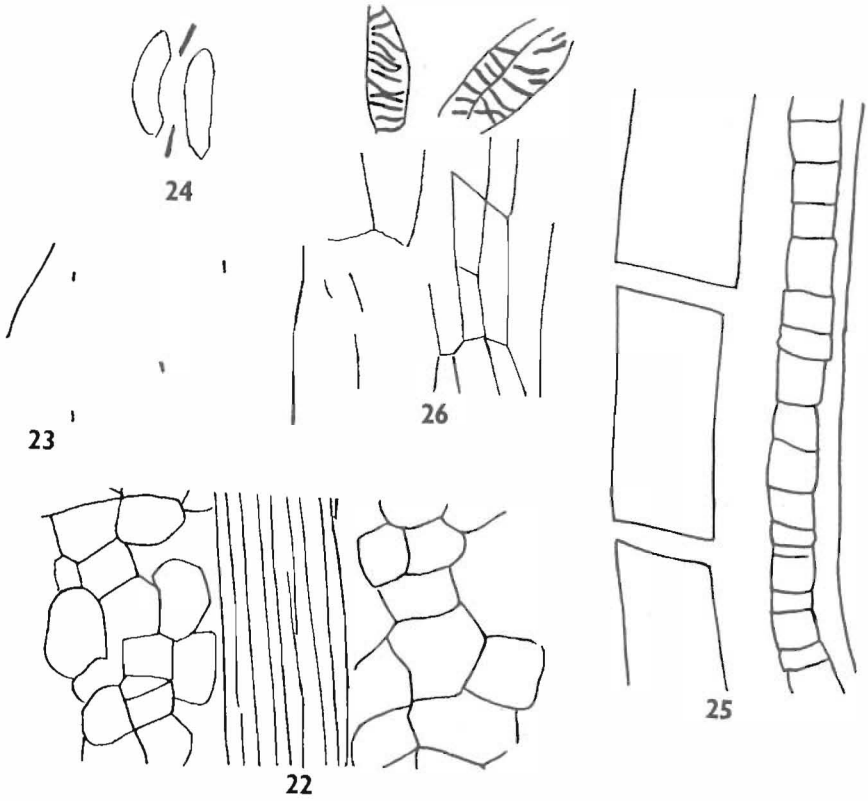


TEXT-FIGS. 19-21 — *Nipaniostrobus aciculifolia* sp. nov. 19, a leaf in cross-section showing the resin cell and transfusion tissue. × *Ca.* 66. 20, showing distribution and orientation of stomata on a part of a leaf. × *Ca.* 106. 21, epidermal cells and few stomata from above. × *Ca.* 533.

in the erect posture of the ovules, single ovule per scale and the mode of attachment of the ovule to the scale. But the possibility that these cones might turn out to be only the younger stages of *N. sahnii* was not overlooked by Rao.

I have not had access to Rao's slides and so I cannot say whether the cones figured by him (RAO, 1943b, PHOTO 19) really represents a younger stage. In size (as determined from the photo and the magnification given by Rao) the cones are slightly bigger than those in my material. And my cones are equally mature as those of *Nipaniostrobus*. My observations do not support Rao's suggestion that these might be the younger cones of *Nipaniostrobus sahnii*.

Amongst the living conifers the distinguishing characters of the genus *Mehtaia* are met with in the genus *Pherosphaera* in the family Podocarpaceae. Some characters, however, are shared with the genera *Phyllocladus* and *Microcachrys* in the same family, but in the absence of aril of phyllocladean ovules and in the absence of any evidence of the occurrence of the postfertilization curvature of the ovules as in the microcachyrean ovules, the genus *Mehtaia* differs from both *Phyllocladus* and *Microcachrys*.



TEXT-FIGS. 22-26 — *Mehtaia rajmahalensis* sp. nov. 22, a part of a vertical section of a leaf showing transfusion tracheids accompanying a vascular bundle. × 300. 23, distribution of stomata on a leaf borne on peduncle. × 70. 24, a stoma with polar and lateral thickenings. × 500. 25, vertical section of a part of integument showing the outer layer of large rectangular cells and the stony layer. × 100. 26, tracheids at the base of an ovule. × 500.

(i) *Mehtaia rajmahalensis* sp. nov.

Pls. 4, 5, Figs. 22-30; Text-figs. 22-28

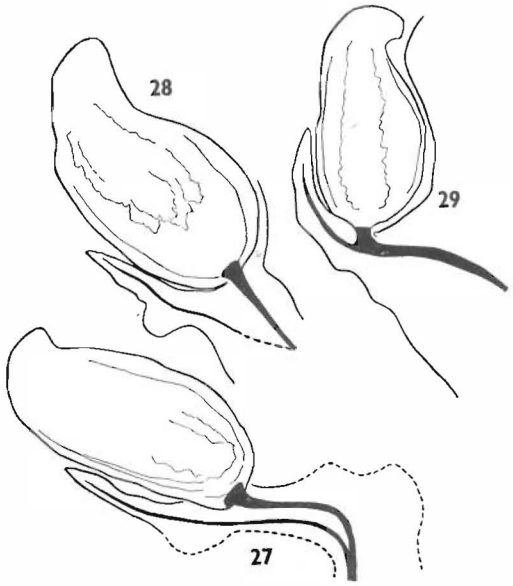
The species is based upon four specimens of seed-cones. In one specimen (PL. 4, FIG. 22) the megastrobilus lies in a very close proximity with a fragmentary shoot towards its apical region. The cone-axis also bears 2-3 leaves which are similar in anatomy and general morphology to the leaves of the shoot. Both the cone and the shoot lie in such a close proximity as if the cone was borne on a lateral branch by the shoot. It is further supported by the presence at the base of the cone of some leaves similar to the leaves of the shoots.

The leaves at the base of the cone (PL. 4, FIG. 25) are short, 1·2 × 0·75 mm., thick, scale-like, overlapping each other. The leaves are traversed by a single vascular bundle which on either side is lined by 3-5 layers of the transfusion tissue (PL. 4, FIG. 26; TEXT-FIG. 22). Mesophyll is loose.

On the upper surface of one of the leaves borne on the peduncle four stomata are noted (TEXT-FIGS. 23, 24). The stomata are oval in shape and orientated more or less parallel to the length of the leaf. No subsidiary cells or the encircling cells are preserved. Of the stomata only thickenings of the guard cells and those of the polar areas are preserved.

The shoot (PL. 4, FIG. 22) consists of two to three fragments lying near the apex of the cone which are evidently the lateral branches of what appears to be a pinnately branched shoot. The longest fragment of the shoot measures 2-3 cm. in length.

Seed-cone — The megastrobili (PL. 4, FIGS. 23, 24) are loose and oval in shape.



TEXT-FIGS. 27-29 — 27, 28, *Mehtaia rajmahalensis* sp. nov. Two seed-scale complexes with the vascular supply. × *Ca.* 28. 29, *M. nipaniensis* sp. nov. A seed-scale complex with vascular supply. × *Ca.* 28.

The cone-axis, about 1·5 mm. thick, has a fairly broad pith which in longitudinal section is made up of squarish to rectangular parenchymatous cells (PL. 5, FIG. 29). On either side of the pith are found xylem tracheids which bear scalariform pitting. Uniseriate bordered pits are also seen.

The cone-scales are spirally and loosely attached and seem to have been fleshy. Each bract-scale, soon after arising from the cone-axis, gradually tends to bend upwards. The free portion of the scale is short and rises to about half the length of the seed. The scale is single and keeled below (PL. 4, FIG. 23).

The Vascular Supply of the Cone-scale — A vascular strand arises from the vascular bundle of the cone-axis and bifurcates at a little distance after its emergence from the cone-axis (PL. 5, FIG. 29; TEXT-FIG. 28). One branch enters the bract-scale while the other terminates at the base of the seed in a cushion-like parenchymatous tissue. Taxinean pitting is noted in the tracheids at the base of the ovule (TEXT-FIG. 26).

The seed-scale complex consists of a single erect ovule borne terminally on a very much reduced megasporophyll. From the base of the cone to the apex the seed-scale complexes show a gradual transition from the horizontal to the erect posture of the ovule (TEXT-FIGS. 27, 28). The ovules are narrowly oval with their bases slightly obliquely flattened.

The micropyles face outwards and/or upwards and two lips of the micropyles are turned inwards (PL. 4, FIG. 24). The outer lip of the micropyle is comparatively longer than the inner and completely goes round it. The micropyle in a cross-section (PL. 5, FIG. 30) shows a slit-like opening surrounded by large columnar cells showing that the integument in the region of micropyle was broad and consisted of the elongated cells.

The integument is made up of two distinct layers — an outer soft and inner stony layer. The outer layer is made up of 4-5-sided, elongated, thick-walled cells usually filled with some black deposit (PL. 5, FIGS. 28, 30). The cells of the outer layer are elongated along the length of the seed. The stony layer is made up of short, thick-walled, pentagonal cells arranged in rows parallel to the length of the seed (PL. 5, FIG. 27; TEXT-FIG. 25). The cells of the stony layer are more or less cubicular in nature.

The embryo is not preserved in any of the ovules. The nucellus is free from the integument except at the base.

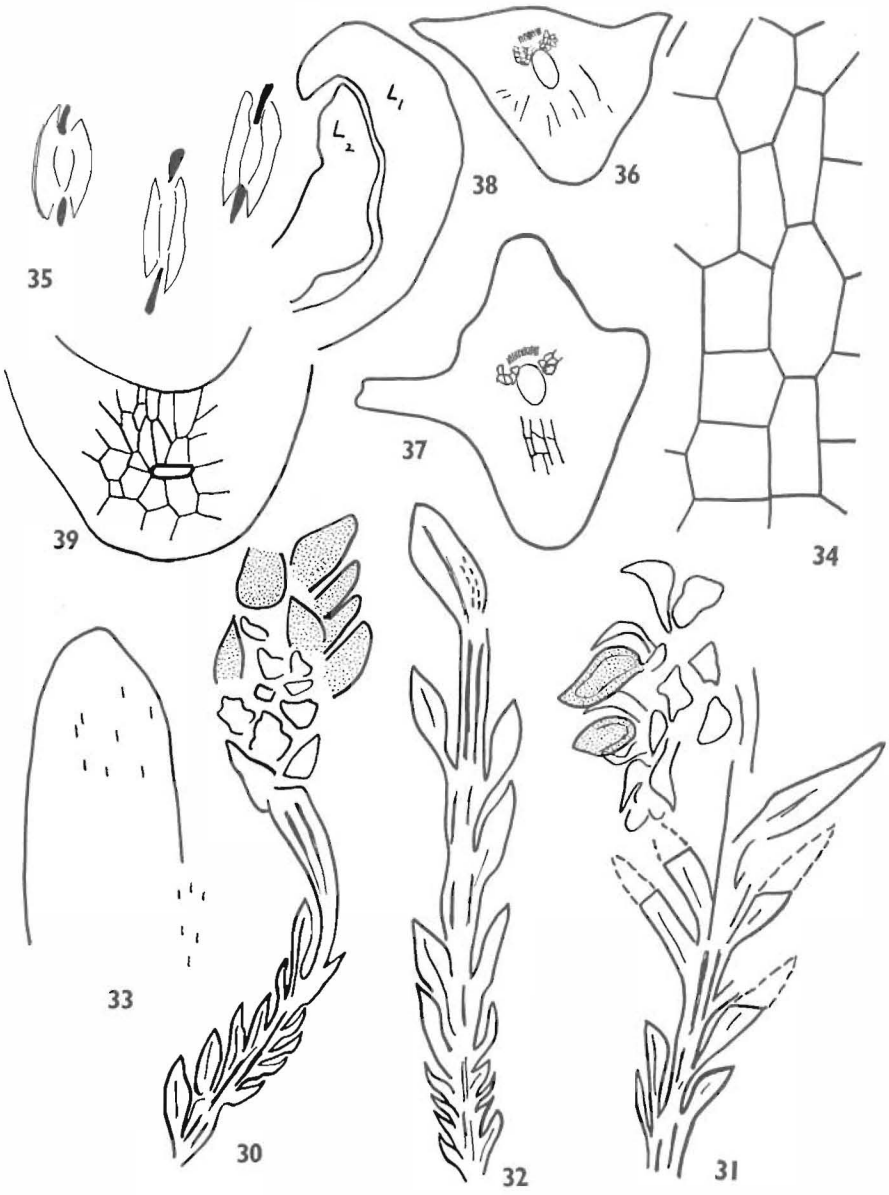
Diagnosis — Shoots pinnately branched. Leaves 1-2 × 0·5-0·75 mm., short, thick, tough, scale-like, overlapping, traversed by a single median vein accompanied by a patch of transfusion tracheids on either side. Stomata orientated parallel to the length of the leaf.

Seed-cone 10 × 5 mm., compact, oblong. Ovule 1-1·5 mm., obliquely vertical to erect. Scales keeled on the abaxial surface. Vascular supply bifurcating soon after emerging out of the cone-axis — one branch supplying the bract-scale while the other terminating at the base of the ovule.

Comparison — The seed-cones described above are unique amongst the fossil seed-cones so far known.

The erect posture of the ovule, its median position on the scale, the absence of any sterile part of the flower and the curved micropyles are some of the outstanding characters in the specimens which recall similar features in the family Podocarpaceae.

The habit of cone-formation in this family is restricted to the genera *Pherosphaera*, *Microcachrys*, *Saxegothaea* and *Phyllocladus*.



TEXT-FIGS. 30-39 — *Mehtaia santalensis* sp. nov. 30, 31, fertile shoots. × *Ca.* 5. 32, a sterile shoot showing distribution and orientation of stomata in the uppermost leaf. × *Ca.* 5. 33, distribution and orientation of stomata on a leaf from shoot in Text-fig. 32. × *Ca.* 35. 34, epidermal cells on a leaf from shoot in Text-fig. 33. × *Ca.* 375. 35, a few stomata showing the polar and lateral thickenings. × *Ca.* 375. 36, cross-section of a leaf from the shoot in Text-fig. 33. × *Ca.* 35. 37, cross-section of a bract-scale from shoot in Text-fig. 33. × *Ca.* 35. 38, vertical section of an ovule from shoot in Text-fig. 32 showing the micropylar canal. × *Ca*, 225. 39, cross-section of the micropylar region of an ovule from shoot in Text-fig. 32. × *Ca.* 60.

The female cones in these genera are compact. More or less spike-like loose cones are, however, known in *Dacrydium franklini* and *Podocarpus spicatus* and the other allied species of *Podocarpus* (FLORIN, 1951, p. 363). The sterile part of the flower is known to be absent only in the genera *Pherosphaera* and *Phyllocladus* (LAWSON, 1923, p. 514; FLORIN,

1951, p. 364). The epimatium is absent in the fossil specimens described above. The aril-like outgrowth as seen in the cones of *Phyllocladus* is also not seen in our specimens.

The erect posture of the ovule is a constant feature in *Pherosphaera* and *Phyllocladus*. In *Microcachrys* and *Saxegothaea*, however, the ovules are erect when young but gradually become recurved as the growth proceeds further. After recurvation, the sterile part of the flower also appears.

The leaves in these fossils being closely overlapping, scale-like, uninerved and with two patches of transfusion tissue, keeled, thick and pointed at the apex differ from those of *Phyllocladus* and resemble those of *Pherosphaera*.

