FRUCTIFICATIONS OF GLOSSOPTERIDAE FROM INDIA

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ABSTRACT

Three new species of *Scutum*, one species of *Cistella* and a new genus of one winged seed, *Indocarpus*, are described in this paper. *Scutum sahnii* has been found attached to a leaf with venation of *Glossopteris longicaulis* type. *Scutum* is interpreted as a gymnospermous female reproductive organ of some *Glossopteris* species consisting of a bilaterally symmetrical receptacle bearing a large number of naked ovules, and covered on one side by a protective scale-leaf with *Glossopteris* type of venation. Both the scale-leaf and the ovule bearing receptacle are carried on a common pedicel which, in its turn, is attached to the petiole of a *Glossopteris* leaf. *Dictyopteridium* is also shown to be a fructification similar in organization to *Scutum*, possessing a cylindrical ovule bearing head and a scale leaf covering one side of the fructification. It is also suggested that some *Cistella* type of fructifications might be the seedless receptacles of *Scutum*.

INTRODUCTION

IN 1952 Plumstead described reproductive organs of six species of *Glossopteris* and created two genera, viz. *Scutum* and *Lanceolatus*, for their reception. *Scutum* is described as a pedicellate bilaterally symmetrical cupule which grows from the midrib of a leaf of *Glossopteris*. The cupule may be round, oval, lanceolate or ovate with a raised central head and a flat surrounding wing which is often fluted or striated. The fertile half of the cupule is described as containing a number of small oval sacs, embedded in the central head. Later Plumstead (1956) interpreted the cupule as a bisexual flower, the fertile half containing the seeds, and the protective half bearing bract-like staminate organs which carried pollen. The other genus *Lanceolatus* has been found only on the leaves of *Glossopteris retifera* and, like *Scutum*, the fertile head consists of a number of small oval sacs. It has neither a wing nor a pedicel and the cushioned surface on which the sacs grow is the leaf surface itself. The cupule in *Lanceolatus* is described as fused with the leaf.

Plumstead (1958a) described *Ottokaria*, which was earlier reported by Zeiller (1902), and placed *Scutum*, *Lanceolatus* and *Ottokaria* under a new class *Glossopteridae*. In 1958b she described three new fructifications under the *Glossopteridae*, *Hirsutum*, *Cistella* and *Pluma*. *Scutum dutoitides* was placed under a new genus *Hirsutum* because its pollen organs were like thin filaments, instead of bract-like flat projections as in *Scutum* and also the wing being much narrower in the former. *Cistella* is described as an unwinged fructification with certain features common to both *Scutum* and *Lanceolatus*. In *Cistella* the cupule is like a heart-shaped casket and is wingless. It consists of two halves, the female half with well developed oval sacs and the protective half concave and made up of harder tissue. *Pluma* is a fructification which grows from the petiole with a characteristic curved droop and a pendulous fringe, which is reminiscent of ostrich feather.

Scutum has 9 species, *Hirsutum* 2, *Lanceolatus* 3, *Ottokaria* 3, *Cistella* 2 and *Pluma* 2 (Plumstead, 1958).

Out of these six types of fructifications, five have been recorded from India. Sen (1955) recorded an ovulate organ from Mohuda coal seam, which Plumstead later (1958b) included under *Lanceolatus communis*. There is also another record of poorly preserved *Lanceolatus* from the lower Barakars of Pachwara coalfield, Bihar (Chatterjee & Sen, 1963). Two impressions (Varma, 1963) from Chintalpudi sandstones were assigned to *Scutum leslium* and *Hirsutum dutoitides* (*Scutum dutoitides*), but the preservation is too poor even for correct generic identification. Mukherjee *et al.* (1966) described a fructification closely resembling *Scutum leslium* attached to the leaf of *G. browniana*. Maceration of the central head yielded unwinged, bilateral, monolete spores and seed-like bodies. They also reported *Scutum dutoitides* attached to a leaf of *G. indica*. Surange & Maheshwari (1970) described *Scutum* and *Cistella* from Orissa. Maheshwari (1965) described a new species, *Cistella indica*, from the Raniganj coalfield. *Ottokaria bengalensis* was instituted earlier by Zeiller (1902) from the Karharbari beds, which, according to

Mukherjee *et al.* (1966) is attached to the leaf of *Glossopteris indica*.

The specimens described here were collected from a thick bed of hard, compact, clayey shale, exposed at Hinjrida Ghati in Dhenkanal district of Orissa.

DESCRIPTION

1. *Indocarpus* gen. nov.

Surange & Maheshwari (1970) reported several "ovule bearing scales", which they assigned to *Scutum* type of fructification. In our collection also a large number of such seeds are present and for which a new generic name, *Indocarpus*, is proposed here.

Generic diagnosis — One winged seed; stalk short, not always visible; nucellus round at chalazal end, pointed or bifid at the micropylar end; wing one, large, flat, extended on one side well beyond nucellar end.

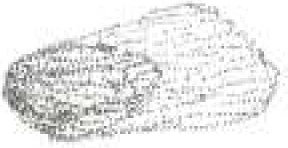
Type species — *Indocarpus elongatus* sp. nov.

Holotype— 35090.

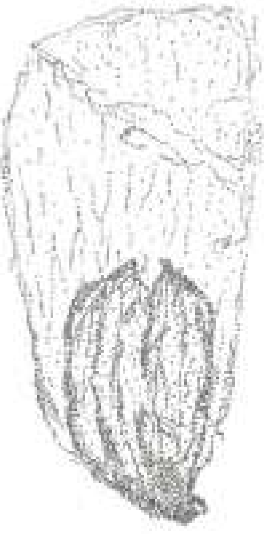
Horizon — Raniganj Stage.

Locality — Handappa, Orissa, India.

Pl. 2 and 4, Figs. 5, 14; Text-figs. 1, 2 illustrate the seeds described under this genus. They are present in large numbers in our collection. The seed has one, expanded, flat wing, projected on one side



TEXT-FIG. 1 — *Indocarpus elongatus* gen. nov. et sp. nov. A group of one winged seeds lying round of squashed axis. × 4.



TEXT-FIG. 2 — One winged seed of *Indocarpus elongatus*. Note the short stalk and bifid micropylar end of the nucellus. × 7.

far beyond the micropylar end. The seed including the wing measures 8-10 mm. in length and 3-4 mm. in breadth (Text-fig. 2). Towards the chalazal end, a few seeds show a short stalk but in majority of them no stalk is seen and the chalazal end looks rounded. The nucellus measures 4 × 2 mm. and occasionally a seed shows pointed or bifid micropylar end (Text-fig. 2). The wing can be regarded as an expansion of the integument of the seed. It is narrow on the sides, which almost closely encloses the nucellus and then expands and extends far beyond the nucellar end for about 3-4 mm. or more. Free part of the wing is flat and measures 4-6 mm. in length from the micropylar end and 3-5 mm. in breadth. Pl. 4, Fig. 14 shows a seed which has thick walled nucellus and a long wing with longitudinal markings. The asymmetrical expansion of wing on one side makes the seed look like an ovule-bearing ovuliferous scale. Earlier Surange & Maheshwari (1970) interpreted the wing as a scale and the inner ovate body as an ovule or seed. The one-winged seed, therefore, was described by them as a ovule-bearing scale. They further assigned these seeds to *Scutum*, suggesting that the wing-like marginal expansion seen in *Scutum* must have been caused by overlapping of the free half of the "scales" (wing). The seed is, however, too large to suggest any relation with the comparatively smaller specimens of *Scutum* present in the collections from this locality. But some South African specimens of *Scutum* seem to possess long and large seeds, giving a broad winged appearance to fructifications. Such large specimens of *Scutum* might have possessed this type of seed, but at present there is no such evidence.

However, there is also a strong possibility that these seeds were borne on a stalked, pad-like disc type of organ. Text-fig. 1; Pl. 2, Fig. 4 show a group of seeds lying close together, as if they have been crushed out of a fructification. There is an impression of a squashed object of irregular shape, lying in the centre of the crowded seeds. One or two seeds appear to have been attached to it, but the attachment is not clearly seen (Text-fig. 1).

The type of seed described here is not comparable to any of the known seeds of the Glossopteris flora and so it is placed under a new name, *Indocarpus elongatus* gen. et sp. nov.

2. *Scutum sahnii* sp. nov.

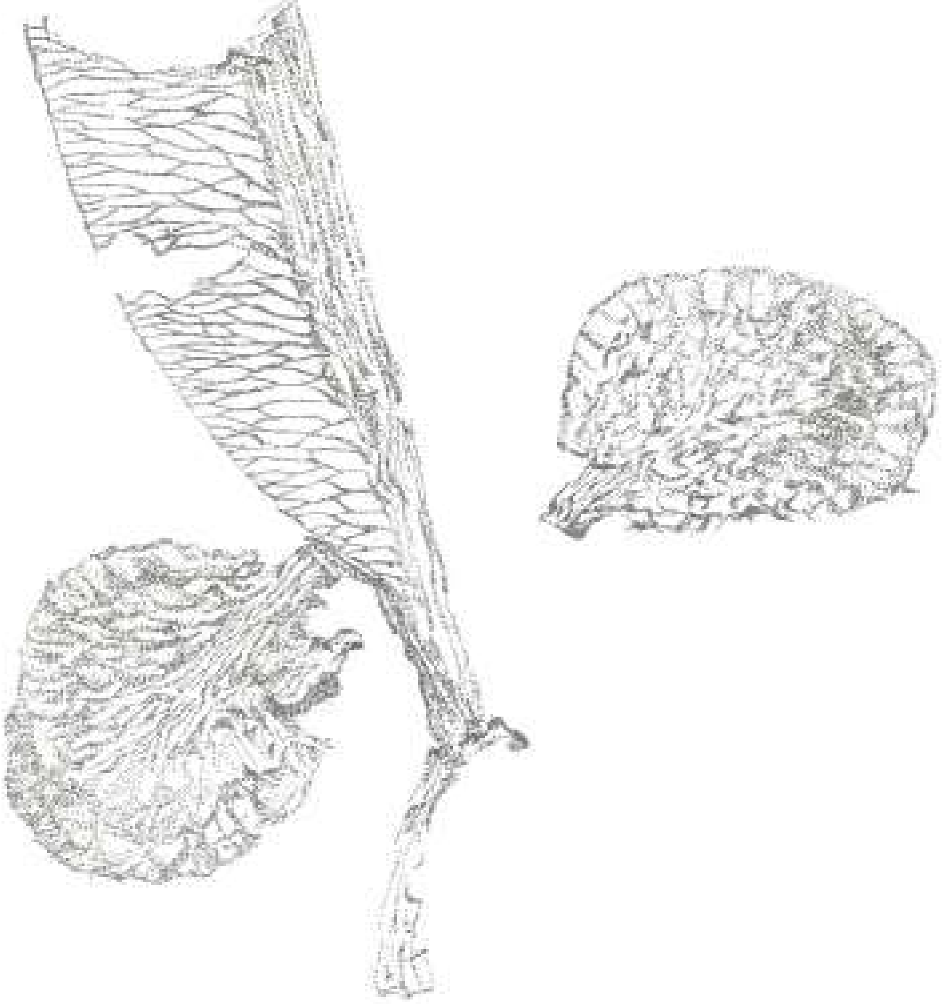
Diagnosis— Fructification attached to leaf showing venation of *Glossopteris longicaulis* type; fructification almost round, consisting of seed bearing head or receptacle and a veined scale leaf borne on common pedicel; scale leaf with distinct midrib, dissolves halfway upwards into bifurcating, secondary veins; secondary veins form meshes; seed bearing head or receptacle convex, lense-shaped, bear ovules or seeds; wing-like rim all round except at the base.

Holotype — 35093.

Horizon — Raniganj Stage.

Locality — Handappa, Orissa, India.

The fructification is attached to a leaf of *Glossopteris* (Pl. 1, Fig. 1; Text-fig. 3). The leaf is incomplete, but the venation indicates that it belongs to *Glossopteris longicaulis* type (Text-fig. 3). The leaf has a long petiole measuring 3 cm. in length and 3 mm. in breadth. The petiole continues into the lamina as a prominent midrib, which in the basal region is as broad as the petiole. The secondary veins are prominent and form broad meshes, lying almost at right angles to the midrib. Each secondary vein arises at an acute angle and bifurcates immediately close to midrib, at the same time curving outwards almost at right angles to it. Each bifurcation



TEXT-FIG. 3 — Holotype of *Scutum sahnii* attached with a long pedicel to a leaf with *Glossopteris conspicua* type of venation. On the right is shown the seed bearing receptacle and on the leaf is its attached counterpart, the veined scale leaf. × 3.

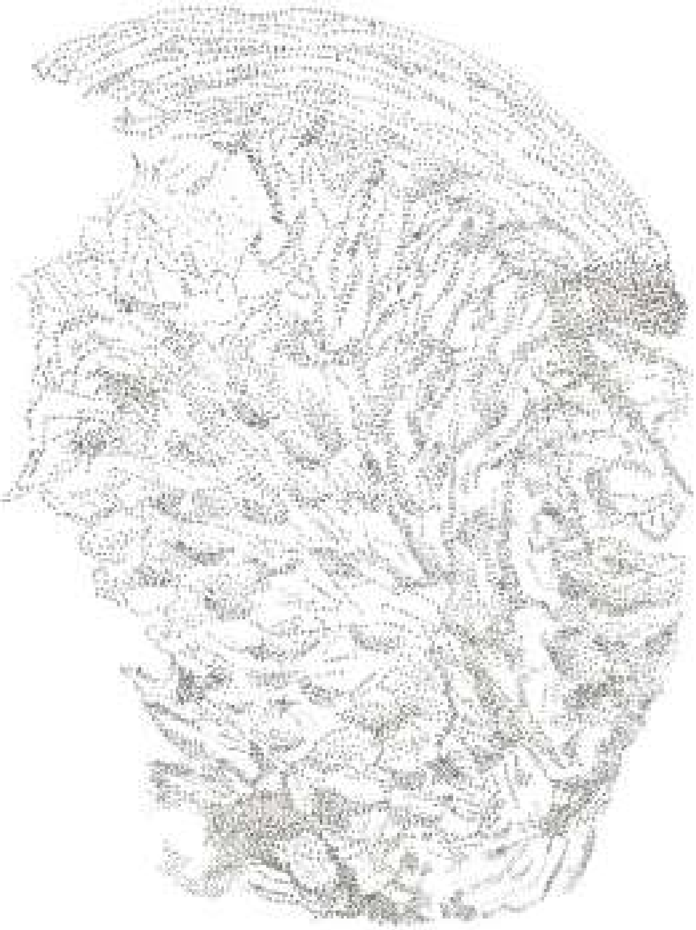
again forks, one of the fork either joins the adjoining vein or gives out a small cross connection which meets the adjoining vein, thus enclosing a mesh. Each secondary vein forks three or four times during its course up to the margin. The meshes near the midrib are large and broad, becoming slightly narrower towards the margin. Near the base the meshes are smaller than those in the middle region of the leaf. Each mesh is diamond-shaped, hexagonal or pointed at both ends, and is much longer than broad. The meshes are straight and not arched.

The fructification is attached to the petiole by a long stalk, 1·3 cm. in length and 2 mm. in breadth (Pl. 1, Figs. 1, 2). The stalk is partly preserved and it is seen lying along the side of the petiole and ultimately joining with it (Text-fig. 3).

The fructification appears to be a bilaterally symmetrical organ, almost round to oval in shape and measures 2×1·8 cm. (Text-fig. 3). The type specimen (Pl. 2, Fig. 2) and its counterpart (Pl. 1, Fig. 1) have left quite different impressions on the rock. The counterpart (Pl. 1, Fig. 1) is a round to oval organ with a short stalk, concave in the middle or saucer-shaped, with 2 mm. wide wing-like rim all round, except at the base, where it is broken by the stalk. Plumstead has described one half of *Scutum* as veined. This organ is also distinctly veined, with a thick midrib, almost as wide as the stalk and, about halfway upwards, dissolving into dichotomizing secondary veins. The midrib also gives out lateral secondary veins, which further bifurcate and anastomose, forming meshes. This type of venation pattern is similar to that of *Glossopteris* leaves or the scale leaves, which are usually associated with reproductive organs described by Surange & Chandra (1973). In our opinion, therefore, the so-called "veined half" of *Scutum* should be regarded as foliar in nature, equivalent to a scale-leaf, a spathe or a protective foliar organ.

The other half, the so-called "fertile half", is a stalked central head or a receptacle, oval to round and convex, and with a wing-like rim as broad as seen in the counterpart (Pl. 2, Fig. 2). The central head shows some oval impressions of what must have been the seeds, and at some places irregular cavities from which the seeds had been torn off. That the central head can be regarded as a receptacle or a swollen, seed-bearing head is clear from comparison with other species of *Scutum* (see Pl. 3, Figs. 6, 7, 8 & 9). The morphology of *Scutum* is discussed in the latter part of this paper.

Pl. 4, Fig. 10 and Text-fig. 4 shows another detached fructification which is round and incomplete, preserved upside down with the scale leaf or the spathe-like foliar covering lying underneath the seed bearing receptacle. A part of the scale leaf



TEXT-FIG. 4 — A seed bearing receptacle of *Scutum sahnii*. A part of the scale leaf lying below the receptacle is seen on the right. × 5.

is seen coming out from below on the right side, somewhat displaced and crushed, forming a sort of wing-like rim (although incomplete) round the seed bearing receptacle.

Comparison— Plumstead (1958b) described *Pluma* type of fructification on *Glossopteris longicaulis* leaf. Our specimen does not compare with *Pluma* or any of the species described under *Scutum* so far. *Scutum leslium* is also a round fructification, but it has very wide "wing" as compared to the "head". *Scutum sahnii* has a narrow rim. *Scutum thomasii* has a 3 mm. wide "wing", but the specimen is egg shaped. *Scutum draperium*, which is borne on *Glossopteris conspicua* (Plumstead, 1958b), is also different from *Scutum sahnii* in possessing large oval head with narrow fluted wing. Most of the South African species appear to possess wider "wings" than the Indian specimens described here. Our specimen is also distinct from *Scutum leslium* and *Scutum dutoitides* described by Mukherjee *et al.* (1966) from India and *Scutum elongatum* and *Scutum indicum* described in this paper.

3. *Scutum elongatum* sp. nov.

Diagnosis — Female reproductive organ; scale-leaf or spathe-like covering veined; seed or ovule bearing receptacle oval-elongate, almost twice as long as broad; marginal seeds large, crowded, arranged in a row, forming a definite rim; seed cushions or seeds on central part of receptacle large, almost round, with small round marking in the centre.

Holotype — 35095.

Horizon — Raniganj Stage.

Locality — Handappa, Orissa, India.

Pl. 4, Fig. 11 illustrates the type specimen which is a cast. Its counterpart shows a poorly and incompletely preserved scale-leaf or a spathe-like covering, with an indication of a midrib on it. Secondary venation is not clearly preserved. There is, however, no doubt that the counterpart is a veined organ and it is not a negative impression of the seed bearing head.

The fructification is elongately oval, measuring 2 cm. in length and 1·2 cm. in breadth with a short stalk, about 2 mm. in breadth. It is broadest in the middle, tapering more rapidly towards the apex than towards the base. The apex and base are rounded; the apex may be somewhat narrower than the base. The marginal ovules or seeds are arranged in a row, overlapping one another and forming a definite "wing-like" rim all round, except at the base, where the receptacle is attached to the stalk. The position of each ovule or seed is marked from the other on the rim by cross markings. The wing-like rim is 2 mm. in breadth which is almost the size of the seed. The marginal seed must have been laterally compressed during preservation and so they are seen here lying in a row, forming a wing-like rim.

Text-fig. 5 shows an incomplete, obliquely preserved specimen, with laterally compressed seeds on the margin, attached to round cushions on the receptacle. The seeds in the middle region were pressed vertically downwards and so are seen preserved as circular mounds, about 2 mm. in diameter, and showing a central circular scar of the micropylar end in the centre. The seed is large and measures about 2·5-3 × 1 mm.

Pl. 3, Fig. 9 illustrates another specimen placed under this species. The fructification is 2 cm. long and 1 cm. broad.

Comparison — *Scutum elongatum* differs from *S. sahnii* and *S. indicum* in shape and size. The seeds of *S. elongatum* are larger than those of *S. sahnii* and shorter than those of *S. indica*. Its scale leaf also has a different type of venation. All the three fructifications look quite distinct from one another. *S. elongatum* does not also resemble with any of the South African species of *Scutum* described by Plumstead. The organization of *Scutum* being the same, the specific differences will naturally be found in shape and size of the seed bearing receptacle and the details of seed structure. In impressions or casts, the details of seed structure being not available, the specific distinctions would necessarily be based on the size, shape and other details of the receptacle and the impressions of seeds.

4. *Scutum indicum* sp. nov.

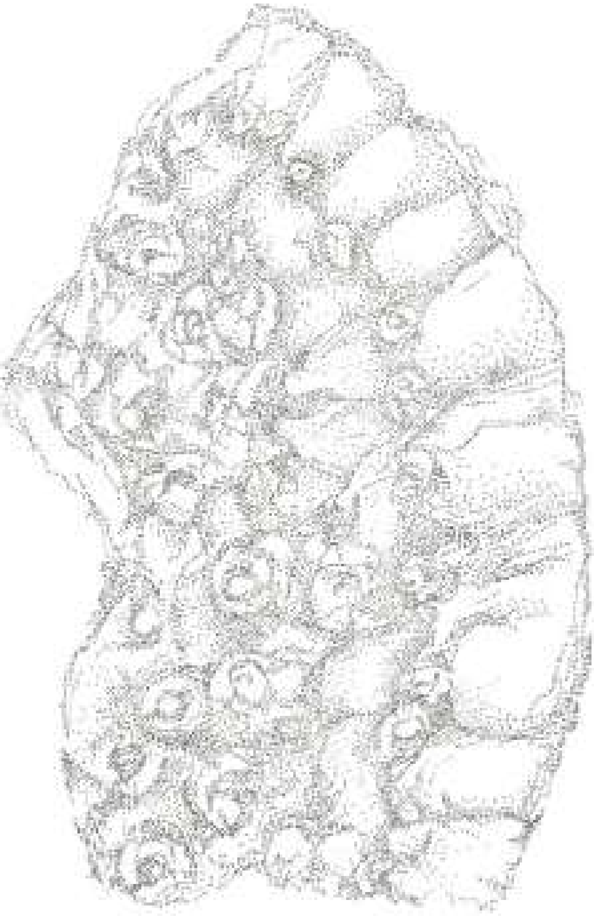
Diagnosis— Fructification broad, flat, apex as wide as base, slightly more long than broad; seeds large, elongated.

Holotype — 35097.

Horizon — Raniganj Stage.

Locality — Handappa, Orissa, India.

Pl. 3, Figs. 6, 7, 8 and Text-figs. 6, 7 show casts of fructifications described under this specific name. In shape and size they are different from those described above



TEXT-FIG. 5 — An obliquely compressed specimen of *Scutum elongatum*. Marginal seeds are laterally compressed and are seen attached to round cushions. Cushions on the right side are round with a circular mark in the middle.

under *S. sahnii* and *S. elongatum*. The stalked fructification in Pl. 3, Fig. 8 is 2·3 cm. long and 1·5 cm. broad. The stalk measures 4 mm. in length. The lateral sides of the fructification are almost parallel to each other, converging into a broad apex and so the fructification looks broad and flat. The marginal seeds are very large, and laterally compressed, and are seen arranged in a row round the margin, thereby forming a broad wing-like rim. The counterparts of all specimens described under this species were lost while breaking the shales. The seeds are large and measure 3-2·5 mm. × 1·5 mm.

The specimen illustrated in Pl. 3, Fig. 7; Text-fig. 6 is a well preserved cast of a seed bearing receptacle in which large, marginal, laterally compressed seeds are clearly seen attached to round seed cushions on the receptacle. The specimen is incomplete and measures 1·5 cm. in length and 1·5 cm. in breadth; the central portion in between the marginal seeds is narrow and about 7 mm. broad. Towards the apex in the middle are seen scars of circular seed cushions, about 1 mm. in diameter. Seeds in this region were perhaps knocked off during preservation, or they were shed in usual course. In the basal region, some seeds are seen obliquely compressed. Marginal seeds were compressed laterally and so were flattened lengthwise. Some of them are seen still attached to the seed

TEXT-FIG. 6 — Holotype of *Scutum indicum* sp. nov. Note the laterally compressed marginal seeds still attached to the cushions. × 8.

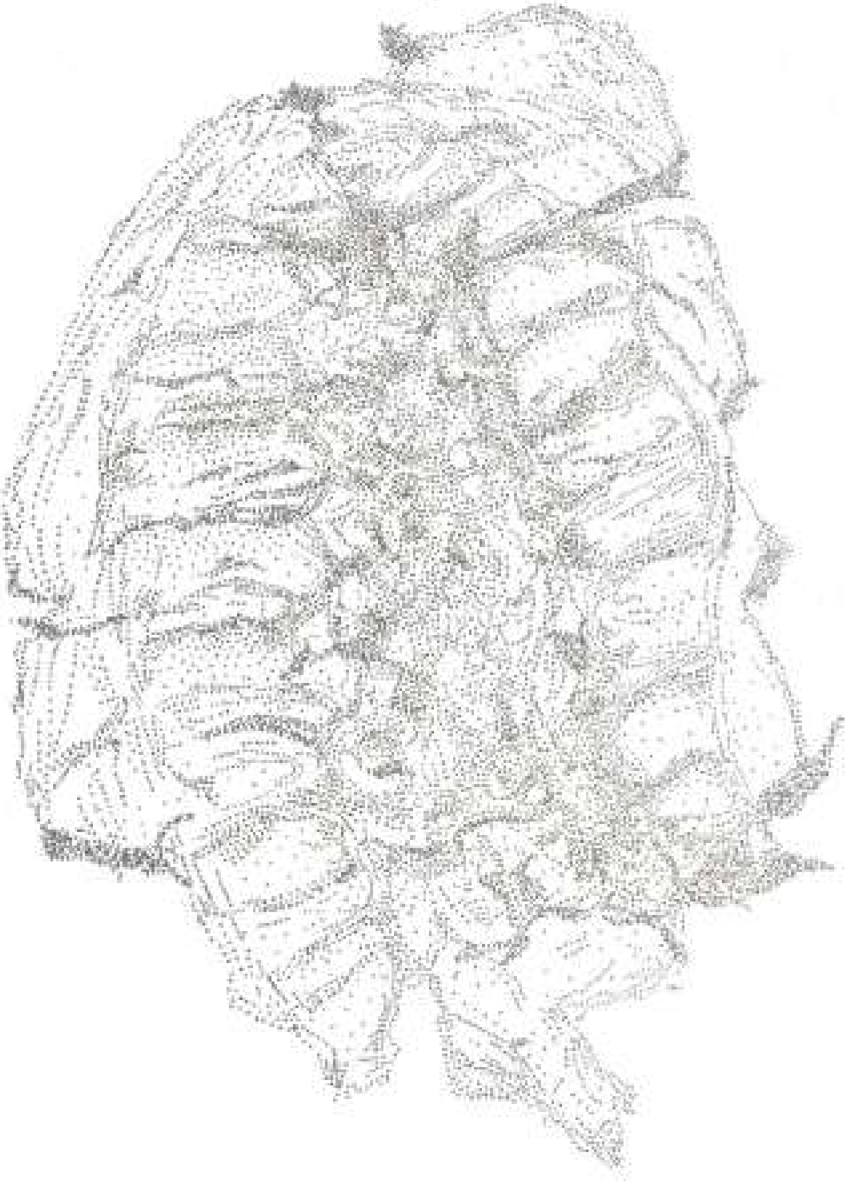
cushions (Text-fig. 6). The seed measures 4×2 mm. in size.

In Pl. 3, Fig. 6 and Text-fig. 7 is shown another specimen of seed bearing receptacle with large, marginal seeds and narrow central region with round scars of seed cushions. This specimen was somewhat obliquely compressed so that the marginal seeds were pushed on to the central part of the receptacle and the scale-leaf lying below it appeared as a rim outside the ovules on the left side. Some marginal seeds on the right are half removed, revealing underneath the impression of a scale-leaf or a spathe-like foliar covering. The wing-like rim seen on the left upper side is also a part of the same scale-leaf. The fructification in this case is preserved with the seed bearing head lying above the scale leaf.

Comparison — *Scutum indicum* is distinct from *S. sahnii* and *S. elongatum* in possessing very large seeds and in shape and size of the receptacle. It is also distinct from other species of *Scutum* described from South Africa.

5. *Cistella ovata*

Diagnosis — Fructification stalked, unwinged, oval; ovate head of receptacle with



TEXT-FIG. 7 — A seed bearing receptacle of *Scutum indicum*. × 8.

round seed scars, spirally arranged; seed cushion round with circular, raised impression in centre.

Holotype — 35100.

Horizon — Raniganj Stage.

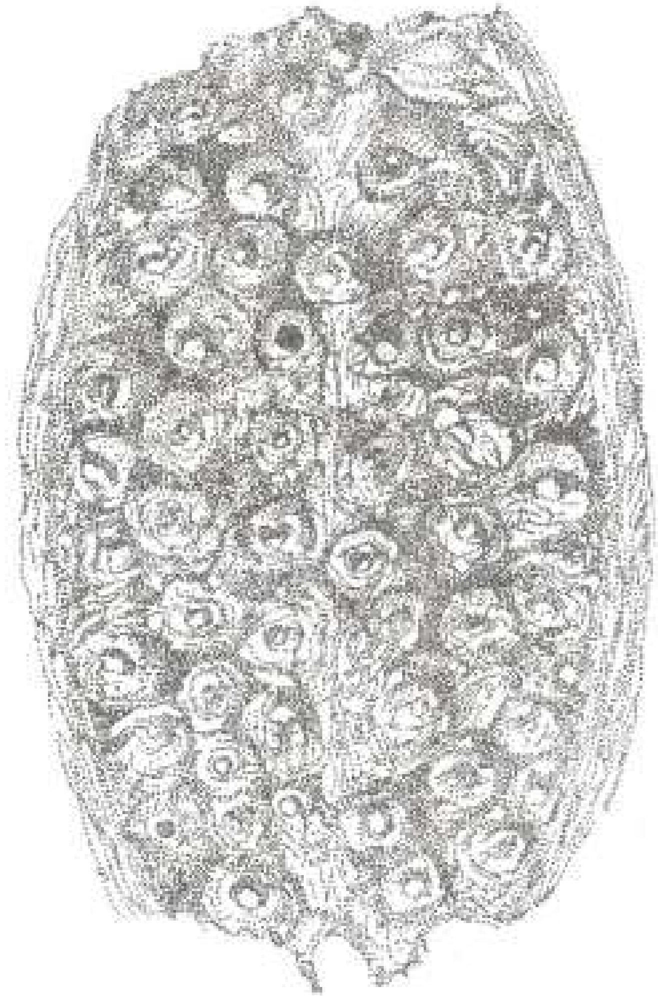
Locality — Handappa, Orissa, India.

Pl. 4, Fig. 13 shows a small fructification measuring 1·4 cm. in length and 7 mm. in breadth. It does not possess a wing-like rim all round as in *Scutum* and, therefore, this specimen is placed under the genus *Cistella*. The fructification has a small stalk, about 2 mm. long and 1 mm. broad. The ovate seed bearing receptacle is dotted with large, spirally arranged, round scars on which the seeds must have been attached. Each scar is distinct, and although those on the margin appear to be arranged in a row one below the other, they do not form a wing-like rim round the fructification.

Each scar measures about 1 mm. in diameter and shows in its centre a round raised impression which must be that of a seed stalk. The counterpart of the specimen shows faint impressions of the seed scars and looks like a negative impression of the specimen. It is not a scale leaf or a veined foliar spathe-like organ, which is absent here.

Pl. 4, Fig. 12 shows another specimen of *Cistella*. It has a long stalk, 1 cm. long and 4 mm. broad. The seed bearing head or receptacle is elongated, almost cylindrical with bluntly rounded apex and measures 2 cm. in length and 7 mm. in breadth.

Text-fig. 8 shows an incomplete, oval receptacle of *Cistella* studded with large round



TEXT-FIG. 8 — Receptacle of *Cistella ovata* studded with round seed cushions. Each seed cushion with central circular marking. × 8.

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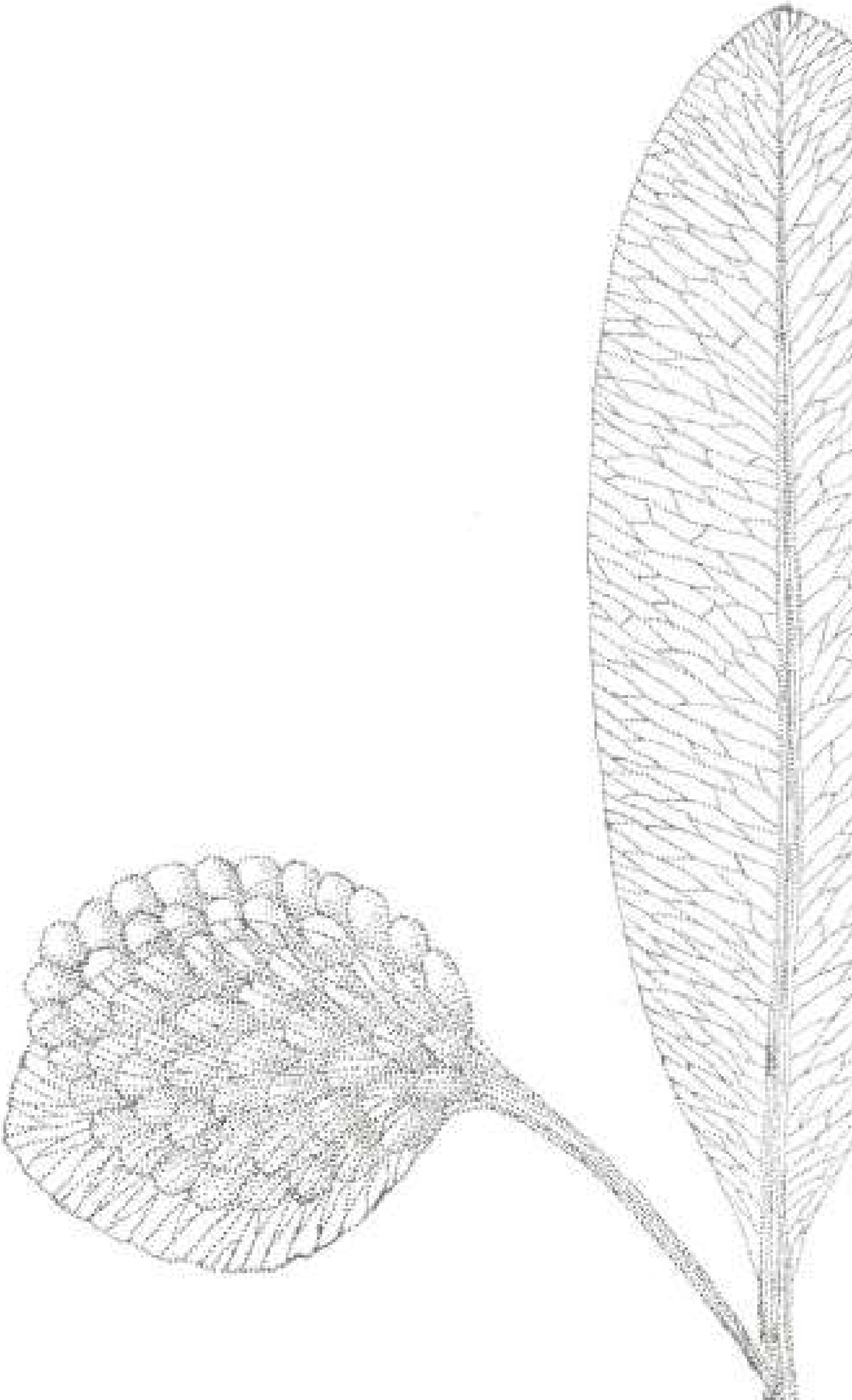
TEXT-FIG. 9 — A reconstruction of *Scutum* attached to a *Glossopteris* by a long pedicel. The scale leaf is partially covering the naked ovule bearing head.



TEXT-FIG 9.

seed scars. Each round scar shows a small, prominent circular marking in the centre.

"Unwinged" *Cistella*, at least some of them, appear to be *Scutum* minus the seeds. *Cistella* perhaps represents a *Scutum* receptacle, covered only with scars of seed cushions, after all the seeds were shed off. Seeds and the scale leaf in *Scutum* were dropped, leaving behind only seedless receptacle studded with seed scars. Such an organ would leave negative impression on the counterpart (not that of a scale leaf) and that is what we found in specimens of *Cistella* in our collection.

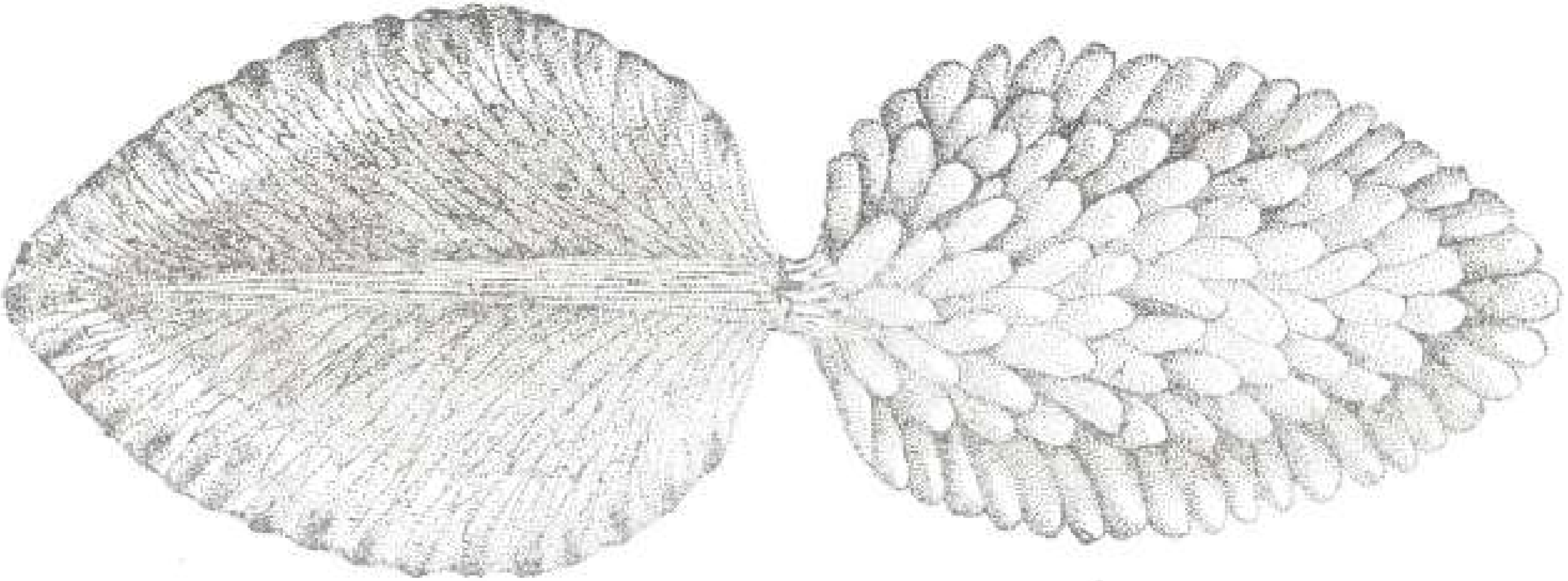
MORPHOLOGY OF *SCUTUM*, *CISTELLA* AND *DICTYOPTERIDIUM*

Scutum

Scutum, according to Plumstead (1952, 1956, 1958b), is a bilaterally symmetrical, two sided cupule, borne on its own pedicel which is attached to the midrib or the top of the petiole of a *Glossopteris* leaf. The cupule may be round, oval or lanceolate. The whole cupule splits into two halves. Each half consists of a central part or head and has fan-shaped venation and a surrounding wing which is fluted, striated or dentate. The adaxial half, called the fertile half, bears on the inside a number of small oval sacs embedded in the tissue of the central head, whilst in the vast majority of cases the opposite abaxial half is empty and apparently only protective. In some specimens, however, the abaxial half, instead of being empty, bore varying number of long, broad bracts or microsporophylls, extending well beyond the wing. Clusters of pollen grains were found on these bracts. *Scutum* (and also *Lanceolatus*) is thus considered by Plumstead as a bisexual organ having so many angiospermic characteristics as to make these members of the Glossopteris flora the Permian forerunners of the Angiosperms.

From our observations on Indian material of *Scutum* (some of which is preserved as casts) we find that *Scutum* is undoubtedly a bilaterally symmetrical, two sided organ which, when split up, shows two quite different surface features on its two halves. One half shows a veined surface, the venation is Glossopteris type, while the other half shows a seed bearing head, surrounded by a wing-like rim of varying breadth, depending upon the species of *Scutum*. Thus *Scutum* appears to be composed of two separate entities (organs) which are closely fitted on each other. Where the two organs join would thus become a weak zone and when the rock containing *Scutum* is split, it breaks along this weak zone, separating the two organs, one veined foliar organ and the other seed bearing head. This is how *Scutum* is generally found in the rocks. When broken into two halves, the two halves are not the negative and positive impressions (as it should be if two halves are parts of one organ) but two impressions with separate surface features. *Scutum*, therefore, appears to consist of two separate organs and not one.

It is difficult to regard the veined half of *Scutum* as part of *one organ, the cupule*, as is done by Plumstead (1952). In our opinion, it would be much better to regard the veined half of *Scutum* for what it really is, a spathe-like foliar organ or an equivalent of a scale leaf, possessing normal type of venation. The Glossopterid fructifications described earlier by us (Surange & Chandra, 1973) have always been found associated with scale leaves with distinct types of venation and such innumerable detached scale leaves are present in our collection. Text-fig. 3 and Pl. 1, Fig. 1 show the veined half of *Scutum sahnii* with a distinct midrib which dissolves into secondary veins halfway upwards. It also gives out laterally anastomosing secondary veins. If this organ is found detached, there would be no hesitation in calling it a scale leaf. We are, therefore, inclined to regard the veined half of *Scutum* as equivalent to a scale-leaf. The scale-leaf in *Scutum* performs perhaps a protective function, as a spathe-like covering to immature, naked ovules borne on a receptacle. In other words, the ovule bearing receptacle is borne in the axil of the scale-leaf and the scale leaf appears to be closely fitted to the ovule bearing head. Both the scale-leaf and the ovule bearing head are carried on a common pedicel, and these two are situated so close to each other that, during preservation, the scale leaf would fall over the fructification, almost entirely covering it (Text-fig. 9). We can well imagine that at the time of fertilization the scale leaf either fell off or opened sufficiently wide to allow wind borne winged pollen grains to land on the mature ovules, attached all round the naked receptacle.



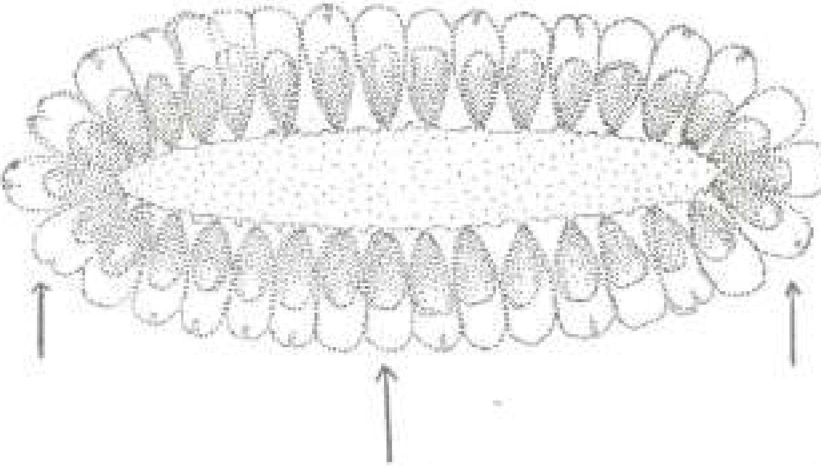
TEXT-FIG. 10 — A reconstruction of *Scutum*. The veined scale leaf is shown completely opened up. Marginal seeds on the receptacle are shown arranged in a row (see Text-fig. 11) and they have left a wing-like impression on the margin of the veined scale leaf.

Text-fig. 9 shows a reconstruction of *Scutum* with the scale leaf covering partly the seed bearing head.

The other half of *Scutum* (the fertile half) is the ovule studded central head or a receptacle which is always found preserved flat. There is, therefore, no doubt that it is a bilateral organ, convex in the middle and thin at the margin. In cross section the receptacle would appear lense-shaped. Text-fig. 11 shows a diagrammatic cross section through an ovule bearing receptacle. The receptacle is shown as convex in the middle and thin at the margin, somewhat like two watch glasses joined together. Its surface is studded with small, hemispherical bulges on which the ovules are attached. During preservation such a lense-shaped organ would always lie flat on the ground and *Scutum* is generally found compressed on the rock in this condition. During fossilization the ovules on the middle convex region of the receptacle would get compressed vertically downwards into a round to oval swellings, whereas those on the margin would get compressed laterally or lengthwise (see arrows in Text-fig. 11). Thus, laterally pressed marginal ovules would become elongated, overlap and come to lie in a row, leaving a rim or a wing-like impressions on the margin of the fructification. This would explain the "wing-like" rim of *Scutum*, which is nothing but the laterally compressed marginal seeds (Text-fig. 11). The width of the "wing" or rim in *Scutum* species would depend upon the size and structure of the seeds. The larger the seed, broader would be the "wing" or rim. The laterally compressed seeds on the margin of the receptacle would also leave their imprint on the veined scale leaf which was lying over it during preservation. Text-fig. 10 shows a reconstruction of *Scutum* in surface view. The marginal ovules, because of the lense-shaped receptacle (thick in the middle, thin at the margin), would tend to lie in one row, thus forming a wing-like rim. The scale-leaf in Text-fig. 10 is shown completely open with venation and the impression of a rim as wide as the ovules on the receptacle.

If a specimen of *Scutum* splits from the scale leaf side, the veined scale leaf appears as a concave impression and the counterpart as a convex ovule-bearing head. If *Scutum* splits from the ovule bearing side, the two parts show the positive and negative impressions of the ovule bearing head. The ovules, therefore, must have been borne on all sides of the receptacle. *Scutum* cannot be regarded as a cupule with ovules borne on one side and enclosed on the other by a veined protective covering. Thus the ovule bearing receptacle of *Scutum* can be compared with the ovule bearing receptacle of *Rajmahalia paradoxa* (Bose, 1966) or that of the ovule bearing cone axis of the Pentoxyleae, *Carnoconites*.

The scale leaf and the ovule bearing head are situated very close to each other and



TEXT-FIG. 11 — A diagrammatic cross section through the receptacle of *Scutum*. It is lense-shaped with ovules attached on cushions all round it. The marginal seeds during fossilization would be compressed lengthwise and those in the middle vertically downwards as shown by arrows.

both these are very near the surface of the vegetative leaf in the axil of which they are borne (Text-figs. 9, 10). The ovule bearing head must have received protection from the scale leaf on one side and the vegetative leaf on the other. The protective function, therefore, appears to have been shared by both these foliar organs (vegetative leaf and scale leaf) when *Scutum* fructification was in young stage and when the protection was required most. It is also likely that the scale-leaf or the spathe-like foliar covering might completely surround the seed bearing head in the young developing stage. As the ovule bearing head grew bigger in size, the scale-leaf opened up and provided a partial cover on one side. When the fructification matured, the scale-leaf perhpas fell off, exposing the ovules for fertilization. *Scutum*, therefore, can be regarded as a reproductive organ of *Glossopteris* which is both functionally and structurally gymnospermous.

We have not found any evidence of male organs on the " veined half " (scale leaf) of *Scutum* in our material. From Plumstead's photographs, which are excellent (Plumstead, 1956, Pl. 9, Figs. 3 & 4) it appears that the so called " male bracts " are merely the impressions of displaced, distorted and long marginal seeds on the receptacle, which got imprinted on the veined counterpart (see Plumstead, 1956, Pl. 9, Figs. 3 & 4). The evidence of pollen from maceration of scrappings of the surfaces of so-called male bracts is untenable. Any scrappings from a shale piece, at least from Indian Lower Gondwanas, is likely to yield quite a number of spores and pollen.

In our opinion, therefore, *Scutum* should be regarded as a gymnospermous, female reproductive organ (and not a bisexual organ) of *Glossopteris*, consisting of a bilaterally symmetrical lense-shaped receptacle bearing a large number of naked ovules (without ovuliferous scales or megasporophylls) all round it. This ovule bearing receptacle is borne in the axil of a scale leaf, which, being protective in function, is closely appressed to it in immature stage. Both the ovule bearing receptacle and the scale leaf are carried on a common pedicel which, in its turn, is attached to the petiole of a vegetative leaf. In other words, this *scale leaf-ovule bearing receptacle complex* is itself borne in the axil of a vegetative leaf of *Glossopteris*. In mature stage, the scale leaf opened out or fell off, exposing the ovules for fertilization by wind borne winged pollen grains.

Cistella

Cistella is also a female reproductive organ of some *Glossopteris* species, possessing the same type of organization as that of *Scutum*. In *Cistella*, however, the receptacle appears to be more convex and, in cross section, it would appear oval. Small ovules are arranged all round the receptacle in close spirals, so that the seeds look as if arranged in longitudinal rows in surface view. When such a fructification is compressed or pressed flat, during fossilization, there would be no wing-like rim. Where the seeds are not preserved, the unwinged *Cistella* could well be the impression of a seedless receptacle of *Scutum*. Seedless *Scutum* receptacle would only show round seed scars on its surface as are seen in many specimens of unwinged *Cistella* in our collection.

Dictyopteridium

Pl. 2, Fig. 3 shows the veined counterpart of a specimen which can be assigned to *Dictyopteridium sporiferum*. The receptacle with seed scars (which is not figured here) measures about 1·8 cm. in length and 4 mm. in breadth at the broadest part and shows typical round to oval markings of *Dictyopteridium* type on its surface. The main interest of this specimen lies in its counterpart (Pl. 2, Fig. 3) which shows unmistakable venation, together with faint round impressions of seed scars. The venation, although not very clearly imprinted on the counterpart, shows a midrib giving out bifurcating secondary veins, which dichotomize once or twice. It means that, as in *Scutum*, this organ is also scale-leaf or an equivalent foliar organ covering one side of *Dictyopteridium* fructification. *Dictyopteridium sporiferum*, therefore, possesses an ovule bearing receptacle borne in the axil of a scale leaf and displays the same type of organization as that of *Scutum*.

It furthermore confirms Maheshwari's (1965) observation on *Dictyopteridium sporiferum* when he saw the scars on one surface only while the other surface showed net venation. The net venation he observed must have been that of the scale leaf present on the other side of the fructification. He made a transfer preparation of his compressed specimen which removed the seed bearing receptacle revealing the veined scale leaf lying below it. Our previously described specimens of *Dictyopteridium sporiferum* (Surange & Chandra, 1973) were either preserved from the other side (not covered by the scale leaf) or the scale leaf had fallen off. A thick ridge round the specimens did suggest to us the possibility of a spathe-like covering over the reproductive organ but because of insufficient evidence, it was not mentioned.

Dictyopteridium, therefore, can now be interpreted as a female reproductive organ consisting of a cylindrical receptacle or axis, bearing, small, oval, ovules or seeds on round cushions in close spirals. The whole ovule bearing receptacle is naked in the sense that there are no ovuliferous scales or megasporophylls. The ovule bearing receptacle is borne in the axil of a scale leaf, which, being protective, closely fits on one side of the fructification.

This brings us to another genus *Isodictyopteridium* instituted by Rigby (1972) for a specimen of *Dictyopteridium sporiferum* described earlier by Walkom (1922) from Australia. According to Rigby the specimen bears tubercles (seed scars) on both surfaces. So does *Dictyopteridium sporiferum* which, as explained above, consists of a cylindrical receptacle bearing ovules or seed all round it in close spirals. Rigby's specimen might have been a mature one, in which case the scale leaf would have already been shed off, so that he could not find any impression of veined structure on the other side as Maheshwari did in his less mature specimen. His emphasis on the presence of a distinct marginal wing in the Australian specimen is untenable, which appears to be only an act of preservation. From his photograph (Rigby, 1972, Text-fig. F2) it does not look like a structural feature. Even if a so-called marginal wing is present in his specimen, this look can be given to *Dictyopteridium sporiferum* by seeds which are arranged along the margin in a single row as described by us (Surange & Chandra, 1973). A little lateral compression of marginal seeds can enhance a wing-like impression in *Dictyopteridium*. There is no justification in creating a new genus for such specimens and *Isodictyopteridium* Rigby, therefore, should be merged with the earlier known genus *Dictyopteridium*.

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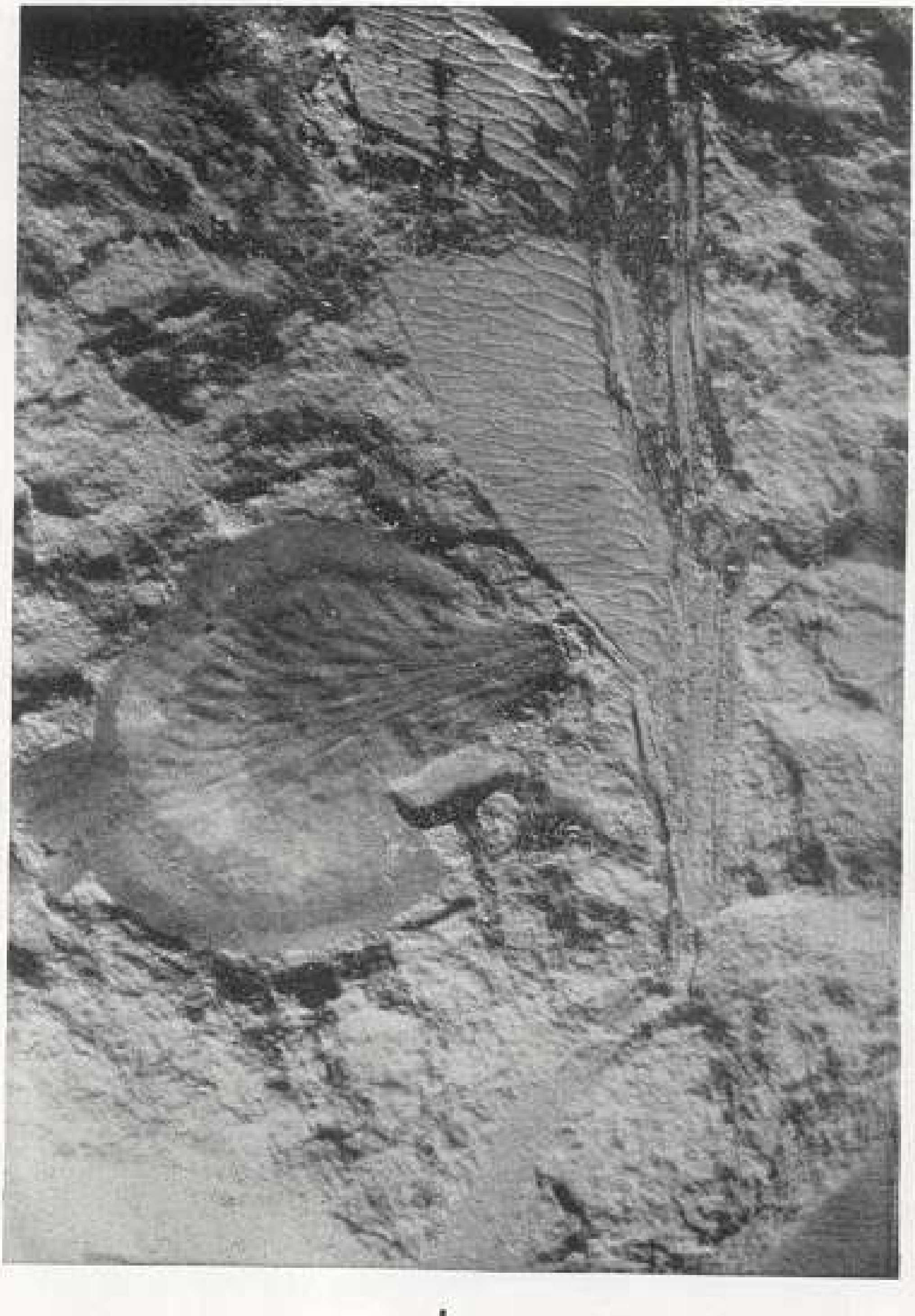

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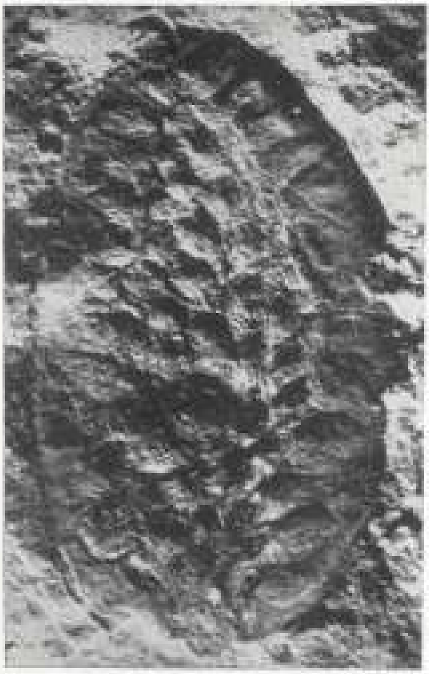

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EXPLANATION OF PLATES

PLATE 1

1. The veined scale leaf (counterpart) of holotype (No. 35093) of *Scutum sahnii* sp. nov. attached with a long stalk (longitudinally split) to the leaf showing *Glossopteris* venation. Note the midrib and the anastomosing secondary veins. × *Ca.* 3·5.

PLATE 2

2. Seed bearing receptacle of the holotype (No. 35093) of *Scutum sahnii* attached on a short stalk and with a wing-like rim all round it. × *Ca.* 6.

3. Counterpart of a fructification of *Dictyopteridium sporiferum* Feist. showing venation. × 4·5.

4. A group of winged seeds assigned to a new genus *Indocarpus*. Holotype (No. 35090). × 3.

5. A winged seed assigned to *Indocarpus elongatus*. × *Ca.* 6.

PLATE 3

6. Seed bearing head of *Scutum indicum* sp. nov. Note the large, laterally compressed seeds, some of them still attached to the seed cushions on the central head. Wing-like rim outside the seeds on the left is perhaps that of displaced scale leaf lying underneath. The same is seen on the right, where the seeds are half broken. × 6.

7. Holotype (No. 35097) of *Scutum indicum* sp. nov. showing the speed bearing receptacle. Laterally compressed marginal seeds, which form a wing-like rim round the fructification, are seen attached to cushion-like outgrowth on the receptacle. Scars of round seed cushions are seen in the apical region where seeds have been knocked off. × 4.

8. Another seed bearing receptacle assigned to *Scutum indicum*. × 4·5.

9. A seed bearing receptacle of *Scutum elongatum* sp. nov. × *Ca.* 5.

PLATE 4

10. A seed bearing receptacle of *Scutum sahnii*. × *Ca.* 4.

11. Holotype (No. 35095) of *Scutum elongatum* sp. nov. The marginal seeds from a rim round the fructification. × 4.

12. A specimen of *Cistella indica*, showing a stalked seed bearing receptacle. × *Ca.* 4·5.

13. Holotype (No. 35100) of *Cistella indica* sp. nov. the receptacle show large round seed scars. × 4.

14. One winged seed of *Indocarpus elongatus*. × 5.

NEOLITHIC PLANT ECONOMY AT CHIRAND, BIHAR

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ABSTRACT

Remains of food plants from the bottom layers of Neolithic horizon at Chirand near Patna, Bihar, comprise lentil, barley, rice, *Pisum arvense*, etc. These constitute the first record of Neolithic plant economy from North India. The Neolithic plant remains known from Burzahom in the Kashmir Valley are of weeds associated with cultivation.

From a series of C14 dates at this site, it appears that the bottom layers are younger (405 B.C.-1570 B.C.) than the overlying layers (1675-1750 B.C.). If no discrepancies are involved, the bottom layers from which the plant remains have been discovered may be dated around 3000-4000 B.C.

INTRODUCTION

THE material of soil samples and remains of food plants from the archaeological site Chirand (Lat. 25° 45'N, Long. 84° 45'gE), District Saran, Bihar, a site about 8 Km. east of Chapra and situated near the confluence of Ghagra and the Ganga, was kindly sent for investigation by Professor B. P. Sinha, Professor and Head of the Department of Ancient Indian History and Archaeology, Patna University, Patna. The soil samples were found devoid of pollen grains. The carbonized grains of cereals and legumes recovered from layer 17 of CRD-XI (Text-fig. 1) from the Neolithic horizon extending from layer 12 to 17 are described here. The layers 10-17 have been radiocarbon dated and surprisingly the top layers are older than the bottom layers (cf. Text-fig. 1). The discrepancy remains unresolved. Dr. D. P. Agarwal of Tata Instt. of Fundamental Research, Bombay, who has dated the samples (Agarwal, 1971) considers involvement of subsidence (personal communication) whereas Prof. Sinha (personal communication) believes that the bottom layers probably got contaminated with water. The layers 10-13 are consistently dated to 1050 B.C., 1580 B.C., 1675 B.C. and 1755 B.C. respectively and layers 14-16 range in age from 405 B.C. to 1570 B.C. and layer 17 is dated to 605 B.C.-1370 B.C. The top one metre of deposit comprising layers 10-13 from 6·5 m. to 7·5 m. has been deposited in 705 years. Presuming that the rate of deposition has been ± uniform, the bottom 2·7 m. (from 7·5 m. to 10·3 m.) of deposit should have been laid in about 1900 years thus dating the sample from layer 17 to 1755+1900 B.C. = 3655 B.C. The rate of deposition of these sediments is variable as seen from the consecutive dates in relation to depth (0·4 m. = 530 years, 0·3 m. = 95 years, 0·3 m. = 70 years), the calculated age could be either between 2000 and 3000 B.C. or between 3000 and 4000 B.C. Narain (1970), however, believes that the lowest layer might be as old as *C.* 2500 B.C.

The samples collected during recent excavations of the site conducted in February 1972 have not been dated yet.

The plant remains described here are the first records of cereals from the Neolithic of North India. Records from the Neolithic of Kashmir (Burzahom) are of weeds indicating indirectly the cultivation of wheat or barley (Vishnu-Mittre, 1968, 1971).

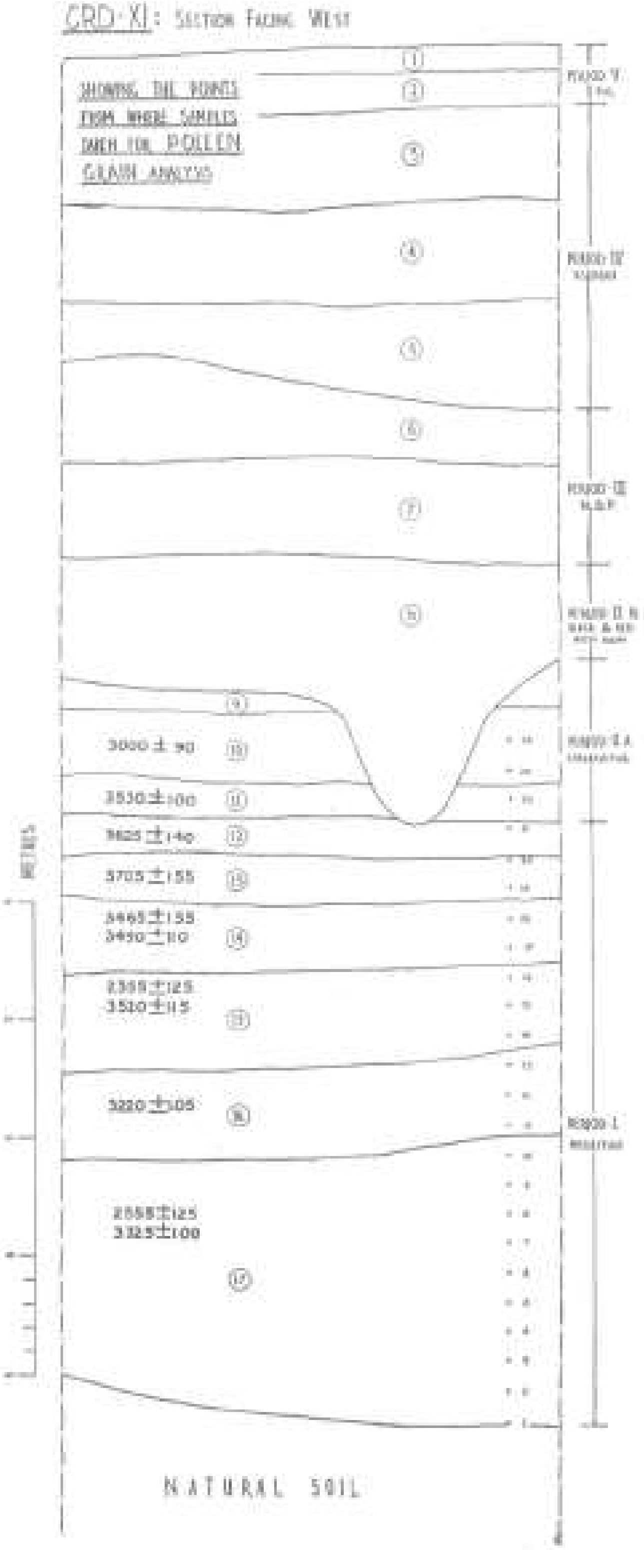
DESCRIPTION OF PLANT REMAINS CEREALS

WHEAT

Pl. 1, Fig. 2

The single kernel of wheat is short, oblong, grooved and thick with the ends broad and blunt. It measures 3·75 mm. long, 2·75 mm. broad and 1·75 mm. thick. The dorsal surface of the grain is domed, and the groove is deep. In these characters the grain of wheat approaches the grains of *Triticum sphaerococcum* Perc. In its lesser L/B, L/T, and higher B/L and T/L indices it further compares with the indices of grains of *T. sphaerococcum* as shown in Table 1 below.

The differences may be due to carbonization. The absence of transverse rippling of the shell precludes the possibility of its belonging to naked grains of barley.



TEXT-FIG. 1 — Stratigraphy of vertical section facing west. The cultural sequence is shown on the right. Position of pollen samples is indicated by black dots. The C14 dates for the layers dated are inserted. Archaeobotanical materials described in this paper were found in layer 17.

TABLE 1 — SHOWING THE VARIOUS INDICES OF MODERN AND CHIRAND WHEATS

(The dimensions of grains of various species of *Triticum* are based upon hundred grains each. The comparative discussion of statistical data of the modern species is discussed in Vishnu-Mittre, 1974)

	L/B	L/T	B/L	T/L	T/B
T. aestivum	2·68	3·07	0·37	0·32	0·87
T. compactum	2·44	3·07	0·40	0·32	0·79
T. sphaerococcum	1·76	1·62	0·56	0·61	1·09
Chirand wheat	1·36	2·14	0·73	0·46	0·63

BARLEY

Pl. 1, Fig. 2

All the thirteen grains referred to barley are very much worn out measuring about 4·5 × 2·25-3·25 × 1·50-2·25 mm. Most of them are naked since the pales are absent and the surface bears rippling marks. The grains are evenly rounded in cross-section apart from the ventral furrow which is shallow and a soft longitudinal depression on the dorsal side. Some grains show slight deviation from the straight shape suggesting that the spike was six-row and probably of the nodding type, a *Hordeum* sp. In three of the grains the surface is characterized by a faint longitudinal stripping arising from the remains of the pales or from the longitudinal surface cells of the seed coat. The cross-section of these grains is not angular. These might have belonged to the hulled barley. The measurements of six random grains are given below (Table 2).

TABLE 2 — MEASUREMENT OF RANDOM CHIRAND GRAINS OF BARLEY

	L	B	T
	4·00	2·50	1·75
	4·25	2·75	2·00
	4·80	2·80	2·25
	5·00	3·00	1·75
	5·00	3·25	1·50
	5·25	2·25	1·50
Average	4·17	2·80	1·70

RICE

Pl. 1, Fig. 1

The kernels of rice, ten in number, are all five-ribbed. Of these five are slender and five broader. The examination of kernels of wild and cultivated species of *Oryza* reveals that slender grains are usually produced by the wild species and the broader ones by the cultivated species. There are no other external morphological characters to distinguish the grains of individual species. The statistical evaluation of the various dimensions and the calculation of L/B × T indices of the wild and cultivated species of *Oryza* in India (cf. Vishnu-Mittre, 1971) has given reliable information to distinguish various species as shown in Table 4. The L/B × T indices of the carbonized grains are calculated and compared with those of the modern species (Tables 3 and 4).

L/B × T index of the large carbonized grains approaches that of *O. sativa* var. *spontanea* and *O. sativa* (cultivated) and that of the small grains is not different

TABLE 3 — DIMENSIONS OF CHIRAND GRAINS OF RICE

	L	B	T	L/B × T index
Large grains	5·00	2·25	1·25	1·85
	5·25	2·50	1·25	1·67
Small grains	4·25	1·50	1·00	2·83
	4·50	1·80	1·00	2·05

TABLE 4 — L/B × T INDICES OF CULTIVATED AND WILD SPECIES OF *ORYZA* BASED UPON HUNDRED GRAINS EACH. THE TABLE ALSO INCLUDES INDICES OF CARBONIZED GRAINS FROM CHIRAND

Species of *Oryza*	L/B × T index
Chirand large grains	1·76
Oryza sativa var. *indica*	1·71
O. sativa var. *japonica*	1·70
O. sativa var. *spontanea* Koenig	1·77, 1·79
O. perennis Moench	2·20
O. officinalis Wall.	2·36
O. rufipogon Griffiths	2·64
Chirand slender grains	2·43

from that of the wild species *O. perennis* and *O. rufipogon*. The differences could be due to carbonization. These statistical comparisons reveal that the carbonized grains were derived from both the cultivated and wild species of *Oryza*.

LEGUMES

The identification of leguminous seeds is based upon the shape of the grain and the position of the hilum scar. There is reduction in dimensions of both the grains and of hilum scar owing largely to carbonization and being uninfluenced by repeated cultivation.

Pisum arvense L.

Pl. 1, Fig. 4

The spherical seeds measuring about 2-4 mm. in size are compressed and provided with an oblong hilum scar about 1×0·50 mm. There are smaller grains also, about 2×1-1·25 mm., which are perhaps the abortive grains of *Pisum arvense* or of some other legume.

Lathyrus sativus L.

Pl. 1, Fig. 4, top right

Three compressed and wedge shaped seeds measuring 4·50×3·50×1 mm. Hilum scar is 1-1·5×0·50-0·70 mm.

Lens culinaris Maedik

Pl. 1, Fig. 3

There are eleven lenticular seeds with keeled edge and measuring about 2·25-3×0·80-1·25 mm. Hilum scar is 1-1·5×0·25-0·50 mm. Compares with small sized grains of *Lens culinaris*.

Other Legumes

Pl. 1, Fig. 5

There are a few extremely small seeds about 2 mm. in diameter. The spherical and flattened among them measure about 2×1 mm. and compare with small lentil grains; a rounded one about 2×2 mm. looks like that of *Pisum* and one 2×1·25 mm., square to oblong seeds, seems to be that of black gram (*Phaseolus mungo*). In view of their extremely small size they may belong to weeds rather than to cultivars. Hilum scar is present in most of them and measures about 1-1·5×0·50 mm.

OTHER REMAINS

UNIDENTIFIED FRUIT

Pl. 1, Fig. 7

Two halves of a fruit measuring about 12 m. long, 6-7 mm. broad and 2·50 m. thick remain unidentified. They are oblong with a wrinkled surface. Inside there is a broad oval area surrounded by a tissue in vertical alignment. A distinct micropylar region is present. The rind outside seems to be less than half a millimetre thick.

UNIDENTIFIED INSECT

Pl. 1, Fig. 6

Mouth parts, the only preserved remains are shown in Plate 1, Fig. 6.

CONCLUSION

The Neolithic plant economy at Chirand consisted of barley, wheat, rice, lentil and *Pisum arvense*. Some leguminous weeds have also been recognized. The rice grains belong to both the cultivated and wild *Oryza sativa*, and probably also to *O. perennis* and *O. rufipogon*. Wheat, barley and *Pisum arvense* as identified belong to the same species as recognized from the Harappan and Chalcolithic sites in western India. The records of lentil, wheat and *Pisum* at this site predate those from the Chalcolithic of Navadatoli Maheshwar dated to 1660 B.C. (Vishnu-Mittre, 1968, 1971). The site Chirand is estimated to date from *C.* 2500 B.C. and the evidence of wheat, barley, lentil and *Pisum arvense* is suggestive of contemporaneity of Neolithic Chirand with the Harappan cultures in western India. Should the site prove earlier in age to the Harappan cultures, it would be an interesting though solitary example of the diffusion of wheat, barley and lentil from western Asia predating the Harappans.

Chirand is the first archaeological site in India which has provided substantial details of plant economy of the Neolithic period in India. Among the other Neolithic sites in the north of India, Burzahom (Kashmir Valley) has yielded indirect evidence of wheat or barley cultivation, and rice from the Neolithic of Orissa has been found to belong to *O. perennis* (Vishnu-Mittre, 1971), a wild progenitor of *O. sativa*.

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EXPLANATION OF PLATE

1. Carbonized grains of rice. The slender grains are on the extreme left of the figure.

2. Wheat grain (*Triticum sphaerococcum*) on the extreme right marked as W. Barley grains are seen on the left of the figure.

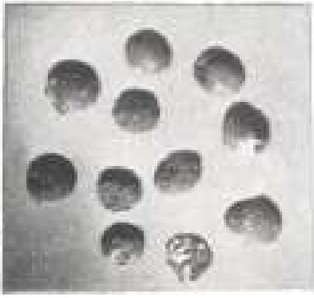
3. *Lens culinaris* Med.

4. *Pisum arvense* L. A single seed of *Lathyrus sativus* is seen on extreme right.

5. Other leguminous seeds

6. Mouth parts of an unidentified insect.

7. Two halves of an unidentified fruit.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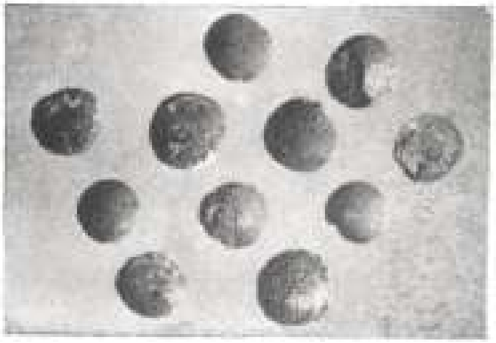
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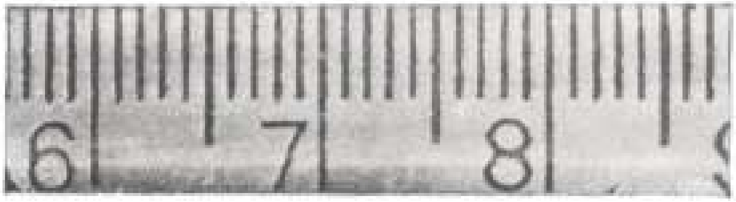

HEPATICAE IN THE SENONIAN OF SOUTH BOHEMIA

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ABSTRACT

Hepaticoid dichotomizing thalli with very narrow segments resembling some *Riccia* but bearing very short stalked oval sporogons of the *Notothylas* type, containing spores, are described from the Senonian fire clays of the locality Zliv-Blana (near České Budějovice in South Bohemia, Czechoslovakia) as *Notothylacites filiformis* gen. et sp. nov. In the same rocks, along with the impressions of these liverworts, two kinds of liverwort spores were also found, one suggesting the spores of *Notothylas* or *Phaeoceros*, the second those of *Oxymitra*. However, no *Riccia* spores have been established. The first named type of spores was also found within the sporogons of the above-mentioned thalli impressions.

DURING the last years a rather rich material of fossil plant remains, macrofossils (F. Němejc) as well as microfossils (B. Pacltová) has been assembled from the Senonian (Santonian) beds in the Zliv-Blana area, west of České Budějovice in South-Bohemia. The attention of the present authors was especially attracted by several specimens of some very thin and dichotomously divided liverwort thalli. They were collected at a depth of about 2-3 m. beneath the surface in a 40-50 cm. thick fossiliferous layer in the fire clays of the industrially important large loam pit, about 5m. deep, on the northern side of the road leading from Munice to Zahájí, west of České Budějovice.

The liverwort thalli occur in a rather thin layer of light greyish very fine-grained fire clay also containing many impressions of angiosperm leaves as well as various smal seeds covered here and there with remains of carbonized cuticles. But all the liverwort thalli found here are mere impressions only. However, in several fertile specimens, sporogons are exceptionally preserved in a carbonized state, especially their spores. Dispersed liverwort spores were found not only in the layer containing impressions of liverwort thalli, but also elsewhere within other layers of the fire clay bed exposed in the above-mentioned loam pit (Pacltová, 1961).

All the liverwort thalli found here belong to one type; they are dichotomously divided five or six times at angles varying between 60° — rarely even more — and 30°. Their individual segments are very narrow; the basal ones measure hardly 0·8 mm. while the distal ones 0·4 mm. only. They are quite smooth without traces of any air chambers. They mostly exhibit a distinct midrib. Their tops are rounded. The whole plantules are thus sparsely and very regularly branched and of semicircular outline (12-16 mm. in diameter). In several rare specimens small and very shortly stalked sporogons are visible. They are inserted just at the point of dividing of the midrib. They are oval in shape, about 450-500 μ long and 430-450 μ wide. By maceration of the respective carbonized mass loosely affixed on their imprints numerous spores were obtained but no cuticles of the sporogon walls. In several imprints of sporogons a sign of a longitudinal slit in their wall seems to be present. No indication of any columella was established within them. The obtained spores were present within the sporogons joined together into tetrads. A close examination showed that the sporangia were oval in shape (length 450-500 μ, width 430-450 μ). They were subjected to maceration: transferred with a preparation needle to the microscope slide, and a drop of 5% KOH was added. This caused gradual disintegration of the sporangium into tetrads, some of which further disintegrated into individual spores (see Pl. 3, Figs. 8-12). During further treatment with H_2O_2, progressive dissolution of the outer layer of the sporoderm-perine was observed; this surrounds the exine and displays an irregular (puckered) sculpture (Pl. 3, Figs. 10, 11). The puckered layer dissolved first, forming small heaps suggesting a "verrucate" sculpture (Pl. 3, Fig. 12). During further chemical treatment the small heaps gradually dissolved and disappeared. Under them a further, chagrenate layer appeared which slowly cracked forming irregular patterns resembling mud cracks (Pl. 4, Figs. 13, 14); this layer also disappeared. Finally, the exine of the spore remained; its morphological structure corresponded to that of the spores found already earlier as dispersed spores (Pacltová, 1961; Pl. 3, Figs. 1-3).

The spores reacted in the same way to the action of the acetic acid (CH_3COOH). During further maceration experiments, the spores did not change. They reacted only to further oxidation agents, e.g. $KClO_3$, changing their brown-yellow colour to a light yellow.

Comparing our fossil liverwort with various extant Hepaticae, we can observe a rather close similarity to some species of the genera *Riccia* and *Anthoceros* growing under extremely wet conditions, or in the genus *Riccia* even floating on a water surface. But the shape of the sporogons does not agree with any of these genera. The shape of the sporogon and the features of the spores found within it seem to agree mostly with the genus *Notothylas*. The spores also exhibit similarity to the genus *Phaeoceros*, but in the latter the sporogons are whip-like, elongated and provided inside with a typical columella as is the case with the genus *Anthoceros*. Thus, the basic features of our fossil liverwort seem to agree mostly with the genus *Notothylas*. However, the present authors have not found in the accessible botanical papers on extant Hepaticae any note whether some species of the genus *Notothylas* under special conditions also exhibit thalli with narrow filiform segments as are those known in several species of the genus *Anthoceros* or *Riccia*. The *Notothylas* thalli are always described as bearing short and rather broad segments (or lobes). And as even in paleobotanical papers (Lundblad, 1954 and J. Oberhel, 1964) no hepaticoid plants in a fossil state are mentioned, which could show such a curious combination of features, the present authors have chosen for the Senonian type under consideration a special generic name, i.e. *Notothylacites* gen. nov.; it is derived from the name *Notothylas* to show the very close relation to this genus. Future investigations may show whether this Senonian type is or is not identical with some of the extant species of *Notothylas*, representing an aberrant life form only, due to special extremely wet conditions. It is also not quite certain whether all the sterile thalli belong to the same genus, although they display the same external morphological features and all were collected at the same place.

SYSTEMATIC DESCRIPTION

HEPATICAE

Genus *Notothylacites* gen. nov.

Type species — *Notothylacites filiformis* gen. et sp. nov.

Diagnosis — As for species.

Notothylacites filiformis sp. nov.

Plates 1-4

Diagnosis — Thalli semicircular in outline dichotomizing into a system of elongated and very narrow laciniae showing a distinct midrib. Thallus laciniae dichotomizing at an angle of 60°-30° narrowing slowly from the base to their tops (0.8-0.4 mm.). The whole plantules are semicircular about 12-16 mm. in diameter.

Very short, stalked sporogon capsules (opening by a longitudinal slit (?) without a distinct columella), oval, about 450-500 μ long and 430-450 μ wide.

Spore trilete biconvex; amb convexly triangular. Equatorial diameter (47) 52 (55) μ. Laesurae straight ±25 μ long, extending to equator. Lips narrow, inconspicuous. Both perine and exine were observed. The perine probably consists of two layers: the outer layer puckered, dissolved during maceration; the second layer very thin, chagrenate, which during maceration first irregularly cracks and also becomes dissolved. Exine 1·5-2 μ, consists of thicker granulate sexine (ectexine) and a smooth nexine (endexine) — 2:1. Three or sometimes more than three small (1-2 μ) pore-like depressions on the exine can usually be seen in the region between laesurae.

Derivation of name — With regard to the similar recent genus *Notothylas*.

Horizon — Fossiliferous fire clay layers, Lower Senonian (Santonian).

Locality — Zliv-Blana, South-Bohemian basin, Czechoslovakia.

Deposition of type specimen — The holotype and all the macrofossils and slides are deposited in the collections of the Department of Palaeontology, Charles University, Prague 2, Albertov 6.

Discussion — The morphological structure of the above-mentioned spores resembles that of the spores of the genus *Notothylas* (Notothylaceae, Anthocerotales) described partly by Erdtman (1965, p. 130) and figured by Dettmann (1933, Pl. XXVII, Figs. 12, 16). It is probable that the spores figured, showing different "sculptures" in the spores of one recent species, namely, *Notothylas breuteli* Gottsche from Cuba, also represent various maceration stages only. A certain similarity can also be observed in the spores of the genus *Phaeoceros* (Anthocerotaceae, Anthocerotales) which are distinguished especially by a thicker exine and a more marked tetrad scar. From the spores of the genus *Riccia* they substantially differ, and, therefore, it cannot be taken into consideration that the thallus of the liverwort studied belongs to the genus *Riccia*.

Spores similar to those dealt with in this paper have been described by Dettmann (1963) as dispersed spores. This author assigns them with a certain reserve to the artificial genus *Foraminisporis* Krutzsch. This problem should be discussed in a complex way, elsewhere. Pacltová (1961, Pl. 3, Figs. 1-3) has figured dispersed spores from the same locality as that considered in this paper (Zliv-Blana); they are morphologically conformable to the spores from the sporangia described here. The spectrum of spores was also investigated on a layer in which liverwort impressions had been found. In this case dispersed spores have also been established, which agree with those from the above-mentioned sporangia. The state of preservation corresponds to the state of the spores after maceration.

In addition to the spores considered here, different liverwort spores have already earlier been found at the locality Zliv-Blana. They have been described by Pacltová (1961, p. 87, Pl. II, Figs. 1-4) under the name *Zlivisporis blanensis* Pacltová. The latter author determined their relationship to the genus *Oxymitra* (Oxymitraceae, Marchantiales and Ricciales).

CONCLUSION

In the Lower Senonian (Santonian) fireclay of the locality Zliv-Blana (South-Bohemian basin) one type of hepaticoid thalli and two types of hepaticoid spores have been established.

The described thallus impressions are divided into narrow, dichotomizing lacinulae like in some species of *Riccia* or *Anthoceros* living under very wet conditions or floating on a water surface. The sporogons and spores bear features common in the genus *Notothylas*. As no similar combination of features has so far been known in any hitherto described fossil hepaticoid type or in any extant liverwort, a new name has been applied to the newly found Senonian type: *Notothylacites filiformis* sp. nov. and, accordingly, a new genus, i.e. *Notothylacites* was described. This genus seems to be closely related to the present *Notothylas*. In addition, it has been recognized that the studied microflora (spores and pollen grains) of the respective Senonian fire clay beds contains two types of hepaticoid spores: one type identical to the spores found within the sporogons of the described species *Notothylacites filiformis* sp. nov. and another one, described as *Zlivisporis blanensis* Pacltová, which resembles the spores of the genus *Oxymitra* (Oxymitraceae, Marchantiales and Ricciales).

The spectrum of spores (see Pacltová, 1961) contains in addition to numerous pollen grains abundant thalli of algae of the genus *Pediastrum*, which fact points to the swamp character of the sediment.

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EXPLANATION OF PLATES

Plate 1

1. Notothylacites filiformis gen. n. et sp. n.; fertile thallus. Sporangium indicated by an arrow. Holotype (× 5).
2. The same, natural size (1 : 1).
3. Sporangium, positive impression (× 100).
4. Negative impression of sporangium (× 100).

Photographed by V. Šilhanová.

Plate 2

5. Sterile thallus of a liverwort (× 5).
6. The same. 1 : 1.
7. Sterile thallus of a liverwort (× 5).

Both from the same locality and layer as Notothylacites filiformis sp. n.

Photographed by V. Šilhanová

Plate 3

Spores from the sporangium of Notothylacites filiformis sp. n.

8. Part of a sporangium. Spores without perine.
9. A tetrad of spores with perine.
10. A spore with perine; distal view.
11. A spore with perine; proximal view.
12. A spore with relics of perine after short maceration with 5% H_2O_2.

All spores × 1000

Microphotos by B. Pacltová

Plate 4

Spores from the sporangium of Notothylacites filiformis sp. n. Different stages of maceration.

13-14. Two layers of perine; overlie the exine; the relics of the upper (puckered) layer are well visible on the lower third of the spore; the second layer chagrenate; in Fig. 1 the manner of its cracking is visible.

15-16. The spores in which the exine is covered with relics of perine forming irregular small heaps. (Fig. 3 — polar view, Fig. 4 — equatorial view).

17-18. Chagrenate spore without perine.

All spores × 1000.

Microphotos by B. Pacltová

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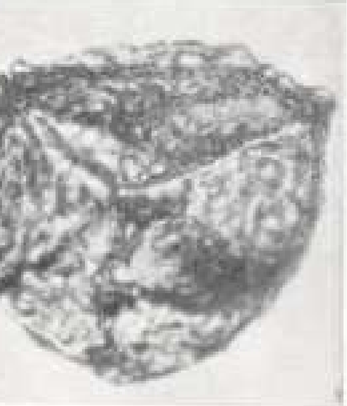

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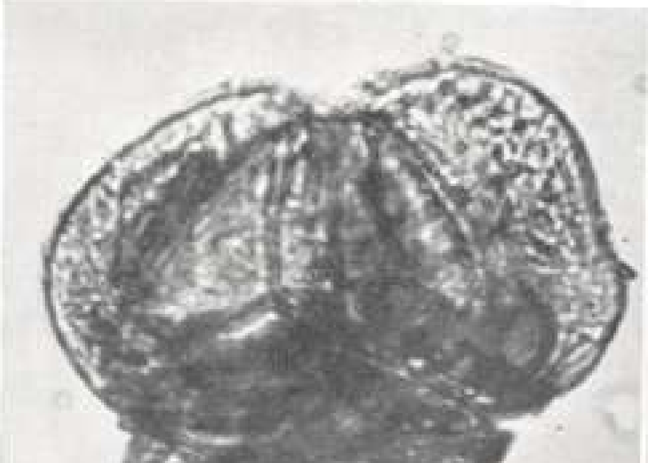

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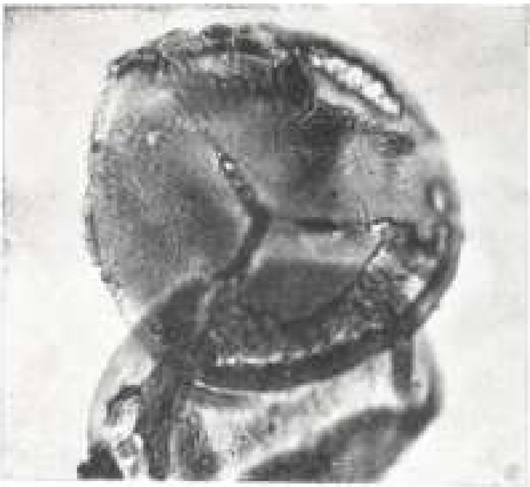

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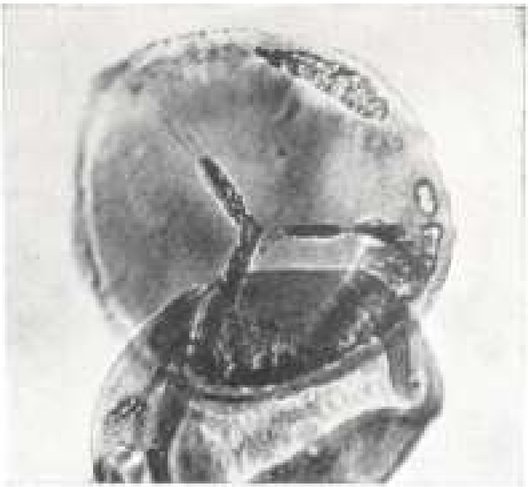

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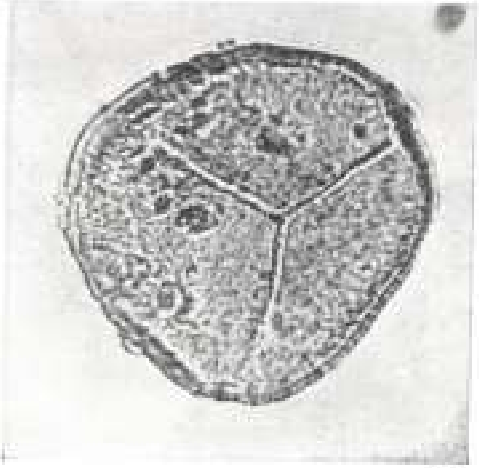

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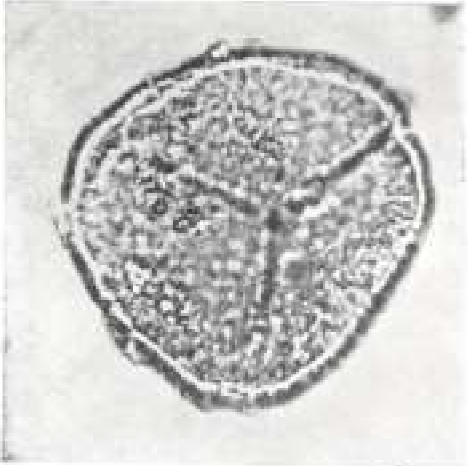

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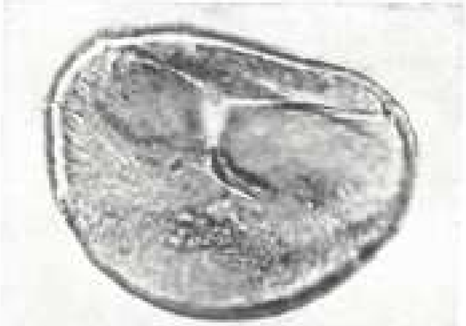

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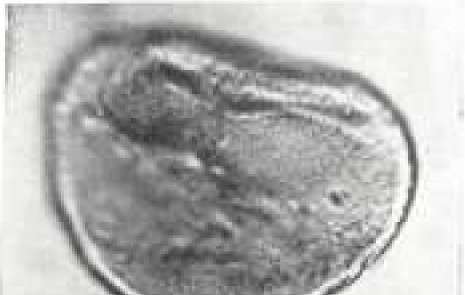

18

ORGANIC REMAINS FROM DHARWAR SEDIMENTS*

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ABSTRACT

Microfossils are recovered from Dharwar-Shimoga Schist belt of the Archaean complex of Mysore State. The fossils are assigned to 13 genera and 21 species of microfossils grouped under Cyanophyceae, Chlorophyceae and Sphaeromorphitae. Unidentifiable organic plates perhaps of animal origin are also recorded. A detailed comparison with the available Precambrian records in the literature is made. It is concluded that the Dharwar microbiota is more advanced than the Early Pre-cambrian and more primitive than the Late Precambrian microbiota. Thus a Middle Precambrian to Early Late Precambrian age is assigned.

INTRODUCTION

THE Archaean complex of South India embraces geologic formations of diverse types and is one of the most important complex stratigraphic entities. Being economically important, it has formed the subject of study by numerous workers for well over a hundred years, yet the stratigraphic sequence, the *inter-se* relationship, in space and time, of the various constituent units and their structural framework have been a subject of much speculation and protracted controversy.

The finding of an interesting assemblage of microfossils from the Dharwar-Shimoga schist belt by Venkatachala & Rawat was reported in the O.N.G.C. Reporter (*Anon.* 1971). The present paper summarizes the results of these studies.

SAMPLE LOCALITIES

A number of samples were collected from Dharwar outcrops marked in Fig. 1 and processed for their fossil contents; all of them come from what is known as the Dharwar-Shimoga band of Bruce Foote (1888) or the West Central Group of Rama Rao (1936).

GEOLOGY

The Dharwar sequence has been subdivided by Rama Rao (1936) into a Lower igneous division and the mainly sedimentary Middle and Upper divisions. Nautiyal (1967), on the other hand, has proposed a different classification in which there is a lower Dharwar meta-sedimentary and metavolcanic division and the mainly metasedimentary Middle and Upper Dharwar divisions all of which, he contends, have been thrust over the Archaeans.

The authors have not tried to go into the relative merits of these and earlier stratigraphic classifications but rest content with stating that their samples come from the Dharwar without indicating the localities. They would, however, like to point out that the samples analysed are from two different localities (near Dharwar city and near Chikmagalur) but that these are from the same Schist belt (hitherto generally regarded as stratigraphic equivalents). The samples belong to widely differing lithologic types (viz., clays/shales of Dharwar area and Schists of Chikmagalur area). This could perhaps be due to the fact that in a regional sense the metamorphism of the Dharwar rocks increases south and southeast within Mysore State, starting from the type area around Dharwar City (Rama Rao, 1936; Pichamuthu, 1962). It seems to the authors that the samples from the vicinity of Dharwar city are younger than those from the Chikmagalur area especially in view of the fact that the Schist belt is the remnant of a great anticlinorium plunging NNW (Pichamuthu, 1962).

A long standing controversy centred round whether the Dharwar Schists and some of the associated rocks were crystalline or sedimentary. Early workers like Bruce Foote (1888) made the important observation that the Dharwars were the remains of a 'great sedimentary series' and that these were different from the surrounding and possibly older gnessic formation. Later systematic work by the Mysore Geological Department during the first two decades of the present century led its head, W. F. Smeeth, and his coworkers (with few ex-

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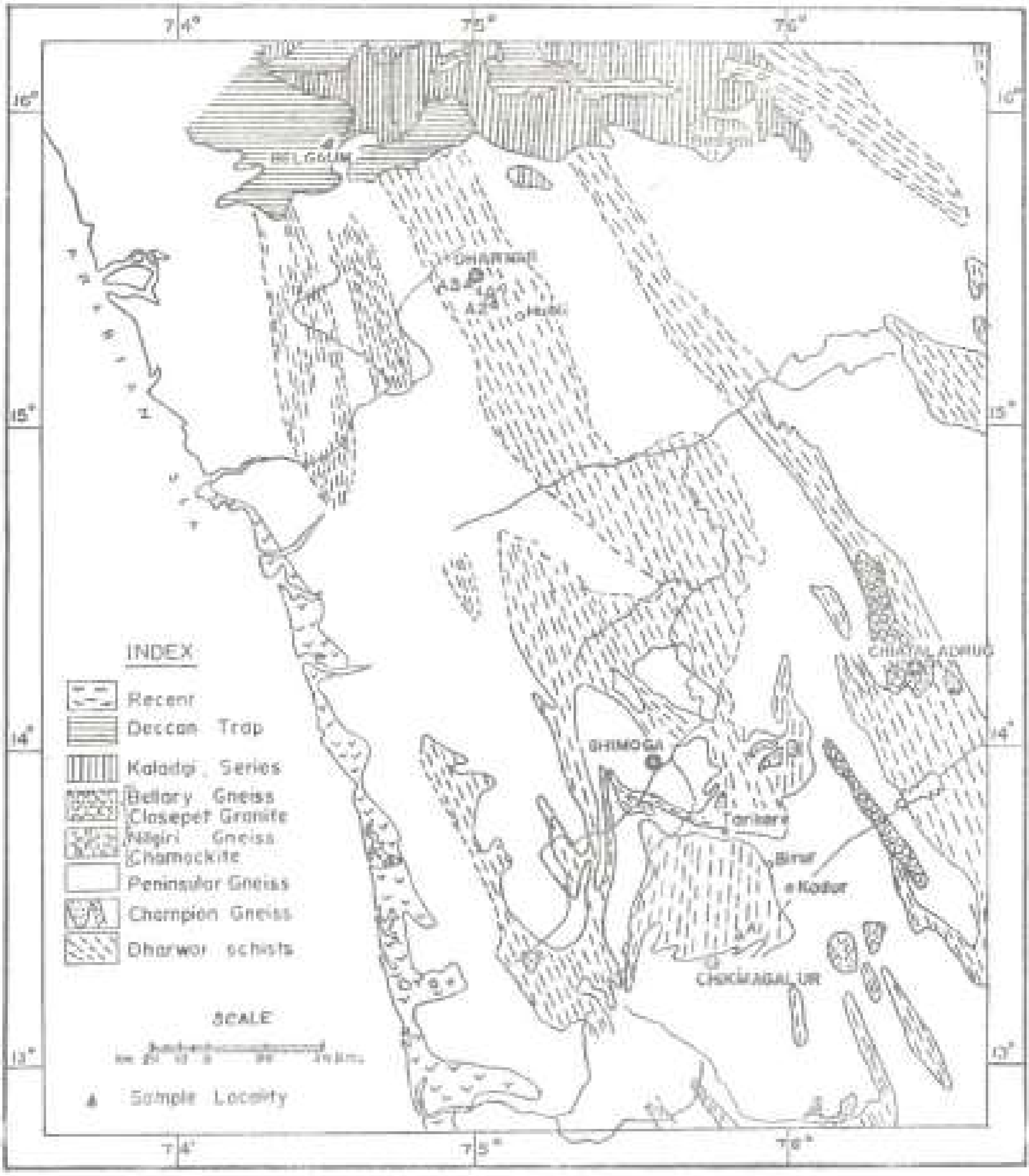

TEXT-FIG. 1 — Geological map of Dharwar schist belt and adjoining areas

ceptions) to the view that Dharwar Schists were the oldest formations in Mysore and that some of the apparently sedimentary rock types were of non-sedimentary origin. Still later, however, by the middle 1930's the official view of the Mysore Geological Deptt. veered (albeit haltingly) towards a truly sedimentary origin for the conglomerates, quartzites, shales and limestones which form such a large part of the Dharwar sequence. The sedimentary origin of the greater part of the Dharwars came to be well established after the writings of Rama Rao (1936) and Pichamuthu (1947).

It, therefore, follows that earlier an obsession with the igneous/metamorphic nature of the Dharwars and later perhaps with their great antiquity did not constitute an incentive to fossil hunters. This was unfortunate, especially in view of some very significant comments of Pichamuthu (1947) concerning the occurrence in the Dharwars of graphite schists, true limestones (associated with current bedded quartzites), banded ferruginous quartzites — all pointing towards possibility of life during the Dharwar times — and lastly those concerning the occurrence of algal structures (? *Haplosiphon*) in some cherts of the Chitaldrug schist belt. Gowda and Sreenivasa (1969) reported fossil Acritarchs from the Guddadaranganahalli Formation of the Chitaldrug Schist belt.

Crawford (1969) gives the radiometric ages of some of the lavas in the Chitaldrug Schist belt as 2345 ± 60 m.y. This is very close to the age reported by Holmes (1955) for a galena from the same area (2450 ± 120 m.y.). No radiometric age from the Dharwar-Shimoga schist belt has so far been reported.

SYSTEMATIC DESCRIPTION OF FOSSILS

In the present study, 12 genera and 20 species of microfossils are recognized and described. 2 genera and 14 species are newly proposed. Detailed descriptive analysis and differential diagnosis are given to exemplify the new taxa.

Group — *Acritarcha* Evitt, 1963
Sub-group — *Leiosphaeritae* Eisenack, 1954

(Leiosphaeridae Eisenack, 1954)
(Sphaeromorphitae Downie, Evitt & Sarjeant, 1963)

General Remarks — Downie & Sarjeant (1963) in a critical review of the smooth walled and ornate vesicles classed under leiospheres, have expressed an opinion " that *Protoleiosphaeridium* should be treated as a synonym of *Leiosphaeridia* and rejected, and that its species should be reattributed to the later genus ". Staplin *et al.* (1965) in a subsequent study discuss this point at length and retain *Protoleiosphaeridium sensu* Timofeev (1959 & 1960). The genus was validated by Timofeev (1960) by designation of *P. conglutinatum* as the type species. The vesicles referred to here to *Protoleiosphaeridium* distinguish from *Leiosphaeridia* in possessing a firm wall, smaller size (up to 30 μ) and ornamentation.

The views expressed by Staplin *et al.* (*l.c.*) to retain this genus is considered practicable in the study of very ancient leiospheres where additional characters are not developed which can form a basis for differentiation into different groups or genera. Size is, thus the only criterion which can help classify these fossils. The authors are of the opinion that vesicle ornamentation also should be used in generic distinction. It will be worth the while to re-examine the other genera proposed by Timofeev (1959). *Vavosphaeridium*, *Orygmatosphaeridium*, *Lophosphaeridium* and *Trachysphaeridium* may be useful groupings in the study of Precambrian-Cambrian fossils. A re-examination of types of all these genera is necessary. As suggested by Downie & Sarjeant (1963), the " other genera *Zonosphaeridium* (thick walls), *Trematosphaeridium* (Perforate test) and *Symplassosphaeridium* (Clusters of vesicles) seem either to be products of accidents of preservation or to be quite different kinds of structure from the typical leiospheres......". In the Dharwar sediments various types of preservations are present and all the above genera can be recognized in one group of fossil vesicles. The following groupings are recognized in this study:

1. Vesicle smooth walled, faint or no ornamentation, wall thickness 1-2 μ, not firm, often folded, 18-60 μ: *Leiosphaeridia* (Timofeev, 1959, 1960; Eisenack, 1958); Downie & Sarjeant, 1963.
2. Vesicle smooth walled, ornamentation scanty, wall up to 2 μ thick, firm, not folded, less than 25 μ: *Protoleiosphaeridium* (Timofeev, 1959, 1960).
3. Vesicle granulose, grana closely spaced, wall up to 2 μ thick, firm, folds rare, 25-30 μ: *Granomarginata* (Naumova, 1961).
4. Vesicle conate, coni distinct, wall firm up to 2 μ thick, 25 μ: *Lophosphaeridium* (Timofeev, 1959).

Hizhnyakov and Shepeleva (1964) have described comparable sphaeromorphs under *Asperatopsophaera*, *Leiopsophosphaera*, *Acanthopsophosphaera* and *Brochopsophosphaera*. These genera have to be reexamined from nomenclatural point of view and compared with generic names already in use and valid according to the International Code of Botanical Nomenclature.

Leiosphaeridia (Eisenack, 1958) Downie & Sarjeant, 1963

Syn. — *Leiosphaeridium* Timofeev, 1959
Leiosphaeridium Timofeev, 1959 ex
Staplin, 1961

Type species — *Leiosphaeridia baltica* Eisenack, 1958.

Leiosphaeridia raoi sp. nov.

Pl. 1, figs. 1, 2

Holotype — Pl. 1, fig. 2.

Type locality — Dharwar exposures near Dharwar city.

Derivation of name — Named after Late Prof. B. Rama Rao who pioneered the idea of the sedimentary nature of the Dharwars.

Description — Vesicles spherical, often folded, 40-60 μ, without pylome, wall smooth, firm, up to 2 μ thick.

Comparison — *L. baltica* Eisenack (1958) is from the Silurian rocks and has a faint ornamentation. *L. pellucida* Salujha *et al.* (1971) is smaller in size and according to the authors is punctate. *L. tenella* Salujha *et al.* (*l.c.*) is also small, up to 22 μ and is granulose. The specimens recorded here from the Dharwar sediments are smooth spheres without any recognizable pylome.

Remarks — Specimen figured in Pl. 1, Fig. 1 is corroded and hence appears granulose in the photograph; the areas which are clear show the smooth exine.

Leiopsophosphaera spp. described by Hizhnyakov and Shepeleva (1964) are closest in comparison to the fossils recorded here. *Leiosphaeridia* is a valid genus and widely used and as such is used in this study.

Leiosphaeridia aglutinata sp. nov.

Pl. 1, figs. 3, 9, 10, 12, 16 & 23

Holotype — Pl. 1, fig. 3.

Description — Vesicle spheroidal, 35-45 μ, holotype 45 μ. Wall thin, folded variously, smooth.

Remarks — Granulose organic debris collects in and around the vesicles giving an ornamented appearance. Similar agglutinated fine organic debris perhaps mixed with mineral particles are also found in several vesicles attributed to this species as well as in the filaments (Pl. 2, figs. 42, 43 & 44) described elsewhere in this report. It is also observed in vesicles described as *L. dharwariana* (Pl. 1, figs. 7, 8, 11 & 15). It is probable that ornamented vesicles attributed to *Granomarginata* by several authors may also belong to this group of thin walled *Leiosphaeridia*.

Comparison — *Leiosphaeridia pellucida* (Salujha *et al.*, 1971) have a thicker vesicle wall and according to the authors are punctate. The punctation is also an artifact and the vesicles are smooth walled. *L. tenella* (Salujha *et al.*, 1971) are smaller in size. The other species recorded are all characterized by thicker vesicle walls and do not give a granulose appearance due to agglutination of organic and mineral debris.

L. Raoi described in this study has a thick firm wall and hence distinguished from this species.

Leiosphaeridia dharwariana sp. nov.

Pl. 1, figs. 7, 8, 11 & 15

Holotype — Pl. 1, fig. 11.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description — Vesicle spherical, folded, 18-25 μ; holotype 18 μ. Pylome not present, wall less than 1 μ thick, often folded.

Remarks — Agglutinated organic debris in the vesicles and surrounding them are commonly seen (see also remarks of *L. aglutinata*).

Comparison — Both *L. Raoi* and *L. aglutinata* are larger in size. *L. aglutinata* is comparable in the nature of the vesicle wall.

Protoleiosphaeridium Timofeev (1959) 1960

Type species — *Protoleiosphaeridium conglutinatum* Timofeev, 1959.

Protoleiosphaeridium problematicum sp. nov.

Pl. 1, fig. 5 & 6

Holotype — Pl. 1, fig. 6.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description— Vesicles spherical, ellipsoidal, bean shaped or acquiring any other shape due to fusion of two or more vesicles. Each vesicle 15-30 μ; wall up to 2 μ thick, smooth or faintly granulose.

Comparison & Remarks — *Protoleiosphaeridium* as designated by Timofeev (*l.c.*) as well as those described by Staplin *et al.* (*l.c.*) are spheroidal vesicles with smooth or granulose ornamented walls. Combaz (1967) in an extensive review and study of the leiospheres has illustrated and described a number of forms with two or more vesicles joined together from the Lower Cambrian of Australia, Wenlockien and Ludlowien of Libya. The Dharwar specimens are very closely comparable to those figured by Combaz (*l.c.*).

Acanthodiacrodium angustum (Downie) Defl. & Defl.-Reg., 1962; Combaz, 1967 described by Combaz (*l.c.*) from the Tremadocien of the Hassi-Messaoud in Africa has a superficial resemblance to *Protoleiosphaeridium problematicum* described here. The genera included under *Trachydiacrodidae*, a family proposed by Deflandre and Deflandre, Rigaud (1962) are bipolar with ornamentation restricted to the polar zones. Some types of vesicles included under this group may have a globular or ellipsoidal outline. The comparison with these is also superficial.

Schopf (1968) and Schopf and Barghoorn (1969) have illustrated and described a number of chroococcalean algae which are comparable to the Dharwar specimens described here. *Sphaerophycus* Schopf (*l.c.*) is small, the unicells are only up to 3·6 μ and the cells enclosed in a sheath. The specimens illustrated by Schopf are distinguishing and do not need any explanation. *Myxococcoides* Schopf (1968) are reticulate, unicells or colonies.

In view of the above discussion, it is difficult to ascertain if the specimens figured here are chroococcalean unicells which have lost the sheath or sphaeromorphs belonging to *Protoleiosphaeridium* comparable to the ones described by Combaz (*l.c.*). The specimen figured here as well as the others studied from the Dharwars do not show any sheath and as such are described under *Protoleiosphaeridium*.

Protoleiosphaeridium sp.

Pl. 1, figs. 4

Description — Vesicle folded, appear to be spheroidal, 28 μ; wall firm less than 2 μ thick, smooth. Germinal aperture not present.

***Granomarginata* Naumova, 1961**

Type species — *Granomarginata prima* Naumova, 1961.

Granomarginata clara sp. nov.

Pl. 1, fig. 14

Holotype — Pl. 1, fig. 14.
Type locality — 8 miles short of Dharwar.
Description — Vesicle spherical, 27 μ; wall up to 2 μ thick, granulose, grana less than 1 μ wide and closely set, discernible in the equatorial outline.
Comparison — *Granomarginata clara* is distinguished by true grana as opposed to the organic agglutination observed in many species of *Leiosphaeridia* described here. *G. primitiva* Salujha *et al.*, is smaller in size.

***Lophosphaeridium* Timofeev, 1959**

Type species — *Lophosphaeridium rarum* Timofeev, 1959.

Lophosphaeridium conatum sp. nov.

Pl. 2, figs. 36 & 40

Holotype — Pl. 1, fig. 40.
Type locality — Dharwar exposures, 8 miles short of Dharwar city.
Description — Vesicle spherical, 10-12 μ, holotype 10 μ, wall thick occasionally folded, beset with sharp tipped up to 1 μ long coni.
Comparison — The specimens ascribed to this genus by Salujha *et al.* (1971), show a thicker wall and closely set ornamentation.

Lophosphaeridium sp.

Pl. 2, fig. 30

Description — Vesicles spherical, 22 μ; wall thick beset with sharp tipped coni, coni less than 1 μ wide.
Comparison — This species differentiates from the ones described by Salujha *et al.* (*l.c.*) in a sparse ornamentation.

***Rugocystis* Gen.Nov.**

Type species — *Rugocystis velaris* sp. nov.
Description — Spherical vesicles or unicells, wall rugose, with branching, anastomosing or free muri, covered by an outer

organic sheath. Sheath hyaline, smooth to granulose.

Comparison — *Globophycus* (Schopf, 1968) is much smaller in size and not as prominently ornamented as the cells of *Rugocystis*.

Rugocystis velaris sp. nov.

Pl. 2, figs. 24-27 & 37

Holotype — Pl. 2, fig. 27.

Type locality — Dharwar exposures, 8 miles short of Dharwar city.

Description — Spheroidal unicells or vesicles, 50-60 μ. Wall with distinct muri, muri low, anastomosing or free, rarely forming meshes, sheath hyaline membranous, smooth-granulose.

Remarks — Pl. 2, fig. 26 illustrates a specimen which is partially broken, showing the irregular muri. Pl. 2, fig. 25 is a overmacerated specimen showing coarse surface structure and the hyaline sheath partially attached to the body.

Trachysphaeridium **Timofeev, 1959**

Type species — *Trachysphaeridium patellare* Timofeev, 1959.

Trachysphaeridium decorum sp. nov.

Pl. 2, fig. 29

Holotype — Pl. 2, fig. 29.

Type locality — Dharwar exposures, 8 miles short of Dharwar city.

Description — Vesicle spheroidal, 11 μ. Wall up to 1 μ thick, granulose, grana uniformly distributed, closely set forming a network in lower focii. Pylome present.

Comparison — *Trachysphaeridium* sp. 2 illustrated by Combaz (1967) is closely comparable.

Trachysphaeridium sp.

Pl. 2, figs. 31 & 41

Description — Vesicles spherical, 15-18 μ, thick walled, up to 2 μ thick, granulose, grana closely set. Pylome circular up to 2 μ wide.

Comparison — *T. decorum* is smaller in size and has a coarse ornamentation.

Sub-group — ***Herkomorphitae*** **Downie ,Evitt & Sarjeant, 1963**

Concentrites **gen nov**

Type species — *Concentrites muricatus* sp. nov.

Description — Vesicles spheroidal, wall thick, ornamented with concentric muri.

Concentrites muricatus sp. nov.

Pl. 2, figs. 32 & 33

Holotype — Pl. 2, fig. 33.

Type locality — Dharwar exposures, 8 miles short of Dharwar city.

Description — Spheroidal, 25-30 μ. Wall up to 2 μ thick, ornamented with concentric ridges and furrows.

Comparison & remarks — *Chemotriletes* described by Naumova (1953) and other specimen referred to this genus by Staplin (1961) are comparable. As no trilete or any other haplotypic mark is observable on the specimens they are considered as algal cysts.

Sub-group — ***Leiofusidae*** **Eisenack, 1938 (*Netromorphitae* Downie, Evitt & Sarjeant, 1963).**

Navifusa **Combaz 1967**

Type species — *Navifusa navis* (Eisenack, 1938) Combaz, 1967.

Navifusa purana sp. nov.

Pl. 1, fig. 22

Holotype — Pl. 1, fig. 22.

Type locality — Dharwar exposures, 8 miles short of Dharwar city.

Description — Ellipsoidal, up to 70 μ long and 20 μ broad, elongated, wall thin, faintly granulose, grana fine, less than 0·5 μ broad, aligned longitudinally giving a pseudo-striate surface pattern in lower focii.

Comparison — *Quisquilites* Wilson & Urban (1963) described from the Devonian of Oklahoma, USA, are bean shaped, oval with a hyaline wall and are larger in size. The other species of *Navifusa* listed by Combaz (*l.c.*) are not comparable. The species described here distinguishes in possessing characteristic granulose ornamentation.

ALGAE

CYANOPHYTA

Class — CYANOPHYCEAE
Order — CHROOCOCCALES
Family — CHROOCOCCACEAE Naegeli, 1849
Genus — MYXOCOCCOIDES Schopf, 1968

Type species — *Myxococcoides minor* Schopf, 1968.

Myxococcoides indicus sp. nov.

Pl. 1, figs. 17, 18 & 19

Holotype — Pl. 1, fig. 17.

Type locality — Dharwar exposures, 8 miles short of Dharwar city.

Description — Ellipsoidal colonies containing few to 40 cells may be more in larger colonies, the number of cells depending on the size of the colony. Cells, circular, oblong or angular due to close approximation of neighbouring cells, 7-10 μ wide, cell walls thin. The colony enveloped by a sheath. Sheath not ornamented appearing granulose due to agglutination of organic mineral debris.

Comparison — *M. minor* Schopf (*l.c.*) is closely comparable to the present species, but differs in possessing a thicker sheath as compared to the thin filmy sheath in *M. indicus*. *M. reticulata* Schopf (1968) has loosely arranged cells and punctate to reticulate ornamentation. *M. inornata* Schopf (1968) has larger cells measuring up to 18 μ. Thus both these species are not comparable.

Myxococcoides elongatus sp. nov.

Pl. 2, figs. 34 & 39

Holotype — Pl. 2, fig. 34.

Type locality — Dharwar exposures, 8 miles short of Dharwar city.

Description — Cells spheroidal, or acquiring derived shapes due to compression, aggregated in a linear filamentous fashion, 4-5 cells observed. Individual cells covered in a granulose amorphous organic matrix, agglutinated with organic debris.

Comparison — The specimens, figured and included here show a filamentous habit. This may be due to chance approximation of a number of cells. *M. inornata* is comparable in characters of the cell as well as the organic cover but has larger individual cells.

?*Myxococcoides* sp.

Pl. 2, fig. 38

Description — 3 celled specimen, cells spheroidal, 18-22 × 22-26 μ. Wall smooth. Sheath thin and opaque.

Comparison — This fossil cannot be compared with *Myxococcoides* recorded by Schopf (*l.c.*) as well as from Dharwars.

***Palaeoanacystis* Schopf, 1968**

Type species — *Palaeoanacystis vulgaris* Schopf, 1968.

Palaeoanacystis puratanum sp. nov.

Pl. 2, fig. 28

Holotype — Pl. 2, fig. 28.

Type locality — Dharwar exposures, 8 miles short of Dharwar city.

Description — Colonial, cells spheroidal to elliptical angular or derived shapes due to approximation of individual cells, 4-5 μ-6-8 μ. Cell wall less than 1 μ thick, smooth. Individual sheaths not present, entire colony of nearly 100-200 cells encompassed by organic matrix.

Comparison — *P. vulgaris* lacks well pronounced organic sheath as in *P. puratanum* described here.

Phylum — CHLOROPHYTA
Class — CHLOROPHYCEAE
Order — (?) CHLOROCOCCALES

***Glenobotrydion* Schopf, 1968**

Type species — *Glenobotrydion aenigmatis* Schopf, 1968.

cf. *Glenobotrydion* sp. 1

Pl. 1, fig. 20

Description — Cells spherical (spheroidal), longish oval (ellipsoidal). Wall thick up to 1 μ, in groups of 3-4 appearing pseudofilamentous. Individual cells 15 μ broad and up to 17 μ long. Sheath of organic matrix not observed.

Comparison — *G. aenigmatis* described by Schopf (1968) is a colony of large number of circular cells and is distinctly different. Not many specimens have been studied/recovered by us and as such are compared with *Glenobotrydion* only.

cf. *Glenobotrydion* sp. 2

Pl. 1, fig. 21

Description— Spheroidal unicell, 21×19 μ. Wall thick, distinct, fairly ornamented.

Comparison — This specimen is comparable to a single cell of *G.* sp. 1.

Globophycus Schopf, 1968

Type species — *Globophycus rugosum* Schopf, 1968.

Globophycus circularis sp. nov.

Pl. 1, fig. 13

Holotype — Pl. 1, fig. 13.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description — Spheroidal, 25-30 μ. Wall covered by sheath. Sheath folded closely giving a pseudoreticulate appearance, agglutination of organic debris common.

Comparison — *G. rugosum* has a larger sheath.

TRILETE SPORE

Spore Type

Pl. 2, fig. 35

Occurrence — Dharwar exposures, 3½ miles from Dharwar city on the Halyal road.

Description — ? spore roundly triangular, 13 μ. Wall up to 1 μ thick, apiculate, apiculae closely spaced, rounded, less than 1 μ long and as wide. A faint trilete mark observed, arms reaching 2/3 radius. Y-rays not open.

Remarks — The mark observed is very faint and may represent only a tetragonal compression mark. The specimen is distinct and may represent a spore of a land plant. The occurrence of a tetrad scar, though not functional points out to their adherence in tetrads, thus leaving a tetrad scar. Only one specimen has so far been recorded.

Incertae Sedis

Algal filament type 1

Pl. 2, figs. 42 & 43

Description — Filament cylindrical, 8-10 μ in diameter, unbranched, non-septate appearing granulose due to agglutination of organic debris.

Comparison— *Siphonophycus* Schopf (1968) has capitate apices. The specimens studied by us are small, tubular filaments with a hoisted apices.

Algal filament type 2

Pl. 2, fig. 44

Description — Filamentous specimen, broken; filament long, cylindrical, about 7-9 μ in diam., probably non-septate, branched. Wall thin, ill-defined, about 0·5 μ.

Organic Plates

Type — 1

Pl. 2, fig. 45

Description — Fragmentary, elongated plate with simple, alternately arranged, circular to lenticular, perforations, 2-4 μ in diam.

FOSSIL ASSEMBLAGE

The assemblage consists of a rich variety of fossils grouped under cyanophyceae, chlorophyceae and sphaeromorphitae. The cyanophycean and chlorophycean algal remains are mostly unicellular with a well preserved sheath enclosing the unicell. Several sphaeromorphs are present in the assemblage, the most dominant of them are those classed under *Leiosphaeridia*. Other vesicles include *Protoleiosphaeridium*, *Granomarginata*, *Lophosphaeridium*, *Concentrites* and *Trachysphaeridium*. The sphaeromorphs do not show any distinct characters on the basis of which the forms can be classified. Ornamentation and size are used in differentiating different genera. The cyanophycean algal fossils are mostly unicellular or colonial chroococcalean forms and no distinct filamentous form has been recovered. *Palaeo-*

TABLE 1

Sample studied	Lithology, locality & other details
A_1	Greyish green Schist, 13 k.m. from Chikmagalur on the Chikmagalur-Kadur road.
A_2 (3 samples)	Red ferruginous sandstone overlain by fissile, soft; red shale 8 miles short of Dharwar on the Habli-Dharwar road.
A_3 (5 samples)	Buff, purple, reddish-brown and white shale, at times sandy; 5.5 k.m. from Dharwar on the Dharwar-Halyal road (a quarry about 100 m. west of the road).
A_4 (4 samples)	Dark grey, fine-grained, hard greywacke with dark grey shales which weather buff on surface; shales are fissile; 2 k.m. from Dharwar on Dharwar Kalgatki road (near building stone quarry).

anacystis, Myxococcoides are common in the assemblage.

Glenobotrydion & Glebophycus both genera erected by Schopf (1968) and classed under chlorophyceae (? Chlorocoaccales) are common in the assemblage. The assemblage is mostly characterized by these algal remains and sphaeromorphs. The sphaeromorphs may represent cysts or reproductive bodies of fossil algae or may themselves be algal bodies. No conclusion is drawn or differentiations made except on external morphology.

A spore-like form is recovered from the Dharwar sediments, exposed near Dharwar city on the Halyal road. This triangular fossil bears a faint triradiate mark. The affinity or relationship of this fossil is not known (see discussion in Syst. Palynology).

A number of organic plates (perhaps of animal origin) are also found.

DISCUSSION

Early Precambrian microbiota recorded from the Onverwacht Series (>3200 m.y.), Fig Tree Formation (3200 m.y.) of Swaziland system near Barberton, South Africa (Engel *et al.*, 1968; Barghoorn & Schopf, 1966; Schopf & Barghoorn, 1966, 1967; Pflug 1966, 1967) and Soudan Iron Formation (2800 m.y.) of Minnesota (Grunner, 1925; Cloud & Licari, 1968) comprises unicellular, spheroidal algal microfossils

TABLE 2 — DISTRIBUTION OF FOSSILS IN THE DIFFERENT SAMPLES STUDIED

Fossil	SAMPLE NOS.			
	A-1	A-2	A-3	A-4
Sphaeromorphitae				
Leiosphaeridia	+	+	+	+
Protoleiosphaeridium	+	+	+	+
Granomarginata		+	+	
Lophosphaeridium		+	+	
Trachysphaeridium		+		+
Concentrites		+		
Rugocystis		+		
Navifusa			+	
Cyanophyceae (Chroococcales)				
Palaeoanacystis		+		
Myxococcoides		+		
Chlorophyceae (Chlorococcales ?)				
Glenobotrydion		+		
Globophycus		+		
Spore type			+	
Algal Filaments		+	+	
Indeterminable organic matter	+	+	+	+

(*Archaeosphaeroids barbertonensis*) similar to modern blue green algae (Chroococcales), globular bodies resembling cysts of flagellates, filamentous forms assigned to nostocalean blue-green algae and organically preserved bacterium-like rod-shaped microfossils (*Eobacterium isolatum*) of eubacterial affinity along with larger remnants of partially organized organic matter.

Early Precambrian biota as recorded above are not comparable with Dharwar assemblage. The Dharwar assemblage contains morphologically complex algal unicells (*Globophycus, Glenobotrydion*) of Chlorococcales and colonial forms (*Palaeoanacystis, Myxococcoides*) of chroococcalean affinity.

The Gunflint (2000 m.y.) and Lower Belcher (1700 m.y.) assemblages comprise the best documented Middle Precambrian microbiota. The microbiota is predominantly composed of filamentous and spheroidal procaryotic microorganisms referable to cyanophycean families (Chroococcaceae, Oscillatoriaceae, Nostocaceae) and a variety of chemosynthetic bacteria (Barghoorn & Tyler, 1963, 1965; Cloud, 1965; Cloud & Hagen, 1965; Schopf *et al*., 1965; Hofmann & Jackson, 1969). The Dharwar assemblage consists of a rich variety of fossils grouped under Cyanophyceae, Chlorophyceae and Sphaeromorphitae. The cyanophycean algal fossils are mostly unicellular or colonial chroococcalean forms and very few ill-defined filamentous forms have been recorded.

Although the Middle Precambrian and Dharwar assemblages are characterized by the abundance of photosynthetic procaryotic plants of cyanophycean affinity, the comparison between well documented Middle Precambrian and Dharwar biotas appears to be difficult at this stage of our knowledge of the Dharwar biota.

Structurally and organically well-preserved microorganisms have been discovered and described in many Late Precambrian sedimentary units of Central, Northern and Southern Australia, Montana, Michigan, South California, Poland and China. The best preserved and diverse assemblage is recorded from the Black Cherts of the Bitter Spring Formation of Central Australia, dated as approximately 1000 m.y. in age (Barghoorn & Schopf, 1965; Schopf, 1968, 1970) and offers some comparison with the Dharwar microfloral assemblage in having the following common constituents. The common constituent genera are: *Palaeoanacystis*, *Myxococcoides* (Chroococcaceae); *Glenobotrydion, Globophycus* (Chlorococcales).

The Bitter Spring microbiota contains well-preserved procaryotic filamentous (Oscilatoriaceae, Nostocaceae and Rivulariacea) blue-green alga, spheroidal green algae (*Caryosphaeroides*) assigned to Chlorellaceae and organic filaments probably related to modern filamentous fungi (Eumycophyta ?). The eucaryotic (Nucleate) nature of Dharwar assemblage is evidenced by the presence of *Globophycus, Glenobotrydion*, and a doubtful trilete spore, also a significant feature of the Bitter Spring microflora. The Dharwar assemblage essentially lacks the filamentous fossils typical of the Bitter Spring assemblage, and thus indicates a major compositional dissimilarity between the two assemblages.

A comparison of the Dharwar assemblage with the well-dated assemblages of Precambrian sediments reveals that Dharwar assemblage is more advanced than the Early Precambrian microbiota, as the latter is characterized by the procaryotic microorganisms consisting of coccoid and filamentous blue-green algae and rod-shaped bacteria and as such the two assemblages are not comparable.

Comparing the fairly well known Late Precambrian Bitter Spring microbiota with the Dharwar assemblage, it becomes apparent that although the two have few common genera viz., *Myxococcoides, Palaeoanacystis* of Cyanophyceae, *Globophycus, Glenobotrydion* of Chlorophyceae; their overall comparison shows a clear distinction between the two. The above common coccoid members exhibit dissimilarity at the specific level. An abundance of filamentous fossils referred to the oscillatoriaceae, Nostocaceae and Fungi (? Eumycophyta) in Late Precambrian sediments is marked. *Palaeolyngbya Barghoorniana* Schopf, *Cephalophytarion grande* described by Schopf (*l.c.*) and other fossils which exhibit evolved cyanophycean features as rounded, attenuated or dilated terminal cells, disc or barrel-shaped middle cells and encompassing organic sheaths and organic filaments (*Eomycetopsis robusta, E. filiformis*) closely comparable to modern filamentous fungi (?) characterize the late Precambrian microbiota. The Dharwar assemblage consists of unicellular and colonial algal remains forming the major constituents of the flora. This comparison affords to suggest that the Dharwar assemblage is less evolved in complexity as compared to the Late Precambrian microbiota.

Thus it is probable that Dharwar Microbiota is more advanced than the Early Precambrian assemblage and more primitive than the Late Precambrian one, ranging between Middle Precambrian to Early late Precambrian in age.

The presence of eucaryotic microfossils *Glenobotrydion*, *Globophycus*, and a doubtful trilete spore in the Dharwar assemblage reveals that the eucaryotic microorganisms of algal affinity were represented during the Dharwar times. The available evidence recorded up till now from the well-documented Precambrian microbiota, suggests that this higher level of biological organization originated during the period between 1800 and 2200 m.y. ago (Schopf, 1967, 1968; Cloud, 1968; Margulis, 1968). Thus the age of the Dharwar microbiota according to comparisons made as above is younger in aspect than the approximate radiometric age of 2400 m.y. (Pichamuthu, 1971).

Gowda and Sreenivasa (1969) have recorded Dharwar fossils from the Goddadaranagayanhalli Formation (G.R. Formation) of the Chitaldrug Schist Belt. The organic fossils come from an age group of 2000-1400 m.y. and referred to Sphaeromorphitae and Netromorphitae of the Group Acritarcha and cuticular remains to *Spongiophyton*, Kräusel. An abundance of Sphaeromorphitae in G.R. Formation and Dharwar assemblage described here exhibits a similarity between the two. Detailed comparison between these two biotas is not made due to poor preservation and lack of details of the morphology of fossils of the G.R. Formation.

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EXPLANATION OF PLATES

(All photomictographs magnified — × 750, except Pl. 1, Figs. 14, 15, 16 & Pl. 2, Figs. 7, 13, 17 which are — × 1000)

PLATE 1

1, 2. *Leiosphaeridia ravi* sp. nov. [Slide No. A2/1].

3. *Leiosphaeridia aglutinata* sp. nov. (Slide No. A2/2).

4. *Protoleiosphaeridium* sp. [Slide No. A2(2)/2].

5, 6. *Protoleiosphaeridium problematicum* sp. no. (Slide No. A2/1).

7, 8. *Leiosphaeridia dharwariana* sp. nov. [Slide No. A2/1, A2(2)/3].

9, 10. *Leiosphaeridia aglutinata* sp. nov. [Slide No. A2(1)/12, A2(1)/3].

11. *Leiosphaeridia dharwariana* sp. nov. [Slide No. A2(1)/8].

12. *Leiosphaeridia aglutinata* sp. nov. [Slide No. A2/2, A1/2].

13. *Globophycus circularis* sp. nov. [Slide No. A2(1)/3].

14. *Granomarginata clara* sp. nov. [Slide No. A2/2].

15. *Leiosphaeridia dharwariana* sp. nov. [Slide No. A3(2)/1].

16. *Leiosphaeridia aglutinata* sp. nov. [Slide No. A2(1)/8].

17, 18, 19. *Myxococcoides indicus* sp. nov. [Slide No. A2/1, A2(1)/8, A2(1)/6]

20. Cf. *Glenobotrydion* sp. 1 [Slide No. A2(1)/12].

21. Cf. *Glenobotrydion* sp. 2 [Slide No. A2(1)/8].

22. *Navifusa purana* sp. nov. [Slide No. A3(2)/1].

23. *Leiosphaeridia aglutinata* sp. nov. [Slide No. A2(1)/12].

PLATE 2

24-27. *Rugocystis velaris* Gen. et sp. nov. [Slide No. A2/1, A2(2)/3, A2(1)/4, A2/2].

28. *Palaeoanacystis puranaum* sp. nov. [Slide A2(1)/6].

29. *Trachysphaeridium decorum* sp. nov. [Slide A2(1)/3].

30. *Lophosphaeridium* sp. [Slide No. A2(1)/12].

31. *Trachysphaeridium* sp. [Slide No. A4(2)/1].

32, 33. *Concentrites muricatus* Gen. et. sp. nov. (Slide No. A2/1, A2/2).

34. *Myxococcoides elongatus* sp. nov. [Slide No. A2(1)/11].

35. Spore type-1 [Slide No. A3(2)/1].

36. *Lophosphaeridium conatum* sp. nov. [Slide No. A2(1)/8].

37. *Rugocystis velaris* Gen. et sp. nov. [Slide No. A2(1)/3].

38. ? *Myxococcoides* sp. [Slide No. A2(1)/6].

39. *Myxococcoides elongatus* sp. nov. [Slide No. A3(2)/1].

40. *Lophosphaeridium sinuatum* sp. nov. [Slide No. A2(1)/12].

41. *Trachysphaeridium* sp. [Slide No. A4(2)].

42, 43. Algal filament type-1 [Slide No. A2(1)/8].

44. Algal filament type-2 [Slide No. A2(1)/3].

45. Organic plate [Slide No. A2(1)/10].


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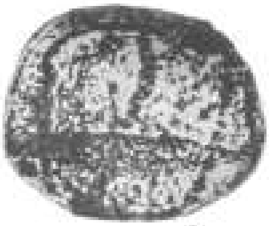
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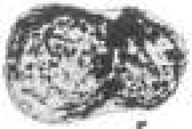
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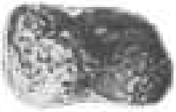
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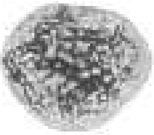
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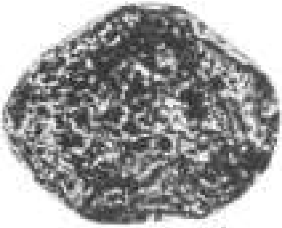
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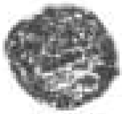
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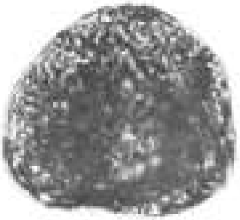
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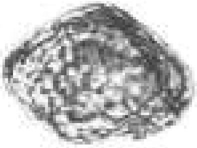
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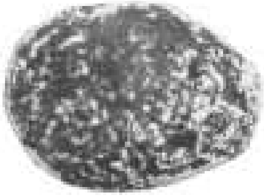
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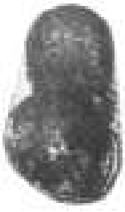
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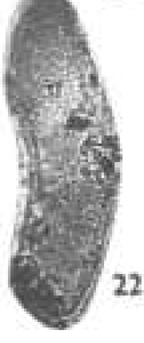
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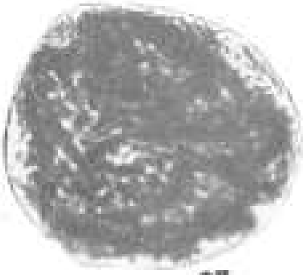
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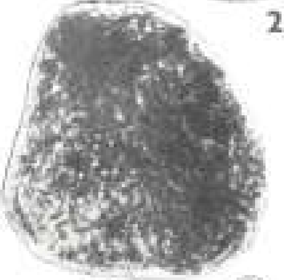
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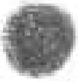
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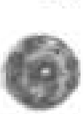
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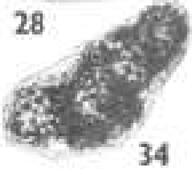
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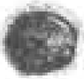
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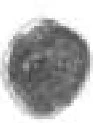
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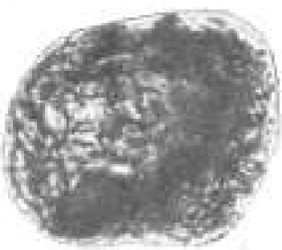
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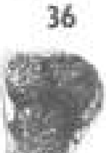
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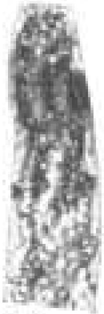
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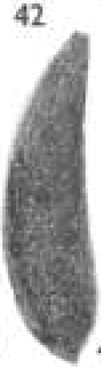
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A PROBLEMATICAL FOSSIL OF PSILOPHYTALEAN ASPECT FROM THE UPPER PENNSYLVANIAN OF EASTERN KANSAS

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Botany Department, University of Kansas, Lawrence, Kansas, U.S.A.

ABSTRACT

Naked, regularly dichotomizing axes have been found in abundance as compressions in Upper Pennsylvanian shales of north-eastern Kansas associated with such typically Pennsylvanian plant remains as *Pecopteris feminaeformis*, *Pecopteris arborescens*, *Neuropteris scheuchzeri*, *Alethopteris* sp. *Lepidophylloides* sp. and *Cordaites* sp. Specimens up to 14 cm. in length showing up to 5 very regular dichotomies, all in one plane, present a psilophytalean aspect which would unhesitatingly be identified as aerial stems if found in Devonian rocks. The specimens are assigned to the form genus *Hostinella* (*Hostimella*) as a new species, *H. pennsylvanica* and reasons are discussed for the probable survival of Devonian plants into the Pennsylvanian Period.

INTRODUCTION

THE occasional occurrence of plants resembling those of the Devonian flora in strata of Middle and Upper Pennsylvanian age indicates that some of these more ancient genera may have survived essentially unchanged into the later geological period in the same way that such "living fossils" as *Equisetum*, *Selaginella* and *Lycopodium* seem to have persisted from the Pennsylvanian to the present. Then as now, however, they probably constituted a very minor element in relation to the more modern flora of the time and are very seldom encountered in the fossil record.

Two Pennsylvanian coal ball genera which have been suggested as possible Devonian type plants are *Microspermopteris* (Baxter, 1949) based on its leafless, flattened branch system and *Stelastellara* (Baxter, 1965) which, while unassignable to any known group of Pennsylvanian plants, shows in its stelar structure striking similarities to the branch and "rachis" of the Devonian *Actinoxylon* (Matten, 1968) and *Archaeopteris* (Carluccio *et al.*, 1966).

The present report deals with an assemblage of compression specimens from the Upper Pennsylvanian of eastern Kansas which also seems more similar to some of the Devonian psilophytalean genera than it does to the Pennsylvanian flora.

GENERAL DESCRIPTION

Over one dozen specimens have been found, those shown in Figs. 1 and 2 being representative of the assemblage. The specimen shown in Fig. 1 measures slightly over 9 cm. in length and shows four regular dichotomies all lying in a single plane so that the branching system is fan-shaped. It measures 2·5 mm. in diameter near the bottom, gradually tapering to less than 0·5 mm. at the top. The small size and rapid taper of the axis in these upper dichotomies probably indicates that this is a terminal portion of the branching system. The specimen is preserved as a carbonaceous film on the shale with a thickened, dark ridge running down the center of the axis, possibly representing the remnants of the central xylem strand. In the axil of one of the upper dichotomies (Fig. 1-a) the axillary area above the dichotomizing central strand has some resemblance to the "webbing" described by Høeg (1942) as occurring in the branch angles of some of the Devonian *Hostinella* (*Hostimella*) specimens. However, nothing similar to the associated "axillary buds" described by Høeg have been found in any of our specimens.

The specimen shown in Fig. 2 measures 13·5 cm. in length while only showing two dichotomies. The large size of the axis, which measures 4 mm. in diameter at the base with only a gradual tapering to 2·5 mm. at the upper end (along with the greater length between dichotomies) suggests that it may represent a more basal part of the plant than that shown in Fig. 1. Indeed, since the 2·5 mm. upper diameter of this specimen equals the basal diameter of the fragment shown in Fig. 1, it is possible that they represent nearly contiguous parts of equivalent axes so that the total length of the dichotomous branch system could be estimated at at least 22 cm.

While the preservation of the specimen in Fig. 1 is in the form of a carbonaceous compression, the more basal fragments, as shown in Fig. 2, are frequently preserved as pyrite infiltrated casts which can be readily removed from the rock surface. Portions of the axis in Fig. 2 (and other similar specimens) were taken out, and polished and etched transverse and longitudinal sections prepared which were then observed at magnifications up to 80X in reflected light. While no cellular details were preserved, the central part of the axis was always occupied by an irregularly lobed strand of nearly pure iron-pyrite which characteristically, frequently seems to infiltrate the open xylem tissues in many coal ball plants.

DISCUSSION

The primary question regarding naked, dichotomizing axes such as the specimens just described, relates to whether they are properly identified as stems or roots. while they would probably be unhesitatingly identified as aerial stems if found in Devonian rocks, their unexpected presence in strata of Upper Pennsylvanian age will undoubtedly influence some to insist that they must represent dichotomously branched root systems of some of the more typical Pennsylvanian plants which are found in association with them.

In the absence of more diagnostic characters than are available to us there seems no way to settle the question conclusively, although the very regular dichotomies and undistorted, flattened fan-like growth are characters which seem more representative of aerial stems than they do of roots. Certainly none of the typical Pennsylvanian genera occurring in the same shale, such as *Pecopteris feminaeformis*, *P. arborescens*, *Neuropteris scheuchzeri*, *Alethopteris* sp., *Lepidophylloides* sp. and *Cordaites* sp. are known to have such flattened spreading root systems.

Occasional swollen tips, suggestive of terminal sporangia have been found associated with the dichotomous axes, but since none were found attached it is unprovable that they are part of the same plant.

It is well known that our present flora includes genera which seem to have survived essentially unchanged from the Pennsylvanian Period to the present. Schlanker & Leisman (1969) have described a Middle Pennsylvanian *Selaginella fraiponti* which they consider almost indistinguishable from the extant *S. selaginoides* while *Lycopodites* is reported in the Devonian and *Equisetites* in the Upper Carboniferous (Banks *et al.*, 1967).

In view of the above, it seems not unreasonable to assume that occasional Devonian plants could have survived the considerably shorter interval (and what were probably less drastic climatic changes) from the Devonian to the Pennsylvanian.

Accordingly it is felt that the evidence justifies provisionally placing these dichotomizing axes in the form genus, *Hostinella* Barr. ex Stur 1882 emend. Potonie & Bernard, 1904 as delimited by Banks (1967) until the time that future collections from this area may further clarify its position.

Hostinella (*Hostinella*) *pennsylvanica*

sp. nov.

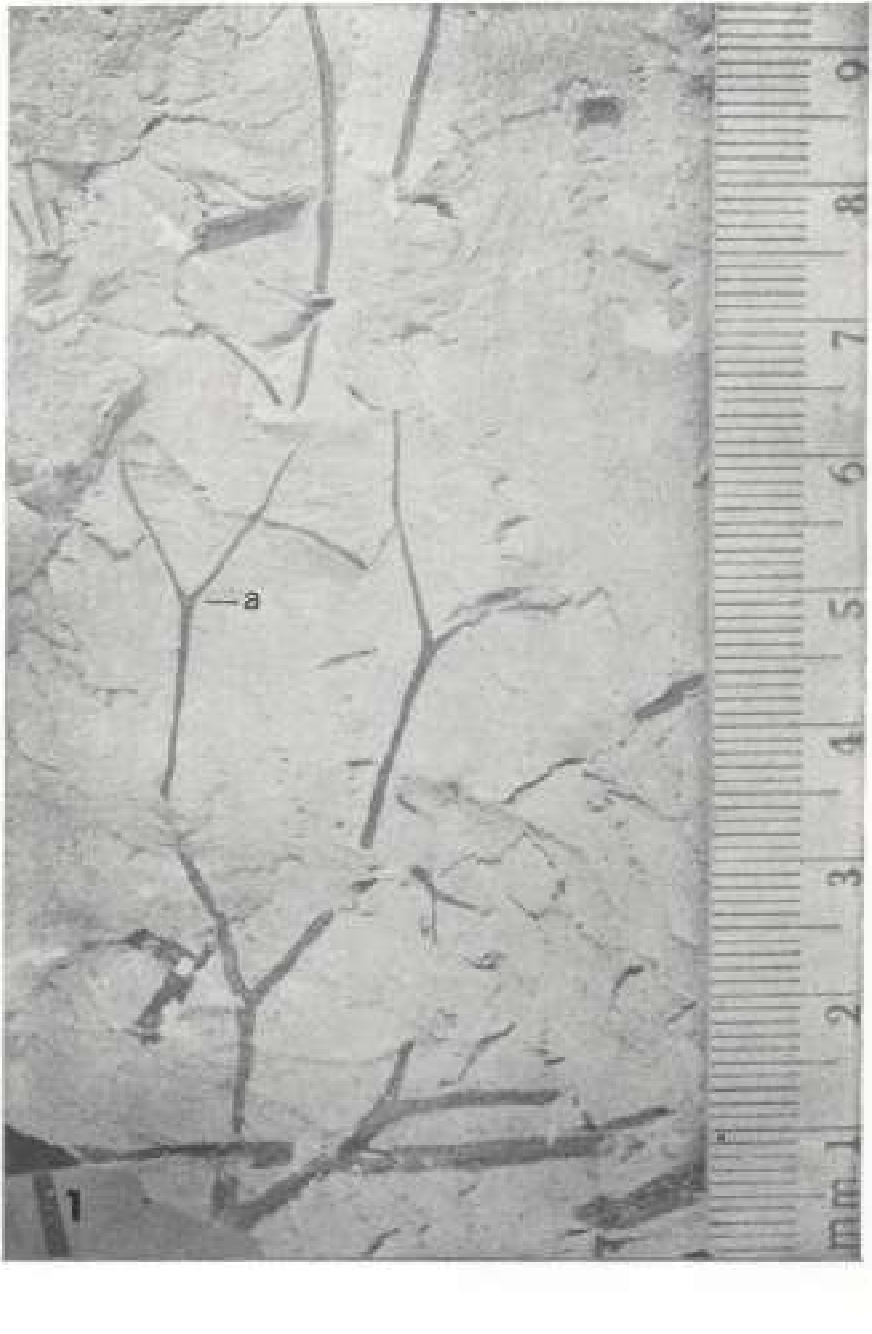
Pls. 1 & 2

Diagnosis — Naked, regularly, dichotomizing axes up to 22 cm. or more in total length with all of the branches in a single plane. Axes gradually tapering from a basal diameter of 4 mm. to 0·5 mm. near the apex.

Holotype — Specimen numbered No. 1449 in the University of Kansas paleobotanical collections. Fig. 1.

Horizon — Severy shale, Wabaunsee group, Virgilian stage, Upper Pennsylvanian of Kansas, U.S.A.

Locality — Severy shale outcrop above railroad tracks approximately 1/4 mile southeast of Valley Falls, Kansas.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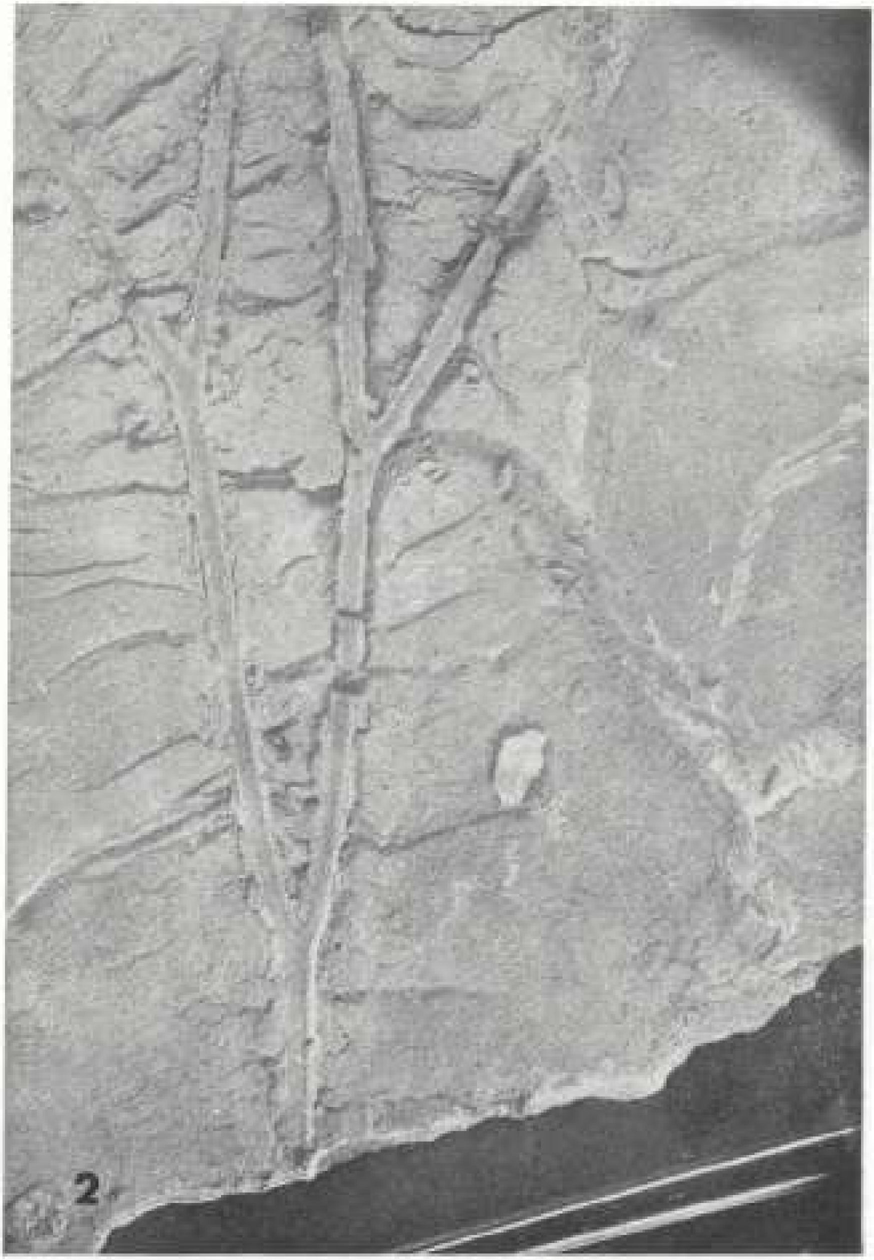
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PALYNOSTRATIGRAPHY OF THE SEDIMENTARY FORMATIONS OF ASSAM: 3. BIOSTRATIGRAPHIC ZONATION OF THE CHERRA FORMATION OF SOUTH SHILLONG PLATEAU*

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ABSTRACT

In the South Shillong Plateau, sediments of the Cherra Formation rest on the erodial surface of the Langpar Formation (Danian) and are in turn conformably overlain by the Lakadong Limestone (Lower Eocene) member of the Sylhet Limestone Formation. Based on the disposition of the Cherra Sandstone in three altitudinal belts, each characterized by a coal-seam, and on the distribution of commonly occurring palynological species, three biostratigraphic zones have been recognized in the Cherra Sequence.

The lower zone can be distinguished by the high frequencies of *Nymphaeoipollis crassimurus*, *Retialetes emendatus* and *Polypodiisporites mawkmaensis*, together with a few other forms restricted only to this zone. The middle zone can be recognized by the common occurrence of *Corrugatisporites formosus*, *Sestrosporites dettmannii*, *Foraminisporis medius*, *Couperipollis rarispinosus*, *Couperipollis wodehousei*, etc., and low frequencies or ± absence of *Nymphaeoipollis crassimurus* and *Polypodiisporites mawkmaensis*. The upper zone is distinct in the absence of palynomorphs characteristic of the lower and middle zones together with increased frequencies of *Foveosporites pachyexinous*, *Polycolpites speciosus*, *Engelhardtioidites parvus*, etc.

A distinct palynological change across the Cherra/Lakadong boundary is apparent, which can be fruitfully used for demarcating this boundary.

INTRODUCTION

THE coal bearing Cherra Sandstone and its directly associated sediments, conglomerate shale, carbonaceous shale and clay, form a sedimentary sequence, best developed near Cherrapunji and hence named as the Cherra Formation. During the course of geological mapping it was felt that the Cherra Formation was clearly divisible into three subdivisions. This feature became apparent by the development of this lithostratigraphic unit in three different altitudinal belts. The idea of subdividing this formation was further strengthened by the occurrence of three coal-seams within this sandstone group. It was noted that the Top-seam characterized the upper belt, the Middle-seam distinguished the middle belt, while the Bottom-seam marked the basal belt. Moreover, these seams are laterally traceable to a considerable distance, sometimes up to as much as 16 km., and the same sequence is observable throughout this lateral distance. However, in the absence of key beds, the three distinct zones remain lithologically indistinguishable. Consequently, qualitative and quantitative analyses of the palynological assemblage was undertaken to find a more reliable basis for demarcating the different stratigraphic levels within the Cherra Formation.

The pollen analytical data from the Cherra Formation were obtained by counting 200 specimens per sample. More than 200 samples from twenty-one escarp and gorge sections were analysed and studied. The complete thickness of the Cherra Formation has not been observed in any single section. Hence, a composite section has been compiled from three ± complete and 18 smaller sections. Similarly, a composite assemblage has been obtained by calculating the mean value of the palynological data from samples representing the same stratigraphic levels within the Cherra Formation. The resulting diagram (distribution chart) gives an idea of the frequencies of the significant spore/pollen species. The diagram at a glance clearly shows:

1. That the Cherra Formation is divisible into three palynological zones.
2. That the Cherra Formation, from base to the top, does not show any major miofloral change. A major floral change

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*The paper was originally presented to the Eastern Himalayan Geology Symposium, held at Shillong, Assam in November 1967. The long delay and uncertainty in the publication of the proceedings of the above Symposium necessitated the revision of the paper in the light of recent palynological studies on the area and its publication elsewhere.

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was not expected because the formation represents a comparatively short time interval to bring about any major evolutionary development.

3. A small but distinct miofloral change of stratigraphic significance is apparent between the assemblages of the Cherra Formation and the overlying Lakadong Sandstone.
4. Another important feature clearly observable is the gradual decline of those species which attained their maximum development at the lower horizons. On the other hand, species with low frequency, in the lower horizons, show progressive development towards the upper horizons until they reach the boundary with the overlying Lakadong Sandstone.
5. Palynological zonation of the Cherra composite section and the lateral persistence of the three cenozones provides corroborative evidence for the subdivision of this formation on lithological and structural grounds. Palynological markers provide a more reliable basis for the identification and correlation of different stratigraphic levels within the formation.

PALYNOSTRATIGRAPHY

The Cherra palynological assemblage is rich in pteridophytic spores and angiosperm pollen. Gymnospermous elements are absent. A total of 103 form species have been identified. Of these, some have a wide range of distribution while others are restricted to a small stratigraphic interval. Similarly, their numerical representation varies from very rare (1), rare (2-6), common (6-15), abundant (16-30), to predominant (above 30). The distribution of the palynological taxa in both time and space and their frequency differences have helped in the selection of certain key species which are of particular biostratigraphic significance in zoning and correlating the Cherra Formation. The following three palynological cenozones have been recognized in the composite section of the Cherra Formation:

NYMPHAEOIPOLLIS CRASSIMURUS CENOZONE

Places of Occurrence — Cherrapunji, Mawmluh, Mawsmai, Pynursla, Laitryngew, Umsawmat, Sohrarim, Mawrap and Lyngkyrdem.

Lithology — Fine to medium-grained sandstones, often white, friable in nature, are the dominant rock types of this cenozone. Beside these, shale, carbonaceous shale and coal are the other associated rock types. The average thickness of the sediments varies from 160-200 ft.

Lower Contact — The Cherra Formation is separated from the underlying Langpar Formation by a prominent band of conglomerate. An erosional unconformity between the two has been observed at fall section 1023'.

Upper Contact — The sandstone below the carbonaceous shale band forming the floor of the middle coal-seam constitutes the roof of this cenozone.

Principal Miofloral Constituents — *Nymphaeoipollis crassimurus*, *Polypodiisporites mawkmaensis*, *Nymphaeacidites clarus*, *Polycolpites ornatus*, *P. cooksonii*, *Lakiapollis matanmadhensis*, *Triorites inferius*, *T. communis*, *Talisiipites wodehousei*, *Liliacidites microreticulatus*, *Corrugatisporites formosus*, *Sestrosporites dettmanii*, *Foraminisporis medius*, *Tricolpites reticulatus*, *Trifossapollenites constatus*, *Dandotiaspora* spp., *Couperipollis brevispinosus*, *C. rarispinosus*, *Palmaepollenites communis*, *P. eocenicus*, *Palaeosantalaceaepites dinoflagellatus*, *Lycopodiumsporites palaeocenicus*, *Retialites emendatus* and *Cyathidites minor*.

Zonal Markers — *Nymphaeoipollis crassimurus*, *Retialetes emendatus*, *Polypodiisporites mawkmaensis*, *Nymphaeacidites clarus*, *Polycolpites ornatus*, *Lakiapollis matanomadhensis*, *Triorites inferius*, *Talisiipites wodehousei* and *Liliacidites microreticulatus*.

Remarks — The conglomerate bed at the base of the Cherra Sequence together with two closely placed coal partings provide a lithological basis for delineating the *Nymphaeoipollis crassimurus* Cenozone from the underlying Langpar Formation. This zone can also be readily distinguished from the Langpar by high frequencies of *Nymphaeoipollis crassimurus* and *Retialetes emendatus*. However, there are also other species which occur in low frequencies in the Langpar Formation but have become common in the *Nymphaeoipollis crassimurus* Cenozone. Two species, *Lycopodiumsporites palaeocenicus* and *Dandotiaspora dilata* have higher frequency value in Langpar Formation as compared to Cherra Formation.

ARALIACEOIPOLLENITES RETICULATUS CENOZONE

Places of Occurrence — Cherrapunji, Umswamat, Sohrarim, Mawmluh, Mawsmai, Pynursla and Bapung.

Lithology — Sandstones, shale, carbonaceous shale and coal are the principal rock types of *Araliaceoipollenites reticulatus* Cenozone. The average thickness of strata constituting this stratigraphic interval is in the order of 150-200 ft.

Lower Contact — Carbonaceous shale forming the floor of the middle coal-seam is the basal boundary of this cenozone. It is conformably underlain by a sandstone member which forms the top of the underlying *Nymphaeoipollis crassimurus* Cenozone.

Upper Contact — A sandstone bed which overlies the middle coal-seam forms the topmost member of *Araliaceoipollenites* cenozone.

Principal Miofloral Constituents — *Corrugatisporites formosus*, *Sestrosporites dettmanii*, *Foraminisporis medius*, *Araliaceoipollenites reticulatus*, *A. psilatus*, *Droseridites parvus*, *Polycolpites speciosus*, *Engilhardtoidites parvus*, *Couperipollis brevispinosus*, *Lycopodiumsporites palaeocenicus*, *Retialetes emendatus*, *Palmaepollenites eocenicus*, *Polycolpites cooksonii* and *Triorites communis*.

Zonal Markers — *Araliaceoipollenites reticulatus*, *A. psilatus*, *Droseridites parvus*, *Corrugatisporites formosus*, *Couperipollis brevispinosus*, *Triorites communis* and *Retialetes emendatus*.

Remarks — A thick massive sandstone overlying the middle coal-seam is the major lithological marker of this cenozone. White friable sandstone layers which constitute a common feature of the underlying *Nymphaeoipollis crassimurus* and the overlying *Tricolpites reticulatus* Cenozones are not met with in this stratigraphic interval.

TRICOLPITES RETICULATUS CENOZONE

Place of Occurrence — Cherrapunji, Laitryngew, Sohrarium, Mawmluh, Lyngkyrdem, Kyndiar, Gumaghat, Langrin and Mawsynram.

Lithology — The principal lithofacies of this interval comprise white friable sandstones underlain by ferruginous sandstone, coal and carbonaceous shale. The thickness of this cenozone varies from place to place but 200 ft. has been estimated as the average thickness.

Lower Contact — The carbonaceous shale forming the floor of the upper coal-seam marks the lower boundary of *Tricolpites reticulatus* Cenozone. It rests conformably over a massive sandstone stratum which constitutes the topmost horizon of the *Araliaceoipollenites reticulatus* Cenozone.

Upper Contact — The white friable sandstone that occurs at the top of the *Tricolpoites reticulatus* Cenozone is conformably overlain by a marine limestone band which is named as the Lakadong Limestone.

Principal Miofloral Constituents — *Corrugatisporites formosus*, *Tricolpites reticulatus*, *Trifossapollenites constatus*, *Polycolpites speciosus*, *P. cooksonii*, *Engilhardtioidites parvus*, *Couperipollis brevispinosus*, *C. rarispinosus*, *Palmaepollenites communis*, *P. eocenicus*, *Retialetes emendatus*, *Triporopollenites vimalii*, *Triorites communis* and *Cyathidites minor*.

Zonal Markers — *Tricolpites reticulatus*, *Trifossapollenites constatus*, *Triporopollenites vimalii* and *Cyathidites minor*.

Remarks — The upper zone of the Cherra Formation is very poor in palynological fossils. A distinct floral decline is discernible at this level which might be related to the advent of arid climate during the closing of the depositional phase of the Cherra Formation. Adverse environmental conditions are not only reflected by the poverty in the plant community but is also indicated by the development of a fairly thick ferruginous sandstone.

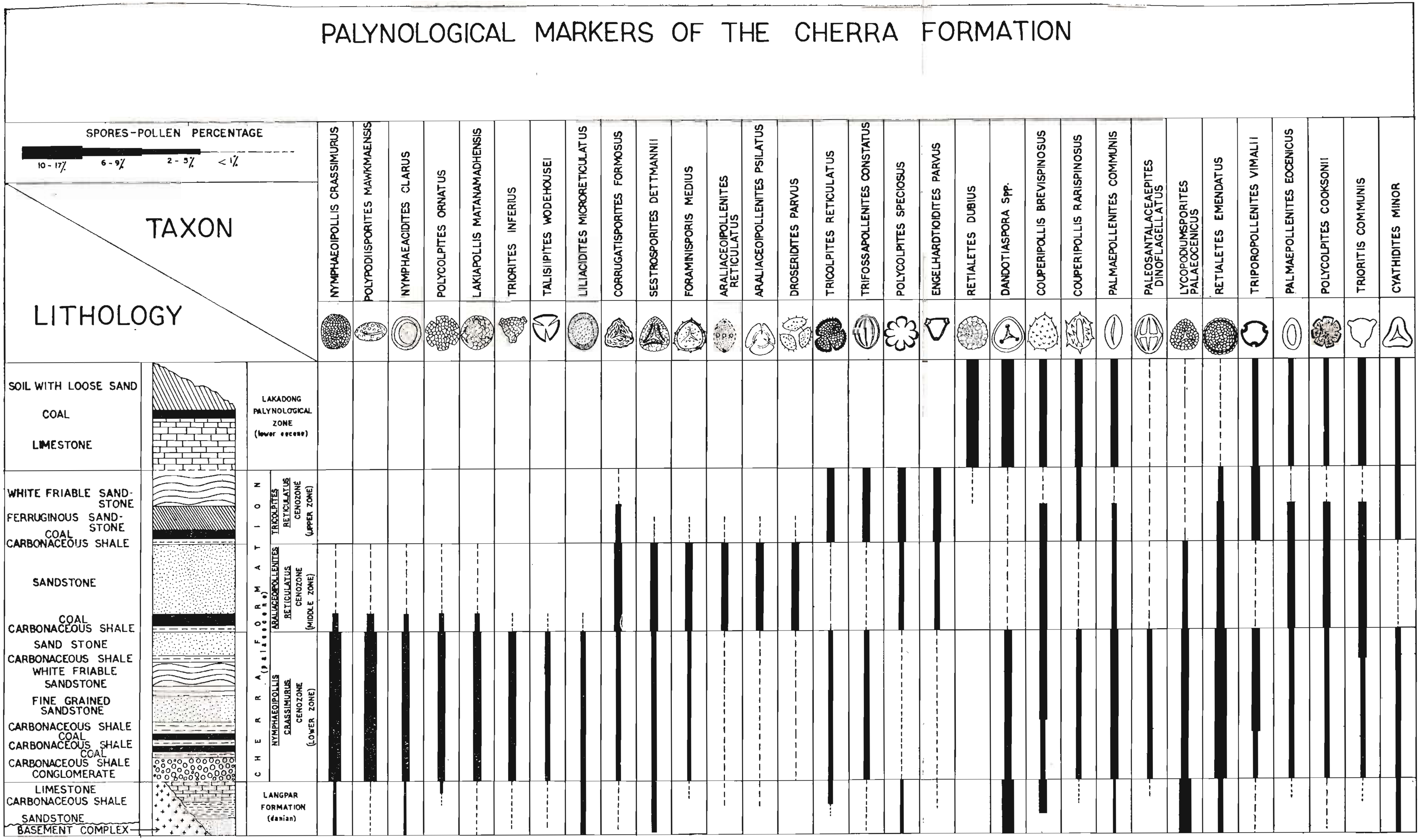
LAKADONG PALYNOLOGICAL ZONE

Places of Occurrence — Cherrapunji, Shella, Laitryngew, Lamshnong, Therriaghat, Mawmluh, Thanjinag and Pynursla.

Lithology — The strata of this cenozone comprise limestone, coal, carbonaceous shale and sandstone. They range from 500 to 600 ft. in thickness and constitute the lower part of the Sylhet Limestone Formation.

Lower Contact — Lakadong Limestone forms the lower boundary of the Lakadong palynological zone. It is underlain by a white friable sandstone which forms the topmost bed of the Cherra Formation.

Upper Contact — Lakadong Sandstone is conformably overlain by the Umlatodoh Limestone, which has yielded typical Laki fossils like *Nummulites*, *Alveolina*, *Discocyclina*, *Miliolidae*, etc., and on this evidence dated as Lower-Middle Eocene in age.


PALYNOLOGICAL MARKERS OF THE CHERRA FORMATION
SPORES-POLLEN PERCENTAGE
10 - 17%
6 - 9%
2 - 5%
< 1%
TAXON
LITHOLOGY
NYMPHAEOIPOLLIS CRASSIMURUS
POLYPODIISPORITES MAWKMAENSIS
NYMPHAEACIDITES CLARUS
POLYCOLPITES ORNATUS
LAKIAPOLLIS MATANAMADHENSIS
TRIORITES INFERIUS
TALISIIPITES WODEHOUSEI
LILIACIDITES MICRORETICULATUS
CORRUGATISPORITES FORMOSUS
SESTROSPORITES DETTMANNII
FORAMINISPORIS MEDIUS
ARALIACEOIPOLLENITES RETICULATUS
ARALIACEOIPOLLENITES PSILATUS
DROSERIDITES PARVUS
TRICOLPITES RETICULATUS
TRIFOSSAPOLLENITES CONSTATUS
POLYCOLPITES SPECIOSUS
ENGELHARDTIOIDITES PARVUS
RETIALETES DUBIUS
DANDOTIASPORA Spp.
COUPERIPOLLIS BREVISPINOSUS
COUPERIPOLLIS RARISPINOSUS
PALMAEPOLLENITES COMMUNIS
PALEOSANTALACEAEPITES DINOFLAGELLATUS
LYCOPODIUMSPORITES PALAEOCENICUS
RETIALETES EMENDATUS
TRIPOROPOLLENITES VIMALII
PALMAEPOLLENITES EOCENICUS
POLYCOLPITES COOKSONII
TRIORITIS COMMUNIS
CYATHIDITES MINOR
SOIL WITH LOOSE SAND
COAL
LIMESTONE
WHITE FRIABLE SANDSTONE
FERRUGINOUS SANDSTONE
COAL
CARBONACEOUS SHALE
SANDSTONE
COAL
CARBONACEOUS SHALE
SAND STONE
CARBONACEOUS SHALE
WHITE FRIABLE SANDSTONE
FINE GRAINED SANDSTONE
CARBONACEOUS SHALE
COAL
CARBONACEOUS SHALE
COAL
CARBONACEOUS SHALE
CONGLOMERATE
LIMESTONE
CARBONACEOUS SHALE
SANDSTONE
BASEMENT COMPLEX
LAKADONG PALYNOLOGICAL ZONE (lower eocene)
CHERRA FORMATION (palaeocene)
TRICOLPITES RETICULATUS CENOZONE (UPPER ZONE)
ARALIACEOIPOLLENITES RETICULATUS CENOZONE (MIDDLE ZONE)
NYMPHAEOIPOLLIS CRASSIMURUS CENOZONE (LOWER ZONE)
LANGPAR FORMATION (danian)

Text-fig 1

Principal Miofloral Constituents — *Retialetes dubius*, *Dandotiaspora* spp., *Couperipollis brevispinosus*, *C. rarispinosus*, *Palmaepollenites communis*, *P. eocenicus*, *Polycolpites cooksonii*, *Triorites communis* and *Cyathidites minor* and some microplanktons.

Zonal Markers — The dominance of *Dandotiaspora* complex and *Retialetes dubius* together with high frequencies of *Palmaepollenites communis* and *Cyathidites minor* distinguishes this zone from the underlying *Tricolpites reticulatus* Cenozone of the Cherra Formation.

Remarks — The passage between the Cherra Formation and the overlying Lakadong Limestone is readily observable by a distinct change in facies from arenaceous to calcareous. This evidence has been used to define the boundary between the two formations as this change seems to be related to the negative movements of the basin of deposition during the Lakadong times. The change in the composition of the palynological assemblages across this boundary conforms to the changes in the depositional basin and hence considered to be stratigraphically significant.

CONCLUSION

The range and relative frequency of the significant taxa shown in the range chart reveal that no sharp miofloral change occurs at the Langpar/Cherra boundary while a significant change is discernible at the Cherra/Lakadong boundary. Although most of the spore-pollen species pass through the Langpar/Cherra boundary without any change in their assemblage composition, there are some species which exhibit distinct change in their relative abundance. These changes seem to be of stratigraphic significance. Palynological data from the Langpar Formation is at present meagre. Hence examination of some more stratigraphic sections from the Langpar Formation is desirable before these changes can be used as reliable indices for delineating the Langpar/Cherra boundary.

The change in assemblage composition across Cherra/Lakadong boundary is of sufficient stratigraphic significance and can be used for delineating this boundary. This change is significant and may be related to the sinking of the basin which resulted in the advent of the transgressive phase at the close of the Cherra depositional cycle.

Study of a large number of stratigraphic sections, representing almost the entire outcrop area of the Cherra Formation, clearly demonstrates the correlative value of the three Cenozones established within the Cherra Composite Section. The position of the three cenozone boundaries in relation to the three coal-seams is essentially the same throughout the sections studied. This indicates close correspondence between lithologic and biostratigraphic boundaries.

Field indications supported by lithological succession indicate that the Cherra Formation of Shillong Plateau is equivalent to the Tura Formation of Garo Hills. Cenozone correlation of the Cherra Formation with the Tura Formation (Sah & Singh, 1974) shows close parallelism between the two. The three Cherra Cenozones closely correspond to the three lower cenozones of the Tura Formation, i.e. *Nymphaeoipollis crassimurus* Cenozone corresponding to *Retialetes emendatus*, *Araliaceoipollenites reticulatus* Cenozone correlating with *Dandotiaspora telonata* and *Tricolpites reticulatus* Cenozone comparing with *Palmidites plicatus* Cenozone of Tura Formation. The relationship between lithological and biostratigraphical boundaries is essentially the same at both these places which clearly establishes the correlative value of these zonal assemblages. Thus, palynology provides conclusive evidence that the Tura Formation of Garo Hills is the westerly extension of the Cherra Formation of Shillong Plateau.

The lateral persistence of these diagnostic biota throughout the Garo, Khasi and Jaintia Hills, the close correspondence in the lithological succession and the outcrop area being restricted to the southern slopes indicate that all these basins were once part of a long foredeep in front of the Assam autochthon and as such they may be parts of the same sedimentary basin. The heavy mineral assemblage is also more or less the same at both these basins indicating that these areas received sediments from the Pre-Cambrian crystalline mass of the autochthon.

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PALYNOSTRATIGRAPHY OF THE SEDIMENTARY FORMATIONS OF ASSAM, INDIA: 4. AGE OF THE LAITRYNGEW-MAWKMA COAL-BEARING SANDSTONES AND THEIR RELATIONSHIP WITH THE CHERRA FORMATION*

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ABSTRACT

The present paper deals with the age of the coal-bearing sandstones of the Laitryngew-Mawkma area and their relationship with the Cherra Formation. Climatic condition and depositional environment at the time of deposition have been summarized. Since Medlicott first distinguished the coal-bearing sandstones of Laitryngew-Mawkma area, the age of these rock units have tacitly been accepted as "Lakadong Sandstone Stage" (Lower-Middle Eocene). On the basis of stratigraphical similarity they have been equated with the coal-bearing sandstone of Mawmluh (Lower Cherrapunji; Longitude 91°42'30"E: Latitude 25°15'15"N). Recent palynological and palaeontological studies of the sedimentary formations of the South Shillong Plateau have shown that these coal-bearing sandstones may be slightly older than what they were previously regarded. The results of the heavy mineral studies also seem to conform to the palynological dating.