(ii) *Mehtaia nipaniensis* sp. nov.

Pl. 5, Figs. 31-35; Text-fig. 29

Diagnosis — Megastrobilus 8 × 4 mm., fleshy loose, cylindrical. Cone-axis fleshy with the decurrent bases of the cone-scale. Ovules narrowly oval, 1 × 0·25 mm., borne erect, parallel and close to the axis. Micropyle facing upwards and curved inwards.

A single vascular supply arising from the cone-axis bifurcates near the base of the ovule, one branch ending at the base of the ovule while the other entering the free part of the bract-scale.

The species is named after the locality.

Description — In one of the ovules is seen a spirally twisted structure, probably the remains of an embryo (Pl. 5, Fig. 33). In the upper region of the same ovule are noted a few pollen grains. This mass includes two- and three-winged pollen grains of variable sizes with bladdery as well as flaccid wings (Pl. 5, Figs. 34, 35). The wings are faintly reticulate.

Comparison — The specimen resembles *M. rajmahalensis* in the nature of the integument, curved micropyles, free nucellus and single-seeded scales each with an erect ovule. It differs from *M. rajmahalensis* in its fleshy nature, loosely arranged scales and in the nature of vascular supply to the seed-scale complex.

(iii) *Mehtaia santalensis* sp. nov.

Pl. 6, Figs. 36-43; Text-figs. 30-39

Diagnosis — Shoots dimorphic. Leaves linear, 1-3 × 0·5-1 mm., sessile, decurrent, bending outwards and slightly twisted; scale-leaves keeled, closely appressed. Leaves traversed by a single vein overlying a resin cell with two patches of transfusion tissue on either side.

Epidermal cells straight-walled, cubicular to rectangular. Stomata orientated vertically along the length of the leaf.

Seed-cones 5-6 × 5 mm., conical and compact.

Description — The species is based upon a fertile shoot (Pl. 6, Figs. 36, 37; Text-fig. 30), a seed-cone lying in very close proximity with a shoot (Pl. 6, Figs. 39, 43; Text-fig. 31) and some fragmentary sterile shoots (Pl. 6, Figs. 40-42; Text-fig. 32).

The free parts of the leaves in the upper region of the fertile shoot, about 1·5 cm. long, fit into the keeled region of the leaf next to it (Pl. 6, Fig. 38). In some shoots the leaves are shorter and scale-like near the apical region (Text-fig. 30) while in others the scale-like leaves occur at the base (Text-fig. 32). The seed-scales in the apical region of the cone appear to be fertile while those at the proximal region are without seeds. The elongated micropylar canal is bounded by two lips with the upper lip curved round the lower. In a cross-section the slit of the micropyle is seen bounded by elongated cells (Text-fig. 39).

Though the organic connection between the isolated seed-cone and the shoot (Pl. 6, Fig. 39; Text-fig. 31) is wanting, yet their very close proximity and continuation and orientation of the shoot towards the cone show that the cone belonged to this shoot and was borne apically. It probably got bent and consequently detached at the time of deposition. This is also supported by the identical anatomy of both the scales (Text-fig. 37) and the leaves (Text-fig. 36). The seed-cone in the specimen shows only two fertile scales.

Some of the sterile shoots, up to about 2·5 cm. long, also show the dimorphic nature of the foliage (Pl. 6, Figs. 41, 42).

The tracheids in the axis of these shoots bear uniseriate, flattened, contiguous, bordered pits and the scalariform pitting also. Xylem parenchyma is also present.

The vascular supply of the cone-scale is not preserved. The structure of the integument is the same as described in the previous species. The orientation and the distribution of the stomata on the leaves of the fertile as well as the sterile shoots are also similar (Text-figs. 32, 33).

Comparison — The compact seed-cones being very small, few-seeded and conical in shape differ from the seed-cones in the other species. The foliage differs from that of *M. rajmahalensis* in showing dimorphism.

4. *Sitholeya* gen. nov.

Diagnosis — Fertile shoot bearing a terminal single-seeded strobilus, seed inverted. Habit similar to that of a modern *Dacrydium* or *Podocarpus*.

The genus is named after Dr. R. V. Sitholey.

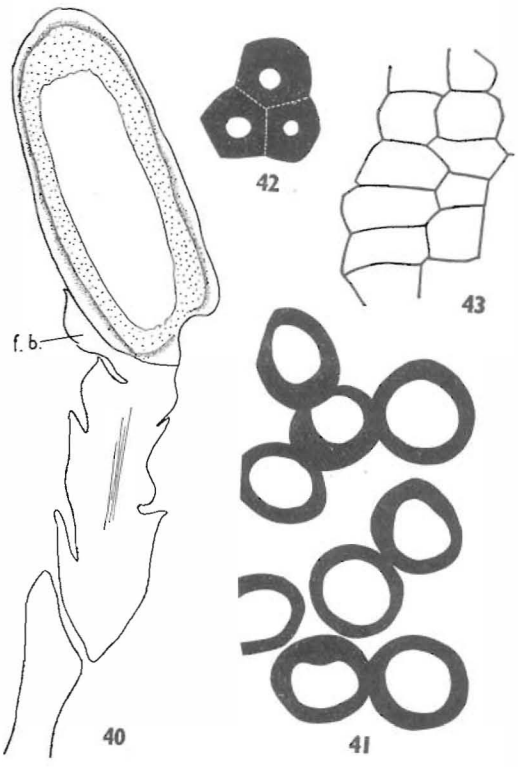
The specimen is referred to a non-committal name since from the available information regarding its morphology it is not possible to show whether the specimen is related to *Podocarpus* or *Dacrydium*. More or less similar fertile and sterile shoots as in our specimen known from the Tertiary and believed to belong to *Podocarpus* (GARDNER, 1836) were transferred to the genus *Podocarpites* Andrae (SEWARD 1919, pp. 405-408).

(i) *Sitholeya rajmahalensis* sp. nov.

Pl. 6, Figs. 44-46; Text-figs. 40-43

Description — The fertile shoot (PL. 6, FIGS. 44, 45; TEXT-FIG. 40), about 6·5 mm. long, bears at its apex a single inverted ovule. The ovule arises in the axil of a leaf (fertile branch, *f.b.*), borne on the vegetative shoot. The leaves (sterile bracts) on the shoot are short, decurrent, scale-like, keeled, closely appressed and overlapping one another. A very young shoot is also seen arising as a lateral branch in the axil of one of the leaves. The bases of these sterile bracts are slightly swollen. Each bract is traversed by a single unbranched vascular bundle and probably accompanied by few transfusion tracheids on either side.

The Ovule — The fairly large ovule (PL. 6, FIGS. 45, 46; TEXT-FIG. 40), 2 × 2 mm., is oval and inverted and seems to have been preserved in a very advanced stage of development. Of all the layers of the integument, it is only the stony layer which is preserved. Nothing of nucellus is preserved. The stony layer consists of thick-walled spherical or hexagonal cells (TEXT-FIGS. 41-43) and is uniformly thick except at the micropylar region where it narrows gradually. The lumina of these stone cells are very short.



TEXT-FIGS. 40-43—*Sitholeya rajmahalense* sp. nov. 40, the type specimen. *f.b.*, fertile bract. × *Ca.* 13. 41-43, tissue of the stony layer. 43 showing the outline of the cells. × *Ca.* 300.

Near the micropylar region these cells are more or less spherical, loose and with comparatively broader lumina (TEXT-FIG. 41). In the other regions of the integument these cells are variously compressed with shorter lumina (TEXT-FIGS. 42, 43). The sterile part of the ovule (epimatium), apical knob or aril is not seen.

The micropyle is close to the chalazal end and is wide open. The vascular supply made up of centripetal tracheids passes right up to the place of attachment of the ovule with the shoot.

Sitholeya rajmahalensis sp. nov.

Diagnosis — Fertile shoot bearing spirally arranged, short, scale-like, uninerved, decurrent leaves, overlapping each other. Ovule inverted, about 3 × 2 mm., oval, with a stony layer made up of stone-cells with short lumina, arising in the axil of a fertile bract.

Comparison — The fossil fertile shoots bearing terminal single-seeded strobili are known from the Triassic under the name *Palaeotaxus radiviva* Nath. (FLORIN, 1944; cf. FLORIN, 1951, p. 349, FIG. 43a) and *Taxus jurassica* from the Jurassic of Yorkshire. There is no other fossil record of fertile shoots bearing single-seeded megastrobili. The specimen differs from the above two Mesozoic fossils in possessing the apical ovule as a lateral organ arising in the axil of a fertile bract and also in being inverted.

Single-seeded megastrobili borne apically amongst the living plants are known only in the family Podocarpaceae and Taxaceae. In Taxaceae the fertile shoot is axillary but the ovule is directly borne on the apex of the fertile shoot. In Podocarpaceae the ovule is lateral in position. In lateral position of the ovule, the specimen shows podocarpinean affinities.

The single-ovulate megastrobili in Podocarpaceae are met with in the genera *Acmopyle*, *Podocarpus* and *Dacrydium*. The ovule in *Acmopyle* is semi-erect, so it differs from our specimen. Since the nature of epimatium cannot be made out in our specimen, the comparisons with *Podocarpus* or *Dacrydium* cannot be extended any further.

5. GENUS *Nipanioruha* (RAO) EMEND.

The genus *Nipanioruha* Rao was instituted by Rao (1946) for petrified coniferous sterile shoots bearing needle-like spiral leaves with decurrent bases. In 1949 Rao described a megastrobilus of *Nipanioruha granthia*.

The shoots described here show a variety of leaf forms, viz. long and needle-like, short and lanceolate, narrow and curved. The leaves are narrowly and spirally attached, spreading, decurrent and each with a hump-like adaxial swelling at the base. Though differing in external morphology, the shoots possess common anatomical characters, viz. leaves uninerved, midrib unbranched accompanied by a resin cell and transfusion tissue. Mesophyll is also similar in all. On the basis of the above similarities these shoots are included in the genus *Nipanioruha*.

The fructifications are either borne on shoots or bear one or two leaves on the peduncle which are correlated with those on the shoots not only on the basis of the external morphology of the leaves but also on their epidermal characters.

The superficial resemblance of the shoots described here is noted with some well-known impressions of Jurassic conifers, viz. the shoots of *N. granthia* resemble those of *Elatides elegans* (ARNOLD, 1947, p. 326, FIG. 162), *E. williamsonianus*, *E. curvifolia* (SEWARD, 1919, pp. 272, 273, FIGS. 742, 743), *Pagiophyllum crassifolium* (SEWARD, 1895, PL. 6, FIGS. 1, 2, 3, 6), *P.* sp. (SITHOLEY, 1940, PL. 5, FIG. 60; PL. 4, FIGS. 56-59), *P.* cf. *crassifolium* (HALLE, 1913, PL. 8, FIG. 11); the shoots of *N. lanceolata* sp. nov. those of *Pagiophyllum* sp. cf. *peregrinum* and *P. peregrinum* (SAHNI, 1928, PL. 3, FIGS. 32-34, 43-47); the shoots of *N. curvifolia* sp. nov. those of *B. expansum* and *Pagiophyllum burmense* (SAHNI, 1928, PL. 2, FIGS. 28, 29, 26b).

But for the superficial resemblance noted above the shoots of *Nipanioruha* are very different from the impressions mentioned above in anatomy and general morphology.

In the light of the discovery of a variety of shoots, the fructifications and the epidermal characters, the diagnosis of the genus *Nipanioruha* is revised as below.

Emended Diagnosis — Leaves persistent, crowded, bilateral, slightly twisted, decurrent with an adaxial swelling near the base, subacute or obtuse, entire, uninerved.

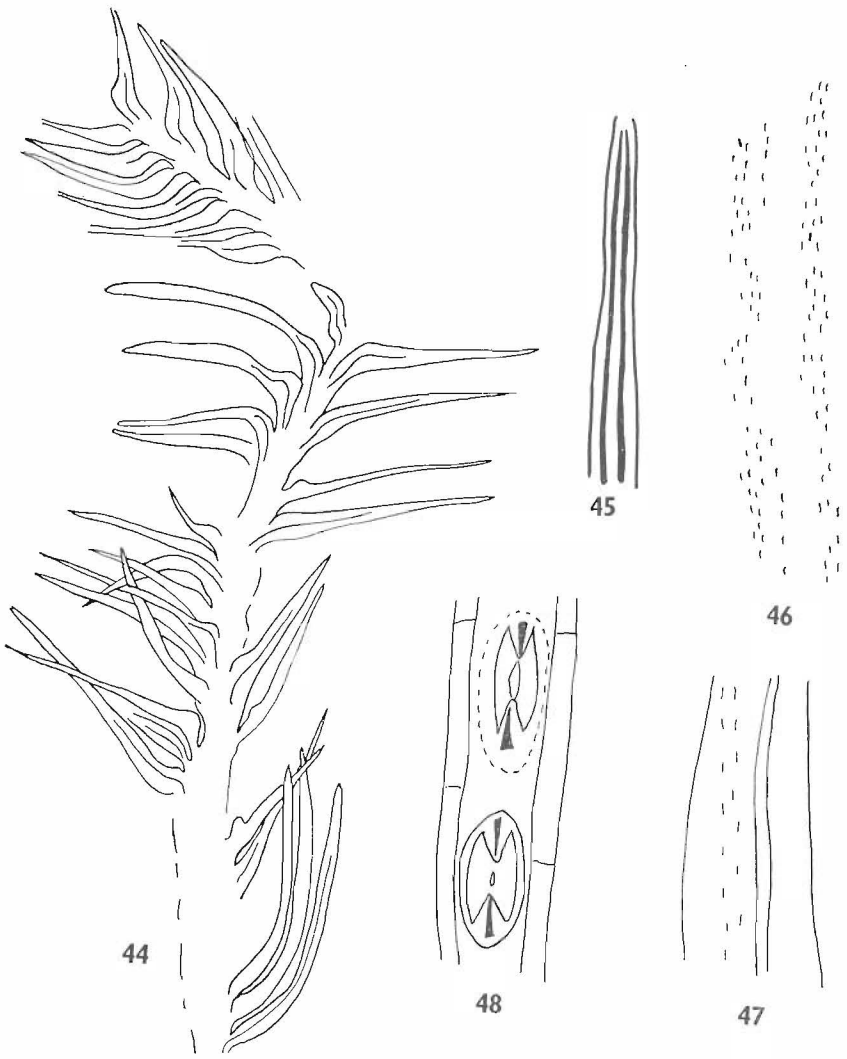
Wood picnoxylic with several vascular bundles. Growth rings marked. Resin cells or canals absent from wood, may or may not be present in the cortex. Tracheids with uni-biseriate pits and scalariform thickening. Medullary rays low and uniseriate. Leaf with a single unbranched median vascular bundle without any external indication of the venation. Vascular bundle overlying a single resin cell. Mesophyll loose with round collecting cells and oval or oblong palisade cells. Transfusion tissue present. Leaf epistomatic. The epidermal cells straight-walled, cubicular or rectangular. Stomata orientated regularly or irregularly.

Cone formation perfect. Cones terminal. Male cones surrounded by needle-like scale-leaves. Microsporophylls bisporangiate, spirally arranged, overlapping and upturned. Microsporangia abaxial, two per scale. Pollen winged, bladders three, smaller than the body. Female cones of *Nipaniostrobus* type.