Since these sandstones apparently seem to be older than the Lakadong Sandstone, they may be a continuation of the sedimentary succession developed at Cherrapunji, and hence Palaeocene in age. The fossils suggest prevalence of subtropical climate and a shallow, fresh-water or lagoonal environment of deposition.

INTRODUCTION

In the absence of lithological markers, the identification and correlation of the Upper Cretaceous-Lower Palaeogene rocks of the South Shillong Plateau have, so far, been largely based on marine invertebrate fossils. The invertebrate fossils are restricted to the Mahadeo, Langpar (Cretaceous) and the Lakadong Limestone member (Lower-Middle Eocene) of the Sylhet Limestone Formation. There is a thick development of non-marine sediments between two limestone bands, the lower belonging to the Langpar Formation (Danian) while the upper limestone band forms the basal member of the Sylhet Limestone Formation (Lower-Middle Eocene). This non-marine section consists primarily of sandstones, intercalated with three coal-seams, shales and clays. Considerable difficulties have been encountered in the recognition and lateral tracing of this succession even in nearby sections. This is because of absence of distinctive marker beds, absence of palaeontologic fossils and the nature and development of this succession at different parts of the basin. The Cherra sequence, best developed near Cherrapunji, could not be reliably correlated with another well-developed sequence at Therriaghat, a few miles south-east of Cherrapunji. Consequently two formation names were erected for these local developments. The sequence at Cherrapunji was named as Cherra Formation while the other was named as Therria Formation. From a perusal of relevant literature it becomes apparent that similar difficulties were encountered in attempts to correlate, from surface exposures, the coal-bearing succession of Laitryngew-Mawkma area. As a result the age and stratigraphical position of the Laitryngew-Mawkma sequence has remained an open question. Correlation based on palynological markers, however, seems to provide a reliable basis for dating this sedimentary sequence.

The first reference to the age of the sandstones at Laitryngew and Mawkma was made by Medlicott (1869) who first recognized these stratigraphic units and assigned a Nummulitic age (equivalent to the Shylhet Limestone Formation).

Palmer (1923) indicated that these sandstones were equivalent to the Cherra Formation and placed them at the top of the Cretaceous sequence.

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*The paper was originally presented to the Eastern Himalayan Geology Symposium, held at Shillong, Assam, in November 1967. The long delay and uncertainty in the publication of the proceedings of the above Symposium necessitated the revision of the paper in the light of recent palynological studies on the area and its publication elsewhere.

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Ghosh (1940) mapped the area and on lithological and structural grounds regarded the Laitryngew-Mawkma coal-bearing sandstones as equivalent to the Lakadong Stage (Lower-Middle Eocene).

Evans (1932) suggested an Upper Eocene age for these coal-bearing sandstones.

Based on the occurrence of an angular unconformity between the underlying Langpar Formation and the overlying Cherra Formation, together with paleontological evidence, Dutta (Dutta *et al.*, 1964) first opined that the limestones occurring at Laitryngew, Umstew and Mawkma belong to the Langpar Formation and the coal-bearing sandstones that immediately overlie these limestones formed the base of the Tertiary sequence.

Later, in the same year Bagchi made a comparative study of the invertebrate fossils from the type area of Langpar with those of the Laitryngew Limestone. He supported Dutta and concluded that the Laitryngew Limestone is a lateral continuation of the one occurring at Langpar.

This paper presents the results of geological and palynological studies of the clastic sediments of the non-marine sandstone group exposed at Laitryngew-Mawkma area and their correlation with the Cherra succession.

GENERAL GEOLOGY

The area in which the present geological and palynological investigations have been carried out forms the southern part of the Shillong Plateau. It lies between Lat. 25°15'30" and 25°20'30"N; Long. 91°40'0" and 19°45'30"E and is covered by Survey of India toposheet 78 0/11, in one-inch scale.

The general geology of the area has been described in detail a number of times (Ghosh, 1940; Biswas, 1962; D. G. M. Bulletin 1964) and hence will not be discussed in the present paper.

STRATIGRAPHY

The basement Archaean rocks and the overlying Jurassic Sylhet traps are exposed only at the gorges or river sections. Overlying the traps are the Cretaceous conglomerate and reddish to purplish sandstones, forming the Mahadeo Formation. This stratigraphic unit is succeeded by the Langpar Formation which is characterized by a massive fossiliferous limestone band and a thin shale band at the top. The Langpar section is overlain by a coal-bearing sandstone sequence, which in turn is conformably overlain by another fossiliferous limestone, known as the Lakadong Limestone.

PALAEONTOLOGY

The Lakadong Limestone that immediately overlies the coal-bearing sandstones is dated as Lower-Middle Eocene because it contains the following fossils:

Nummulites thalicus, *N. sindensis*, *Lockhartia haimei*, *Miscellania miscella*, *M. meandrina*, *Operculina* cf. *canalifera*, *Alveolina*, *Orbitosiphon tibetica*, *Discocyclina ranikotensis*, *Gypsina* sp. and some calcareous algae (Krishnan 1960, p. 518). According to Wadia (1961, p. 340) " The Lakadong beds contain foraminifers which indicate a Ranikot age ". Based on palaeontological evidence Rama Rao (1964, p. 18) also suggested an Upper Ranikot age for these beds.

Dutta *et al.* (1964, pp. 51-52) recorded fossils like *Cypraea* sp., *Solariella* cf. *radiatula* Forb., *Exogyra* cf. *suborbiculata* Lam., *Cardium* cf. *pilatum* Stol., *Plicatula* sp. from the underlying Langpar Limestones. Of these, *Solariella* cf. *radiatula* Forb. ranges from Cenomanian to Turonian; *Exogyra* cf. *suborbiculata* Lam. is indicative of Turonian to Senonian age, while *Cardium* cf. *pilatum* Stol. is a Danian form (Pascoe, 1959, pp. 1237, 1248 and 1258). These genera have, so far, not been recorded from any other horizon younger than the Upper Cretaceous.

HEAVY MINERAL COMPOSITION

Heavy mineral analysis of the coal-bearing sandstone shows that the sandstone is characterized by *zircon*, *rutile*, *magnetite*, *hematite*, *ilmenite*, *apatite*, *tourmaline*, *garnet*, *kyanite* and *sphene*. The composition of this suite is thus more or less identical to that of the Cherra Formation.

PALYNOLOGICAL COMPOSITION

The coal-bearing sandstone unit of Laitryngew-Mawkma area contains a rich and varied flora. The assemblage is characterized by the abundance of angiospermic pollen and pteridophytic spores while the gymnosperms are meagrely represented. The palynological fossils shall be described elsewhere. The stratigraphically significant palynological markers and their relative abundance are given below.

1. *Nymphaeoipollis crassimurus* — dominant
2. *Polypodiisporites mawkmaensis* — dominant
3. *Retialetes emendatus* — dominant
4. *Nymphaeacidites clarus* — dominant
5. *Polycolpites ornatus* — dominant
6. *Lakiapollis matanmadhensis* — common
7. *Lycopodiumsporites palaeocenicus* — common
8. *Triorites inferius* — common
9. *Talisiipites wodehousei* — rare
10. *Corrugatisporites formosus* — rare
11. *Sestrosporites dettmanii* — rare
12. *Foraminisporis medius* — rare
13. *Araliaceoipollenites reticulatus* — rare
14. *A. psilatus* — rare
15. *Droseridites parvus* — rare
16. *Monolites (Laevigatosporites) discordatus* — rare
17. *Tricolpites crassireticulatus* — rare
18. *Trifossapollenites constatus* — rare
19. *Foveotriletes pachyexinous* — rare
20. *Polycolpites speciosus* — rare
21. *Engelhardtioidites parvus* — rare
22. *Palaeosantalaceaepites dinoflagellatus* — rare

The most striking feature of the Laitryngew-Mawkma assemblage is the dominance of three species, viz. *Nymphaeoipollis crassimurus*, *Retialetes* and *Polypodiisporites mawkmaensis*. These species have approximately the same relative abundance as in the *Nymphaeoipollis crassimurus* Cenozone (Lower Zone 1) of the Cherra Formation (Sah & Dutta, 1973).

The distribution and frequency of the other palynological taxa, e.g. *Nymphaeacidites clarus*, *Polycolpites ornatus*, *Lakiapollis matanmadhensis*, *Triorites inferius*, *Talisiipites wodehousei*, *Corrugatisporites formosus*, *Sestrosporites dettmanii*, *Lycopodiumsporites palaeocenicus*, *Foraminisporis medius*, *Araliaceoipollenites reticulatus*, *Tricolpites crassireticulatus*, *Trifossapollenites constatus*, *Foveotriletes pachyexinous*, *Polycolpites speciosus*, etc., in the Laitryngew-Mawkma assemblage, is also the same as in the Cherra Formation.

The coal-bearing sandstone unit at Laitryngew-Mawkma area overlies a marine limestone which on faunal evidence is considered to be equivalent to the Langpar Formation. This excludes the possibility of the Laitryngew-Mawkma Sandstone unit being Cretaceous in age. The other two possibilities are whether this coal bearing succession is equivalent to the Cherra Formation or the Lakadong Sandstone member of the Sylhet Limestone Formation. Palynological cenozone correlation indicates that the Laitryngew-Mawkma coal bearing unit is more or less identical to the Cherra coal bearing unit. Palynological markers like *Couperipollis*, *Retialetes dubius*, together with high frequencies of *Dandotiaspora* complex, *Palmaepollenites communis*, *Cyathidites minor*, which characterize the Lakadong sandstone interval are missing from the Laitryngew Mawkma coal bearing unit.

On the other hand, the Lakadong assemblage is characterized by the dominance of *Retialetes dubius*, *Dandotiaspora* spp. and a large number of monosulcate spinose grains which in the Cherra assemblage are either absent or very rare. All the dominant species of the Cherra assemblage are absent in the Lakadong assemblage, hence the coal bearing sandstone succession at Laitryngew-Mawkma area does not correspond to the Lakadong Sandstone member of the Sylhet Limestone Formation.

In view of the above comparisons it becomes apparent that the Laitryngew-Mawkma coal bearing stratigraphic unit is equivalent to the Cherra Formation. This interval is, therefore, Paleocene in age. The microfloral and lithological identity together with close proximity of the Laitryngew-Mawkma Sandstone unit with the Cherra Sandstone unit indicates that the former might be the northern and north-western continuation of the latter.

CONDITIONS OF DEPOSITION

In 1940 Ghosh (p. 15) suggested that Lower Eocene time was a period of oscillation of land and sea in the Khasi Hills when marine conditions alternated with those of estuarine and deltaic. The ecological environment of the palynological taxa recovered from the Laitryngew-Mawkma Sandstone unit clearly indicates that the sandstones were deposited under continental conditions. As these sandstones are underlain and overlain by marine limestones it is reasonable to assume that they were deposited during the temporary withdrawal of the sea from the area. The presence of pollen of *Potamogeton*, *Nymphaea*, *Lentibulariaceae*, etc., indicates a fresh-water aspect. This is also borne out by the presence of a plant bearing bed at Laitryngew from where a rich megaflora (palm leaves, etc.) have been collected. The absence of brackish-water or marine elements further substantiates a fresh-water environment. The presence of pollen grains referable to the Palmae, Rhizophoraceae, Chenopodiaceae, etc., indicate coastal aspect. The occurrence of ripple-marks and current bedding in these sediments suggest shallow water deposition. It is therefore reasonable to deduce that these sandstones were laid down under near-shore, fresh-water to estuarinal or lagoonal conditions.

The palynological composition of the Laitryngew-Mawkma assemblage further indicates the prevalence of humid subtropical climate during the time of deposition of this stratigraphic interval.

CONCLUSION

The assembled data (palynological, palaeontological and heavy mineral) clearly indicate that the stratigraphical position of the Laitryngew-Mawkma sandstone unit is younger than the Langpar Formation (Danian) and older than the Lakadong Limestone member of the Sylhet Limestone Formation (Lower-Middle Eocene). This coal bearing sandstone interval appears to be the equivalent of the Cherra Formation. The close lithological and microfloral identity between the two clearly indicates that the Laitryngew-Mawkma coal bearing sandstone unit is the northern and north-western continuation of the Cherra Formation and hence Palaeocene in age.

The geological and palynological data indicate that the place of deposition was a shallow, fresh-water to estuarinal or lagoonal environment and that humid sub-tropical climate prevailed during the time of deposition.

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ON SOME CONIFER REMAINS FROM BANSA, SOUTH REWA GONDWANA BASIN

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ABSTRACT

Leafy twigs of *Brachyphyllum bansaensis* n. sp., *B. eikaiostomum* n. sp., *B. suryanarayanaii* n. sp. and *Marwaria latifolia* (Feistmantel) n. comb. are described here from the Lower Cretaceous of Bansa, South Rewa Gondwana Basin. *Marwaria* is a new genus, based on the specimen originally described by Feistmantel (1882) as *Araucarites latifolius*. Cone-scales of *Araucarites fibrosa* n. sp. and *Araucarites macropterus* Feistmantel have also been described.

INTRODUCTION

FROM Bansa, Madhya Pradesh, three species of *Pagiophyllum* have already been described by us (Bose & Sukh-Dev, 1972). *Brachyphyllum bansaensis*, *B. eikaiostomum*, *B. suryanarayanaii*, *Marwaria latifolia*, *Araucarites fibrosa* and *A. macropterus* Feistmantel are now described. Except *Araucarites macropterus* all the new species are based on cuticular features.

DESCRIPTION

Genus *Brachyphyllum* Brongniart

Brachyphyllum bansaensis n. sp.

Pl. 1, Figs. 1-3; Text-fig. 1A-F

Diagnosis — Twigs irregularly branched. Branches 3-4 mm. wide, straight or slightly curved. Leaves spirally arranged, ovate, typically measuring 4×2·5 mm. (range 2-4×1.5-2.5 mm.), slightly longer than the rhomboidal leaf-base cushion, directed forward or sideways. Margin entire; occasionally with a microscopic frill in parts. Apex acute. Lower side keeled.

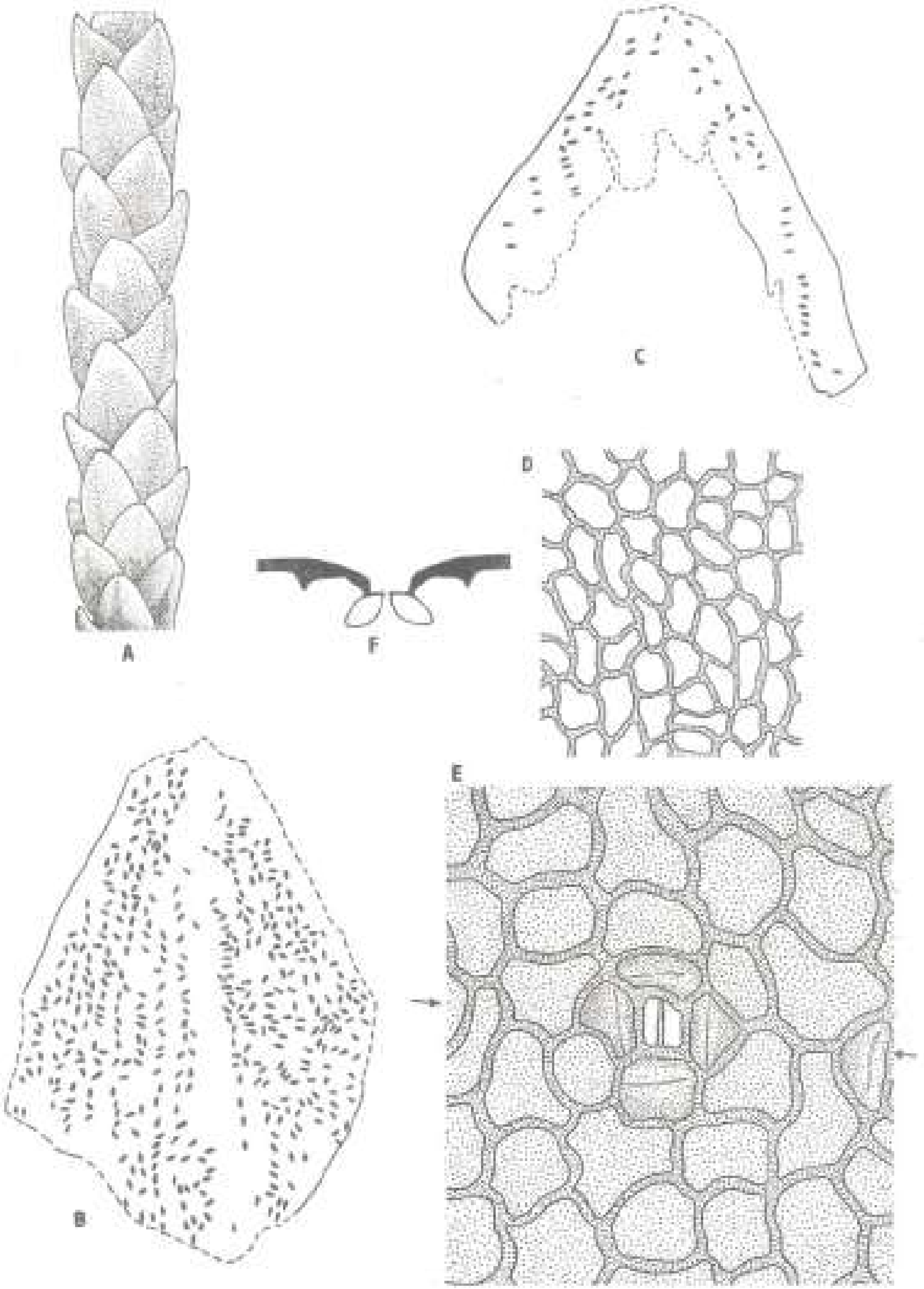
Leaves amphistomatic. Cuticle about 6 μ thick. Upper surface: stomata fewer as compared to lower surface, present near margins in single, short files, leaving a wide central non-stomatic area. Each file consisting of 3-7 stomata. Stomata mostly transversely orientated, some obliquely or longitudinally placed. Guard cells sunken. Subsidiary cells 4-6, mostly 4 or 5, slightly sunken; surface wall more cutinized than epidermal cells and possessing a prominent thin slit. Epidermal cells polygonal; lateral and end walls moderately thick and almost straight, at places slightly wavy; some cells show a longitudinal or transverse slit. Lower surface: epidermal cells mostly like cells of upper side but with lateral and end walls sometimes pitted or slightly undulate. Epidermal cells between stomata and stomatal files polygonal, a few rectangular, more or less serially arranged. Stomata present over entire surface, arranged in single, short to long files, some irregularly placed; separated by 2-3 (sometimes 5) cells; longitudinally or transversely orientated, a few obliquely placed. Subsidiary cells 4-6, mostly 4 or 5, slightly sunken; surface wall more thickened than that of the ordinary epidermal cells and showing a prominent thin slit. Guard cells sunken, thinly cutinized. Aperture narrow and slit-like. A few stomata with an incomplete ring of encircling cells. Trichomes absent. Hypodermis present on both surfaces.

Holotype — No. 29989 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Marwar Ghat about ¾ km. N.E. of Bansa.

Horizon and Age — Jabalpur Series; Lower Cretaceous.

Comparison and Discussion — The twigs of *Brachyphyllum bansaensis* are somewhat similar to the twigs of *B. mamillare* Brongniart and *B. scalbiensis* Kendall (1947). Both, like *B. bansaensis*, are amphistomatic. But in *B. mamillare* stomata are occasionally absent from the upper surface. The distribution of stomata on the upper surface is more regular in *B. scalbiensis* than in *B. bansaensis*. In the former the stomata are arranged in well-marked longitudinal rows. In *B. bansaensis* the upper surface is more reduced with a few stomata placed in ill-defined files. In *B. bansaensis* the stomata are mostly transversely or longitudinally orientated while in *B. scalbiensis* they are irregularly orientated. From *B.*



TEXT-FIG. 1

tropidimorphum Wesley (1956) *B. bansaensis* can readily be distinguished by the distribution of the stomata which in the former species occur over the entire upper surface.

Systematic Position — In the form of the leaves and the stomatal distribution *B. bansaensis* resembles somewhat *Dacrydium colensoi*. However, in *D. colensoi* the leaves appear more keeled, the stomata comparatively less crowded on the lower surface and the subsidiary cells less cutinized towards their inner side. In *Dacrydium kirkii*, as in *B. bansaensis*, the stomata are fewer on the upper surface but on the lower surface they occur densely in two broad marginal bands and unlike *B. bansaensis* are mostly longitudinally placed. Though *B. bansaensis* shows some resemblances with certain species of *Dacrydium*, its systematic position is not yet certain and we prefer to keep it under the form-genus *Brachyphyllum*.

Brachyphyllum eikaiostomum n. sp.

Pl. 1, Figs. 4-7; Pl. 2, Fig. 16; Text-fig. 2A-F

Diagnosis — Leafy twigs straight, stiff, 2-4·5 mm. wide. Leaves small, rhomboidal, typically 2·5 × 4 mm., arranged spirally and closely placed, appressed, not keeled and projecting. Leaf-base slightly concealed by adjacent leaves. Longer diagonal of leaf transverse to stem. Attachment area rhomboidal. Upper surface of leaf much reduced, slightly convex. Leaf tip directed forward and overlapping the basal portion of the leaf in front. Margin with a microscopic frill. Apex acute, obtuse or rounded.

Leaf amphistomatic. Lower cuticle 4 to 9 μ thick in folds, upper slightly thinner. Stomata irregularly distributed over entire lower surface, excepting the apical and sometimes the central portion, usually widely spaced, never forming longitudinal rows, sometimes 2 or 3 stomata occurring in contact. Stomata on upper surface few. On both surfaces stomata mostly obliquely, sometimes transversely or longitudinally orientated. Stomatal apparatus oval or circular. Subsidiary cells slightly sunken, 4 to 7, mostly 5 or 4; inner surface wall less thickened than epidermal cells, often showing one or two slits. Polar and lateral subsidiary cells not distinguishable. Outer anticlinal wall of subsidiary cells slightly raised above general level of the epidermis. Bottom of stomatal pit oval. Guard cells slightly sunken, with aperture and surface wall thinly cutinized. Ring of encircling cells not always complete.

Epidermal cells on both surfaces polygonal, isodiametric, irregularly packed. Anticlinal walls prominent, commonly interrupted by pits or not clear, 1·5-5·5 μ thick, straight, sometimes undulate. Periclinal walls frequently marked with a longitudinal slit, sometimes slit may be dividing. Marginal frill one cell thick, 21-117 μ broad; frill cells usually narrower, their free ends rounded or obtuse.

Holotype — No. 30030 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Marwar Ghat about ¾ km. N.E. of Bansa.

Horizon and Age — Jabalpur Series; Lower Cretaceous.

Comparison and Discussion — *Brachyphyllum eikaiostomum* looks like *Brachyphyllum rhombicum* (Feistm.) Sahni (1928) described from the same flora. From Marwar Ghat we have another new species of *Brachyphyllum* (not described in this paper) which also resembles *B. rhombicum* in external features. But unfortunately the cuticle of the original specimens of *B. rhombicum* is unknown and therefore none of the Marwar species can be identified with it.

B. expansum (Sternb.) var. *indica* Sahni (1928) agrees with *B. eikaiostomum* in the presence of stomata on both the surfaces and in stomatal structure. In both the stomata are irregularly distributed, but in *B. expansum* var. *indica* the leaf tip is microscopically thick and pointed and there

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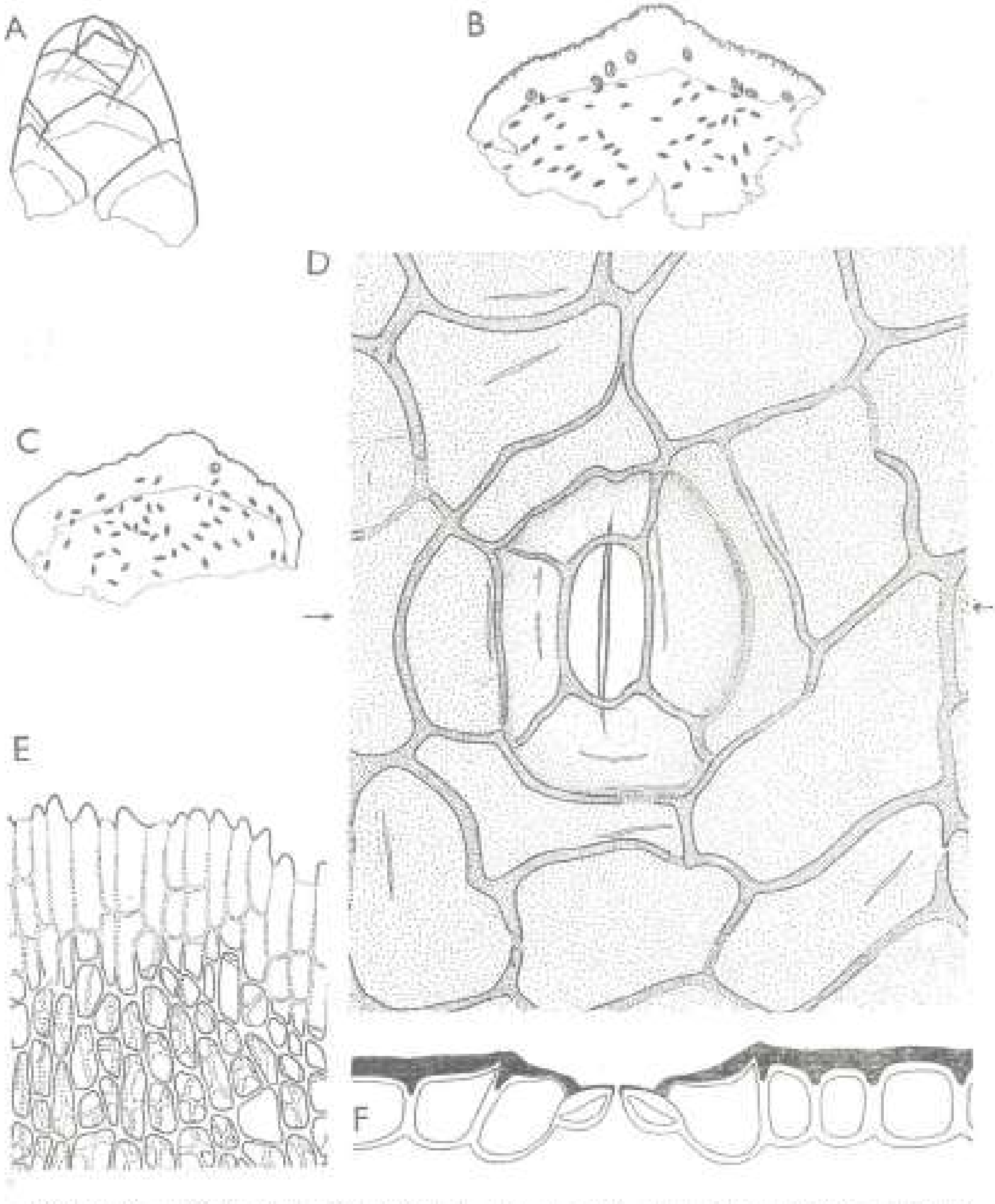
TEXT-FIG. 1 — *Brachyphyllum bansaensis* n. sp.: A, specimen no. 29989, × 5. B, lower cuticle, showing orientation and distribution of stomata, slide no. 4428 (from specimen no. 29989), × 20. C, upper cuticle, showing orientation and distribution of stomata, slide no. 4428 (from specimen no. 29989), × 20. D, epidermal cells of upper cuticle, slide no. 4428 (from specimen no. 29989), × 250. E, stoma and epidermal cells, slide no. 4428 (from specimen no. 29989), × 500. F, reconstructed transverse section of stoma of Fig. E along the line denoted by arrows.



TEXT-FIG. 2 — *Brachyphyllum rihaistomum* n. sp.: A, × 10. B, C, leaves showing cuticle of both the surfaces and distribution of stomata. Short thick lines enclosed in a ring represent the stomata of the upper surface, the unenclosed ones denote lower surface, slide nos. 5-2, 4428A, × 20. D, stoma and epidermal cells, slide no. 4428A, × 800. E, apical portion of a leaf showing both surfaces and a marginal frill, slide no. 5-2. F, reconstructed transverse section of stoma of Fig. D along the line denoted by arrows.

is no marginal flange. Moreover, the leaves in this variety are smaller and elongate. *B. expansum* var. *indica* appears to need a new specific name because Kendall (1949) has shown that *B. expansum* (Sternb.) Seward with its papillate stomata is a different species.

B. eikaiostomum looks similar to several other species of *Brachyphyllum* but in all these the cuticular characters differ. *B. mamillare* (Kendall, 1947) resembles *B. eikaiostomum* in having an apical marginal frill but its stomata are arranged in longitudinal rows. *B. crucis* Kendall (1949) has a frilled margin near the apex and scattered stomata towards the leaf-base, but these stomata are papillate. *B. expansum* (Sternb.) Seward (Kendall, 1949) has a frilled margin and papillate stomata arranged in longitudinal rows. *B. kendallianum* Wesley (1956) agrees with *B. eikaiostomum* in its subsidiary cells but differs in having the stomata placed in longitudinal rows and in the absence of marginal frill. *B. appropinquatum* Wesley (1956) agrees in its often scattered stomata but these have papillate subsidiary cells; there is also no marginal frill in this species.

Systematic Position — *Brachyphyllum eikaiostomum* shows some resemblances in its gross features with *Dacrydium biforme* (Hook.) Pilg., *D. colensoi* Hook. and *Athrotaxis cupressoides* Don. In all these the leaves have a marginal flange. But while in *D. colensoi* the stomata are irregularly scattered in *D. biforme* and *A. cupressoides* they are placed in bands though in the latter species the stomata sometimes become scattered at the leaf-base. In *D. biforme* the epidermal cells are pitted, but the subsidiary cells are thickly cutinized. The walls are not pitted in *D. colensoi* and the subsidiary cells are more thickly cutinized in their outer portion than the inner. In the other species of *Dacrydium*, viz. *D. cupressinum* Sol., *D. elatum* (Roxb.) Wall., *D. intermedium* Kirk and *D. kirkii* F. Muell. the subsidiary cells are either sunken or at level with the general surface, but, in contrast to *B. eikaiostomum*, the inner portion of their subsidiary cells is always at a higher level than the outer portion.

In conclusion, while *B. eikaiostomum* does have a few characters in common with some species of *Dacrydium*, its systematic position remains uncertain.

Brachyphyllum suryanarayanai n. sp.

Pl. 2, Figs. 11, 14, 18; Pl. 3, Fig. 25; Text-fig. 3A-H

Diagnosis — Main twig 5 mm. wide; branches 2·5-4·0 mm. wide, arising irregularly at angle of 25-45°. Leaves persistent, more or less rhomboidal, typically 4×2 mm., borne spirally. Most of lower surface exposed but base concealed; upper surface small, somewhat concave. Leaf rounded in section, not keeled, with a rhomboidal area of attachment. Leaf apex obtusely pointed, projecting outwards and forwards at an angle of about 45° to the stem. Margin entire, occasionally with a microscopic frill in parts.

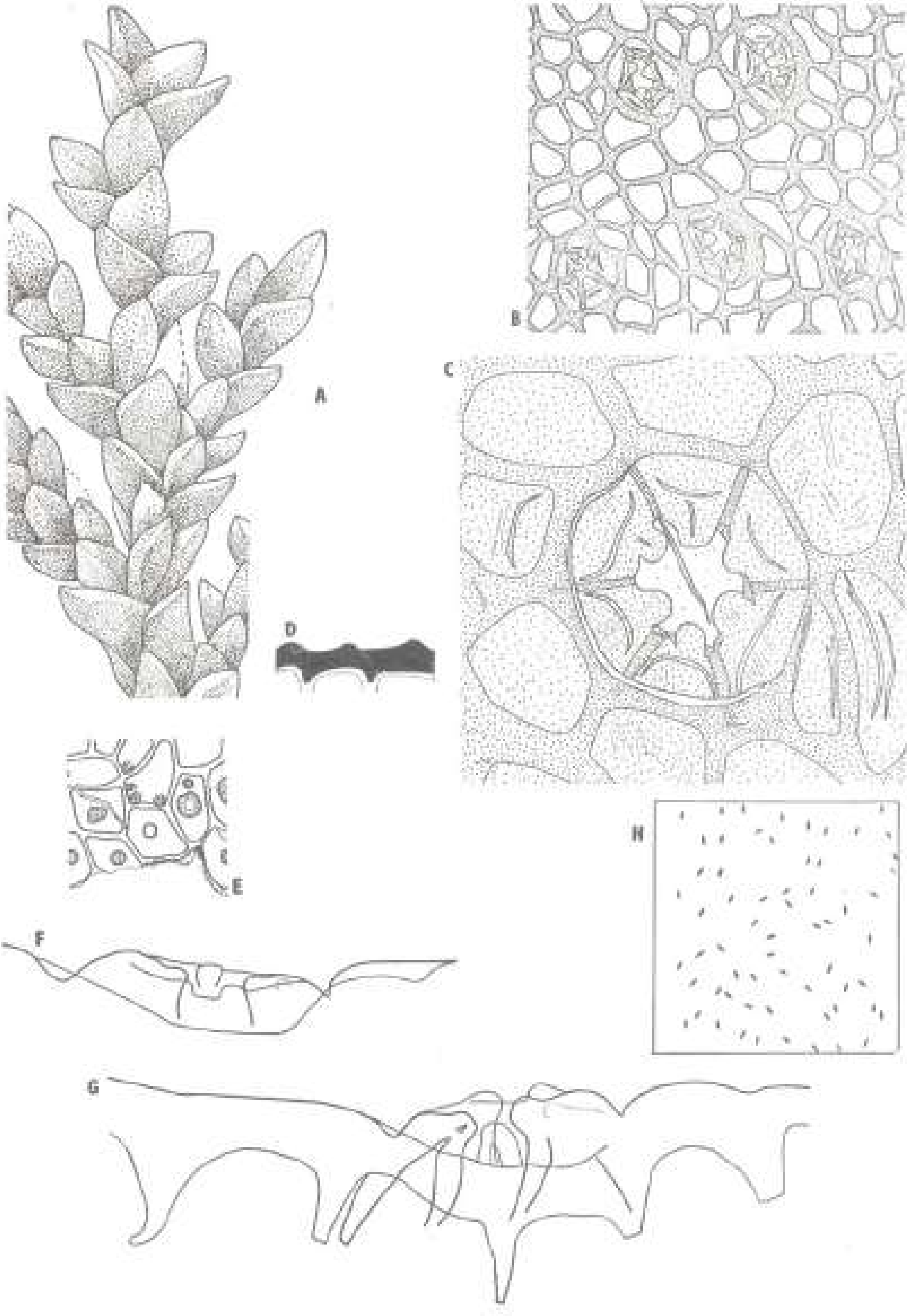
Cuticle about 8-13 μ (in folds) thick; upper cuticle slightly thinner than lower. Stomata irregularly distributed on both surfaces, not in rows, widely or closely spaced, occasionally with subsidiary cells in contact. Stomata longitudinally or obliquely placed, a few transverse. Stomatal apparatus oval or circular, typically 61×49 μ. Guard cells deeply sunken, thinly cutinized.

Subsidiary cells 4-5, sometimes 6 or 7, slightly sunken, as thickly cutinized as epidermal cells and possessing a thin strip placed parallel to their inner margin and separating an inner from an outer thick area. All subsidiary cells alike, polar ones unspecialized. Subsidiary cells sharply separated from encircling cells by a deep, narrow groove. Surface of subsidiary cells strongly convex showing faint radial striations. Stomatal pit angular. Subsidiary cells provided with a papilla overhanging the stomatal pit; some or all papillae occasionally absent. Papillae 3-9 (—12) μ long, with rounded ends, sometimes faintly striated. Papillae sometimes crowded over stomatal pit even concealing it. Encircling cells similar to other epidermal cells, not raised, their outer margins not forming a definite ring.

Epidermal cells similar on both surfaces, polygonal, often isodiametric, tending to form longitudinal rows or irregularly packed. Anticlinal walls very thick, 3-11 μ, straight. Periclinal walls smooth or slightly mottled, sometimes with fine striations and one or more thin strips. Epidermal cells at leaf-base papillate.

Holotype — No. 30662 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — About ¾ km. N.N.W. of Bansa.



TEXT-FIG. 3

Horizon and Age — Jabalpur Series; Lower Cretaceous.

Comparison and Discussion — *Brachyphyllum suryanarayanaii* agrees rather closely in its stomata with *B. expansum* (Sternberg) Seward (Kendall, 1949), *B. appropinquatum* Wesley (1956) and *B. praetermissum* Wesley (1956). In all these species the stomatal apparatus is rounded, the subsidiary cells have strong papillae and are marked off from the encircling cells by a deep groove. But there are differences also. The leaves of *B. suryanarayanaii* are rather more divergent than the leaves in the other species. *B. expansum* differs from the Bansa species in its longitudinal rows of stomata, a hypodermis and frilled margin. The leaves of *B. appropinquatum* show very little exposed upper surface; also the periclinal wall of the subsidiary cells is here less cutinized than the epidermal cells and they also lack thin strips. In *B. praetermissum* stomata are present only on the lower surface. Moreover, in this species the anticlinal walls of the epidermal cells are comparatively thinner and both the subsidiary and epidermal cells lack thin strips and striations.

Systematic Position — *Brachyphyllum suryanarayanaii* rather closely resembles in its shoots and leaves *Athrotaxis cupressoides* Don and *Dacrydium colensoi* Hook. It also resembles *Glyptostrobus* Endl. but the two are very different in cuticular structure. *A. cupressoides* differs from *B. suryanarayanaii* in having leaves with scarious and toothed margin. But *D. colensoi* is like *B. suryanarayanaii* in this respect. *D. colensoi* also resembles in having a similar type of stomatal distribution. In the papillate basal cells of its leaves *B. suryanarayanaii* is like *A. cupressoides* but not *D. colensoi*.

In stomatal structure *B. suryanarayanaii* is more like *D. colensoi* and a few other species of *Dacrydium* than *Athrotaxis*. Both *B. suryanarayanaii* and *Dacrydium* share the feature of a deep groove round the subsidiary cells while this is absent in *Athrotaxis*. Like *B. suryanarayanaii D. biforme* has thin strips in the subsidiary cells and some of the epidermal cells, though in other species of *Dacrydium* such strips are feeble or lacking.

In conclusion, *B. suryanarayanaii* shows more features in common with *Dacrydium* than with *Athrotaxis*, but clearly much more evidence is needed before this species can be placed in the Podocarpaceae.

Genus *Marwaria* n. gen.

Diagnosis — Twigs bearing simple leaves. Leaves sessile, spirally borne, narrowing towards base and apex. Venation simple, parallel. Leaves amphistomatic. Stomata haplocheilic. Subsidiary cells 4-6, surface wall thickened.

Type Species — *Marwaria latifolia* (Feistmantel) Sukh-Dev & Bose.

Marwaria latifolia (Feistmantel) n. comb.

Pl. 3, Figs. 19-24; Text-fig. 4A, B

1882 — *Araucarites* (*Araucaria*) *latifolius* Feistmantel, p. 45, Pl. 2, Fig. 6.
1920 — *Araucarites latifolius* Feist.: Seward & Sahni, p. 35, Pl. 2, Fig. 27.
1928 — *Araucarites latifolius* Fst.: Sahni, p. 31.

Diagnosis — Twigs bearing spirally arranged leaves. Leaves typically 14×5 mm. (available range 11-15×3·5-5 mm.), elliptic-lanceolate; attached by a narrow base, lower basal margin sometimes slightly decurrent; apex pointed or bluntly rounded. Veins simple, parallel, obscure towards apex. Lamina apparently thick and coriaceous.

Cuticle thick, of almost same thickness on both sides. Leaves amphistomatic with fewer stomata on upper surface. Stomata on upper surface confined to leaf-base, irregularly distributed, distant, sometimes two stomata may be lying close. Epidermal

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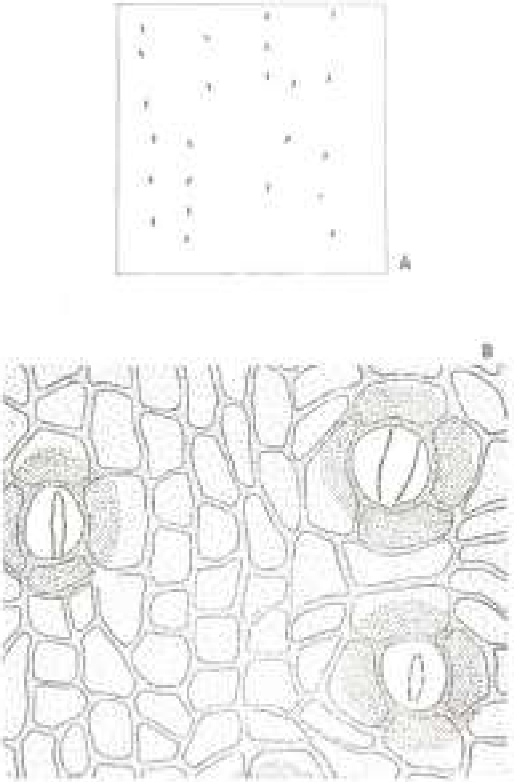
TEXT-FIG. 3 — *Brachyphyllum suryanarayanaii* n. sp.: A, specimen no. 30662, × 5. B, lower cuticle, slide no. 4431 (from specimen no. 30227), × 250. C, stoma and epidermal cells. Note the deep groove on the left round the subsidiary cells, slide no. 4431 (from specimen no. 30227), × 800. D, papillate cells in side view, slide no. 4434, × 250. E, basal papillate cells of lower surface, slide no. 4434, × 250. F, G, two stomata in side view, slide no. 4431 (from specimen no. 30227), × 800. H, orientation and distribution of stomata in 1 sq. mm. of the lower surface, slide no. 4435 (from specimen no. 30227).



TEXT-FIG. 4 — *Marauaria latifolia* (Feistmantel) n. comb.: A, showing orientation and distribution of stomata in 1 sq. mm. of lower cuticle, slide no. 4426 (from specimen no. 30152). B, lower cuticle, slide no. 4437 (from specimen no. 30152). × 250.

cells serially arranged, 22-66 × 15-35 μ, rectangular, rarely polygonal, anticlinal walls about 3 μ thick, almost straight and fairly well marked, periclinal wall unspecialized.

Stomata on the lower surface placed generally in single rows, distant, a few lying outside rows, sunken, longitudinally orientated, sometimes slightly oblique, rarely transverse. Subsidiary cells mostly 4 (2+2), rarely 5; forming a ring, surface more cutinized than in epidermal cells. Stomatal pit oval or circular. Guard cells thinly cutinized, sunken. Aperture narrow, oval or elliptic. Encircling cells like epidermal cells. Epidermal cells outside stomatal rows rectangular, squarish or polygonal, anticlinal walls more or less straight, periclinal wall smooth. Epidermal cells between stomata polygonal, broader than their length. Trichomes absent.

Holotype — No. 5/386 of the Geological Survey of India, Calcutta. (Feistmantel 1882, Pl. 2, Fig. 6; same here Pl. 3, Fig. 20).

Locality — Bansa.

Horizon and Age — Jabalpur Series; Lower Cretaceous.

Comparison and Discussion — In gross features *Marauaria latifolia* somewhat resembles *Araucaria crassifolia* Corda described by Kräusel (1922) and *A. toucasi* Saporta (1879). But the cuticle of *A. crassifolia* differs considerably from that of *M. latifolia*. In *A. crassifolia* the stomata are mostly transversely orientated, but in *M. latifolia* they are mostly longitudinally orientated. In *M. latifolia* there are mostly 4 subsidiary cells, whereas in *A. crassifolia* they are mostly 6. The cuticular structure of *A. toucasi* is not known. In external form the leaves of *Pagiophyllum peregrinum* (?) (L. & H.) described by Walkom (1919) from ?Briton Shaft may also be compared with *M. latifolia*. The leaves in *P. peregrinum* (?) (L. & H.) are more distantly placed than *M. latifolia*. Among the fossil forms, *Araucaria balcombensis* Selling (1950) from Balcombe Bay, Australia, comes close to *M. latifolia*. In both the leaves are amphistomatic, the stomatal rows are quite distant from one another and inside the rows stomata are longitudinally orientated. In *A. balcombensis* the subsidiary cells are 4-6 in number, whereas in *M. latifolia* they are mostly 4, rarely 5. In both the stomatal opening resembles in shape. However, the leaves of *A. balcombensis* are larger and have, unlike the leaves of *M. latifolia*, a large number of stomata on the upper surface which are obliquely or transversely placed.

Among the recent species of *Araucaria*, *M. latifolia* comes closest in general form and size of leaf to *Araucaria biramulata* Buchholz and *Araucaria muelleri* Br. & Gr. But the cuticle of *A. biramulata* is quite different from that of *M. latifolia*. The stomata in *A. biramulata* are arranged on both the surfaces of the leaf in close longitudinal rows, and the stomata are mostly transversely orientated. Also the anticlinal walls of the epidermal cells in this species are pitted or sinuous. *A. muelleri* has also mostly transversely orientated stomata but the stomatal rows are here distant as in *M. latifolia*. The epidermal cells in *A. muelleri* are markedly sinuous walled.

Genus *Araucarites* Presl

Araucarites fibrosa n. sp.

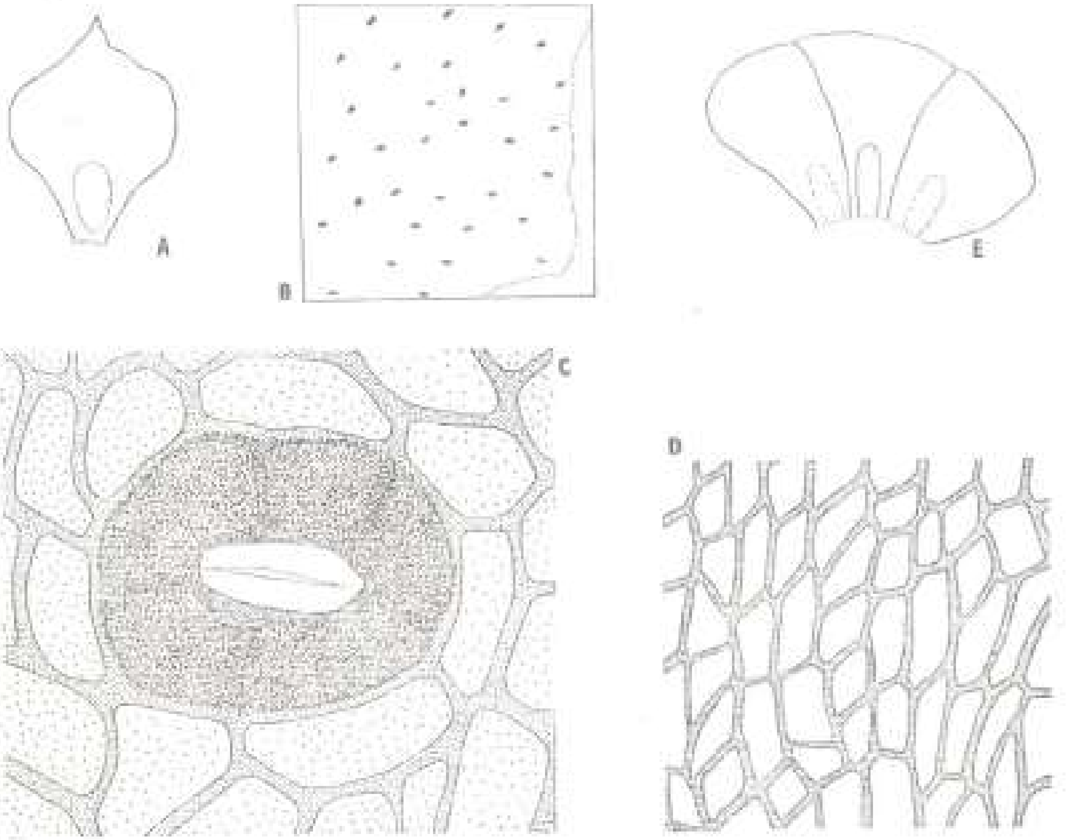
Pl. 2, Figs. 12, 13, 15, 17; Text-fig. 5A-D

1877 — *Araucarites macropterus* Feistmantel (*partim*), p. 24, Pl. 8, Fig. 10.

1928 — *Araucarites macropterus* Fst.: Sahni (*partim*), p. 33, Pl. 6, Fig. 76.

Diagnosis — Detached cone-scales with a single adaxially placed obovoid seed. Cone-scale broadly deltoid, narrowing proximally and with a broad distal end, prolonged into a short narrow tip. Base truncate. Cone-scale 2·8-6 × 2·6-4·4 cm.; seed 1·2-1·7 cm. long and 0·5-0·9 cm. broad. Veins prominent, numerous, almost parallel, branching from two basal veins, which run parallel on each side of the basal part of cone-scale. Veins sometimes bifurcated. (Ligule doubtful.)

Cuticle of scale with stomata present only on lower surface. Upper cuticle slightly thinner than lower; cells rectangular or squarish, sometimes polygonal, serially arranged, anticlinal walls straight, periclinal wall unspecialized. On lower cuticle stomata abundant, irregularly distributed, mostly transversely or obliquely placed, rarely longitudinal. Stomatal apparatus oval or circular. Subsidiary cells 4-6, mostly 5, rather more heavily cutinized than epidermal cells. Encircling cells not clearly marked. Guard cells slightly sunken, forming a slit-like aperture. Epidermal cells polygonal, rectangular or squarish, irregularly distributed, anticlinal walls straight,



TEXT-FIG. 5 — *Araucarites fibrosa* n. sp. (A-D); *Araucarites macropterus* Feistmantel (E). A, specimen no. 30585, × 1. B, lower cuticle showing orientation and distribution of stomata in 1 sq. mm., slide no. 4432 (from specimen no. 29992). C, stoma and epidermal cells, slide no. 4432 (from specimen no. 29992), × 500. D, upper cuticle, slide no. 4432 (from specimen no. 29992), × 250. E, *Araucarites macropterus*, specimen no. 30383, × 1.

periclinal wall unspecialized. (Seed cuticle not known.)

Holotype — No. 30377 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — About ½ km. N.N.W. of Bansa.

Horizon and Age — Jabalpur Series; Lower Cretaceous.

Comparison and Discussion — The present specimens resemble *Araucarites macropterus sensu* Feistmantel (1877, Pl. 8, Fig. 10, reproduced by Sahni, 1928, Pl. 6, Fig. 76) in shape and more or less in size. But unlike Feistmantel's specimen the veins in *A. fibrosa* join the two principle veins which are running on two sides of the base and also the seed of *A. fibrosa* is comparatively smaller in size. The cuticle of *A. fibrosa* differs from that of *Araucaria cutchensis* (Feistmantel) Pant & Srivastava (1968) in having the stomata confined to the lower side, irregularly distributed and mostly transversely orientated. *A. cutchensis* is amphistomatic, the stomata are placed in rows and are commonly longitudinally orientated.

Araucarites macropterus Feistmantel

Pl. 1, Figs. 8-10; Text-fig. 5E

1877 — *Araucarites macropterus* Feistmantel (*partim*), p. 24, Pl. 8, Fig. 9.
1879 — *Araucarites macropterus* Fstm.: Feistmantel, p. 28, Pl. 14, Figs. 13, 14; Pl. 16, Fig. 11.
1882 — *Araucarites macropterus* Fstm.: Feistmantel, p. 45, Pl. 3, Fig. 18.
1920 — *Araucarites macropterus* Feist.: Seward & Sahni, p. 34, Pl. 6, Fig. 65.
1928 — *Araucarites macropteris* Fst.: Sahni (*partim*), p. 33.

Emended Diagnosis — Cone-scale deltoid, narrow towards base and broader, membranaceous upwards, 1·8-3·5 × 1·6-3·4 cm., bearing adaxially a small oval seed. Proximal end of cone-scale truncate; distal end rounded, sometimes with a small pointed apex. (Ligule not observed.)

Holotype — Specimen no. 4/584 of the Geological Survey of India, Calcutta (Feistmantel, 1877, Pl. 8, Fig. 9; same here Pl. 1, Fig. 10).

Locality — Holotype — Gollapalle, East Coast Gondwana.

Horizon and Age — Holotype — Rajmahal Stage, U. Jurassic.

Discussion — Feistmantel (1877) instituted *Araucarites macropterus* on some specimens of fossil cone-scales (Pl. 8, Figs. 9-12) from Gollapalle, East Coast. Under this species he had included two or three different species. Out of these, the one figured in Pl. 8, Fig. 9 (here reproduced in Pl. 1, Fig. 10) is similar to some of the specimens collected from Bansa and nearby localities. For all these we have adopted the name *Araucarites macropterus*. Outside India somewhat similar specimen has been figured by Seward (1903, Pl. 6, Fig. 6) from Cape Colony as *Araucarites rogersi*.

ACKNOWLEDGEMENTS

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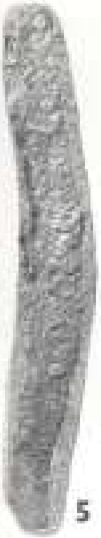
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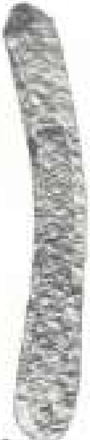
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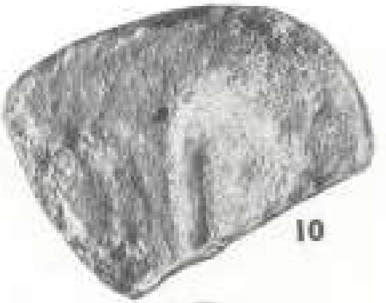
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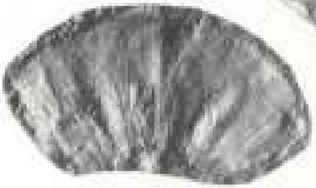
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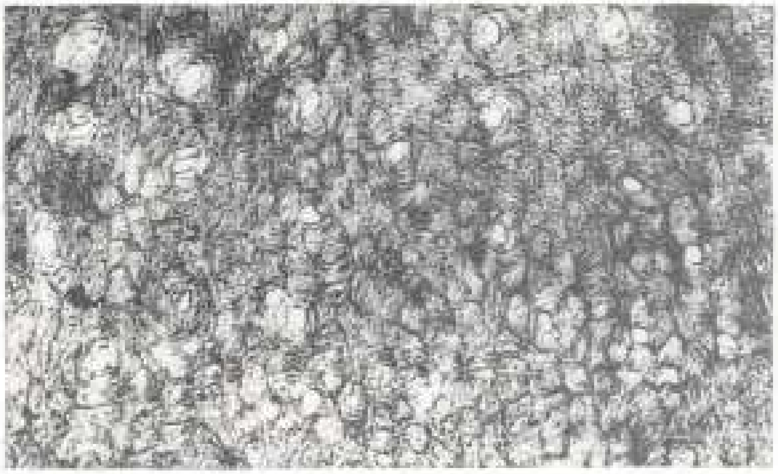
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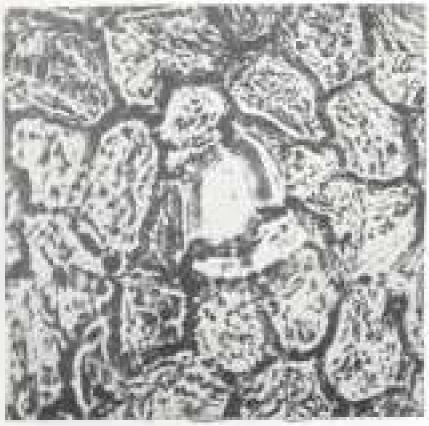
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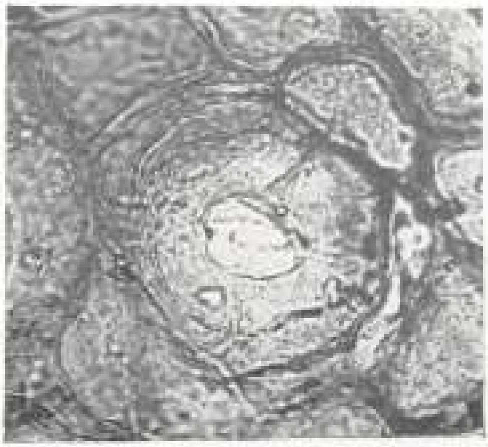
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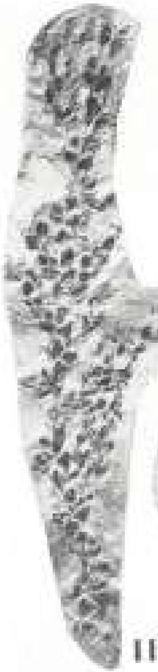
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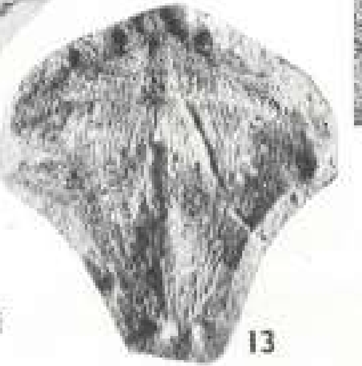
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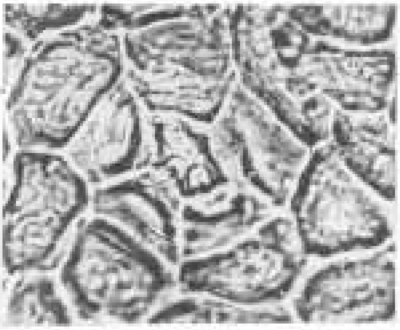
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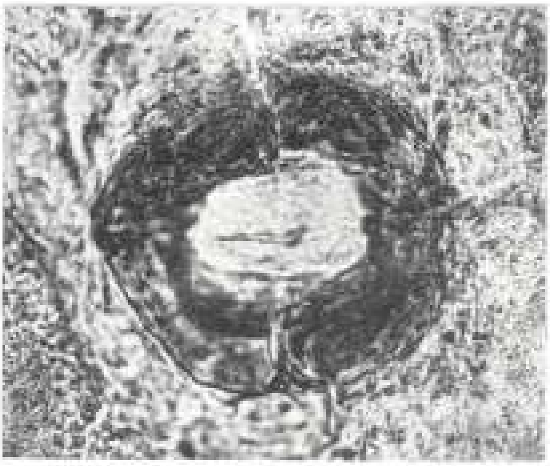
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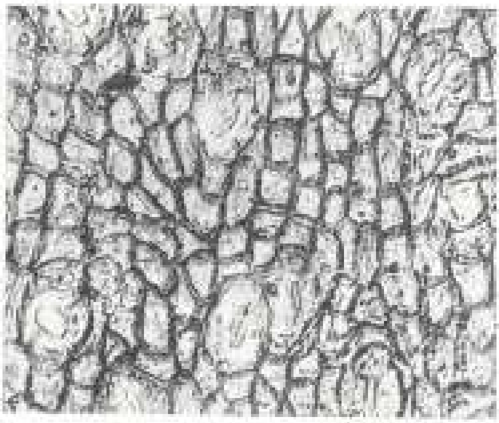
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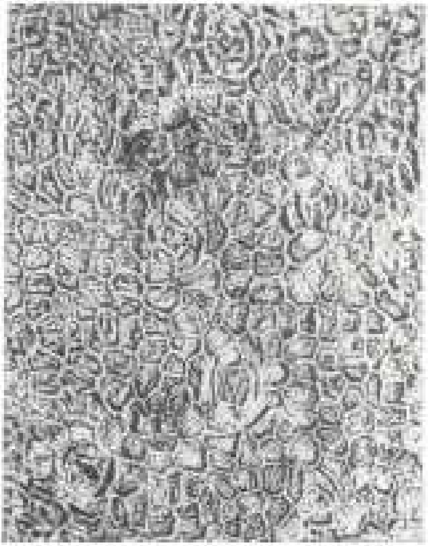
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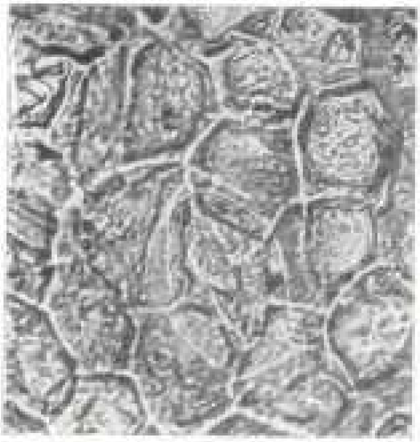
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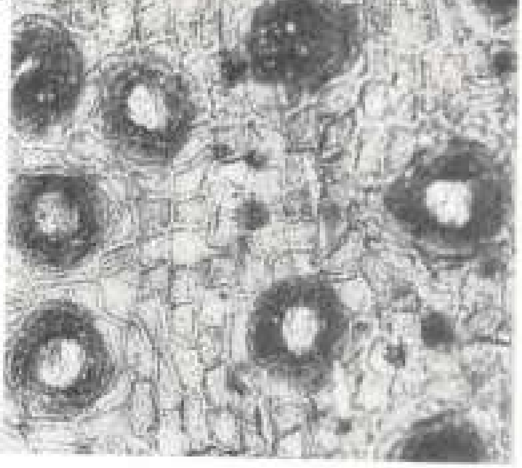
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EXPLANATION OF PLATES

PLATE 1

1. *Brachyphyllum bansaensis* n. sp. No. 29989, holotype, × 1.

2. *B. bansaensis*, lower cuticle. Sl. No. 4428 (from specimen no. 29989), × 150.

3. *B. bansaensis*, a stoma magnified. Sl. No. 4429 (from specimen no. 29989, × 500.

4. *Brachyphyllum rihaistomum* n. sp. No. 30030, holotype, × 1.

5. *B. rihaistomum*, No. 30033, × 1.

6. *B. rihaistomum*. No. 35016, × 1.

7. *B. rihaistomum*, a stoma magnified. Sl. No. 4430 (from specimen no. 30269), × 500.

8. *Araucarites macropterus* Feistmantel, No. 30438, × 1.

9. *A. macropterus*, No. 35017, × 1.

10. *A. macropterus*, No. 4/384 (G.S.I., Calcutta), holotype, × 1.

PLATE 2

11. *Brachyphyllum suryanarayanaii* n. sp. No. 30662, holotype, × 1.

12. *Araucarites fibrosa* n. sp. No. 30377, holotype, × 1.

13. *A. fibrosa*, No. 30483, × 1.

14. *Brachyphyllum suryanarayanaii*, a stoma magnified. Sl. No. 4431 (from specimen no. 30227), × 500.

15. *Araucarites fibrosa*, a stoma magnified. Sl. No. 4432 (from specimen no. 29992), × 500.

16. *Brachyphyllum rihaistomum*, lower cuticle, Sl. No. 4430 (from specimen no. 30269), × 150.

17. *Araucarites fibrosa*, lower cuticle. Sl. No. 4432 (from specimen no. 29992), × 150.

18. *Brachyphyllum suryanarayanaii*, lower cuticle, Sl. No. 4431 (from specimen no. 30227), × 150.

PLATE 3

19. *Maraaria latifolia* (Feistmantel) n. comb. No. 30152, × 1.

20. *M. latifolia*, No. 5/386 (G.S.I., Calcutta), holotype, × 1.

21. *M. latifolia*, No. 30683, × 1.

22. *M. latifolia*, No. 35018, × 1.

23. *M. latifolia*, lower cuticle. Sl. No. 4433 (from specimen no. 30152), × 150.

24. *M. latifolia*, a stoma magnified. Sl. No. 4433 (from specimen no. 30152), × 500.

25. *Brachyphyllum suryanarayanaii*, two stomata magnified. Sl. no. 4431 (from specimen no. 30227), × 500.

A REVISION OF THE LOWER GONDWANA *SPHENOPTERIS* FROM INDIA

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ABSTRACT

Occurrence of *Sphenopteris* Brongn. is long known from the Lower Gondwana Formations of India. Detailed morphological studies of these fronds have revealed that they differ distinctly from *Sphenopteris* and represent a new morphological type. Hence, a new genus *Neomariopteris* has been instituted to accommodate these fronds.

The previous records, *Neomariopteris* (*Sphenopteris*) *polymorpha* (Feistm.) n. comb., *N.* (*S.*) *hughesi* (Zeill.) n. comb. and *N.* (*S.*) *lobifolia* are redefined and a new species *Neomariopteris talchirensis* is instituted.

INTRODUCTION

FERN fronds from the Lower Gondwanas of India showing deep cut or lobed habit of the pinna have been described under *Sphenopteris* Brongniart. Three species of *Sphenopteris*, viz. *S. polymorpha* Feistmantel (1876, 1881), *S. hughesi* (Feistm.) Zeiller (1902) and *S. lobifolia* Morris (1845), are known from India. The first named two species are known from the Barakar to the Raniganj Formations, whereas the third species is known only from the Raniganj Formation.

In some recent collections well-preserved remains of *Sphenopteris* have been collected from a number of Lower Gondwana Coalfields of India. The geological horizons of these beds range from Barakar to Raniganj Formations. A critical study of these fronds suggests that the forms up till now described under *Sphenopteris* are morphologically distinct from typical forms of *Sphenopteris* Brngn. and represent entirely a new morphological type. The same is discussed here with a revision of previous records from the Lower Gondwanas of India and other countries.

MATERIAL AND METHODS

The observations presented in this paper are based upon the examination of specimens earlier described by Feistmantel (1876, 1881, 1882) and Zeiller (1902) preserved at the Museum of the Geological Survey of India, Calcutta, and the specimens described by Srivastava (1954), Maheshwari & Gyan Prakash (1965), Kar (1968), Maithy (1969) and Kulkarni (1970) preserved at the Birbal Sahni Institute of Palaeobotany, Lucknow. In addition to this 300 hand specimens collected from the Lower Gondwana Formations of Raniganj Coalfield, Jharia Coalfield, South Karanpura Coalfield, Auranga Coalfield, Daltonganj Coalfield, Ib-river Coalfield and Tattitola beds (Rajmahal Hills) have been examined. The specimens are commonly preserved in form of impressions, however, in many cases a carboniferous crust is preserved. A collodion pulls of plant substances often appears brown and translucent under transmitted light. Examination of pull under the microscope reveals various structural details. Maceration of leaf substances by usual Schulze's method results complete dissolution of plant substance, however, in cases one gets trace of cuticles.

DESCRIPTION

Neomariopteris gen. nov.

Generic Diagnosis — Imparipinnate fronds, deeply divided, tripinnate or quadripinnate; rachis winged, pinnules small to medium size, shape variable, decurrent, attached to rachis by broad base, apex variable (acute, obtuse or broadly rounded), pinnule margin entire, dentate, crenulate or undulated (lobed); median vein of each pinnule usually gives off simple or bifurcating nervules towards margin of pinnules (sphenopteroid venation).

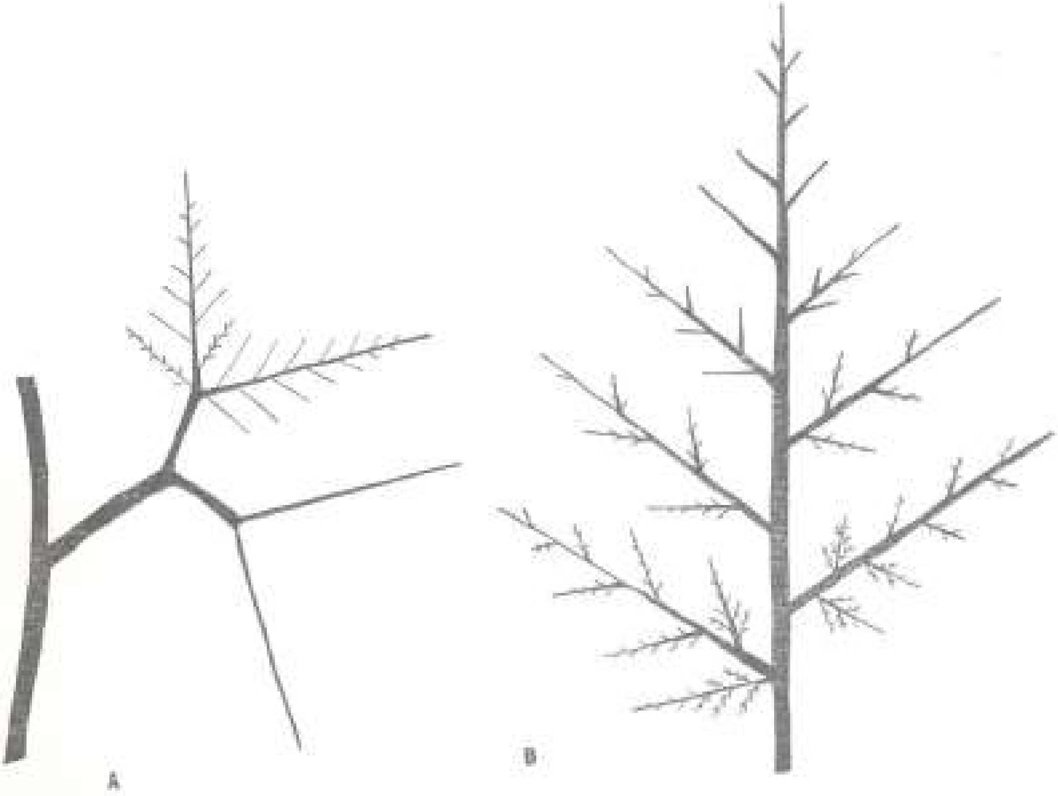
Genotype — *Neomariopteris polymorpha* (Feistm.) n. comb.

Generic Description — The shape of the complete frond is a bobilateral triangle, because the petiole is continued as a central shaft to the apex and bore its subdivisions in pinnate manner (Text fig. 1B). Near the apical region the division of pinnule is not complete and one can count the number of pinnules only by the emergence of midveins laterally from the pinnae rachis. The decurrent nature of the pinnules is well marked in all the species. The shape of the pinnules and its apex is distinguishable feature for the different species. Each pinnule has one distinct midvein. The midvein arises at ± 45°, from the point, where the lower margin of the pinnules joins the pinnae rachis. The midvein gives lateral nervules. The nervules passes to the margin either simple or bifurcating. Course of nervules may be straight or flexuosus.

Comparison—Brongniart (1828) instituted *Sphenopteris* to accommodate fern fronds with the following characters:

> " The pinnules contracted at base and often attached by short stalks, usually small, oval or oblong in outline and lobed or toothed or sometimes cut into narrow acute or obtuse lobes. Midvein is straight or flexuosus. The lateral veins depart at acute angle and dichotomise a few times and then pass either singly or in groups to the tips or the lobes of the pinnules."

The type species of *Sphenopteris*, viz. *S. adiantoides* Schloth. (=*S. elegans* Brongniart, in Sternberg, 1825) is a typical sphenopteroid frond showing pinnules deeply lobed with cuencate base. Pinnules are laterally free, i.e. non-decurrent, though the forms from the Lower Gondwana of India are referred to *Sphenopteris* because of its venation characters. However, the Lower Gondwana forms differ from *Sphenopteris* because the pinnules are attached to the pinnae rachis by their broad bases and are decurrent in nature. This feature has also been marked by previous workers. Even Zeiller (1902, p. 7) while describing *Sphenopteris hughesi* has opined " Ces pinnules, quelque peu arquees en faux, prennent alors une grande ressemblance de forme avec celles de certains *Odontopteris* du terrain houiller, de l'*Odontopteris minor*



TEXT-FIG. 1 — A. Branching pattern in *Mariopteris* Kidston. B. Branching pattern in *Neomariopteris* gen. nov.

Brongniart, notamment, bien que la nervation, totalement differente, ne permette pas de les confondre". Dueto these morphological peculiarities the Indian forms warrant their separation from *Sphenopteris*.

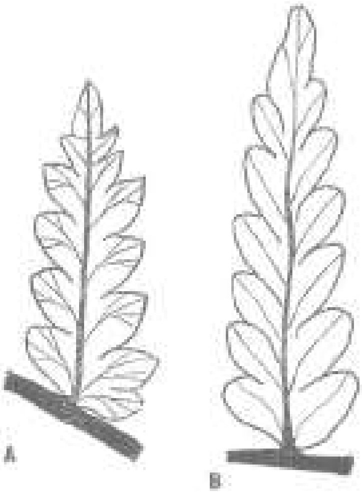
In its decurrent nature of pinnules the Lower Gondwana forms are comparable to *Alathopteris* Sternberg, *Alloiopteris* H. Potonié, and *Mariopteris* Zeiller. *Alethopteris* Sternberg differs from the Gondwana form in possessing a distinct midvein in the pinnules arising at right angle from pinnae rachis and the lateral nervules are also emerging oppositely from midvein at ± 90°. These nervules are either simple or branched into two. *Alloiopteris* is characterized by very small pinnules alternately arranged, decurrent and more or less united laterally. The veins entering the pinnule branches two or three times and the veinlets pass at a steep angle to the apex where they terminate usually in three more or less prominent teeth. Beside this the fertile leaf of *Alloiopteris* (*Corynopteris*) is known.

The Lower Gondwana forms show a close agreement both in the attachment of the pinnules and venations to *Mariopteris*. However, *Mariopteris* has dimorphic pinnules, i.e. basal, most pinnule on the posterior side of pinnae is distinctly larger than the other pinnules and is prominently bilobed. This pinnule also receives two distinct midveins. Beside this the branching pattern in both the fronds is different. In *Mariopteris* fronds, the petiole are forked near the top into equal branches, which has a second dichotomy producing four branches into two pairs (Text-fig. 1A) whereas in the present specimens the petiole is continued as a central shaft to the apex and bore its subdivisions in pinnate manner (Text-fig. 1B).

MORPHOLOGICAL CHARACTERS FOR SPECIFIC DELIMITATION

The fronds of *Neomariopteris* show superficial resemblances to one another. But a close and careful study of the morphological details of the fronds recorded in our collection shows that certain characters are variable from one species to another species and they can be well utilized for the identification of species. The following characters are recognized important for specific delimitation:

1. Nature of rachis: The main rachis may be either broadly winged giving a robust appearance to frond or narrow winged giving frail appearance to frond.
2. Outline of the pinnae: Ovate or lanceolate or linear or obovate.
3. Angle of attachment of pinnae to the rachis: Pinnae may be attached at right angles to the rachis or at an angle of 45° or less than 45°.
4. Shape of the pinnules: Oblong, lanceolate, spathulate, ovate or obovate, etc.
5. Apex of the pinnules: It may be either acute, obtuse or broadly rounded.
6. Margin of the pinnules: It may be entire, serrate, crenulate or undulated.
7. Attachment of pinnules to pinnae rachis: Pinnules are either attached at right angles to pinnae rachis or obliquely to rachis.
8. Shape of terminal pinnule: The terminal pinnule may be either broadly triangular in shape or lanceolate shape or linear shape.
9. Course of midvein and lateral veins: Veins may be either straight or flexuosus.
10. Number of nervules in one pinnule.



TEXT-FIG. 2 — A.A complete pinnae of *Mariopteris* showing dimorphic nature of pinnules. B.A complete pinnae of *Neomariopteris*.

Neomariopteris polymorpha (Feistm.) n. comb.

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

Synonymy

1876 — *Sphenopteris polymorpha* Feistmantel, p. 365, pl. XVI, figs. 5-7, pl. XVII, figs. 1-3.

1881 — *Sphenopteris polymorpha* Feistmantel, p. 76-77, pls. XVA, XVIA, XVIIIA, fig. 3.
1905 — *Sphenopteris polymorpha* Arber, Glossopteris flora, p. 131-133, text-fig. 31.
1966 — *Sphenopteris polymorpha* Surange, p. 66-67, figs. 36A-B.

Emended Diagnosis — Fronds large, at least tripinnate. Rachis broadly winged, secondary rachis broad, emerge alternately or subopposite from primary rachis at an angle of ± 90°. Pinnae ovate shape, arranged alternately, attached to secondary rachis at an angle of 70°-90°. Lateral pinnules oblong shape, shows ± equal width in the entire length, 4-10 mm. long and 2·5 mm. broad, i.e. the length to breadth ratio of the pinnule is 2: 1; lateral pinnules alternately arranged standing at right angles or slightly obliquely to pinnae rachis, decurrent, attached by broad base, lateral fusion of two pinnules margin is ± ½ length of the pinnules from the base, apex broadly rounded; margin entire; the lower margin of the pinnule shows strong curvature towards the apex, whereas the upper margin is straight, terminal pinnules larger than the adjacent pinnules, triangular in shape, apex rounded. Median vein distinct, emerges at 45° from the point where lower margin of pinnule joins the pinnae rachis, course straight, median vein gives fine lateral nervules which dichotomises once before reaching the margin. 12-14 nervules are recorded in one pinnule.

Lectotype — 5165. Geological Survey of India, Calcutta.

Locality — Raniganj Coalfield, Bengal.

Horizon — Raniganj Formation.

Specimen Figured — 35020/1386, 35021/1386, Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Raniganj Coalfield, West Bengal.

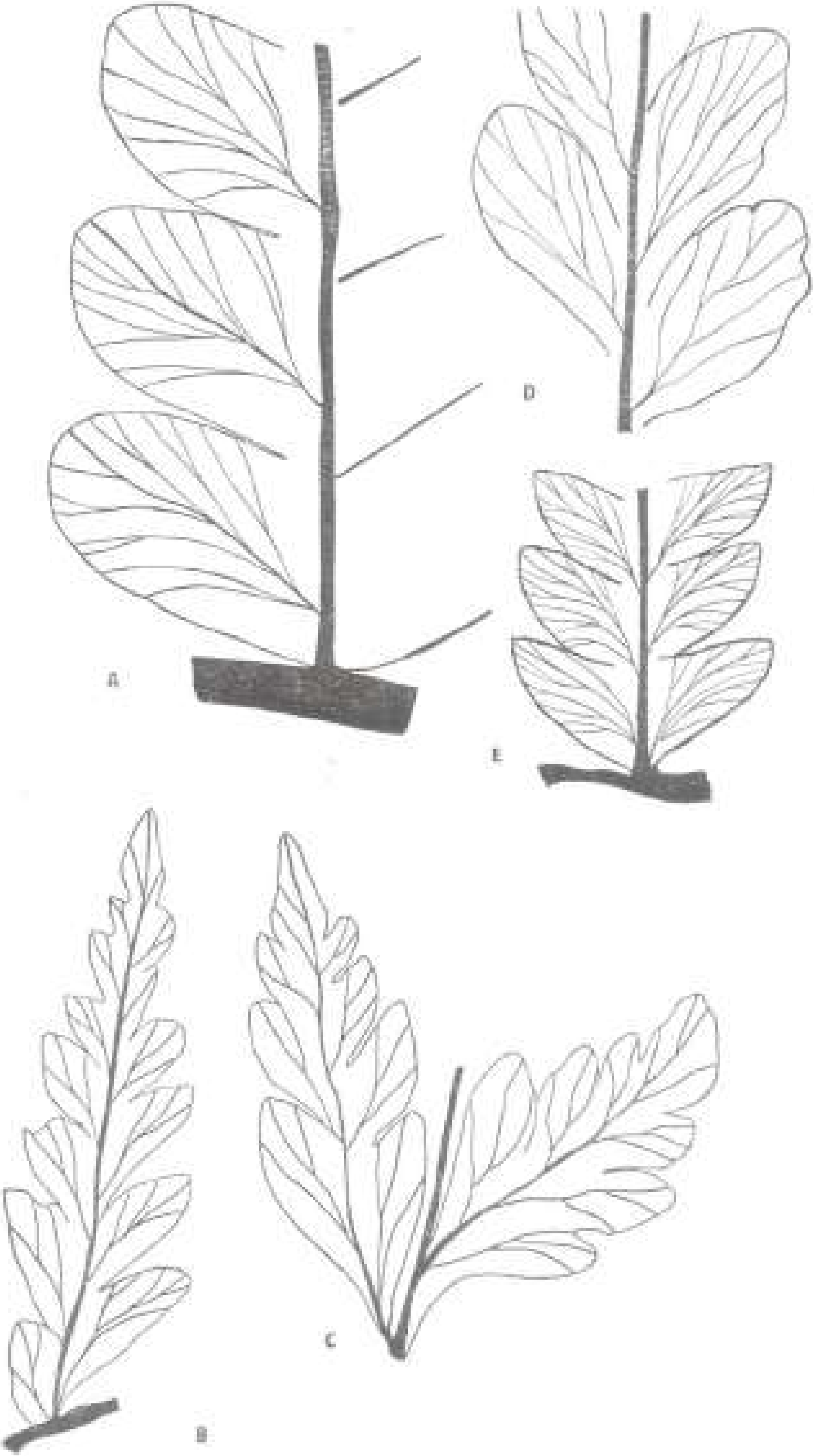
Horizon — Raniganj Formation.

Description — 25 specimens of this type are in the collection. Beside this the type specimens of Feistmantel (1876) preserved at the Geological Survey of India have been examined. The specimens figured in Pl. 1, Fig. 1 show the apical portion of frond. Both the impressions are incomplete at the apical portion. The pinnae near the apex are not completely lobed. Pinnules show distinct decurrent nature. Lateral pinnules oblong shape with obtuse apex and attached to pinnae rachis more or less at right angle. The terminal pinnule (Pl. 1, Fig. 3) is asymmetrical, broadly triangular in shape, bigger than the adjoining lateral pinnules. The pinnule margin on the superior side is larger drawn than the inferior side.

The specimen figured in Pl. 1, Fig. 2 represents the middle or the lower portion of frond. The rachis is broadly winged 3 mm broad. Pinnae are alternate or subopposite arranged, ± at 90°. Pinnae rachis is distinct, 1 mm. broad. Pinnae rachis gradually diffuses into fine nervules as it enters the basal region of terminal pinnule. Lateral pinnules oblong shape, decurrent at base (Pl. 1, Fig. 4). Lateral margin fusion of two pinnules is ± ½ length of the pinnules. Apex of the pinnules broadly obtuse

Comparison and Discussion — The specimens earlier described by Feistmantel (1876, 1881) under *Sphenopteris polymorpha* are now transferred to the new genus because of the decurrent nature of pinnules and sphenopteroid venation.

Kulkarni (1970) described a specimen from the Lower Nakari Seam (Barakar) of the South Karanpura Coalfield under *Sphenopteris polymorpha* Feistm. On the basis of her examined specimens she expressed the opinion that both the species *S. polymorpha* Feistm. and *S. hughesi* Zeiller (1902) are identical, and proposed to merge the latter species with the former species. According to her the only distinction between the two species is that the pinnules are unlobed in *S. polymorpha* and lobed in *S. hughesi*. She had observed in her specimen that the pinnules are unlobed (cf. *S. polymorpha* type) at the apical portion of frond and lobed at the posterior side (cf. *S. hughesi*). The specimen of Kulkarni (*l.c.*) preserved at the Birbal Sahni Institute of Palaeobotany has been reexamined by me. From the examination of frond it appears to me that Kulkarni (*l.c.*) has failed to understand the variations present in complete fern frond from apex towards base. The present study does not support the view of Kulkarni (*l.c.*) for the specific identification, rather confirms with the original specific identification proposed by Feistmantel (1881), Zeiller (1902) and Arber (1905). The present study has brought to light a number of distinguishable morphological characters present in between the two species. The same has been discussed on p. 76 and Table 1.



TEXT-FIG. 3

TABLE 1 — SHOWING COMPARISON OF MORPHOLOGICAL CHARACTERS OF SPECIES OF *NEOMARIOPTERIS* RECORDED IN THE PRESENT COLLECTION

Name of species *Morphological characters*	*N. polymorpha*	*N. hughesi*	*N. lobifolia*	*N. talchirensis*
1. Nature of rachis	Broadly winged	Narrowly winged	Narrowly winged	Mediumly winged
2. Pinnae outline	Ovate	Linear	Linear-lanceolate	Lanceolate-ovate
3. Angle of attachment of pinnae to rachis	± 90°	± 45°	± 45°	± 70°
4. Shape of pinnules	Oblong	Lanceolate	Obovate	Ovate
5. Apex of pinnules	Broadly rounded	Acute	Obtuse	Acute
6. Margin of pinnules	Entire	Crenulate	Undulated	Entire
7. Angle of attachment of pinnules to pinnae rachis	At right angle	Oblique	Oblique	At right angle
8. Shape of terminal pinnule	Broadly triangular	Lanceolate	Linear	Lanceolate
9. Number of nervules in one pinnule	12-14	5-7	8-12	12-16

According to present study the specimens of Kulkarni (*l.c.*) recorded from South Karanpura belongs to *S. hughesi* Zeiller.

In view of this confusion it will be of utter importance to record here the previously reported specimens which confirm with the diagnosis of *Neomariopteris polymorpha* n. comb.

1876 *Sphenopteris polymorpha* Feistmantel, p. 356, pl. 16, fig. 5-7, pl. 17.
1881 *Sphenopteris polymorpha* Feistmantel, p. 76-77, pl. 15A, fig. 3, pl. 16A bis, figs. 1-6.
1922 *Sphenopteris polymorpha* Walkom, pl. 5, figs. 26, 26A.
1958 *Sphenopteris polymorpha* Archangelsky, fig. 25, 26.

The following are regarded distinct from *Neomariopteris polymorpha*:

1902 *Sphenopteris polymorpha* Arber, p. 12, pl. 1, figs. 4-5.
1958 *Sphenopteris polymorpha* Archangelsky, fig. 29.
1961 *Sphenopteris polymorpha* Lele, p. 71-72, pl. 1, fig. 5.
1969 *Sphenopteris polymorpha* Maithy, p. 266-267, pl. 1, fig. 4.

Neomariopteris hughesi (Zeiller) n. comb.

Pl. 2, Figs. 7-11; Text-fig. 3B,C

Synonymy

1877 *Dicksonia* cf. *concina* Feistmantel, p. 198, figs. 10, 11.
1881 *Dicksonia hughesi* Feistmantel, Palaeont., p. 78, pl. 23A, figs. 1, 3, 12, 12a, 13.
1902 *Sphenopteris* (*Dicksonia*) *hughesi* Zeiller, p. 6, figs. 1, 2, 2a, 2d.
1905 *Sphenopteris hughesi* Arber, p. 133-135, text-fig. 32.
1966 *Sphenopteris hughesi* Surange, p. 66-67, figs. 37A-B.
1970 *Sphenopteris polymorpha* Kulkarni, p. 208-211, pl. 1, text-fig. 1-4.