(i) *Nipanioruha granthia* (Rao) emend.

Pls. 7, 8, Figs. 47-57 ; Text-figs. 44-57

Some additional observations in connection with the morphology of the shoots, the



TEXT-FIGS. 44-48 — *Nipanioruha granthia* (Rao) emend. 44, a sterile shoot. × *Ca.* 6. 45, 46, distribution of stomata in two bands on a leaf. × 9, × *Ca.* 30. 47, vertical section of a part of a leaf showing distribution of stomata on the upper flank of a leaf. × *Ca.* 35. 48, epidermal cells and two stomata. × *Ca.* 375.

epidermal characters and the female fructifications are described. The male fructifications which were not known so far have also been described.

Morphology — Several shoots, up to about 4 cm. long, are examined. The shoots are pinnately branched (TEXT-FIG. 44).

The intercalary swellings on which Rao (1946.) based the genotype *Nipanioruha granthia* are not found a character at all worthy of specific importance. In similar specimens as figured by Rao (1946, PLS. 1, 2) I believe that these intercalary swellings might be attributed either to crushing during preservation or to the diseased condition of the plant. This character, therefore, should not be considered a regular morphological feature of this species.

Epidermal Characters — The epidermal cells are occasionally preserved and are rectangular, narrow, longer than broad, with straight walls (TEXT-FIG. 48).

The leaves are epistomatic. The stomata occur in two bands, one on either side of the midrib (PL. 7, FIG. 48; TEXT-FIGS. 45, 46). The stomata are regularly arranged in short or long files which vary from 2 to 4 in number. The stomata are vertical or oblique with the long axis parallel to the length of the leaf. Of the whole of the stomatal apparatus only the thickenings of the guard cells are preserved.

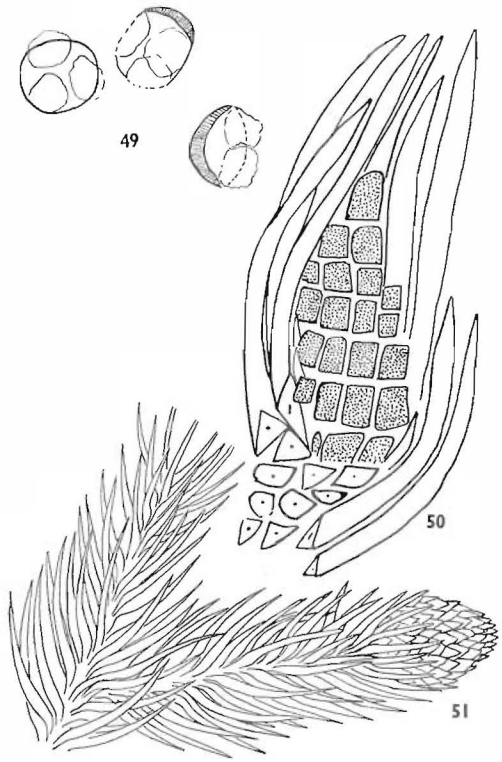
In thin vertical section of a leaf the stomata are only seen on the upper flank of the leaf (TEXT-FIG. 47). The two bands of the stomata, one on each flank, are noted only when the leaf is preserved from the upper surface. The two bands are separated by a non-stomatic region.

The Male Fructification — The cones were borne apically and were surrounded at the base by scales very much similar to the vegetative leaves (PL. 7, FIGS. 49, 50, 53, 54). The leaves in the young stage were longer than the cone itself and enclosing the cone converged and extended beyond it (PL. 7, FIGS. 53, 54; TEXT-FIG. 50). In mature cones the leaves were not longer than two-thirds of the entire length of the male cone (Pl. 7, FIG. 50; TEXT-FIG. 51).

The cones, 4-5 × 2-3 mm., were oblong and nearly twice longer than broad. Each cone consisted of a stout central axis (PL. 7, FIG. 51) on which the scales were borne spirally, the free ends of the scales were upturned and overlapping those above. The scales were hypopeltate and bisporangiate. The microsporangia longer than 1 mm., rectangular, broad distally and tapering gradually towards the proximal end. In cross-section the sporangia, about 0·5 to 1 mm. broad, appear to be rhomboidal in shape. The microspores, 33·2 × 33·2 μ (including wings), were three-winged (TEXT-FIG. 49). The wings, 15 × 13 μ, reticulate, swollen to flaccid in nature, were attached on the ventral surface of the body. The body, 33·2 μ in diameter, comparatively larger than the wings, was granular with a thick dorsal wall.

The fossil male cones described under the name *Masculostrobus sahnii* Vishnu-Mittre (1956) bearing needle-like leaves on the peduncle and producing three-winged, one- and four-winged abnormal pollen grains also probably belonged to *Nipanioruha granthia*.

The Female Fructification — Recently another seed-cone bearing some needle-like leaves on the peduncle as reported by Rao



TEXT-FIGS. 49-51 — *Nipanioruha granthia* Rao emend. 49, pollen grains from above. × *Ca.* 372. 50, vertical peripheral section of another male cone. × Ca. 66. 51, reconstruction of a male fertile shoot (cf. Pl. fig.). × *Ca.* 5.

(1949) is discovered (PL. 8, FIG. 55). The seed-cone, 7 × 4 mm., is compact, oblong and is smaller than that reported by Rao (1949). The leaves on the peduncle (PL. 8, FIG. 57; TEXT-FIG. 52), 3 × 1 mm., decurrent, uninerved and with a characteristic adaxial swelling, are epistomatic. In the fragmentary cuticle the vertical to slightly oblique stomata are seen arranged in short files (TEXT-FIGS. 53, 54). The external morphology and the epidermal characters of the leaves on the peduncle resemble those of the leaves of *Nipanioruha granthia*. The seed-cone is exactly similar to the cones of *Nipaniostrobus sahnii* but differs in having the bracts of cone-scales prominently keeled below (PL. 8, FIG. 56; TEXT-FIGS. 55, 56). The keeled lower portion is variously lobed. Few stomata are observed on one of the scales which are alike in distribution to those of the leaf (TEXT-FIG. 57).

TEXT-FIGS. 52-57 — *Nipanioruha granthia* Rao emend. 52, a part of the peduncle bearing a needle-like leaf. × *Ca.* 20. 53, orientation and the distribution of stomata on above leaf. × *Ca.* 51. 54, a part of above enlarged showing two stomata and the epidermal cells. × *Ca.* 375. 55, 56, showing the seed-scale complexes. *ep* and *ov.s.*, sterile part of the flower; *b.s.*, bract-scale. × *Ca.* 22. × *Ca.* 51. 57, a part of the seed-scale complex showing stomata on the bract-scale. × *Ca.* 51.

(i) *Nipanioruha granthia* (Rao) emend.

Emended Diagnosis — Shoots pinnately branched, branches arising at a narrow angle, older branches with oval scars of the decurrent leaf-bases. Leaves needle-like, linear, 8-9 × 0·3-0·5 mm., apex acute, uninerved, triangular to oval or rhomboidal in cross-section. Transfusion tissue not noted. Leaves epistomatic. Epidermal cells rectangular, several times longer than broad; stomata vertical to slightly oblique, parallel to the length of leaf, in 3-4 rows each single stoma thick on either side of the midrib. Stomatal apparatus oval. Subsidiary cells not preserved. Wood parenchyma profusely present. Bordered pits uniseriate, flattened and contiguous. Scalariform tracheids present. Medullary rays uniseriate, 1-12 cells high. Cones perfect. Male fructifications

in young stage surrounded and enclosed by the vegetative leaves. Male cones cylindrical, 2-4 × 1-2 mm.; pollen grains 33·2 μ in diameter, three-winged; wings flaccid, bladdery and faintly reticulate. Female cones *Nipaniostrobus*-like, compact, 7-10 × 4-5 mm., bract-scales very much keeled below, keels lobed.

Comparison — While dealing with the comparisons and the affinities Rao (1949) showed that *N. granthia* might belong to Podocarpaceae. The male cones possessing small three-winged pollen grains with faintly reticulate wings and the *Nipaniostrobus*-like megastrobili further enhance the podocarpinean affinities.

(ii) *Nipanioruha lanceolata* sp. nov.

Pl. 8, Figs. 58-63; Text-figs. 58-60

Diagnosis — Shoots with lanceolate leaves, 2-5 × 1-1·5 mm., spreading, uninerved, stiff, with obtuse apex. Transfusion tissue present. Leaves epistomatic. Epidermal cells polygonal in rows. Stomata, 41·6-48 × 25·6-27·2 μ, orientated vertical to oblique, irregularly distributed. Subsidiary cells not preserved. Medullary rays uniseriate, 1-9 cells high, rays with 1-4 cells high predominant.

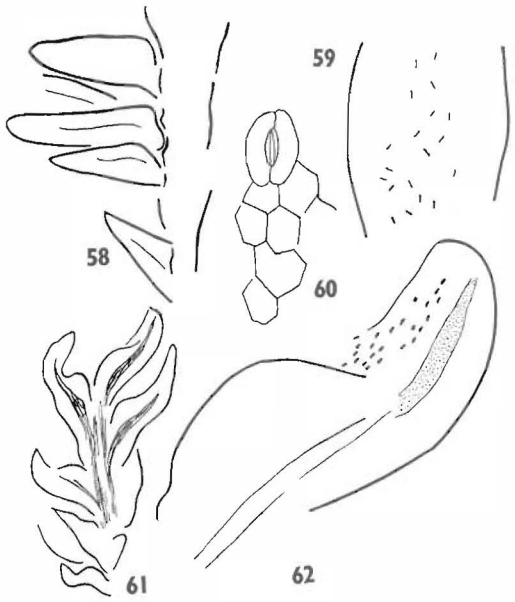
Description — The species is based upon four fragmentary shoots (Pl. 8, Figs. 58-60) up to about 2 cm. long and up to about 1 cm. broad. In one of the shoots leaves do not appear to be as stiff as in the other shoots, but in size, shape of leaves and epidermal characters this shoot is identical with the other shoots.

Comparison — These shoots differ from the shoots of *N. granthia* in broader, stiff and lanceolate leaves. Further, the irregular distribution of the stomata and the polygonal shape of the epidermal cells (Text-figs. 59, 60) are different.

(iii) *Nipanioruha curvifolia* sp. nov.

Pl. 8, Figs. 64-67; Text-figs. 61, 62

Diagnosis — Shoots pinnately branched. Leaves, 2 × 0·5 mm., short, narrow, curved upwards, loosely overlapping, uninerved, with two patches of transfusion tissue, one on each side of the bundle. Leaves epistomatic. Stomata vertically orientated along the length of the leaf, confined into 3-4 rows on either side of the midrib, each row single stoma thick. Epidermal cells not preserved.



Text-figs. 58-62 — 58-60, *Nipanioruha lanceolata* sp. nov. 58, a shoot. × *Ca.* 5½. 59, distribution and orientation of stomata. × *Ca.* 18. 60, epidermal cells and a stoma. × *Ca.* 180. 61-62, *Nipanioruha curvifolia* sp. nov. 61, a shoot. × *Ca.* 5½. 62, distribution and orientation of stomata on the upper flank of a leaf. × *Ca.* 27.

Description — The species is based on four specimens up to 4 cm. long and about 0·5 cm. broad (Pl. 8, Figs. 64, 65). Loosely attached, short and narrow, upturned leaves (Text-fig. 61) each with an adaxial swelling. The leaves are broader than those of *N. granthia*, but narrower than those of *N. lanceolata*.

Comparison — The shoots resemble in the distribution and orientation of the stomata the shoots of *N. granthia* Rao emend., but in habit, in size and form of leaves the shoots differ from *N. granthia*. In the distribution and orientation of the stomata (Text-fig. 62) and the nature of the foliage the shoots of *N. curvifolia* are very much different from those of *N. lanceolata*.

6. *Indophyllum* gen. nov.

There are some shoots in the vegetative remains from Nipania which possess external characters common to *Brachyphyllum*, *Pagiophyllum* and *Dactylethrophyllum* (Wesley, 1956, p. 54), but at the same time possess such characters which are not found in these

genera. As in *Brachyphyllum* the leaves are appressed but extend far above their cushion. The stomata are all longitudinally orientated and in this respect the shoots here described differ from *Brachyphyllum*, *Pagiophyllum* and *Dactylethrophyllum* in which the stomata are circular and transversely orientated.

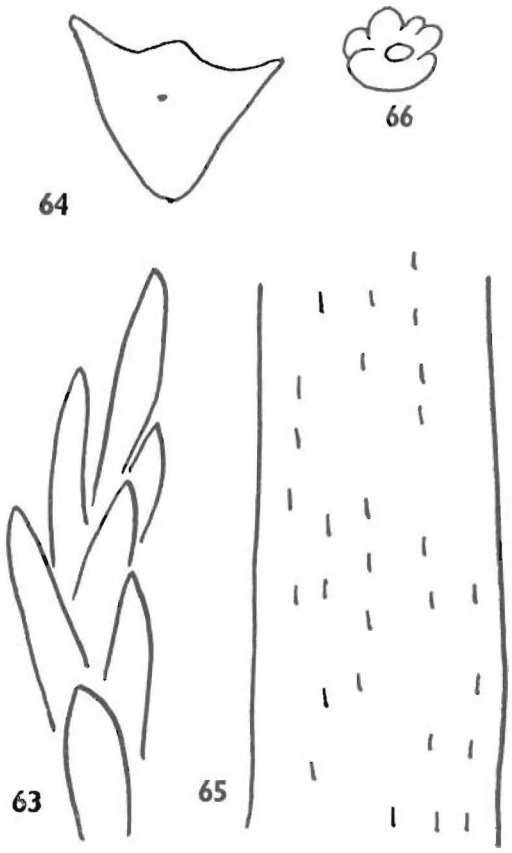
The epidermal characters show that these shoots might belong to the family Podocarpaceae. The occurrence of two-winged pollen grains in some fragmentary fertile shoots further supports this view. This is also supported by the anatomy of stem in one of the shoots. For these shoots the genus *Indophyllum* is proposed.

Diagnosis — Shoots with closely appressed leaves, free margin of lamina extending beyond the leaf cushion. The stomata longitudinally orientated, vertical, oblique or nearly transverse. Stomatal apparatus haplocheilic. Trichomes and hairs absent from the epidermal cells.

Three species of the genus *Indophyllum*, *I. sahnii*, *I. raoi* and *I. nipanica*, are described. These species agree with one another in essential characters of the genus but differ from one another in well-defined characters. The shoots bear loosely arranged leaves in *I. sahnii* and *I. raoi* while the leaves are closely clasping in *I. nipanica*. *I. raoi* differs from the other two species in having rhomboidal leaves in cross-section, while in possessing transfusion tracheids in two patches and a resin cell below the vascular bundle it resembles the leaves of *I. sahnii*. The leaves are triangular in cross-section in *I. sahnii* and *I. nipanica* but the upper surface of leaves in *I. sahnii* is ridged in the middle.

Vertical to slightly oblique orientation of the stomata is noted in *I. sahnii*, only vertical in *I. nipanica*, and vertical in the upper surface of the leaf and irregular (vertical tending to be transverse) on the lower surface of the leaves in *I. raoi*.