Emended Diagnosis — Fronds large, at least tripinnate. Rachis extremely narrow, 1-2 mm, secondary rachis narrow emerge alternately, subopposite or ± opposite from primary rachis at an angle of 45°-60°. Pinnae linear in shape, attached alternately to the secondary rachis at an angle of 45°. Lateral pinnules lanceolate shape, pinnules show maximum width at their middle portion, 2-6 mm. long and 1-3 mm. broad, the length to breadth ratio of the pinnules is 2:1, pinnules arranged alternate, arising

←—

TEXT-FIG. 3 — Pinnules enlarged to show shape and venations. A. *Neomariopteris polymorpha* n. comb. B-C. *Neomariopteris hughesi* n. comb. D. *Neomariopteris lobifolia* n. comb. E. *Neomariopteris talchirensis* sp. nov. (All specimens figured × 5).

obliquely from the rachis, attached by their broad base, pinnules near the base shows lateral fusion, apex acute, margins crenulate, both the lateral margins show equal curvature, terminal pinnule lanceolate, longer than broad, apex acute, margin crenulate; a gradual increase in size of the pinnules is present from apex to base of the pinnae; venation thin, median vein arises from the point where the basal margin of pinnule joins the pinnae rachis, median vein gives fine lateral nervules, which show rare dichotomy before reaching to the margin. 5-7 nervules are recorded in one pinnae.

Lectotype — 5207 Geological Survey of India, Calcutta.

Locality — Jharia Coalfield, Bihar.

Horizon — Raniganj Formation.

Specimen Figured — 35022/1069, 35023/1227, Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Churulia pit, East Raniganj Coalfield, West Benal.

Horizon — Barakar Formation.

Description — 100 hand specimens of this type were examined. Beside this the type specimens described by Feistmantel (1881) and Zeiller (1902) were also examined. The specimen is a tripinnate frond. Primary rachis thin measuring 1 mm. broad. Secondary rachises emerge at an angle of 60° from primary rachis. They are arranged alternate or subopposite. Secondary rachis is also narrow (1 mm.) like primary rachis. Pinnae linear shape, varying size, smaller towards apex and bigger towards proximal side. Pinnae attached to rachis alternately at an angle of 45°. Pinnae at the very extreme apex of the frond is unlobed. However, the subsequent pinnae show gradual lobing resulting in the formation of pinnules. Pinnules show a variation in their shape. Pinnules near the apical portion of frond small linear lanceolate shape with slight crenulation of pinnule (Pl. 2, Fig. 7). The pinnules towards the posterior side are lanceolate-spathulate shape, comparatively bigger in size and the margins of the pinnules show pronounced crenulation (Pl. 2, Fig. 8, Text-fig. 4D). Veins fade out and arise at the point where lower margins of the pinnule join the pinnae rachis (Pl. 2, Figs. 7, 8). It gives lateral nervules which dichotomise rarely before reaching the margin of the pinnules.

Cuticle — Epidermal structure is seen in translucent pulls of pinnules. Although the preservation is not very good but under the binocular two layers of epidermis are marked. Stomatiferous and non-stomatiferous surfaces. The stomatiferous surface is thick (Pl. 2, Fig. 10). Epidermal cells are trapezoidal or polygonal in outline. Intervening cell walls thick, the stomata at certain places is well marked. They are haplocheilic with thickened lateral lamellae. The subsidiary cells are like ordinary epidermal cells, and the polar subsidiary cells are not different from the lateral ones (Pl. 2, Fig. 11, Text-fig. 4). Non-stomatiferous surface is thin (Pl. 2, Fig. 9). Cells are polygonal in outline. Intervening cell wall is thin.

Comparison and Discussion — Feistmantel (1881) described these fronds under *Dicksonia concina* Heer. The same was transferred by Zeiller (1902) to a new species of *Sphenopteris*, *S. hughesi*. Since the form shows decurrent nature of pinnules, it is, therefore, proposed to transfer them under the new genus. Kulkarni (1970) considered this species similar to *Neomariopteris* (*Sphenopteris*) *polymorpha*. The present morphological study of fronds shows that both the species are different. *N. polymorpha* is a robust form, because of strong wide rachis with bigger oblong pinnules, attached to rachis at ± 90°, pinnule apex is obtuse with entire margins. Contrary to this *N. hughesi* is a weak form with a delicate narrow rachis. The form has small linear pinnules, attached to rachis obliquely, ± 45°, pinnule apex is acute with crenulate margins. Thus the two forms are morphologically different, hence it is proposed here to keep *N. hughesi* as distinct from *N. polymorpha*.

It will not be out of place to list those previous records which agree with the diagnosis of *N. hughesi*. They are as follows:

1881 *Dicksonia hughesi* Feistmantel, p. 78, pl. 23A, figs. 1, 3, 12, 12*a*, 13.
1882 *D. hughesi* Feistmantel, p. 28, pl. 12, figs. 3, 3a, 3b.
1902 *Sphenopteris* (*Dicksonites*) *hughesi* Zeiller, p. 6, pl. 4, figs. 1, 2, 2a-2d.
1965 *S. hughesi* Maheshwari & Gyan Prakash, p. 120, pl. 1, fig. 10.
1970 *S. polymorpha* Kulkarni, p. 208-211, pl. 1, figs. 1-5, text-figs. 1-4.

The following are recorded as distinct from *Neomariopteris hughesi*:

1968 *Sphenopteris hughesi* Kar, p. 245, pl. 1, figs. 3, 4.

Neomariopteris lobifolia (Morris) n. comb.

Pl. 2, Figs. 12-13; Text-fig. 3D

Synonymy

1845 *Sphenopteris lobifolia* Morris in Strzelecki's New South Wales, p. 246, pl. vii, figs. 3, 3a.
1847 *Sphenopteris lobifolia* McCoy, p. 149.
1905 *Sphenopteris lobifolia* Arber, p. 135-138, pl. V, fig. 2, 3.
1954 *Sphenopteris lobifolia* Srivastava, p. 70-71, pl. 1, figs. 1-3.
1966 *Sphenopteris lobifolia* Surange, p. 68-69, fig. 38A, B.
1966 *Sphenopteris lobifolia* Rigby, p. 128-129, pl. 33, fig. 32.
(For other Synonymy see Arber, 1905)

Emended Diagnosis — Fronds probably tripinnate, triangular in contour. Rachis extremely narrow 1-2 mm. broad, winged. Pinnae linear-lanceolate shape, attached alternate to subopposite to the rachis at an angle of 45°. Lateral pinnules obovate shape, pinnules show maximum width at their middle portion, 3-8 mm. long and 2-4 mm. broad, pinnules arranged alternate, standing obliquely to the rachis, attached by their contracted base, pinnules at the base are decurrent in nature; apex obtuse with slight lobed margin, both the margins show equal curvature, terminal pinnule linear in shape, median vein of the pinnule sinuate, supplying simple or bifurcating branches to the margins. 8-12 nervules are found in one pinnule.

Holotype — Morris 13,530 Mus. Geol. Soc. London.

Locality — New South Wales, Australia.

Horizon — Permo-Carboniferous.

Specimen Figured — 35024/1384, Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Mahavir Colliery, East Raniganj Coalfield.

Horizon — Raniganj Formation.

Description — The figured specimen is a tripinnate frond. The extreme apical portion is not preserved. Pinnae are arranged alternately towards the basal portion and show a subopposite tendency towards apical part. The pinnae near the terminal portion are unlobed. The lobing increases as we pass to the posterior side of frond (Pl. 2, Fig. 12). Pinnules are attached obliquely (30° angle) to the pinnae rachis. Pinnules obovate shape and closely placed. Pinnules show lateral fusion of margins near the base. The lateral fusion of pinnules is about 1/5th length of the pinnule from base. Median vein of pinnule arises from the point where the lower margin of pinnules joins the narrow pinnae rachis. Median vein sinuate (Pl. 2, Fig. 13) supplying simple or bifurcating branches to margin. Bifurcating branches are rare.

Comparison and Discussion — Due to the decurrent nature of pinnules the fronds earlier described under *Sphenopteris lobifolia* Morris are now transferred under the new genus *Neomariopteris*.

Neomariopteris polymorpha differs from *N. lobifolia* in having broad and strong rachis, oblong pinnules with entire margin attached ± right angles to the pinnae rachis. The present form shows a close comparison to *N. hughesi* by the narrow rachis and oblique attachment of pinnules. However, *N. hughesi* differs by lanceolate shape of pinnules with acute apex, attached to the rachis by their broad base; whereas the pinnules in *N. lobifolia* are obovate with obtuse apex and slightly contracted base.

Neomariopteris talchirensis sp. nov.

Pl. 1, Figs. 5-6; Text-fig. 3E

Synonymy

1876 *Sphenopteris polymorpha* (*partim*) Feistm., p. 356.
1881 *Cyathea* cf. *tchihatcheffi* Feistmantel, p. 75-77, pl. 16A, figs. 1-2 & 4.
1969 *Sphenopteris polymorpha* Maithy, p. 266-267, pl. 1, fig. 4.

Diagnosis — Fronds tripinnate. Rachis broad 3 mm. wide, winged. Secondary rachises broad emerge alternately or subopposite from primary rachis at a wide angle, i.e. 70°. Pinnae lanceolate-ovate shape, arranged alternately, attached to the secondary rachis ± right angles. Lateral pinnules 6-8 mm. long and 3-4 mm. broad, ovate shape, decurrent, standing ± at right angles to the pinnae rachis, attached by their broad base. Lateral fusion is about ¼ length of the pinnule from the base; apex acute, margin entire, lower margin of the pinnule shows strong curvature from base towards apex, whereas the upper margin is ± 90° (straight) from pinnae rachis. Terminal pinnule lanceolate with acute apex. Venation distinct. Median vein somewhat sinuous, dichotomises once before reaching to the margin. 12-16 nervules are recorded in one pinnule.

Lectotype — 5169, Geological Survey of India, Calcutta (Pl. 16A, Fig. 4).

Locality — Talchir Coalfield.

Horizon — Barakar Formation.

Figured Specimen — 33119/838, Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Junction of Lobjee and Sadabaha rivers, Daltonganj Coalfield.

Horizon — Barakar Formation.

Description — The present description is based upon the specimens No. 5166 (Feistm., 1881, Pl. 16A, Fig. 1), 5167 (Pl. 16A, Fig. 27) and 5169 (Pl. 16A, Fig. 4) preserved at the Geological Survey of India, Calcutta. The best preserved specimen is 5169 which is a tripinnate frond, whereas 5166 shows the apical portion of frond and 5167 the middle portion of frond.

The specimens figured here have earlier been described by Maithy (1969) under *Sphenopteris polymorpha* from the Barakar beds of Daltonganj Coalfield. The portion of the frond figured here shows that the pinnae rachises are arranged alternately at a distance of 0·5-0·8 cm. Pinnae 0·5 cm. to 3 cm. long. Pinnae lanceolate, pointed towards apex. Pinnule small, 3-4 mm. long and 1-2 mm. broad, ovate shape, acute apex, attached to pinnae rachis by their sessile wide base. Pinnules are decurrent in nature. Margin of the pinnules is entire. Secondary veins emerge at acute angle, dichotomous and flexuosus.

Comparison and Discussion — These specimens were first described by Feistmantel (1876) under *Sphenopteris polymorpha*. Later Feistmantel (1881, p. 75, 76) opined that these specimens are different from *Sphenopteris polymorpha* and show a resemblance to *Cyathea tchihatcheffi*. A reexamination of the specimens of Feistmantel (*l.c.*) and Maithy (1969) shows that they conform with the generic diagnosis of the new genus proposed here. The decurrent nature of the pinnules at the base has also been marked by Feistmantel (Feistm. *l.c.* p. 76). Hence the forms described under *Cyathea* cf. *tchihatcheffi* and *S. polymorpha* Maithy (*l.c.*) from Daltonganj Coalfield are now transferred under a new species of *Neomariopteris*, *N. talchirensis*.

The present form compares closely with *Neomariopteris polymorpha* (Feistm.) n. comb. due to its winged rachis, and the pinnules being attached ± 90° to pinnae rachis. However, *N. talchirensis* differs by the ovate shape of pinnules with acute apex and lanceolate shape of terminal pinnules. *N. hughesi* n. comb. and *N. lobifolia* n. comb. differs in having narrow rachis, pinnules attached obliquely to the rachis, and in the different shape of the pinnule.

REMARKS ON *SPHENOPTERIS ALATA* (BRONGNIART) STERNBERG AND OTHER LOWER GONDWANA *SPHENOPTERIS*

The species discussed here are based only on the basis of literature. No referable specimens are available in our collections.

A good deal of nomenclatural confusion exists about the species *Sphenopteris alata* (Brngn.) Sternberg, because many of the authors who have mentioned this fossil have fallen into error in some form or the other. The main cause of this is due to the fact that Brongniart described and figured in 1828, two ferns with the specific title *alata*; (1) *Pecopteris alata* (p. 361, pl. cxxvii) from New South Wales and (2) *Sphenopteris alata* (p. 180, pl. xlviii, fig. 4) from Germany. Sternberg (1820-38, Pt. ii, pp. 59 & 131) transferred the form described under *P. alata* to *Sphenopteris*. Therefore, in his work two different forms are described, one under (1) *Sphenopteris alata* (Brngn.) and the other under (2) *Sphenopteris alata* Brongniart. However, the German type (2) is now known as *Sphenopteris grandini* (Goepp.) Schimper (1869, Vol. 1, p. 404). Thus the only *Sphenopteris* with the specific title *alata* is the Australian form earlier described under *Pecopteris alata* Brngn. Very little is known about this form. The only specimens recorded are of Brongniart (1828) obtained from the coal mines on the Hawkesbury river near port Jackson and the other specimen reported by McCoy (1847) from New Castle, New South Wales. Dutoit (1932) reported a specimen from a locality north-west of Bergville, Natal (Lower Beaufort beds). All these specimens show decurrent nature of pinnules and conform with the diagnosis of *Neomariopteris*. Since no referable material is in our collection, therefore, it is proposed to keep it under *Sphenopteris* till fresh material is collected or the type forms are examined.

The same holds true also for *Sphenopteris hastata* McCoy (1847), *S. flexuosa*

McCoy (*l.c.*), *S. plumosa* McCoy (*l.c.*) and *S. germanus* McCoy (*l.c.*) which are based upon fragmentary specimens. Arber (1905, p. 135) has considered them synonymous to *S. lobifolia* Morris.

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EXPLANATION OF PLATES

PLATE 1

Neomariopteris polymorpha n. comb.

1. Apical portion of frond, × 1·5 (specimen no. 35020/1396, Raniganj Coalfield, Raniganj).
2. Portion from the middle region of frond, × 1·5 (specimen no. 35021/1396, Raniganj Coalfield, Raniganj).
3. A pinnae enlarged to show the terminal pinnule and lateral pinnules, × 3.
4. Pinnules enlarged to show venation and decurrent nature of pinnules, × 5.

Neomariopteris lalchirensis sp. nov.

5. A portion of frond, × 1 (specimen no. 33119/838, Daltonganj Coalfield, Barakar).
6. The same enlarged to show venation and shape of pinnules, × 5.

PLATE 2

Neomariopteris hughesi n. comb.

7. A portion of frond showing the arrangement of pinnae and the decurrent nature of pinnules, × 5. (specimen no. 35022/1069, Raniganj Coalfield).

8. Median portion of frond is enlarged to show pinnules and venation, × 5 (specimen no. 35023/1227, Raniganj Coalfield, Barakar).

9. Epidermal structure of non-stomatiferous surface, × 250.

10. Epidermal structure of stomatiferous surface, × 100.

11. A stomata and subsidiary cells enlarged (S = stomata), × 500.

Neomariopteris lobifolia n. comb.

12. A portion of a frond showing arrangement of pinnae, × 1·5 (specimen no. 35024/1384, Raniganj Coalfield, Raniganj).

13. Portions of pinnae enlarged to show the nature of pinnules, × 5.

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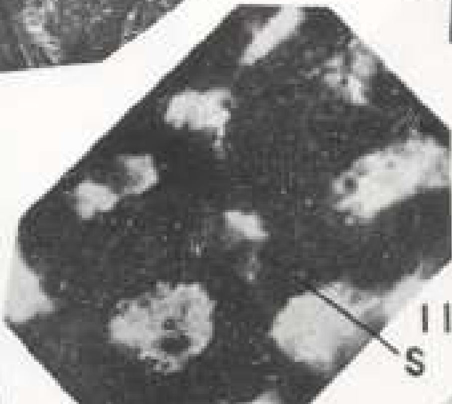
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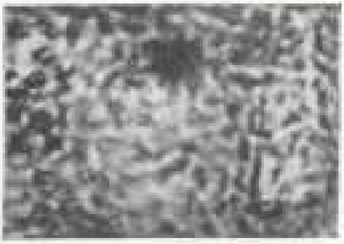
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PALAEOBOTANICAL EVIDENCES ON THE AGE OF THE COAL-BEARING LOWER GONDWANA FORMATION IN THE JAYANTI COALFIELD, BIHAR

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ABSTRACT

The coal-bearing Lower Gondwana beds overlying the Talchir Formation in the Jayanti Coalfield are investigated for their mega- and microfloras. The megaflora, comprising 7 genera and 18 species (2 new), is characterized by *Noeggerathiopsis*, *Gangamopteris*, *Glossopteris* and platyspermic seeds and by the peculiar presence of *Gondwanidium*. The mioflora (33 genera and 57 species) is characterized by the dominance of trilete taxa *Punctatisporites* and *Callumispora* together with the monosaccates *Plicatipollenites*, *Virkkipollenites*, *Potonieisporites* and *Vestigisporites*. Other quantitatively significant genera are *Parasaccites*, *Caheniasaccites*, *Vesicaspora*, *Cuneatisporites*, *Striatites*, *Lunatisporites*, *Faunipollenites* and *Guttulapollenites*.

The mega- and miofloral composition of the assemblages is analysed qualitatively and quantitatively to assess their relative ages. The evidence, especially of the megaflora, leaves no doubt that the coal-bearing succession of the Jayanti basin belongs to the Karharbari Formation and is likely to be of Lower Karharbari age. Palynostratigraphic aspects of the better known Karharbari miofloras are compared and discussed in the light of the present palaeobotanical evidence.

INTRODUCTION

IN the Jayanti coal basin the Talchir Formation is overlain by the coal-bearing strata which have been referred to the Barakar Stage or Karharbari Stage by different workers. Puri (1953) reported the occurrence of Karharbari plants in this area. He recorded *Gondwanidium validum*, *Buriadia sewardii*, *Phyllotheca* sp., *Cordaicarpus* sp., *Squama forma integrima*, *Samaropsis raniganjensis* and *Noeggerathiopsis hislopi*. Niyogi and Sanyal (1962) also mentioned the occurrence of plants in the carbonaceous shales and considered that the evidence supported a Barakar age for the rocks. Lele and Maithy (1966) again suggested a Karharbari age for these rocks on the basis of megafossil evidence.

The present study was undertaken to collect substantial palaeobotanical evidences, both mega- and microfossil, with a view to resolve the controversy. It is now concluded that the coal-bearing strata belong to the Karharbari Formation.

MATERIAL AND METHODS

The material for micro- and megafossil studies was collected from the following places: (1) *Misra village* — Megafossils were collected from a section exposed in a tributary of Patharjore Nala about one furlong south of Misra village. The beds show a general northern dip. Details of the section are given below. Most of the fossils were recovered from bed No. 5 (Sample No. DF2). Unfortunately due to deep weathering of the rock, the plant impressions are rather poorly preserved.

Beds	Thickness in ft.	Field sample No.	Remarks
8. Grit with pebbly concentrations			
7. Greyish sandy micaceous shale with few plant fossils	1½	D17	Occasional plant fossils
6. Grit with stem impressions	1		
5. Yellow micaceous muddy, sandy shales	1½	DF2 D18	Rich megaflora and Miospores
4. Carbonaceous shale slightly sandy	1½	D19	Miospores
3. Grit	12		
2. Micaceous shale	½		
1. Grit			

Field observations indicate that the beds at Misra village are stratigraphically closer to the underlying Talchir Formation, the latter being exposed south of Madankata in the Patharjore Nala (Lele & Makada, 1972).

(2) *Banskupi Colliery Area* — Megafossils were collected from the outlying carbonaceous shale dumps belonging to the coal-bearing succession of the deserted Banskupi Colliery (Sample No. DF3). Some fossils were also collected from an old dump near the terminus of the siding branch line near Madankata railway station (Sample No. DF4). Although the stratigraphical location of the Banskupi shales is unknown, it seems highly probable that they are younger than the beds at Misra village. The plants are carbonized and have yielded cuticles.

For cuticular preparations from the megafossils a thin film of cellulose acetate in acetone was applied over a small part of the carbonized crust and when it was dry the pull was taken off. It was then put into concentrated or dilute commercial nitric acid with or without potassium chlorate. Cuticles of *Noeggerathiopsis* were quite resistant and took 2-3 days for maceration. *Glossopteris* cuticles were oxidized in less than 24 hours. Hydrogen peroxide was also tried for maceration but it took even a longer period for oxidation of pulls. As crust turned brown on completion of oxidation, the pieces were thoroughly washed with water and then treated with a few drops of 5 per cent potassium hydroxide solution, washed with water and during these processes the two cuticular layers became generally separate, or otherwise they were separated by dissecting needles.

The cuticular pieces were stained in 10 per cent aqueous safranin. Permanent preparations were made in Canada balsam.

MEGAFOSSILS

The megafossil assemblage consists of 7 genera belonging to 18 species. Plants marked with an asterisk are described here.

1. *Paracalamites* sp. (Loc. 1)
*2. *Gondwanidium validum* (Feistmantel) Gothan, 1927. (Loc. 1)
3. *Gangamopteris cyclopteroides* Feistmantel, 1876. (Loc. 2)
4. *Gangamopteris* sp. cf. *G. clarkeana* Feistmantel, 1890. (Loc. 1)
*5. *Gangamopteris* sp. cf. *G. gondwanensis* Maithy, 1965c. (Loc. 2)
*6. *Gangamopteris* sp. (Loc. 2)
7. *Glossopteris communis* Feistmantel, 1876. (Loc. 2)
*8. *Glossopteris* sp. cf. *G. fibrosa* Pant, 1958. (Loc. 2)
9. *Glossopteris browniana* Brongniart, 1828. (Loc. 2)
*10. *Glossopteris jayantiensis* sp. nov. (Loc. 2)
*11. *Glossopteris* sp. (Loc. 2)
12. *Noeggerathiopsis hislopii* (Bunbury) Feistmantel, 1879. (Loc. 1 & 2)
*13. *Noeggerathiopsis spathulata* (Dana) Maithy, 1965c. (Loc. 1)
*14. *Noeggerathiopsis conspicua* sp. nov. (Loc. 2)
*15. *Noeggerathiopsis bunburyana* Pant & Verma, 1965. (Loc. 2)
*16. *Samaropsis feistmantelii* Maithy, 1965b. (Loc. 1)
*17. *Samaropsis goraiensis* Surange & Lele, 1957. (Loc. 1)
*18. *Cordaicarpus zeilleri* Maithy, 1965b. (Loc. 1)
*19. Scale leaves: Types 1 & 2. (Loc. 1 & 2)
*20. Branched axes. (Loc. 1)

Genus—*Gondwanidium* Gothan, 1927

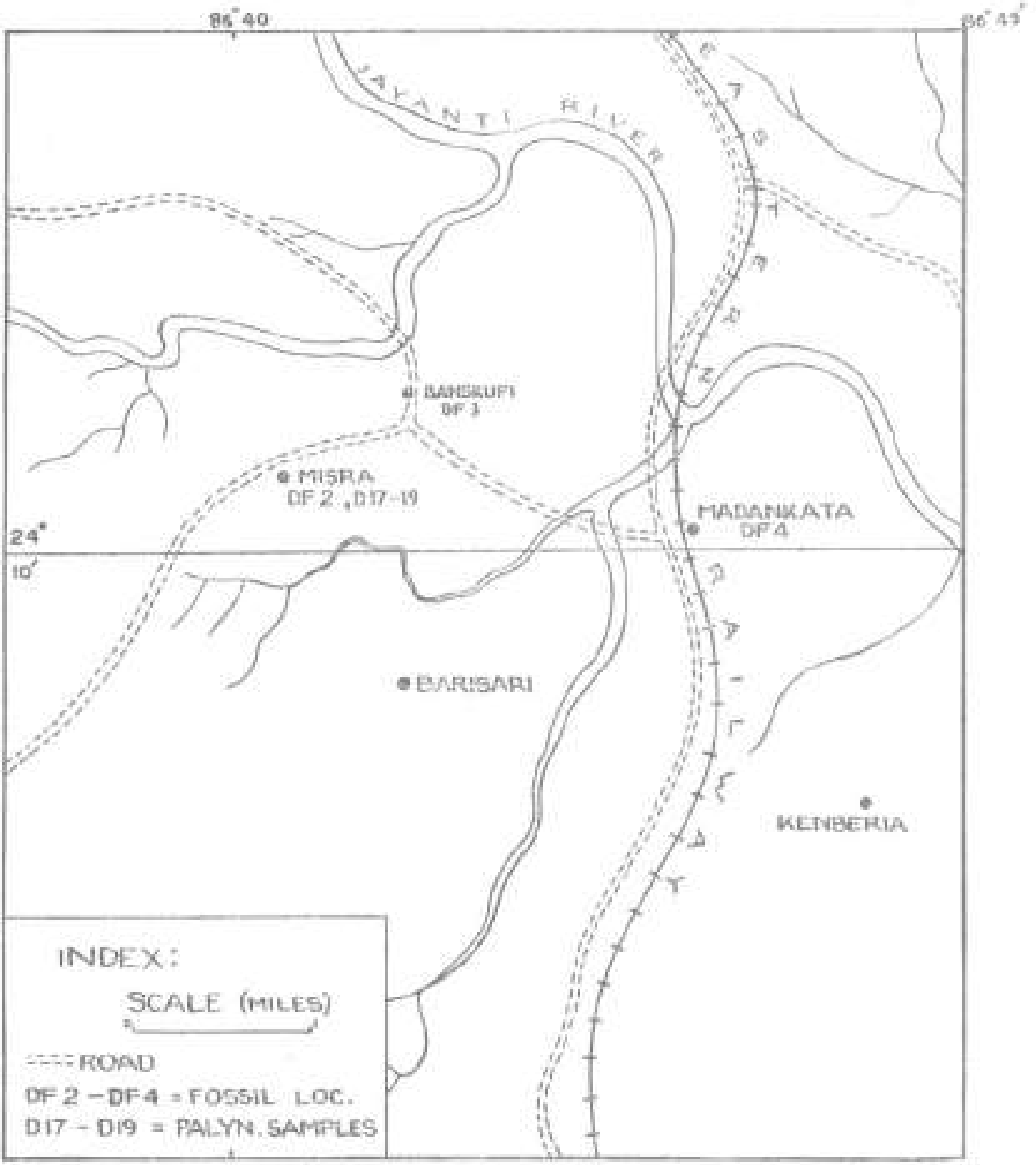
Type species—*Gondwanidium validum* (Feistmantel) Gothan, 1927.

Gondwanidium validum (Feistmantel) Gothan, 1927

Pl. 1, Fig. 6

Description — The solitary specimen (and counterpart) is an impression on a buff grey clayey shale. The incomplete specimen measures 5 cm. in length and 3·6 cm. in breadth. The rachis is strong and flat and 4 mm. in breadth. Pinnules are oval, 4 on either side, 2 cm. long and 1·4 cm. at the broadest, with entire to slightly lobed margin and bluntly rounded apex. They are subopposite to alternate and attached to the rachis obliquely along the whole length of their base. The venation of the pinnules is very obscure.

Comparison — This specimen compares in gross morphological features with *Gondwanidium validum*. Although the venation details are not clearly seen, there are other



Location of palaeobotanical material in the Jayanti Coalfield, Bihar.

detached pinnules in the collection which show the lobing and venation characteristic of *G. validum*.

Occurrence — Misra village (Loc. 1).

Genus — *Gangamopteris* McCoy, 1861

Type species — *Gangamopteris angustifolia* McCoy, 1861.

Gangamopteris sp.

Pl. 1, Fig. 7.

Description — This leaf impression represents only the basal part. The incomplete specimen measures 6·5 cm. in length and 1·5 cm. in breadth from the centre of the lamina to the margin. The lamina strongly tapers towards base but no petiole is formed. The median part shows subparallel veins which anastomose here and there. The meshes are polygonal, 4-5 times longer than broad and nearly uniform in size on the lamina.

Comparison — The specimen is not sufficiently complete and well-preserved for definite identification. The venation is like that of *Gangamopteris karharbariensis* Maithy (1965c)

Occurrence — Banskupi Colliery area (Loc. 2).

Gangamopteris sp. cf. *G. gondwanensis* Maithy, 1965c

Pl. 1, Figs. 8-11

Description — Few incomplete specimens are referable to this species. Nothing is known about the size and shape of the complete leaf. The median region of the leaves is occupied by 1-5 subparallel veins which give rise to lateral veins at acute angles. The veins dichotomize and anastomose to form elongate-polygonal meshes which gradually become narrower towards the margin.

Cuticle — Only one specimen (Pl. 1, Fig. 8) has yielded cuticle. Only one surface is stomatiferous which, by analogy with existing land plants, is possibly the lower cuticle (Sahni, 1923).

Upper Cuticle — This surface is non-stomatiferous and moderately thick. Vein and mesh areas are not marked. Cells are usually four-sided, sometimes irregular, mostly arranged end to end, longer than broad and measure 90-190 × 25-50 µ. The lateral walls are straight, and end walls generally oblique, 3-4 µ thick; surface walls are unspecialized.

Lower Cuticle — This surface is stomatiferous, comparatively thin and the vein and mesh areas are not marked. Cell outlines are indistinct, walls are straight. Outline of epidermal cells are ill-preserved.

The stomata are haplocheilic, irregular in distribution and orientation. The subsidiary cells (number not known) are unspecialized. Guard cells are 37-70 µ long, elliptical to broadly oval in shape and are thickened towards inner and outer margin. Stomatal opening is a linear-elliptical slit, 22-37 µ long and up to 5 µ broad in the middle.

Comparison — The specimens of Maithy as well as the present specimens compare in venation with *Gangamopteris cyclopteroides* Feistmantel (1876b). Epidermal features of this species were studied by Maithy under incident light. The present material, recovered by maceration, is comparatively better preserved and suggests general agreement with *G. gondwanensis*, with the exception that vein and mesh areas are not distinct in our cuticles.

Occurrence — Banskupi Colliery area (Loc. 2).

Genus — *Glossopteris* Sternberg, 1825

Type species — *Glossopteris browniana* Brongniart, 1828.

Glossopteris sp. cf. *G. fibrosa* Pant, 1958

Pl. 1, Fig. 12

Description — Some incomplete impressions show a strong midrib, running as a groove up to the ± pointed apex (Pl. 1, Fig. 12). The secondary veins are 30-36 per cm. near the margin and form elongate-narrow meshes. Inside the meshes slender, thin interstitial veins are seen occasionally, running ± parallel to the secondary veins.

Comparison — Interstitial veins have so far been reported from *Glossopteris fibrosa* Pant (1958) and *Glossopteris* sp. of Maheshwari (1956). The present specimens resemble rather closely one of the specimens of

G. fibrosa (Pant, 1958, Fig. 1c) in the nature and concentration of the secondary veins but differ in the nature of the apex. Also, the cuticle of the present specimens is not known for definite identification with *G. fibrosa*.

Occurrence — Banskupi Colliery area (Loc. 2).

Glossopteris jayantiensis sp. nov.

Pl. 1, Figs. 13-16; Pl. 2, Figs. 17-19; Text-fig. 1.

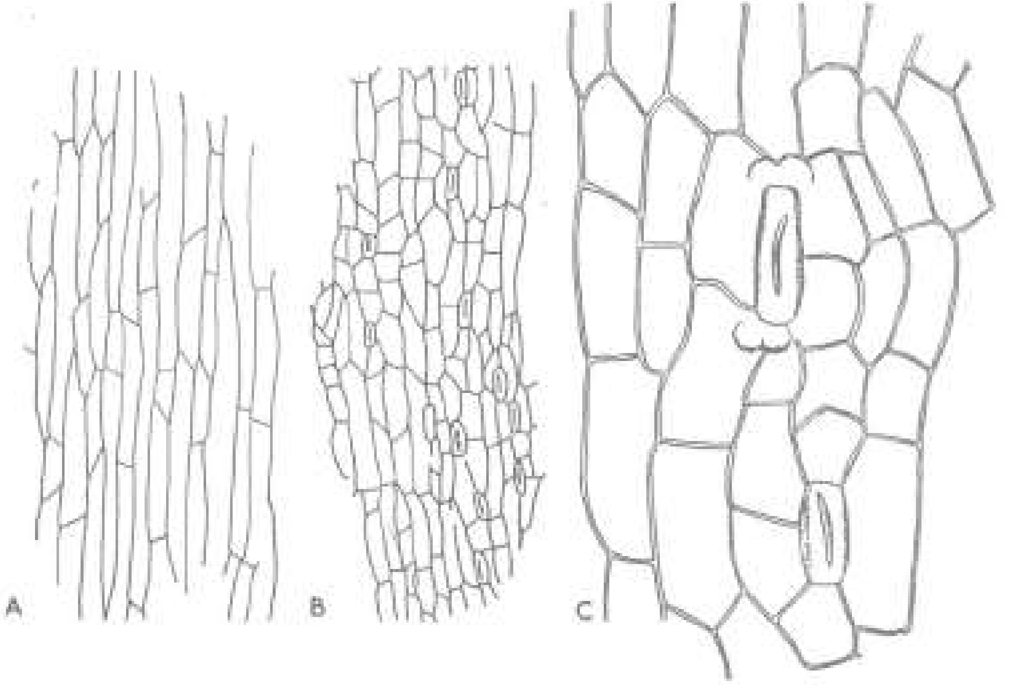
Diagnosis — Leaf simple, midrib flat, longitudinally striated; secondary veins arise at very acute angles, obliquely passing towards the margins; meshes narrow-elongate, uniformly broad throughout.

Cuticle hypostomatic, upper cuticle non-stomatiferous. Cells rectangular to elongate polygonal; cell walls straight and unspecialized.

Lower cuticle stomatiferous; stomata monocyclic, haplocheilic, longitudinally orientated in irregular linear rows; guard cells thin, slightly sunken; faintly thickened at lateral and polar regions and also around stomatal aperture; subsidiary cells 4-6, unspecialized, not forming a ring around stomata.

Description — This species is represented by 3 incomplete specimens (Pl. 1, Figs. 13, 14) all of which have yielded identical cuticles. The best cuticles are from the holotype. The larger specimen (Pl. 1, Fig. 13) measures 7·8 cm. in length and 2·7 cm. in width. The apex is acute to slightly rounded. The midrib is flat and longitudinally striated. The secondary veins arise from the midrib at very acute angles (5-15°) dichotomize and anastomose, forming elongate narrow meshes of almost equal width. The concentration of secondary veins near the margin is 25-35 per cm.

Upper Cuticle — This surface is non-stomatiferous and moderately thick. Vein and mesh areas are not marked. The cells are rectangular to elongate polygonal, much



TEXT-FIGURE 1. A-C. *Glossopteris jayantiensis* sp. nov.

A. Line drawing of the upper cuticle from the holotype. × 105.

B. Line drawing of the lower cuticle from the holotype showing longitudinally distributed stomata. × 105.

C. Two stomata enlarged. Note the polar caps of the guard cells. × 625.

longer than broad, measuring 60-150× 25-42 μ. The lateral walls are straight and the end walls are truncate or oblique and 2·5 μ thick. Surface walls are unspecialized.

Lower Cuticle — This surface is stomatiferous, comparatively less thick with indistinctly marked vein and mesh areas. The cells over the veins are longer and narrow and arranged end to end. The cells in the mesh areas are sometimes rectangular to polygonal and arranged end to end. They are 50-90×18-30 μ in size with straight walls. The surface walls are unspecialized.

The stomatal apparatus is monocyclic. The stomata are haplocheilic and longitudinally orientated in 3-5 linear rows. Stomatal frequency is 80-120 per sq. mm. The guard cells are thin, slightly sunken, ± rectangular, with ± convex outer margin and are 37-45 μ long. The guard cells are slightly thickened along the outer walls as well as around the slit like stomatal aperture which is 17-25 μ long. Occasionally polar caps are also seen on guards cells. Sometimes the stomatal aperture is open. The subsidiary cells usually do not form a ring around the stomata, are 4-6 in number, usually 5 (3 lateral and 2 polar) and practically indistinguishable from other epidermal cells. No papillae have been observed.

Comparison — Morphologically the venation of the leaf is somewhat like *Glossopteris communis* Feistmantel (1876a). However, the cuticle of *G. communis* is totally different from the present species in being amphistomatic with irregularly orientated stomata. The present species is characterized by the longitudinal orientation of the stomata in more or less linear rows, a character which is known so far only from *G. indica* Zeiller (1896) and *G. conspicua* Srivastava (1957). However, in *G. indica* the cells of the lower cuticle are small and rectangular with very thick walls. Details of stomatal apparatus are not known. In *G. conspicua* the subsidiary cells form a ring around the stomata and are much smaller in size than other epidermal cells, and the guard cells are also smaller in size (25 μ). Besides, *G. conspicua* is morphologically very distinct from *G. jayantiensis*.

Holotype — Specimen No. 35008, Pl. 1, Fig. 13.

Type Locality — Banskupi Colliery area (Loc. 2); Jayanti Coalfield, Bihar.

Horizon — Karharbari Formation, Lower Gondwana.

Glossopteris sp.

Pl. 2, Figs. 20-22; Text-fig. 2

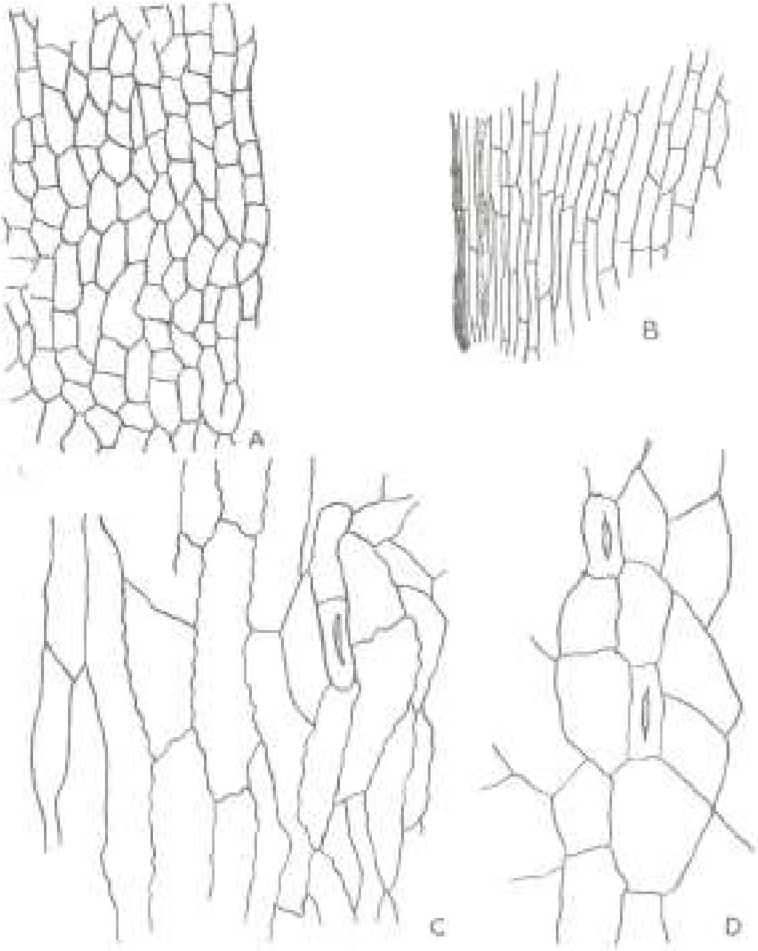
Description — Incomplete leaf with well preserved carbonized crust. The leaf is linear in shape, but the apex and base are not preserved. The midrib is 1·5 mm. broad at the base and continues throughout the preserved length of the leaf lamina. The secondary veins (Pl. 2, Fig. 20) are very close, 25-30 per cm., arise at acute angles. The meshes are narrow-elongate and nearly of equal size throughout.

Cuticle — The cuticle is hypostomatic.

Upper Cuticle — This surface is moderately thick and non-stomatiferous. The cells are elongate, rectangular, polygonal or trapezoid and usually arranged end to end; measure 40-89×28-37 μ. The cell walls are straight to undulated, about 3 μ thick. The surface walls are unspecialised.

Lower Cuticle — This surface is thin and stomatiferous. The cuticle pieces are too small to show vein and mesh areas. The cells are elongate to polygonal, measure 58-78×24-33 μ in size. Some fragments have more irregular cells with stomata, they may be the mesh regions; while fragments where cells are more elongated may be the regions along the veins. Often the walls of the few subsidiary cells as well as of the cells in the neighbourhood may become sunken. The surface walls are unspecialized except that they show faint granulation. The stomatal apparatus is monocyclic. The stomata are haplocheilic and irregularly distributed and orientated. Subsidiary cells are 5-6 in number and similar to other epidermal cells. Guard cells are thin, sometimes their lateral walls are thick and slightly cutinized, sunken, 30-37 μ long with thin hyaline polar caps. Stomatal slit ± extends up to the cap. The stomatal aperture is 18-25 μ long, slit walls slightly thickened.

Comparison — In venation pattern the present leaf compares with *Glossopteris zeilleri* Pant & Gupta (1968) and *G. angustifolia* Brongniart (1828), but the apex is not preserved in our specimen. The epidermal features of the specimen compares with *G. zeilleri* inasmuch as the cells are



TEXT-FIGURE 2. A-D. *Glossopteris* sp.

A. Line drawing of the uppe cuticle from the leaf represented in Pl. 2, Fig. 20. × 105.
B. Line drawing of the upper cuticle near the margin of the above leaf. × 105.
C-D. Enlarged line drawing of the lower cuticle from the above leaf showing stomata and straight to sinuous walled cells. × 265

non-papillate and sinuous. However, *G. zeilleri* is distinct in that the papillae overhang the stomatal pit. *G. tenuifolia* Pant & Gupta (1968) differs in having papillate sinuous cells. Our leaf is probably a distinct species, but specimens are insufficient for justifying a new name.

Occurrence — Banskupi Colliery area (Loc. 2).

Genus—*Noeggerathiopsis* (Feistmantel) Maithy, 1965d

Type species — *Noeggerathiopsis hislopii* (Bunbury) Feistmantel, 1879.

Remarks — In the light of the considerable data on the epidermal structure of *Noeggerathiopsis* contributed by Lele & Maithy (1964a) and Pant & Verma (1965), the definition of this genus has been elaborated by Maithy (1965d). It should, however, be remembered that *Noeggerathiopsis* was originally based on an impression occurring in the much younger strata of Kamthi age. The species with cuticular data and other typical forms (in impression state) are, however, more characteristic of the older formations of Talchir and Karharbari age. Maithy (1965d) has marked out the impression-species from the cuticular species although his emended diagnosis of *Noeggerathiopsis* includes the external and cuticular characters.

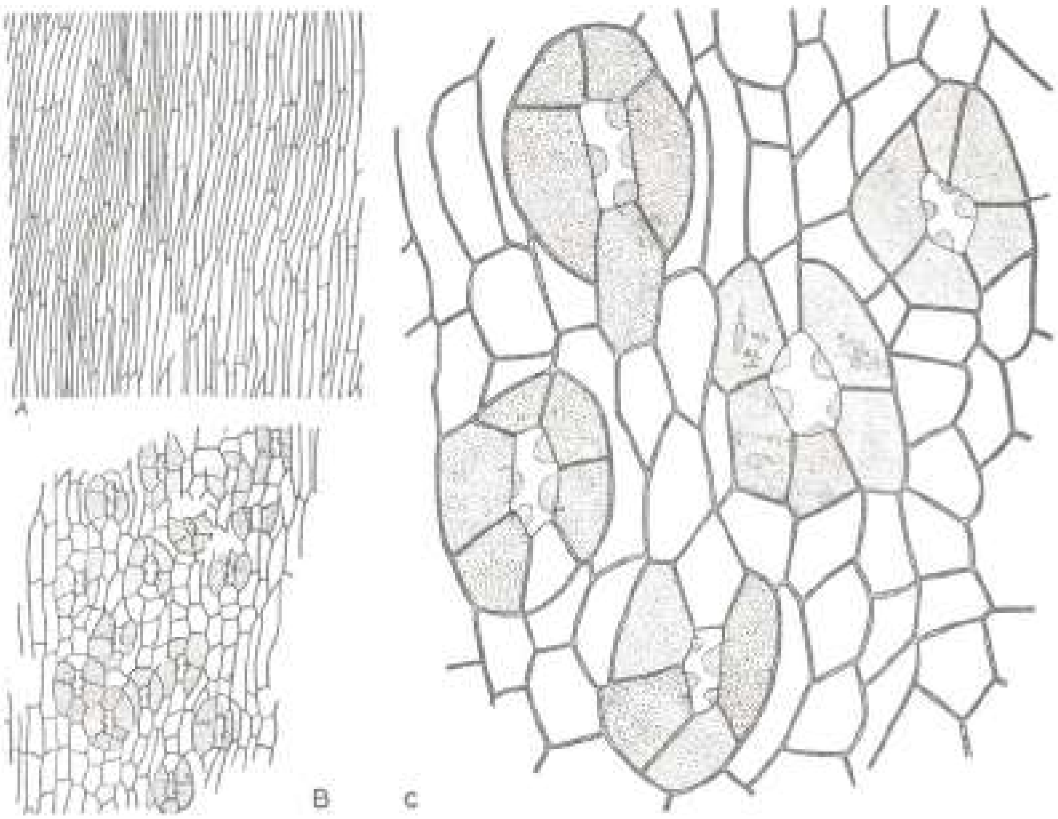
Cuticular studies have already shown that some significant external features such as the leaf apex and venation may be common to different species of *Noggerathiopsis* based on epidermal characters. Similarly we have now more information with regard to the specialization trends in the stomatal apparatus of *Noeggerathiopsis*. Of particular interest in this connection is the conspicuous occurrence of papillae on the subsidiary cells which overhang the guard cells. This specialization is at present known in two species, viz. *N. papillosa* Pant & Verma (1965) and *N. conspicua* sp. nov. described below.

Noeggerathiopsis conspicua sp. nov.

Pl. 2, Figs. 23-26; Pl. 3, Fig. 28; Text-fig. 3, 3A

Diagnosis — Leaves simple, lanceolate-spathulate, apex broadly rounded, lamina gradually tapering forming a narrow base; veins distinct, divergent, straight, 16-20 per cm. in apical part.

Cuticle hypostomatic, cells of upper cuticle arranged in linear rows, mostly end to end, non-papillate, cell walls straight, end walls usually oblique; lower cuticle with alternating stomatiferous and non-



TEXT-FIGURE 3. A-C, *Noeggerathiopsis conspicua* sp. nov.

A. Line drawing of the upper cuticle from the leaf represented on Pl. 2, Fig. 24. × 105.

B. Line drawing of the lower cuticle from the above leaf showing longitudinally orientated stomata. × 100.

C. Stomata from the lower cuticle enlarged to show thickened subsidiary cells with papillae. × 625.

stomatiferous zones, cells of non-stomatiferous zone similar to upper cuticle, cells of stomatiferous zone polygonal, stomata haplocheilic, arranged in 2-6 longitudinal rows stomata of adjacent rows usually alternate, stomatal apparatus monocyclic, subsidiary cells 4-7, 4 lateral subsidiary cells differentially stained, lateral subsidiary cells and very rarely polar subsidiary cells show prominent dome-shaped papillae overhanging guard cells.

Description — Five specimens have been assigned to this species on the basis of similarity in the cuticular structure. The leaves are lanceolate-spathulate in shape. One of the syntypes (Pl. 2, Fig. 23) is complete, measuring 13·5 cm. in length and 2·8 cm. in breadth at the widest part. The largest leaf is 16·2 cm. long and 3 cm. broad. In all the cases the apex is broadly round. The leaf lamina gradually tapers to form a narrow base which is, however, sessile. About 4-6 veins enter the leaf base. The veins are distinct and after 1 or 2 dichotomies pass out divergently but following a straight course. The number of veins per cm. at the broadest region is 16-20.

Cuticle — Both the syntypes have yielded identical cuticles but the best information is obtained from one of them (Pl. 1, Fig. 24). The cuticle is hypostomatic. Monosaccate pollen of *Crucisaccites* type are often found sticking to the cuticles.

Upper Cuticle — On this surface vein and intervein areas can be distinguished. Cells of the intervein areas are comparatively broad than the cells on the veins.

The cells in general are arranged in linear rows, mostly end to end. The lateral cell walls are straight and end walls are usually oblique. The cells are elongate, quadrilateral or many sided, 95-205 μ long and 8-18 μ broad; the cell walls are about 2 μ thick. Cells are non-papillate.

Lower Cuticle — This surface shows alternating stomatiferous and non-stomatiferous zones. The cells of non-stomatiferous zone are similar to the upper cuticle in all the characters. The cells of the stomatiferous zone are polygonal, 27-70 μ long and 18-30 μ broad. Stomatal frequency varies from 140-200 per sq. mm. The stomata are arranged in 2-6 longitudinal rows. The stomata of adjacent rows usually tend to alternate with each other, rarely they may be found lying opposite. The stomatal apparatus is monocylic. The stomata are haplocheilic, surrounded by 4-7 subsidiary cells, frequently by 6 cells, of which 2 are polar and 4 lateral. The 4 lateral subsidiary cells take a differential staining, darker than the other epidermal cells, probably because of heavy cutinization. The polar subsidiary cells are, however, of the same thickness as that of the other epidermal cells. The epidermal cells are devoid of any papillae. On the other hand, the lateral subsidiary cells and very rarely the polar subsidiary cells show prominent dome-shaped papillae on their inner walls. These papillae overhang the guard cells, though they never completely close the stomatal opening. The guard cells are hyaline, thin and 17-37 μ long, in some cases a slit like stomatal aperture is visible.

Comparison — Morphologically the present leaves are similar to *N. bunburyana* Pant & Verma (1965) but their epidermal characters are very distinctive.

The cuticle of the present species is characterized by the presence of closely placed stomata with characteristically thickened guard cells and the strong papillae of the subsidiary cells overhanging the guard cells. In the close distribution of the stomata and the highly cutinized subsidiary cells the present species compares closely with *N. bunburyana* Pant & Verma (l.c.), but differs in being hypostomatic, in having non-papillate cells and in the presence of prominent papillae of the subsidiary cells overhanging the guard cells. The present species resembles *N. papillosa* Pant & Verma (1965) in being hypostomatic and in the presence of prominent papillae on the subsidiary cells overhanging the guard cells. However, in the case of *N. papillosa* all the cells of the lower cuticle show prominent papillae and the subsidiary cells are otherwise unspecialized and indistinguishable from the epidermal cells. On the other hand, in *N. conspicua* sp. nov. the general epidermal cells of lower cuticle are non-papillate but the subsidiary cells (particularly the lateral ones) are highly cutinized and have overhanging papillae. *N. indica* Lele & Maithy (1964a) differs in having dense papillae on epidermal cells.

Syntypes — Specimen No. 35011, Pl. 2, Fig. 23.
Specimen No. 35012, Pl. 2, Fig. 24.

Type Locality — Banskupi Colliery area (Loc. 2); Jayanti Coalfield, Bihar.

Horizon — Karharbari Formation, Lower Gondwana.

Noeggerathiopsis bunburyana Pant & Verma, 1965

Pl. 2, Fig. 27; Pl. 3, Figs. 29-31

Description — Few leaves have been referred to this species. The figured one is complete though smallest in the collection (3·6 cm. in length and 1·7 cm. in width). It has a well-preserved carbonized crust. The apex is obtusely rounded. The base is narrow and tapering. The veins are distinct, divergent and dichotomizing, 16-28 per cm. in the broadest part.

Upper Cuticle — Cells are ± rectangular arranged in linear rows, 40-80 μ long and 5-10 μ broad, non-papillate. No stomata are seen.

Lower Cuticle — shows alternating stomatiferous and non-stomatiferous zones. The cells of the non-stomatiferous zone are similar to those of the upper cuticle. Stomata are arranged in 2-6 subsidiary cells, heavily cutinized and non-papillate. The epidermal cells are also devoid of any papillae.

Comparison — The present specimens may indicate the lower size range of *Noeggerathiopsis bunburyana* which is not mentioned by Pant and Verma (1965). The cuticular structure of our specimens is almost similar to that described for *Noeggerathiopsis bunburyana*, except for the differences that stomata are not observed on the upper surface and that the epidermal cells are apparently non-papillate. In *N. bunburyana* papillae are occasionally present.

Remarks — There is some overlapping of the characters between the two species of *Noeggerathiopsis*, viz. *N. indica* Lele & Maithy (1964a) and *N. bunburyana* Pant & Verma (1965). However, in favourably preserved material the two forms can be distinguished from each other on the following grounds: *N. indica* has dense papillae but their density varies, papillae are best developed in non-stomatiferous region, moderately present in the stomatiferous region and rudimentary papillae seen on the subsidiary cells. In *N. bunburyana* the papillae are occasionally present on epidermal cells and absent on subsidiary cells. Cuticular preparations from the basal portion of leaf lacks papillae in *N. bunburyana*. From our present knowledge, therefore, it appears desirable to retain the two species separately as also suggested by Pant and Verma, 1965.

Occurrence — Banskupi Colliery area (Loc. 2).

SCALE LEAVES

Type 1: Pl. 3, Fig. 32 — Some very small leaves are found in the present collection, showing venation of *Noeggerathiopsis*-type. The leaves are spathulate to oval, 1·7-2·3 cm. long and 6-9 mm. broad. The apex is obtuse to broadly rounded. A few veins enter the base and then dichotomize once or twice.

Squama forma integrima of Seward and Sahni (1920, Pl. 2, Fig. 17) differs from the present scale leaves in shape and in having acute to acuminate apex.

Occurrence — Misra village (Loc. 1).

Type 2: Pl. 3, Fig. 33 — Incomplete impression of a scale leaf with a broad base. About 5 veins originate at the base and after a few dichotomies pass straight to the apical margin.

The specimen compares favourably with *squama forma integrima* of Seward and Sahni (1920, Pl. 2, Fig. 17).

Occurrence — Banskupi Colliery area (Loc. 2).

PLATYSPERMIC SEEDS

Pl. 1, Figs. 1-3

Impressions of platyspermic seeds are common on the shales of the Misra village locality. In some examples a thin carbonized crust is seen but it is not suitable for cuticular preparations. Among the seeds at least three well-known species could be distinguished. These belong to the genera *Samaropsis* and *Cordaicarpus*. The species here recorded are:

1. *Samaropsis goraiensis* Surange & Lele; Pl. 1, Fig. 2
2. *Samaropsis feistmantelii* Maithy; Pl. 1, Fig. 1
3. *Cordaicarpus zeilleri* Maithy; Pl. 1, Fig. 3

Occurrence — Misra village (Loc. 1).

BRANCHED AXES

Pl. 1, Figs. 4, 5

Linear axes are often encountered in various states of preservation on the sandy micaceous shale. They range in width from nearly 1 to 5 mm. Their length is unknown. Some of them taper at one end. In some examples the axes may appear to arise from a common point (Fig. 5); in others sparse branching is noticed at intervals. In wider examples a median dark line runs through the length (Fig. 4). These remains possibly include rootlets, leaflets or lacerated ribbed stems. It is difficult to assign them to any plant, although their close association with *Paracalamites* is noteworthy.

Occurrence — Misra village (Loc. 1).

MIOFLORA

The following 57 miospore species belonging to 33 genera have been recorded from the Karharbari assemblage of Jayanti Coalfield. Species marked with an asterisk are described here:

1. *Leiotriletes sphaerotriangulus* (Loose) Potonié & Kremp, 1954
2. *L. psilatus* Kar & Bose, 1967
*3. *Psilalacinites indicus* sp. nov.
4. *Calamospora exila* Bharadwaj & Salujha, 1964
*5. *Punctatisporites plicatus* (Tiwari & Navale 1967) comb. nov.
6. *P. reticulatus* Pant & Srivastava, 1965
7. *P. gretensis* Balme & Hennelly, 1956b
8. *Callumispora barakarensis* Bharadwaj & Srivastava, 1969
9. *Microfoveolatispora foveolata* Tiwari, 1965
10. *M. directa* (Balme & Hennelly) Bharadwaj, 1962
*11. *Indotriradites* sp.
12. *Tiwariasporis gondwanensis* (Tiwari) Maheshwari & Kar, 1967
13. *Virkkipollenites densus* Lele, 1964
14. *V. triangularis* (Mehta) Lele, 1964
15. *V. obscurus* Lele, 1964
16. *Plicatipollenties indicus* Lele, 1964
17. *P. gondwanensis* (Balme & Hennelly) Lele, 1964
18. *P. diffusus* Lele, 1964
19. *P. trigonalis* Lele, 1964
20. *Rugasaccites ovatus* Lele & Makada (1972)
21. *Parasaccites obscurus* Tiwari, 1965
22. *P. distinctus* Tiwari, 1965
23. *P. talchirensis* Lele & Makada (1972)
24. *Tuberisaccites lobatus* Lele & Makada (1972)
25. *Caheniasaccites flavatus* Bose & Kar, 1966
26. *C. ovatus* Bose & Kar, 1966
27. *C. decorus* Lele & Makada (1972)
28. *Crucisaccites latisulcatus* Lele & Maithy, 1964b
29. *Vesicaspora sulcata* Hart, 1960
30. *V. obliqua* Singh, 1964
31. *Vestigisporites novus* Tiwari, 1965
32. *V. diffusus* Maithy, 1965a
33. *Potonieisporites jayantiensis* Lele & Karim, 1971
34. *P. neglectus* Potonié & Lele, 1961
35. *P. lelei* Maheshwari, 1967
36. *P. elegans* (Wilson & Kosanke) Wilson & Venkatachala, 1964
37. *P. barrelis* Tiwari, 1965
38. *P. triangulatus* Tiwari, 1965
*39. *Striomonosaccites* sp.
40. *Cuneatisporites radialis* Leschik 1955
41. *C. flavatus* Bose & Kar, 1966
42. *Limitisporites diversus* Lele & Karim, 1971
43. *Sulcatisporites barakarensis* Tiwari, 1965
44. *Striatites tentulus* Tiwari, 1965
*45. *S. medius* sp. nov.
46. *Lahirites rarus* Bharadwaj & Salujha, 1964
47. *Lunatisporites rhombicus* Lele & Makada (1972)
48. *L. amplus* (Balme & Hennelly) Potonié, 1958
49. *L. globosus* Maithy, 1965a
50. *Faunipollenites varius* Bharadwaj, 1962
*51. *Vittatina* cf. *V. subsaccata* Samoilovich, 1953
52. *Gnetaceaepollenites diffusus* sp. nov.
53. *Quadrisporites horridus* Hennelly, 1953
*54. *Pilasporites ovatus* sp. nov.
55. *Balmeela gigantea* Bose & Maheshwari, 1968
*56. *Punctatasporites* sp.
57. *Greinervillites undulatus* Bose & Kar, 1967.

Anteturma — *Sporites* H. Pot., 1893
Turma — *Triletes* (Rein.) Pot. & Kr., 1954
Subturma — *Azonotriletes* Luber, 1935
Infraturma — *Laevigati* (Ben. & Kid.) Potonié, 1956

Genus — Psilalacinites Kar, 1969

Type species — *Psilalacinites triangulus* Kar, 1969.

Psilalacinites indicus sp. nov.

Pl. 3, Figs. 34-35

Diagnosis — Miospores triangular, 42-52 ×48-54 μ (average, 47×51 μ) in size; trilete mark distinct, rays reaching equator; exine laevigate.

Description — Miospores triangular, apices bluntly rounded, interapical margins straight to convex; exine 2-5 μ thick, laevigate; trilete mark distinct, rays equal in length, reaching equator; straight to sinuous, labra raised, uniformly wide.

Comparison — The type species *Psilalacinites triangulus* Kar (1969) differs in its larger size and thinner exine.

Holotype — Pl. 3, Fig. 35.

Type Locality — Misra village (Loc. 1), Jayanti Coalfield, Bihar.

Horizon — Karharbari Formation.

Number of specimens studied: 16.

Genus — *Punctatisporites* Ibrahim, 1933

Type species — *Punctatisporites punctatus* Ibrahim, 1933.

Punctatisporites plicatus (Tiwari & Navale) comb. nov.

Pl. 3, Fig. 36

Synonym — *Calamospora plicata*, Tiwari & Navale, 1967, Pl. 1, Fig. 2 (Holotype).

Remarks — The present specimens resemble *Calamospora plicata* Tiwari & Navale (1967) in having trilete rays more than 2/3 radius long with thick lips, and intramicropunctate exine with many prominent folds. The present specimens are however, smaller in size (64-85 μ) as compared with the Brazilean specimens (96-102 μ).

The Brazilean specimens as well as the present ones do not show *area contagionis* which is a generic character of *Calamospora* Schopf, Wilson & Bentall (1944). Besides the trilete mark is also much longer than known in *Calamospora*. As such the species *Calamospora plicata* is being transferred to *Punctatisporites* as *P. plicatus* comb. nov. The longer trilete mark and folds are both consistent with the definition of *Punctatisporites*. The spores are not referred to *Callumispora* due to their thin exine and lack of exinal differentiation in the trilete area.

Occurrence — Misra village (Loc. 1).

Turma — *Zonales* (Bennie & Kidston) Potonié, 1956
Subturma — *Zonotriletes* Waltz, 1935
Infraturma — *Cingulati* Potonié & Klaus, 1954

Genus — *Indotriradites* Tiwari, 1964

Type species — *Indotriradites korbaensis* Tiwari, 1964.

Indotriradites sp.

Pl. 3, Fig. 37

Description — Very few miospores, subtriangular with convex sides, apices slightly pointed to rounded, 45-52 μ in size; cingulum serrate to dentate, 2-4 μ wide, small confluent coni seen on the cingulum; trilete mark distinct, rays uniformly broad, entering the cingulum, slightly wavy, labra thick, vertex raised; central area proximally infrapunctate or laevigate, distally vermiculate or with small coni confluent at the base; exine apparently double-layered.

Remarks — These spores are referable to *Indotriradites* on the basis of general resemblance. The specific identification is not possible due to lack of specimens. Some resemblance with *Cristatisporites papillatus* (Pant & Srivastava) Tiwari & Navale (1967) is suggested. In our opinion *Cristatisporites papillatus* needs reallocation.

Occurrence — Misra village (Loc. 1).

Anteturma — *Pollenites* Potonié, 1931
Turma — *Saccites* Erdtman, 1947
Subturma — *Monosaccites* (Chitaley) Potonié & Kremp, 1954
Infraturma — *Striasacciti* Bharadwaj, 1962

Genus — *Striomonosaccites* Bharadwaj, 1962

Type species — *Striomonosaccites ovalus* Bharadwaj, 1962.

Striomonosaccites sp.

Pl. 3, Fig. 38

Description — Single miospore, monosaccate, but appears to be tetrasaccate due to notches, 110×115 μ in size; central body oval, 37×67 μ in size, thick, exine in the saccus free area intramicroreticulate; proximally 7 unbranched horizontal striations; saccus broad, width not uniform all round due to notches, saccus reticulation coarse.

Comparison — This rather abnormal specimen differs from all species of *Striomonosaccites* Bharadwaj (1962) in having a notched saccus.

Occurrence — Banskupi Colliery area (Loc. 2).

Subturma — *Disaccites* Cookson, 1947
Infraturma — *Striatiti* Pant, 1950

Genus — *Striatites* (Pant) Bharadwaj, 1962

Type species — *Striatites sewardi* (Virkki) Pant, 1954.

Striatites medius sp. nov.

Pl. 3, Figs. 39-40; Text-fig. 4

Diagnosis — Miospores, disaccate, 74-82 × 44-54 µ (average, 76 × 49 µ) in size; central body rhomboid, dense, 38-42 × 40-50 µ in size, proximally with 10-12 horizontal striations, distal sulcus narrow, sacci fine intramicroreticulate.

Description — Miospores haploxylonoid; central body rhomboid to vertically oval, distinct, exine microverrucose, proximally with 10-12 horizontal striations, rarely branched, without any vertical partitions; distal saccus attachment straight, distal saccus free area narrow, slit like; sacci ± hemispherical, intrareticulation fine.

Comparison — Present species resembles in rhomboid shape of central body to *Striatites rhombicus* Bharadwaj & Salujha (1964) but the latter differs in having a distinct marginal rim, vertical partitions and convex saccus attachment. *S. karharbariensis* Maithy (1965a) is much bigger (140-170 × 80-110 µ) in size and shows thin central body. Other species differ in shape of the central body.

Holotype — Pl. 3, Fig. 39.

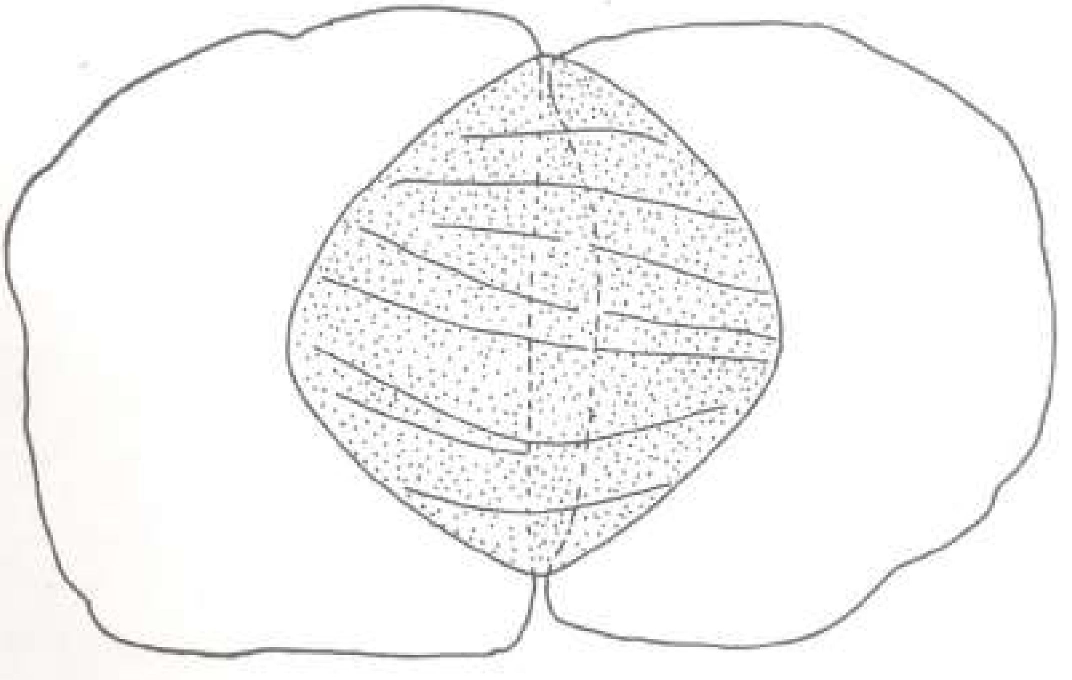
Type Locality — Banskupi Colliery area (Loc. 2); Jayanti Coalfield, Bihar.

Horizon — Karharbari Formation.

Number of specimens studied: 21.

Genus — *Vittatina* (Luber) Wilson, 1962

Type species — *Vittatina subsaccata* Samoilovich, 1953.



TEXT-FIG. 4 — *Striatites medius* sp. nov. drawing of the holotype showing dense and rhomboid central body. ca. × 1750.

Vittatina sp. cf. *V. subsaccata* Samoilovich, 1953

Pl. 3, Fig. 41

Description — Single miospore bilaterally symmetrical, bisaccate folded, 57-61 μ in size; central body 57 μ high, distinct, bigger than sacci, exine ±2 μ thick, 15 horizontal striations; exine in between striations intramicropunctate; sacci rudimentary, intrareticulate.

Remarks — The sacci in this specimen are comparatively more well developed than in the holotype; one of the sacci has overturned on the body.

Occurrence — Misra village (Loc. 1).

Turma — *Plicates* (Naumova) Potonié, 1960
Subturma — *Polyplicates* Erdtman, 1953

Genus — *Gnetaceaepollenites* Thiergart, 1938

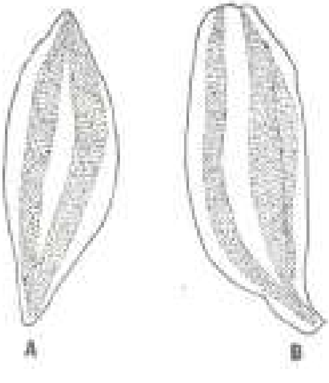
Type species — *Gnetaceaepollenites ellipticus* Thiergart, 1938.

Gnetaceaepollenites diffusus sp. nov.

Pl. 3, Figs. 42-43, Text-fig. 5, A-B

Diagnosis — Miospores ellipitical to spindle-shaped, 90-116×23-48 μ (average, 98×31 μ) in size, usually with 2 rarely 4-5 arcuate folds along the longer axis; exine granulose to punctate.

Description — Miospores elliptical to spindle-shaped with pointed long drawn ends, exine granulose to punctate with usually 2, sometimes 4-5 arcuate folds along longer axis; sometimes exine ruptured in between folds simulating a colpus, split only partial, not from end to end.



TEXT-FIG. 5 A-B — *Gnetaceaepollenites diffusus* sp. nov. drawing of the syntypes, each showing two arcuate folds along longer axis. × 360.

Comparison — The genotype *Gnetaceaepollenites ellipticus* Thiergart (1938) from Tertiary horizons differs from the present species in having a laevigate exine. The spores studied by Bharadwaj (1962) from Raniganj Stage also exhibit characteristically punctate exine. *G. sinuosus* (Balme & Hennelly) Bharadwaj (1962) is smaller in size with only two folds and has smooth exine. *G. grandis* Maheshwari (1967) differs in being much larger in size (78-101×100-210 μ) and in having intrabaculate exine.

Syntypes — Pl. 3, Figs. 42, 43

Type Locality — Misra village, Jayanti Coalfield, Bihar.

Horizon — Karharbari Formation.

Number of specimens studied: 30.

Turma — *Aletes* Ibrahim, 1933
Subturma — *Azonaletes* (Luber) Potonié & Kremp, 1954
Infraturma — *Psilonapiti* Erdtman, 1947

Genus — *Pilasporites* (Balme & Hennelly) Tiwari & Navale, 1967

Type species — *Pilasporites calculus* Balme & Hennelly, 1956a.

Pilasporites ovatus sp. nov.

Pl. 3, Fig. 45; Text-fig. 6

Diagnosis — Miospores suboval, elliptical, 50-57×72-80 μ (average, 54×76 μ) in size; exine thick (1·5-4 μ), smooth, generally splitting along longer axis.

Description — Miospores oval, elliptical to suboval in shape; exine smooth, somewhat faintly infrastructured, 1·5-4 μ thick at the equator, outline smooth, in most of the specimens 1/2 or 3/4 of exine is split, mostly along the longer axis.

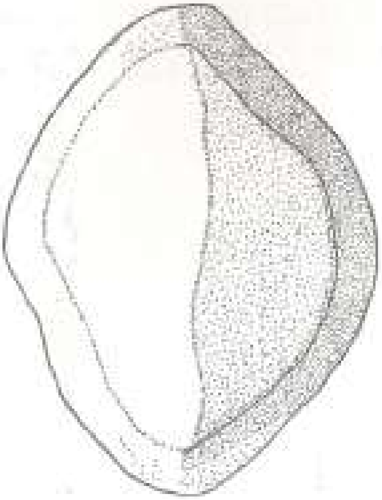
Comparison — *Pilasporites calculus* Balme & Hennelly (1956a) differs from the present species in being ± circular in shape and in having a thicker exine (up to 8 μ). *P. plurigenus* Balme & Hennelly (1956a) is much smaller (12-36 μ) in size.

Holotype — Pl. 3, Fig. 45.

Type Locality — Misra village, Jayanti, Coalfield, Bihar.

Horizon — Karharbari Formation.

Number of specimens studied: 13



TEXT-FIG. 6 — *Pilasporites ovatus* sp. nov., drawing of the holotype showing thick exine. × 900.

Genus — *Punctatasporites* Ibrahim, 1933

Type species — *Punctatasporites sebulosus* Ibrahim, 1933

Punctatasporites sp.

Pl. 3, Fig. 44

Description — Miospores subcircular, variously irregularly folded; without any mark; exine 1-2 μ thick, fine infra-micropunctate; *extrema lineamenta* uneven.

Remarks — The specimens do not show any tetrad mark. They are otherwise closely comparable with *Punctatisporites plicatus* (Tiwari & Navale) comb. nov. which also occurs in the material.

DISCUSSION AND CONCLUSION

The fossil flora of the Karharbari Stage of Jayanti Coalfield comprises megafossils and miospores. Megafossils are few in number but the miospore assemblages are rich both quantitatively and qualitatively.

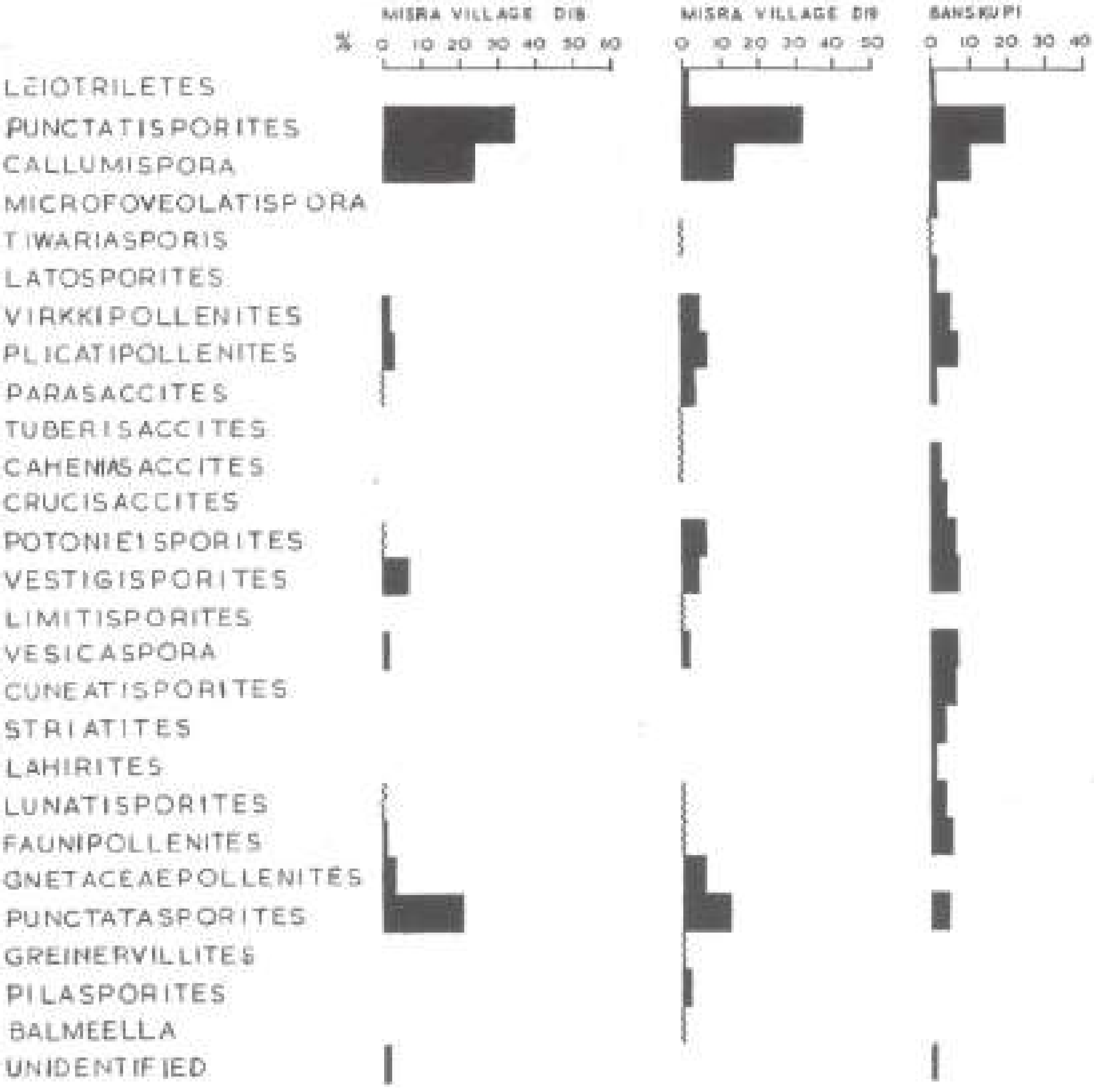
MEGAFLORA — The plant megafossils recovered from the two localities are represented by *Gondwanidium* (1 species), *Gangamopteris* (4 species), *Glossopteris* (5 species), *Noeggerathiopsis* (4 species), *Samaropsis* (2 species), *Cordaicarpus* (1 species) and some indeterminate remains.

Gangamopteris and *Noeggerathiopsis* are common to the floras from Misra village and Banskupi Colliery area. However, in the details of composition and incidence of the various taxa, the two megafloras indicate notable differences. The Misra flora is rather imperfectly preserved to permit a clear quantitative assessment. However, the presence of *Gondwanidium* and platyspermic seeds in this assemblage is striking. *Paracalamites*, *Gangamopteris*, and *Noeggerathiopsis* are moderately represented. *Glossopteris* has not been encountered. On the contrary, the Banskupi flora is more well preserved and shows an abundance of *Gangamopteris*, *Glossopteris* and *Noeggerathiopsis*. *Paracalamites*, *Gondwanidium* and platyspermic seeds have not been found. On the whole, the Banskupi flora appears more diversified and younger in aspect than the Misra flora. This may lend support to the possibility that the Banskupi carbonaceous shales are stratigraphically higher than the micaceous shales in the Misra section.

MIOFLORA — The miospore assemblage consists of 57 species belonging to 33 genera. The quantitative distribution of important miospore genera in various samples is shown in Histogram 1 and Table 1. The percentage frequencies are based on a count of 200 specimens.

Qualitative considerations

In the present paper the genera *Callumispora* and *Punctatisporites* are followed. *Callumispora* is used in a somewhat restricted sense for only those forms which show all the features typified by the genoholotype. Other specimens of *Callumispora* tend to confuse and overlap with *Punctatisporites*. For instance, *Callumispora tenuis* var. *minor* can hardly be distinguished from *Punctatisporites* as the forms are not appreciably thick (2 μ), the exine is non-stratified and the inter-ray area is only faintly differentiated. Similarly *Punctatisporites reticulatus* Pant & Srivastava (1965) also shows a wide range of variation in the exine, so that its transfer to *Callumispora* as proposed by Bharadwaj & Srivastava (1969) needs further critical study.



HISTOGRAM 1 — Quantitative distribution of important miospore genera in the Karharbari samples of the Jayanti Coalfield.

Quantitative Analysis

Assemblage from Misra Village

The assemblage from Misra village shows a more or less uniform distribution of miospore taxa in the two samples (Table 1). Both the samples are characterized by the dominance of the trilete genera *Punctatisporites* and *Callumispora*. The high percentage of aletes and the significant proportion of polyplicates (*Gnetaceaepollenites*) is also a noteworthy feature of the assemblage. Monosaccates are more conspicuous in sample D19 as compared to D18. Among these the more significant genera are *Virkkipollenties*, *Plicatipollenites*, *Potonieisporites*, *Vestigisporites* and *Parasaccites*. The Disaccates are poorly represented in both samples. Based on miospore

TABLE 1 — PER CENT DISTRIBUTION OF MIOSPORE GENERA IN SAMPLES OF KARHARBARI FORMATION OF JAYANTI COALFIELD

GENERA	MISRA VILLAGE		BANSKUPI COLLIERY AREA
	D18	D19	
1. *Leiotriletes*	—	1·5	1·0
2. *Punctatisporites*	35·0	31·5	19·5
3. *Callumispora*	24·0	14·0	10·0
4. *Microfoveolatispora*	—	—	1·5
5. *Tiwariasporis*	—	0·5	—
6. *Latosporites*	—	—	1·5
7. *Virkkipollenites*	2·0	5·0	5·0
8. *Plicatipollenites*	3·0	7·0	7·5
9. *Parasaccites*	0·5	3·5	1·5
10. *Tuberisaccites*	—	0·5	—
11. *Caheniasaccites*	—	0·5	2·5
12. *Crucisaccites*	—	—	4·0
13. *Potonieisporites*	0·5	6·5	6·5
14. *Vestigisporites*	0·5	3·4	7·5
15. *Vesicaspora*	1·5	2·0	7·0
16. *Limitisporites*	—	0·5	—
17. *Cuneatisporites*	—	—	6·5
18. *Striatites*	—	—	3·5
19. *Lahirites*	—	—	1·0
20. *Lunatisporites*	0·5	0·5	3·5
21. *Faunipollenites*	1·0	0·5	5·0
22. *Gnetaceaepollenites*	3·0	6·0	—
23. *Punctatasporites*	21·0	12·0	4·5
24. *Greinervillites*	—	0·5	—
25. *Pilasporites*	—	2·0	—
26. *Balmeella*	—	0·5	—
27. *Unidentified*	1·5	—	1·0

group distribution, the following position is obtained in the Misra samples:

Dominant Taxa	D18 %	D19 %	Average %
Triletes	59	47·0	53·0
Subdominant Taxa			
Monosaccates	8·0	28·4	18·2
Aletes	21·0	15·0	18·0
Polyplicates	3·0	6·0	4·5
Rest Taxa			
Disaccates	1·5	1·5	1·5
Monoletes	—	0·5	0·3

Assemblage from Banskupi Area

The Banskupi assemblage also contains a high proportion of the monosaccates and the trilete genera *Punctatisporites* and *Callumispora*. However, there are some significant differences from the previous assemblages. Firstly, in the Banskupi assemblage the trilete group has apparently lost its dominating position to the monosaccates. Secondly, the disaccates have also risen to prominence. Thirdly, the polyplicates are not represented. Based on generic group distribution, the following position is obtained for the Banskupi assemblage:

Dominant Taxa	%
Monosaccates	41·5
Subdominant Taxa	
Triletes	32·0
Disaccates	19·5
Rest Taxa	
Aletes	4·5
Monoletes	1·5

The above quantitative assessments indicate that the assemblage from Misra village is distinguishable from that of the Banskupi area in details. Both are, however, closely linked with each other by the characteristic abundance of Monosaccates and Triletes (*Punctatisporites* and *Callumispora*). Among the two assemblages the Banskupi assemblage is more diversified and apparently younger as is also indicated by the megafloristic evidence. It contains a significant number of the following genera which are absent from the Misra village assemblage; *Microfoveolatispora*, *Latosporites*, *Cahenisaccites*, *Crucisaccites*, *Cuneatisporites*, *Striatites*, *Lahirites*, *Lunatisporites* and *Faunipollenites*. On the contrary, *Gnetaceaepollenites* (polypicates) is restricted to the Misra assemblage. From stratigraphical point of view, however, both the assemblages are referable to the Karharbari Formation on the basis of comparisons with the known Karharbari miofloras.

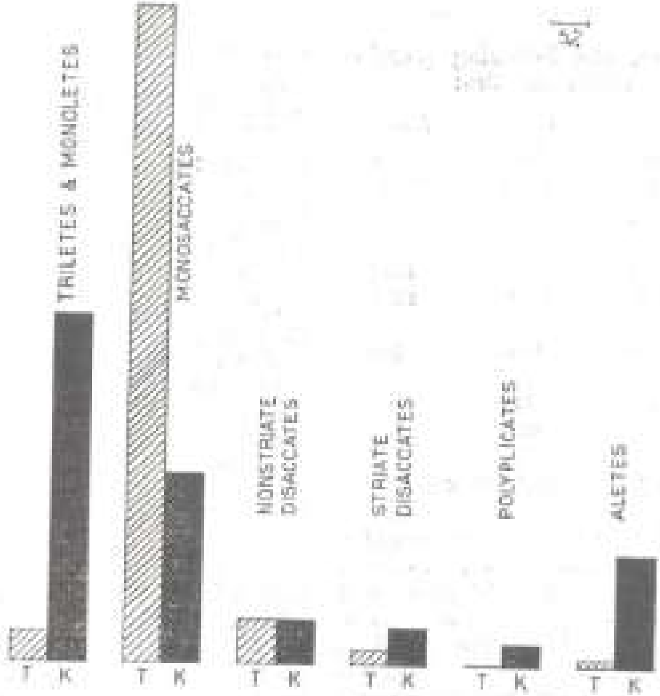
AGE OF THE COAL-BEARING BEDS

The age of the coal-bearing beds in the Jayanti Coalfield has remained controversial. Niyogi & Sanyal (1962) and Niyogi (1964) continue to refer the beds to the Baralar Formation, although Puri (1953) suggested a Karharbari age on plant fossil evidence. The findings of Lele and Maithy (1966) also supported a Karharbari age for the beds.

The present investigation has made it possible to reconsider the problem both from megafossil and miofloral standpoints.

The plant fossils recovered from Misra and Bauskupi shales are essentially those that characterize the Karharbari Formation in the type area (Giridih basin) and elsewhere. The abundance of the genera *Noeggerathiopsis* and *Gangamopteris* (often yielding cuticular structure), along with the significant occurrence of platyspermic seeds and above all, the characteristic presence of *Gondwanidium* provide unmistakable proof in support of a Karharbari age. The Karharbari age of the Misra section is particularly attested by the presence of *Gondwanidium*. The Bauskupi shales are apparently younger than the Misra section.

Miofloristically also, the Jayanti assemblages approach closest to the Karharbari miofloras in their abundance and variety of monosaccate taxa along with a significant proportion of triletes and/or bisaccates. The presence of *Crucisaccites* in the Jayanti mioflora adds emphasis to its Karharbari age. In contrast, the older miofloras of the Talchir Formation are distinguishable by the supreme dominance of the Monosaccates (especially *Parasaccites*, *Plicatipollenites*) and the sporadic presence of Triletes and disaccates (for Jayanti Coalfield *vide* Histogram 2 & Tables 2 & 3). On the other hand,



HISTOGRAM 2 — Comparative quantitative distribution of important miospore groups in the Talchir (T) and Karharbari (K) Formations of the Jayanti Coalfield.