The cuticle tends to show that these three species might belong to the Podocarpaceae. Stem anatomy and the winged pollen in *I. nipanica* further confirm the evidence of the cuticular anatomy.



TEXT-FIGS. 63-66 — *Indophyllum sahnii* sp. nov. 63, part of a shoot. × *Ca.* 11. 64, cross-section of a leaf. × *Ca.* 36. 65, distribution and orientation of stomata on a part of a leaf. ×*Ca.* 120. 66, a stomatal apparatus showing the raised subsidiary cells. × *Ca.* 600.

(i) *Indophyllum sahnii* sp. nov.

Pl. 9, Figs. 68-73; Text-figs. 63-66

Diagnosis — Shoots curved or straight, pinnately branched; lateral branches making an angle of 30° with the axis. Twigs 1-1·5 mm. in diameter, unflattened.

Leaves spirally arranged. Leaf-base cushion rhomboidal, broad; leaf up to 1 mm. broad and as long as the leaf-base cushion. Apex acuminate, pointing upwards and outwards. Leaf traversed by a single unbranched vein and more or less triangular in cross-section, upper surface forking a central ridge in the region of the midrib accompanied by two longitudinal furrows or grooves. Vascular bundle overlying a resin cell and accompanied by two patches of transfusion tissue. Margin entire. Stomata both on the upper and the lower flanks of the leaf, 33·6 × 19·2 μ, crowded, disposed in short and long files, vertical or slightly oblique,

orientated parallel along the length of the leaf. Trichomes, hairs or papillae absent. Subsidiary cells raised above the surface of the epidermis, 4-6, two polar and the rest lateral. Stomatal pit oval. Epidermal cells not preserved.

Description — The slide shows two fragments of the shoot lying over one another in the inverse orientation (PL. 9, FIG. 68). The larger fragment, about 3·2 cm. long, shows four lateral branches. The other fragment is about 1 cm. long. Fragments up to about 1 cm. long are frequently met with in other slides and the slices of the chert.

A fragmentary specimen (PL. 9, FIG. 72), about 3-4 × 3 mm., though possessing larger leaves, about 2 × 1 mm., is believed to belong to this species since in the distribution and the orientation of the stomata (PL. 9, FIG. 73) and the nature of the leaves the specimen possesses similar characters as in the shoot described above.

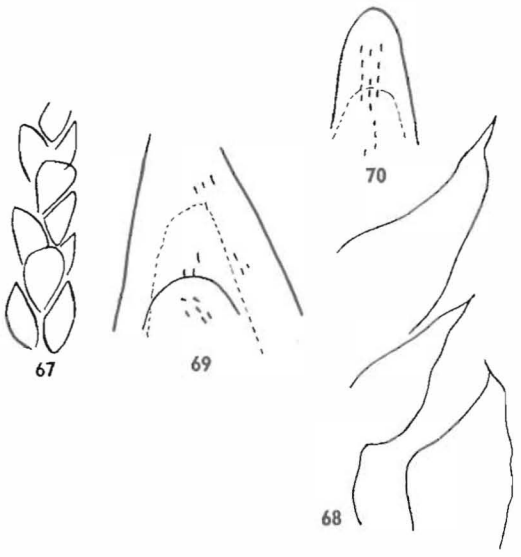
(ii) *Indophyllum raoi* sp. nov.

Pls. 10, 11, Figs. 74-76; Text-figs. 67-70

Diagnosis — Shoots curved or straight, pinnately branched, lateral branches making an angle of 45°. Shoots unflattened. Leaves spirally attached, arising from rhomboidal leaf-base cushions. Leaf up to 1 mm. broad, free portion of lamina nearly one-third turned and pointed upwards. Margin entire. Vascular bundle single and unbranched traversing the whole length of the leaf and accompanied by transfusion tissue on either side of it. Leaf in cross-section rhomboidal, vascular bundle overlain by a resin cell.

Leaves probably amphistomatic. Stomata, 30·4 × 17·6 μ, on the upper surface regular in very much separated short and long files. On the lower surface irregular, oblique, tending to be transverse. Epidermal cells not preserved. Papillae or trichomes absent.

Description and Comparison — The species is represented by branched shoots up to about 2·5 cm. long and about 2 mm. broad. Fragments up to about 5 to 6 mm. long are commonly met with in sections of the chert. The shoots are distinguishable from *I. sahnii* in their loosely overlapping short leaves with very much pointed apices. Further differences are noted in the orientation of the stomata.

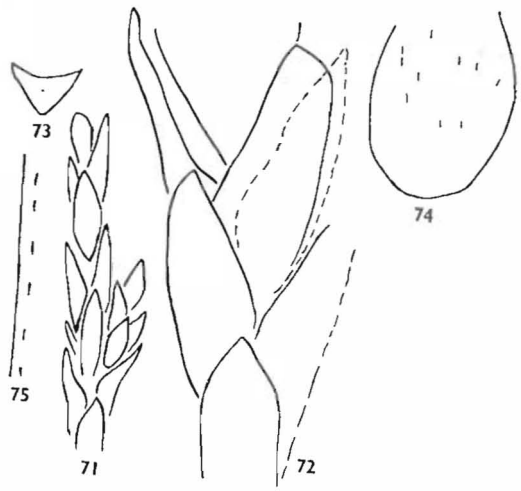


TEXT-FIGS. 67-70 — *Indophyllum raoi* sp. nov. 67, part of the shoot. × *Ca.* 7. 68, part of shoot showing the apex. × *Ca.* 35. 69, 70, distribution and orientation of stomata on two opposite surfaces of a leaf. × *Ca.* 75.

(iii) *Indophyllum nipanica* sp nov.

Pls. 10, 11, Figs. 77-87; Text-figs. 71-79

Diagnosis — Shoots curved or straight, pinnately branched, lateral branches making an angle of 30°-45°, unflattened; leaves up to 1 mm. long and 0·5 mm. broad and 0·6-0·8 mm. thick, decurrent, spirally attached, arising from the rhomboidal leaf-base cushions. Free portion of the lamina is nearly as long as the leaf-base cushion and pointing upwards and frequently inwards. Leaf is traversed by a single unbranched vein. In cross-section the leaf is triangular with the upper surface concave and lower convex and keeled, no resin cell is observed below the vascular bundle. Margin entire and apex acute. Leaf with a single-layered palisade and round collecting cells. Stomata in regular rows, vertical and parallel to the length of the leaf. Subsidiary cells not preserved, only the thickenings of the guard cells preserved, trichomes absent. Epidermal cells not preserved. Wood picnoxylic. Growth rings present. Medullary rays uniseriate, 1-8 cells high, rays with 1-2 cells dominant, parenchyma present. Bordered pits uni- and biseriate, free and circular or



TEXT-FIGS. 71-75—*Indophyllum nipanica* sp. nov. 71, part of a shoot. × *Ca.* 6½. 72, part of a fertile shoot. × *Ca.* 15. 73, cross-section of a leaf. × *Ca.* 15. 74, Distribution and orientation of stomata on a leaf. × *Ca.* 37½. 75, distribution and orientation of stomata on a leaf-base cushion. × *Ca.* 37½.

flattened, or biseriate opposite. Field pits, 1-4, elliptic. Spirals present in the tracheids. Male cones surrounded by long and thick leaves. Pollen grains two-winged, 38-42 μ including wings; wings bladdery and reticulate.

Description — The species is represented by several specimens. One of the specimens (PL. 11, FIG. 86) bears a fragmentary male cone apically; while another (PL. 11, FIG. 80) is attached with a stem whose anatomy is also well preserved. There is another fragmentary fertile shoot (PL. 11, FIG. 84) bearing an apical fructification probably female. In all essential characters these specimens are similar and are, therefore, included in this species.

The longest fragment, the twig, a part of the foliage of which is shown in Pl. 11, Fig. 80, measures 2·3 cm. in length and 0·6 cm. in breadth with the bark, cortex and phloem also preserved.

The bark is scaly, unstratified and undifferentiated into outer and inner bark. Bark fibres, parenchyma cells and sclerenchymatous cells are all intermixed. Medullary rays are also preserved. There are some cells with narrow lumen, probably the remains of the sieve tubes. Stone cells are scattered. The outer region of the cortex has some broad, probably oleo-resin, cavities.

Few stomata are sometimes seen on the upper and sometimes on the lower flanks of a leaf (TEXT-FIG. 74). These are regularly orientated in short files but are scattered on the leaf-base cushion (TEXT-FIG. 75).

Male Cone — The fragmentary male cone (PL. 11, FIG. 84) is borne apically. Apex of the shoot is invaginated forming a sort of receptacle on which the fructification is placed. The cone is surrounded by unusually longer and thicker, incurved leaves. The incomplete male cone is 1·6 mm. broad and 0·8 mm. long. It consists of 4 more or less crushed microsporangia, 0·8 × 0·7 mm.

Microspores (PL. 11, FIG. 85) are 2-winged and measure about 38-42 μ from wing to wing. The body of the spores is club-shaped and larger than the wings. Wings are inflated and reticulately ornamented. Ventral and the dorsal walls of the body appear to be equally thick.

The other fertile fragmentary shoot (PL. 11, FIG. 86), about 8 mm. long, bears a fructification at the apex. The fructification, about 3 × 2·5 mm., is compact and oblong in shape. The cone-scales consisting of a stalk-like structure attached directly to the cone-axis broaden out in their distal region into a triangular structure and are keeled below. The cone-scales appear to be woody with a sort of spinous, downwardly pointed outgrowth arising from the lower surface of the scale. The lowermost pair of the scales is sterile. One of the cone-scales marked 'a' (PL. 11, FIG. 87) shows two sac-like, swollen structures borne in a hypopeltate condition. The cone-scales are very much crowded and the sac-like bodies are sectioned in various planes so the exact number and the nature of these sac-like bodies are not made out. These sac-like bodies are bounded by a thin membranous wall made up of short to long polygonal cells arranged in rows along the length of the sac (TEXT-FIG. 79). The wall of the scale is made up of thick-walled rectangular cells arranged in vertical rows (TEXT-FIG. 78).

The free ends of the scales are short and point upwards. The distal part of a scale possesses leafy mesophyll. The sterile part of the seed-scale complex is not made out, probably it is fused with the bract-scale.

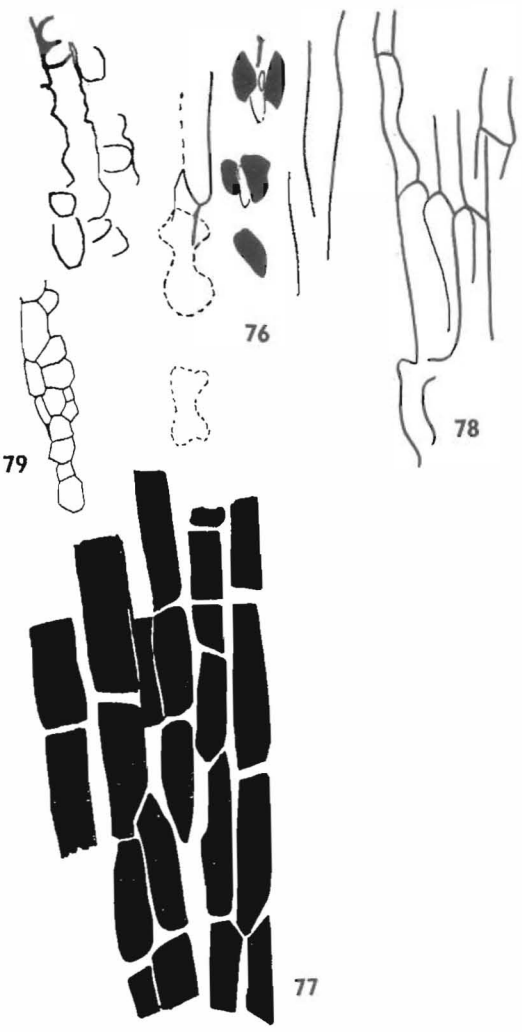
Each sac-like body is broader towards the distal and narrower towards the proximal end of the scale. It is the broadest in the middle region.

It is not possible to make out the exact nature of these sac-like bodies whether they represent the remains of the seed or of the microsporangia. The spores are not found *in situ* or near the vicinity of the cone. The swollen nature of the sac-like bodies indicates that these might be the remains of the seeds or might represent the remains of immature aborted ovules.

Till more material is discovered, it may not be possible to know whether the fructification was a male or a female cone.

Comparison — The specimens differ from the shoots of *I. sahnii* and *I. raoi* in habit, in possessing very closely clasping leaves and in the distribution and the orientation of the stomata. The stomata are in rows and are all vertical as contrasted from the vertical to oblique stomata in *I. sahnii*. In *I. raoi* oblique tending to be transverse orientation of the stomata is noted which is different from that of stomata in *I. nipanica*. The presence of transfusion tissue and the resin cell lying below the vascular bundle in the leaves of *I. sahnii* and *I. raoi* constitutes further difference from the above species.

The unusually longer and thicker scale-like leaves encircling the base of the male cone as seen in our fertile specimen are, however, noted surrounding the base of a male cone in some living representatives of the family Podocarpaceae, viz. *Pherosphaera*, *Saxegothaea*, *Dacrydium taxoides* and *Podocarpus imbricatus* (PILGER, 1903). In small size and nature of the wings the pollen grains also show podocarpinean affinities. It is further supported by the anatomical characters of the stem, though the spirals have not been noted in the podocarpinean tracheids.



TEXT-FIGS. 76-79 — *Indophyllum nipanica* sp. nov. 76, distribution and orientation of stomata from the lower flank of a leaf. × *Ca.* 375. 77, part of a cellular tissue from a cone-scale. × *Ca.* 375. 78, epidermal cells from a leaf. × *Ca.* 375. 79, cellular tissue from a sac-like body. × *Ca.* 375.

7. GENUS *Elatocladus* HALLE

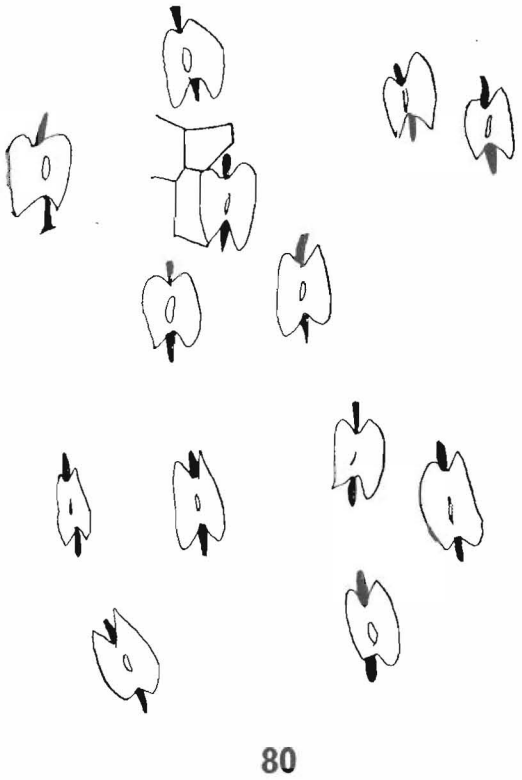
Several species of *Elatocladus* are known as impressions from the Mesozoic. Only the cuticular structure is known in some species (SAHNI, 1928, p. 14; HARRIS, 1935, pp. 60-77). The internal structure of *Elatocladus* is not known yet.

(i) *Elatocladus sahnii* sp. nov.

Pl. 12, Figs. 88-91; Text-fig. 80

Diagnosis — Branchlet showing dimorphism. Leaves at the base small, scale-like, 1-2 × 0·5 mm., closely appressed, overlapping, triangular, keeled and broadly decurrent. Linear leaves bifacial, 4-5 × 0·75 mm., decurrent, biseriate and spirally attached, expanded in the same plane and spreading outwards. Margins entire, apex pointed. Leaves traversed by a single unbranched median vein accompanied by two patches of 3-5-celled transfusion tissue, one on each side of the vein. Vein probably overlying a resin cell.

Stomata 35·7 × 20·4 μ, scattered over the undersurface tending to form longitudinal rows. Orientation longitudinal to oblique.



TEXT-FIG. 80 — *Elatocladus sahnii* sp. nov. Distribution and orientation of stomata on the upper flank of a leaf. × *Ca.* 562.

Stomatal apparatus monocyclic. Subsidiary cells 4-6. Two polar, the rest lateral, guard cells sunken. Epidermal cells rectangular, elongated, with straight to slightly wavy walls.

Description and Comparison — The species is based on three specimens, up to about 1·4 cm. long, resembling superficially some of the impressions described under the name *Elatocladus tenerrima* (SAHNI, 1928, p. 14, PL. 1, FIGS. 10-15) but differing from them in being bifacial.

Amongst the living conifers comparisons may be made with some shoots of *Podocarpus*. The leaves in sections *Microcarpus* and *Nageia* of *Podocarpus* are unlike the specimen, being scale-like and overlapping in the former and many-nerved in the latter. In *Dacrycarpus* the leaves are bilateral. Bifacial leaves as in the specimen are met with in the section *Eupodocarpus* of the genus *Podocarpus*.

Araucariaceae

8. GENUS *Brachyphyllum* (BRONGT.) KENDALL

Brachyphyllum florini sp. nov.

Text-figs. 81-85

Diagnosis — Branched, straight or curved shoots about 2 mm. in diameter. Leaves probably spirally attached. Leaves uninerved, up to about 0·5-0·75 mm. broad, triangular, keeled and about 0·75-1 mm. long. Apex pointed. Mesophyll consisting of a single-layered palisade and round collecting cells.

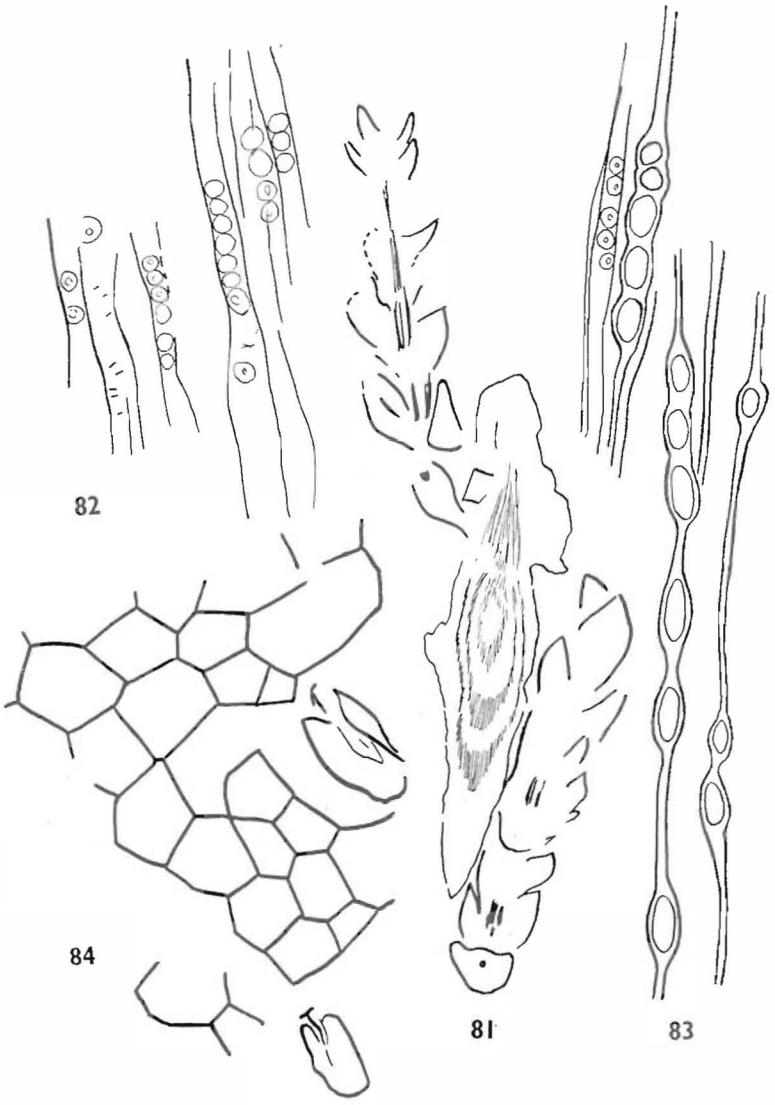
Leaves amphistomatic. On one, probably the upper, surface the stomata seem to form two small bands each along the margin and below the apical half of the median line. The bands either forked into two distinct groups or joined in the middle and converging at the apex. The stomata are irregularly arranged varying in their orientation from vertical to transverse. On the other, probably the lower, surface beginning with the margin occur two groups of stomata, each along one of the margins. The stomata show the same orientation as on the opposite surface. Epidermal cells polygonal, 5-6-angled, thick and straight-walled.

Wood picnoxylic. Medullary rays uniseriate, 1-5 cells high. Bordered pits uniseriate, free or contiguous.

Description — A fragmentary shoot, about 1-2 cm. long, consists of an oblique cross-section of the stem with two fragments of the branches in slightly oblique, vertical sections (TEXT-FIG. 81). From the vertical section of the shoot, the nature of the phyllotaxy is not clearly made out. The mesophyll is preserved in some leaves. The anatomy of the stem is poorly preserved. Of the stomata only the thickenings of the guard cells are preserved. Their distribution and the orientation are clearly seen in Text-fig. 85.

The transfusion tissue and the resin cells are not observed.

Comparison — *B. florini* differs from the other species of *Brachyphyllum* chiefly in the distribution and the orientation of the stomata. In the irregular orientation of the stomata the specimen resembles *Brachyphyllum expansum* Var. *indica* Sahni (SAHNI, 1928, PL. 23, FIGS. 39-42) but differs in the distribution of stomata and in habit. Such a distribution of the stomata in the *Brachyphyllum* leaves, to the best of the author's knowledge, is not described so far.



TEXT-FIGS. 81-84 — *Brachyphyllum florini* sp. nov. 81, the specimen. × *Ca.* 10. 82, radial longitudinal section of stem showing bordered pits. × *Ca.* 375. 83, radial tangential section of stem showing medullary rays. × *Ca.* 375. 84, epidermal cells showing two stomata. × *Ca.* 375.

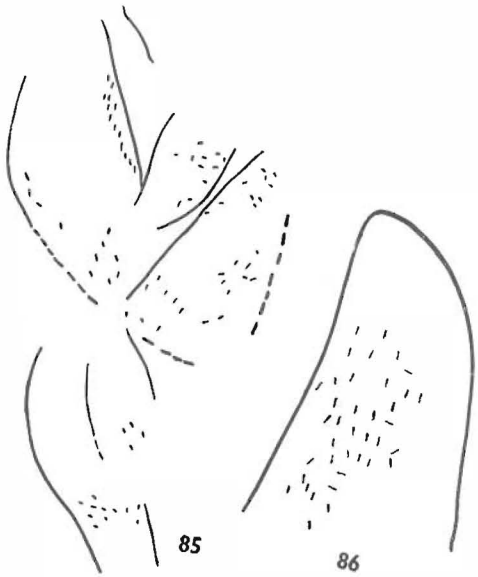
9. GENUS *Pagiophyllum* HEER

Pagiophyllum araucaroides sp. nov.

Pl. 12, Figs. 92-95; Text-fig. 86

Diagnosis — Straight twigs, about 4-5 mm. wide. Leaves 4 × 1 mm., not very crowded, decurrent, projecting at an angle of about 50° from the concealed bases. Leaves lanceolate, curved upwards and inwards; apex acute. Upper surface of leaf concave, lower convex, probably keeled. Margins entire. Leaf-base cushion rhomboidal, raised on stem. Each leaf traversed by a single median unbranched vein accompanied by two patches of transfusion tissue, one on either side, and a resin cell underlying it. Mesophyll loose, made up of palisade parenchyma.

Stomata 44·2 × 23·8 μ, irregularly distributed on the upper flank of a leaf, a few on



TEXT-FIGS. 85, 86 — 85, *Brachyphyllum florini* sp. nov. A part of shoot or leaves showing distribution and orientation of stomata. × 75. 86, *Pagiophyllum araucaroides* sp. nov. Distribution and orientation of stomata on a leaf. × 35.

the lower also. Subsidiary cells not preserved. Orientation of the stomata vertical, oblique and transverse. Epidermal cells cubicular, polygonal, straight-walled. Trichomes and papillae absent.

Comparison — The specimen (PL. 12, FIG. 92), 1·4 × 0·5 cm., a single fragment of which is available, looks very much similar to the specimens of *Nipanioruha* but differs from the genus *Nipanioruha* in the absence of adaxial swelling — an important character of *Nipanioruha* shoots, and in possessing transversely orientated stomata. Superficially the specimen resembles *P. insigne* Kendall but differs in its epidermal characters. The specimen differs in habit and the epidermal characters from the Indian specimens of *P. peregrinum* (SAHNI, 1928).

DISCUSSION

The conifer remains now known from Nipania include the genera *Masculostrobus* (4 spp.), *Mehtaia* (3 spp.), *Nipaniostrobus* (3 spp.); *Sitholeya* (1 sp.), *Nipanioruha* (3 spp.); *Indophyllum* (3 spp.); *Elatocladus* (1 sp.); *Brachyphyllum* (1 sp.), *Pagiophyllum* (1 sp.), and *Araucarites* (1 sp.).

These plant-remains represent only two families of conifers, the Podocarpaceae and the Araucariaceae, with a larger representation of the podocarps than those of the araucarias. Although several undoubted records of the Araucarias from the Jurassic horizon of India and other countries are known, the kind of Jurassic podocarps described here have not been known so far. Further the fossil podocarps described here possess several characters common with those of modern representatives of the Podocarpaceae so much so that these Jurassic podocarps may be looked upon as the immediate ancestors of modern Podocarps without any intermediate forms to have existed in the geological periods between the Recent and the Jurassic horizon.

Besides small size of the pollen grains, nature and number of wings which are distinctly podocarpinean, one of the species of *Masculostrobus*, *M. podocarpoides* sp. nov., seems to be very closely related to that of a modern *Podocarpus*. The occurrence of *Podocarpus*-like remains is further enhanced by the presence of *Sitholeya* in which a single inverted ovule is either like that of a *Podocarpus* or a *Dacrydium*. This shows that the habit of single-seeded strobilus had already been attained in the Jurassic horizon. The seed-cones of *Nipaniostrobus* approach those of the loose megastrobili of some species of modern *Podocarpus*, viz. *P. spicatus*, and not those of *Dacrydium* as believed by Rao (1943) since, firstly, the genus *Dacrydium* is devoid of compact seed-cones and, secondly, *Dacrydium*-like fossils are now discovered as described in this paper. So far the Rhaetic and the Jurassic fossils known as *Stachyotaxus* sp. (SEWARD 1919, pp. 406-407) were believed to be allied to *Dacrydium*, though in contrast to modern *Dacrydium* or podocarps on the whole, the cones of *Stachyotaxus* bore two-seeded scales. In the light of undoubted *Podocarpus* or *Dacrydium*-like plant-remains as found in *Sitholeya*, the evidence of *Stachyotaxus* as being allied to *Dacrydium*, once believed to be the most promising, cannot be upheld any longer.

Regarding the Eocene fossils, viz. *Podocarpites*, *Concocephalum ricthofeni* Schenk, which were once believed to belong to *Podocarpus* and *Dacrydium* according to Seward (1919, pp. 406, 407), are devoid of any substantial ground for such comparisons.

The compact seed-cones of *Nipaniostrobus* also remind one of mature seed-cones of

Microcachrys, though the seed-cones of the latter are comparatively much smaller than those of *Nipaniostrobus*.

The seed-cones of *Mehtaia* possess remarkably the essential characters of the seed-cones of *Pherosphaera*, a genus of limited distribution in Tasmania and New South Wales about the fossil history of which nothing is known. The modern genus has only two species living today while there are three species of the genus *Mehtaia* in the Jurassic deposits at Nipania.

The other podocarpinean plant-remains described here are *Elatocladus sahnii* and the genus *Indophyllum*. The cuticular evidence of the *Brachyphyllum-Pagiophyllum*-like shoots described under the name *Indophyllum* distinctly points towards Podocarpaceae. In *I. nipanica* two-winged pollen grains are also obtained in a fragmentary male cone. The correlation between some of the isolated cones and shoots is not known yet, but in general habit they seem to have been *Microcachrys* or *Pherosphaera*-like though differing in spiral arrangement of the leaves.

The genus *Nipanioruha* along with its fructifications is another podocarp whose parallel in the living podocarps is not met with.

The family Araucariaceae is represented by *Brachyphyllum florini*, *Pagiophyllum araucaroides* and *Araucarites nipaniensis*.

Origin and History of Podocarpaceae — Stiles (1912) expressed for the first time that the Araucarineae and the Podocarpineae are nearly related together. He opined (Stiles, 1912, p. 50) that Podocarpineae could not have evolved from the Cordaitales but from the Lycopods. In 1936 Hirmer, instituting a new family Cheirolepidaceae for some fossil conifers showing podocarpinean characters, postulated the origin of Podocarpaceae from the Sphenophyllales (Hirmer, 1936, pp. 6-10).

Florin (1951) has recently outlined the evolution of the conifer cone-scales. He has shown that there have been several lines of evolution in the female cones of the conifers. The line of evolution headed by lebachias (where the flower in the axil of a bract consists of several sterile scales and a single fertile one) is more or less continuously followed by Florin (1951) with the help of fossil record through the successive reduction and fusion of several sterile scales into the so-called ovuliferous scale of modern conifers. This line of evolution, as shown by Florin, terminates in the members of the Taxodiaceae, Pinaceae and Araucariaceae.

On account of possessing completely fertile flowers hitherto known, fossil fructifications of the Podocarpaceae (*Stachyotaxus* and *Palissya*) are believed by Florin to be more comparable to the *Ernestiodendron* type of the primitive conifers than to *Lebachia* (Florin, 1951, p. 348). Though *Stachyotaxus* and *Palissya* are not directly related to the modern podocarps nor to the fossil seed-cones described here, they probably belong to the same trend of evolution as shown by the modern podocarps. This line of evolution has not been discussed by Florin (1951) for want of fossil material.