TABLE 2 — DISTRIBUTION OF SPECIES IN THE TALCHIR AND KARHARBARI FORMATIONS OF THE JAYANTI COALFIELD

SL. No.	SPECIES	TALCHIR	KARHARBARI
1.	Leiotriletes sphaerotriangulus	−	+
2.	,, psilatus	−	+
3.	Leiotriletes sp.	+	−
4.	Psilalacinites indicus sp. nov.	−	+
5.	Calamospora exila	−	+
6.	Punctatisporites minutus	+	−
7.	,, ganjrensis	+	−
8.	,, reticulatus	−	+
9.	,, gretensis	+	+
10.	,, plicatus comb. nov.	−	+
11.	Callumispora barakarensis	−	+
12.	Henellysporites sp.	+	−
13.	Granulatisporites granulatus	+	−
14.	,, sp.	+	−
15.	Plicatisporites distinctus gen.	+	−
16.	Cyclogranisporites plicatus	+	−
17.	,, gondwanensis	+	−
18.	Verrucosisporites varius	+	−
19.	,, sp.	+	−
20.	Horriditriletes novus	+	−
21.	,, bulbosus	+	−
22.	,, sp.	+	−
23.	Lacinitriletes badamensis	+	−
24.	,, minutus	+	−
25.	Acanthotriletes filiformis	+	−
26.	Microfoveolatispora directa	+	+
27.	,, foveolata	−	+
28.	Brevitriletes unicus	+	−
29.	Indotriradites sp.	−	+
30.	Jayantisporites pseudozonatus	+	−
31.	Jayantisporites indicus	+	−
32.	,, conatus	+	−
33.	Tiwariasporis gondwanensis	−	+
34.	Virkkipollenites densus	+	+
35.	,, obscurus	+	+
36.	,, triangularis	−	+
37.	Plicatipollenites indicus	+	+
38.	,, trigonalis	+	+
39.	,, diffusus	+	+
40.	,, gondwanensis	+	+
41.	,, densus	+	−
42.	,, stigmatus	+	−
43.	,, maculatus	+	−
44.	Rugasaccites obscurus	+	−
45.	,, orbiculatus	+	−
46.	,, ovatus	+	+
47.	Parasaccites obscurus	+	+
48.	,, diffusus	+	−
49.	,, densus	+	−
50.	,, perfectus	+	−
51.	,, fimbriatus	+	−
52.	,, talchirensis	+	+
53.	,, plicatus	+	−
54.	,, distinctus	−	+
55.	Parastriopollenites segmentus	+	−
56.	,, indicus	+	−
57.	,, sp.	+	−
58.	Tuberisaccites varius	+	−
59.	,, lobatus	+	+
60.	,, tuberculatus	+	−
61.	Caheniasaccites ovatus	+	+
62.	,, densus	+	−

TABLE 2 — DISTRIBUTION OF SPECIES IN THE TALCHIR AND KARHARBARI FORMATIONS OF THE JAYANTI COALFIELD — *Continued*

SL. No.	SPECIES	TALCHIR	KARHARBARI
63.	Caheniasaccites distinctus	+	—
64.	,, decorus	+	+
65.	,, flavatus	—	+
66.	Divarisaccus lelei	+	—
67.	,, scorteus	+	—
68.	,, sp.	—	—
69.	Crucisaccites latisulcatus	+	+
70.	Vestigisporites diffusus	+	+
71.	,, novus	+	+
72.	,, nigratus	+	—
73.	Potonieisporites neglectus	+	+
74.	,, densus	+	—
75.	,, lelei	Cf. +	+
76.	,, magnus	+	—
77.	,, jayantiensis	+	+
78.	,, elegans	—	+
79.	,, barrelis	—	+
80.	,, triangulatus	—	+
81.	Cf. Illinospora	+	—
82.	Striomonosaccites sp.	—	+
83.	Cuneatisporites radialis	—	+
84.	,, flavatus	—	+
85.	Valiasaccites densus	+	—
86.	,, indicus	+	—
87.	Limitisporites diversus	+	+
88.	,, elongatus	+	—
89.	,, cf. monosaccoides	+	—
90.	,, cf. congoensis	+	—
91.	,, cf. hexagonalis	+	—
92.	,, cf. leschikii	+	—
93.	Labiisporites granulatus	Cf. +	—
94.	,, densus	+	—
95.	Gigantosporites indicus	+	—
96.	Platysaccus papilionis	+	—
97.	Alisporites opii	+	—
98.	Illinites purus	+	—
99.	,, notus	+	—
100.	,, sp.	+	—
101.	Vesicaspora obliqua	+	+
102.	,, ovata	+	—
103.	,, brockmanii	+	—
104.	,, crassa	+	—
105.	,, sulcata	—	+
106.	Sulcatisporites maximus	+	—
107.	,, tentulus	+	—
108.	,, barakarensis	—	+
109.	Rhizomaspora singula	+	—
110.	Strotersporites rhombicus	+	—
111.	,, sp.	+	—
112.	Faunipollenites varius	+	+
113.	,, goraiensis	+	—
114.	,, sp.	+	—
115.	Circumstriatites talchirensis	+	—
116.	,, obscurus	+	—
117.	,, ovatus	+	—
118.	Striatites tentulus	—	+
119.	,, medius	—	+
120.	Lahirites singularis	+	—
121.	,, rarus	—	+
122.	Lunatisporites rhombicus	—	+
123.	,, amplus	—	+
124.	,, globosus	—	+

TABLE 2 — DISTRIBUTION OF SPECIES IN THE TALCHIR AND KARHARBARI FORMATIONS OF THE JAYANTI COALFIELD — *Continued*

SL No.	SPECIES	TALCHIR	KARHARBARI
125.	Crustaesporites sp.	+	—
126.	Striasulcites sp.	+	—
127.	Vittatina subsaccata	—	Cf. +
128.	Ginkgocycadophytus novus	+	—
129.	Gnetaceaepollenites diffusus	—	+
130.	Quadrisporites horridus	—	+
131.	Pilasporites calculus	+	—
132.	,, ovatus	—	+
133.	Balmeela gigantea	—	+
134.	Punctatasporites sp.	—	+
135.	Greinervillites undulatus	—	+
136.	Leiosphaeridia talchirensis	+	—

TABLE 3 — AVERAGE PERCENTAGE OF IMPORTANT MIOSPORE GENERA AND MAJOR GROUPS IN THE TALCHIR AND KARHARBARI FORMATIONS OF THE JAYANTI COALFIELD. Genera present, but not appearing in average, are shown by (+) sign; genera absent are indicated by (—) sign

MAJOR GROUPS	SPORE GENERA	TALCHIR-AVERAGE OF SAMPLE D1-D16		KARHARBARI-AVERAGE OF MISRA AND BANSKUPI ASSEMBLAGES	
Triletes & aletes	1. Leiotriletes	—	3·8	0·8	46·4
	2. Punctatisporites	1·1		28·5	
	3. Callumispora	—		16·0	
	4. Plicatisporites	0·9		—	
	5. Granulatisporites	0·2		—	
	6. Lacinitriletes	+		—	
	7. Verrucosisporites	+		—	
	8. Acanthotriletes	+		—	
	9. Apiculatisporis	+		—	
	10. Horriditriletes	0·2		—	
	11. Microbaculispora	+		—	
	12. Microfoveolatispora	+		0·5	
	13. Jayantisporites	1·0		—	
	14. Spore tetrad	0·4		—	
	15. Tiwarisporis	—		0·1	
	16. Latosporites	—		0·5	
Monosaccates	17. Virkkipollenites	10·1	89·0	4·0	28·4
	18. Plicatipollenites	25·8		5·8	
	19. Parasaccites	35·3		1·8	
	20. Parastriopollenites	1·6		—	
	21. Tuberisaccites	4·4		0·2	
	22. Caheniasaccites	1·1		1·0	
	23. Divarisaccus	0·7		—	
	24. Vesicaspora	1·6		3·5	
	25. Crucisaccites	+		1·4	
	26. Vestigisporites	5·9		6·2	
	27. Potonieisporites	2·5		4·5	
Nonstriate Disaccates	28. Platysaccus	+	3·9	—	2·4
	29. Valiasaccites	0·5		—	
	30. Limitisporites	2·8		0·2	
	31. Labiisporites	0·4		—	
	32. Gigantosporites	+		—	
	33. Illinites	+		—	
	34. Sulcatisporites	0·2		—	
	35. Cuneatisporites	—		2·2	

TABLE 3 — contd.

MAJOR GROUPS	SPORE GENERA	TALCHIR-AVERAGE OF SAMPLE D1-D10		KARHARBARI-AVERAGE OF MISRA AND BANSKUPI ASSEMBLAGES	
Striate disaccates	36. Striatites	—	2·0	1·2	5·2
	37. Lahirites	—		0·3	
	38. Lunatisporites	0·1		1·5	
	39. Striatopodocarpites	+		—	
	40. Faunipollenites	1·2		2·2	
	41. Circumstriatites	0·7		—	
	42. Rhizomaspora	+		—	
Polyplicates	43. Gnetaceaepollenites	—		3·0	3·0
Aletes, etc.	44. Punctatisporites	+	1·3	12·6	14·4
	45. Greinervillites	0·2		0·2	
	46. Pilasporites	—		0·6	
	47. Balmeela	—		0·2	
	48. Leiospheres	+		—	
	49. Unidentified	1·1		0·8	

the Barakar miofloras are characterized by *Lophotriletes*, *Retusotriletes* (*Hennellysporites*), *Indotriradites*, *Dentatispora*, *Microbaculispora* and *Latosporites* (*sensu* Bharadwaj, 1966) along with increasingly diversified disaccates. According to more recent reappraisals, the Lower Barakar miofloras are believed to be characterized by zonate trilete spores and other genera like *Brevitriletes* and *Microbaculispora* (Bharadwaj, 1969: 264). In the North Karanpura basin, the Barakar miofloras are generally characterized by striate disaccates, especially *Strotersporites*, *Striatopiceites* and *Striatites* (Kar, 1972). It is thus clear that the characteristic Barakar taxa are practically missing from the Jayanti mioflora which cannot, therefore, be referred to the Barakar Formation. It is evident from these comparisons that the beds near Misra and those of Banskupi area in the coal-bearing succession of the Jayanti Coalfield belong to the Karharbari Formation.

PALYNOSTRATIGRAPHIC COMPARISONS

Beyond the type area of the Giridih Coalfield (Maithy, 1965a), only few basins have so far been investigated for the palynostratigraphy of the Karharbari Formation. Among these are:

(i) Mohpani Coalfiled, where a succession ranging from the Talchir to the Karharbari Formation has been studied palynologically (Bharadwaj & Anand-Prakash, 1972).

(ii) South Karanpura Coalfield, Argada sector, where the Argada 'S' coal seam and associated shale as well as some shales lying 70 ft. above the Argada 'S' seam have been palynologically referred to the Karharbari Formation (Lele & Kulkarni, 1969; Bharadwaj & Anand-Prakash, 1972a).

(iii) Korba Coalfield, where a 689 metres deep sub-surface bore-core (No. NCKB 19) has been delimited into palynological zones ranging from the Talchir to the Karharbari Formation (Bharadwaj & Srivastava, 1973).

(iv) North Karanpura Coalfield, where the Lower Gondwanas, ranging from the Talchir to the Raniganj Formation, have been delimited palynologically (Kar, 1972).

The above investigations have, no doubt, given some glimpse of the miospore associations of the Karharbari Formation, but much more remains to be done in order to establish the palynological sequences across the formation, and more specially along its lower and upper limits. Notwithstanding these difficulties, the available data indicates that in some areas the Karharbari miofloras are characterized by the abundance of *Sulcatisporites* together with certain pteridophytic trilete taxa (e.g. *Brevitriletes*, *Indotriradites*, *Lophotriletes*, *Horriditriletes*, *Microbaculispora*, etc). Such miofloral associations are typically known from the Argada 'S' coal and associated shale and from the Assemblage Zone II in the Mohpani Coalfield. However in the Korba bore-core, the younger subzone in Biozone I (Lower part of the Karharbari Formation) shows dominance of *Callumispora* (average 28%) together with *Parasaccites* (average 27%). Higher up, in the Biozone II *Parasaccites* is dominant with subdominant *Sulcatisporites* and in Biozone III, *Sulcatisporites* attains a dominating position together with a conspicuous representation of some striate disaccate taxa. Bharadwaj & Srivastava (1973) refer the younger subzone of Biozone I along with the Biozones II and III to the Karharbari Stage. Studies in the North Karanpura Coalfield (Kar, 1972) indicate that the Lower Karharbari Formation is marked by an almost abrupt dominance (50%) of the triletes (especially, *Punctatisporites*/*Callumispora*, *Indotriradites* and *Lacinitriletes*) followed by monosaccates (32%); in the Upper Karharbari Formation monosaccates become dominant (60%) followed by disaccates (25%). Curiously enough, *Sulcatisporites* does not find any recognition in the Karharbari miofloras of the North Karanpura Coalfield. The Giridih mioflora (Maithy, 1965a) which is likely to be Lower Karharbari gives yet another picture. The assemblage is dominated by monosaccates along with a significant proportion of striate disaccates and a recognizable presence of *Welwitschiapites*. Trilete taxa are conspicuously insignificant.

The above brief survey indicates that the miofloral associations are not of the same kind in the Lower Karharbari of different basins. To this list, we may now add the Jayanti miofloral associations of Misra village and Banskupi area which are also very likely to be Lower Karharbari in position. A characteristic feature of the Jayanti mioflora is the dominance of *Callumispora*/*Punctatisporites* together with monosaccates. This aspect is evidently very close to the miofloral composition of the Biozone I (Younger subzone) in the Korba bore-core as well as to that of the Lower Karharbari in the North Karanpura Coalfield. However, a noteworthy difference is that the Korba assemblage also carries a significant proprotion of other pteridophytic triletes (14%) including *Leiotriletes*, *Lophotriletes*, *Horriditriletes* and *Microbaculispora* in particular. These trilete elements are wanting in the Jayanti mioflora. At any rate, the available evidences tend to indicate that a *Callumispora* + *Parasaccites* dominant association can be well identified in the lower Karharbari Formation at least in the coalfields of Korba, North Karanpura and Jayanti. This miofloral association is succeeded by a *Parasaccites* + *Sulcatisporites* rich mioflora in the Korba bore-core.

Note — While this paper was in press Srivastava (1973) has also recognized a *Callumispora-Parasaccites* rich assemblage in the basal Karharbari Formation of the Giridih Coalfield (Type area). Thus a Lower Karharbari age for the coal-bearing beds of the Jayanti basin is now well established.

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EXPLANATION OF PLATES

(Figured specimens and type slides are preserved at the B. Sahni Institute of Palaeobotany Museum, Lucknow)

Plate 1

1. *Samaropsis feistmantelii* Maithy. × 5.

2. *Samaropsis goraiensis* Surange & Lele. × 5.

3. *Cordaicarpus zeilleri* Maithy. × 5.

4-5. Branched axes. 35003. × Nat. size.

6. *Gondwanidium validum* (Feistm.) Gothan. 35004. × Nat. size. A part of the pinnate frond.

7. *Gangamopteris* sp. 35005. × Nat. size.

8. *Gangamopteris* sp. cf. *G. gondwanensis* Maithy. 35006. × Nat. size.

9. Upper cuticle from the leaf in Fig. 8. × 100 (Slide No. 4389).

10. Lower cuticle from the leaf in Fig. 8. × 100 (Slide No. 4390).

11. Stomata enlarged from the cuticle in Fig. 10. × 500 (Slide No. 4390).

12. *Glossopteris* sp. cf. *G. fibrosa* Pant. 35007. × Nat. size.

13-14. *Glossopteris jayantiensis* sp. nov. Specimens showing different regions of leaf lamina. 35008, 35009. × Nat. size.

15. Leaf in Fig. 13 enlarged to show details of venation. × 4.

16. Upper cuticle from the leaf in Fig. 13. × 100 (Slide No. 4391).

Plate 2

17. Lower cuticle from the leaf in Fig. 13. × 100 (Slide No. 4392).

18-19. Stomata enlarged from the Lower cuticle of specimen in Pl. 1, Fig. 13, Slide No. 4392.

20. *Glossopteris* sp. showing linear leaf with broken apex and base. 35010. × Nat. size.

21. Upper cuticle from the leaf in Fig. 20. × 100 (Slide No. 4398).

22. Lower cuticle from the leaf in Fig. 20. ×100 (Slide No. 4399).

23. *Noeggerathiopsis conspicua* sp. nov. complete leaf showing both apical and basal portions. 35011. × Nat. size.

24. *Noeggerathiopsis conspicua* sp. nov. showing apical part of the leaf 35012. × Nat. size.

25. Upper cuticle from the leaf in Fig. 24. ×100 (Slide No. 4400).

26. Lower Cuticle from the leaf in Fig. 24. ×100 (Slide No. 4401).

27. *Noeggerathiopsis bunburyana* Pant & Verma showing an immature complete leaf. 35013 × Nat. size.

PLATE 3

28. *Noeggerathiopsis conspicua* sp. nov. stoma enlarged from the Lower cuticle of specimen in Pl. 2, Fig. 24 (Slide No. 4401).

29. *Noeggerathiopsis hislopi* Pant & Verma Upper cuticle from the leaf in Fig. 27. × 100 (Slide No. 4404).

30. Lower cuticle from the leaf in Fig. 27. × 100 (Slide No. 4404).

31. Stomata enlarged from the Lower cuticle in Fig. 30. × 100 (Slide No. 4404).

32. Scale leaves — Type 1, 35014.

33. Scale leaf — Type 2. 35015

MICROFOSSILS (All × 500)

34-35. *Psilalacinites indicus* sp. nov. Slide Nos. 4380, 4381 (Holotype).

36. *Callumispora plicata* comb. nov. Slide No. 4382.

37. *Indotriradites* sp. Slide No. 4383.

38. *Striomonosaccites* sp. Slide No. 4384.

39-40. *Striatites medius* sp. nov. Slide Nos. 4385, 4384 (Holotype).

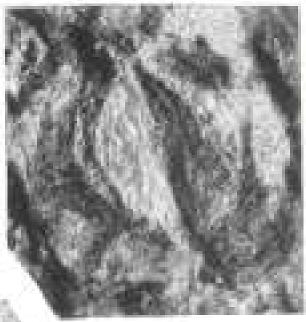
41. *Vittatina* cf. *V. subsaccata* Samoilovich, Slide No. 4382.

42-43. *Gnetaceaepollenites diffusus* sp. nov. Syntypes. Slide Nos. 4386, 4387.

44. *Punctatisporites* sp. Slide No. 4386.

45. *Pilasporites ovatus* sp. nov. Slide No. 4388 (Holotype).


1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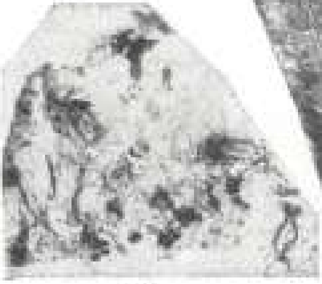
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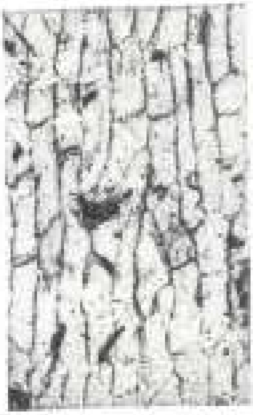
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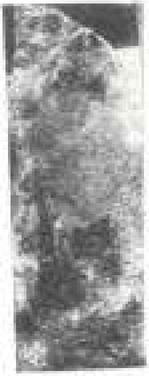
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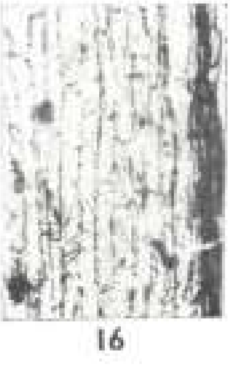
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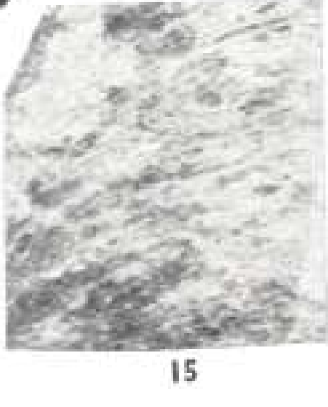
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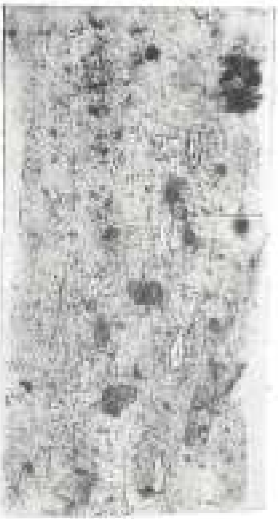
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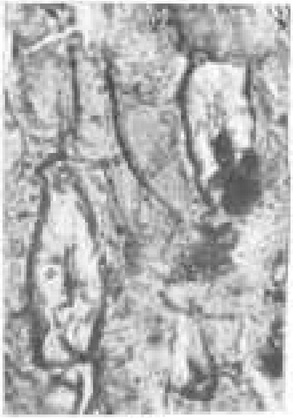
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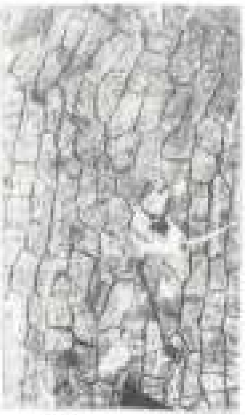
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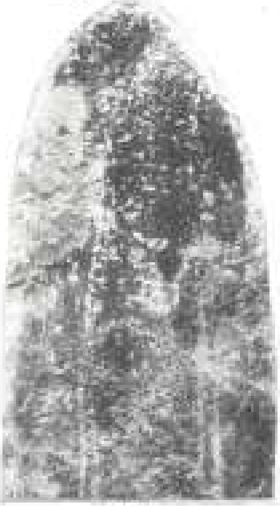
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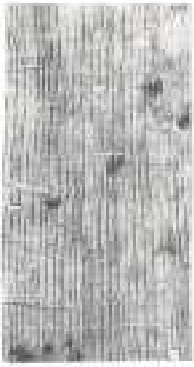
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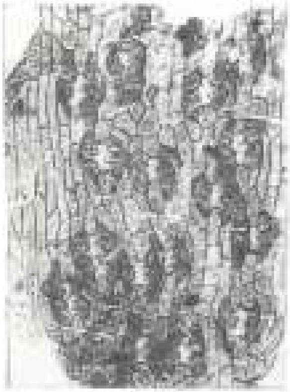
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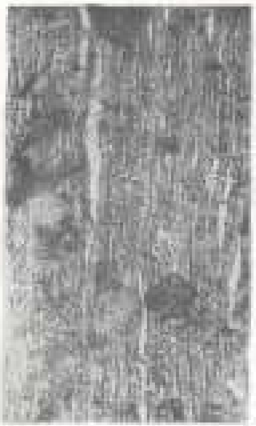
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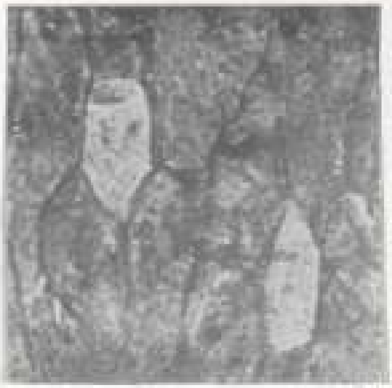
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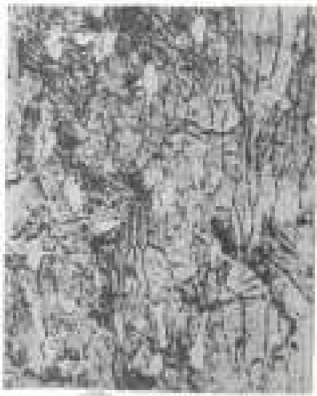
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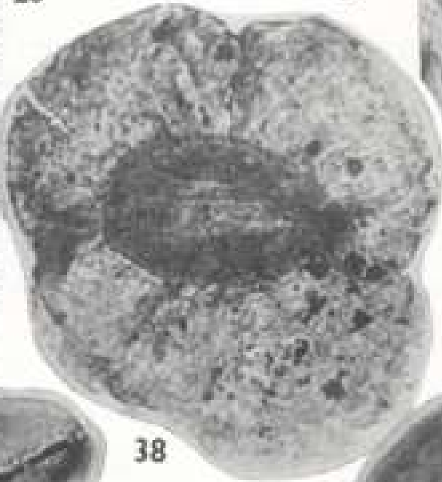
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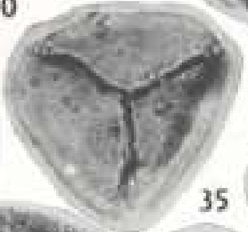
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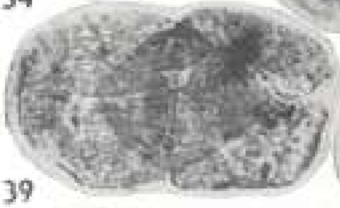
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CHACASSOPTERIS — A FOSSIL INTERMEDIATE FORM

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ABSTRACT

A reconstruction of *Chacassopteris mongolica* from the Lower Carboniferous period is given.

The *Chacassopteris* leaf is discussed in its morphological relations to *Archaeopteris*, Coenopteridales, *Ginkgo* and *Polygala*.

Chacassopteris is regarded as a Lower Carboniferous intermediate from (missing link) which connects *Archaeopteris* with the Ferns and Ginkgophytes and perhaps also with the Pteridosperms and Angiosperms.

INTRODUCTION

NOBODY will suppose that species once existed in nature which correspond to our abstract conception of " the Fern ", " the Pteridosperm " or " the Angiosperm ". Such a " Nullwertahne "[1] (zero value ancestor) would not have been viable and would be an illusion created by our way of thinking that is oriented to abstractions and types. In the beginning of a period which led to a new, unprecedented structure there were intermediate forms, established by fossil finds, which make it possible to compare the structure of the old species and classes with that of the later species and classes, i.e. to homologize. These intermediate forms in biological history show specializations of their period, their habitat and their origin. They are valuable for us because they exemplify the transition from one structure to another, confirm assumed homologies or make us look for homologies that agree with their structures. The intermediate forms found in the history of the earth and of life on earth were biological systems in which the new element had already materialized while the old element was still present.[2]

Perhaps the actual intermediate forms are difficult to determine because they were too specialized in their way. The new element is typical and thus convincing only when its mosaic of characteristics has become simple enough. So the intermediate forms referred to by the scientists are probably always the descendants of the real missing links.

The finding of an intermediate form supplies essential facts for a determination in the history of the earth and of life on earth: The period of the transition from one morphology to the next, from one form being effective to another form being effective and becoming even more effective is recognized, and thereof the circumstances which may have been essential conditions, can be examined. It is important to know whether an intermediate form had a wide or a locally limited distribution and whether its habitat flourished in the periods following or the whole interesting development of a continent was irretrievably lost by a transgression. Such considerations are necessary in view of a synthetic theory of evolution and thus, keep us from overestimating developments as that of Euramerican Petridosperms of the Carboniferous which were far ahead of the general evolution.

Figure 1 shows in outline the geography of a large part of the earth during the Carboniferous age. In the Devonian and Carboniferous periods Europe remained directly in the zone of the equator, while Siberia and Northeastern China lay in changing latitudes: Their climate, which had been cool to temperate in the Devonian age, grew warmer. These Asiatic regions served as the basis for the further development of the flora even in the Permian and Triassic periods when in Europe, the rich development of the flora in the Upper Carboniferous had been replaced by a poor, largely arid development of the flora.

Chacassopteris had a wide distribution on the continent of Siberia in the upper Lower

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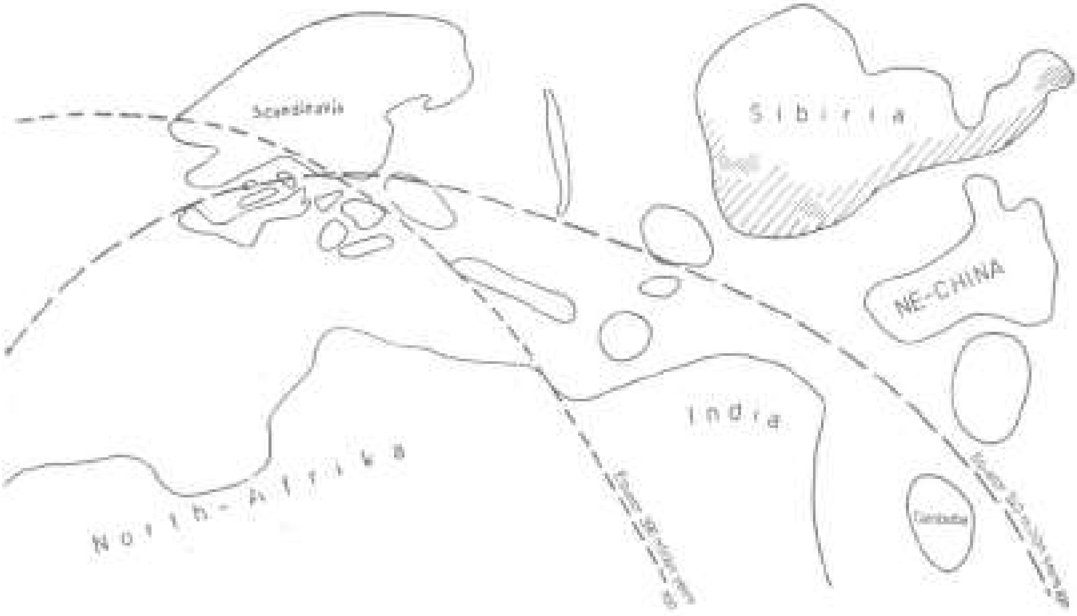
[1] Remane (1956, p. 238) used the term " Nullwertahne " (zero value ancestor) to point out the limits of the assumption of a law of specialization and thus the limits of the assumption of an " adaptive radiation ".

Engels (Dialectics of Nature, Notes and Fragments) already disagreed with Darwin on this assumption and referred to Hegel (§ 238, speculative method).

[2] Mosaic nature of evolution, heterochrony in the development of the characteristics, heterobathism (various terms are used in the literature, cf. Takhtajan 1959, p. 13).



TEXT-FIG. 1 — Continents of the Lower Carboniferous age and their position in relation to the equator. Distribution of *Chacassopteris* in Siberia (hatched).

Carboniferous (Visé). This permits the conclusion that the intermediate morphology of *Chacassopteris* is significant.

MORPHOLOGICAL COMPARISONS

There can be no doubt that in the Upper Devonian age *Archaeopteris* played a part in the biological history leading to the Ferns and Pteridosperms (Beck 1960, 1962, 1965). *Archaeopteris* was distributed over almost the whole of the earth, and only 40 million years after the first settlement of psilophytes on the continents it was the morphologically most advanced type of a land plant.

The morphology of both the sterile and the fertile leaf of *Chacassopteris* connects it with that of the *Archaeopteris* pinnule. With the *Archaeopteris* pinnule as well as with the *Chacassopteris* leaf the telomes grow fan-shaped, symmetrically "dachübergipfelnd" (roof overtopping). *Chacassopteris* has this "Dachübergipfelung" (roof overtopping) in a particularly primitive and clear form. Contrary to *Archaeopteris*, the sterile shoots of *Chacassopteris* still do not show any "Pendelübergipfelung" (oscillating overtopping) (fern-frond structure). The shoot of *Chacassopteris* appears to be morphologically more primitive than the frond of *Archaeopteris* which is characterized by oscillating overtopping (Pendelübergipfelung) with intermediate pinnules. Dichotomously branching sterile shoots of *Chacassopteris*, bearing the forking leaves, thus resemble *Cladoxylon scoparium* KR. & W.

The fertile shoots of *Chacassopteris* show an apparently primitive overtopping: Main shoot and fertile lateral shoots along with the intervening pinnules on the main shoot.

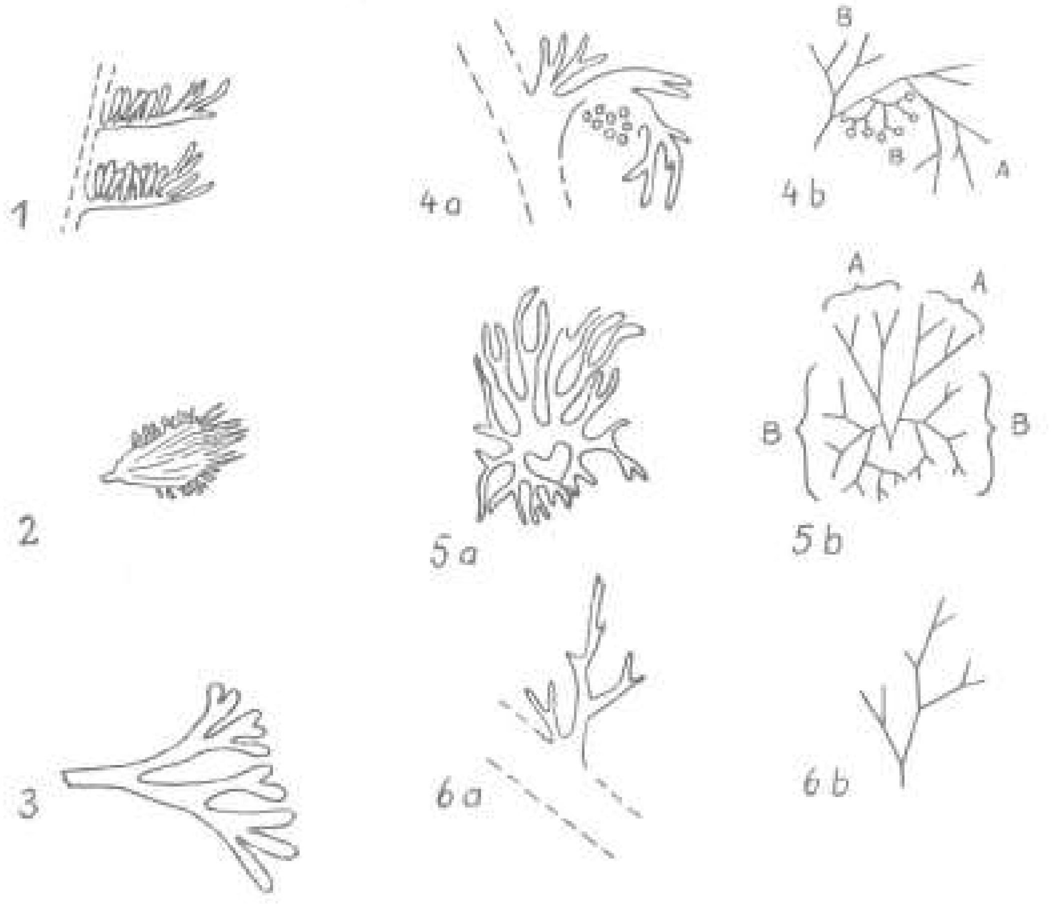
The fertile pinnules of *Chacassopteris* greatly resemble the fertile pinnules of *Archaeopteris*. It is clearly discernible that the roof overtopped (dachübergipfelnden) and shortened lateral ends bear the sporangia, while the two median ends, which incline towards the symmetry plane, remain free and sterile. While earlier figures of the fertile *Archaeopteris* leaf Arnold (1939), Andrews (1961), Zimmermann (1959) and others showed it bordered with sporangia on one side and ending in one sterile telome, Beck (1962) (p. 374) was well advised to let in his reconstruction the pinnules terminate in two or more sterile telomes. The sporangia of *Archaeopteris* and *Chacassopteris* can be equally interpreted as fertile roof overtopping (dachübergipfelnde) telomes which may be formed on both halves (on

TEXT-FIG. 2 — Reconstruction of *Chacassopteris mongolica* from finds in the Lower Carboniferou (Tournai/Visé) layers of the People's Republic of Mongolia.

either half) of the pinnule. While in *Archaeopteris* they are directed towards the apex, in *Chacassopteris* they are curved inwards towards the base. A pinnule of *Archaeopteris* which was fertile on both sides as an exception was figured by Ananiev (1959) (table 18, fig. 3). The fertile pinnules of *Chacassopteris mongolica*, however, scarcely show the morphology of the sterile pinnules which is restricted to symmetrical roof overtopping, instead, they are combined with a small shoot, revealing a mixture of the *Chacassopteris* pinnule with the tendency of forming a small shoot.

The results of these comparisons of the leaf of *Chacassopteris* with those of *Archaeopteris* and *Cladoxylon scoparium* may be summed up in the conclusion that the principle of symmetrical roof overtopping as it is evident in the *Chacassopteris* leaf can be regarded as the basic pattern for the leaf forms of the Pterophytes.

Chacassopteris belongs to the "transition forms leading to 'typical' Cormophytes" as Zimmermann (1969, p. 75) called them in the sixth stage of plant life. But *Chacassopteris* is not a Middle Devonian plant as one might be tempted to conclude from its



TEXT-FIG. 3 — Comparisons between *Chacassopteris mongolica* (parts 4, 5) and *Archaeopteris* (parts 1, 2) or *Cladoxylon scoparium* (part 3) (according to Andrews, Phillips, Radforth 1965, Weyland 1964, Daber 1972).

Part 1 Fertile *Archaeopteris* pinnules with terminal, sterile forked tips.

Part 2 *Archaeopteris* pinnule fertile on both sides (according to Ananiev 1959).

Part 3 *Cladoxylon scoparium* pinnule with a tendency to roof-overtopping (Dachübergipfelung) (according to Weyland).

Part 4a Fertile leaf of *Chacassopteris mongolica*, schematized and explained in Part 4b.

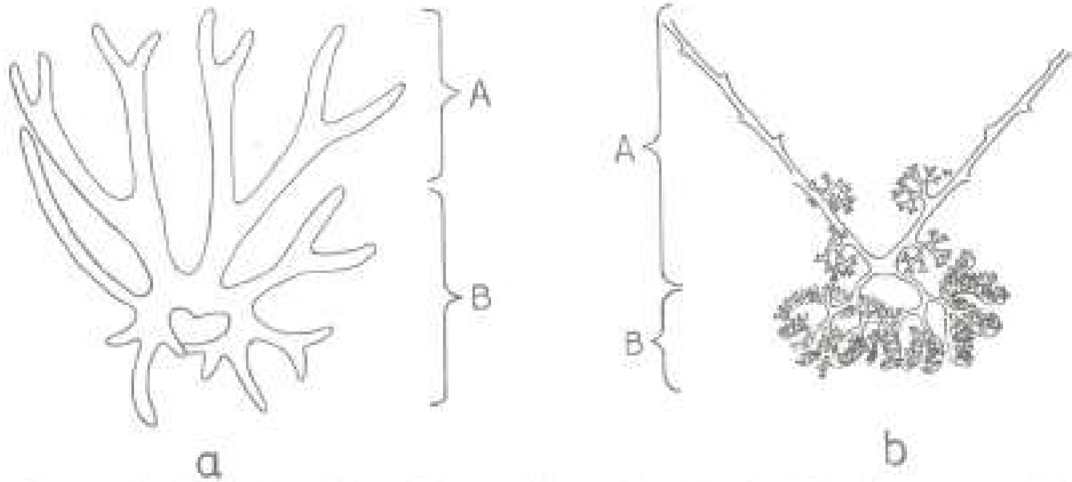
Part 5a Sterile pinnule of *Chagassopteris mongolica*, schematized and explained in Part 5b.

Part 6a Sterile pinnule of *Chacassopteris mongolica* which differs by oscillated overtopping (pendelnde Übergipfelung), schematized and explained in Part 6b.

The usual sterile leaf of *Chacassopteris mongolica* (Part 5b) differs in the behaviour of the forkings A from that of the forking B which are directed towards the base. With the fertile leaf the forkings A remain sterile while the roof overtopping forkings B become fertile. Strictly speaking, the whole fertile lateral shoot (the phyllophore and the fertile pinnules at it) is homologous to a sterile pinnule and originated by the addition of a oscillated overtopping to the symmetrical roof overtopping. Juxtaposed are the two forms of pinnules (Parts 5a and 6a), juxtaposed are sterile leaf and phyllophore, the fertile pinnule repeats the form of the sterile leaf, but modified.

morphological position between *Cladoxylon scoparium* and *Archaeopteris*. *Chacassopteris* lived for a long time-about 20 million years after the period of *Archaeopteris* (= Upper Devonian) and was a contemporary of the Zygopterideae and the Pteridospermae. *Chacassopteris mongolica* had microsporangia and megasporangia, which suggests heterospory — a fact already proved for *Archaeopteris*.

Radczenko (1960, p. 45) already included *Chacassopteris* among the Coenopteridales



TEXT-FIG. 4 — Comparison between *Chacassopteris mongolica* (a) and *Rhacophyton zygopteroides* (b) (according to Leclercq). The "aphlebiae" arising at the phyllophores and the forked frond are compared with the sterile *Chacassopteris* leaf. The forkings B of the *Chacassopteris* leaf which are directed towards the base correspond to the sterile or fertile "aphlebiae" of *Rhacophyton*. The forkings A of *Chacassopteris*, which do not overtop, have been transformed into "fern fronds" by (pendelnde Übergipfelung) oscillated overtopping.

incertae sedis. The morphology of the *Chacassopteris* leaf offers a possibility to interpret the morphology of the Coenopteridales. If we take Leclercq's reconstruction (1950/51) as the basis for *Rhacophyton*, the shoot axes (T) of *Rhacophyton* may be compared to the creeping and also erect, irregularly branching and in the fertile region also overtopping shoots of *Chacassopteris mongolica*. The phyllophores of *Rhacophyton* would be comparable to the uniform, long shoots of *Chacassopteris* which bear the fertile pinnules. The complex of the V-shaped forked frond and its basal sterile or fertile aphlebiae would in its entirety correspond to the *Chacassopteris* pinnule. The morphology of the frond of *Rhacophyton*, developed by oscillating overtopping as with all the later Coenopteridales, would be equivalent to the two inner branched shoots (turned towards the symmetry plane) of the *Chacassopteris* leaf which do not show any tendency to overtopping. The aphlebiae of *Rhacophyton* would correspond to the leaf tips of *Chacassopteris* that are turned towards the base and originated by roof overtopping. These "aphlebiae" which are often fertile in *Rhacophyton* and other Coenopteridales of later periods would thus be interpreted not as independently developed organs but as belonging to the complex of the forked frond. This interpretation would modify the exceptional position of those Coenopteridales that bear their sporangia not on the leaf fronds but on these "aphlebiae".

This comparison would result in the following conclusion: *Chacassopteris mongolica* may be regarded as a model for an intermediate form between Coenopteridales (*Zygopterideae*) and *Archaeopteris* and *Cladoxylon scoparium*. Consequently, *Chacassopteris mongolica* would be understood as a geographically very remote relative of *Saccopteris* Stur (=*Alloiopteris* Potonié) which had morphologically remained particularly primitive. While in the more favourable climate of Europe the evolution had advanced to *Saccopteris*, the morphological development in Siberia had remained in an undifferentiated state, related closer to the morphology of the psilophytes.

The publications of Andrews, Mamay and Phillips suggest the idea of the Coenopteridales as a Carboniferous group of Ferns which may have evolved into the modern leptosporangiate families of Ferns. Takhtajan published a scheme of such a phylogenetic tree in his manual "Foundations of Palaeontology" (1963, p. 339). In any case, the variety of the developments of the Coenopteridales in the Upper Carboniferous and Lower Permian periods is surprising. It seems that the original patterns

TEXT-FIG. 5 — A symmetrically roof overtopping "tag" at the petal of the flower of *Polygala* (here *P. oxyptera* RCHB.) as an example of a *Chacassopteris*-leaf-like rudiment in a highly differentiated dicotyledonous Angiosperm of the present (according to Pawlowski).

of the modern developments of the Ferns were at least experimented with already by the Upper Carboniferous species. Thus it is by no means incorrect to expect a recurrence of the morphology of the *Chacassopteris* leaf in much more highly developed plants of later periods.

The fact that the leaf of recent species of *Platycerium* corresponds in its outline and its bifurcation to the leaf of *Chacassopteris* illustrates the following problem: How can the pinnate frond of leptosporangiate Ferns be related to an originally branched, symmetrically roof overtopping basic form? The finds of *Chacassopteris* prove that the pattern of this recent *Platycerium* leaf does not result only from a prehistory on the level of seaweed or psilophytes but can be related to a morphology of Lower Carboniferous Ferns. In this connection also the Lower Cretaceous Fern *Weichselia* may be mentioned whose forked fronds have never been convincingly explained.

The *Ginkgo* leaf, too, is comparable to the *Chacassopteris* leaf, as Zimmermann (1959, p. 407) stated. It shows the asymmetrical roof overtopping in both halves of the leaf. *Ginkgo* apparently developed an insecticid instead of a reticulate venation, and thus it was not at so great a disadvantage by its archaic venation as Potonié (1906, 1912) originally assumed. Consequently, the development of the Ginkgophytes also started from an actual Lower Carboniferous morphological state, and it hardly makes sense to seek the origin of the Ginkgophytes in earlier periods.

If the assumptions are correct that the pinnate leaf must have developed somehow from the forked leaf and that accordingly possibilities of a convincing homologization must yet be found, then this problem generally applies also to the morphology of the Angiosperm leaf. As the Carboniferous Pteridosperms had forked fronds, such a question is justified.

In the approximately 500 species of the recent genus *Polygala* we find in the region of the flowers a so-called "tag" which so far has been difficult to explain. This "tag" shows the forking and the roof overtopping which we know from *Chacassopteris*. Perhaps the "tag" of the *Polygala* species is a rudiment or atavism and indicates an ancient morphology of the leaf on which other chains of characteristics have been superimposed.

In this connection it seems reasonable to doubt the interpretation of *Polygala* as the last (youngest) branch of the phylogenetic tree of the Angiosperms. Considering that the species of the genus *Polygala* are distributed over Europe, North America and South America, Australia and Tasmania and also that the related genus *Securidaca* includes tropical trees and climbing lianas and was even identified with a fossil samara of the Eocene in the UAR (Egypt), these geographical and geological facts make it probable that the Polygaleae extend back to the Lower Cretaceous.

The forked venation of the Angiosperm herbs *Kingdonia* and *Circaeaster*, however, can not be as clearly related to the symmetrically roof overtopping leaf of *Chacassopteris*, even if some leaves of *Circaeaster* (e.g. Foster 1961, p. 972, fig. 2) resemble this basic pattern. The few specimens of leaves of primitive Angiosperms that are available for comparisons suggest that on the old morphology of the leaves which was due to symmetrical roof overtopping a dominant oscillated overtopping was superimposed, and that this produced the variety in the morphology of the leaves which is now so difficult to interpret.

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EXPLANATION OF PLATES

PLATE 1

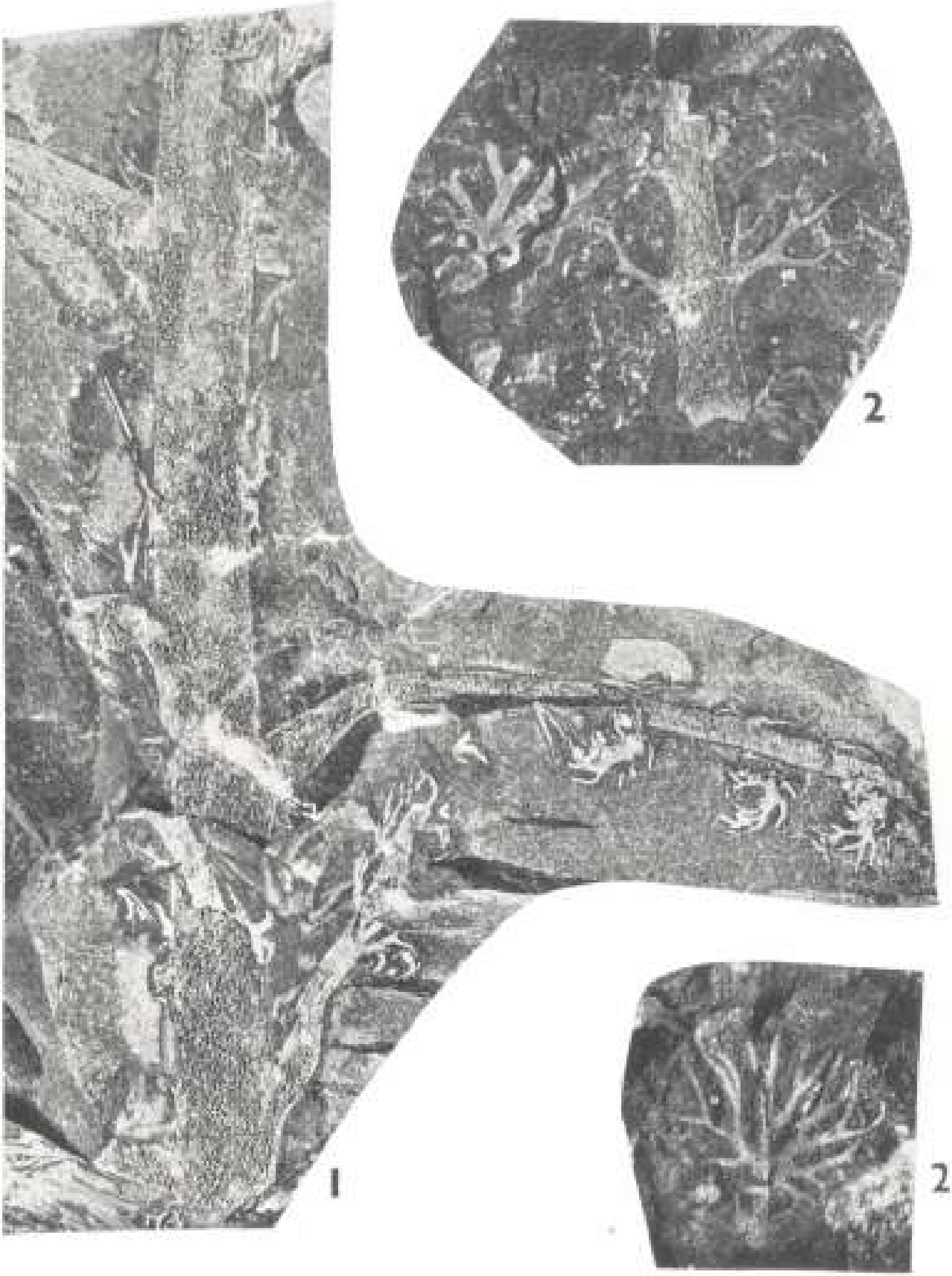
1. *Chacassopteris mongolica* Daber, fertile, stem phyllophore, divided leaflets with Sporangia 2/1. (Peoples Republic of Mongolia, Aimak Bejanchongor, Zogt Chairman Unl; Tournai).

2. *Chacassopteris mongolica*, sterile leaflets 2/1.

PLATE 2

3. *Chacassopteris mongolica*, Phyllophore with fertile leaflets, Sporangia single on apices curved towards the base 4/1.

4. *Chacassopteris mongolica*, sterile leaflets 4/1.



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A PRELIMINARY SPOROLOGICAL ANALYSIS OF SOME CARBONACEOUS SHALE SAMPLES FROM KAMPTEE COALFIELD, NAGPUR DISTRICT, M.S., INDIA*

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ABSTRACT

The present paper is a part of the paleopalynological investigation of coal bearing beds of Lower Gondwana age occurring in the north-eastern region of Maharashtra State. The paper deals with the sporological analysis of two bore-core carbonaceous shale samples geologically belonging to the Barakar Series of the Damuda System of Lower Gondwana group, collected from Dahegaon camp area in Kamptee Coalfield in Nagpur District. Both core samples have predominance of trilete spore genera such as *Brevitriletes* Bharadwaj & Srivastava and *Lophotriletes* (Naum.) Pot. & Kr. Next in abundance are the bisaccate grains such as *Striatites* (Pant) Bharadwaj and *Sulcatisporites* Bharadwaj.

INTRODUCTION

DURING the last decade paleopalynological studies have been done on various Lower Gondwana strata by several workers (Bharadwaj, 1960, 1968; Bharadwaj & Srivastava, 1969; Lele, 1963, Lele & Maithy, 1963; Navale & Tiwari, 1966; Tiwari, 1967; Kar, 1967). They have analysed coal samples palynologically from the Talchirs, Raniganj, Karharbari and other horizons from various collieries situated mostly in the north-eastern region and M.P. region of India.

A review of literature has indicated that very little work has been done on the palynological studies of coal bearing rocks of Lower Gondwana occurring in Maharashtra State. Hence a research project was undertaken by us to investigate paleobotanically the Lower Gondwana Strata occurring in Maharashtra State. There are four major coalfield areas in Maharashtra State as listed below.

i. Kamptee Coalfield in Nagpur District.
ii. Umrer Coalfield in Nagpur District.
iii. Bokhar Coalfield in Nagpur District.
iv. Wardha Velley Coalfield in Wardha and Chandrapur District.

Presently, 10 coal mines are working in this area and the coal deposits are of second grade as compared to the Jharia grade and are of non-coking variety.

We have made extensive collections of shales containing megafossils and other shale and coal samples for microfossil studies from various coalfields mentioned above and started the palynological analysis of some of the samples (Agashe & Chitnis, 1969, 1971). Recently, N.C.D.C. Ltd. has started drilling operations for prospecting of coal in the Kamptee Coalfield in a place called Dahegaon which is about 9 Km. from Nagpur. The present paper is a preliminary report on the mioflora preserved in two carbonaceous shale-core samples collected from Dahegaon drilling camp area through the kind courtesy of N.C.D.C. Ltd. The results obtained so far are encouraging and it is intended to intensify the palynological studies of these coal bearing beds which will ultimately help in the demarcation of the suspected Karharbaris from the overlying Barakars and other problems of stratigraphic correlation.

MATERIAL AND METHODS

The material used in the present investigation consisted of two fine-grained grey-coloured carbonaceous bore-core samples which have been numbered as S4 and S5. These samples were collected from the freshly drilled bore-cores in N.C.D.C.'s, Dahegaon drilling camp area in Kamptee Coalfield which is about 9 Km. from Nagpur. Sample S4 was taken from an area about a kilometre from where S5 was taken. Sample S5 was taken from a depth

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*Contributed to the Palaeobotanical Conference, Birbal Sahni Institute of Palaeobotany Silver Jubilee, December 1971.

of 215 meters, whereas sample S4 was taken from a depth of 169 metres.

The maceration of the samples was carried out as per the method described by Bharadwaj (1960). About 50 gm. of material was first subjected to treatment with dilute hydrofluoric acid for few days in order to get rid of siliceous matter. After the hydrofluoric acid treatment the material was washed thoroughly with water and later treated with commercial nitric acid (40%) for 3-4 days. The macerate after washing with water was subjected to treatment with 5% KOH for few minutes. Part of this material was sieved through test sieves No. 150 and No. 300 respectively. The residue on the sieve No. 300 was washed thoroughly in water. In order to separate the lighter organic matter containing spores and pollen grains from heavier matter such as sandy particles, cuticles, etc., a small portion of the residue was taken into a watch glass containing water. The watch glass was shaken gently and the lighter floating organic matter containing spores was drawn off by a pipette. After centrifuging the concentrated spore residue was mounted on slides in glycerine jelly. This material was used for qualitative study. For quantitative study the unsieved material was used. About 1000 counts per sample were taken for quantitaive studies. For classification and identification of the spores and pollen grains mainly the work of Potonié (1956, 1958), Potonié & Kremp (1954) and Bharadwaj (1960) was referred.

OBSERVATIONS

Investigations carried on so far indicated that both core samples are rich in various types of well preserved spores and pollen grains. The mioflora recovered from both core samples S4 and S5 appeared to be similar in floristic contents. However, the percentage of individual spores in total population differs markedly in both core samples. The various polospore types recovered and identified so far from these core samples are listed below.

Punctatisporites (Ibr.) Pot. & Kr.
Leiotriletes (Naum.) Pot. & Kr.
Callumispora Bharadwaj & Srivastava
Lophotriletes (Naum.) Pot. & Kr.
Acanthotriletes (Naum.) Pot. & Kr.
Brevitriletes Bharadwaj & Srivastava
Microbaculispora Bharadwaj
Microfoveolatispora Bharadwaj
Gondisporites Bharadwaj
Latosporites Pot. & Kr.
Laevigatosporites (Ibr.) Schopf, Wilson & Bentall
Pseudoreticulatispora Bharadwaj & Srivastava
Virkkipollenites Lele
Plicatipollenites Lele
Nuskoisporites Pot. & Kr.
Crucisaccites Lele & Maithy
Densipollenites Bharadwaj
Caheniasaccites Bose & Kar
Illinites (Kos.) Pot. & Kr.
Striatites (Pant) Bharadwaj
Verticipollenites Bharadawaj
Faunipollenites Bharadwaj
Lunatisporites (Lesch) Bharadwaj
Sulcatisporites (Lesch) Bharadwaj
Gnetaceaepollenites Thiergart
Tiwariaspora Maheshwari & Kar
Welwitschiapites Bolchowit
Ginkgocycadophytus Samoilowitz

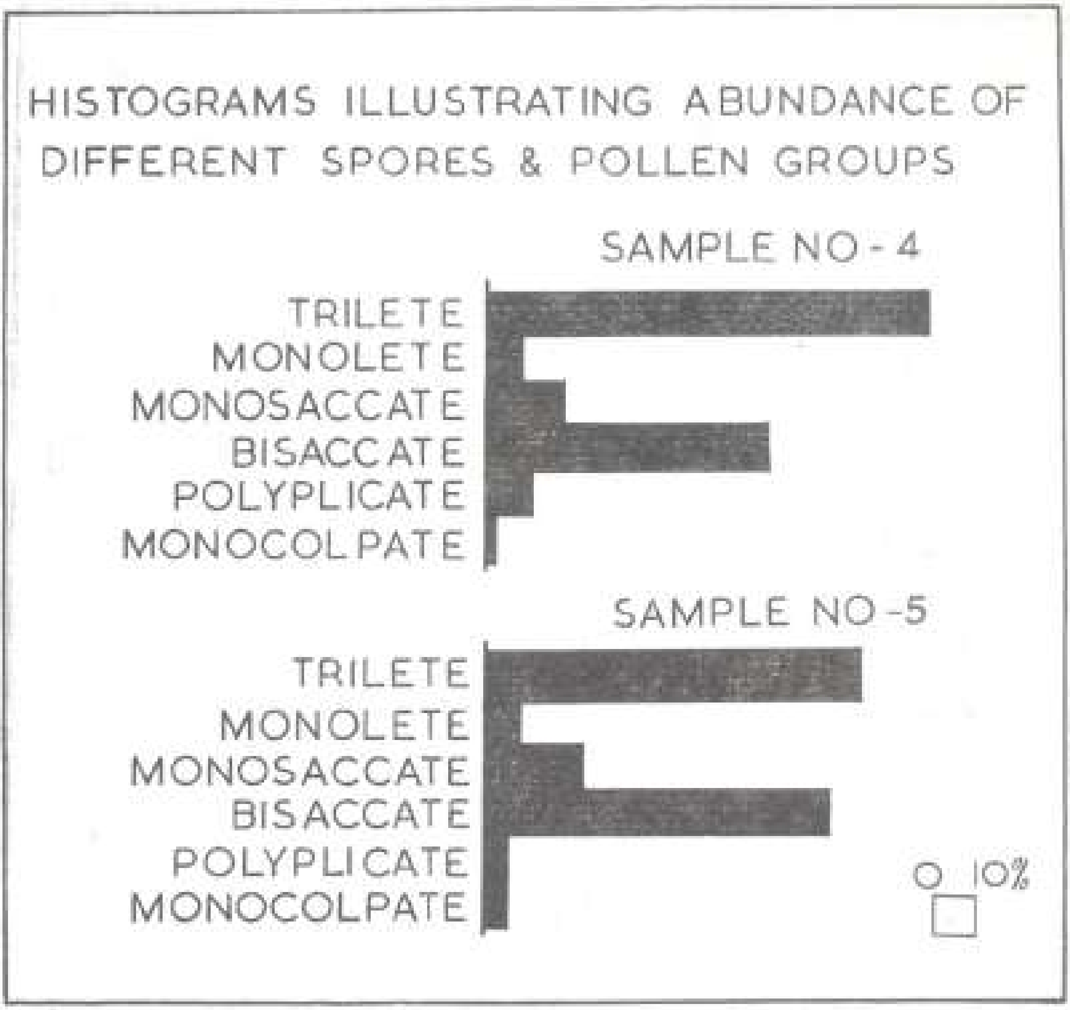
Some of the most significant spore genera are illustrated in Plate 1.

DISCUSSION

The paleopalynological investigation of the bore-core carbonaceous shale samples has indicated the presence of rich assemblage of microfossils particularly the spores and pollen grains of various kinds. Microflora recovered from these samples is composed of at least 29 different genera of spores and pollen. Both of these samples, i.e. S4 and S5, were studied qualitatively and quantitatively.

The results obtained regarding the representation of different groups of polospores in both samples are shown in Histogram No. 1. It shows that the trilete group of spores is dominant in both samples. Striated bisaccate pollen grains form the subdominant group. Monosaccate, monolete, polyplicate and colpate grains are less common. Sample S4 is characterized by 50% triletes and 31% bisaccates in the total population. Whereas sample S5 has 42% triletes and 38% bisaccates in the total population.

The detailed analysis of sample S4 (Histogram No. 2) has shown that among the trilete spores, the genus *Brevitriletes* representing 31·1% of the total population is most dominant. *Lophotriletes* and *Acan-*

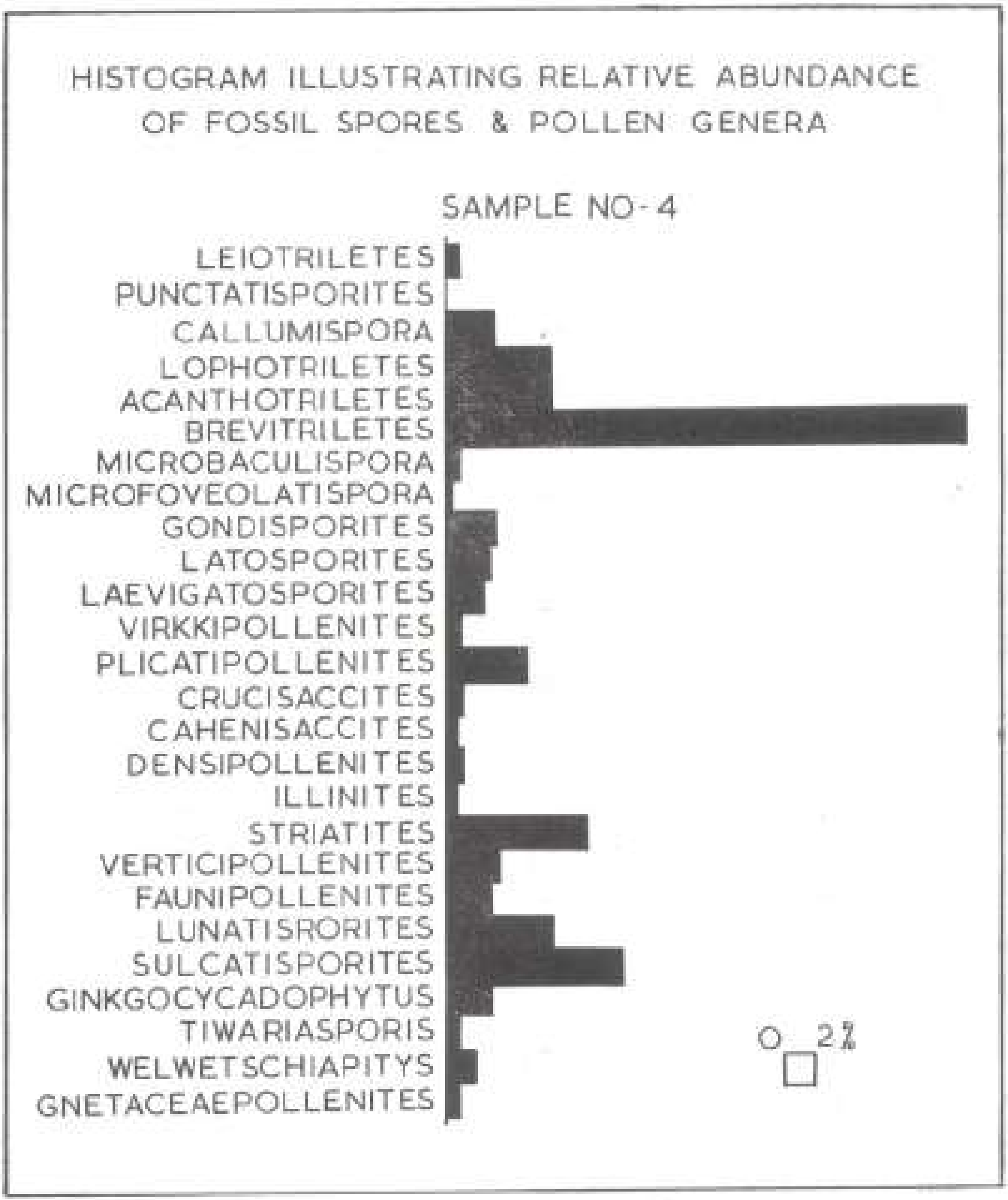


HISTOGRAM 1

hotrilates together represent 6·2% of the total population. Among the bisaccate grains *Sulcatisporites* and *Striatites* are dominant and represent 10% and 8% of the total assemblage respectively. Monosaccates which form 8·7% of the assemblage are represented by *Virkkipollenites*, *Plicatipollenites*, *Nuskoisporites*. Polyplicates which form nearly 5% of total assemblage are represented by genera like *Tiwariaspora*, *Gnetaceaepollenites*, etc. Monocolpates form less than 1% of total assemblage.

As shown in Histogram No. 3, sample S5 is characterized by the predominance of trilete genus *Brevitriletes* representing 21·9% of the total assemblage. The subdominant group of bisaccates representing 38% of the total assemblage consists of *Striatites* (15%), *Faunipollenites* (7·6%), *Lunatisporites* (7%), etc. Monosaccate grains contributing 10% to the total assemblage are represented by *Plicatipollenites* (4·5%), *Virkkipollenites*, *Crucisaccites*, etc. Polyplicates and monocolpates are rather insignificant contributors to the total assemblage in sample S5.

Thus the palynological investigation of the bore-core samples S4 and S5 has shown the presence of identical spore and pollen genera with slight differences in their percentages in the total assemblage. In both the samples the series Apiculati is dominant.

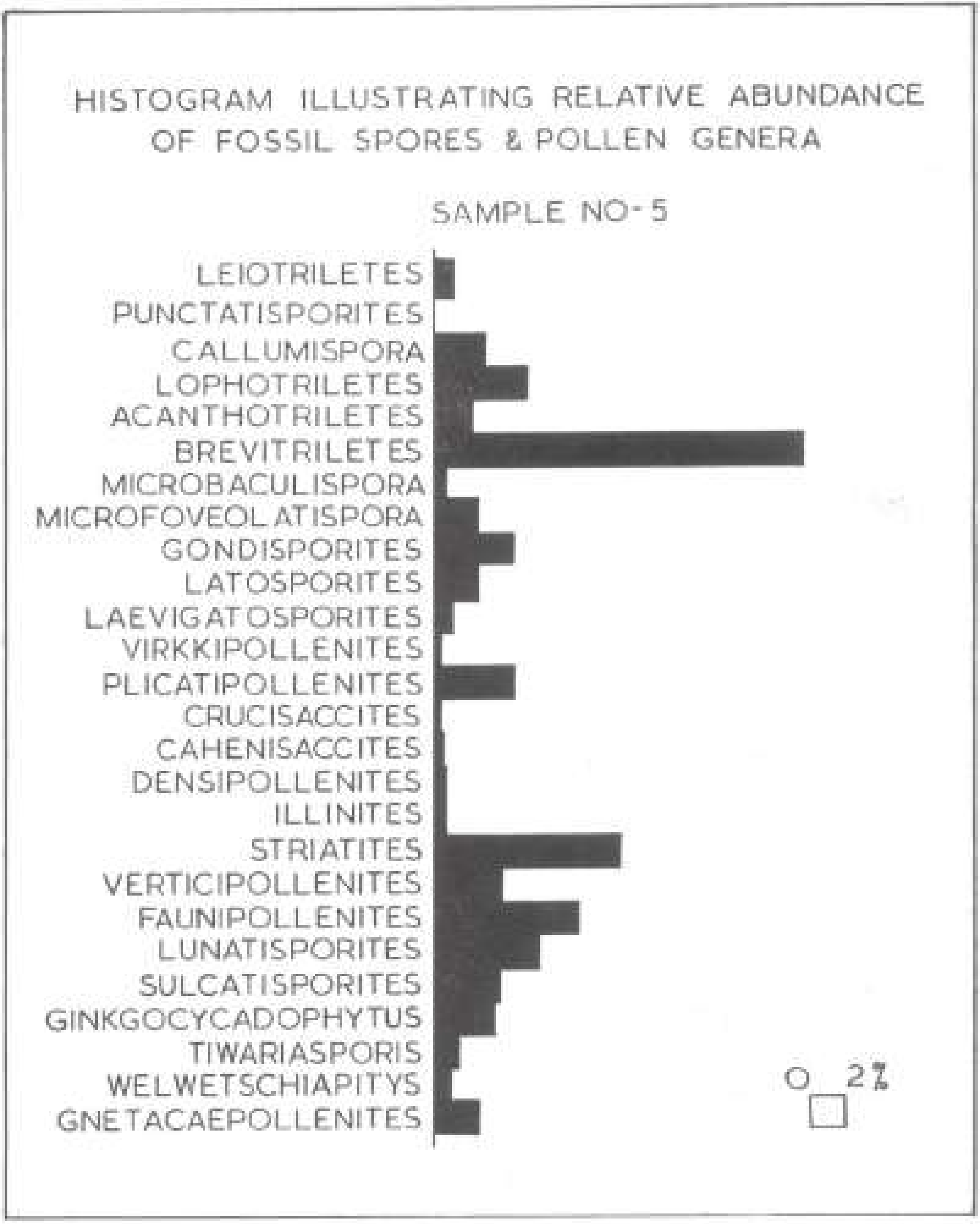


HISTOGRAM 2

However, the subdominant group of bisaccates is represented more commonly by series Striatiti and Disaccitrileti in sample S4 whereas it is represented mostly by series Striatiti in sample S5. The monosaccates, monocolpates and polyplicates are nearly same in both the samples.

CONCLUSIONS

The foregoing account of the paleopalynological investigation of two bore-core carbonaceous shale samples taken from Dahegaon drilling camp area shows the identical mioflora though the samples are



Histogram 1

from two different borings taken from areas separated by a kilometre. The mioflora is closely comparable, with the mioflora of certain coal seams (Agashe & Chitnis, 1971) from nearby Chandrapur District. This study has indicated that the paleopalynology of shale samples and coal samples will be of great help in stratigraphic correlation. It is contemplated therefore, to make additional collection of bore-core samples of coal as well as shale from various drilling areas in the Nagpur District and analyse them palynologically so that the data obtained from this work could be used for the purpose of the correlation of coal seams.

ACKNOWLEDGEMENTS

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EXPLANATION OF PLATE

Figs. 1-10 are magnified × 500
Figs. 11-15 are magnified × 300

1. *Lophotriletes* (Naum.) Pot. & Kr. Slide No. S4/Sl. 16.
2. *Lophotriletes* (Naum.) Pot. & Kr. Slide No. S4/Sl. 17.
3. *Acanthotriletes* (Naum.) Pot. & Kar. Slide No. S5/Sl. 18.
4. *Brevitriletes* Bharadwaj & Srivastava Slide No. S4/Sl. 18.
5. *Ginkgocycadophytus* Samoilovich Slide No. S4/Sl. 16.
6. *Laevigatosporites* (Ibr.) Schopf, Wilson & Bentall Slide No. S5/Sl. 5.
7. *Microbaculispora* Bharadwaj Slide No. S4/Sl. 16.
8. *Tiwariaspora* Maheshwari & Kar Slide No. S4/Sl. 18.
9. *Gutlaccarpollenites* Thiergart Slide No. S4/Sl. 10.
10. *Illinites* (Kosanke) Potonié & Klaus in Pot. & Kar. Slide No. S5/Sl. 5.
11. *Striatites* (Pant) Bharadwaj Slide No. S5/Sl. 11.
12. *Verticipollenites* Lele Slide No. S4/Sl. 17.
13. *Cahenisaccites* Bose & Kar Slide No. S4/Sl. 13.
14. *Nuskoisporites* Pot. & Kr. Slide No. S4/Sl. 4.
15. *Crucisaccites* Lele & Maithy Slide No. S4/Sl. 4.


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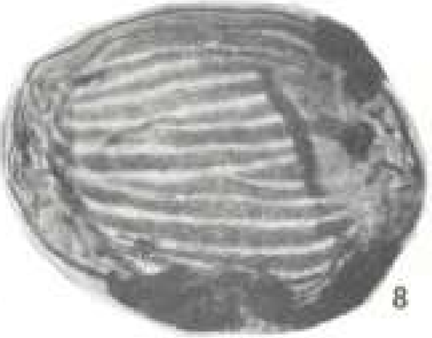
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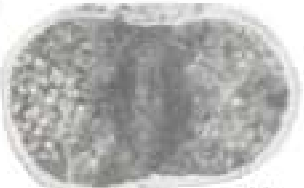
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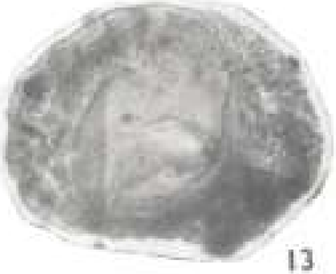
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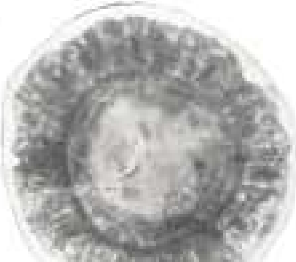
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15

FOSSIL DIATOMS AND BIOSTRATIGRAPHY OF THE LOWER KAREWA FORMATION OF KASHMIR

D. K. ROY

Geological Survey of India

ABSTRACT

During the course of geological mapping of the Karewa sediments of Kashmir to assess the economic potentialities of diatomaceous earth, the author collected nearly one thousand samples from 32 measured sections. The samples were analysed for fossil diatoms.

The study has indicated that while the lower Karewa is very rich in fossil diatoms, the upper Karewa is devoid of them. It is further observed that there is a uniformity in the trend of distribution and assemblages of fossil diatoms in the lower Karewa beds. Based on these two factors, the lower Karewa is divided into two biozones, the lower — Centrales Assemblage Zone, characterized by the predominance of centric diatoms and the upper — Pennales Assemblage Zone, characterized by the predominance of pennate diatoms.

The lower age limit of the Karewa is known to be Pliocene (pre-glacial) as postulated by earlier workers but the present study indicates that it may be even Miocene.

INTRODUCTION

THE Karewa of Kashmir possess different set of extinct life ranging from invertebrate, vertebrate to plant yet none of them have been applied so far for bio-stratigraphic classification of these thick sedimentaries. This has been mainly due to following reasons: (I) the record of animal life has been too scanty for such a study, and (II) the mega plant fossils did not show such a uniform trend of distribution which could be relied upon for such studies. However, in view of this, the, author while mapping the Karewa in order to asses the economic potentialites of some of the suspected diatomaceous earth, collected about one thousand samples from 32 measured sections between Nichahom (34°23′ 25″: 74° 08′ 40″) and Kurigam (33° 35′ 45″: 75° 09′ 05″). The samples were analysed for diatom study. The study thus undertaken has shown a uniform trend of distribution of diatoms which can be successfully applied for the bio-stratigraphic classification. As such an attempt to classify the Karewa bio-stratigraphically based on diatoms has been made and consequently the controversial age problem has been discussed.

GENERAL GEOLOGY

The lower Karewa beds are extensively developed over a length of 130 km and are 10 to 16 km wide. They rest upon pre-Tertiary rocks and are about 600 metre thick. They represent mainly an argillaceous facies composed of soft, dark grey, tough clays, shales and seams of lignite. Minor pebble beds, conglomerates, sands and sandy clays are also met with. The upper Karewa, about 300 metre thick, represent mainly an arenaceous facies composed of sands, silts, sandy clays and granular clays, varve clays, boulders and erratics, moraines, conglomerates etc. Structurally the lower Karewa sequence is disturbed while the upper Karewa is horizontally bedded. They are separated from one another by well marked unconformity. According to Wadia (1941, 1948) the lower units of the lower Karewa, on fossil evidence, are pre-glacial and not of the I inter-glacial period, as De Terra (1939) has inferred on physical evidence. De Terra while agreeing with Lydekker's two-fold classification of the Karewa into lower and upper, further subdivided the lower Karewa into five lithozones such as: 1. Basal clay zone, 2. Lower lignite zone, 3. Upper lignite zone, 4. Upper clay zone, 5. Upper sand and gravel zone.

Roy (1971) carried out geological mapping of the Karewa of Kashmir valley during 1968-1970 in collaboration with the officers of the J & K Circle, Geological Survey of India. The following table (Table I) shows the stratigraphic succession of the Karewa of Kashmir as worked out by De Terra, Wadia, and Roy.

The rock types belonging to the lower Karewa are described briefly in the following paragraphs:

Clays: Thin and thick bedded bluish grey, dark grey, brown, light yellow, buff, almost white, sometimes with yellow limonitic materials. They form the main constituent of the lower Karewa. These clays are extremely plastic and have large capacity of water absorption. The thickness of the individual beds varies from less

TABLE 1 — STRATIGRAPHIC SUCCESSION OF THE KAREWAS

	De Terra (1939)			Wadia (1948)			Roy (1971)	
Pleistocene	u.K.	II. Interglacial	Pleistocene	u.K.	Well bedded sands and clays with boulders and erratics, varve clays	Pleistocene	u.K.	Horizontally bedded sands and silts, sandy and granular clays, boulders and erratics, also tillites, loamy materials, conglomerates and gravels
					Basal boulder bed			
	300 m	II. Glacial		300-500 m	II. Glacial		300 m	Glacial
				UNCONFORMITY				
	l.K.	I. Interglacial		l.K.	Blue buff and blue grey shales, sands and gravel cross-bedded varve clays	Mio Pliocene	l.K.	Folded and faulted soft, dark grey, tough clays, shales and sands with seams of lignite and well bedded pebble beds
	600 m	I. Glacial	Pliocene	1350-1675 m	I. Glacial Dark, often carbonaceous, shales, sandstones with thick conglomerate beds and lignite seams		600 m	
					Pre-Glacial			
				UNCONFORMITY				
Older rocks (Triassic limestones, Panjal Volcanics, etc.)				Pre-Tertiary			Pre-Tertiary	

l.K. = Lower Karewa, u.K. = Upper Karewa than a metre to several metres and their contact with the overlying and underlying beds is fairly sharp. The clays are often carbonaceous. They are rich in fossil plants, diatoms and insects.

Shales: Buff, grey, brown and dark shales constitute the second major rock type of the lower Karewa. Their thickness varies from a fraction of a metre to ten metres. They are normally rich in fossil plants, diatoms, insects and occasionally fishes.

Sandy clays: Black and ash-grey, brown and yellow coloured sandy clays with varying proportions of sand and clay form another constituent of the lower Karewa. They are several metres thick but beds less than a metre thick are not infrequent. They are very poor in fossil plants and diatoms.

Lignites: Generally two lignite horizons but sometimes more, each not exceeding five metres thick, have been noticed almost everywhere in the lower Karewa sequence. They have been noticed in the Upper Ningle valley, Sochalpathri, Nichahom, Sonyan-Saidnar, Kulgam-Kurigam, Shaliganga valley, Nagbal-Sitarsiran, Laredura, Wanim nala etc. They have yielded rich miofloral assemblages, the study of which is under progress. Middlemiss (1932) reported rich deposits of lignite in the lower Karewa of the Kashmir valley.

Besides the above, sporadic occurrences of pebble beds, conglomerates and sands have also been noticed in the lower Karewa.

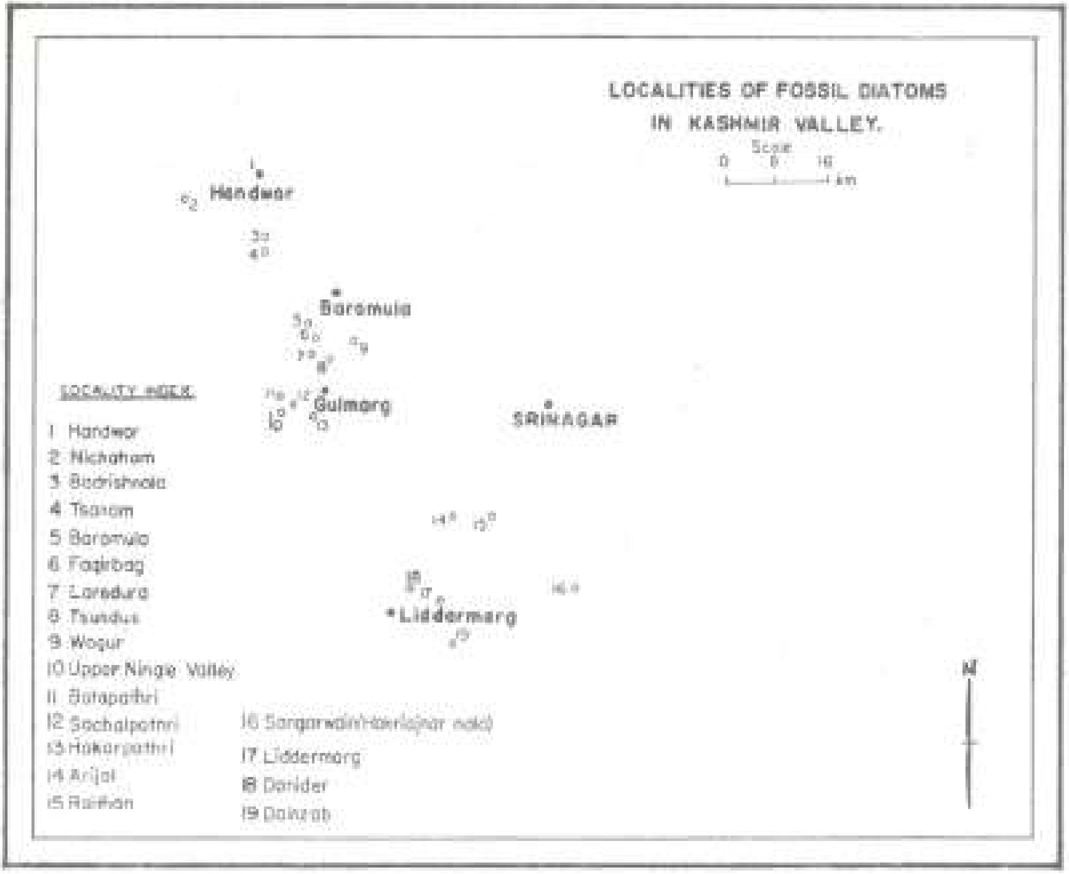
BIO-STRATIGRAPHY

No bio-stratigraphic classification of the Karewa in general and the lower Karewa in particular has been made so far though the general vegetational difference between the lower and upper Karewa was observed by Wodehouse (1935). His palynological studies led him to the conclusion that during the lower Karewa there were grassy plains which might have been absent during the upper Karewa. Later, Nair (1960) in his analysis of the pollens from the Karewa of Kashmir suggested a vegetational succession in the lower Karewa. He observed that during the early stages of lower Karewa, there was possibly an aquatic vegetation dominated by *Typha*. This was gradually replaced by a forest vegetation dominated by *Alnus*. This climax forest underwent destruction and there was open land occupied by *Plantago*, Chenopods, etc. The recent pollen analytical study of the Karewa by Vishnu-Mittre *et al.* (1962) has brought out a prominent Oak phase in the lowermost strata of the lower Karewa (litho zone 1 of De Terra). This Oak phase is replaced by the open Pine-mixed woods which are preceded and followed by a phase each devoid of vegetation. These two phases are referred to as the Lower Transition Zone (I glacial sequence in the lower Karewa according to them) and the Upper Transition Zone, respectively. The Lower Transition Zone corresponds to the top of litho zone I and entire litho zone II while the Upper Transition Zone corresponds to the base of litho zone IV. The Upper Transition Zone is succeded by a brief phase of Oak-mixed woods followed by a phase of Picea-Oak woods which are replaced towards the top of the profile by the Juglan-elm phase.

No attempt has so far been made to classify the Karewa on fossil diatoms. However, an account of the previous work on fossil diatom may be given here: Conger (in De Terra, 1939) reported a number of fossil diatoms from the Karewa for the first time. Thereafter, Iyengar and Subramanyan (1943) described some diatoms from them. Subsequently, Rao and Awasthi (1962) recorded and described some centric diatoms from the Karewa rocks exposed at Laredura, Kashmir. Recently Roy (1970) recorded 72 species of diatoms belonging to 29 genera from the lower Karewa of the Kashmir valley. The accompanying (Text-fig. 1) shows the distribution of fossil diatoms in the Kashmir valley.

Before summarizing the results of the present study a general account of the importance of diatoms in bio-stratigraphic zonation is necessary here. Diatoms occur in the Mesozoic, Tertiary and Quaternary deposits throughout the world but their maximum development is noticed in the Tertiary and Quaternary sediments. There is no satisfactory evidence of their occurrence in the Palaeozoic. Most of the extinct genera belong to the centrales and many genera represented by numerous species in the past have now only a few living ones. A thorough study of the literature in this sphere seems to support the view that the centrales are older than the pennales.

The great beauties that the diatoms possess due to the remarkable sculpturing



TEXT-FIG. 1

of their silicified cell-walls have attracted the microscopists for a very long period. Too much stress has so long been laid down on points of minute details with complete disregard to the stratigraphic and other geologic importance and as a result countless species have been created. But the Russian scientists have made significant advances in this subject and have successfully used the diatoms in the stratigraphic subdivisions and local and regional correlations of various formations, particularly the Palaeogene and Neogene formations of U.S.S.R. and other European countries. Similar attempts have also been made by a few workers in many other countries. While dealing with the lowest known Tertiary diatoms in California Hanna (1927a) opines "...... It will be possible to correlate the important shale-depositing epochs of the California Miocene, one with other; to be of greatest value such correlation should depend upon common 'marker species' of fossils, and it is believed that these exist in the diatoms, radiolarians, and silicoflagellates. Not only it is believed that local correlation will be possible, but because of the extremely great geographic range of these organisms, they should be a valuable aid in the world-wide age determinations of formations". The veteran Japanese scientist Ichikawa (1967) also felt that the assemblages of diatoms, peculiar to a deposit, may be used in correlating the strata of a given age in different places or even in different countries.

The studies of Zhuze, Shlapina, Gaponov, Proteskii, Krishtofovish and several other Russian workers have demonstrated beyond doubt that the diatom assemblages of Palaeocene, Eocene, Oligocene, Miocene and Pliocene ages differ markedly from each other. They have also brought out distinct assemblages for lower, middle and upper Miocene and Pliocene sediments. Zhuze (in Krishtofovish, 1949) and Shliapina (in Krishtofovish, 1949) carried out researches independently and correlated, on the basis of fossil diatoms, the Lower Miocene strata of North Caucasus with Tamansk and Kerchensk. Similarly, Shliapina (in Krishtofovish, 1949) correlated the Middle Miocene of Kargans with that of Konks. The Upper Miocene (Lower Sarmatian in particular) of Kamanets-Podolsk has been correlated with that of Dnepropetrovsk by Gaponov (in Krishtofovish, 1949).

On the basis of fossil diatoms Hanna (1927b) correlated the Moreno shale of California (Upper Cretaceous) with that of the Upper Cretaceous sediments of the Simbirsk area of U.S.S.R. and remarks 'A similar assemblage with some identical species occurs in northern Russia at Archangelsk Kurojedowo in Simbirsk'. In one of his subsequent papers Hanna (1934) described some additional forms of diatoms from the Cretaceous of California and observes 'Some of these are of much interest because they further confirm the closeness of these beds in age to those of the Simbirsk area of Central Russia'. Hanna (in Hertlein, 1933) assigned a Upper Miocene age for the Tertiary shale of Turtle Bay, Lower California, and observes 'it is believed that a sufficient number of diagnostic forms was found to definitely place the sample in the Upper Miocene'. In this connection he further opines 'Relationship with the deposit on Maria Madre Island is evident and the diatomites of comparable age are widespread in California'.

Colom (1952) made an exhaustive study of the Aquitanian-Burdigalian diatom deposits of the North Betic Strait, Spain and found their wide distribution in the eastern provinces of the Peninsula (Alicante, Southern Valencia). He also found relationship between the Spanish deposits and the Burdigalian deposits of the Balearics and observed the continuation of the Balearic sediments and those of the same age and composition at St. Laurent-La-Vernide (Gard, France) containing identical associations of benthonic diatoms.

Ichikawa (1950) recognized the stratigraphic significance of the Tertiary Diatomacene of Japan and correlated the diatom bearing late Miocene or early Pliocene mudstones of Iizuka, Tsukada, Wakura, Yamatoda, Awara, Hijirikawa and Mitsukoji in the Nato Peninsula and the vicinity of Kanazawa city.

The author made an extensive study of the fossil diatoms from the Karewa and found that the lower Karewa is very rich in fossil diatoms while the upper Karewa is devoid of them. The uniform distribution of these fossils and their greatly differing assemblages in the lower Karewa have been utilized as tools in classifying them into two bio-zones; the lower — Centrales Assemblage Zone, characterized by the predominance of centric diatoms and the upper — Pennales Assemblage Zone, characterized by the predominance of pennate diatoms.

Centrales Assemblage Zone: This zone is characterized by the centric forms like *Cyclotella*, *Melosira*, *Coscinodiscus*, and *Stephanodiscus*. A few pennate forms like *Amphora*, *Caloneis*, *Cymbella*, *Eunotia*, *Epithemia*, *Fragilaria*, *Gomphonema*, *Hantzschia* and *Synedra*, are also present. The percentage of centric diatoms in this zone varies from 90 to 98. This zone is equivalent to lithozone I of De Terra and is represented by dark grey, bluish grey, brown, light yellow buff clays and shales with very little interbedded sands. This zone is present in the, Upper Ningle valley, Botapathri, Sochalpathri, Tsundus, Baramula, Sangarwain Sukhnag valley, Liddermarg and Tsarum.

Pennales Assemblage Zone: This zone is characterized by the predominance of pennate diatoms. The assemblage includes: *Navicula*, *Achnanthes*, *Tetracyclus*, *Cocconeis*, *Synedra*, *Fragilaria*, *Surirella*, *Nitzschia*, *Gomphonema*, *Rhopalodia*, *Mastogloia*, *Pinnularia*, *Cymbella*, *Caloneis*, *Rhaphoneis*, *Hantzschia*, *Tabellaria*, *Diploneis*, *Licmophora*, *Peronia*, *Rhoicosphenia*, *Frustulia*, *Stauroneis*, *Amphipleura*, *Epithemia*, *Campylodiscus*, *Pleurosigma*. The presence of centric forms in this zone is very insignificant and includes *Cyclotella*, *Melosira*, *Coscinodiscus* and *Stephanodiscus*. The pennales in this zone constitute more than 90% of the total diatoms. Lithologically, this zone is characterized by laminated blue-grey and light grey clays, shales; generally two, often more horizons of lignite, silts and some sands and sandy clays. This zone corresponds to the lithozones II to IV of De Terra and is exposed in the Upper Ningle valley, Botapathri, Sochalpathri, Hakarpathri, Baramula, Handawar, Faqirbagh, Wogur, Badrish valley, Shaliganga valley etc.

The proposed bio-stratigraphy is tabulated below:

AGE OF THE LOWER KAREWA

As regards the age of lower Karewa there are, at present, two views --- (I) they are Pleistocene (De Terra, 1939; Pilgrim, 1944) and (II) they extend down to Pliocene (Lydekker, 1878 and 1883; Middlemiss, 1923; Wadia, 1948). The protagonists of the first school of thought led by De Terra were guided by the fact that the lower Karewa sediments belong to the I interglacial. The second school does not believe in the presence of basal glacial deposits. The principal basis for dating the Karewa were the vertebrate fossil remains from the 'bone bed' of Sombur which yielded *Elephas hysudricus* and *Palaeoloxodon anticus* (*namadicus*) suggestive of a Lower Pleistocene age (Tripathi & Chandra, 1962). Roy (1971) has recently grouped the Sombur bone bed and the Karewa sequence exposed at Hatwar, Gogjipathri etc. with upper Karewa and opines that the Lower Pleistocene age indicated by the fossil vertebrate remains of these beds is valid for upper Karewa only and thus can not be generalised for the entire Karewa Group.

From the study of the fossil diatoms of the lower Karewa of Kashmir it is evident that they may be used as valid stratigraphic markers which is in accordance with the usage by a number of Russian workers on their works on the various formations of U.S.S.R. and other European countries. The great abundance (90 to 98%) of the centric forms in the lowest unit of the lower Karewa (lithozone I of De Terra) as compared to the diminished frequency (sometimes as low as 2%) in the rest of the lower Karewa beds (lithozones II to IV of De Terra) is a significant fact. Equally significant is the reverse trend shown by the pennate forms which have very low representation in lithozone I and very high percentage (90 and above) in lithozones II to IV. This sudden decline of the centric forms and the appearance of pennate forms in time implies that certain typical assemblage of diatoms reigned over others during the course of geological time.

Fritsch (1956) regards that the oldest and the most evolved diatoms are the centrales and are represented by forms like *Cyclotella*, *Coscinodiscus*, *Melosira*, *Stephanodiscus* and *Stephanopyxis* etc. Pia (in Fritsch, 1956) concludes that at the period of maximum development of diatoms in the Miocene centric forms preponderate. Hanna (1927a) found mainly centric diatoms with a few pennate forms from the Miocene strata of California. He further (Hanna, 1929) noted abundant pennate diatoms from the Pliocene beds and only centric diatoms from Cretaceous deposits of California (Hanna, 1927b). Okuno (1952) recorded only centric diatoms from the Miocene diatomite deposits of Kumaki, Tsuzureko, Yonaizawa, and Kitaura in Japan. Krishtofovish (1949) in his monumental work 'Diatom analysis' writes that the centrales dominated in the pre-Tertiary and Tertiary times, giving away to pennales through evolution. He further writes that large number of species of the pennate diatoms have evolved in Pliocene. He also noted that *Navicula* first appears in the Lower Sarmatian and is typical of Sarmatian. He cited the following assemblage to be typical of Sarmatian: *Achnanthes*, *Amphora*, *Campylodiscus*, *Coscinodiscus*, *Mastogloia*, *Navicula*, *Rhopalodia*,

TABLE 2 — BIO-STRATIGRAPHY OF LOWER KAREWA FORMATION

LITHOZONES (modified after DE TERRA)	PROPOSED BIO-ZONES	CHARACTERISTIC FOSSIL DIATOMS
Upper clay zone (140 m)	Pennales Assemblage Zone	*Navicula*, *Achnanthes*, *Tetracyclus*, *Cocconeis*, *Surirella*, *Rhopalodia*, *Mastogloia*, *Pinnularia*, *Rhaphoneis*, *Tabellaria*, *Gomphonema*, *Diploneis*, *Licmophora*, *Peronia*, *Rhoicosphenia*, *Frustulia*, *Stauroneis*, *Amphipleura*, *Campylodiscus*, *Pleurosigma*, etc.
Upper lignite zone (205 m)		
Lower lignite zone (135 m)		
Basal clay zone (180 m)	Centrales Assemblage Zone	*Cyclotella*, *Melosira*, *Stephanodiscus* and *Coscinodiscus*

Surirella, and *Synedra*. Proteskii (in Krshtofovish, 1949) while dealing with the fresh water Pliocene and later flora in the diatomites of Georgia (Kisatib deposit) and Armenia (Nurnus and Arzin deposits) in Caucasus opines that all presently known genera of pennales such as *Navicula*, *Amphora*, *Rhopalodia*, *Achnanthes*, *Mastogloia* etc. appeared in the Mio-Pliocene. He further opines that in Neogene pennales dominate over centrales which flourished and dominated in Lower Tertiary. He continued to remark that all the known genera of centrales appeared before Neogene and most of them died in Neogene. Conger (in De Terra, 1939) reported rich diatomaceous flora, dominated by pennales, from the Tatrot beds (Astian) of Naushahra, Salt Range.

A critical study of the lower Karewa flora shows that the typical Lower Sarmatian genus *Navicula* is completely absent in the proposed bio-zone I. It shows its first appearance in the lower part of bio-zone II (lithozone II of De Terra). Here the assemblage is: *Achnanthes*, *Amphora*, *Coscinodiscus*, *Mastogloia*, *Navicula*, *Rhopalodia*, *Synedra* and *Campylodiscus*. In the proposed bio-zone II also appears for the first time the other pennate forms like *Peronia*, *Pinnularia*, *Tetracyclus*, *Tabellaria*, *Licmophora*, *Rhoicosphenia*, *Frustulia*, *Stauroneis*, *Amphipleura*, *Pleurosigma*, *Nitzschia*, etc. All the above evidences suggest a Mio-Pliocene age to the lower Karewa.

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The author is grateful to Shr M. V. A. Sastry, Director, Palaeontology and Stratigraphy Division, Geological Survey of India, for his constant guidance and valuable suggestions in carrying out the present work. He is also thankful to his friends S/Shri Gopal Singh, Dr. S. K. Chandra, Dr. Anjan Kr. Chatterjee, S. C. Shah and M. N. Gururaja for various help.

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EXPLANATION OF PLATES

PLATE 1

1. *Cyclotella comta* (Ehrenberg) Kutzing. × 1200.
2. *Cyclotella* sp. × 530.
3. *Cyclotella comensis* Grünow. × 1200.
4. *C. transilvanica* Pantocsek. × 530.
5. *C. meneghiniana* Kützing. × 530.
6. *C. comta* (Ehrenberg) Kützing. × 530.

7a and 7b. *Melosira granulata* (Ehrenberg) Ralfs. × 530. Girdle view.

8a and 8b. *M. ambigua* (Grünow) O. Müller var. *karewana* Rao & Awasthi. × 530. Valve and Girdle view respectively.

9. *Cyclotella* sp. II. × 530.
10. *Coscinodiscus marginatus* Ehrenberg. × 1200.
11. *Cyclotella* sp. III. × 530.
12. *Melosira* sp. × 530.
13. *Coscinodiscus morroensis* Hanna. × 530.

PLATE 2

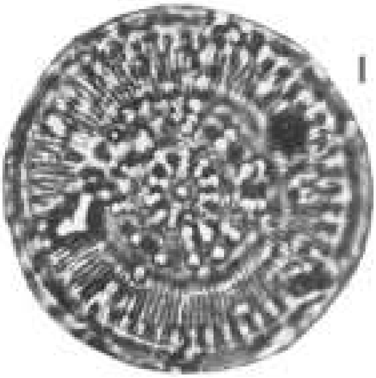
14. *Navicula americana* Ehrenberg. × 530.
15. *Achnanthes* sp.

16-18. *Fragilaria construens* (Ehrenberg) Grünow. × 530.

19. *F. pinnata* Ehrenberg var. *lancettula* (Schumann) Hustedt. × 1200.
20. *Rhopalodia gibba* (Kutzing) O. Muller. × 530.
21. *Rhopalodia* sp. × 530.
22. *Meridion* sp. × 1200.
23. *Synedra* sp. × 1200.
24. *Diploneis ovalis* (Hilse) Cleve. × 1200.
25. *Tabellaria flocculosa* (Roth) Kützing. × 530.
26. *T. fenestrata* (Lyngbye) Kützing. × 530.
27. *Amphora* sp. × 1200.
28. *Tetracyclus emarginatus* (Ehrenberg) W. Smith. × 530.
29. *Cocconeis placentula* Ehrenberg. × 530.
30. *C. disculus* (Schumann) Cleve. × 530.
31. *Surirella* sp. × 1200.

PLATE 3

32. *Cymbella aspera* (Ehrenberg) Cleve. × 1200.
33. *Gomphonema acuminatum* Ehrenberg. × 530.
34. *G. clevei* Fricke. × 530.
35. *Stauroneis phoenicenteron* Ehrenberg. × 530.
36. *Denticula* sp. × 1200.
37. *Pinnularia gibba* Ehrenberg. × 530.
38. *Navicula elongata* Poretzky. × 530.
39. *Epithemia sorex* Kützing. × 530.
40. *Cymbella cistula* (Hemprich) Kirchner. × 530.
41. *Eunotia valida* Hustedt. × 530.
42. *E. pectinalis* Rabenhorst var *undulata* Ralfs. × 530.
43. *E. robusta* Ralfs. × 530.
44. *Synedra crystallina* (Agardh) Kützing. × 1200.
45. *Rhoicosphenia curvata* (Kützing) Grünow. × 530.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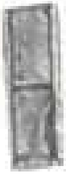
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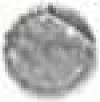
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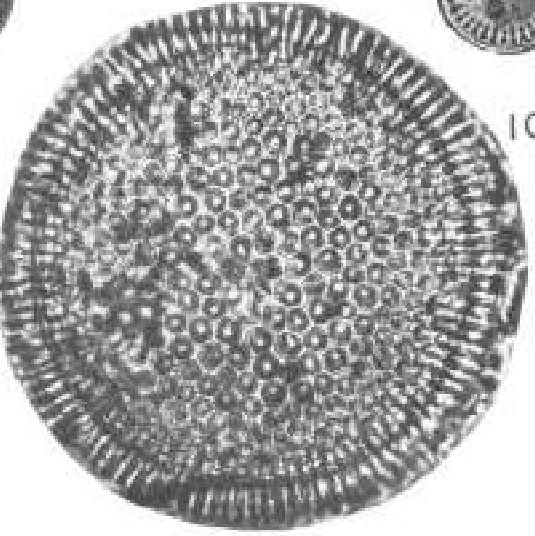
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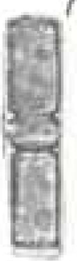
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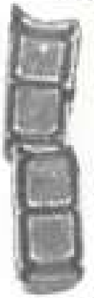
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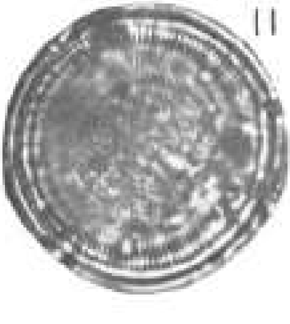
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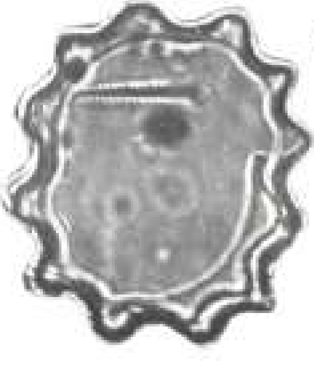
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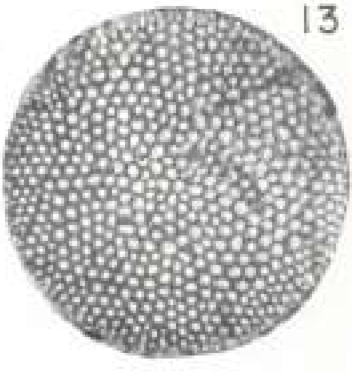
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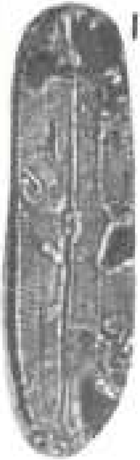
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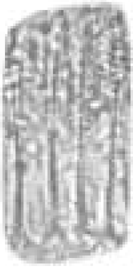
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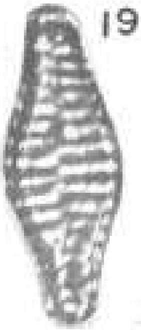
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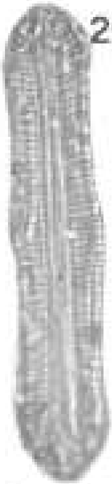
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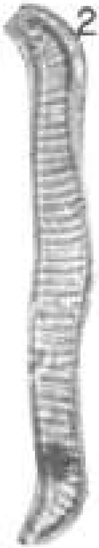
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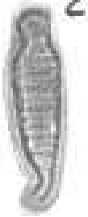
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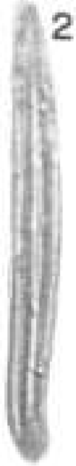
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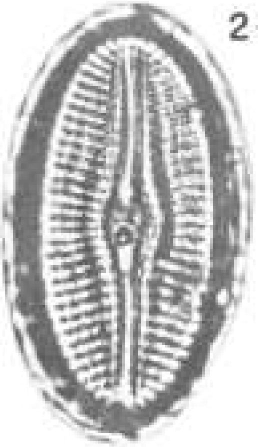
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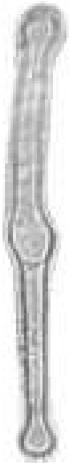
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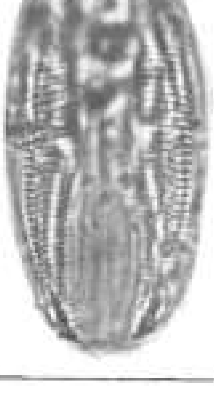
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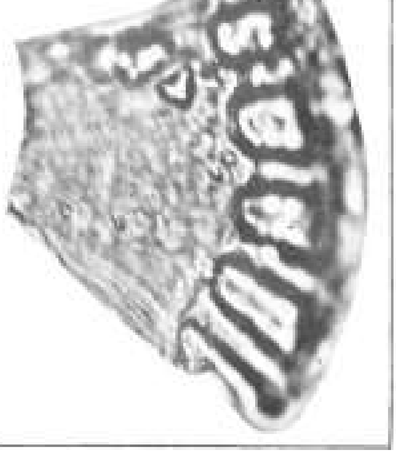
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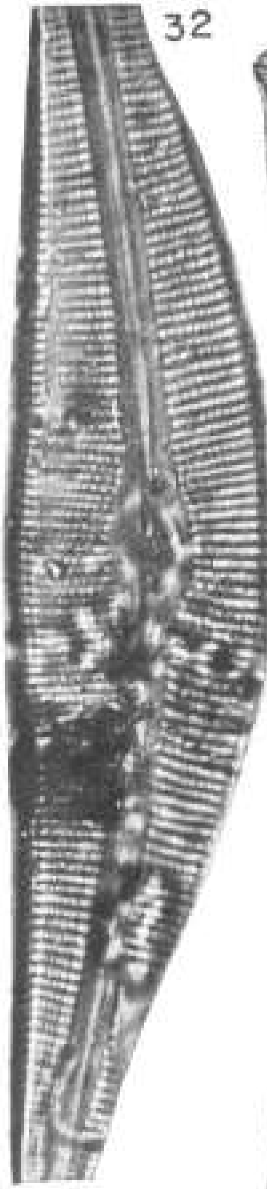
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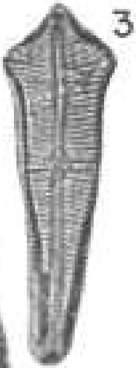
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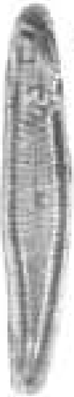
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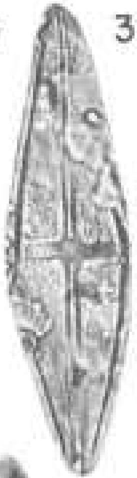
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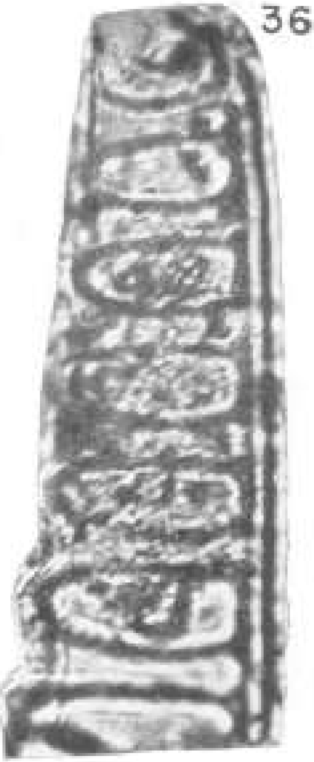
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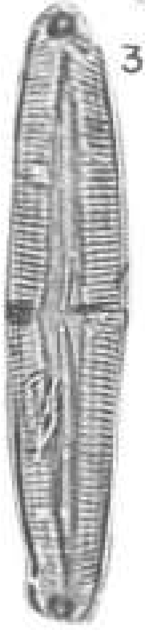
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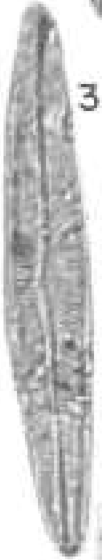
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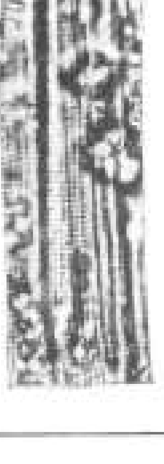
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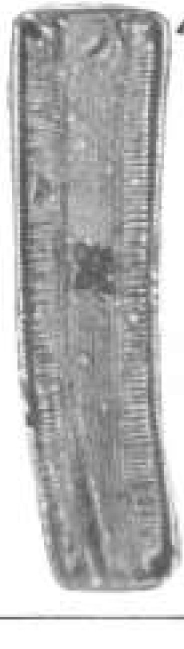
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LIDGETTONIA MUCRONATA SP. NOV. A FEMALE FRUCTIFICATION FROM THE LOWER GONDWANA OF INDIA

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ABSTRACT

A new species of *Lidgettonia*, *Lidgettonia mucronata* has been described. It consists of a spathulate fertile leaf with veins spreading out from the base, dichotomise and form meshes. Eight short pedicels, each carrying one cupulate disc at its apex are attached on the basal part of the fertile leaf, 4 on either side. Cupulate disc is almost circular, carrying small seeds on its underside.

INTRODUCTION

THOMAS (1958) described from a place called Lidgetton in Natal, South Africa a collection of fossil plants which consisted of sterile leaves of *Glossopteris*, some fertile leaves, a few sporangium-like organs and isolated seeds. Under a new generic name, *Lidgettonia*, he included these sterile leaves of *Glossopteris* found in association with the fertile leaves, bearing two rows of 4-6 small, disc-like cupules. The type species is *Lidgettonia africana*. Thomas's idea of *Lidgettonia* was that the plant had foliage leaves of *Glossopteris* type which were accompanied by smaller fertile leaves bearing cupules. In these plants the reproduction was probably effected through the agency of structures produced in small and delicate cupules, borne on stalks of the fertile leaves. He further observed that while there is no direct and indisputable evidence as to the nature of the bodies borne in the "cupules", there is considerable likelyhood that the cupules contained small elongated sporangia and also small seeds in some of them. Both these were occuring in considerable abundance in the matrix with fertile leaves. Therefore, the idea of Thomas was that these fertile leaves carried sporangia as well as seeds.

Surange and Maheshwari (1970) instituted from India another species, *Lidgettonia indica* and regarded it as only a female fructification. The fertile leaf of *L. indica* possessed spathulate lamina with dichotomising veins, but the anastomosing was not clear. From the long stalk of the fertile leaf sprang 2-4 (mostly 4) pedicels in a single row, bearing what looked like ovules; each pedical carried one ovule at its apex. What Thomas described as cupules in *L. africana* were regarded as ovules or seeds in *L. indica* by Surange and Maheshwari. Furthermore, Surange and Maheshwari's *Lidgettonia* had only a single row of so called ovules, whereas Thomas's *Lidgettonia* had two rows of cupulate discs. Recently Surange and Shaila Chandra placed *Lidgettonia indica* under a new name, *Partha indica*.

White (1964) described *Lidgettonia australis* from Australia. It consisted of supposedly seed-bearing scale leaves, which do not have the arrangement characteristic of *Lidgettonia*. The type specimen of *Lidgettonia* is a fertile leaf and it may be better to restrict only fertile organs to this genus as suggested by Surange and Maheshwari (1970). White's specimen should therefore, be excluded from *Lidgettonia*.

The material for the present paper comes from a thick bed of hard, compact, clayey shale, exposed in a road cutting at Hinjrida Ghati, north of Handappa in Orissa. The age is probably Upper Raniganj. There is only one specimen, fairly well preserved in the form of impression in our collection.

DESCRIPTION

Genus — *Lidgettonia* Thomas

Emended diagnosis — Fertile leaves short, spathulate lanceolate with broadly round apex; veins spreading from base, forking and anastomosing; lower portion of the leaf or petiole with two longitudinal rows of disc-like cupules; cupules 3-4 in each row, carried on short stalks, flat, almost circular, disc-like; margin undulating.

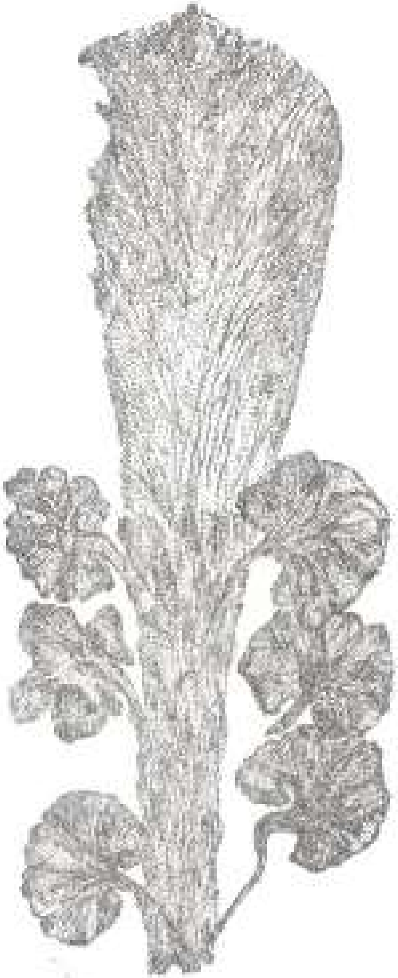
Lidgettonia mucronata n. sp.

Diagnosis — Fertile leaf 7 cm. long, spathulate, apex broadly rounded with mucronate tip; lamina 1·6 cm. broad at the broadest part; no midrib, veins spread out from the base, dichotomise, form meshes; eight short pedicels attached on basal portion of the leaf, four on either side, pedicels 6-7 cm. long, 1 mm. broad; cupulate discs 8 mm. in diameter, almost circular but circle incomplete, margins undulating; small, unwinged seeds probably on the under side of the cupulate discs.

Holotype — B.S.I.P. No. 35035
Age — Raniganj Stage.
Locality — Handappa, Orissa, India.

The one specimen in our collection occurs on a fine grained, grey shale and the fossil also is grey in colour. It is, therefore, difficult to photograph because of the lack of contrast with the matrix. The holotype and its counter part are shown in Pls. 1, 2, Figs. 1, 2, 6; Text-Figs. 1, 2. Fertile leaf is almost complete and it is 7 cm. long and 1·6 cm. broad at the broadest part. The leaf is spathulate in shape with broadly rounded apex, which is drawn out in the middle into a mucronate tip (Pl. 2, Fig. 6; Text-Figs. 1, 2). The lamina is contracted towards the base into a long petiole, measuring about 6 mm. in breadth. The

TEXT-FIG. 1 — Holotype of *Lidgettonia mucronata* B.S.I.P. No. 35035 showing seven cupular discs attached by their stalks to the basal portion of the fertile leaf. The fourth cupular disc on the right side is missing. × 2.



TEXT-FIG. 2—Counter part of the holotype. Here only six cupular discs are seen. Mucronate tip of the spathulate fertile leaf is clearly seen here. × 2.

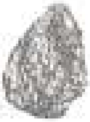
venation is clearly preserved in some portions of the leaf (Pl. 2, Fig. 6; Text-Figs. 1, 2). There is no midrib. A number of veins spread out from the base of the lamina, those in the middle running straight upwards. All secondary veins dichotomise a number of times and form short meshes right up to the margin. The meshes are comparatively long, narrow and hexagonal. The meshes mostly occur near the margin.

The disc-like cupules are attached by their stalks on the basal portion of the leaf (Pls. 1, 2, Figs. 1, 3, 6; Text-Figs. 1, 2). The stalked cupules are borne in two rows, four on either side of the leaf. One cupule on the right side (Text-Fig. 1) is missing, thus only seven cupules are present in the specimen, but the total number must have been eight. The stalks or pedicels, measuring 6-7 mm. in length and 1 mm. in breadth, spring from the petiole in a row one below the other on each side. It appears likely that the stalks are attached on the upper side of the petiole. The stalks bear more or less circular, fluted, cupular discs at their apical ends (Text-Fig. 3). It looks as if the stalk has branched into finger-like fashion or broadened at its apical end where it is attached to the disc (Pl. 1, Figs. 3, 4; Text-Fig. 3).

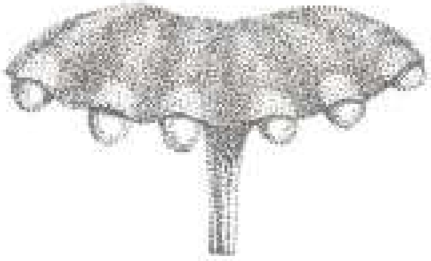
The cupular discs measure about 8 mm. in diameter and are almost circular in outline, but the circle is not complete (Text-Fig. 3). The disc is thus more like a horse-shoe and appears broken at a place where the stalk is attached with it (Pl. 1; Figs. 3, 4). It appears to us that the incompletely circular cupule is like an umbrella type shallow disc, which has given to it a fluted appearance at the margin. All the cupules in the specimen are preserved in such a way that only their upper sides are visible. Oval to round swellings are seen on this surface and it appears certain that the underside of the disc contain seeds. The swellings indicate the positions of the seeds attached on the undersides of the cupular discs (Pl. 1, Figs. 3, 4; Text-Figs. 3, 4, 5, 6).

One detached seed, which might have been ejected out of a cupulate disc, is seen lying near the fructification (Pl. 1, Fig. 3;

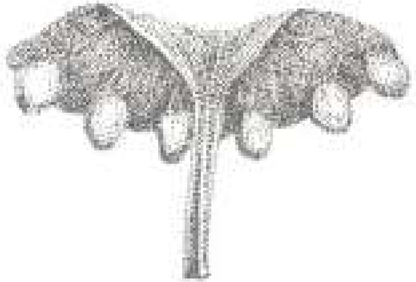
TEXT-FIG. 3—A cupular disc enlarged to show the swellings on its upper surface, probably indicating the positions of the seeds on its under side. × 8.



TEXT-FIG. 4—An unwinged seed lying close to the specimen shown in Pl. 1, Fig. 3. Such isolated seeds are found in large numbers in the material. × 5.



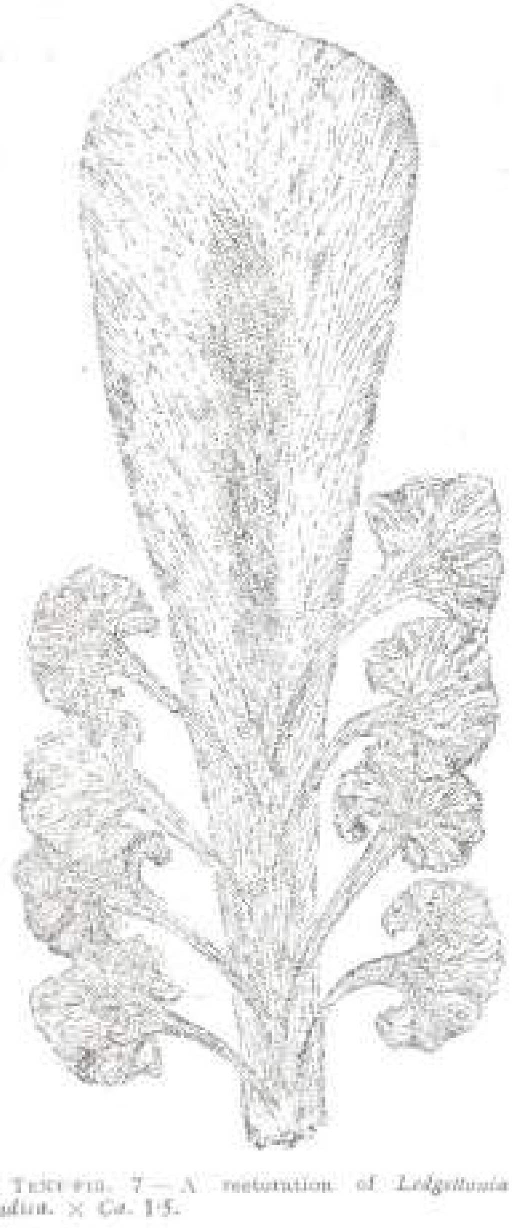
TEXT-FIG. 5—A diagrammatic restoration of a stalked cupular disc showing how the seeds might have looked when viewed from the side. × 6.



TEXT-FIG. 6—A diagrammatic view of the under side of the cupular disc showing the attachment of seeds. × 6.

Text-Fig. 4). The swellings on the cupulate discs are almost of the same size as the detached seed and, therefore, this seed could be assigned with fair amount of certainty to this fructification. The seed is small, unwinged, 3 mm. long and 2 mm. broad (Pl. 1, Fig. 5). A number of such detached seeds are present in our collection.

It is undoubtedly true that the attachment of seeds to the cupulate disc has not been proved by the find of such a specimen so far. But there appears to be no reason also to suppose that these cupulate disc bore sporangia as Thomas (1958) had suggested. The male fructifications of Glossopteridales known so far are constructed on entirely different patterns (Surange and Maheshwari, 1970). Moreover the sporangia are too small in size; on the other hand seeds could easily be correlated with the swellings on the cupulate discs. The possibility that the cupules bore seeds is, therefore, much greater.



TEXT-FIG. 7 — A restoration of *Lidgettonia indica*. × Ca. 1.5.

RECONSTRUCTION

Text-fig. 7 shows a restoration of *Lidgettonia mucronata*. Eight cupular discs, four springing out from each side are shown attached to the upper side of the petiole. The umbrella type cupular discs partly shield small seeds, which are attached on their under surface. Text-figs. 5 and 6 show how the seeds must have been attached on the disc.

COMPARISON AND DISCUSSION

Our specimen compares favourably with the type species of *Lidgettonia africana* figured in Pl. 23, figure 4 by Thomas (1958). In this figure only half of the fertile leaf is preserved, which is about 4 cm. in length but the entire leaf must have been longer than this. The upper part being absent, it is not known what was the shape of the fertile leaf of *L. africana*. The shape of the fertile leaf of *L. mucronata* is as shown in Text-Figs. 1 and 2 and is different from Thomas's fertile leaf of *L. africana* as shown in his Text-fig. 2 (Thomas, 1958). Thomas regarded the contracted lower part of the fertile leaf as a petiole, but in our specimen we do not know if it can be called a true petiole. Further, cupulate discs in our specimens are larger in size than those of *L. africana*. Moreover, *Lidgettonia mucronata* and *L. africana* are found in two different continents and perhaps there may be some difference in age also. We have, therefore, described our specimen under a new specific name.

Surange and Maheshwari's species, *Lidgettonia indica* does not appear to belong to *Lidgettonia* at all. Fertile leaf of *L. indica* Surange and Maheshwari is different in every respect from that of *Lidgettonia africana* and *Lidgettonia mucronata* described here. The so-called ovules or seeds in the former arise in a *single row* from the stalk, whereas in *L. africana* and *L. mucronata* the cupulate discs arise in *two rows*. The entire specimen of *L. indica* gives a completely different look from the specimens of *L. africana* and *L. mucronata*. Thus *L. indica* is different in its organization from *Lidgettonia* and, therefore, it has now been transferred to a new genus *Partha*.

Thomas (1958) also included some sterile leaves under the genus *Lidgettonia* which were found associated with the fertile leaves. Such association of sterile and fertile leaves does not prove anything, particularly when, as a rule, diverse types of detached organs and taxa lie close together on a piece of shale in the Gondwana material. The description of the sterile leaves should, therefore, be deleted from the generic diagnosis of *Lidgettonia* as given by Thomas (1958, p. 180) and the genus should be confined to the fertile leaves only. The generic diagnosis has been emended accordingly in the present paper.

Thomas (1958) regarded that some of the cupulate discs of *Lidgettonia* carried sporangia, and some carried small seeds. The male organ bearing sporangia of *Glossopteris* have a different type of organization as is evident from the known male fructifications like *Glossotheca* and *Eretmonia*. It is more likely that these cupulate discs, like those of peltaspermaceous pteridosperms, carried only female type of reproductive organs in the form of ovules or seeds.

The structure of the cupulate disc as has been restored in Text-Figs. 5, 6 show superficial resemblances with the cupulate disc of *Lepidopteris* of the Peltaspermaceae. But in size, shape and other structural details *Lidgettonia mucronata* is distinct from *Lepidopteris*. The presence of Mesozoic peltaspermaceous type of fructification in the Permian is rather interesting. These might represent blind evolutionary lines culminating into extinct gymnosperm groups.

Thomas (1958) ascribed *Lidgettonia* to *Glossopteris* on the evidence of association. The anastomosing of secondary veins into distinct meshes in the fertile leaf shows similarity to *Glossopteris* as well as *Gangamopteris*. The latter is without midrib, but it may be added that most of the scale leaves in the *Glossopteris* flora (many of them could really be the fertile leaves) do not possess midrib. It is not necessary at all to presume that *Glossopteris* leaves will have fertile scale leaves with midrib. The fertile leaves are specialized types of leaves and, therefore, there is nothing to prevent a normal *Glossopteris* plant to have fertile leaves which are distinct from the sterile leaves. *Lidgettonia mucronata*, therefore, could be regarded as female fructification of either *Glossopteris* or *Gangamopteris* type of leaf genus. However, the possibility of its belonging to *Glossopteris* is more because there is not a single species of *Gangamopteris* present in the fossil locality where *L. mucronata* is found. On the other hand, there are present more than twenty species of *Glossopteris*. In any case *Lidgettonia mucronata* could be assigned to Glossopteridales without any doubt.

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EXPLANATION OF PLATES

PLATE 1

1. Holotype of *Lidgettonia mucronata* B.S.I.P. No. 35035. Fertile leaf with four cupules attached on the left side and three cupules on the right side (see arrows) at its basal portion. The venation is clearly seen. × *Ca.* 1·5.

2. Counter part of the holotype with three cupules on either side of the basal portion of fertile leaf. × *Ca.* 1·5.

3. Six stalked cupules as seen in Fig. 2. magnified to show their attachment to the basal portion of the leaf. Note an isolated seed (see arrow) on the top left. × *Ca.* 3.

Fig. 4. A cupular disc enlarged to show fluted margin and the swellings on the surface. × 4.

5. The isolated seed seen in Fig. 3 enlarged. × 6.

PLATE 2

6. Holotype of *Lidgettonia mucronata* as shown in Fig. 1. (B.S.I.P. No. 35035) enlarged to show the venation of the fertile leaf and seven cupules attached to its basal portion, four on the left and three on the right side (see arrows). × 3.

3

5

4

2

1

6

PROFESSOR JOHN WALTON (1895-1971)

PROFESSOR JOHN WALTON (1895-1971)

DIVYA DARSHAN PANT
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BY the death of Professor John Walton on February 13, 1971 the world has not only lost an eminent scientist but also one of the noblest and most gentle personalities whom the writer of these lines has ever known in that most courteous tribe of British gentlemen called "Professors".

Born in 1895, John Walton was the son of the famous British artist, Mr. E. A. Walton who was one of the leading artists in the group known as Glasgow School and President of the Royal Water Colour Society of Scotland.

After having his early education at Daniel Stewart's College in Edinburgh, he entered St. John's College, Cambridge in 1915 and from there he passed his Part II Tripos Examination in Botany with first class, honours. His academic degrees included M. A., and Sc.D. from Cambridge, D.Sc. from Manchester and honorary degrees of LL.D. from McMaster University, Canada, and Dr.es Sc. from Montpellier and Lille Universities in France.

Having been brought up in the Quaker faith he did not join the Army during World War I but in 1918 served on an ambulance train under the Red Cross. He returned to Cambridge in 1918 and joined the brilliant group of palaeobotanists who were at that time researching under Sir Albert Charles Seward, then Professor of Botany and Head of the Cambridge Botany School.

He was botanist to the first Oxford Expedition to Spitzbergen in 1921. In 1922-23 he served as Demonstrator in Botany at Cambridge and from 1924 to 1930 as Lecturer in Botany at the University of Manchester. In 1930 he succeeded Professor F. O. Bower to the coveted Regius chair of Botany at the University of Glasgow and served there with distinction till his retirement in 1962, when he was honoured by being made Regius Professor Emeritus of Botany and from 1967 till his death the Dean of Faculties at the University.

He was a Fellow of the Royal Society of Edinburgh and Vice-President from 1937-40. He was President of the Botany Section of the British Association for Advancement of Science. He was also corresponding member of the Botanical Society of America and honorary member of the Botanical Society of Poland and Geological Society of Belgium. Being deeply interested in nature conservancy, he worked from 1949 to 1952, as a member of the Scottish Society for Nature Conservancy. From 1949-1954 he was a Forestry Commissioner, Forestry Commission of Great Britain and editor of several National Forest Park Guide Books for Scotland. His other activities included work as Chairman and Vice-President of the Scottish Youth Hostels Association, Governor of West of the Scotland College of Agriculture and Chairman of its Research Committee, President of the Glasgow Tree Lovers Society for many years, President of the Andersonian Society (Naturalists), Glasgow, Member of the Board of Consultants, Muskeg Research Institute, University of New Brunswick, Canada. He inherited a love for the fine arts from his illustrious father and became the Honorary Curator of the Fine Arts Collections at the University of Glasgow. In paying a tribute to Professor Walton after his death, Professor McLaren Young, Professor of Fine Arts in Glasgow University wrote that they found such a sensitive appreciation of art in him that he was an ideal person to whom to turn for a variety of different kinds of advice.

In 1918 he married Dorothy Seward, daughter of his Professor, Albert Seward. Mrs. Walton survives him along with their son, who is a geologist in Canada and daughter, who is a medical doctor in Scotland.

His major contributions include numerous papers on Palaeozoic plants and particularly those from the Lower Carboniferous of Scotland and Wales and from the Lower Gondwanas of Africa. His book, "*Introduction to Fossil Plants*", of which there were two editions in his life time, is still widely used by students of palaeobotany all over the world. Professor Walton's name will remain immortal as the originator of the cellulose peel and transfer preparation techniques and as the discoverer of the first structurally preserved bryophytes from the Carboniferous. The new techniques which he developed created a revolution in the study of fossil plants. Petrified fossils, could now be studied by cutting serial sections like those obtained from living plants by the use of microtome. Nay, what is not possible even today with a microtome in living plants became possible with the peel section technique in fossils, e.g., the cylindrical peels which he obtained from petrified stems by etching the surface of axes of *Lepidophloios wunschianus* and, thereafter rotating them on a klinostat till the peel solution dried. His transfer technique made it possible to turn compressed fossils upside down by uncovering the surface which used to remain permanently hidden by the rock previously. His new techniques thus enabled palaeobotanists to study fossils in a manner that had never been possible before and what is more, they have helped in locating newer details in previously worked out material.

He was no mere palaeobotanist but his interest included work on living plants like the release of antherozoids from the antheridia of bryophytes and the anatomy of roots of *Equisetum limosum*. His international status as a botanist led to his being invited to give lectures in various countries, France, U.S.A., Canada, Poland, Holland and in India where he was invited to deliver the Seward Memorial Lecture at the Birbal Sahni Institute, Lucknow.

His papers are characterized by a remarkable originality of approach, e.g., his work on the mode of formation of fossil compressions (*Phil. Trans. R. Soc. London*), *Calathospermum*, *Protocalamostachys* (*Trans. R.Soc. Edinburgh*), etc. His theoretical conclusions are marked by a rare brevity and critical appraisal of earlier work so much so that the reader must not only go through the lines of his cryptic remarks but also read between them.

In the proper assessment of his work as Professor of Botany at the University of Glasgow, it would be best to quote from a tribute published in the "*College Courant*" by one of his colleagues, Major S. A. Hutchinson:

"The broad understanding of his subject was reflected in the contributions which he made to many sides of the department's work in his thirty-two years as Regius Professor. His inheritance was a powerful tradition of taxonomic and morphologic teaching, an old building, and the severe financial restrictions of the early 1930's. With enthusiastic vigour he overcame this situation by obtaining a private donation for a new laboratory. His alertness to changing needs was shown by his decision to allocate this laboratory for advanced teaching and research in plant physiology and mycology. This was the start of other developments which produced a very broadly based department by the time of his retirement. He took a full part in other University affairs, serving as Dean of the Faculty of Science during the difficult period of the Second World War".

"... This is a bare summary of some of the professional achievements of a wise and hardworking man. But those of us who served on his staff know many characteristics which it doesn't reveal. He was a firm, but tolerant and kindly leader. He encouraged his colleagues to develop their ideas in a free intellectual atmosphere, he smoothed their paths and supported them in all ways available to him. He was an unequivocally, almost uncomfortably, honest man, who had a short sharp way with pretentiousness or deceit. But to those who met his standards he was an open-hearted, courteous and sincere friend. His prowess on the tennis and badminton court and earlier on the rugby football field, are well remembered by his contemporaries. His great personal bravery made light of physical disbilities in later life ..."

I have had the good fortune of associating myself with him in 1954-1955 and, like many other palaeobotanists all over the world, I owe him a deep debt of gratitude for his generous help in giving material for my work and for his invaluable guidance. A handsome personality, always immaculately dressed, he overwhelmed me by his innate goodness. My stay at Glasgow was made particularly memorable by his and Mrs. Walton's kindnesses and their week-end At Homes and dinners. After leaving Glasgow, I had only one opportunity of meeting him and this was at Lucknow when he came to India in 1964 to deliver the Seward Memorial Lecture. I found him just the same as at Glasgow but he appeared a trifle weak. Needless to say that I shall always cherish the sweetest memories of my visit to Glasgow. In this respect, I am not alone since I have heard many other botanists remembering the kind hospitality of the Waltons with utmost gratitude.

STUDIES ON PETROGRAPHY AND MIOFLORISTICS OF COALS OF KARHARBARI AND BARAKAR STAGES FROM PARTS OF NORTH KARANPURA COALFIELD, BIHAR

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ABSTRACT

In the North Karanpura Coalfield, around Bachra-Khalari two coal measures of lower Gondwana age are exposed having diversified coal characters. The coals show marked differences in their physico-chemical and floral conditions of deposition as revealed by detailed petrographic and palynological studies. Based on palynological findings, the status of the two coal measures — the lower measure belonging to upper Karharbari Stage and the upper measure to lower Barakar Stage — is ascertained. Miofloristic aspect of distribution reveals a close affinity of the Karharbari Stage with the Barakar Stage. This is also supported by geological evidences in the area and suggests a gradual passage of one measure to the other.

INTRODUCTION

THE area under study is a part of North Karanpura Coalfield and is situated at the southern fringe of it, bounded by the latitudes 23°38′ and 23°42′-30″ North and longitudes 84°59′30″ and 85°6′30″ East and includes thirteen coal seams of various thicknesses within the lower Gondwana Group of rocks.

The area was investigated by many workers like Jowett (1925), Banerjee (1958), Ghosh (1958), Mukherjee *et al.* (1959), Mehta *et al.* (1963) but attention was given mainly on the eastern sector, i.e. in the Bachra area, Pareek (1965) etc. and Western sector, i.e. Khalari area was least emphasized. From the field study, the following dissimilarities of coal and coal bearing strata between the eastern sector and the western sector are discernible.

EASTERN SECTOR

Dip varies from 6°-10° towards N30°W-W20°W.
Topography is highly undulating.
High grade fire clay association.
Roof rock-sandstone.
Seam thickness varies greatly.
A pebble bed is present at the base, and another occasionally above the lower seams.
Structural disturbances considerable.
Two major coal seams with average thickness of 4·5 metres.
Coal is dull, soft, massive or incipiently banded.
Pyrite content high.
Spontaneous heating common.
Shale bands within coals are almost absent.
Vitrain bands are rare, mostly found as streaks.
Ash is brownish to buff in colour.
Matured coal with high heat value.

WESTERN SECTOR

Dip varies from 12°-15° towards S23°W.
Peneplaned country.
No fire clay.
Roof rock-shale.
Seam thickness more or less persistent.
No association of pebble bed with the coal seams.
Structurally less disturbed.
Ten major coal seams with average thickness of 6·7 metres.
Coal is bright, hard, compact banded and well cleaved.
Low pyrite content.
Spontaneous heating rare.
Numerous shale bands (2·3 cm to 7·6 cm) are always present.
Persistent and numerous thick vitrain bands.
Ash is whitish to bluish grey.
Maturity less and low heat value.

The existence of two coal bearing horizons (i.e. lower measure and upper measure) have been assumed on the basis of aforesaid account, i.e. on the basis of diversified coal characters, occasional presence of a pebble bed between them (only in the eastern sector, which marks the base of the upper horizon) and rarely by the lithological characters of the associated sediments. In this work comparative studies on detailed petrography and miofloral assemblages have been made with a view to understand the genetic history of the coals and paleogeography of the area. An attempt has also been made to determine and correlate the stratigraphic position of the two measures.

GEOLOGY OF THE AREA

The lower measure occurring in the eastern sector overlies Talchir Formation with a pebble bed at the base. Towards the north, it grades into upper measure in the eastern part of the area, extending ENE and SSW with an inconsistent, thin pebble bed which marks the base of the upper horizon. The lower measure pinches out at the south central part along with the underlying Talchir Formation and in the western sector, the upper measure is seen to rest on the Pre-cambrians along the southern margin. The lower measure contains two coal seams of variable thickness of which the bottom seam (lower Bachra seam) varies in thickness from 4·8-5·5 m and top seam (upper Bachra seam) varies from 3·2-3·7 m and dip 6°-10° towards N30°W to N20°W. The upper measure includes ten major coal seams in the western sector and one in the eastern sector, the order of sequence and average thicknesses of these (as revealed from drilling record) are as follows:

Seam	*Thickness*
Karkata IV	5·8 m
Karkata III	1·83 m
Karkata II	3·96 m
Karkata I	2·73 m
Karkata	3·35 m to 4·25 m
Bisrampur	6·7 m
Bukbuka	19·5 m
Dakra	7·62 m
Dhub	2·13 m
Damodar	17·3 m
Damodar-Saphi (?)	Over 2·9 m

The stratigraphic position of Damodar-Saphi seam could not be ascertained due to lack of data but from other studies it seems to be an independent seam (since its structural attitude and other special coal characters are different from those of the western sector). All the seams dip 12°-15° towards S23°W and excepting Damodar-Saphi seam which has a dip of 2°-3° towards N65°W.

Out of all the mentioned seams, both the seams of lower measure and Karkata II, Karkata, Bisrampur, Bukbuka and Dakra seams of upper measure are economically exploited. The Damodar seam is in its development stage. Lithologically, the lower measure is represented by a basal orthoquartzitic sandstone unit with intercalation of coal, subarkosic sandstone, shale, fire clay etc. and upper measure is represented by coarse gritty, friable and white subarkosic sandstone, carbonaceous shale, coal, siltstone and medium to coarse grained arkosic sandstone.

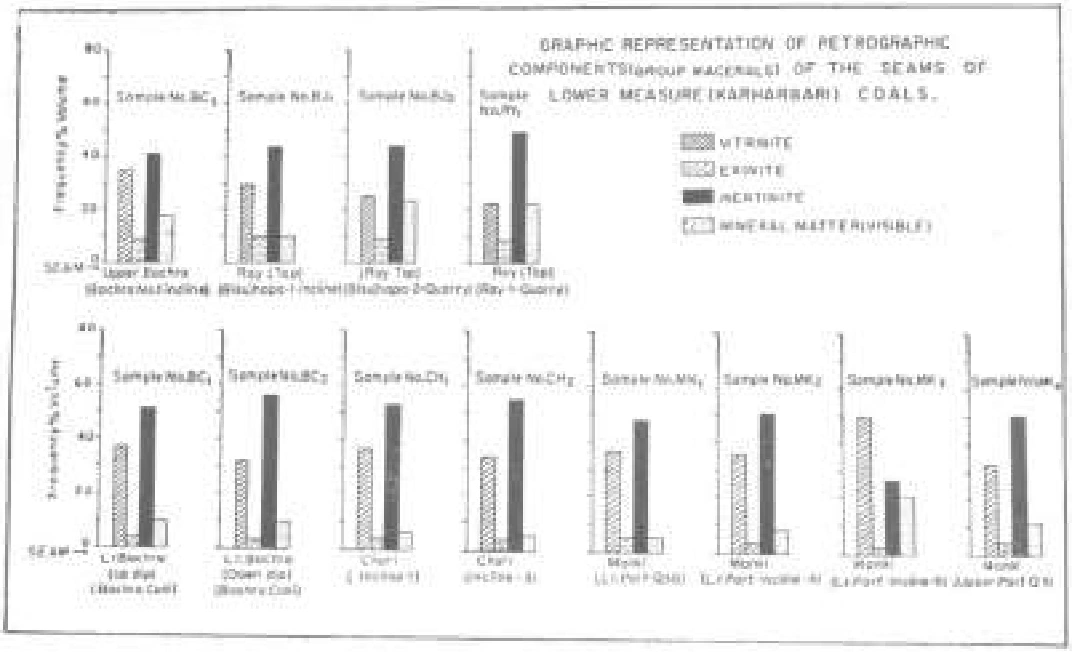
PHYSICAL CHARACTERS OF COALS

The lower measure coals are greyish black in colour, very finely banded and dull in appearance. Durain forms the major bulk of the coal and fusain is subdominantly present.

The upper measure coals are bright, coarsely banded and hard and compact. Vitrain and durain constitute the major bulk of which vitrain is present in higher fraction.

MATERIALS AND METHODS

Coal samples were collected from all working sections of the inclines, and from the places where coal is otherwise exposed. By choosing a fresh surface, samples were collected by channelling a seam profile and block and pellet samples were prepared for petrographic studies and representative homogeneous coal matrix of 2·5 mm size were taken for palynological studies. To envisage the quantitative distribution of the miospores, pillar samples were critically studied. For separating the miospores, the coal samples were treated with Schulze's solution (HNO_3 and $KClO_3$) in a jar in 1 : 1 proportion, some nitric acid was added after 24 hours. After 2 to 3 days when the oxidation was complete, the supernated solution was decanted off and the sample was thoroughly washed with distilled water, then the material was treated with 10% KOH solution for about 10 minutes. The residues were then thoroughly washed with distilled water to make them completely



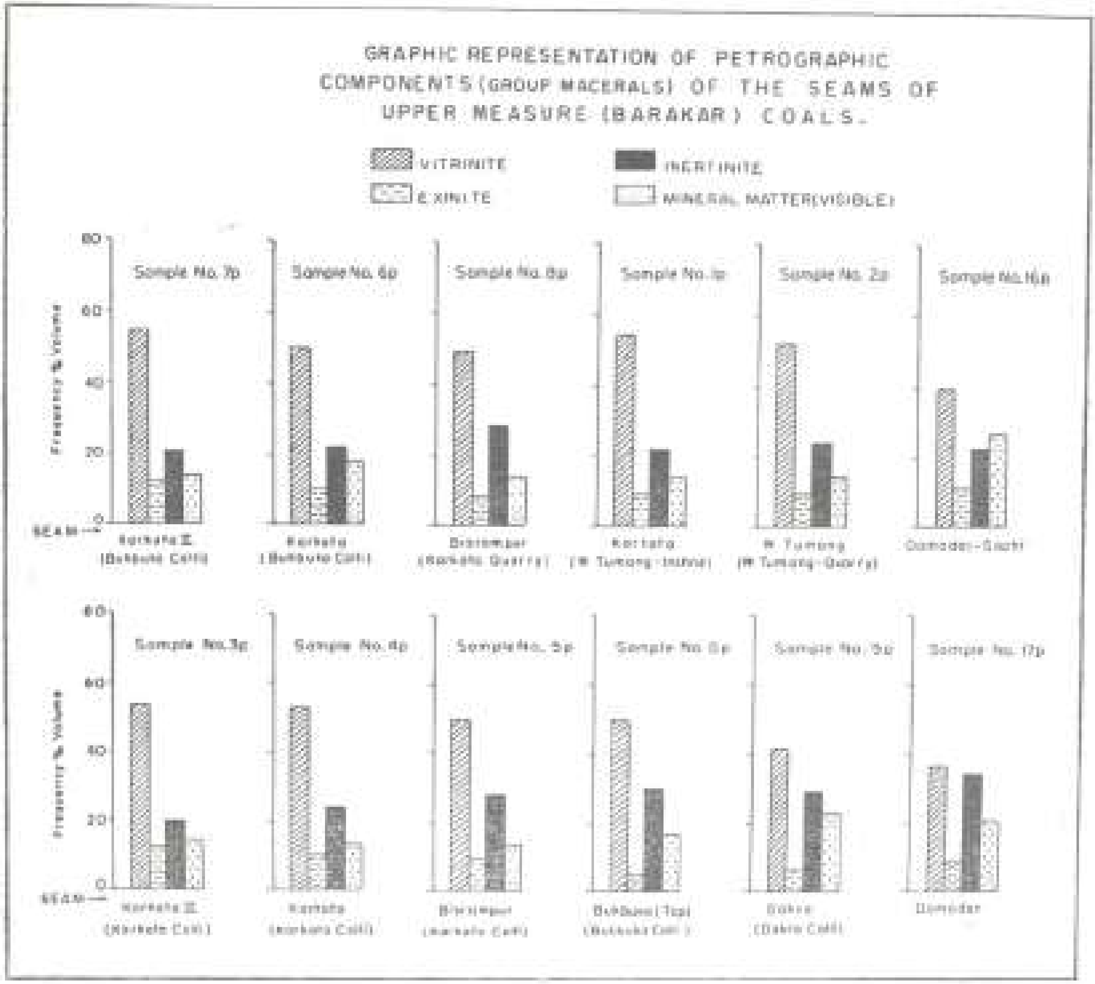
TEXT-FIG. 1

free of alkali. This end product contained miospores whose concentration was increased by series of centrifuge operations. The glycerine soaked material was then mounted in glycerine jelly and formaline was used as hardener.

PETROGRAPHIC STUDIES

From the qualitative maceral study, it was revealed that the lower measure coals show fine bandings of vitrinites and exinites and thick lenses or bands of fusinites or semifusinites (Plate 1; Figs. 1, 2 & 3); whereas upper measure coals constitute thick alternate bands of vitrinitic and exinitic masses with lenses and thin bands of semifusinites (Plate 1; Figs. 4, 5 & 6). Telinite is not very well represented in lower measure and different transitions in fusinites are present (Plate 1, Fig. 2). These coals include resin bodies which are mostly carbonized although resin content is poor. Different types of sclerotia are seen to occur in considerable proportion (Plate 1, Fig. 3). Upper measure coals contain low amount of sclerotia. Micrinite is sporadically distributed in both the measures. Cutinite is represented in both the measures in low amount (Plate 1, Fig. 6). Visible mineral matters are mostly associated with the exinitic masses or sometimes impregnated in the cell cavities of fusinites. The lower measure shows higher mineral concentration whereas it is disseminated in the upper measure. Pyrite is the dominant mineral matter in lower measure coals and clay is present in very high proportion in the upper measure coals.

Quantitatively the general order of abundance of group macerals in lower measure is inertinite (49·2-65·5%), vitrinite (27·6-41·2%) and exinite (3·2-11·5%), and in upper measure is vitrinite (45·9-63·1%), inertinite (23·2-43·1%) and exinite (8·9-15·2%). The quantitative maceral studies have been shown in the tables (Tables 1 & 2) and are illustrated by Histograms (Text-figs. 1 & 2). From the maceral study, the concentration of inertinite group in lower measure is quite distinctive and possibly accounts for an aerobic condition of bacterial attack during the formation of coal which resulted in its concentration. This decay of vegetable debris under the above-mentioned condition provided a direct contact with the atmosphere in a dried up climate which

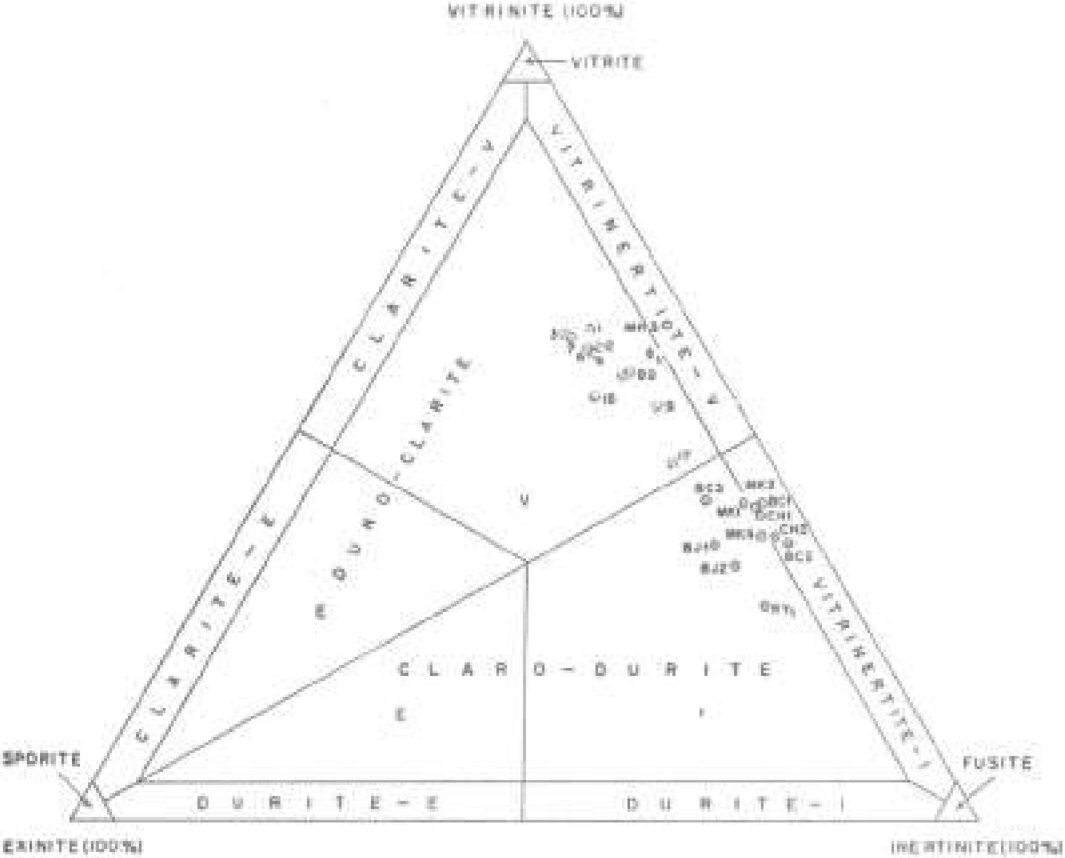


Text-fig. 2

allowed a rapid loss of volatiles. On the other hand, the condition of formation of coals of upper measure was considerably wet and water being sole preservative promoted an anaerobic condition which resulted in the concentration of homogeneous collinite from a colloidal stage.

The maceral study was further aided by microlithotype analysis to get a better understanding of the coal characters. From the quantitative analyses, it was revealed that in the lower measure coals clarodurite and in upper measure coals duroclarite predominates. This is also evident from tri-component triangular diagram (Text-fig. 3). Vitrite is low in lower measures whereas it is significantly high in upper measures. Durite is high and clarite is low in lower measure and reverse is true for the upper measure. The variation is also marked in the intra-formational seams. Vitrite decreases in top seam of lower measure with increase of duroclarite whereas upper measure coals show increasing proportion of vitrite in the upper seams. The results have been tabulated (Tables 3 & 4) and illustrated by pillar diagrams (Text-fig. 4).

From the study of the reflectance, vitrinite masses of all the samples also gave some supporting idea about the maturity and rank of the coal. Reflectances were measured in a MOP microscope fitted with photovoltmeter and the scale was calibrated with respect to carborundum and reflectance



MODAL COMPOSITION OF LOWER MEASURE (KARHARBARI) AND UPPER MEASURE (BARAKAR) COALS

(Group Macerals on visible mineral matter free basis)

◦ UPPER MEASURE (BARAKAR) COALS, ⊙ LOWER MEASURE (KARHARBARI) COALS.

TEXT-FIG. 3

values in comparison to the upper measure coals suggesting a higher maturity of the lower measure coals. Coal metamorphism due to superincumbent pressure is also observed in both the measures where the values increase considerably from upper part to the lower part of the formation. Some variations having considerably high values may be explained due to the effect of local faulting which is very common in this field. The samples from Bisrijhapa Quarry and Ray Colliery show considerably high values which could be explained by the existence of a concealed fault running NE-SW.

SYSTEMATIC PALYNOLOGY

The spore and pollen grains recovered from the materials of both the measures have been arranged as follows (according to Potonié's 1956, 1958, 1960 classification):

* = Restricted to lower measure
** = Restricted to upper measure

Anteturma — *Sporites* H. Potonié, 1893
Turma — *Triletes* (Reinsch) Pot. & Kremp, 1954
Subturma — *Azonotriletes* Luber, 1935
Infraturma — *Laevigati* (Bennie & Kidston) Potonié, 1956

TABLE 1 — MODAL ANALYSIS OF MACERAL COMPOSITION OF LOWER MEASURE (KARHARBARI) COALS

SAMPLE No.	SEAM	LOCATION	VITRINITE			EXINITE			INERTINITE			VISIBLE MINERAL MATTER
			COLLINITE	TELLINITE	TOTAL	SPORINITE	CUTINITE	TOTAL	FUSINITE & SEMI-FUSINITE	MICRINITE & SCLEROTINITE	TOTAL	
BC$_5$ (⊥)	Up. Bachra	Bachra Colliery	30·4	3·6	34·0 (41·12)	6·8	1·2	8·0 (9·68)	37·2	3·5	40·7 (49·20)	17·3
BJ$_1$ (⊥)	Ray (Top)	Bisujhapa Colliery (Incline 1)	27·7	1·2	28·9 (35·3)	8·1	1·3	9·4 (11·5)	40·7	2·8	43·5 (53·2)	18·2
BJ$_2$ (⊥)	Ray (Top)	Bisujhapa Colliery (Quarry 2)	22·8	2·6	25·4 (32·7)	6·2	1·9	8·1 (10·5)	42·2	1·6	41·8 (56·8)	22·7
RY$_1$ (⊥)	Ray (Top)	Ray Colliery (Quarry 1)	20·6	1·1	21·7 (27·6)	6·5	1·3	7·8 (9·9)	46·5	2·6	49·1 (62·5)	21·4
BC$_2$ (⊥)	Lr. Bachra	Bachra Colliery (Up dip)	35·1	1·7	36·8 (40·72)	2·9	0·2	3·1 (3·43)	45·8	4·7	50·5 (55·85)	9·6
BC$_3$ (⊥)	Lr. Bachra	Bachra Colliery (Down dip)	31·4	0·6	32·0 (35·43)	2·6	0·3	2·9 (3·21)	50·5	4·9	55·4 (61·36)	9·7
CH$_1$ (⊥)	Churi Seam (Incline 1)	Churi Colliery N.E. of CH$_2$	35·1	1·6	36·7 (39·09)	3·1	1·1	4·2 (4·47)	51·1	1·9	53·0 (56·49)	6·1
CH$_2$ (⊥)	Churi Seam (Incline 3 — near local fault)	Churi Colliery	34·03	0·07	34·10 (36·48)	2·7	1·3	4·0 (4·27)	54·2	1·2	55·4 (59·25)	6·5
MK$_1$ (⊥)	Manki Seam (Lower)	Manki Colliery (Quarry 3)	34·6	1·9	36·5 (40·54)	4·3	0·9	5·2 (5·78)	45·2	3·1	48·3 (53·68)	10·0
MK$_2$ (⊥)	Manki Seam (Lower)	Manki Colliery (Incline 4)	36·1	1·02	37·12 (40·6)	3·7	0·1	3·8 (4·1)	44·1	6·48	50·58 (55·3)	8·5
MK$_3$ (∥)	Manki Seam (Lower)	Manki Colliery (Incline 5)	50·1	—	50·1 (63·41)	1·3	0·9	2·2 (2·70)	20·6	6·2	26·8 (33·9)	20·9
MK$_4$ (⊥)	Manki Seam (Upper)	Manki Colliery (Quarry 3)	30·3	2·1	32·4 (36·8)	3·6	1·2	4·8 (5·41)	44·7	6·1	50·8 (57·8)	12·0

*Figures within parentheses are on visible mineral-matter-free basis.
(⊥) = Section perpendicular to bedding.
(∥) = Section parallel to bedding.

TABLE 2 — MODAL ANALYSIS OF MACERAL COMPONENTS OF UPPER MEASURE (BARAKAR) COALS

Sample No.	Seam	Location	Vitrinite			Exinite			Inertinite			Visible Mineral Matter
			Collinite	Tellinite	Total	Sporinite	Cutinite	Total	Fusinite & Semifusinite	Sclerotinite & Micrinite	Total	
7	K_2	Bukbuka Colliery	51·2	2·3	54·4 (62·2)	10·6	1·5	12·1 (14·2)	18·6	1·9	20·5 (23·6)	13·0
3	K_2	Karkata Colliery	50·5	2·9	53·4 (62·0)	11·6	1·2	12·8 (14·8)	18·2	1·8	20·0 (23·2)	13·8
6	Karkata	Bukbuka Colliery	46·5	3·3	49·8 (60·6)	10·0	0·2	10·2 (12·4)	21·1	1·2	22·3 (27·0)	17·7
4	Karkata	Karkata Colliery	50·0	2·8	52·8 (60·6)	10·5	0·1	10·6 (12·2)	22·8	0·9	23·7 (27·2)	12·8
2	W. Tumang	W. Tumang Colliery	50·0	2·1	52·1 (60·9)	9·1	0·6	9·7 (11·3)	21·9	1·9	23·8 (27·8)	14·4
1	Karkata	W. Tumang Colliery (Incline)	51·4	2·6	54·0 (63·1)	9·2	0·2	9·4 (11·1)	20·7	1·4	22·1 (25·8)	14·5
5	Berampur	Karkata Colliery	47·9	1·7	49·6 (57·1)	8·6	0·8	9·4 (10·8)	23·1	4·8	27·9 (32·1)	13·1
8q	Berampur	Karkata Colliery (Quarry)	48·4	1·3	49·7 (57·7)	7·3	0·9	8·2 (9·5)	22·5	5·7	28·2 (32·8)	13·9
8	Bukbuka	Bukbuka Colliery	46·7	2·5	49·2 (59·0)	4·2	0·3	4·5 (5·4)	26·6	3·1	29·7 (35·6)	16·6
9	Dakra	Dakra Colliery	38·6	2·5	41·1 (53·1)	6·4	0·5	6·9 (8·9)	26·7	2·7	29·4 (38·0)	22·6
17	Damodar Seam	Pit	36·0	0·3	36·3 (45·9)	6·6	2·1	8·7 (11·0)	31·5	2·6	34·1 (43·1)	20·9
16	Damodar Saphi Seam	Pit	38·1	1·7	39·8 (54·1)	10·2	1·0	11·2 (15·2)	20·4	2·2	22·6 (30·7)	26·4

*Figures within parentheses are on visible mineral-matter-free basis.

TABLE 3 — MODAL ANALYSIS OF MICROLITHOTYPES OF LOWER MEASURE (KARHARBARI) COALS

SAMPLE NO.	VITRITE	FUSITE	VITRINERTITE	DURITE	CLARITE	DURO-CLARITE	CLARO-DURITE
BC_3	9·5	5·1	8·3	14·4	8·6	23·9	30·2
BI_4	6·9	6·1	3·6	16·2	11·9	25·1	30·2
BJ_1	6·1	4·3	5·5	20·6	9·2	22·9	31·4
RY_1	2·1	6·5	11·3	16·2	7·6	20·1	36·2
BC_2	7·1	10·6	13·4	3·5	1·2	19·8	44·4
BC_2	5·9	13·7	18·2	6·3	0·8	17·2	37·9
CH_1	8·6	16·5	14·9	4·5	1·1	20·3	34·1
CH_2	7·2	15·1	19·2	5·1	2·3	16·9	34·2
MK_1	8·1	6·8	12·6	3·2	5·6	22·9	40·8
MK_2	7·2	8·1	13·2	16·9	3·2	20·8	30·6
MK_4	5·2	10·6	10·1	6·2	5·1	18·1	44·7

TABLE 4 — MODAL ANALYSIS OF MICROLITHOTYPES OF UPPER MEASURE (BARAKAR) COALS

SAMPLE NO.	VITRITE	FUSITE	VITRINERTITE	DURITE	CLARITE	DURO-CLARITE	CLARO-DURITE
7	20·2	3·1	4·7	3·6	24·5	28·8	13·1
3	19·8	1·2	3·0	6·3	26·2	30·9	12·6
6	13·9	3·5	6·8	11·6	22·9	32·1	9·2
4	16·7	2·8	5·6	10·3	25·1	30·0	9·5
2	11·2	3·1	6·9	10·4	27·9	30·8	9·7
1	14·3	1·7	4·6	12·7	25·9	30·6	10·2
5	9·99	4·4	5·2	11·3	20·6	31·7	16·9
8	13·2	5·9	4·1	10·5	19·9	30·1	16·3
8	10·5	10·5	2·1	9·6	16·1	28·9	22·3
9	13·6	9·1	4·9	10·3	18·2	30·7	13·2
17	8·9	11·6	10·2	13·1	6·2	23·9	26·1
16	21·9	8·3	16·3	3·9	14·1	26·2	9·3

Leiotriletes (Naum.) Pot. & Kr. 1954
Punctatisporites (Ibr.) Pot. & Kr. 1954
Retusotriletes Naum. 1953

Infraturma — *Apiculati* (Benn. & Kids.) Pot. 1956
Sub-Infraturma — *Granulati* Dyb. & Jacho. 1957
Cyclogranisporites Pot. & Kr. 1954

Sub-Infraturma — *Verrucati* Dyb. & Jacho. 1957
Verrucosisporites (Ibr.) Pot. & Kr. 1954

Sub-Infraturma — *Nodati* Dyb. & Jacho. 1957
Lophotriletes (Naum.) Pot. & Kr. 1954
Apiculatisporites (Ibr.) Pot. & Kr. 1956

Sub-Infraturma — *Baculati* Dyb. & Jacho. 1957
Horriditriletes Bharad. & Salujha 1964
***Cyclobaculisporites* Bharad. 1955

Sub-Infraturma — *Varitrileti* Venk. & Kar 1965
***Microbaculispora* Bharad. 1962
***Microfoveolatispora* Bharad. 1962
**Lacinitriletes* Venk. & Kar 1965

Turma — *Zonales* (Benn. & Kids.) Pot. 1956
Subturma — *Zonotriletes* Waltz 1935
Infraturma — *Cingulati* Pot. & Kr. 1954
***Dentatispora* Tiwari 1964

Infraturma — *Zonati* Pot. & Kr. 1954
***Indotriradites* Tiwari 1964

Turma — *Monoletes* Ibr. 1933
Subturma — *Azonomonoletes* Luber 1935
Infraturma — *Psilamonoleti* Hamm. 1955
***Latosporites* Pot. & Kr. 1954

Infraturma — *Ornati* Pot. 1956
***Punctatosporites* Ibr. 1933

Anteturma — *Pollenites* Pot. 1931

TABLE 5 — SUMMARY OF REFLECTANCE STUDY OF COALS

SL. NO.	SAMPLE NO.	LOCATION	REFLECTANCE IN AIR	REFLECTANCE IN OIL
1	7	K_{II} Seam (Bukbuka Colliery)	7·670	0·778
2	3	K_{II} Seam (Karkata Colliery)	7·912	0·821
3	6	Karkata Seam (Bukbuka Colliery)	7·988	0·771
4	4	Karkata Seam (Karkata Colliery)	7·655	0·840
5	2	West Tumang Seam (Bisrampur-W. Tumang Quarry)	7·971	0·794
6	1	Karkatu Seam (West Tumang Colliery)	7·092	0·829
7	5	Bisrampur Seam (Karkata Colliery)	7·763	0·854
8	8	Bukbuka Seam (Bukbuka Colliery)	7·938	0·873
9	9	Dakra Seam (Dakra Colliery)	7·933	0·897
10	17	Damodar-Saphi Seam	7·126	0·719
11	16	Damodar Seam	7·931	0·837
12	BC_3	Upper Bachra Seam (Bachra Colliery)	8·465	0·972
13	BJ_1	Ray (Top) Seam (Bisujhapa Colliery — Incline)	8·018	0·913
14	BJ_2	Ray (Top) Seam (Bisujhapa Colliery — Quarry)	8·321	1·061
15	RY_1	Ray (Top) Seam (Ray Colliery — Quarry)	8·226	0·987
16	BC_4	Lower Bachra Seam (Bachra Colliery — Down dip)	9·332	1·279
17	BC_2	Lower Bachra Seam (Bachra Colliery — Up dip)	9·137	1·183
18	CH_1	Churi Seam (Churi Colliery — Incline 1)	8·935	1·168
19	CH_2	Churi Seam (Churi Colliery — Incline 3)	9·216	1·220
20	MK_1	Manki (Lower) Seam (Manki Colliery)	9·153	1·019
21	MK_3	Manki (Lower) Seam (Manki Colliery)	9·937	1·230
22	MK_4	Manki (Upper) Seam (Manki Colliery)	9·716	1·129

Turma — *Saccites* Erdtm. 1947
Subturma — *Monosaccites* (Chit.) Pot. & Kr. 1954
Infraturma — *Monosaccireticuloidi* Tiwari 1964
**Potonieisporites* Bharad. 1962

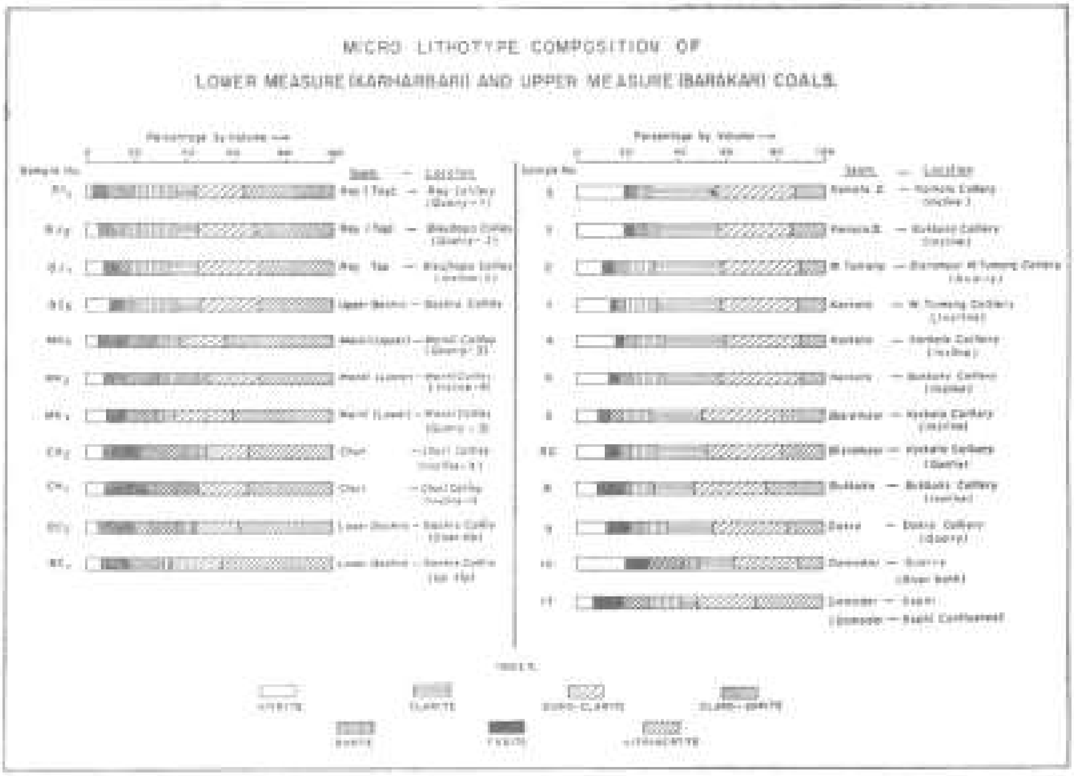
Infraturma — *Amphisacciti* Lele 1963
Parasaccites Bharad. & Tiwari 1964
**Crucisaccites* Lele & Maithy 1964

Infraturma — *Apertacorpiti* Lele 1964
Plicatipollenites Lele 1964
Virkkipollenites Lele 1964
***Divarisaccus* Venk. & Kar 1965

Subturma — *Disacciti* Cookson 1947
Infraturma — *Striaticuloiditi* Tiwari 1964
Rhizomaspora Wilson 1962
***Primuspollenites* Tiwari 1964

Infraturma — *Striatiti* Pant 1954
Striatites (Pant) Bharad. 1962
Faunipollenites Bharad. 1962
***Verticipollenites* Bharad. 1962

Infraturma — *Disacciatrileti* (Lesch) Pot. 1958
**Vesicaspora* Schemel 1951
***Sulcatisporites* (Lesch) Bharad. 1962



TEXT-FIG. 4

TABLE 6 — DISTRIBUTION OF DIFFERENT MIOSPORES IN THE SEAMS OF LOWER MEASURE (KARHARBARI) OF THE PRESENT AREA AND THAT OF KARHARBARI FORMATION OF GIRIDIH COALFIELD

SPORE GENERA SEAM AND LOCATION	LOWER BACHRA (BACHRA COLLIERY)	CHURI (CHURI COLLIERY)	MANKI (LOWER MANKI COLLIERY)	MANKI (UPPER MANKI COLLIERY)	RAY (TOP) (BISUJHAPA COLLIERY)	UPPER BACHRA (BACHRA COLLIERY)	GIRIDIH COALFIELD (MAITHY, 1965)
Punctatisporites	18·0	17·2	18·3	17·6	10·2	12·5	0·3
Apiculatisporites	6·2	6·5	5·8	4·8	8·3	8·0	—
Lophotriletes	9·5	8·9	7·6	8·9	4·3	5·2	0·3
Horriditriletes	4·8	5·0	6·4	4·5	4·1	2·5	0·3
Parasaccites	6·5	7·2	6·4	6·1	11·9	10·0	24·1
Virkkipollenites	18·2	19·9	18·1	18·3	14·3	16·5	0·6
Plicatipollenites	10·5	9·6	11·3	9·2	11·1	12·5	16·6
Faunipollenites	5·5	5·1	5·6	5·6	3·9	4·0	14·8
Striatites	1·5	2·7	2·0	1·1	0·7	1·0	15·4
Vestigisporites	3·5	2·6	4·2	2·8	1·5	2·5	—
Others	15·8	15·3	14·3	21·1	29·6	25·3	27·6

Infraturma — *Disaccimonoleti* Pot. & Kr. 1954
Vestigisporites Lele & Maithy 1964

Turma — *Plicates* (Naum.) Pot. 1960
Subturma — *Polyplicates* Erdtm. 1952
Welwitschiapites Bolch. 1953

Subturma — *Monocolpates* Ivers. & Troels-Smith 1950

Infraturma — *Intortes* (Naum.) Pot. 1958
***Vittatina* (Lubor.) Wilson 1962
***Ginkgocycadophytus* Samoilowitz 1953

TABLE 7 — FREQUENCY DISTRIBUTION OF DIFFERENT SPORE GENERA IN THE BARAKAR COAL SEAMS UNDER STUDY

SPORE GENERA	COAL SEAMS (WITH NAMES OF MINES)										
	KARKATA (W.TUMANG)	W.TUMANG (BISRAMPUR)	K II (KARKATA)	KARKATA (KARKATA)	BISRAMPUR (KARKATA)	KARKATA (BUKBUKA)	K II (BUKBUKA)	BUKBUKA (BUKBUKA)	DAKRA (DAKRA)	DAMODAR (PIT)	DAMODAR (PIT)
1. Leiotriletes	3·5	3·0	4·8	4·0	3·5	3·2	3·0	3·5	2·8	3·0	3·8
2. Retusotriletes	0·8	1·0	0·5	0·5	—	0·8	0·5	1·0	1·0	1·2	0·5
3. Punctatisporites	1·2	1·0	0·8	0·5	0·8	1·0	1·5	1·2	2·0	1·5	1·8
4. Verrucosisporites	0·5	—	0·5	—	0·8	1·0	0·8	—	0·5	—	—
5. Horriditriletes	6·5	8·0	7·5	8·8	7·2	7·5	6·8	6·5	6·0	6·2	4·8
6. Apiculatisporites	4·5	6·2	4·2	5·5	5·0	5·2	4·8	4·2	5·0	4·6	3·5
7. Lophotriletes	3·2	4·0	4·8	4·5	4·0	4·8	3·5	4·0	4·5	2·8	3·8
8. Cyclogranisporites	2·8	2·0	1·8	2·0	2·0	1·8	1·5	2·0	1·8	3·2	2·8
9. Cyclobaculisporites	3·0	2·5	3·2	2·5	2·5	3·0	2·8	1·2	1·5	3·2	2·5
10. Microbaculispora	4·5	4·0	3·5	3·0	3·5	3·2	4·0	4·0	3·5	3·4	2·5
11. Microfoveolatispora	7·8	6·2	6·0	6·0	6·5	7·0	6·8	6·5	6·0	3·6	4·8
12. Indotriradites	1·2	1·5	1·0	1·2	0·8	0·5	1·0	0·8	0·5	1·6	1·8
13. Dentatispora	0·8	0·5	—	0·8	1·0	0·8	1·0	0·5	0·5	—	—
14. Latosporites	2·5	3·0	4·5	4·0	3·2	3·0	2·8	3·0	2·5	2·4	2·6
15. Punctatosporites	2·0	1·8	2·0	1·5	1·8	1·5	2·0	1·8	1·5	3·0	2·8
16. Plicatipollenites	5·0	4·8	6·0	5·0	4·5	4·0	5·0	4·8	6·5	3·6	4·8
17. Virkkipollenites	4·2	4·0	6·5	4·5	6·5	4·0	4·5	5·0	6·0	4·8	5·4
18. Divarisaccus	1·8	1·5	0·7	1·2	—	1·0	1·0	1·5	0·8	1·2	0·2
19. Parasaccites	1·0	1·8	2·0	0·8	1·0	2·0	1·5	1·8	2·0	1·6	2·8
20. Rhizomaspora	2·0	3·0	1·0	2·2	2·5	2·8	2·0	2·3	2·8	1·8	2·4
21. Primuspollenites	1·5	1·2	—	0·8	0·8	—	1·0	—	0·8	1·2	0·8
22. Striatites	12·0	10·5	10·0	11·2	10·5	8·9	9·6	8·5	8·0	11·2	10·8
23. Verticipollenites	3·5	2·0	1·5	1·8	1·2	1·5	1·8	1·6	2·6	1·4	11·2
24. Faunipollenites	6·5	8·0	8·5	9·5	10·0	11·2	10·5	10·0	10·5	14·2	14·8
25. Schizopollis	2·4	2·0	1·5	2·5	2·0	2·8	2·5	1·8	1·5	1·8	1·6
26. Vittatina	1·6	0·8	0·5	—	2·1	1·0	0·8	0·5	1·0	0·5	0·8
27. Ginkgocycadophytus	0·5	—	0·2	0·4	—	0·8	0·5	1·0	1·0	0·8	1·2
28. Welwitschiapites	1·2	1·0	—	0·8	0·8	—	1·0	1·5	1·5	0·8	0·8
29. Sulcatisporites	12·0	14·0	13·0	12·5	11·5	12·5	13·0	13·5	13·5	15·2	14·2
30. Vestigisporites	—	0·7	3·5	2·0	4·0	1·2	2·5	6·0	3·5	—	—

Infraturma — *Monoptyches* (Naum.) Pot. 1958

Incertae Sedis ***Schizopollis* Venk. & Kar 1964

The spore and pollen grains of both the measures have been illustrated by photographs (Plates 2-5).