The line of evolution headed by *Ernestiodendron*, probably of the Late Carboniferous and the Early Permian, shows a big gap in the Middle and the Upper Permian periods. In the Upper Triassic, Lower and Middle Jurassic we see traces of this evolution in the *Stachyotaxus* and *Palissya* which probably represent the ramifications of the main line of evolution from the *Ernestiodendron*-like types. In the Upper Jurassic (of Nipania) some of the final stages of these ramifications are met with in the seed-cones of *Mehtaia*, which with a single bract-scale and a reduced single megasporophyll, probably represent the termination of the main line of evolution. In *Mehtaia* several megasporophylls of the *Ernestiodendron* type are believed to be reduced to a single erect ovule and the bifurcation of the single bract-scale has been lost since long in the geological periods. The characters of the seed-cones of *Mehtaia* are retained by modern *Pherosphaera* and *Phyllocladus*, though in the latter an aril is also present.

The line of evolution leading to the formation of the seed-cones of *Nipaniostrobus* and *Sitholeya rajmahalensis* is not clear since *Nipaniostrobus*, *Sitholeya* and *Mehtaia* are of the same age.

Though *Saxegothaea* is considered to be the most primitive in the family Podocarpaceae (Stiles, 1912, p. 494), yet the primitive podocarpinean plant as visualized by Stiles bore seed-cones, in which each megasporophyll bore in its axil a single erect ovule surrounded by a single integument, a condition seen in the seed-cones of *Mehtaia*, *Pherosphaera* and *Phyllocladus*. This is also supported by the ontogeny of the seed-cones of *Saxegothaea* (Norén, 1908; Tison, 1909). Further, from the intergeneric relationships of the

modern podocarps it seems that they all belonged to one main line of evolution with short ramifications terminating here and there.

The common ancestor of the podocarps was not very much different from the seed-cones of *Mehtaia* from which one line of evolution gave rise to the seed-cones of *Mehtaia* and later to those of *Pherosphaera* and *Phyllocladus*. A branch from this line of evolution, somewhere in the pre-Jurassic times, developed into a condition which is noted in the seed-cones of *Nipaniostrobus* and later in the seed-cones of *Microcachrys*, *Saxegothaea* and some species of *Dacrydium* (*D. franklini*) and *Podocarpus* (*P. spicatus* and *P. andinus*). A secondary branch from this, again in the pre-Jurassic times, further evolved probably according to the scheme suggested by Wilde in 1944 into the single-seeded fructifications of *Sitholeya* and later into those of *Podocarpus* and *Dacrydium*.

The Interpretation of the Epimatium — The exact morphological nature of the epimatium is still debatable. Amongst the fossil podocarps epimatium is absent in *Mehtaia* but is present in the genera *Nipaniostrobus* and probably also in *Sitholeya*. The epimatium receives vascular supply in *Nipaniostrobus* but nothing about it is known in *Sitholeya*. In living podocarps epimatium is absent in two genera *Pherosphaera* and *Phyllocladus* and in the young cones of *Saxegothaea* and *Microcachrys*. Further, in modern podocarps epimatium is not known to receive any vascular supply except in *Podocarpus spicatus* and *Dacrydium bidwillii* (FLORIN, 1951, p. 367), although in these two cases it is so intimately fused with the integument that it is impossible to demarcate between the boundaries of epimatium and the integument.

In the light of evolution of podocarps outlined above it becomes clear that the common ancestors of podocarps which were not different from the seed-cones of *Mehtaia* had no epimatium in their seed-scale complexes. The ernestiodendrons and the walchias from which they had evolved had no sterile scales. On the other hand, the sterile scales in the line of evolution headed by lebachias were evolved into the ovuliferous scale of modern conifers. The epimatium thus appears to be an organ *dé novó*. It is considered homologous with the ovuliferous scales of other conifers as believed by some workers (FLORIN, 1951, pp. 364, 365). The ontogeny of *Saxegothaea* seed-cones (in which epimatium is absent in the young cones when the ovules are erect, but appears on recurvation and change of position of the ovules on the scale; *see* TISON, 1909, p. 143), shows that the epimatium appears very late in the evolution of the podocarps. It probably arose in those geological times when the erect ovules in the ancestor were trying to adopt recurvation, a character which later became persistent in the majority of the podocarps.

The epimatium of the podocarps is either derived from the stalk of the megasporophyll or from the bract or from both and is not in any way derivable from the sterile part of the flower which was not present in the ancestral condition.

The walchias, ernestiodendrons and lebachias are believed to have evolved from the Cordaitales, in the female flowers of which the sterile scales were present. Even in some of the walchias, viz. *Walchiostrobus* (FLORIN, 1951, p. 334, FIG. 34e & f), the sterile scales are known to be present. Further, the lebachias are believed to be more primitive than the walchias and ernestiodendrons. It thus shows that in the remote ancestors from which the lines of evolution headed by ernestiodendrons came off possessed the sterile scales in the seed-scale complexes which were lost in the *Ernestiodendron* and walchias. This character remained lost even when the evolution had reached the Mesozoic *Mehtaia*-like ancestors. This lost character reappeared in the form of epimatium probably in the early Mesozoic and is seen in the *Sitholeya*, *Nipaniostrobus* and several of the modern podocarps (Arber's Law of Loss).

Remarks on the Fossil History of Indian Conifers — Writing about the fossil history of conifers in India Professor Sahni in 1931 remarked that by about the Tertiary times the group had become practically extinct. Recent work on the fossil woods belonging to the post-Jurassic horizons in India has greatly advanced our knowledge hitherto confined to a probably Cretaceous doubtful *Dadoxylon* sp. and an indeterminable conifer wood (SAHNI, 1931, p. 76) and to a Tertiary wood *Mesembrioxylon schinidianum* (SAHNI, 1931, p. 54). The recent report of the occurrence of two species of *Mesembrioxylon*, *M. trichinopoliense* Varma and *M. sarmai* Varma (VARMA, 1954), in the Cretaceous rocks of Trichinopoly and four species in the Tertiary deposits at Tiruvakkarai, Tirumangalam and

Pondicherry, viz. *M. sahnii*, *M. triuvakkarianum* (RAMANUJAM, 1953), *M. tirumangalense* (SURYANARAYANA, 1953) and *M. speciosum* (RAMANUJAM, 1954), and several species of *Dadoxylon* described by Shukla (1938, 1944) and Chitaley (1949a, 1949b) from the Deccan Intertrappean series coupled with a recent discovery of a silicified seed-cone different from the hitherto known Tertiary megastrobili from India (UTTAM PRAKASH, 1956), shows that the abundant conifer vegetation of the Indian Jurassics had a gradual reduction in its composition during the Cretaceous and the Tertiary horizons. Of the two important families of these fossil conifers, the Araucariaceae probably became completely extinct in the post-Tertiary period while the Podocarpaceae, which once constituted a great bulk of Jurassic conifers, was gradually reduced to a single survivor *Podocarpus latifolia* which grows in the Indian Peninsula today.

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EXPLANATION OF PLATES

PLATE 1

Masculostrobus podocarpoides sp. nov.

1. Type specimen. × 12.
2. Another cone. × 6.
3. *Masculostrobus* sp. A pollen grain. × 480.

Nipaniostrobus sahnii Rao emend.

4-6, 8. Compact seed-cones. × 8.
7. A loose seed-cone. × 8.
9. Distribution and orientation of stomata from a loose cone. × 150.

PLATE 2

Nipaniostrobus sahnii Rao emend.

10. Cross-section of a seed-cone. × 9.
11. Cross-section of cone-axis showing resin cells (*r*) and vascular supply (*Vas. b.*) to a seed-scale complex. × 27.
12. Stony layer in surface view. × 155.
13. Vertical section of a part of integument, showing the outermost layer (*ot. l.*), outer layer (*o.l.*), middle layer (*m.l.*) and inner layer (*i.l.*). × 600.
14. Cross-section of a part of integument showing three distinct layers as in Fig. 12. × 600.

PLATE 3

Nipaniostrobus pagiophylloides sp. nov.

15. Type specimen. c = cone. × 3·5.
16. Top portion of above enlarged showing the seed-cone (c). × 6.

Nipaniostrobus aciculifolia sp. nov.

17. Type specimen. c = cone. × 2.
18. Another shoot (sterile). × 3.
19. A section of shoot in Fig. 17. × 7.
20. Distribution and orientation of stomata and epidermal cells on a leaf. × 100.
21. A part of above enlarged to show the stomatal apparatuses. × 250.

PLATE 4

Mehtaia rajmahalensis gen. et sp. nov.

22. A megastrobilus lying in close proximity with a shoot. × 5.
23. Megastrobilus from above enlarged. × 12.
24. Another megastrobilus. × 12.
25. Proximal region of seed-cone in Fig. 23 showing leaves on the peduncle. × 25.

26. A part of shoot with a leaf shown in Fig. 22 enlarged. × 25.

PLATE 5

Mehtaia rajmahalensis sp. nov.

27. Stony layer in surface view. × 200.
28. A part of integument in vertical section. × 200.
29. A part of vascular supply to a seed-scale complex. *a* = single vascular supply arising from a bundle of the cone-axis. *b*, *c* = two branches of above vascular supply, '*b*' terminating at the base of the ovule and '*c*' entering the bract-scale. × 100.
30. A part of a seed showing the cross-section of the micropyle (*m*) bounded by palisade tissue and the tissue of the outer layer of the integument in surface view. × 200.

Mehtaia nipaniensis sp. nov.

31. Type specimen. × 11.
32, 33. Seed-scale complex. × 26.
The seed in Fig. 33 shows a twinning embryo (*e*), nucellus (*n*) and pollen grains (*p.g.*) and a marked micropyle (*m*).
34, 35. Pollen grains from the ovule shown in Fig. 33.

PLATE 6

Mehtaia santalensis sp. nov.

36, 37. The type specimen. × 2, × 6.
38. A part of the shoot showing the leaves. × 20.
39. Another shoot with a seed-cone lying in close proximity. × 3.
40-42. Other fragmentary shoots. × 3.
43. The cone enlarged from above. × 15.

Sitholeya rajmahalensis sp. nov.

44, 45. The type specimen. × 7, × 15.
46. A part of the specimen showing the proximal region of the ovule, micropyle (*a*) and the fertile bract (*b*).

PLATE 7

Nipanioruha granthia Rao emend.

47. A sterile shoot. × 3.
48. Showing the distribution and orientation on a part of a leaf. × 100.
49, 50. Fragmentary male cone bearing shoots. × 8, × 6.
51. An oblique vertical section of the male cone in shoot shown in Fig. 50. × 100.
52. A cross-section of a cone from a slice of chert. × 45.
53, 54. Another male cone apical portion of which is seen in Fig. 54: the cone is surrounded by leaves at its base. × 20.

PLATE 8

Nipanioruha granthia Rao emend.

55. A seed-cone. × 11.
56. A part of the cone showing the seed-scales. 'a' a bract-scale with lobed lower margin. × 18.
57. The proximal region of the cone showing the presence of a needle-like leaf on the peduncle. × 18.

Nipanioruha lanceolata sp. nov.

58-60. Sterile fragmentary shoots. × 3, × 9.
61. The epidermal cells. × 70.
62, 63. The distribution and orientation of the stomata. × 140.

Nipanioruha curvifolia sp. nov.

64, 65. Sterile fragmentary shoots. × 3.
66. A part of shoot in Fig. 65 enlarged. × 9.
67. Leaves in cross-section from above shoot. × 9.

PLATE 9

Indophyllum sahnii sp. nov.

68. The type specimen. × 3.
69. A part of above enlarged. × 12.
70. Showing the distribution of stomata on a part of a leaf. × 230.
71. Two stomatal apparatuses shown enlarged. × 740.
72. The epidermal remains of another fragmentary shoot. × 35.
73. Distribution and orientation of stomata on a leaf from above. × 70.

PLATE 10

Indophyllum raoi sp. nov.

74. Type specimen. × 3.
75. A part of above enlarged. × 12.
76. Distribution and orientation of stomata on a leaf. × 70.

Indophyllum nipanica sp. nov.

77, 78. Shoots. × 3.
79. A part of shoot in Fig. 78 enlarged. × 12.

PLATE 11

Indophyllum nipanica sp. nov.

80. Another shoot attached with a stem not shown in the figure. × 7.
81. A part of vertical longitudinal section of tracheids showing the pitting. × 250.
82. A part of vertical tangential section of tracheids showing medullary rays. × 100.
83. A part of vertical longitudinal section of tracheids showing spirals. × 400.
84. A part of fragmentary male shoot. × 25.
85. Pollen from above. × 250.
86. Another fertile shoot. × 7.
87. The fructification from above shown enlarged. × 28.

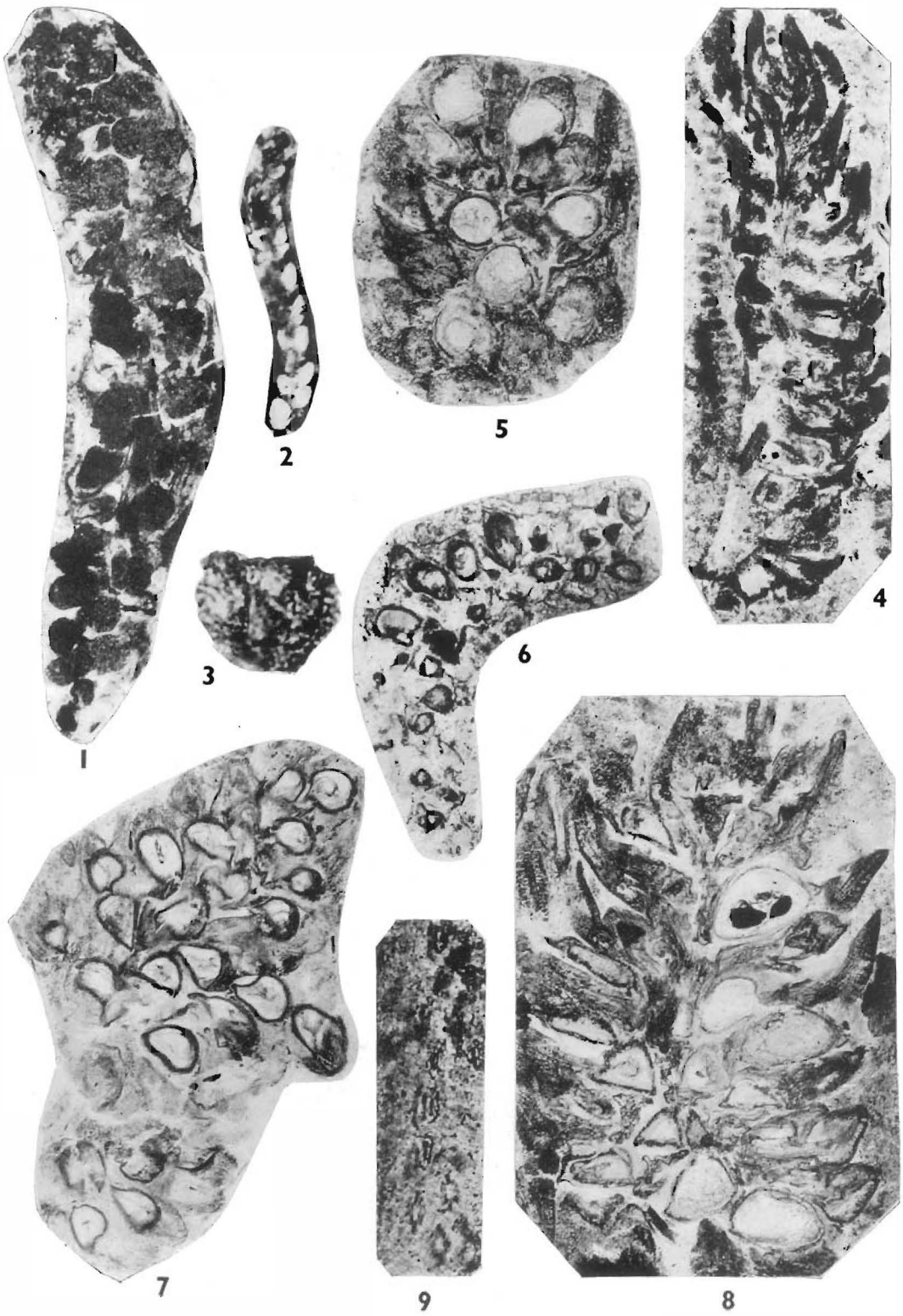
PLATE 12

Elatocladus sahnii sp. nov.