DISTRIBUTION OF MIOSPORES AND STRATIGRAPHIC EVALUATION

Lower Measure — From the stated types taxonomically described above, only 20 miospore genera are present in this measure; out of them 9 genera are triletes, 5 genera are monosaccates, 3 genera are non-striated disaccates, 2 genera are striated disaccates, 1 genus is plicate and monolete each. Alete and monocolpate grains are totally absent. A detailed sporological study of the coal seams of this measure indicates a diversified assemblage with some characteristic dominance of triletes and monosaccate grains (Table 6). The miospores show a close resemblance with that of Karharbari Stage by the common presence of *Punctatisporites*, *Cyclogranisporites*, *Virkkipollenites*, *Plicatipollenites*, *Parasaccites*, *Crucisaccites*, *Potonieisporites*, *Vestigisporites*, *Rhizomaspora*, *Vesicaspora*, *Faunipollenites* and *Welwitschiapites*.

The dominant presence of monosaccates accompanied by *Punctatisporites* clearly suggests a Karharbari age. The presence of the genera *Lophotriletes*, *Lacinitriletes*, *Retusotriletes*, *Rhizomaspora* and *Vesicaspora* indicate an affinity of the assemblage with the

TABLE 8 — COMPARATIVE DISTRIBUTION PATTERN OF DIFFERENT SPORE GENERA IN THE PRESENT AREA AND THAT OF OTHER BARAKAR FORMATIONS OF INDIA

Spore Genera	Korba (Bharadwaj) 1966	Chirimiri (Bharadwaj) 1966	West Bokaro (Bharadwaj) 1966	South Karanpura Coalfield (Bharadwaj) 1966	Present area (N. Karanpura Coalfield) (Mukherjee & Ghosh) 1971
1. Leiotriletes	2·1	1·0	7·2	6·0	3·4
2. Retusotriletes	3·9	6·8	—	0·3	0·7
3. Punctatisporites	5·5	2·8	—	0·6	1·2
4. Verrucosisporites	0·2	2·6	—	0·8	0·45
5. Horriditriletes	2·5	1·5	9·1	9·9	7·1
6. Apiculatisporites	4·2	—	1·9	0·4	4·9
7. Lophotriletes	3·7	10·1	6·5	5·0	4·1
8. Cyclogranisporites	0·2	4·2	3·3	0·1	1·9
9. Cyclobaculisporites	0·1	3·5	5·0	17·4	2·4
10. Microbaculispora	4·9	13·7	0·3	5·5	3·6
11. Microfoveolatispora	1·9	0·1	2·0	0·6	6·4
12. Indotriradites	23·3	6·8	0·7	1·5	0·94
13. Dentatispora	18·7	0·2	0·1	2·5	0·65
14. Latosporites	0·1	3·6	—	1·9	3·1
15. Punctatosporites	—	0·7	—	0·6	1·7
16. Plicatipollenites	1·6	1·8	—	—	4·8
17. Virkkipollenites	0·2	0·7	—	0·1	4·9
18. Divarisaccus	—	—	—	—	0·98
19. Parasaccites	3·0	2·4	—	1·2	1·5
20. Rhizomaspora	0·6	0·8	3·5	1·0	2·8
21. Primuspollenites	0·3	—	1·0	0·1	0·67
22. Striatites	3·3	1·2	9·0	10·3	9·9
23. Verticipollenites	—	0·3	—	—	1·7
24. Faunipollenites	7·0	3·4	21·0	12·3	9·4
25. Schizopollis	—	—	—	—	2·1
26. Vittatina	0·2	0·6	—	0·3	0·68
27. Ginkgocycadophytus	0·9	2·2	0·1	—	0·55
28. Welwitschiapites	0·6	0·4	—	—	0·86
29. Sulcatisporites	4·4	10·0	18·0	14·0	13·92
30. Vestigisporites	—	—	—	—	2·8

Barakar Stage. The total absence of *Quadrisporites* and *Stellapollenites* (which strictly belong to Talchir Stage) indicates its remote connection with the Talchir Stage.

Thus from the above comparison and distribution pattern of the spores of the two coal seams (Table 6) along with that of Karharbari Stage of Giridih Coalfield (Maithy, 1965) suggest its assignment to Upper Karharbari Stage.

Upper Measure—The coals of this measure reveal 30 miospore genera out of which 13 genera belong to triletes, 2 genera belong to monoletes, 4 genera belong to monosaccates, 5 genera belong to striated disaccates, 4 genera belong to monostriated disaccates, 1 genus each to monocolpate and plicates.

From the foregoing account of the distribution pattern (Table 7) of the various spore genera, it appears that the trilete types along with disaccates and few monosaccates form the bulk of the assemblage. The index association of *Sulcatisporites*, *Indotriradites*, *Lophotriletes*, *Microbaculispora*, *Latosporites*, *Faunipollenites* and *Retusotriletes* suggests the assignment of this measure to Barakar Stage (Bharadwaj, 1966) and relatively high percentage of monosaccate pollen grains indicates its close relation with the underlying Karharbari Stage. Hence from the present analysis and comparative study of the distribution pattern of the present area and other Barakar stages of India (Table 8) this measure can be placed within Lower Barakar Stage.

MIOFLORISTICS

From the present stage of knowledge about the affinity of the miospore genera, a close relation between the stated stages is apparent. The Gangamopterids and Glossopterids assemblages suggest a close association of the two stages with distinct variation. Cycadoginkgopsids are low in representation but percentage is little higher in Barakar Stage. Cryptogams are lower in proportion in Karharbaris than Barakar and gymnosperms are higher in Karharbaris. The floral characteristics of the two stages are clear from the table (Table 9), which have been deduced from the present knowledge of the affinity of the '*sporae dispersae*'

TABLE 9 — SUMMARY OF MIOFLORISTICS OF THE PRESENT AREA WITH THAT OF GENERALIZED DISTRIBUTION OF BARAKAR AND KARHARBARI FORMATIONS OF INDIA

STAGE	CRYPTOGAMS		CORDAITALES		GANGAMOPTERIDS		GLOSSOPTERIDS		CONIFERS		CYCADOGINKGOIDS	
	Authors	Bharadwaj 1966	Authors	Bharadwaj 1966	Authors	Bharadwaj 1966	Authors	Bharadwaj 1966	Authors	Bharadwaj 1966	Authors	Bharadwaj 1966
Barakar	45·72	56·4	—	0·9	12·18	3·5	24·09	19·3	15·7	16·8	1·41	3·0
Karharbari	28·3	11·3	—	0·2	39·0	37·0	11·8	32·1	19·8	18·3	1·2	1·4

with the palaeobotanical entities (Bharadwaj, 1964).

A richer vegetation during Barakar time is clearly indicated by rich coal deposits (11 coal seams with thickness ranging 3 m. to 20 metres) of the upper measure than the lower measure (Karharbari) which contains only 2 coal seams of 0·4 m to 7·8 metre thickness. This is also supported by the amount and types of spores between the stages.

The present study reveals that the two measures do not have very wide floral differences in the case of generalized data given by Bharadwaj (1964) and rather a strong floral affinity is apparent (Table 9). The geological features like continuity in sedimentation, lithological similarities etc. of the two stages under consideration also suggest a gradual passage of Karharbari Stage to Barakar Stage in the area.

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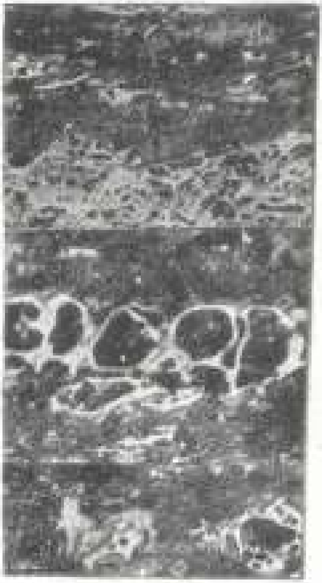

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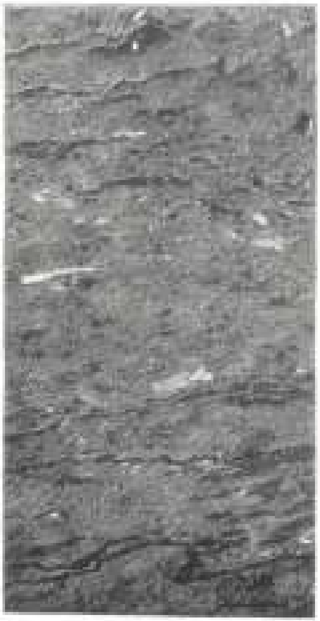

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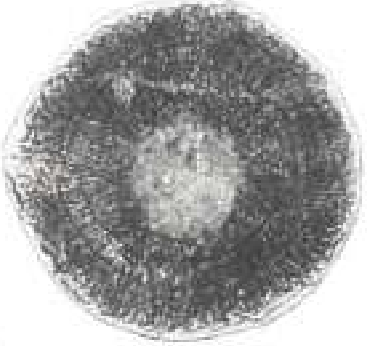

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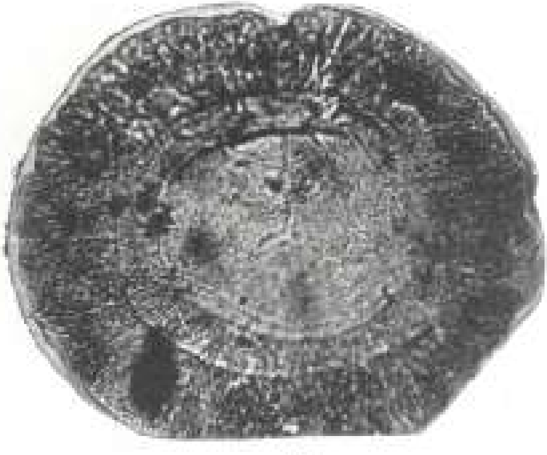

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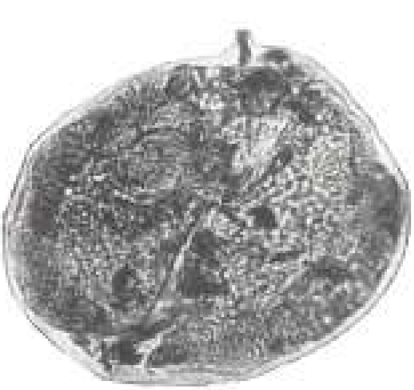

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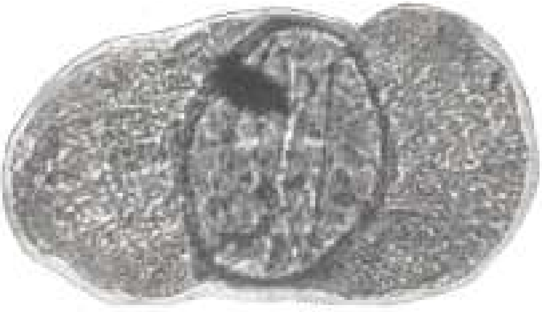

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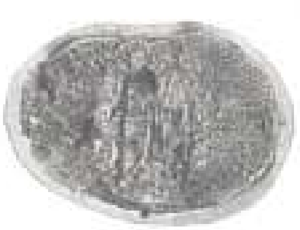

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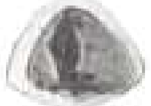

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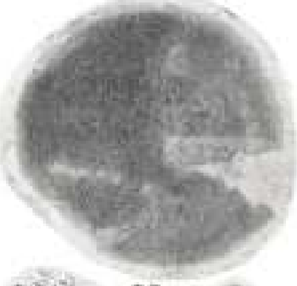
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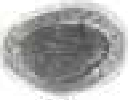
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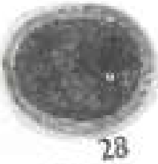
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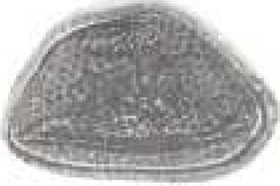
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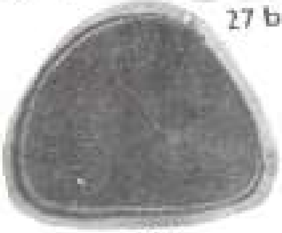
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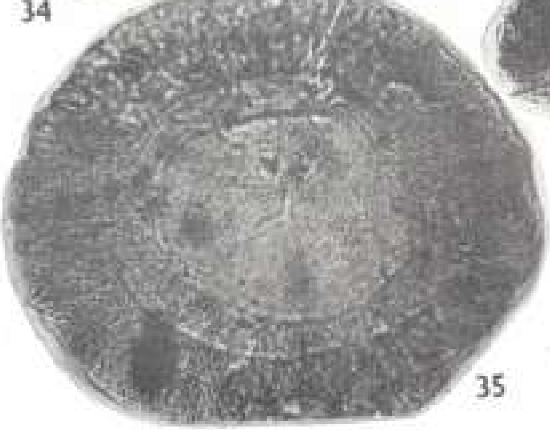
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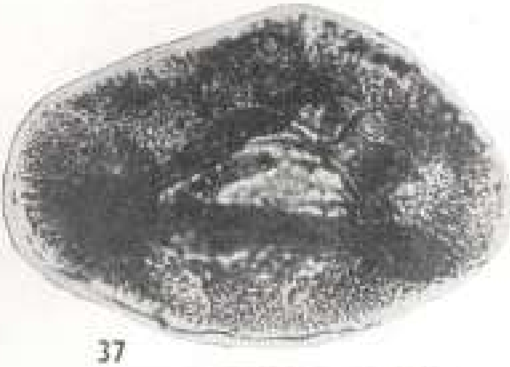
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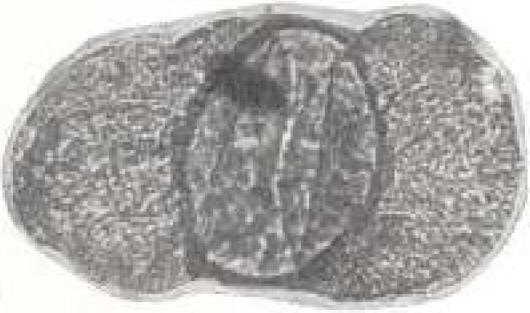
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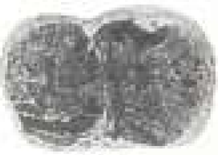
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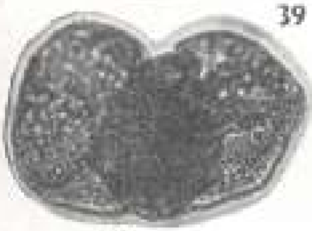
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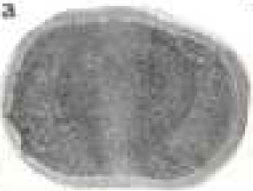
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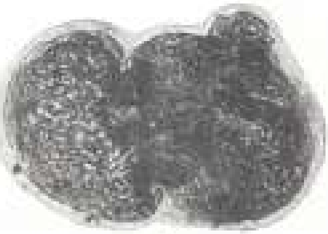
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EXPLANATION OF PLATES

[Photo-micrograph of lower measure (Karharbari) and upper measure (Barakar) coals. (magnification: × 400).]

PLATE 1

1. Typical lower measure coal showing thinly banded nature of the different components.

2. Lower measure coal showing different types of fusinitic cell structures.

3. Several types of sclerotinites in lower measure coals.

4. A representative of upper measure coal showing thickly banded nature.

5. A thick band of exinite showing impregnation of spores and cuticles in vitrinitic groundmass.

6. Upper measure coal showing banding of vitrinite and cutinite.

PLATE 2

7. *Punctatisporites gretensis* (Magnification: × 400)

8a, b. *Punctatisporites mukherjii* sp. nov. (Magnification: × 400)

9. *Retusotriletes diversiformis* (Magnification: × 400)

10. *Apiculatisporites levis* (Magnification: × 400)

11. *Cyclogranisporites* sp. (Magnification: × 400)

12. *Virkkipollenites triangularis* (Magnification: × 400)

13. *Virkkipollenites obscurus* (Magnification: × 400)

14. *Plicatipollenites indicus* (Magnification: × 400)

15. *Vesicaspora* sp. (Magnification: × 400)

16. *Potonieisporites neglectus* (Magnification: × 400)

17. *Rhizomaspora reticulata* sp. nov. (Magnification: × 400)

18. *Vestigisporites diffusus* (Magnification: × 400)

19. *Faunipollenites goraiensis* (Magnification: × 400)

20. *Lacinitriletes* sp. (Magnification: × 400)

PLATE 4

21. *Leiotriletes* sp. (Magnification: × 400)
22. *Retusotriletes* sp. ,, ,,
23. *Punctatisporites* sp. ,, ,,
24. *Verrucosisporites* sp. ,, ,,
25. *Horriditriletes* sp. ,, ,,
26. *Apiculatisporites* sp. ,, ,,
27. *Lophotriletes* sp. ,, ,,
28. *Cyclogranisporites* sp. ,, ,,
29. *Cyclobaculisporites* sp. ,, ,,
30. *Microbaculispora* sp. ,, ,,
31. *Microfoveolatisporites* sp. (Magnification: × 400)
32. *Dentatispora* sp. ,, ,,
33. *Indotriradites* sp. ,, ,,
34. *Latosporites* sp. ,, ,,
35. *Plicatipollenites* sp. ,, ,,
36. *Virkkipollenites* sp. ,, ,,

PLATE 5

37. *Divarisaccus* sp. (Magnification: × 400)
38. *Parasaccites* sp. ,, ,,
39. *Rhizomaspora* sp. ,, ,,
40. *Striatites* sp. ,, ,,
41. *Verticipollenites* sp. ,, ,,
42. *Faunipollenites* sp. ,, ,,
43. *Schizopollis* sp. ,, ,,
44. *Vittatina* sp. ,, ,,
45. *Sulcatisporites* sp. ,, ,,
46. *Vestigisporites* sp. ,, ,,
47. *Welwitschiapites* sp. ,, ,,
48. *Primuspollenites* sp. ,, ,,

STUDIES IN THE LATE-QUATERNARY VEGETATIONAL HISTORY IN HIMACHAL PRADESH—1. KHAJIAR LAKE

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ABSTRACT

The paper discusses the results of pollen analytical investigations of Late-Quaternary deposits from Khajiar Lake in Himachal Pradesh.

At about 2000 B.C. the vegetational history begins with the predominance of oak woods. The oak woods along with some associated elements remain dominant throughout the pollen sequence except for a temporary decline which corresponds to the rise in elm and walnut and dated to 150 A.D. This change is perhaps suggestive of deforestation. Oak woods again declined at about 700 A.D. and were replaced by deodar. This change in vegetation is attributed to the biotic factor.

INTRODUCTION

THE lake at Khajiar (76°4'E, 32°32'N) almost circular in outline and about 60 metres in diameter, is situated in the Ravi Basin of outer Himalayas, about 13 km north-east of Dalhousie on way to Chamba (Fig. 1). Lying at an altitude of about 1,950 metres A.S.L., it occurs in the centre of an open meadow, within the closed Deodar-mixed forest.

A small 'floating island' (Fig. 2) oval in outline, measuring about 15 and 10 metres in length and breadth with a thickness varying from 1·5 to c.2 metres and overgrown with *Phragmites communis*, occurs in the lake. The 'floating island' glides over the lake surface due to wind action, with *Phragmites* acting as sails, and is held sacred by the local inhabitants.

The lake has a surrounding wide marshy zone which is followed by a meadow, measuring about 2·5 km in its periphery, beyond which stands the surrounding mixed Deodar forest (Figs. 3 and 4). A short account of the ecology of the Khajiar Lake was first published by Sahni (1927). Our observations of modern vegetation are given below:

(i) *The submerged and floating vegetation* — Leafy aquatics, seen growing in the lake, are *Potamogeton natans*, *Callitriche stagnalis*, *Spirodela polyrhiza*, *Utricularia flexuosa*, *Myriophyllum spicatum* etc. The centre of the lake is apparently devoid of any vegetation.

(ii) *Phragmites communis Community* — A gregarious growth of *Phragmites communis*, which is constantly maintained by the active regeneration from old rootstocks is seen covering the whole of the 'floating island'. The reed is restricted to the 'island' only and is not seen elsewhere in the area within several miles. The other few plants seen growing on the 'island', are *Acorus calamus*, *Polygonum aviculare*, *Ranunculus diffusus*, *Rubus niveus*, *Ludwigia adscendens* and *Menyanthes trifoliata*.

(iii) *Vegetation of inner marshy zone* — In the marshy area surrounding the open water, *Acorus calamus* is the most dominant plant. Its other common associates are: *Scirpus mucronatus*, *Carex* spp., *Alisma plantago*, *Bidens cernua*, *B. tripartita* and some other aquatics, such as *Ludwigia adscendens*, *Potamogeton natans*, *Myriophyllum spicatum*, *Callitriche stagnalis*, *Spirodela polyrhiza*, *Utricularia flexuosa*, and *Marsilea* sp. In this zone are seen a few annuals, namely *Primula denticulata* (very common), *Lycopus europaeus*, *Prunella vulgaris*, *Verbena officinalis*, *Erigeron canadensis*, *Conyza aegyptiaca*, and *Arundo donax*.

(iv) *Vegetation of outer transitional zone* — In this region *Polygonum aviculare*, a small procumbent annual, is the most dominant species, and the other abundant annuals are *Limnophylla indica*, *Elatine triandra* and *Eleocharis chaetaria*. Besides these elements, other species frequently seen in this habitat are *Nasturtium palustre*, *Mazus japonicus*, *M. surculosus*, *Trifolium repens*, *Bidens tripartita*, *B. cernua*, *Anaphalis busua*, *A. adnata*, *Callitriche stagnalis*, *Ranunculus diffusus*, *Prunella vulgaris*, *Potentilla kleiniana*, *Erigeron canadensis*, *Conyza aegyptiaca chinensis*, and a few sedges and grasses.

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TEXT-FIG. 1 — Close up of the Khajjar lake.

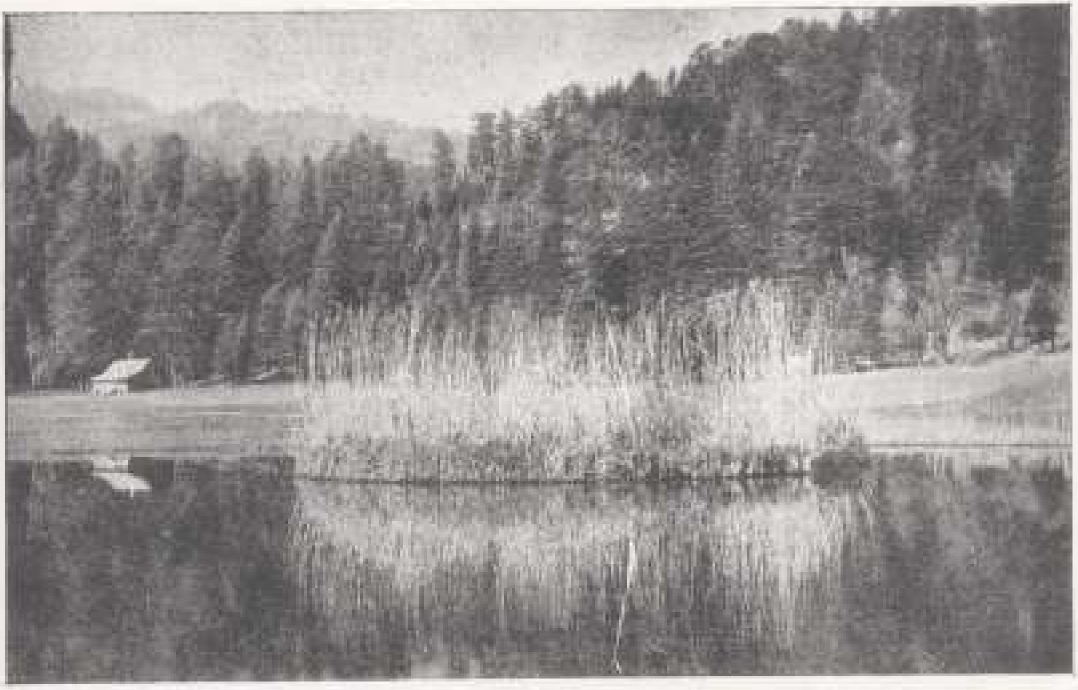
such as *Cyperus globosus*, *Polypogon fugax*, *Poa annua*, and *Echinochloa crusgalli*. Also sometimes small patches of *Riccia* sp. and mosses (*Pohlia* and *Webera*) are seen occupying this zone.

(v) *Meadow* — The chief meadow forming grass is *Bothriochloa pertusa*. Other plants met with are *Taraxacum officinalis*, *Plantago lanceolata*, *Potentilla kleiniana*, *P. nepalensis*, *Cnicus argyracanthus*, *Trifolium repens*, *Nasturtium palustre*, *Mazus japonicus*, *M. surculosus*, *Achillea millefolium*, *Veronica* sp., *Gentiana pedicellata*, *Prunella vulgaris*, etc.

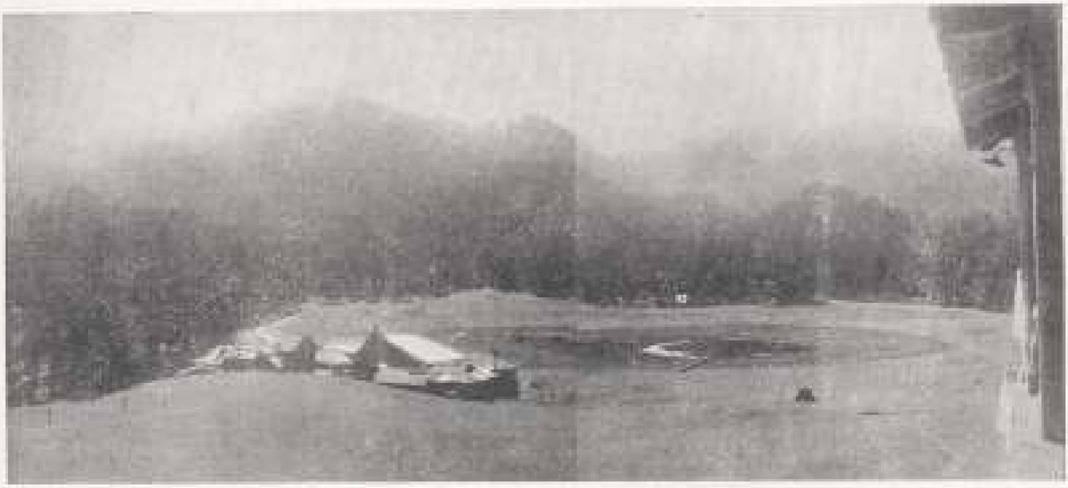
Bordering the above meadow occur thick *Cedrus deodara* forests (Fig. 5), mixed with some broad-leaved elements. The woodlands surrounding the meadow between 1,800 and 2,000 m A.S.L. elevation constitute the Khajjar Demarcated Protected Forest (D.P.F.C.I.) (Fig. 4). The net area of this forest is 190 acres. It comprises of thick and almost pure forests of *Cedrus deodara*, having a slight admixture of *Abies* in depressions, and some oaks along the western boundary. Also a thirty years old *Cedrus* plantation, *c*. 35 acres is seen in the south-east of the Khajjar meadow.

To the north and west of the D.P.F.C.I. is the D.P.F.C. II with a net area of *c*. 107 acres situated at about 1,800 to 1,900 m elevation. It is mainly constituted of *Cedrus deodara* (80%), mixed with *Quercus incana* — the second dominant element, and scattered trees of *Abies* and *Picea*. Numerous small blanks indicating the sites of past fellings and now covered with shrubs (*Viburnum*, *Indigofera*, *Sarcococca*, *Spiraea*, *Rosa*, *Symplocos*, etc.) are found throughout the forest.

Towards the east-north-east of D.P.F.C. I. is the Kangar Rakh D.P.F., situated at about 1,300 to 1,800 m elevation. It is comprised of mainly oak and other broad-leaved elements, such as *Rhododendron arboreum*, *Celtis australis*, *Carpinus*, *Juglans regia*, *Ulmus wallichiana*, *Pyrus*, *Populus*



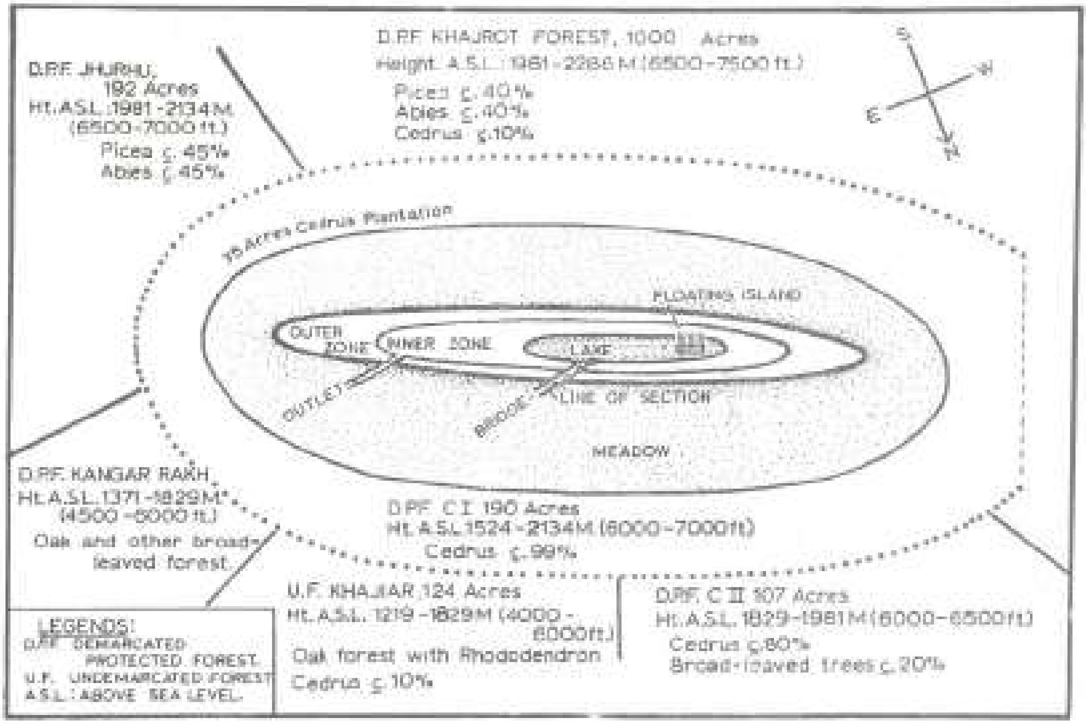
TEXT-FIG. 2 — The 'floating island' of *Phragmites communis* in the Khajiar lake.



TEXT-FIG. 3 — A panoramic view of the Khajiar lake and its surroundings.

ciliata, *Acer*, *Rhus*, *Rosa*, *Colebrookia*, *Ephedra*, *Berberis*, etc. *Pinus roxburghii* often growing in pure formation, occupies the lower elevations of this forest. Scattered trees of other conifers, such as *Cedrus*, *Picea* and *Abies* are met with in the upper elevations.

Towards the south-west of the Khajiar D.P.F. C. I. (Fig. 4) is situated the Khajrot D.P.F. at an elevation varying from 1,900 to 2,300 m with an area of *c*. 1,000 acres. This forest comprises of chiefly *Picea* and *Abies* (40% each), followed by *Cedrus* (10%) and scattered oak.



TEXT-FIG. 4 — Diagrammatic explanation of the panoramic view of the Khajiar lake and its surroundings as given in Fig. 3.

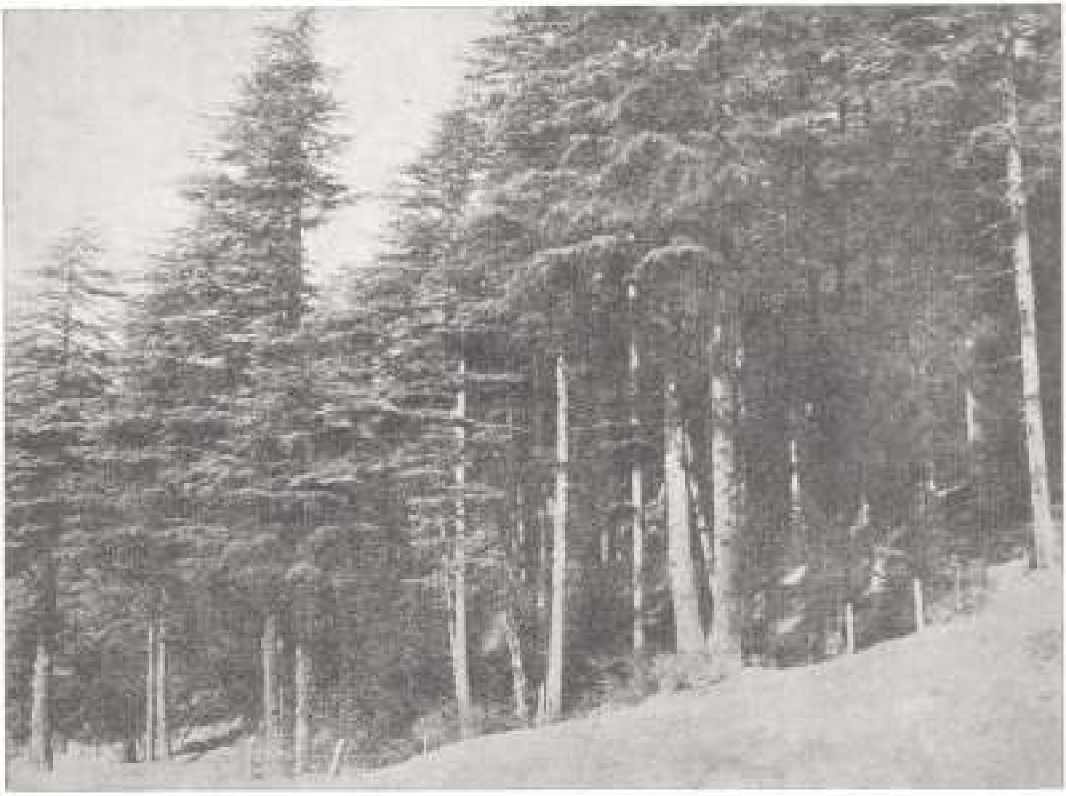
To the east of Khajrot forest lies the Jhurhu D.P.F. more or less at the same elevation, i.e. 1,900 to 2,200 m covering an area of *c.* 192 acres. This forest mainly comprises of *Abies* and *Picea* occurring to the extent of about 45% each.

Since the above two forests have more or less identical aspects and are situated in the same range of elevation, the forest composition is almost the same. The occasional broad-leaved elements met with are — *Aesculus indica*, *Juglans regia*, *Betula alnoides*, *Acer*, *Ulmus*, *Populus*, *Ilex*, *Rhododendron arboreum*, *Skimmia laureola*, *Viburnum*, *Mahonia*, *Sarcococca*, *Berberis*, etc.

To the north-east of the Khajiar meadow is situated the Khajiar Undemarcated Forest (U.F.) between 1,200 and 1,800 m elevation covering an area of *c.*124 acres. This forest covers the north-eastern slopes which grade steeply towards the river Ravi. The forest is open to frequent human interference, and a good part of the area has been brought under terrace cultivation. The main crops grown in the area are — wheat, barley, rice, maize, *Panicum miliaceum*, *Setaria italica*, *Sorghum vulgare*, *Phaseolus mungo*, *P. radiatus* and potato, apart from occasional cultivation of *Fagopyrum emarginatum*, *F. esculentum*, *Amaranthus caudatus*, *Sesamum indicum*, *Dolichos uniflorus*, *Lens culinaris*, tobacco, etc.

METHODS

Stratigraphy was built up with the help of Hiller peat borer with 50 cm long chamber and samples collected at an interval of 10 cm each. Approximately 2 gm of material was taken in each case and boiled in 10% potassium hydroxide solution for 5-7 minutes. The material was then sieved through a mesh to remove the coarse debris. The residue was washed thoroughly to remove alkali and other megascopic remains. The filtrate was centrifuged and then subjected to acetolysis. In the case of clayey samples, the filtrate was treated with 40% hydrofluoric acid for 8-10 days. The material was then washed with dilute hydro-



TEXT-FIG. 5 — A view of the *Cedrus* forest surrounding the Khajiar meadow.

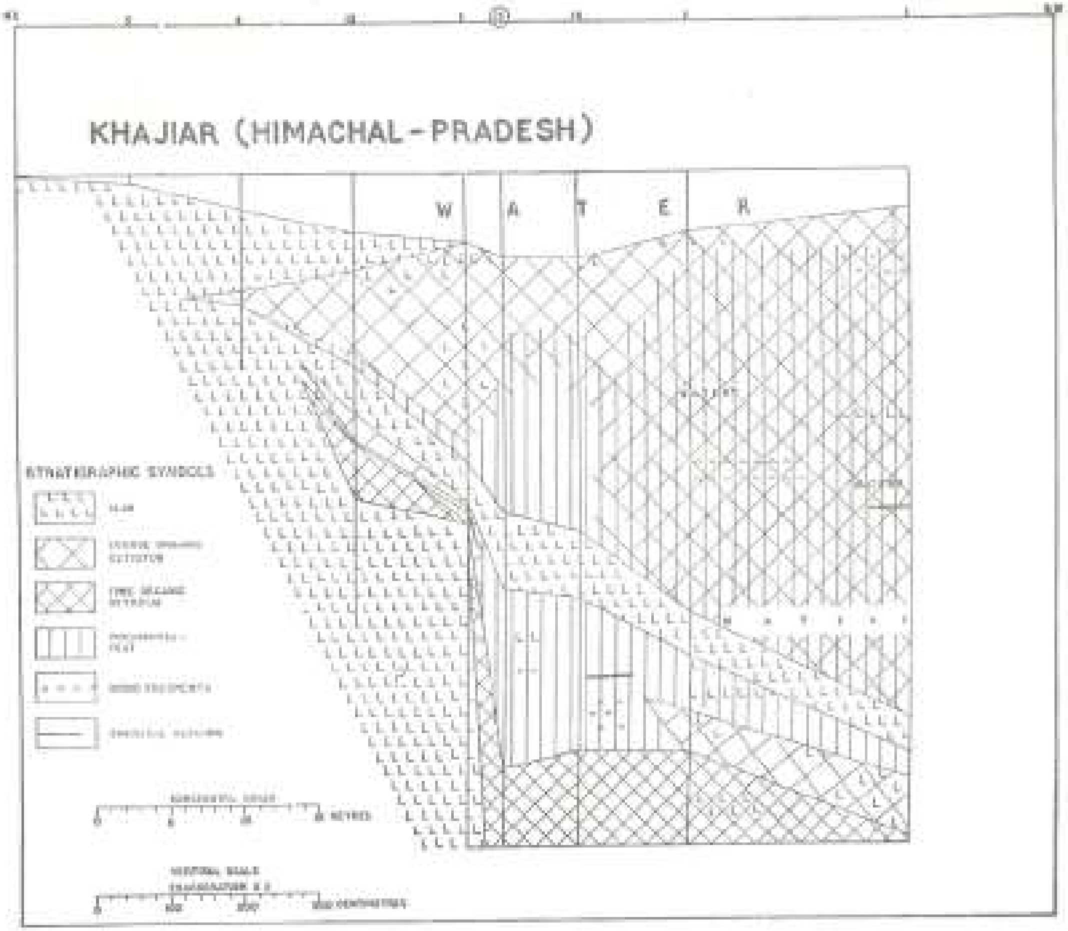
chloric acid (1: 2) after decanting off the hydrofluoric acid. Thereafter it was treated with 5 c.c. of glacial acetic acid in order to dehydrate the material. Acetolysis was then done by following the technique of Erdtman (1943), and the slides were prepared in 50% glycerine.

Pollen sum is based upon about 200 arboreal pollen grains. The percentages were calculated in terms of this sum. Arboreal and non-arboreal pollen diagrams have been constructed each of which is drawn separately. In addition, a total pollen diagram showing both arboreal and non-arboreal elements has also been constructed, calculating the percentage frequencies in terms of total land plant pollen excluding Ferns and Bryophytes. Percentages up to 0·5% are indicated by a plus(+) sign. The percentage frequencies of extremely sporadic elements met with are given at the right hand side of each AP and NAP diagram. In the case of the total AP/NAP diagram, the percentages are shown in the middle, as well as, to the right-hand side of the diagram.

STRATIGRAPHY

The stratigraphy of the lake has been studied by digging bore-holes along a line running NE-SW of the lake (Fig. 6). The maximum depth reached is nine metres, without touching the base. The basin is full of *Phragmites*-peat, intercalated with layers of coarse and fine organic detritus, a limnic deposit with abundant *Botryococcus* colonies. The *Phragmites*-peat is interrupted by a bed of clay, running ± horizontally all through it.

A coarse organic detritus about one metre or so overlies the *Phragmites*-peat. The clay filling the meadow, along the shores of the lake appears to have been derived both from the hill wash, and from the boulder clay. Charcoal remains together with wood fragments, were encountered at various levels in the bore-holes. In view



TEXT-FIG. 6 — Stratigraphical section of the lake deposit at Khajiar. The sampling was carried out from point 15, in the section.

of the abundance of *Phragmites*-peat in the lake basin, it is certain that *Phragmites communis*, now confined solely to the 'floating island' once occupied the lake margins. The bore-core 15 (nos. 6-12 through the meadow not included in the stratigraphical section) was selected for final sampling. The stratigraphical details of which are as follows:

cms	
0-112	Open water.
112-135	Coarse organic detritus. Seeds of *Carex* common.
135-150	Brown coarse organic detritus with *Carex* seeds & some nodes of *Phragmites*.
150-188	Brown coarse organic detritus, with *Carex* seeds. Moss shoots abundant.
188-208	Brown coarse organic detritus with a few seeds of *Chenopodium*, *Scirpus* and *Carex*. Moss fragments abundant.
208-220	Coarse organic detritus, with lesser proportion of moss shoots and *Carex* seeds.
220-250	Brown coarse organic detritus, with *Phragmites* remains. Moss leaves abundant.
250-260	*Phragmites*-peat. Moss leaves abundant, *Phragmites* leaf fragments present.
260-300	Brown *Phragmites*-peat. Moss leaves abundant.

300-350	Brown *Phragmites*-peat with moss leaves, *Phragmites* leaf fragments present.
350-400	Brown *Phragmites*-peat with a few *Phragmites* nodes, leaf fragments, and one *Carex* seed. Moss leaves abundant, with a few moss shoots and wood fragments.
400-452	Same as above but *Carex* seed absent.
452-535	Grey clay, with a few plant remains. Moss leaves rarely seen.
535-553	Same as above, but becoming slightly organic towards the bottom.
553-600	*Phragmites*-peat. Moss shoots and *Phragmites* nodes present. *Scirpus* and *Carex* seeds abundant.
600-627	Same as above, but with some clay.
627-650	*Phragmites*-peat. Moss shoots present along with a few *Scirpus*, *Carex* and *Lycopus* seeds.
650-675	Same, with some wood fragments at 652 cm.
675-700	Coarse, compact *Phragmites*-peat. Moss leaves and shoots present. *Scirpus* and *Carex* seeds also seen along with a few *Phragmites* nodes.
700-750	Same as above.
750-794	Coarse, compact *Phragmites*-peat. A few seeds of *Scirpus*, *Carex* and *Potamogeton*, together with a few *Phragmites* nodes. Moss leaves and shoots also present.
794-800	Dark-brown fine organic detritus. Moss leaves abundant.
800-850	Same as above, but becoming more humified towards the bottom.
850-900	Dark brownish-grey, fine organic detritus. Moss leaves present.
900-?	

VEGETATIONAL DEVELOPMENT

ZONATION

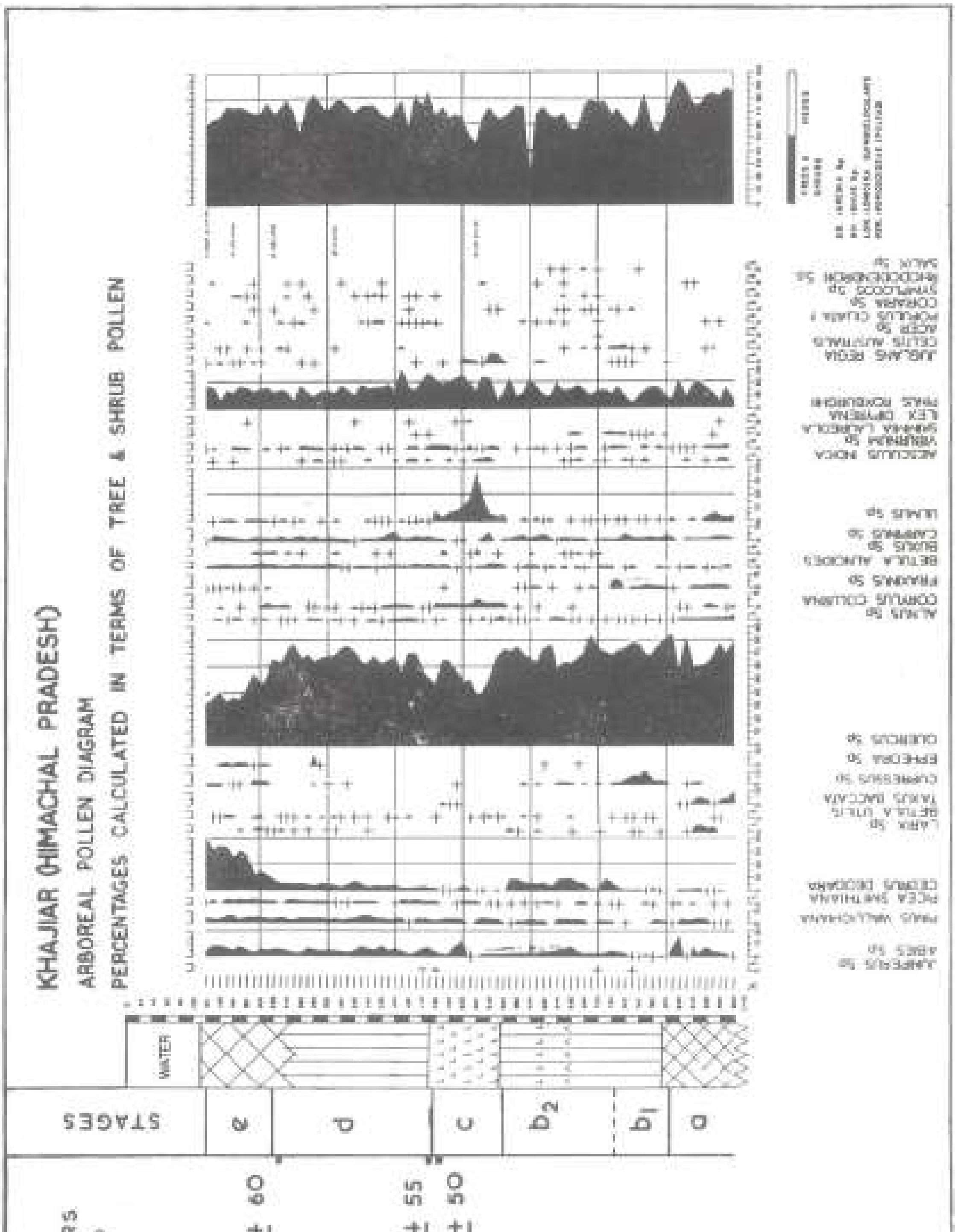
At present, there is no common system of zonation for zoning the Late-Quaternary pollen diagrams in India. Despite the fact that pollen-analytical studies of Late-Quaternary deposits in northwest Himalayas have been underway since the late fifties (Singh, 1960, 62, 63; Sharma, 1964; Vishnu-Mittre & Sharma, 1966; Gupta, 1966; and Vishnu-Mittre *et al.*, 1967), no attempt has so far been made to evolve a uniform system of zonation based on either regional parallelism, or absolute chronology by means of C-14 dating of successive levels in the pollen profiles. This has been due partly to the paucity of the pollen data available, and partly to the rather late introduction of technique of C-14 dating in the country.

In north western Himalayas the Pollen-analytical studies have so far been carried out in the temperate areas of the State of Jammu and Kashmir — centred on the Kashmir valley, and the subtropical areas in the district of Nainital.

In the present studies on Himachal Pradesh, the evidence of C-14 datings of the pollen profile has provided an absolute basis for the consideration of the pollen sequence in its proper chronological order. But, as there is only one more C-14 dated profile, so far, available from north-western Himalayas (Sharma & Singh, 1973) it is premature to evolve a common system of zonation for Himachal Pradesh, leave alone north-western Himalayas, as a whole. Hence, the vegetational sequence as deduced from the Khajiar pollen profile is independent of any other profile from western Himalayas and is divided into five stages, namely a, b, c, d, & e.

POLLEN DIAGRAMS
(Figs. 7, 8 & 9)

'*Stage a*' (900-810 cm) — The lower limit of 'Stage a' cannot be fixed as the stratigraphical sequence is incomplete. The vegetation as judged from the combined 'tree and shrub' pollen ratios on the whole, presents the picture of a closed forest. The tree vegetation is dominated by high values of *Quercus* (80%). *Pinus roxburghii* pollen which occurs to the extent of 10-20%, appears to have come from comparatively lower slopes. The conifers, which form more or less continuous but short curves are *Pinus wallichiana*, *Cedrus deodara*, *Taxus baccata* and *Larix*. Broad leaved elements, such as *Alnus*, *Carpinus*, *Fraxinus*, *Ulmus* and *Viburnum* also form short but continuous curves. Other tree and shrub pollen grains



Text-fig. 7 — Arboreal pollen (AP) diagram from the Khajiar lake.

found in low frequencies are those of *Picea smithiana*, *Cupressus*, *Corylus colurna*, *Betula alnoides*, *Aesculus indica*, *Rhododendron*, *Betula utilis*, *Populus ciliata*(?) and *Celtis australis*. Single grains of *Skimmia laureola* and *Ilex dipyrena* are also met with in this stage.

Non-arboreal plants are comparatively poorly represented and chiefly consist of Gramineae, Cyperaceae, *Artemisia* and Cheno-Amarant type, whose values reach up to 20%, 15%, 7% and 3% respectively. Cerealia type pollen grains are seen almost from the beginning of the pollen sequence in low numbers and they even form a continuous curve in the lower half of 'Stage a'. Other non-arboreal elements represented sporadically, and rarely forming discontinuous curves, are Compositae (Tubuliflorae), *Cannabis sativa*, Caryophyllaceae, Umbelliferae and Primulaceae. The pollen of *Impatiens*, Boraginaceae, Labiatae, *Polygonum* type, *Ammannia* and Leguminosae occurs sporadically up to 0·5%.

The aquatic vegetation is largely represented by colonies of *Botryococcus* whose curve shows an ascending trend, attaining its maximum value of about 85% in the middle of the stage. It, however, shows a sudden decline immediately after reaching its maximum and is later met with in low frequencies. Amongst the other aquatics, *Potamogeton* forms a low, but an almost continuous curve. The pollen of *Typha angustata* occurs rather sporadically. *Nymphaea* occurs as a single grain and the colonies of *Pediastrum* are met with sporadically in the middle of the stage.

Fern spores (both monolete and trilete) are present in low frequencies.

A number of tree and shrub elements, such as *Abies*, *Pinus wallichiana*, *Cedrus*, *Larix*, *Taxus*, *Quercus*, *Carpinus*, *Ulmus*, *Aesculus* and *Viburnum* show sudden decline at varying intervals throughout. The inter-relationship between the fall in the curves of *Quercus*, *Taxus*, *Ulmus*, *Carpinus* and *Viburnum* on one hand, and the rise in the curves of Cyperaceae, Gramineae, Cerealia type and *Cannabis* in the lower half of the stage on the other, is particularly noteworthy, and may be well diagnostic of a small scale clearance in the otherwise closed forest. The curves for all the above non-arboreal elements fall together with the recovery of the oak curve in the second half of the stage, indicating a regeneration of the oak forest. The 'Stage a' ends at 810 cm, where the curve for *Abies* falls and that of *Cupressus* rises.

'Stage b' (810-560 cm)— It is divisible into two sub-stages 'b_1' and 'b_2'.

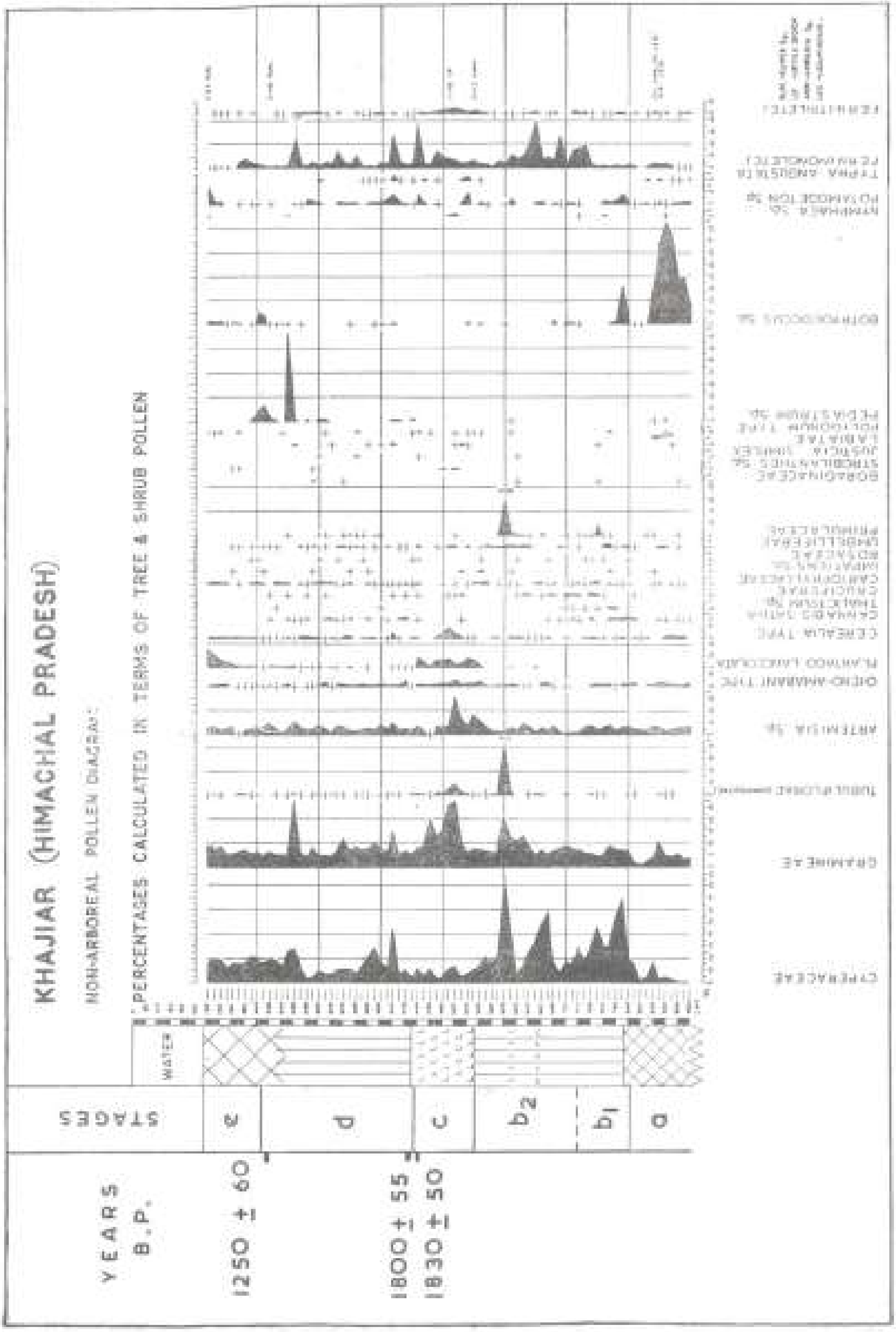
'Stage b_1' (810-560 cm)— It is divisible with the rise of the *Cupressus* curve, accompanied by a general fall in the 'tree and shrub' pollen ratios. The oak curve shows a sudden decline. Both *Carpinus* and *Fraxinus* mark a slight increase in their values. *Taxus* and *Corylus*, are not represented in this sub-stage. The curve for *Larix* becomes sporadic. Other tree and shrub elements present in low frequencies are *Abies*, *Pinus wallichiana*, *Picea smithiana*, *Cedrus deodara*, *Betula utilis*, *Alnus*, *Betula alnoides*, *Ulmus*, *Aesculus indica*, *Viburnum*, *Skimmia laureola* and *Celtis australis*. Stray pollen of *Juniperus*, *Juglans regia*, *Coriaria* and *Salix*, is also met with in this sub-stage. The curve for *Pinus roxburghii*, however, maintains more or less similar values as in the previous stage with slight fluctuations.

Non-arboral elements show a considerable increase in this sub-stage. The curve for Cyperaceae reaches up to 70%, but soon declines afterwards. The values of Gramineae reach to about 20%. There is very slight increase in the values of *Artemisia* and the Cheno-Amaranth type maintains an almost low continuous curve. *Cannabis sativa* begins a fresh curve and its values rise in the lower half of the sub-stage. Other non-arboreal elements represented either in short curves, or in a sporadic form, are Compositae (Tubuliflorae), Cerealia type, *Thalictrum*, Cruciferae, Caryophyllaceae, Rosaceae, Umbelliferae and Primulaceae. The pollen of Labiatae and *Polygonum* type, is also seen in this sub-stage.

Aquatic vegetation chiefly comprises of high values of *Botryococcus* colonies (33%), *Potamogeton* (8%) and of very low frequencies of *Nymphaea* pollen. The values of *Cyperaceae*, *Botryococcus* and *Potamogeton*, rise together at the beginning of the sub-stage, later on, they all decline.

Fern spores (both monolete and trilete) are represented in low values.

'Sub-stage b_2' (730-560 cm)— The 'sub-stage b' comes to an end at 730 cm and 'Sub-stage b_2' starts, where the *Cupressus* curve falls and those of *Abies* and *Cedrus deodara* rise. The curve for *Abies* declines in the later half of the stage. *Pinus wallichiana* forms a fresh, but discontinuous curve. The curves for *Carpinus* and *Fraxinus*



TEXT-FIG. 8 — Non-arboreal pollen (NAP) diagram from the Khajiar lake.

fall but the curve for *Carpinus* rise once again in the later half. The oak curve, but for the two isolated fluctuations, on the whole, tends to decline. Other tree and shrub pollen represented in low values are *Picea smithiana*, *Larix*, *Betula utilis*, *Cupressus*, *Alnus*, *Betula alnoides*, *Buxus*, *Ulmus*, *Aesculus indica*, *Viburnum*, *Celtis*, *australis*, *Populus ciliata*, *Coriaria* and *Salix*. The pollen of *Juniperus*, *Ephedra*, *Corylus colurna*, *Skimmia laureola*, *Juglans regia*, *Symplocos* and *Rhododendron* occurs sporadically. Single grain of *Acer* is also met with in this sub-stage. The curve for *Pinus roxburghii*, however, maintains almost similar frequencies as in the 'Sub-stage b_1' with some fluctuations.

The non-arboreal vegetation mainly comprises of Cyperaceae, Gramineae and *Artemisia*, whose values reach up to 60%, 26% and 6% respectively. Umbelliferae and Cheno-Amaranth type form fresh curves in the second half of the sub-stage. Other non-arboreal elements, present either in short curves or sporadically, are Compositae (Tubuliflorae) Cerealia type, *Cannabis sativa*, Cruciferae, Rosaceae, Umbelliferae and Primulaceae. Stray pollen of *Thalictrum*, *Impatiens*, Boraginaceae, *Justicia simplex* and *Polygonum* type is also met with. A few pollen grains of *Plantago lanceolata* are seen for the first time in this sub-stage. At 600 cm, Primulaceae and Tubuliflorae attain exceptionally high frequencies reaching up to 1250 and 110% respectively, apparently as a result of the local occurrence.

Aquatic vegetation is represented by low frequencies of *Potamogeton*, and the sporadic occurrence of *Pediastrum* colonies.

The curve for Fern spores (monolete), shows a considerable increase with its values reaching up to 40%. It, however, declines in the second half of the sub-stage. Other type of Fern spores (trilete) continue to occur in low values.

The fall in the curves of *Abies* and *Quercus* at the beginning of 'Stage b', together with a general rise in the non-arboreal pollen ratios, especially in conjunction with the rise in the values of Cyperaceae, Gramineae, Cheno-Amaranth type and *Cannabis*, and a little later of Cerealia type, is indicative of small scale clearance. In both the sub-stages the successive rise and fall in the oak curve corresponds respectively with the fall and rise in the Cyperaceae curve.

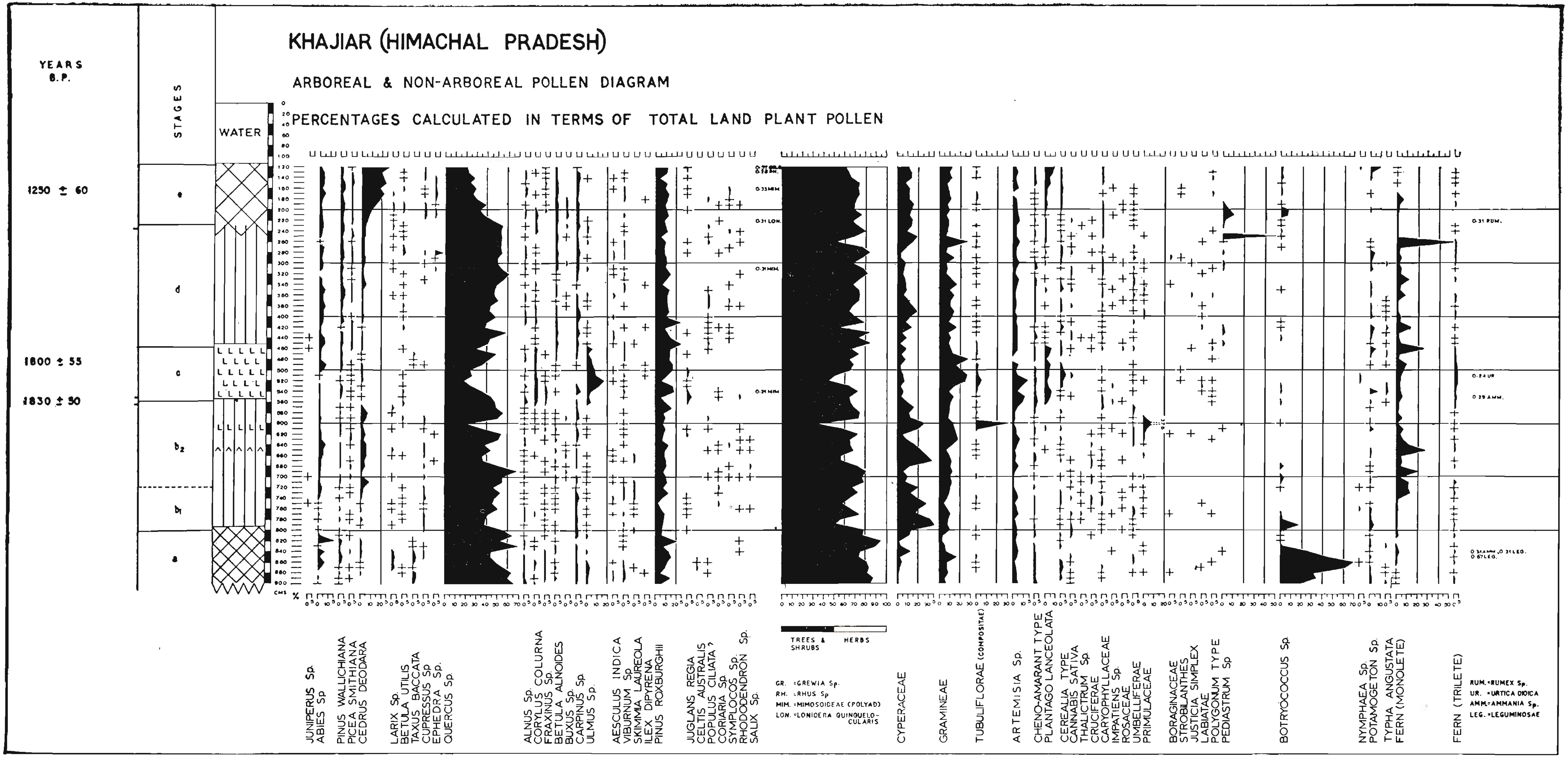
'*Stage c*' (560-460 cm)—The 'Sub-stage b_2' is brought to an end at 560 cm and 'Stage c' begins where the *Quercus* curve registers a sudden fall and *Ulmus*, *Juglans* and *Corylus* start fresh curves. The latter broad leaved three species reach their respective maximum at 38%, 8% and 6% in this stage. The *Cedrus deodara* curve abruptly ends. The curve for *Carpinus* becomes sporadic. The values for *Abies* show a rise from the middle of the stage and the curve for *Pinus wallichiana* tends to fluctuate throughout the stage. There is a slight increase in the curve for *Pinus roxburghii*. Other tree and shrub elements present in low frequencies are *Picea smithiana*, *Betula utilis*, *Alnus*, *Betula alnoides*, *Buxus*, *Aesculus indica* and *Viburnum*, together with very low frequencies of *Cupressus*, *Fraxinus*, *Skimmia laureola*, *Coriaria*, *Symplocos*, *Rhododendron* and Mimosoideae (polyad). The pollen of *Taxus baccata* and *Ilex dipyrena*, which remains unrepresented in 'Stage b' is met with sporadically in this stage.

There is a sudden rise in the frequencies of a number of non-arboreal elements, such as *Artemisia*, *Plantago lanceolata* and Cheno-Amaranth type at the beginning of the stage, accompanying the fall in the *Quercus* and *Cedrus* curves. A little later Cerealia type, Compositae (Tubuliflorae), and Gramineae, also mark an increase in their values. Cruciferae, Caryophyllaceae, Umbelliferae and *Polygonum* type of pollen grains are either sporadic or are present in the form of discontinuous curves. Stray pollen of *Cannabis sativa*, *Urtica dioica*, *Ammannia*, *Impatiens*, Primulaceae, *Strobilanthes*, *Justicia simplex* and Labiatae, are also met with in this stage. While the curve for *Plantago* continues more or less uniformly throughout this stage, the curves for Gramineae, Compositae (Tubuliflorae), *Artemisia* and Cerealia type fall in the later half of 'Stage c' together with the recovery of the oak curve.

The aquatic vegetation is represented by low values of *Potamogeton* and *Typha*, together with stray occurrence of *Botryococcus* colonies and *Nymphaea* pollen.

The curve for Fern spores (both monolete and trilete) show an increasing trend in this stage.

The transitory increase in all the non-arboreal elements in conjunction with the fall in the values of oak and *Cedrus*,



TEXT-FIG. 9 — Total pollen diagram (AP/NAP) from the Khajiar lake.

accompanied by a stratigraphical change from *Phragmites*-peat to clay at the beginning of 'Stage c' is perhaps indicative of a large scale clearance of tree vegetation in this stage. The fall in the tree vegetation accompanied by an increase in the Cerealia type curve, shows that the clearance was perhaps carried out with the idea of short term agriculture. Further, in view of the fact that the oak values started rising once again in the second half of 'Stage c' accompanied by fall in the curves for Gramineae, Tubuliflorae, *Artemisia* and Cerealia type, it is evident that the forest closed once again. Thus, a 'landnam' type of agriculture (Iversen, 1949) appears to have been practised at Khajiar in 'Stage c' which entailed the cutting down of the forest as a first step. This was perhaps followed by a period of agriculture and later by the abandonment of the site, so that the forest started regenerating once again. The deposition of the clay during this stage perhaps resulted from the above clearance of forests in and around the Khajiar meadow, and the clay deposition ceased as soon as the oak forest was re-established in early 'Stage d'. The lower border of 'Stage c' is C-14 dated around the first century A.D. from the two C-14 dates 1800 ± 55 B.P. (WIS-416) and 1830 ± 50 B.P. (WIS-428) taken from the stages b/c boundary.

'Stage d' (460-220 cm)—The 'Stage c' comes to an end at 460 cm, with the fall in the curves for *Ulmus* and *Corylus*, and 'Stage d' begins with a consistent rise in the values of *Quercus*, which reach up to about 75% in this stage. *Abies* maintains more or less similar values as in earlier stage with slight fluctuations. There is slight increase in the values of *Pinus wallichiana* as compared to the earlier stages. The curve for *Pinus roxburghii* does not show any change, except that its values show a slight decline at the beginning of the stage. *Cedrus* and *Carpinus* start fresh curves. Their curves, together with that of *Betula alnoides* show a consistent rise, and while the curves for *Carpinus* and *Betula alnoides* show a temporary decline in middle of the stage, the curve for *Cedrus* continues unbroken. Both *Alnus* and *Corylus*, show a transitory rise in the lower half of this stage. Other tree and shrub elements present either in the form of low discontinuous curves, or met with rather sporadically, are *Picea smithiana*, *Larix*, *Betula utilis*, *Cupressus*, *Ephedra*, *Buxus*, *Ulmus*, *Aesculus indica*, *Viburnum*, *Celtis australis*, *Popoulus ciliata* (?), *Symplocos* and *Rhododendron*. Of these, the values of *Picea* show a marked increase, as compared to the earlier stages. Stray pollen of *Juniperus*, *Ilex dipyrena*, *Juglans regia* and Mimosoideae (polyad) is also met with.

The non-arboreal pollen ratio fall in this stage. There is a sudden decline in the frequencies of *Plantago lanceolata* at the stages c/d boundary. As the fall in the curve for *P. lanceolata* is on the whole, accompanied by the rise in the values of tree vegetation, it is apparent that its decline resulted from the closing in the forest, following the 'landnam' phase of 'Stage c'. The curve for Cheno-Amaranth type, is seen almost continuously up to the middle of the stage, after which it becomes discontinuous. The values of Cyperaceae and Gramineae tend to increase at the beginning of the stage, but later show a rather fluctuating trend. *Artemisia* maintains more or less similar values throughout the stage with slight fluctuations. Other non-arboreal elements present in low frequencies are Compositae (Tubuliflorae), Cerealia type, *Cannabis*, Cruciferae, Caryophyllaceae, Umbelliferae, Primulaceae and Boraginaceae. Stray pollen of *Thalictrum*, *Impatiens*, Rosaceae, *Strobilanthes*, *Justicia simplex*, Labiatae and *Polygonum* type, is also met with in this stage.

The aquatic vegetation is mainly represented by *Pediastrum* colonies, whose curve is seen in the upper half of the stage, with the values reaching up to 75%. *Potamogeton* forms a continuous curve in the beginning, becoming discontinuous later on. The pollen of *Typha angustata* and colonies of *Botryococcus*, are seen in low values. A few grains of *Nymphaea* are seen at the 250 cm level.

The curve of Fern spores (monolete) shows a fluctuating trend, with frequencies reaching up to 110%. The other type of Fern spores (trilete) decline in this stage.

'Stage e' (220-120 cm)—The 'Stage d' is brought to an end at 220 cm, where there is a consistent fall in the curve for *Quercus*, and 'Stage e' begins with the sudden rise in the frequencies of *Cedrus* whose values ascend gradually, and reach up to nearly 40% at the top end of the stage. There is a slight increase in the

curve for *Picea* and *Abies*. The former increases in the first half while the curve for *Abies* is seen to rise in the later half. *Cupressus* forms a short curve in the beginning, while *Ephedra* a little later. *Pinus wallichiana*, *Pinus roxburghii*, *Betula alnoides* and *Carpinus*, maintain pollen values more or less similar to 'Stage d'. The pollen of *Fraxinus*, which is not represented in 'Stage d' is seen in low values in this stage. Other tree and shrub elements present in low frequencies are *Larix*, *Betula utilis*, *Viburnum*, *Juglans*, *Celtis*, *Populus ciliata* (?), *Symplocos* and *Rhododendron*. Stray pollen grains of *Buxus*, *Aesculus indica*, *Ilex*, *Coriaria*, Mimosoideae (polyad), *Lonicera*, *Grewia* and *Rhus* are also seen in this stage.

Amongst the non-arboreal elements, *Plantago lanceolata* shows a progressive rise, and its values reach up to 15%. The curve for Cerealia type also becomes continuous. The pollen of Cheno-Amaranth type and Caryophyllaceae forms a continuous curve in the upper half of the stage. The curves for Gramineae, Cyperaceae and *Artemisia* maintain more or less similar values as in 'Stage d' with slight fluctuations. Other non-arboreal elements present in low frequencies are Compositae (Tubuliflorae), Umbelliferae and *Polygonum* type, together with stray pollen of *Impatiens*, *Rosaceae*, *Strobilanthes* and *Rumex*.

The aquatic component is represented by the transitory occurrence of colonies of *Pediastrum* and *Botryococcus* in the lower half of the stage. *Botryococcus*, however, forms a curve once again in the upper half, together with *Potamogeton*. Its values reach up to 15%. *Nymphaea* pollen is seen at low value at the top end of the stage.

Fern spores (both monolete and trilete) are poorly represented.

The rise in the curve for *Plantago lanceolata*, Cerealia type, Umbelliferae, Cheno-Amaranth type, accompanying the fall of the *Quercus* curve, is indicative of clearance, for perhaps agriculture in the vicinity of Khajiar. The spectacular increase in the *Cedrus* curve in 'Stage e' may be mainly due to the large scale replacement of *Quercus* by *Cedrus* around Khajiar as a result of selective feeling of oak and the artificial plantations of *Cedrus* carried out during the last several decades. A level just below the lower border of 'Stage e' has been C-14 dated at 1250 ± 60 B.C. (WIS-418).

DISCUSSION AND CONCLUSIONS

STRATIGRAPHY AND THE AGE OF THE LAKE DEPOSIT

The present studies have brought out the vegetational history of the later part of the Post-glacial period only, for the lake sediment at Khajiar could not be investigated beyond the depth of nine metres which though is the maximum depth hitherto penetrated for the Late-Quaternary sediments in India by means of a Hiller peat borer. Further penetration was not possible due to the limited capacity of the boring equipment available. But it is envisaged that in future it will be possible to penetrate the sediment to a deeper extent and thus bring to light the remaining part of the Post-glacial history of vegetation and climate.

The deepest sediment reached at nine metres is comprised of fine organic detritus (Fig. 6). The lake basin deepens abruptly in the north-eastern part of the section. The lake deposits are largely organic in nature derived through a normal hydrosere succession. The lake bottom was not reached except at the lake margins where the organic sediments lie directly over a derived clayey material. The profile obtained from point **15** in the section is incomplete as a part of the organic deposit at the base remains inaccessible. The three C-14 dates — 1800 ± 55 B.C. (WIS-416), 1830 ± 50 B.P. (WIS-428) and 1250 ± 60 B.P. (WIS-418), first two from about the middle and third from the upper part of the profile investigated, may not extend 4000 years B.P. It is quite obvious that deposits of still older age lie at the depths below the levels reached under the present investigations.

VEGETATIONAL HISTORY

With the available C-14 datings, and from the foregoing account of lake deposit investigated at Khajiar, the vegetational history seems to represent the later part of the Post-glacial period.

'*Stage a*' — The picture of vegetation at the beginning of 'Stage a' is seen in a fully developed state rather than as one emerging as a result of some climatic change. The stratigraphical continuity of fine organic detritus below 'Stage a' deposit, without any apparent change in the nature of sediments, preclude the possibility of any climatic change at the beginning of the pollen sequence. The vegetational history begins with a closed forest, in which *Quercus* appears to have been preponderant. The pollen of *Pinus roxburghii*, which is represented by a prominent curve, appears to have come from comparatively lower slopes as it is seen in the present-day surface samples from this site (Sharma, 1973). Other trees and shrubs are lowly represented. The overall dominance of *Quercus* is in great contrast to the present-day conditions at Khajiar, in which *Cedrus* dominates the landscape, together with other conifers, such as *Abies* and *Picea*. Almost pure *Quercus* forests are now, seen occupying the lower slopes below Khajiar. *Quercus* occurs regularly at higher elevations, together with *Abies* and *Picea* forests but mostly in small numbers. The overall preponderance of *Quercus* may, thus, be indicative of relatively warmer conditions than that of the present-day, in this stage. To this extent the purely broad-leaved character of the forests compares closely with mid-post-glacial part of the Toshmaidan pollen sequence from Kashmir, which is taken to represent the Post-glacial 'Climatic optimum' in the area (Singh, 1963). The C-14 datings from Khajiar, in fact, do suggest that the history of 'Stage a' may extend only up to about 4000 B.P. and may, therefore, represent the later part of the 'Post-glacial Climatic Optimum'.

The presence of *Larix* pollen up to 5%, in this stage, suggests that *Larix* was perhaps present, in Himachal Pradesh, in the past, as opposed to its present-day absence in the western Himalayas. Subfossil pollen grains, tentatively identified as those of *Larix*, are also recorded from Post-glacial vegetational sequence from Toshmaidan, indicating the extension of this species westwards up to Kashmir, during the later half of the Post-glacial period (Singh, 1960).

The occurrence of Cerealia type of pollen together with that of *Cannabis*, from the beginning of the pollen sequence, in low frequencies, suggests that cereal cultivation was perhaps prevalent in the area. The history of cereal agriculture in Himachal Pradesh, is almost unknown. In the plains of N.W. India, however, cereal cultivation is definitely known to have been practised since the Harappan times (2,500 B.C.). That the practice of cereal cultivation at Khajiar is accompanied by small scale clearance is shown by the small decline in the curves for *Quercus*, *Taxus*, *Ulmus*, *Carpinus* and *Viburnum* together with a corresponding rise in the curves for Cyperaceae, Gramineae, Cerealia type and *Cannabis*, in the lower half of the stage. The curves for all the above non-tree elements, however, fall with the recovery of the oak curve in the second half of the stage, indicating that the forest closed once again.

Locally, *Botryococcus* colonies appear to have been preponderant in the lake waters, and aquatics, such as *Potamogeton*, *Nymphaea* and *Typha angustata* perhaps grew at the site. *Pediastrum* colonies are represented only in the middle of the stage.

'*Stage b*' — This stage is marked by the establishment of a mixed oak-conifer forest. *Quercus* occurs together with *Cupressus* to start with, and is later joined by *Cedrus* and *Abies*. In 'Sub-stage b$_1$', there is a progressive rise in the *Cupressus* curve, together with a slight increase in the curves for *Fraxinus* and *Carpinus*. Later, in 'Sub-stage b' *Cupressus* declines, accompanied by a general rise in the curves for *Cedrus* and *Abies*. The oak curve tends to decline as a whole in this stage. The tendency towards the establishment of a mixed oak-conifer forest in 'Stage b', may be indicative of perhaps a slight change in the environment towards colder conditions favouring the growth of conifers. All the above coniferous elements, i.e. *Cupressus*, *Cedrus* and *Abies* grow in association with each other at altitude above 1800-2100 m (6,000′-7,000′) with *Abies* occupying highest position.

There is no evidence of any large scale cutting of forests but there is clear possibility that small scale cutting of trees continued throughout this stage.

'*Stage c*' — This stage is characterized by the rise in the frequencies of *Ulmus*, *Corylus* and *Juglans*, accompanied by a sudden fall in the curves for *Quercus* and *Cedrus*. The curve for *Carpinus* becomes discontinuous. The sudden fall in the frequencies of *Cedrus*, *Quercus* and *Carpinus*, appears to be associated with the felling of these elements as their decline is accompanied by a corresponding rise in the frequencies of *Artemisia*, *Plantago*, Cheno-Amaranth type and Ferns, followed by those of Gramineae, Compositae and Cerealia type, indicating the opening of the forest, for perhaps short-term agriculture. The clearing of the forest, also appears to have resulted in bringing about soil instability over mountain slopes, leading to the deposition of clay in this stage. The clearing was in all probability, affected in the present-day meadow surrounding the Khajiar lake. From the two C-14 dates — 1800 ± 55 B.P. (WIS-416) and 1830 ± 50 (WIS-428) available from the stages b/c boundary, the date of this clearance can be placed around the first century A.D. This period was marked by the expansion of Buddhism in India, and Buddhist places of worship were founded in many parts of the country. But, whether the clearance of the forest at Khajiar in 'Stage c' was in any way associated with this phenomenon cannot be ascertained. Elsewhere, in the Himalayas, Buddhist have established several centres, mostly around natural lakes, which are invariably held in high esteem.

The rise in *Ulmus* and *Juglans* frequencies, is of a temporary nature, and it may have been induced as a result of some local plantations at the site. The increase in the relative frequencies of *Corylus*, an element of open, dry, sunny habitats, on the other hand, appears to be natural, and may have resulted from the opening of the forest in this stage. Oak values start rising once again in the second half of the 'Stage c' accompanied by a fall in the frequencies of non-arboreal elements, indicating that the forest closed afterwards.

'*Stage d*'— This stage is characterized by the re-establishment of the mixed oak-conifer forest which is marked by the consistent increase in the values of *Quercus* and the slight rise in the values of *Abies*, *Pinus wallichiana*, *Cedrus*, *Carpinus* and *Betula alnoides*. The deposition of clay ceases with the regeneration of the forests, and it appears that the soil is stabilized once again in early 'Stage d'. *Alnus* and *Corylus* show a transitory rise in the lower half of the stage, but decline afterwards. All the non-arboreal elements, whose frequencies rise as a result of forest clearance in 'Stage c' decline in 'Stage d'. The curve for Cyperaceae, which shows a transitory rise at the beginning of the stage, falls afterwards. However, it rises once again, towards the top end of the stage.

'*Stage e*'— This stage is characterized by a sudden rise in the frequencies of *Cedrus*, accompanied by an equally significant fall in the *Quercus* pollen curve. There is little evidence of the destruction of the oak forest through felling, as there is little change in the curve for AP/NAP ratios, prior to the establishment of the *Cedrus* forest. Thus, the possibility of large scale clearance followed by *Cedrus* plantation, as being the primary cause can be eliminated. In the absence of any large scale forest clearance, however, the question is raised as to how the *Cedrus* forest had come to replace the ancient *Quercus* forest which is seen to have been so well established in the area, since the mid-post-glacial times. That the change had come as a result of some alteration in the climate is ruled out, as other coniferous elements, fail to respond in the same manner as *Cedrus*. The answer in all probability lies in the selective feeling of oak over a long period (a practice still prevalent in the area) which appears to have given an edge to the growth of *Cedrus* in the area. It would be interesting to note that in the otherwise demarcated forest, oak trees are still allowed to be felled for firewood by the forest department, as a result of which, stumps of oak trees can be seen scattered in the almost pure *Cedrus* forest. From the single C-14 date 1250 ± 60 B.P. (WIS-418), available from a level slightly below the stages d/e boundary, the beginning of the *Cedrus* rise can be dated around 1200 B.P. (700 A.D.).