88. Type specimen. × 3.
89. The same enlarged. × 7.
90. Epidermal cells. × 350.
91. Two stomatal apparatuses. × 350.

Pagiophyllum araucaroides sp. nov.

92. Type specimen. × 7.
93. A part of vertical section of a leaf showing the transfusion tissue and mesophyll. × 100.
94. A few stomata on a leaf. × 200.
95. A few epidermal cells on a leaf. × 200.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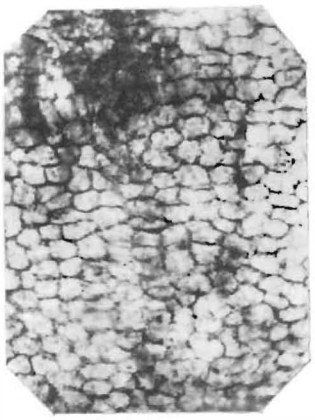

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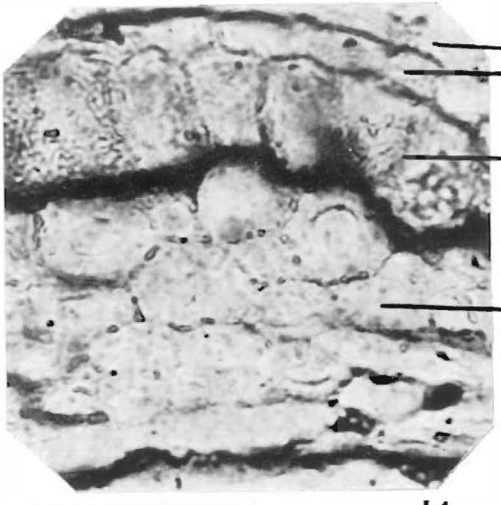

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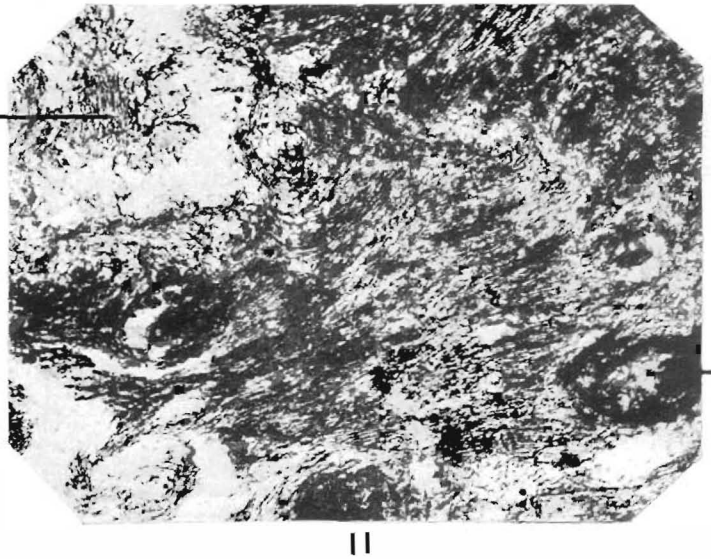

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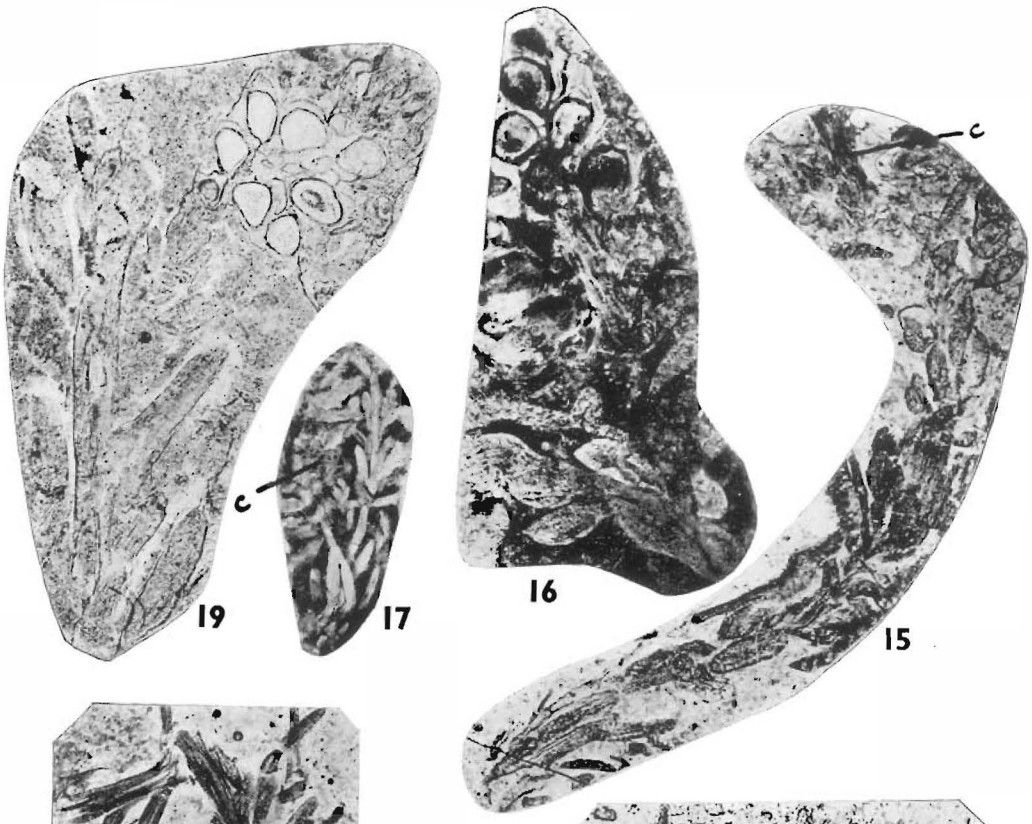
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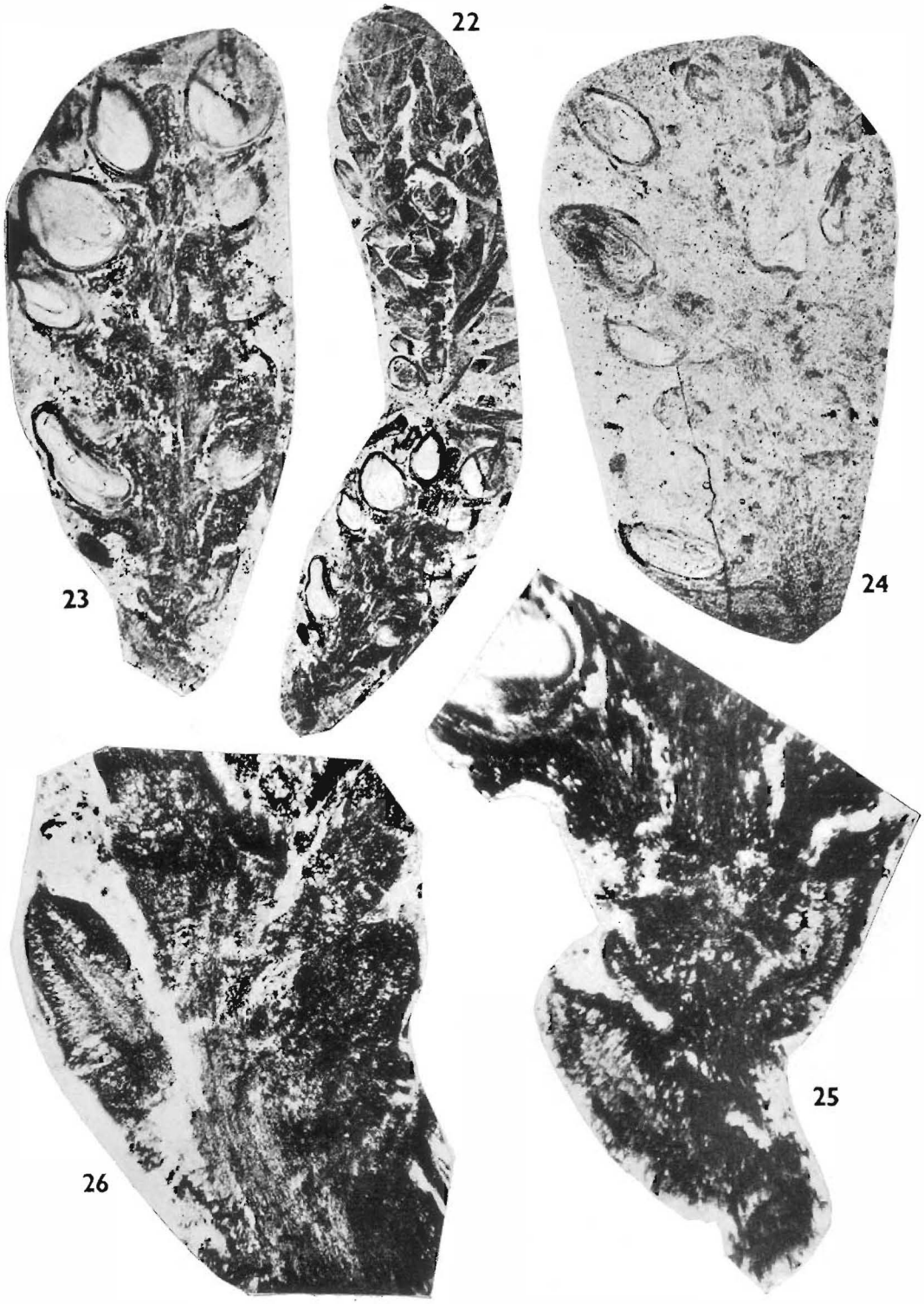
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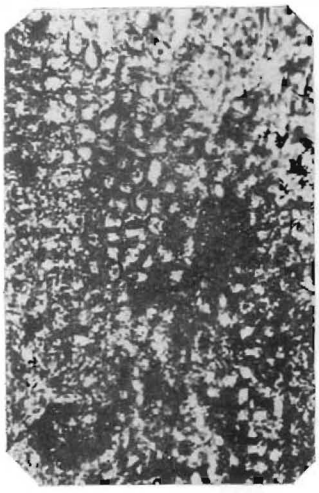

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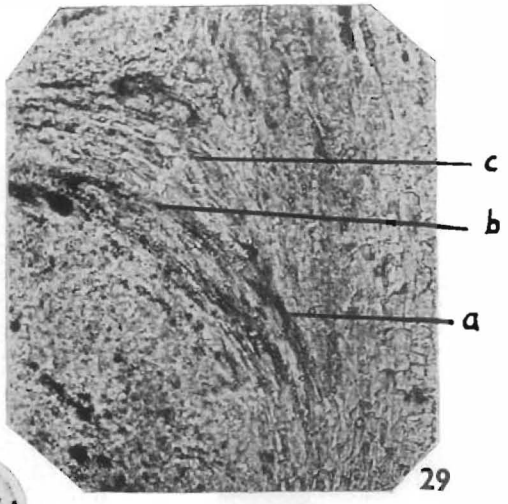

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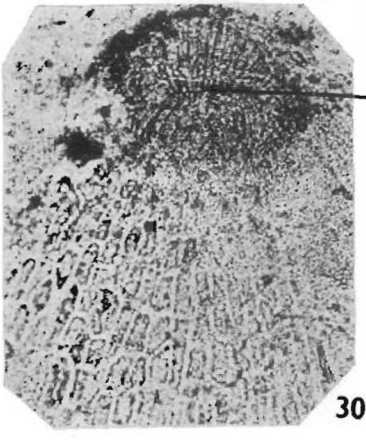

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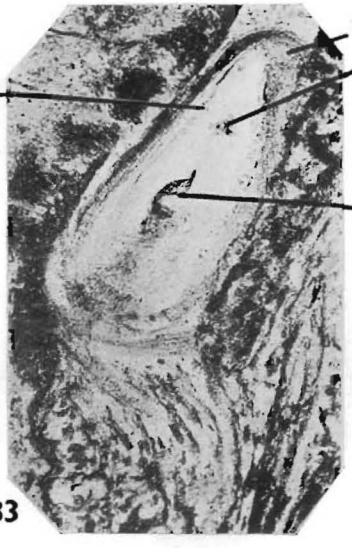

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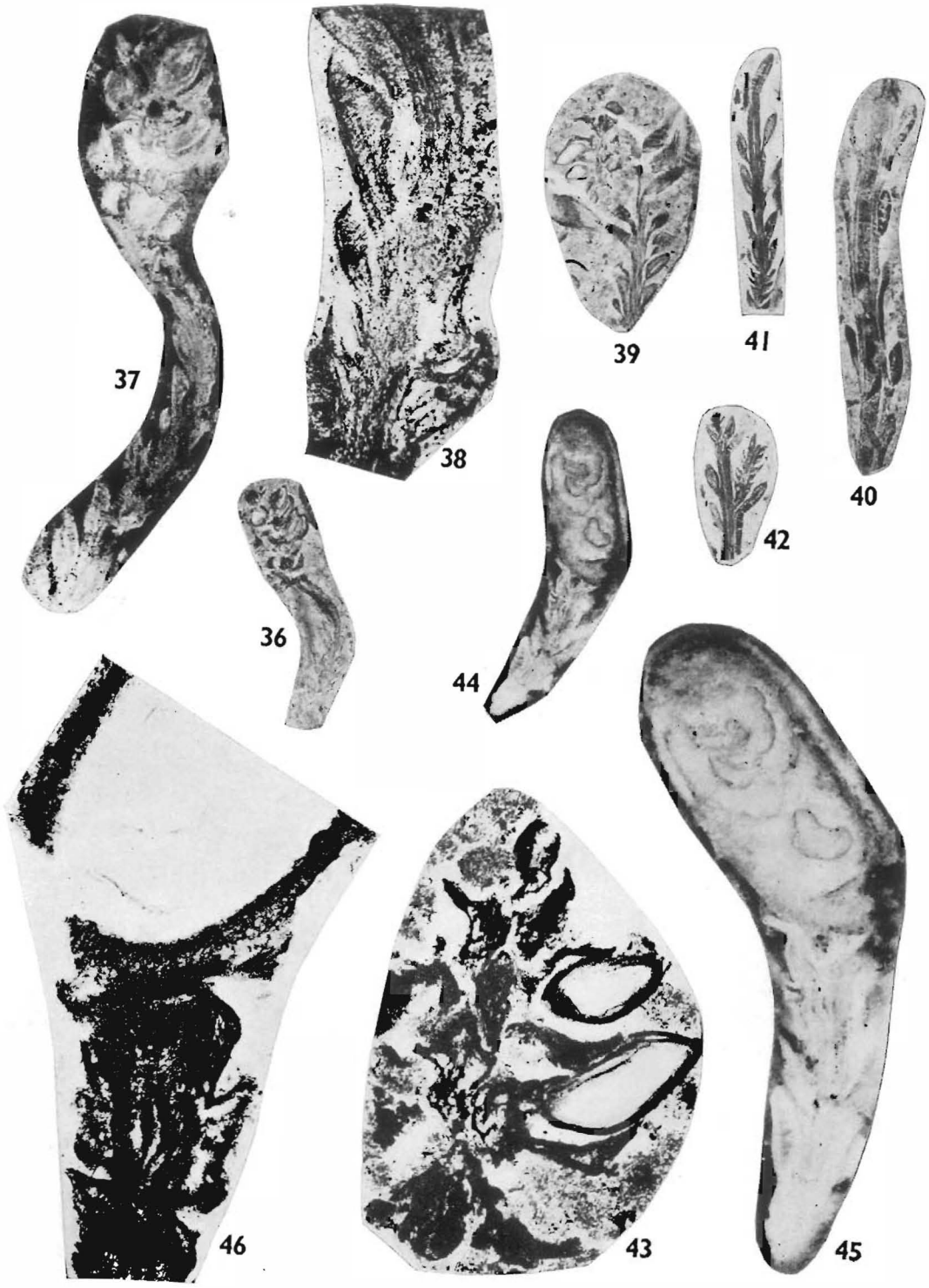
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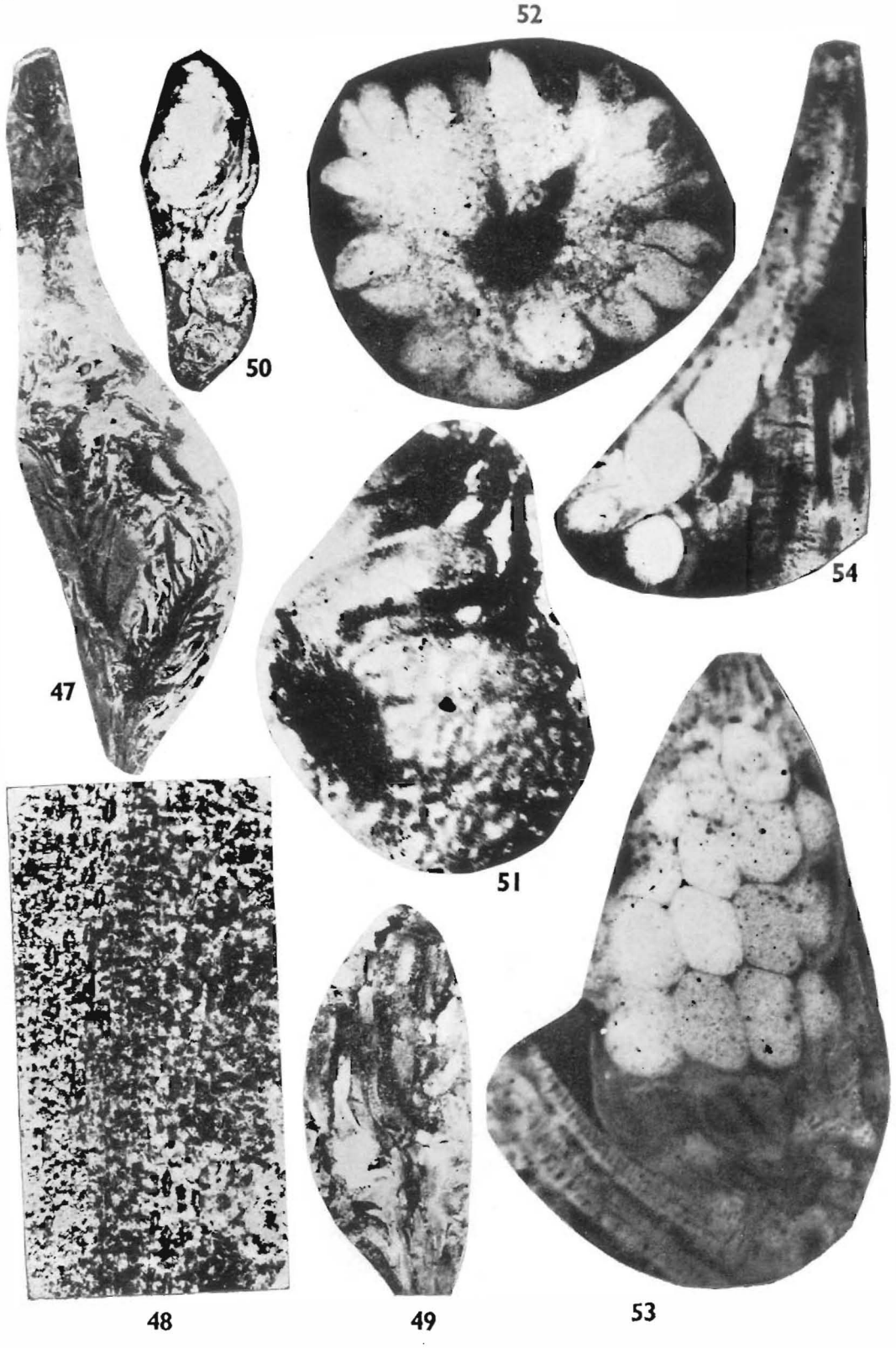
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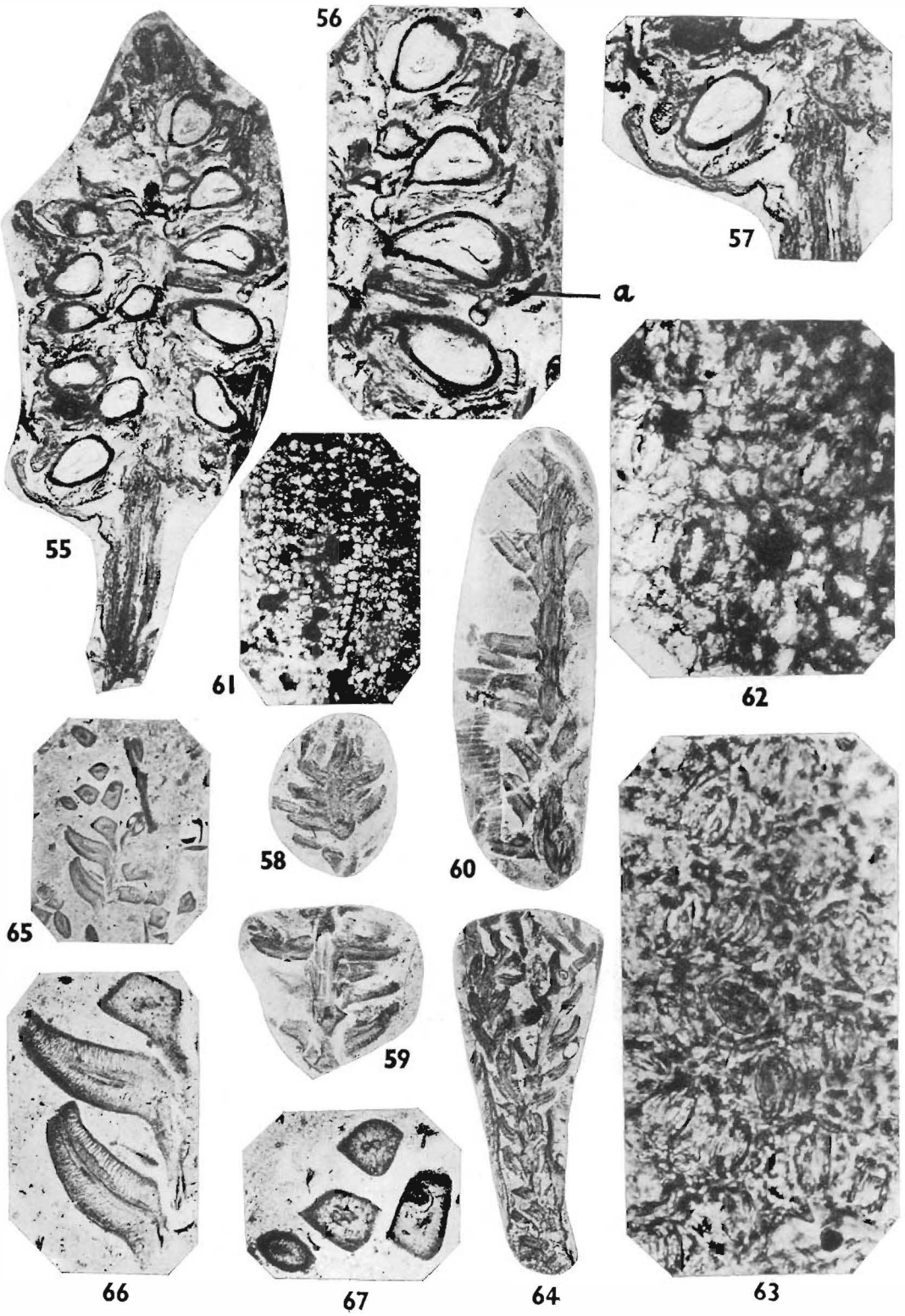
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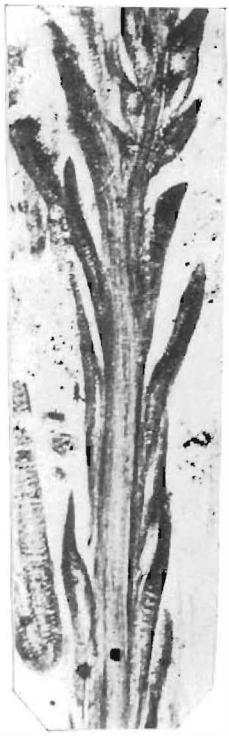

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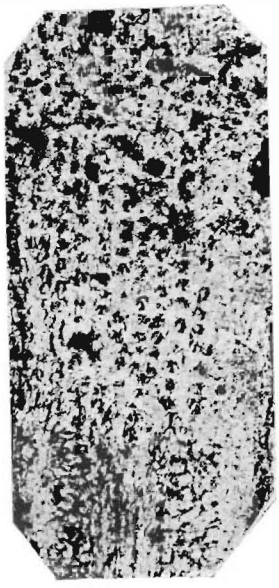

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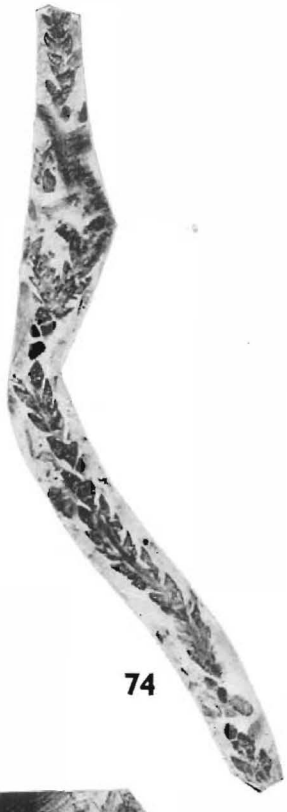

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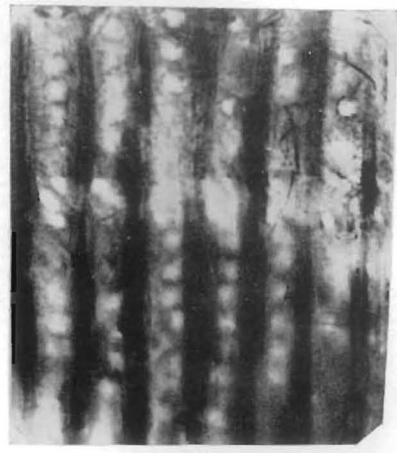

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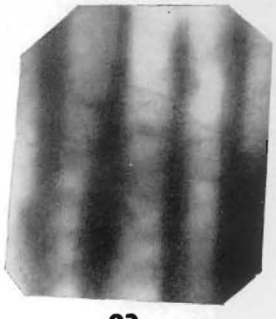

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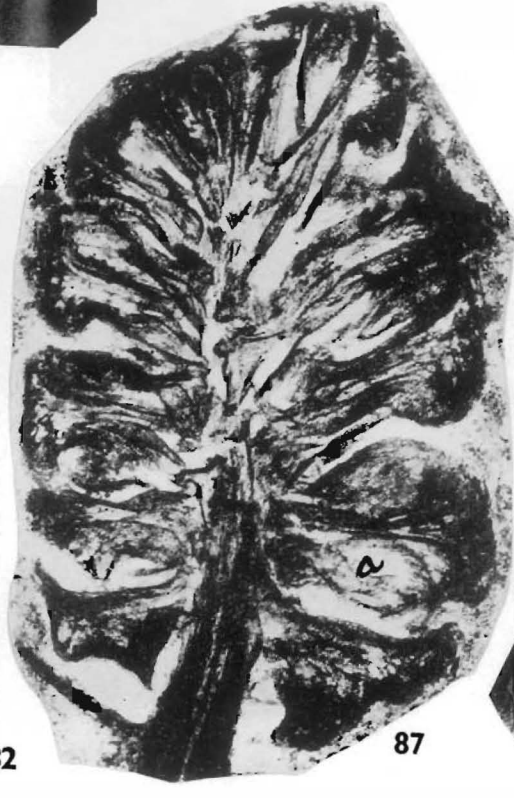

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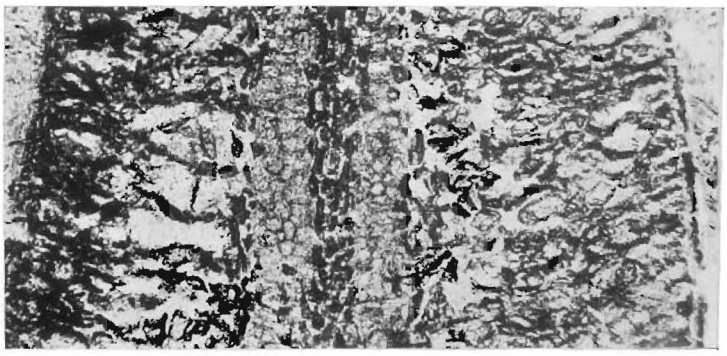

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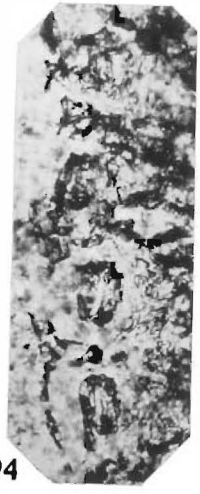

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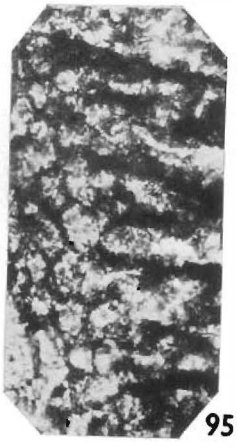

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