Apart from the *Cedrus* curve, there is slight increase in the values of *Picea*, *Abies*, *Cupressus* and *Ephedra* but the extent to which their rise is influenced through the felling of the oak forest cannot be ascertained.

In the later half of 'Stage e' the rise in the curves for *Plantago lanceolata*, Cerealia type, Umbelliferae and Cheno-Amaranth type, together with further fall in the oak curve, is indicative of a marked clearance in the area for perhaps agriculture.

Phragmites ceases to exist in the organic sediment in this stage. This is particularly interesting as *Phragmites* is totally absent at and around Khajiar except for a small patch constituting the 'floating island'. The disappearance of *Phragmites* from the edges of the Khajiar lake, appears to have been affected at about the beginning of

'Stage e', together with the fall in the oak curve. It is likely that both the felling of the oak forest, started with the establishment of permanent settlement in the Khajiar area dating back to about 1200 B.P. (700 A.D.).

ORIGIN OF 'FLOATING ISLAND'

Sahni (1927) was the first to report the occurrence of a 'floating island' in the Khajiar lake. He was greatly impressed by the abundant *Phragmites communis* growing on the 'floating island' at this site, for the plant is completely absent on the fringes of the lake as well as elsewhere in the area within several miles. Sahni (*loc. cit.*), further stressed upon the need for successional studies to unravel the mystery of the 'floating island'.

It has been already established from the stratigraphy of the deposits at Khajiar (Fig. 6) that but for the upper half to one metre of the lake deposit, the peat comprised of mainly *Phragmites* remains, and forms the bulk of the organic deposit filling the lake basin. It is also clear from the section that prior to the deposition of *Phragmites*-peat, fine organic detritus, a limnic sediment with abundant remains of *Botryococcus* colonies, was being laid down under deep water conditions. The sequence of *Phragmites*-peat, is interrupted by a bed of clay running laterally all through the deposit. Immediately following the deposition of the clay bed, *Phragmites* appears to have become preponderant once again in the upper levels. The otherwise, continuous sequence of *Phragmites*-peat is interrupted by watery gaps, from which it seemed reasonable to believe that thick mats of *Phragmites*-peat floated unanchored over the open waters of the lake in the past. It is clear that *Phragmites* continued to grow at Khajiar-lake-site throughout the sub-recent history of the lake, except for the time span of the upper half to one metre of the lake deposit. The extermination of *Phragmites communis* from the lake margin would, therefore, seem to be a recent phenomenon. It is needless to say that the *Phragmites* growing on the 'floating island' is a remnant of the once flourishing *Phragmites communis* stand in the lake at Khajiar. It is also clear that the 'floating island' which may have been a part of the *Phragmites* stand in the long past, perhaps started its independent life after getting separated from the mother stand. Whether the phenomenon was purely a chance occurrence or it was initially induced through the agency of man is difficult to answer.

The reason for the extermination of *Phragmites communis* from the lake margin is not clear. It is possible that either the *Phragmites* stand was cut down by man for thatching purposes at the time of the establishment of the Khajiar Village, or it was eaten away by domestic animals.

The 'floating island', however, does not appear to have been separated prior to the deposition of the clay bed, as the stratigraphy of the 'floating island' does not show any band of clay intercalated in the peat profile, as it is seen in the stratigraphy of Khajiar lake deposit. On the other hand vegetational history built from the 'floating island' (Sharma, 1972) compares closely with the main characteristics of 'Stage e' of the Khajiar pollen diagram. The lower part of 'Stage e' in the main profile is C-14 dated at 1250 ± 60 B.P. (700 A.D.) (WIS-418), but the pollen diagram from the 'floating island' may not represent the whole time period of 'Stage e'. In any case, the history of the 'floating island' at Khajiar, cannot be pushed back any farther than 'Stage e' that is 700 A.D. Actually, it may be much younger unless it is assumed that the bottom of the 'floating island' has continued to be eroded from time to time through its contact with the shallower parts of the lake basin.

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PALYNOLOGY OF THE TERTIARY SEDIMENTS OF PALANA, RAJASTHAN

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ABSTRACT

The Palana palynological assemblage described here consists of 8 genera and 11 species of pteridophytic spores, 24 genera and 36 species of angiospermic pollen grains, 9 genera and 16 species of algal and 3 genera and 4 species of fungal remains. Of the total of 44 genera and 67 species recorded, 10 genera and 31 species are new.

Quantitative analysis of the assemblage shows that angiospermous elements dominate the assemblage (70%), followed by pteridophytes (20%). Prominent monocot families are Potamogetonaceae, Palmae and Liliaceae. Dicots are comparatively better represented, the principal families include Nymphaeaceae, Leguminosae, Cruciferae, Rubiaceae, Anacardiaceae, Hippocrateaceae, Guttiferae, Meliaceae, Proteaceae and Onagraceae. Pteridophytic spores are mainly represented by Osmundaceae, Matoniaceae, Polypodiaceae, Schizaeaceae and Cheilanthaceae. The algal genus *Botryococcus* along with microplanktons are found in abundance in some stratigraphic levels.

INTRODUCTION

PALYNOLOGICAL investigation on the Palana beds of Rajasthan was initiated by Rao and Misra (1949) when they described *Botryococcus braunii*-like alga from them. Rao and Vimal (1950) also described plant microfossils from these beds. They followed an artificial classification and described the sporomorphs as type 1, type 2, etc. The present paper deals with the systematic description of the spores and pollen grains, algal and fungal remains obtained from different subsurface sections from Palana lignitic field.

The lignitic deposit at Palana in the district of Bikaner, Rajasthan has been commercially exploited since 1898. The following lithologies are observed in this field (see Bhadada, 1968):

Sand	... ...	up to 3 m
Kankar with ferruginous nodules	... ...	15-20 m
Weathered sandstone and clay	... ...	6-12 m
Multani matti (fuller's earth) with nummulitic limestone bands	...	15-20 m
Shale with sandstone bands	... ...	3-9 m
Lignite	... ...	8-15 m
Clay, fire clay	up to	1-2 m

Samples were collected from different lithologies from several subsurface sections and macerated. A very rich palynological assemblage was recovered. The slides were prepared in Polyvinyl alcohol and mounted in canada balsam. The slides and unused material have been deposited in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

SYSTEMATIC PALYNOLOGY

Anteturma — ***Sporites*** **H. Pot., 1893**
Turma — ***Triletes*** **(Rein.) Pot. & Kr., 1954**
Subturma — ***Azonotriletes*** **Lub., 1935**
Infraturma — ***Laevigati*** **(Benn. & Kids.) Pot., 1956**

Genus — *Todisporites* Coup., 1958

Type species — *Todisporites major* Coup., 1958.

Todisporites flavatus Sah & Kar, 1969

Pl. 1, Fig. 1

Holotype — Sah & Kar, 1969, Pl. 1, Fig. 9.

Remarks — The specimens assignable to *T. flavatus* have 52-60 μ size range. Trilete rays are either equal or unequal, extending two-thirds to three-fourths radius, sometimes open. Exine up to 2 μ thick, laevigate, sometimes slightly intrapunctate, exine generally not folded.

Genus — *Dictyophyllidites* Coup., 1958

Type species — *Dictyophyllidites harrisii* Coup., 1958.

Dictyophyllidites sp.

Pl. 1, Fig. 2

Description — Spores triangular, 44-50 μ. Apices rounded, interapical margins ±

straight to slightly concave. Trilete, rays well developed, extending up to equator, associated with folds on distal side. Exine 2-3 μ thick, laevigate and intrapunctate particularly at interradial areas, may be irregularly folded.

Comparison — *Dictyophyllidites* sp. A & B described by Sah & Kar (1969) from the Kaloli Formation in Kutch resemble the present species.

Genus — *Dandotiaspora* Sah, Kar & Singh, 1971

Type species—*Dandotiaspora dilata* (Math.) Sah, Kar & Singh, 1971.

Dandotiaspora plicata (Sah & Kar) Sah, Kar & Singh, 1971

Pl. 1, Fig. 17

Infraturma — *Apiculati* (Benn. & Kids.) Pot., 1956

Genus — *Osmundacidites* Coup., 1953

Type species — *Osmundacidites wellmanii* Coup., 1953.

Osmundacidites sp.

Pl. 1, Fig. 3

Description — Spore subcircular, 54×50 μ. Trilete, rays extending less than two-thirds. Exine about 2 μ thick, granulose-microverrucose, sculptural elements closely placed, evenly distributed.

Comparison — *Osmundacidites wellmanii* Coup. (1953) resembles the present species in shape and size range but is readily distinguished by its confluent bases of the sculptural elements and granulose lacerate margin. *O. ciliatus* Sah (1967) has grana-papillae on the proximal and irregularly distributed coni on the distal surface. *O. minutus* Sah & Jain (1965) resembles the present specimen in general organization but is distinguished by its smaller size. *O. kutchensis* Sah & Kar (1969) has sparse grana as sculptural elements.

Turma — ***Monoletes*** **Ibr., 1933**
Subturma — ***Azonomonoletes*** **Lub., 1935**
Infraturma — ***Psilamonoleti*** **v.d. Hamm., 1955**

Genus — *Laevigatosporites* Ibr., 1933

Type species — *Laevigatosporites vulgaris* (Ibr.) Ibr., 1933.

Laevigatosporites lakiensis Sah & Kar, 1969
L. cognatus Sah & Kar, 1969

Infraturma — *Sculptatomonoleti* Dyb. & Jach., 1957

Genus — *Schizaeoisporites* Pot., 1951

Type species — *Schizaeoisporites phaseolus* Delc. & Spru., 1955.

Schizaeoisporites palanaensis sp. nov.

Pl. 1, Figs. 4-5

Holotype — Pl. 1, Fig. 4, Size 54×32 μ. Slide no. 4353/22.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Spores ± elliptical, 40-55 μ. Monolete distinct or indistinct, extending up to three-fourths along longer axis. Exine 1·5-2·5 μ thick, ribs 8-14, well developed, 3-7 μ broad, parallel to each other, mostly extending from one end to other.

Comparison — *Schizaeoisporites* sp. described by Sah and Kar (1969) resembles the present species in shape and size range but is distinguished by its very fine striations-like ribs. *Schizaeoisporites* sp. described by Sah and Dutta (1966) has smaller size range than the present species. *Schizaea pusilla* Pursh described by Ghosh, Jacob and Lukose (1964) possesses punctate exine.

Schizaeoisporites sp.

Pl. 1, Fig. 6

Description — Spores oval-elliptical, 46-50 μ. Monolete distinct or indistinct, extending up to three-fourths radius. Exine 1·5 μ thick, laevigate, fine striations-like ribs present on both surfaces.

Comparison — *Schizaeoisporites palanaensis* is distinguished from the present species by its coarse ribs. *Schizaeoisporites* sp. described by Sah and Kar (1969) from Kutch closely resembles the present specimens.

Genus — *Seniasporites* Sah & Kar, 1969

Type species—*Seniasporites verrucosus* Sah & Kar, 1969.

Seniasporites verrucosus Sah & Kar, 1969
S. minutus Sah & Kar, 1969

Genus — *Cheilanthoidspora* gen. nov.

Type species — *Cheilanthoidspora enigmata* sp. nov.

Generic Diagnosis — Spores subtriangular, subcircular or oval. Trilete to monolete with various transitional phases. Exoexine well developed, translucent, forming reticulation on both surfaces, exine ± laevigate.

Description — Spores with trilete mostly subtriangular or subcircular in shape with straight-convex interapical margins while in case of monolete, shape varies from broadly oval to oval. Haptotypic mark well developed, extending mostly up to equator, closed or open. In the case of monolete, an open suture looks like a colpus. There are various transitional phases from trilete to monolete or *vice versa* among present specimens. In some spores haptotypic mark is bent simulating a bilete mark while in others, third ray is shorter than rest and hardly recognizable. Exoexine in all specimens well developed, reticulation mostly broad, muri high, meshes ± squarish, in some specimens exoexine is totally or partially lost due to hard process of maceration. This condition is observed both in trilete or monolete spores. Nature of exoexine and pattern of reticulation are same in trilete and monolete spores. Exine is visible only when exoexine is dissolved, it is 1·5-3 μ thick, generally laevigate, in some specimens a few grana are also observed.

Comparison — *Lycopodiumsporites* Thierg. (1938) is comparable to the present genus in subtriangular-subcircular shape and presence of reticulation on both the surfaces. In the present genus, however, the reticulation is formed by the exoexine and the haptotypic mark is variable from trilete to monolete. *Weylandispollis* Taka. (1964) resembles *Cheilanthoidspora* in oval shape and broad reticulation on both the sides but is differentiated by its distinctly monocolpate nature. *Monocolpopollenites* Thom. & Pfl. (1953) also apparently approximates the present genus in shape and broad reticulation but is readily separated by its well developed colpus (see Manum, 1962; Takahashi, 1964). *Cheilanthoidspora* instituted here is distinguished from all of the known genera by its variable haptotypic mark, shape and presence of broad reticulation on both sides formed by the exoexine.

Remarks — *Cheilanthoidspora* commands some special attention for some of its peculiar features. The variable haptotypic mark from trilete to monolete condition with various transitional phases in the present genus is noteworthy. It may be mentioned here that in the extant pteridophytes, the haptotypic mark is also quite variable in a number of species. Nayar (1963) recorded trilete to monolete spores with intermediate forms in *Loxogramme* (Bl.) Pr. belonging to the family Polypodiaceae. Kremp (1967) studied extensively the haptotypic characters of ferns and fern allies embracing 277 genera. He observed that in 29% of cases the spores are wholly trilete, in 49% cases they are monolete while in 22% they are either mixed or show transitional forms. *Botrychium* of Ophioglossaceae, *Stenosemia* of Aspidiaceae, *Cerosora* of Pteridaceae and *Lophosoria* of Cyatheaceae are some of the genera which produce trilete as well as monolete spores. The present genus is, however, unfortunately not comparable to any of the genera mentioned above. In the dispersed fossil spores and pollen grains, a lot of variations of the haptotypic mark are also observed. The bisaccate genera, viz., *Illinites* (Kos.) Pot. & Kl., 1954, *Jugasporites* (Lesch.) Kl. (1963) and *Limitisporites* Lesch. (1956), are similar in all the major characters except that *Illinites* has trilete, *Jugasporites* has bilete and *Limitisporites* has monolete mark. The transitional phases are found in all these genera making it difficult to identify the pollen grain properly (see Leschik, 1956; Manum, 1960; Klaus, 1963; Bose & Kar, 1966).

Lele (1964) observed that in *Plicatipollenites indicus* Lele (1964) though the pollen grains are mostly having trilete mark but some of them show bilete and monolete condition through various transitional phases. Bharadwaj (1964) also noticed monolete to bilete condition in *Potonieisporites* (Bharad.) Bharad. (1964).

The presence of exoexinal layer in the extant pteridophytic spores is of common occurrence (Nayar & Devi, 1964, 1966, 1967, 1968). In the fossil spores this layer is mostly lost due to preservational factors and maceration. The presence of exoexinal thickening forming various ornamentational pattern, observed in *Velamisporites* by Bharadwaj and Venkatachala (1962) from the Carboniferous of Spitsbergen and in *Perotrilites* by Couper (1953) from the Upper Mesozoic sediments of New Zealand. Potonié (1956) also observed the same phenomenon in the megaspore genus *Thy-*

lakosporites Pot. (1956) from the Lower Cretaceous sediments of England.

The present genus is very much comparable to Cheilanthoid group of extant ferns because only in this group a definite perinal layer is observed in the tetrahedral spores. Moreover, the size range of this group (40-60 μ) falls within the size range of the present genus. In this group some plants also produce monolete forms in abnormal cases. In India, Cheilanthoid ferns are quite commonly found in dry places where the humidity is comparatively low. *Cheilanthes tenuifolia* Sw., *C. ferinosa* Kaulf. and *C. bulbosa* Kunze are very common in South India while *C. varians* Hook. and *C. mysorensis* Wall. are restricted to higher hilly tracts (Beddome, 1970). It is, however, difficult to ascertain which particular extant species resembles the fossil ones most because the spores in all those above-mentioned species are more or less similar to each other.

Cheilanthoidspora enigmata sp. nov.

Pl. 1, Figs. 7-10

Holotype — Pl. 1, Fig. 7, Size 51 μ; Slide no. 4354/4.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Spores subtriangular-subcircular, 42-59 μ. Trilete, rays almost reaching margin. Exoexine well developed, forming broad reticulation on both sides.

Description — Apices of spores broadly angular, interapical margins straight-slightly convex, uneven due to projection of muri. Trilete well developed, generally open, rays equal, uniformly broad, commissure recognizable in most of specimens. Exoexine 2-4 μ thick, regularly anastomosing to form broad reticulation, muri up to 5 μ high, meshes squarish, 6-12 μ broad. Exine laevigate to slightly granulose, observed only when exoexine is dissolved.

Remarks — Some of the spores figured by Macko (1957, pl. 75; Figs. 4-12) compares with the present species in shape and reticulation on both the surfaces but the former is differentiated by its absence of haptotypic mark. *Acanthotriletes* sp. described by Sah (1967, Pl. 1; Figs. 25, 30) from the Neogene of Rusizi valleys, Congo, also somewhat resembles the present species in shape and nature of ornamentation.

Cheilanthoidspora monoleta sp. nov.

Pl. 1, Figs. 11-14

Holotype — Pl. 1, Fig. 11, Size 74 × 60 μ; Slide no. 4357/11.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Spores oval, monolete distinct or indistinct. Exoexine forming very broad reticulation on both sides.

Description — Spores with equally broad lateral ends. Monolete generally well recognizable, open, extending almost one end to other. Sometimes it is bent and one short ray emerges from main ray at right angle. Exoexine 3-5 μ thick, muri raised, meshes squarish to rectangular, 6-13 μ broad. Exine up to 2 μ thick, laevigate to slightly granulose.

Comparison — *Cheilanthoidspora enigmata* resembles the present species in the nature of broad reticulation on both surfaces but the former is readily distinguished by its triangular-subcircular shape and presence of trilete rays.

Cheilanthoidspora reticulata sp. nov.

Pl. 1, Figs. 15-16

Holotype — Pl. 1, Fig. 15, Size 60 × 44 μ; Slide no. 4354/11.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Spores oval, monolete, exoexine forming reticulation of meshes, 3-6 μ wide on both sides.

Description — Spores with rounded or slightly pointed lateral ends, 54-65 × 40-48 μ. Monolete distinct or indistinct, straight or curved, closed or open, extending more than three-fourths radius. Exoexine well developed, muri up to 3 μ high, meshes ± same size, exine laevigate.

Comparison — *Cheilanthoidspora monoleta* closely resembles the present species in shape, size range and extension of the monolete but is differentiated by its broader reticulation and stronger muri. *C. enigmata* is triangular-subcircular and has distinct trilete rays.

Anteturma — ***Pollenites* Pot., 1931**
Turma — ***Aletes* Ibr., 1933**
Subturma — ***Azonaletes* (Lub.) Pot. & Kr., 1954**
Infraturma — ***Subpilonapiti* (Erdt.) Vim., 1952**

Genus — *Retipilonapites* Raman., 1966

Type species — *Retipilonapites arcotense* Raman., 1966.

Retipilonapites arcotense Raman., 1966

Pl. 1, Fig. 18

Remarks — The specimens assigned here to *R. arcotense* Raman. (1966) have subcircular-circular shape and densely placed bacula forming negative reticulum on surface view. According to Ramanujam (*l.c.*) the ornamentational pattern in *Retipilonapites* is retipilate.

Retipilonapites sp.

Pl. 1, Fig. 19

Description — Pollen grain nonaperturate, subcircular, 52 μ. Exine less than 2 μ thick, heavily sculptured with pila, pila 3-4 μ long forming negative reticulum on surface view.

Comparison — *Retipilonapites arcotense* Raman. (1966) and *Retipilonapites* sp. described here have both subcircular-circular shape and closely placed sculptural elements. *R. arcotense* Raman. (1966) is baculate whereas in the present species it is pilate. *R. delicatissimus* also described by Ramanujam from the South Arcot lignite of Madras has very delicate pila and coni on the exine. *Retipilonapites* sp. recorded here is readily separated from the former by its heavy sculptural elements.

Turma — *Plicates* (Naum.) Pot., 1960
Subturma — *Monocolpates* Iver. & Tr.-Sm., 1950

Genus — *Palmaepollenites* Pot., 1951

Type species — *Palmaepollenites tranquillus* (Pot.) Pot., 1951;

Palmaepollenites nadhamunii Venkat. & Kar, 1969.

Palmaepollenites sp.

Pl. 1, Fig. 20

Description — Pollen grain longish oval with somewhat pointed lateral ends, 31 × 15 μ. Colpus distinct, end to end, slit-like. Exine about 1 μ thick, laevigate.

Comparison — *Palmaepollenites* sp. described here is comparable to *P. nadhamunii* Venkat. & Kar (1969) in extension of colpus from one end to other end and in laevigate exine, the former is, however, distinguished by its longish oval shape. *P. kutchensis* Venkat. & Kar (1969) and *P. indicus* Raman. (1966) are larger in size range than the present species. *P. neyvelii* Raman. (1966) approximates the present species in shape and size but is distinguished by its thick exine (2·5 μ).

Genus — *Liliacidites* Coup., 1969

Type species — *Liliacidites kaitangataensis* Coup., 1953.

Liliacidites reticulatus sp. nov.

Pl. 1, Figs. 21-22

Holotype — Pl. 1, Fig. 21, Size 50 × 84 μ; Slide no. 4361/5.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Pollen grains monosulcate, 45-60 μ, sulcus distinct, end to end. Exine reticulate, meshes broader in middle region and narrower at ends.

Description — Pollen grains with intact sulcus rarely found in present material. Sulcus ruptures at one or both ends causing splitting of pollen grains. Exine 1-2·5 μ thick, sexine as thick as nexine, meshes well developed, simplibaculate, 3-5 μ in middle and 1-2 μ at ends.

Comparison — *Liliacidites ellipticus* Venkat. & Kar (1969) described from Kutch, Gujarat, is comparable to the present species in widening of sulcus but is readily distinguished by its uniformly small size of the meshes. *L. kaitangataensis* Coup. (1953) resembles the present species in different mesh sizes but is separated by longish oval shape. *L. intermedius* Coup. (1953) approximates the present species in shape, size range and extension of the sulcus but is differentiated by its clavate-baculate structures.

Liliacidites ellipticus Venkat. & Kar, 1969

Pl. 1, Fig. 23

Remarks — Pollen grains oval with rounded lateral ends; 42-50 μ. Sulcus distinct, ± uniformly broad, extending one end to other. Exine 1-2 μ thick, very finely reticulate.

The pollen grains referred here to *Liliacidites ellipticus* resemble the extant pollen grains of *Scilla* of Liliaceae in size range, shape and ornamentational pattern (Erdtman, 1952).

Liliacidites sp.

Pl. 1, Figs. 24-25

Description — Pollen grains monosulcate, 54-60 μ, sulcus distinct, extending from one end to other. Exine 4-6 μ thick, sexine thicker than nexine, tegillate, retipilate.

Comparison — *Liliacidites intermedius* Coup. (1953) closely resembles the present species in shape and size range but the latter is separated by its thicker exine. *L. baculatus* Venkat. & Kar (1969) is also comparable to the present species in size range but is distinguished by its intrabaculate structures forming negative reticulum on surface view.

Genus — *Couperipollis* Venkat. & Kar, 1969

Type species — *Couperipollis perspinosus* (Coup.) Venkat. & Kar, 1969.

Couperipollis rarispinosus (Sah & Dutta) Venkat. & Kar, 1969

Pl. 1, Figs. 26-27

Remarks — Specimens referred to this species have well developed spines, 4-8 μ long with pointed tip, spines sparsely placed, interspinal space granulose.

Couperipollis brevispinosus (Bis.) Venkat. & Kar, 1969

Pl. 1, Fig. 28

Remarks — Pollen grains oval with rounded lateral ends, 48-55 μ. Spines closely placed, with bulbous base and pointed tip, interspinal space granulose, sulcus discernible only in few specimens.

C. kutchensis Venkat. & Kar, 1969

Pl. 1, Fig. 30

Couperipollis sp.

Pl. 1, Fig. 29

Description — Pollen grain elliptical with pointed lateral ends, 46 × 20 μ. Exine 1.5 μ thick, spinose, spines 4-6 μ long, not very closely placed, interspinal space granulose. Sulcus lip-like, extending from one end to other.

Comparison — The present specimen closely resembles *Couperipollis perspinosus* (Coup.) Venkat. & Kar (1969) in size range and disposition of the spines, the former is, however, distinguished by its more elongated shape. *C. rarispinosus* (Sah & Dutta) Venkat. & Kar (1969), *C. brevispinosus* (Bis.) Venkat. & Kar (1969) and *C. kutchensis* Venkat. & Kar (1969) are separated by their broadly oval shape.

Infraturma — *Sphaerozonisulcates* Venkat. & Kar, 1969

Genus — *Nymphaeoipollis* Venkat. & Kar, 1969

Type species — *Nymphaeoipollis marginatus* Venkat. & Kar, 1969.

Nymphaeoipollis marginatus Venkat. & Kar, 1969

Pl. 2, Fig. 31

Remarks — The specimens assignable to this species do not show distinct scrobiculate structures as has been reported by Venkatachala & Kar (1969).

Nymphaeoipollis flavatus Venkat. & Kar, 1969

Pl. 2, Fig. 33

Nymphaeoipollis sp.

Pl. 2, Fig. 32

Description — Pollen grain subcircular, 42 μ, zonisulcate, sulcus distinct. Exine 2 μ thick, granulose-microverrucose, sculptural elements closely placed.

Comparison — The present species is distinguished from *Nymphaeoipollis marginatus* Venkat. & Kar (1969) and *N. flavatus* Venkat. & Kar (1969) by its granulose-microverrucose ornamentational pattern.

Subturma — *Triptyches* (Naum.) Pot., 1960

Genus — *Tricolpites* (Erdt.) Pot., 1960

Type species — *Tricolpites reticulatus* Cook., 1947.

Tricolpites reticulatus Cook., 1947
Pl. 2, Fig. 34

Tricolpites cf. *T. reticulatus* Cook., 1947
Pl. 2, Fig. 36

Description — Pollen grains broadly oval in equatorial view, 47-53 μ. Colpi long, extending almost end to end. Exine up to 3 μ thick, pilate-baculate, sculptural elements closely placed forming negative reticulum on surface view.

Tricolpites matauraensis Coup., 1953
Pl. 2, Fig. 37

Description — Pollen grain oval in equatorial view, 45 × 40 μ. Colpi long extending from one end to other. Exine 2 μ thick, pilate, tegillate, reticulate.

Tricolpites pachyexinus Coup., 1953
Pl. 2, Fig. 35

Description — Pollen grains subcircular in polar view, 42-50 μ. Colpi long, mesocolpia broad. Exine 2 μ thick, laevigate.

Tricolpites levis Sah & Dutta, 1966
Pl. 2, Fig. 41

Remarks — The exine is about 2 μ thick in the present specimen and it is weakly intrastructured.

Tricolpites paucireticulatus sp. nov.
Pl. 2, Figs. 39-40

Holotype — Pl. 2, Fig. 39, size 40 μ; Slide no. 4361/2.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Pollen grains subcircular-circular, 38-46 μ; 3 colpate, colpi broad, colpi margin laevigate. Exine reticulate only in middle part of mesocolpate region.

Description — Pollen grains generally subcircular in polar view with 3 prominent notches due to colpi. Colpi funnel shaped, long, reaching up to polar region. Exine up to 2 μ thick, reticulation ill — well developed in middle region of mesocolpi.

Comparison — The present species is comparable to *Tricolpites pachyexinus* Coup. (1953) in subcircular-circular shape and in the presence of long colpi, the former is, however, distinguished by its uniformly psilate exine. *T. levis* Sah & Dutta (1966), *T. longicolpus* Sah & Dutta (1966) and *T. brevis* Sah & Kar (1970) have smaller size range and laevigate exine. The present species is distinguished from all the other known species of *Tricolpites* by its reticulation present only in the middle region of mesocolpi.

Tricolpites sp.
Pl. 2, Fig. 42

Description — Pollen grain subcircular, 40 μ, 3 colpate, colpi long, funnel shaped. A triradiate ridge like structure present in middle region of pollen. Exine 1·5 μ thick, granulose, grana about 1 μ high.

Comparison — The present specimen closely resembles *Tricolpites pachyexinus* Coup. (1953) in shape, size range and nature of the colpi. The latter is, however, conspicuous by its presence of triradiate ridge like area in the middle.

Subturma — *Ptychotriporites* (Naum.) Pot., 1960

Infraturma — *Prolati* Erdt., 1943

Genus — *Cupuliferoipollenites pullius* (Pot.) Pot., 1951

Cupuliferoipollenites sp.
Pl. 2, Fig. 38

Description — Pollen grain oval in equatorial view, 52 × 30 μ. 3 colporate. Colpi long, extending almost end to end. Pore distinct, lalongate. Exine 1·5 μ thick, weakly intrastructured.

Comparison — *Cupuliferoipollenites ovatus* Venkat. & Kar (1969) is comparable to the present specimen in shape and general organization but the former is distinguished by its smaller size range.

Genus — *Rhoipites* Wode., 1933

Type species — *Rhoipites bradleyi* Wode., 1933.

Rhoipites pilatus sp. nov.
Pl. 2, Figs. 43-44

Holotype — Pl. 2, Fig. 43, size 26 × 18 μ; Slide no. 4360/19.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Pollen grains oval in equatorial view, 22-30 × 14-20 μ, 3 colporate. Exine pilate, pila forming negative reticulum on surface view.

Description — Pollen grains only in equatorial view have met with. Colpi long, extending almost one end to other. Pore distinct or indistinct. Exine 1-2 μ thick, pila 2-3-5 μ long, sometimes interspersed with bacular elements.

Comparison — Among the species of *Rhoipites* described from India, *R. kutchensis* Venkat. & Kar (1969) approximates the present species in size range but is distinguished by its finely reticulate ornamentation. *R. striatoreticulatus* Sah (1967) is striatoreticulate and thus is easily differentiated from the present species.

Genus — *Caprifoliipites* Wode., 1933

Type species — *Caprifoliipites viridifluminis* Wode., 1933.

Caprifoliipites subglobosus sp. nov.

Pl. 2, Fig. 52

Holotype — Pl. 2, Fig. 52. Size 42 μ; Slide no. 4359/10.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Pollen grains subcircular, 36-45 μ. Tricolporate, pore distinct, lalongate, margin thickened. Exine finely reticulate.

Description — Pollen grains with entire margin except three notches due to apertures. Colpi distinct, long, funnel shaped, colpi margin ± laevigate, pore margin appreciably thickened, sexine thicker than nexine, reticulation distinct, meshes uniformly broad.

Comparison — *Caprifoliipites superbus* Sah (1967) described from Neogene of Congo broadly corresponds to the present species in shape and size range, the former is, however, distinguished by its retipilate nature of ornamentation. The species instituted here is differentiated from the other species by its subcircular shape and finely reticulate structure.

Genus — *Hippocrateaceaedites* Raman., 1966

Type species — *Hippocrateaceaedites vancamposae* Raman., 1966.

Hippocrateaceaedites constrictus sp. nov.

Pl. 2, Figs. 45-46

Holotype — Pl. 2, Fig. 46. Size 46 μ; Slide no. 4354/9.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Pollen grains triangular with marked constriction at apices. 3 colporate, pore margin thickened. Exine pilate-reticulate.

Description — Pollen grains 40-50 μ with straight to slightly convex margin. Colpi long, funnel shaped, margin generally thickened. Pore distinct, well developed, margin 3-5 μ thick. Exine 3-5 μ thick, sexine as thick as nexine, pilate, pila 3-5 μ long with prominent bulbous head, closely placed, forming reticulate pattern.

Comparison — *Hippocrateaceaedites vancamposae* Raman. (1966) resembles the present species in shape, size range and general organization but the former is distinguished by its presence of punctitegillate exine.

Genus — *Margocolporites* Raman., 1966

Type species — *Margocolporites tsukadai* Raman., 1966.

Margocolporites sitholeyi Raman., 1966

Remarks — Pollen grains subcircular, 35-43 μ; 3 colporate. Colpi long, funnel shaped, pore generally inconspicuous in polar view. Exine 2-3 μ thick, sexine slightly thicker than nexine, tegillate, reticulate.

Margocolporites sahnii Raman., 1966

Margocolporites complexum Raman., 1966

Remarks — Pollen grains subcircular with three lobes in polar view, 48-57 μ; 3 colporate, colpi well developed, mesocolpia broad. Pores mostly indistinct in polar view. Exine up to 3 μ thick, sexine as thick as nexine or slightly thicker, punctate-reticulate, muri not raised.

Genus — *Lakiapollis* Venkat. & Kar, 1969

Type species — *Lakiapollis ovatus* Venkat. & Kar, 1969.

Lakiapollis ovatus Venkat. & Kar, 1969

Lakiapollis matanamadhensis Venkat. & Kar, 1969

Genus — *Verrutricolpites* Pier., 1961

Verrutricolpites triangulus Sah & Kar, 1970

Pl. 2, Fig. 51

Genus — *Verrucolporites* Sah & Kar, 1970

Type species — *Verrucolporites verrucus* Sah & Kar, 1970.

Verrucolporites verrucus Sah & Kar, 1970

Pl. 2, Fig. 54

Genus — *Platoniapollenites* gen. nov.

Type species — *Platoniapollenites iratus* sp. nov.

Generic Diagnosis — Pollen grains 3-4 colporate, colpi long, pore mostly distinct, pore margin sometimes thickened. Colpi bordered by relatively thin exine, pore lalongate. Exine ± laevigate, thickened at mesocolpate regions.

Description — Pollen grains always found in polar view, 60-85 μ. Colpi conspicuous, funnel shaped, reaching up to polar region; colpi margin mostly dissolve due to its thinness providing a cross like appearance. Pore generally indistinct and not traceable in polar view because colpi margin mostly dissolve, while traceable pore seems to be lalongate, margin sometimes appreciably thickened. Exine 2-6 μ broad, sexine generally thinner than nexine, nexine more thickened in mesocolpial region. Exine mostly laevigate, in some specimens weakly intrastructured. In the present samples, the pollen grains have been badly infected by bacteria/viruses forming white specks all over the exine providing a pseudo-ornamentational pattern.

Comparison — *Meliapollis* Sah & Kar (1970) resembles the present genus in colporate condition and laevigate exine; the former is, however, distinguished by its short colpi and uniformly thickened exine. *Tetracolporites* Coup. (1953) approximates the present genus in tetracolporate nature but the apertures are placed in constricted regions of the polygonal shaped pollen grains. *Quadripollenites* Stov. (1966) is circular-subcircular in shape, tetracolporate and laevigate. This genus is distinguished from *Platoniapollenites* by its thickened margin of the colpi. *Platoniapollenites* proposed here is differentiated from all the colporate genera by its thinner margin of the colpi which generally dissolve to form a cross like appearance in the case of 4 colporate pollen grains and its thickened exine in the mesocolporate region.

Remarks — Tetracolporate pollen grains in the extant angiosperms are mostly found in the families Cucurbitaceae, Guttiferae, Loganiaceae, Meliaceae, Rutaceae and Violaceae. The pollen grains of *Cyclanthera naudiniana* of Cucurbitaceae are 4 colporate and the shape and size range resemble *Platoniapollenites;* but in the former, the sexine is thicker than nexine and is punctitegillate. The pollen grains of *Labordia* of Loganiaceae are comparable to the present genus in shape but are 4 porate and apertural margin is appreciably thickened. The pollen grains of *Viola tricolor* of Violaceae are also 4 colporate, and the size range also approximates the present genus but the exine is more or less uniformly thick and the colpi are comparatively short. The pollen grains of *Platoniapollenites*, however, very much resemble the extant pollen grains of *Platonia insignis* of Guttiferae in size range, 4 colporate condition, thin colpi margin and thickened mesocolpate region. In the present specimens, the colpi margin are mostly dissolved to form wide, funnel shaped colpi. This also provides a cross like appearance for the pollen grains.

In India, now-a-days no species of living *Platonia* is found though it is very common in the tropical forest of Brazil.

Platoniapollenites iratus sp. nov.

Pl. 2, Figs. 57-59

Holotype — Pl. 2, Fig. 57, Size 68 μ; Slide no. 4360/26.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Pollen grains 4 colporate, colpi long, margin thin, pores distinct or indistinct, pore margin thickened. Exine thickened at mesocolpate region, laevigate.

Description — Pollen grains always found in polar view, shape originally squarish-subcircular but appears as a cross due to dissolving of colpi margin, 61-78 μ. Colpi very distinct, funnel shaped, pores while discernible lalongate, margin appreciably thickened. Exine 2·5 μ thick, sexine generally thinner than nexine, thickening at mesocolpate region well developed in some specimens.

Platoniapollenites (*Tetracolporites*) *kivuensis* (Sah) comb. nov.

Holotype — Sah, 1967, Pl. 9, Fig. 8.

Type Locality — Burundi, Rusizi valley, Kundava, Congo. Bore hole Ru. 231, Neogene.

Comparison — *Platoniapollenites* (*Tetracolporites*) *kivuensis* (Sah) comb. nov. is distinguished from *P. iratus* by its intact colpi margin. Moreover, the pore margin is also not thickened in the former species.

Genus — *Calophyllumpollenites* gen. nov.

Type species—*Calophyllumpollenites rotundus* sp. nov.

Generic Diagnosis — Pollen grains subcircular-circular with three constriction due to apertures. Tricolporate, colpi long, pore margin ± thickened. Exine thick, ± laevigate-finely reticulate.

Description — Pollen grains mostly found in polar view, 36-48 μ. Colpi conspicuous in most specimens but in some specimens seem to be slit-like. Pore distinct or indistinct in polar view, margin somewhat thickened in most specimens. Exine 2·5-5 μ thick, sexine as thick as nexine or slightly thicker, exine generally folded along margin. Exine structure sometimes indistinct, reticulation while discernible very fine, otherwise it appears as laevigate.

Comparison — *Nyassapollenites* Thierg. (1937) approximates the present genus in the presence of tricolporate condition but is distinguished by its triangular-subtriangular shape and intrapunctate exine. *Villipites* (Wode.) Pot. (1960) is also triangular-subtriangular, and has thin exine. *Hippocrateaceaedites* Raman. (1966) resembles the present genus in tricolporate nature and thickening of the pores around the margin, but is readily separated by its triangular shape and strongly built reticulation. *Lakiapollis* Venkat. & Kar (1969) is comparable to the present genus in subcircular-circular shape and tricolporate condition. The apertures in *Lakiapollis* are, however, not placed at margin in polar view. Moreover, the colpi are very small and inconspicuous in most specimens. *Caprifoliacidites* Sah (1967) is subtriangular-circular in shape, 3 colporate but the colpi are short and the exine is distinctly reticulate. *Calophyllumpollenites* instituted here is distinguished from all the tricolporate genera by its well developed, long colpi, thickened pore margin, thick exine and laevigate-finely reticulate structure.

Remarks — *Callophyllumpollenites* closely resembles the extant pollen grains of *Calophyllum* belonging to the family Guttiferae (Selling, 1947; Pl. 6, Figs. 121-122). The pollen grains of *C. inophyllum* have a size range of 35-45 μ whereas the fossil pollen studied here closely correspond to the former with a size range of 36-48 μ. Both are 3 colporate, longicolpate with thick exine and finely reticulate structure. In the case of fossil pollen, however, reticulation is sometimes obscure and seems to be ± laevigate. The pollen grains of *Garcinia* of Guttiferae are also comparable to *Calophyllumpollenites* by circular-subcircular shape and 3 colporate condition, the former is, however, distinguished by its smaller size range (29 × 26 μ). Moreover, the sexine in *Garcinia* pollen grain is thinner than nexine and the structure of the exine is indistinct. The pollen grains of *Endodesmia calophylloides* also of Guttiferae approximate the present genus in size range (30 × 26 μ) but is easily distinguished by its brevicolpate nature.

It may be mentioned here that fossil leaves, fruits and woods of Guttiferae have already been reported from the various Tertiary formations of India. Chowdhury and Tandon (1949) described *Kayeaxylon assamicum* from the Upper Miocene of Assam. Lakhanpal and Bose (1951) recorded fossil leaves comparable to *Mesua* and *Garcinia*. Guttiferae is a big family with its restricted distribution to tropical, evergreen forests of Asia and America. The genus *Calophyllum* has about 25 species and they are mostly found in tropical Asia (Lakhanpal & Bose, *l.c.*). Some of the species are commonly found along the coast forming groves here and there (Selling, 1947).

Calophyllumpollenites rotundus sp. nov.

Pl. 2, Figs. 47-49

Holotype — Pl. 2, Fig. 47. Size 38 μ; Slide no. 4360/25.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Pollen grains subcircular-circular in polar view, 36-48 μ; 3 colporate, colpi long, pore margin thickened. Exine thick, laevigate to finely reticulate.

Description — Pollen grains with smooth margin except 3 notches due to apertures. Colpi mostly distinct, funnel shaped, sometimes slit-like. Pores distinct in most specimens, margin uniformly thickened. Exine 2·4-5 μ thick, sexine as thick as nexine or slightly thicker, reticulation while discernible very fine.

Genus — *Kielmeyerapollenites* gen. nov.

Type species — *Kielmeyerapollenites eocenicus* sp. nov.

Generic Diagnosis — Pollen grains mostly in tetrahderal tetrads, 3 colporate, colpi long, pore margin thickened, tetrads 60-77 μ. Exine thick, tegillate, retipilate.

Description — Tetrads mostly triangular-subtriangular, interconnecting area of tetrads thick, appear as triradiate ridge. Individual pollen triangular-subtriangular in shape. Apertures distinctly visible opposite to ridge. Colpi funnel shaped. Pore well developed, margin appreciably thickened in most specimens. Exine 2-5 μ thick, sexine as thick as nexine or slightly thicker, pilate, pila forming reticulate pattern.

Comparison — *Ericipites* Wode. (1933) is comparable to the present genus in the nature of the tetrads, the former is, however, distinguished by laevigate-granulose exine and smaller size range. *Ericaceoipollenites* (Pot.) Pot. (1960) also resembles the present genus in size range and ridge like contact area. *Kielmeyerapollenites* is differentiated from *Ericaceoipollenites* by its tricolporate condition. *Dicotetradites* Coup. (1953) has smaller size range (48 μ) than the present genus and is either colpate or orate (see Potonié, 1960). *Droseradites* Cook. (1947) approximates the present genus in size range but is spinose. *Ricciisporites* Lund. (1954) is a spore genus which is found in tetrads and has verrucose sculptural elements.

Remarks — Tetrad spores and pollen grains are found in most of the geological ages. Chaloner (1958) recorded *Didymosporites* from the Lower Carboniferous while Hennelly (1958), Potonié and Lele (1960) recorded *Quadrisporites* from the Gondwanas. Lundblad (1954) recorded *Ricciisporites* from the Lias of Sweden.

Among the extant angiosperms, the pollen grains in tetrads are found in Droseraceae, Epacridaceae, Ericaceae, Gentianaceae, Guttiferae, Hydrostachyaceae, Monimiaceae, Orchidaceae, Saxifragaceae and Tiliaceae, etc. The tetrahedral tetrads in Droseraceae are polyaperturate and the exine is spinose (Chanda, 1965). *Epacris microphylla* of Epacridaceae has isodynamosporous tetrahedral tetrads and are tricolporate but the size range of the tetrads are smaller (38 μ) than the present genus. *Rhododendron catawbiense* of Ericaceae has also tetrads. The size range is similar to the present genus but the former is distinguished by its laevigate exine. The tetrads of *Helia brevifolia* belonging to the family Gentianaceae are porate. The tetrads of *Hydrostachys verruculosa* of Hydrostachyaceae are rhomboidal and most probably nonaperturate. *Carpodetus serratus* of Saxifragaceae has also subtriangular tetrads but are tricolpate and the exine is ± laevigate-granulose. The orientation of the individual pollen grains in the tetrads of *Neotessmannia uniflora* of Tiliaceae is very different from the present genus.

The genus instituted here, however, closely resembles the pollen grains of *Kielmeyera* of Guttiferae. In both, the pollen grains are mostly found in tetrahedral tetrads and the size range is also same. Moreover, the position of the apertures in the tetrads are also identical and both are 3 colporate. The thickness and nature of the ornamentation are also closely resembling each other. *Kielmeyera*, however, is mostly confined to the tropical forest of Brazil in the present day.

Kielmeyerapollenites eocenicus sp. nov.

Pl. 2, Figs. 60-61

Holotype — Pl. 2, Fig. 60; Size 70 μ; Slide no. 4368/24.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Pollen grains mostly in tetrahedral tetrads. 3 colporate, colpi distinct, pore margin thickened. Exine thick, retipilate.

Description — Tetrads 65-72 μ, triangular-subtriangular, individual margin also triangular-subtriangular, ± equal in size. Contact area distinct, appears as a ridge, exine 2-4 μ thick, sexine as thick as nexine or slightly thicker, tegillate, retipilate.

Genus — *Meliapollis* Sah & Kar, 1970

Type species — *Meliapollis ramanujamii* Sah & Kar, 1970.

Meliapollis ramanujamii Sah & Kar, 1970

Remarks — Pollen grains subcircular-circular, 52-65 × 48-61 μ. Tetracolporate, colpi small, funnel shaped. Pores well developed, margin thickened. Exine 2·4 μ thick, laevigate.

Subturma — *Ptychopolyporines* (Naum.) Pot., 1960

Genus — *Polybrevicolporites* Venkat. & Kar, 1969

Type species — *Polybrevicolporites cephalus* Venkat. & Kar, 1969.

Polybrevicolporites cephalus Venkat. & Kar, 1969

Genus — *Polycolpites* Coup., 1953

Type species — *Polycolpites clavatus* Coup., 1953.

Polycolpites granulatus Sah & Kar, 1970
Polycolpites flavatus Sah & Kar, 1970

Genus — *Pseudonathofagidites* Venkat. & Kar, 1969

Type species — *Pseudonathofagidites kutchensis* Venkat. & Kar, 1969.

Pseudonathofagidites kutchensis Venkat. & Kar, 1969

Turma — *Poroses* (Naum.) Pot., 1960
Subturma — *Diporines* (Naum.) Pot., 1960

Genus — *Diporites* v.d. Ham., 1954

Type species — *Diporites grandiporus* v.d. Ham., 1954.

Diporites sp.

Pl. 2, Fig. 50

Description — Pollen grain oval, 36 × 30 μ. Diporate, pore distinct, margin not thickened. Exine about 2·5 μ thick, finely reticulate.

Comparison — *Diporites* sp. described by Sah & Kar (1970) approximates the present specimen in size but is distinguished by its laevigate exine. *D. grandiporus* v.d. Ham. (1954) is much larger in size than the present specimen and the pore margin is thickened.

Subturma — *Triporines* (Naum) Pot., 1960

Genus — *Trilatiporites* Raman., 1966

Type species — *Trilatiporites erdtmani* Raman., 1966.

Trilatiporites kutchensis Venkat. & Kar, 1969

Genus — *Proteacidites* Cook., 1950

Type species — *Proteacidites adenanthoides* Cook., 1950.

Proteacidites protrudus Sah & Kar, 1970

Remarks — Pollen grain triangular, 44 μ; 3 porate, pore distinct, margin not thickened. Exine 1·5 μ thick, sexine and nexine equally thick, scrobiculate.

Genus — *Triorites* (Erdt.) Coup., 1953

Type species — *Triorites magnificus* Cook., 1950.

Triorites triangulus Sah & Kar, 1970
Triorites hirsutus sp. nov.

Pl. 2, Fig. 53

1966 — *Triorites* sp. 1. Sah & Dutta, p. 83, Pl. 2, Fig. 35.

Holotype — Pl. 2, Fig. 53; Size 46 μ; Slide no. 4375/4.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Pollen grains triangular, 38-50 μ, 3 orate, ora protruding. Exine pilate-baculate, forming negative reticulum on surface view.

Description — Pollen grains generally triangular with ± straight interoral margin. Ora conspicuous, protruding up to 20 μ, margin not thickened. Exine 1-1·5 μ thick, sexine as thick as nexine. Pilate-baculate elements 2-4 μ long, closely placed, uniformly distributed.

Comparison — *Triorites triangulus* Sah & Kar (1970) resembles the present species in the peesance of pilate-baculate elements but is differentiated by its larger and nonprotruding ora. *T. minutus* Sah & Kar (1970) is comparable to the present species in size and shape but it has finely scrobiculate structure. *T. communis* Sah & Dutta (1966) is ± subtriangular in shape and has granulose sculptural elements.

Incertae sedis

Tetracolporate Pollen Type 1

Pl. 2, Figs. 55-56

Description — Pollen grains tetracolporate, 44-61 × 34-42 µ. Colpi short, slit-like, pore distinct, margin thickened. Exine up to 2 µ thick, sexine as thick as nexine, reticulate at two ends in equatorial view.

Pollen Mass Type-1

Pl. 2, Fig. 62

Description — Pollen mass subcircular in outline, 86 µ, seems to be octad, tricolporate, colpi long. Exine about 3 µ thick, sexine thicker than nexine, tegillate, retibaculate.

ALGAE

Family — BOTRYOCOCCACEAE

Genus — *Botryococcus* Kutz., 1849

Botryococcus palanaensis sp. nov.

Pl. 3, Figs. 63-64

1953 — *Botryococcus braunii* Kutz.: Vimal, pp. 375-376, Figs. 1-6.

Holotype — Pl. 3, Fig. 63; Size 62 µ; Slide no. 4352/8.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Colonial algae, colony subcircular in shape with slightly serrated margin, 20-110 µ. Individual cells 5-10 µ long with swollen tip, tip somewhat lacerated, covered with a ± translucent wall providing a thimble like appearance. Individual cell divides longitudinally and is surrounded by a thick, cup shaped structure at each end.

Comparison — *Botryococcus luteus* described by Traverse (1955) from the Brandon lignite of Vermont closely resembles the present species in general organization. In *B. luteus*, the individual cells are rod shaped and not swollen at tip like the present species. *B. braunii* Kutz. reported by Cookson (1953) also approximates the present species in shape and nature of the colony but is distinguished by its very well developed cup shaped depression at each side of the rod like thimble.

Remarks — *Botryococcus* is a cosmopolitan genus found in both fresh and saline water. Its existence has been traced up to Ordovician and seems to be responsible for good amount of boghead coal in various countries. In India, *Botryococcus* is known from the Tertiary sediments. Rao and Misra (1949) reported for the first time *Botryococcus* from the Palana lignites. They described the algae but did not include them into any species. It may, however, be mentioned that the specimens resemble *Botryococcus braunii* described by Cookson (1953) from the different Cainozoic deposits of Australia. Since the present material also comes from the same locality it was possible to study many specimens resembling those photographed by them. It has been assumed that the specimens described by them also belong to the present species.

Vimal (1953) also reported *Botryococcus braunii* Kutz. from Eocene lignites of Kutch, Western India. From the photomicrographs provided by Vimal (1953), it seems that individual cells are mostly swollen at tips and the surrounding cup shaped cavities are not well pronounced. So it has been transferred into the present species.

Mathur (1964) pointed out the occurrence of *Botryococcus* along with other algal fossils in Subathu beds of Himachal Pradesh. The *Botryococcus* described by her (*l.c.*) also belongs to the present species.

Botryococcus palanaensis proposed here is thus quite frequently found in the Lower Eocene sediments of Palana, Kutch and Himachal Pradesh. The occurrence of *Botryococcus* in the similar sediments in Assam has not yet been reported so far. The general association of this genus along with the lignites in Western India perhaps point out their role in making the same.

Genus — *Tetraporina* (Naum.) Naum., 1950

Type species — *Tetraporina antiqua* Naum., 1950.

Tetraporina apora sp. nov.

Pl. 3, Fig. 65

Holotype — Pl. 3, Fig. 65; Size 50×36 μ; Slide no. 4353/26.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis—Squarish to rectangular spores (? aplanospores), 45-55×31-37 μ. No pore is observed in any specimen. Margin may be constricted in middle, laevigate, a scar may be observed in central region in some specimens.

Comparison—*Tetraporina horologia* (Stap.) Playf. (1963) is distinguished from the present species by its tetraporate nature. *Tetraporina* sp. described by Segroves (1967) is comparable to the present species by its nonporate condition and slight constriction at two lateral ends.

Remarks — The genus *Balmeella* instituted by Pant & Mehra (1963) from the Bacchus Marsh tillite (Lower Permian) of Australia has been regarded by Segroves (1967) as the junior synonym of *Tetraporina*. It has been observed that the specimens may be with or without pores. The pore number varies from one to four.

The stratigraphic range of *Tetraporina* is from Lower Carboniferous to Recent. Churchill (1960) thought them to be the aplanospores of *Cyanophyceae*. He reported many *Tetraporina* like spores from the subrecent peat deposits of Australia. He also reported *Tetraporina* from the Lower Tertiary glauconitic shales from the Perth basin. One of the figures (Churchill, 1960, Fig. 3) resembles very much the present species.

Tetraporina pachyderma sp. nov.

Pl. 3, Fig. 66

Holotype — Pl. 3, Fig. 66; Size 59×48 μ; Slide no. 4351/31.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — More or less rectangular, 48-65×42-50 μ. Spore coat 3-5 μ thick, laevigate. Margin may be undulated, ± constricted in middle region.

Comparison—*Tetraporina apora* resembles the present species in shape and size range but the latter is readily distinguished by its thickness of the spore coat.

Genus — *Psilosphaera* gen. nov.

Type species — *Psilosphaera plicata* sp. nov.

Generic Diagnosis — Microplanktons subcircular-circular. Operculum distinct, subcircular. Wall generally one layered but may be stratified to form several layers, laevigate. A subcircular fold present parallel to margin.

Description — Microplanktons with entire margin, 45-65 μ. Operculum conforms overall shape, opening smooth, operculum may be associated with minor fold. Wall 2-8 μ thick, generally one layered but may be stratified up to 8 layers. Wall strongly folded on opposite side of operculum along entire margin. It is always situated in between operculum and margin. Sometimes this fold is very juxtaposed to margin. In some specimens, some very weak plates seem to be present but their exact nature cannot be discernible.

Comparison — *Leiosphaeridia telmatica* described by Sarjeant & Strachan (1968) from the Pleistocene peats of Staffordshire, England is comparable to the present genus in shape, laevigate wall and circular opening. The present genus is, however, distinguished by its presence of regular, strong fold system parallel to margin and generally more than one layered wall.

Psilosphaera plicata sp. nov.

Pl. 3, Figs. 67-70

Holotype — Pl. 3, Fig. 67; Size 48 μ; Slide no. 4360/24.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Microplanktons subcircular-circular, 45-65 μ. Operculum distinct, subcircular-circular, opening smooth. Wall 2-8 μ thick, laevigate, mostly one layered but may be stratified up to 8 layers. A strongly built subcircular regular fold system is always found in between operculum and margin. This fold system seems to be present on opposite side of operculum.

Genus — *Temporina* gen. nov.

Type species — *Temporina globata* sp. nov.

Generic Diagnosis — Microplanktons subcircular-circular, a median suture generally present on one side, on other side four plates observed in some specimens. Wall 1·5-6 μ thick, laevigate-verrucose.

Description — Microplanktons generally subcircular, 45-98 μ. Median suture on one side while decipherable, simulates a sinuous line extending from one end to other. In some specimens, however, it falls short. Suture generally divides into two at one or both ends near margin. Sometimes, a small branching also observed in middle region perpendicular to median one. On other side four plates observed in some specimens. In most cases, however, these plates are not discernible. Outer margin of wall mostly smooth, a few verrucae found in some specimens. They are generally irregularly distributed but sometimes aligned in rows parallel to margin to provide a dentate appearance. Wall may be irregularly folded and unevenly thick in some specimens forming a depressed area in middle.

Comparison — *Psilosphaera* resembles the present genus in subcircular-circular shape but is distinguished by its presence of operculum and a subcircular fold parallel to margin.

Temporina globata sp. nov.

Pl. 3, Figs. 71-73

Holotype — Pl. 3, Fig. 71; Size 45 μ; Slide no. 4360/24.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Microplanktons generally subcircular, 75-94 μ. Median suture on one side mostly discernible. It is more or less sinuous and generally divides into two at ends. A small branching is also observed in middle region. On other side, wall is divided into four plates in few specimens. Wall up to 3·5 μ thick, mostly laevigate, sometimes scantily verrucosed.

Temporina dentata sp. nov.

Pl. 3, Figs. 74-75

Holotype — Pl. 3, Fig. 74; Size 90 μ; Slide no. 4376/1.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Subcircular-circular microplanktons, 80-98 μ. Median suture mostly not traceable. Wall up to 6 μ thick, verrucose, verrucae generally align into rows parallel to margin to furnish a dentate appearance, a few irregularly distributed verrucae also observed in middle. Wall may be unevenly thickened, a depressed area in middle may be observed in few specimens.

Comparison — *Temporina globata* fairly resembles the present species in shape and size, the former is, however, readily separated by its prominent median suture and a few irregularly distributed verrucae.

Genus — *Cephalia* gen. nov.

Type species — *Cephalia globata* sp. nov.

Generic Diagnosis — Microplanktons subcircular-oval. Plates generally not discernible, while discernible it seems to have a median suture with a branch in middle on one side. Numerous oil globules present. Apical appendage present in most specimens.

Description — Microplanktons vary greatly in shape, many transitional shapes from subcircular-oval found in present preparation. Size range in subcircular microplanktons 50-70 μ while in oval ones 50-80 × 40-50 μ. Apical appendage looks like a small projection at one end, in some specimens it may be septate. Suture generally obscure, in a few specimens a sinuous median suture observed, sometimes another suture emerges perpendicularly from it in more or less middle region. Thus in these specimens, one side is made of three plates only. Oil globules translucent and provide pseudoreticulate appearance. In oval specimens, a short antapical projection also seen in some.

Comparison — *Temporina* proposed earlier resembles the present genus in the presence of subcircular shape and a median suture. The former genus is, however, distinguished by its presence of four plates on one side and laevigate-verrucose wall. *Psilosphaera* also resembles *Cephalia* in subcircular-circular shape but is conspicuous by its presence of operculum.

Cephalia globata sp. nov.

Pl. 3, Figs. 76-77

Holotype — Pl. 3, Fig. 76; Size 70 × 64 μ; Slide no. 4360/6.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Microplanktons ± subcircular, 55-77 × 49-72 μ. Sutures generally not traceable, while discernible it appears to have a median suture with a branch ± in middle at one side. Numerous oil globules present to provide pseudoreticulate appearance. Wall up to 2·5 μ thick, intrastructured. Apical appendage conical, short, mostly discernible.

Cephalia ovata sp. nov.

Pl. 3, Figs. 78-80

Holotype — Pl. 3, Fig. 78; Size 60 × 38 μ; Slide no. 4377/22.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Microplanktons generally oval, 52-81 × 36-53 μ. Sutures not discernible in most specimens, in some a longitudinal suture is distinguishable. Oil globules many. Apical appendage present, sometimes septate. A small, antapical horn like projection also observed in some specimens.

Comparison — *Cephalia globata*, the type species of the genus, is distinguished from the present species by its subcircular shape.

Genus — *Octaplata* gen. nov.

Type species — *Octaplata rotunda* sp. nov.

Generic Diagnosis — Microplankton subcircular-oval. Plates mostly distinct, 8 in number, subcircular, squarish-polygonal in shape, wall thin or thick, laevigate.

Description — Microplanktons generally subcircular, sometimes oblongoid and ovate, 48-82 × 44-71 μ. Suture straight or sinuous, distinct. In case of subcircular specimens, one subcircular plate on each side in middle region observed. Other plates also seem to be irregularly subcircular in outline. Among oblongoid and ovate specimens, plates ± polygonal in shape. Wall may be as thin as 1 μ, in some it is quite thick and may be up to 5 μ. No opening observed in any specimen.

Comparison — *Psilosphaera* resembles the present genus in shape but is readily distinguished by its presence of distinct operculum. *Temporina* is also subcircular-circular but has mostly a median suture on one side and four plates on the other. Moreover, in some specimens of *Temporina*, verrucae are observed more or less parallel to margin. In *Cephalia*, plates are generally not discernible. *Octaplata* instituted here is conspicuous by its distinct plates which are mostly 8 in number.

Octaplata rotunda sp. nov.

Pl. 3, Fig. 81

Holotype — Pl. 3, Fig. 81; Size 58 × 56 μ; Slide no. 4368/21.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Microplanktons subcircular-circular, 48-77 × 46-75 μ. Plates distinct, 8 in number. Central plate on each side ± subcircular, other plates also subcircular, plates 21-39 μ in size. Wall laevigate, opening not observed.

Octaplata palanaensis sp. nov.

Pl. 3, Fig. 82

Holotype — Pl. 3, Fig. 82; Size 74 × 62 μ; Slide no. 4363/8.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Microplanktons oblongoid to ovoid, 62-82 × 50-71 μ. Plates prominent, 8 in number, plates ± polygonal in shape, 27-42 × 23-36 μ. Wall up to 4 μ thick, laevigate, opening not observed.

Comparison — *Octaplata rotunda* comes closer to *O. palanaensis* in the presence of same number of plates but is differentiated by its subcircular-circular shape. Moreover, in *O. rotunda*, the shape of the plates are subcircular whereas in the present species it is polygonal.

Genus — *Palanara* gen. nov.

Type species — *Palanara granulosa* sp. nov.

Generic Diagnosis — Microplanktons rectangular, generally tabular. Wall up to 3 μ thick, laevigate, granulose-warty. In some specimens, a few appendages are observed at one end.

Description — Microplanktons mostly with equally broad apical and antapical ends; in some specimens apical end slightly narrower than other one, 56-138 × 38-70 μ. Tabulation generally not distinct. It seems that apical and antapical ends composed of single plate. Lateral ends, on one side made of two rectangular plates, one being quite bigger than other. On other side, lateral ends seem to be made of three plates. At this view, 1-5 appendages sometimes observed at apical region. They are translucent, squarish to tubular in shape and originate below apical margin. In one specimen, it was observed that one of the appendages swollen at tip to form a dark brown, subcircular cyst like body. Grana while observed uniformly distributed, in some a few warts also observed.

Comparison — *Palanaca* does not closely resemble any of the genera described here. *Octaplata* is subcircular-oval in shape and is readily separated from the present genus by its presence of eight plates.

Derivation of Name — After the name of Palana lignite field.

Palanaca granulosa sp. nov.

Pl. 3, Figs. 83-84

Holotype — Pl. 4, Fig. 83; Size 118-60 μ; Slide no. 4379/18.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Microplanktons rectangular, 98-138 × 50-70 μ. Tabular, tabulation on one side seems to be formed by two plates at lateral ends of unequal size. In some specimens, one lateral plate at each end only traceable. On other side, lateral ends appear to be made of 3 plates. Apical and antapical ends made of one plate each. A few apical appendages arising below apical margin observed in some specimens. Wall up to 3 μ thick, uniformly granulose, a few warts also interspersed with them.

Palanaca laevigata sp. nov.

Pl. 4, Fig. 85

Holotype — Pl. 3, Fig. 85; Size 100 × 50 μ; Slide no. 4360/12.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Microplanktons rectangular, 60-110 × 34-55 μ. Lateral ends made of one plate on each side. Apical and antapical regions also made of one plate each. Wall 1·5 μ thick, laevigate, may be irregularly folded.

Comparison — *Palanaca granulosa* is distinguished from *P. laevigata* by its granulose-warty wall. Moreover, the former has also a bigger size range than the present species.

Genus — *Cryptosphaera* gen. nov.

Type species — *Cryptosphaera pachyderma* sp. nov.

Generic Diagnosis — Microplanktons subcircular-oval, 1-many chambered, operculum seems to be present. Within each chamber, a thick walled body present which on its turn bears another body with thin wall and generally with a pore. Outermost wall of microplanktons thick, mostly laevigate and intrastructured.

Description — Microplanktons conspicuous by their lobed appearance due to chambers. 36-88 × 32-81 μ. Chambers hardly of same size and some of them abortive. As a result, the specimen may be unichambered, bi, tri, quadri or many chambered. An operculum to each chamber seems to be present because each chamber has a thick outer wall and inner thin layer. In some specimens, a piece of operculum found detached (Pl. 4, Fig. 87). It is as thick as outermost wall and also similarly ornamented. Outermost wall thick, laevigate and intrapunctate, in some translucent verrucae also observed. In a few chambers, a subcircular-oval body seen. Its size varies from 36-87 μ, wall 3-8 μ thick, laevigate. Within it, another body develops conforming with the shape of inner body, its size ranges 30-80 μ, wall up to 2 μ thick, granulose-verrucose, sometimes it may be intrastructured. In mature specimens, a circular pore observed in this body. Detached bodies frequently found in present preparation. In addition to this pore in innermost body, another pore also observed in outermost wall in some specimens.

Comparison — *Cryptosphaera* instituted here is very peculiar in its organization and as such is not closely comparable to any of the known microplankton genera. *Psilosphaera* is somewhat comparable in shape but is readily distinguished by subcircular-circular operculum.

Cryptosphaera pachyderma sp. nov.

Pl. 4, Figs. 86a-86b

Holotype — Pl. 4, Figs. 86a, 86b; Size 68 × 65 μ; Slide no. 4351/7.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Microplanktons subcircular, one chambered, other chambers abortive. 45-68 × 41-65 μ. Operculum seems to be present but not observed. Outermost wall laevigate and intrapunctate, within it, a thick walled (3-8 μ), subcircular body seen. This on its turn gives rise to granulose-verrucose body. In mature stage, this may have a circular pore. Detached inner bodies frequently found in present preparation.

Cryptosphaera valvata sp. nov.

Pl. 4, Figs. 87-88

Holotype — Pl. 4, Fig. 87; Size 44×41 μ; Slide no. 4350/4.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Microplanktons 2-6 chambered, chambers of varying sizes, 41-64×37-61 μ. Operculum found detached only in one specimen. Outermost layer laevigate and intrapunctate, sometimes may be verrucose. Thick walled inner body not observed in most specimens. Apart from pore in innermost body, an additional pore noticed in outermost wall.

Comparison — The present species is comparable to *Cryptosphaera pachyderma* in general organization but the latter is distinguished by its presence of only one chamber.

Genus — *Cornplanktona* gen. nov.

Type species — *Cornplanktona fracta* sp. nov.

Generic Diagnosis — Microplanktons subcircular-oval. Appendages mostly present at both ends. Outer wall laevigate and intrastructured, sometimes verrucose-spinose, thick. Middle region thin, providing a cavity like appearance, one surface in middle region generally ruptures. In some specimens, a circular, inner body observed within cavity.

Description — Microplanktons generally thick walled (3-16 μ), thickness of wall in most specimens not uniform. Size range 41-115×34-107 μ. Appendages present at one or both ends. In most specimens, a horn like appendage observed at one end (? apical) with broad base and pointed tip, in others they may be up to 4 and look like nipples. In opposite end, appendage may be present or absent, it may be one and hornlike or may be up to 4, in others it may be ± rectangular. Appendages when present mostly at same plane, but in some rare cases they are not found in same plane. Inner cavity subcircular-oval, distinct, at one surface it ruptures irregularly, other surface generally remains intact, this latter surface mostly laevigate, sometimes intrastructured, in others this may be verrucose-spinose, sculptural elements ± translucent forming pseudoreticulate appearance on surface view. Within this cavity, in some specimens, inner body observed, in some five plates noticed on one surface of this inner body, in others they are absent, inner body may be granulose or intrapunctate.

Comparison—*Cryptosphaera* approximates the present genus in the possession of thick wall but is readily distinguished by its absence of any appendages at ends. Moreover, the specimens in *Cryptosphaera* are mostly chambered and there is a pore in the innermost body. *Apteodinium* Eisen. (1958) has an apical appendage but its wall is thin and devoid of prominent inner cavity as found in the present genus.

Cornplanktona fracta sp. nov.

Pl. 4, Figs. 89-90

Holotype — Pl. 4, Fig. 89; Size 81×76 μ; Slide no. 4377/17.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis —Microplanktons subcircular-oval in shape, 74-115×62-107 μ. Appendages present at one or both ends, number varies from 1-4. Wall up to 16 μ thick, laevigate and intrapunctate, a few spines or verrucae may also be present. Inner cavity well defined, generally ruptures at one surface, an inner body with 5 plates at one surface sometimes found within it.

Cornplanktona unicorna sp. nov.

Pl. 4, Fig. 91

Holotype — Pl. 4, Fig. 91; Size 76×57 μ; Slide no. 4379/26.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Microplanktons subcircular-oval, 61-82×54-75 μ. Appendage generally one at each end. At one end (? apical) it is horn shaped whereas in other it is broad and ± rectangular. Inner cavity distinct, generally irregularly ruptures at one surface, other surface sculptured with translucent verrucae and spines forming negative reticulum. Within cavity in some specimens a granulose inner body with intrastructure observed.

Comparison — *Cornplanktona unicorna* closely resembles *C. fracta* in general organization, the former species is, however, distinguished by its presence of one horn like appendage at one end and rectangular on other. In addition to it, the wall is also verrucose-spinose forming pseudoreticulum.

Cornplanktona sp.

Pl. 4, Fig. 92

Description — Microplankton oval, 56×39 μ. Outer wall thick, laevigate and intrapunctate. One horn like appendage present at each end in one plane. Cavity distinct, ruptured at one surface.

Comparison — *Cornplanktona fracta* and *C. unicorna* are differentiated from the present specimen by their bigger size range. Moreover, horn like appendage at each end in the present specimen is also very characteristic.

cf. *Cornplanktona* sp.

Pl. 4, Fig. 93

Description — Microplankton subcircular, 82×80 μ with a horn like appendage at one end. Below the appendage, a precingular archaeopyle seems to be present. Outer wall up to 3 μ thick, foveo-reticulate. Inner cavity not observed.

Remarks — The specimen described here is distinguished from *Cornplanktona* by its absence of inner cavity though it resembles in general shape and its horn shaped appendage at one end. The presence of archaeopyle is also very remarkable and hence the present specimen has only been compared to *Cornplanktona*.

Microplankton Type-1

Pl. 4, Fig. 94

Description — Microplanktons oval, 61-76×50-64 μ. Outer wall laevigate, an inner cavity in middle region present, this may or may not conform general shape, in some specimens, a subcircular opening noticed at one surface of inner cavity.

Microplankton Type-2

Pl. 4, Fig. 95

Description — Microplankton oval, 58×48 μ. A precingular archaeopyle present. Plates not clearly discernible. Outer wall wrinkled, laevigate.

FUNGI

Genus — *Inapertisporites* (Ham.) Els., 1968

Type species — *Inapertisporites variabilis* van der Ham., 1954.

Inapertisporites kedvesii Els., 1968

Pl. 4, Fig. 96

Holotype — Elsik, 1968, Pl. 5, Fig. 8.

Description — Fungal spores, 55-77×49-72 μ, inaperturate. Wall less than 1 μ thick, irregularly folded.

Inapertisporites globatus sp. nov.

Pl. 4, Fig. 97

Holotype — Pl. 4, Fig. 97; Size 49×45 μ; Slide no. 4377/16.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Spores subcircular, inaperturate, 34-50×32-47 μ. Wall 3-6 μ thick, not folded.

Comparison — *Inapertisporites kedvesii* Els. (1968) resembles the present species in subcircular shape but is distinguished by its thin wall and irregular folds.

Inapertisporites sp.

Pl. 4, Fig. 98

Description — Fungal spores subcircular, 60-90 μ, inaperturate. Wall up to 1-2 μ thick, not much folded.

Comparison — *Inapertisporites kedvesii* Els. (1968) has thin wall with many folds.

Genus — *Dicellaesporites* Els., 1968

Type species — *Dicellaesporites popovii* Els., 1968.

Dicellaesporites constrictus sp. nov.

Pl. 4, Fig. 99

Holotype — Pl. 4, Fig. 99; Size 104×64 μ; Slide no. 4352/14.

Type Locality — Palana lignite field, Palana, Rajasthan.

Diagnosis — Two celled, psilate, inaperturate fungal spores, 89-120 × 40-101 μ, constricted in middle, uniseptate. Individual cell subcircular-oval.

Comparison — *Dicellaesporites popovii* Els. (1968) is much smaller in size range than the present species. Moreover, in the present species, constriction in the septate region is also much pronounced.

Genus — *Callimothallus* Dil., 1965

Type species — *Callimothallus pertusus* Dil., 1965.

Callimothallus assamicus Kar, Singh & Sah, 1972

Holotype — Kar, Singh & Sah, 1972, Pl. 2, Fig. 19.

Description — Ascomata subcircular with or without undulated margin, one celled thick, nonostiolate. Cells in middle region ± squarish, outer cells rectangular, thicker, pseudoparenchymatous, cells uniporate in middle region.

DISCUSSION

General Considerations — The samples from Palana lignite field, Rajasthan, yielded a rich palynological assemblage comprising algal filaments, microplanktons, fungal spores and microthyriaceous fruiting bodies; pteridophytic spores and angiospermic pollen grains. Not a single gymnospermous pollen was recovered from the present material. The assemblage consists of 8 genera and 11 species of pteridophytic spores, 24 genera and 36 species of angiospermic pollen, 9 genera and 16 species of algal and 3 genera and 4 species of fungal remains.

PTERIDOPHYTA

Pteridophytic spores are very common in the present material. Generally speaking they are found in abundance in shales than in lignites. 8 genera and 11 species representing the following 5 families have been recognized: Osmundaceae, Matoniaceae, Polypodiaceae, Schizaeaceae and Cheilanthaceae.

Osmundaceae — 2 genera, viz., *Todisporites* and *Osmundacidites*, belong to this family. The family is rather meagrely represented in the assemblage. The family is found both in tropical and temperate climate.

Matoniaceae — This family is also rarely found in the present material. The spores assigned to *Dictyophyllidites* most probably belong to this family.

Polypodiaceae — The typical bean-shaped, monolete, verrucose spores of Polypodiaceae is not commonly found in the assemblage. The spores of *Laevigatosporites* represented here by *L. lakiensis* and *L. cognatus* have also been assigned to this family.

Schizaeaceae — The family is very well represented. The monolete, striate, oval spores resembling the extant genus *Schizaea* have been referred as *Schizaeoisporites*. The trilete, subtriangular, laevigate spores resembling *Lygodium* are very commonly met with.

Cheilanthaceae — This family is also quite abundant like Schizaeaceae. The spores of this family have distinct perine and the haptotypic mark is also variable. Three species, viz., *Cheilanthoidspora enigmata*, *C. monoleta* and *C. reticulata* belong to this family. In India, cheilanthoid ferns are found in dry places where the humidity is relatively low.

ANGIOSPERMAE

The angiospermic pollen together with the pteridophytic spores constitute more than 90% of the assemblage. The former has been referred to 24 genera comprising 36 species. Both the monocotyledonous and dicotyledonous plants are well represented in the assemblage.

MONOCOTYLEDONEAE

The monocotyledonous plants are represented by 3 families, viz., Potamogetonaceae, Palmae and Liliaceae. 4 dispersed genera have been included in them.

Potamogetonaceae — This acquatic family of annual or perennial herbs is meagrely represented in the present assemblage. *Retipilonapites arcotense* and *Retipilonapites* sp. belong to this family.

Palmae — This family is quite abundant. *Palmaepollenites* and *Couperipollis* both belong to this family. This family is one of the earliest known families from the Upper Mesozoic and is confined to tropical to subtropical region. They are either shrubs or trees and rarely climbers.

Liliaceae — This family is represented by the genus *Liliacidites*. The pollen grains of Liliaceae can be conveniently identified by its oval shape, monosulcate nature and presence of bigger meshes in middle region. In some samples this genus is quite common. This family comprises mostly herbaceous plants and are distributed in tropical as well as in temperate climate.

DICOTYLEDONAE

Nymphaeaceae — This family comprises the acquatic perennial herbs and is found both in temperate and tropical climate. In some samples this family is well represented by *Nymphaeoipollis marginatus*, *N. flavatus* and *Nymphaeoipollis* sp. The pollen grains belonging to this family have subcircular-circular shape, zonisulcate condition and scrobiculate structure.

Leguminosae — This is a very big family consisting of three suborders, viz., Papilionaceae, Caesalpiniaceae and Mimosaceae. The former is the largest of the three and cosmopolitan in its distribution. Caesalpiniaceae and Mimosaceae, on the other hand, do not extend beyond the tropical and warm temperate zones. The pollen grains of *Margocolporites* in all probability represent Caesalpiniaceae (see Ramanujam, 1966). The pollen grains of *Margocolporites* are frequently met with and are represented by three species, viz., *Margocolporites sitholeyi*, *M. sahnii* and *M. complexum*. Besides some tricolpate pollen grains described under the genus *Tricolpites* may also belong to Caesalpiniaceae.

Cruciferae — The presence of pollen grains belonging to Cruciferae is rather doubtful. Only one species, i.e. *Tricolpites levis*, may be attributed to this family. Cruciferae, it may be mentioned here, is a large and widely distributed family and mostly abundant in temperate and cooler regions though some species may be found in tropical belt only.

Rubiaceae — The presence of Rubiaceae in the present assemblage cannot be properly ascertained. However, *Cupuliferoipollenites* sp. described here may be referred to this family. This family is mostly confined to tropical-subtropical belts.

Anacardiaceae — This family consists either of trees or shrubs and is chiefly tropical. *Rhoipites pilatus* most probably belongs to this family.

Hippocrateaceae — The pollen grains of this family is perhaps represented by *Hippocrateaceaedites constrictus*.

Guttiferae — This family is very well represented in the assemblage. *Platoniapollenites*, *Calophyllumpollenites* and *Kielmeyerapollenites* closely resemble the extant pollen grains of *Platonia*, *Calophyllum* and *Kielmeyera* respectively. Guttiferae, it may be recalled here, was one of the most dominant forest flora during Tertiary in India. Most of the genera belonging to Guttiferae are found in the evergreen and semievergreen forests of the tropical zone or in areas with relatively mild monsoon climate.

Meliaceae — The tetracolporate, laevigate pollen grains resembling the extant pollen of *Melia* are quite commonly met with in the present assemblage and have been placed in the dispersed genus *Meliapollis*. This family consists mostly of trees and shrubs and is quite widespread in tropical belt.

Proteaceae — The family is represented by pollen grains referred to as *Proteacidites protrudus* and *Proteacidites* sp. This family seems to be widely distributed during Tertiary.

Onagraceae — This family in the present assemblage is mostly represented by triangular shaped pollen grains with 3 protruded ora. *Triorites triangulus* and *T. hirsutus* have been attributed to this family. The plants belonging to Onagraceae are chiefly subtemperate though some acquatic forms are also found in tropical belt.

Most of the algal and fungal elements cannot be traced up to family level and so their affiliations except in one or two cases remain open.

Comparison with the known Lower Tertiary assemblages from India

The present palynological assemblage from Palana closely resembles that of Kakdi Formation of Kutch, Gujarat, investigated by Mathur (1963, 1966), Sah and Kar (1969, 1970) and Venkatachala and Kar (1969). The Kakdi palynological assemblage so far known consists of total 64 genera and 98 species. Out of these 21 genera and 30 species belong to pteridophytes, 4 genera and 4 species to gymnosperms and 39 genera and 64 species to angiosperms. The Palana palynological assemblage is, however, not so diversified as it consists of

44 genera and 67 species. Of them, 9 genera and 16 species belong to algal and 3 genera and 4 species to fungal remains. Most of the spores-pollen genera found in Palana are also found in Kakdi Formation. Thus of the 8 pteridophytic genera, 7 are common to both the assemblages. They are: *Todisporites*, *Dictyophyllidites*, *Osmundacidites*, *Dandotiaspora*, *Laevigatosporites*, *Schizaeoisporites* and *Seniasporites*. Among the angiospermic genera, 20 are common to both: *Palmaepollenites*, *Liliacidites*, *Cupuliferoipollenites*, *Rhoipites*, *Hippocrateaceaedites*, *Margocolporites*, *Lakiapollis*, *Verrutricolpites*, *Verrucolporites*, *Meliapollis*, *Polybrevicolporites*, *Polycolpites*, *Pseudonothofagidites*, *Diporites*, *Trilatiporites*, *Proteacidites* and *Triorites*.

From the above mentioned data, it is evident that both Palana and Kakdi assemblages are homotaxial, though the latter assemblage is more diversified than the former. It may be stated here that the palynological assemblage of Kakdi Formation has been investigated intensively through a number of borehole cores from different localities whereas in Palana it could not be studied so thoroughly due to limited area of exposure.

The palynological assemblage of Cherra Formation worked out by Sah and Dutta (1966, 1968), Dutta and Sah (1970) consists of 49 genera and 103 species. Of them, 18 genera and 34 species belong to pteridophytes, 2 genera and 2 species to gymnosperms and 29 genera and 67 species to angiosperms. Among the pteridophytes, 5 genera are common to both Palana and Cherra Formation. They are: *Dictyophyllidites*, *Dandotiaspora*, *Laevigatosporites*, *Seniasporites* and *Schizaeoisporites*. Of the angiosperms, the following 10 genera are common to both: *Retipilonapites*, *Palmaepollenites*, *Couperipollis*, *Liliacidites*, *Nymphaeoipollis*, *Tricolpites*, *Polycolpites*, *Diporites*, *Proteacidites* and *Triorites*.

The palynological assemblage of Cherra Formation, though broadly corresponds to that of Palana, is different in some respects. Lycopodiaceous spores represented by *Lycopodiacidites* and *Lycopodiumsporites* are very common in Cherra but have not been recorded from Palana. Moreover, the overwhelming abundance of *Retialetes* and *Schizosporis* (50%) which is the main feature of Cherra assemblage is conspicuous by their absence in Palana. Besides, *Cheilanthoidspora* which is quite common in Palana is absent in Cherra. Perhaps, ecological factors and endemic vegetation were responsible for this dissimilarity in the assemblage.

Palynological assemblage described from Subathu sediments by Salujha *et al.* (1969) comprises a total of 28 genera and 45 species. Of them, 10 genera belong to pteridophytes, 1 to gymnosperms, 12 to angiosperms and 5 to microplanktons. Palynological fossils described by them are rather ill preserved and so a close comparison is not possible. However, among the pteridophytes the following genera seem to be common to both: *Todisporites* (*Scabratriletes* sp. D, pl. 3, fig. 13), *Dandotiaspora* (*Psilatriletes lobatus* Salujha *et al.*, pl. 3, figs. 7-8), *Osmundacidites* (*Scabratriletes* sp. A, pl. 3, figs. 10, 16) and *Seniasporites* (*Retimonoletes* sp. A, pl. 3, fig. 1). The angiospermic pollen grains are poorly represented in Subathu sediments in comparison to Palana and only 3 genera seem to be present in both the assemblages, viz., *Palmaepollenites* (*Retemonocolpites* sp., pl. 3, fig. 38), *Diporites* (*Brandiporites* sp., pl. 3, fig. 39; *Psilodiporites ovatus* Salujha *et al.*, pl. 4, fig. 41), *Tricolpites* (*Scabratricolpites* sp., pl. 4, fig. 43).

The miospore assemblage from Tura Formation worked out by A. K. Ghosh (1940), Sen (1948), Biswas (1962), T. K. Ghosh (1969) and others appear to come closer to that of the Cherra Formation than that of Palana because of the presence of forms like *Lycopodiumsporites* (*Stenozonotriletes kangmanni* Biswas: Ghosh, 1969, pl. 1, fig. 1, *Reticulatisporites* sp. Ghosh, 1969, pl. 1, fig. 2), *Retialetes* (*Microreticulatipites inlecta* Baksi: Ghosh, 1969, pl. 1, fig. 3) and *Favitricolporites* (*Tricolporipites tiliaceaeformis* Biswas: Ghosh, 1969, pl. 1, fig. 25). Some of the genera are, however, common in both Palana and Tura Formation, viz., *Dandotiaspora* (*Leiotriletes vimali* Ghosh, 1969, pl. 2, fig. 48), *Seniasporites* (*Laevigatosporites* sp. Ghosh, 1969, pl. 2, fig. 32), *Palmaepollenites* (*Palmaepites* Biswas: Ghosh, pl. 1, fig. 3), *Couperipollis* (*Colocasioideaepites* sp. Ghosh, 1969, pl. 1, fig. 28), *Margocolporites* (*Paleocaesalpiniaceaepites eocenica* Biswas: Ghosh, 1969, pl. 2, fig. 33) and *Tricolpites*.

ECOLOGICAL INTERPRETATION

The Palana palynological assemblage comprising algal and fungal elements, spores and pollen grain reveal that this assemblage is a mixed one: there being the tropical, subtropical, temperate and acquatic elements. The general composition of the mioflora also indicates that most of the microfossils might have been terrestrial. A perusal of the different families present in the assemblage shows that out of the 22 families, 10 are confined to the present day tropical-subtropical regions while 12 are cosmopolitan in distribution. Not a single family recorded here has a strictly temperate distribution (Table 1).

Palynological evidence provided by the spores-pollen families suggests a tropical climate during the deposition of Palana beds. The abundance of pollen grains belonging to Guttiferae and Meliaceae further indicates an evergreen, moist forest not far from the place of deposition. The presence of pteridophytic spores in good number suggests a moist, humid climate.

The place of deposition of the Palana lignite beds was coastal, probably deltaic. This is evidenced by the presence of brackish-water elements like microplanktons which have been described here. That the shore line was not very far is also borne by the presence of pollen grain of fresh-water plants like Potamogetonaceae and Nymphaeaceae. It is also possible that areas fringing the shore line were swamps where fern and fern-allies found a natural habitat.

TABLE 1 — SHOWING THE CLIMATIC DISTRIBUTION OF DIFFERENT FAMILIES PRESENT IN PALANA ASSEMBLAGE

TROPICAL-SUBTROPICAL	COSMOPOLITAN (TROPICAL-TEMPERATE)
1. Microthyriaceae	1. Botryococcus (acquatic)
2. Matoniaceae	2. Cyanophyceae (acquatic)
3. Cheilanthaceae	3. Dinoflagellates (mostly marine)
4. Palmae	4. Osmundaceae
5. Leguminosae (*Caesalpiniaceae*)	5. Polypodiaceae
6. Rubiaceae	6. Schizaeaceae
7. Anacardiaceae	7. Potamogetonaceae (acquatic)
8. Guttiferae	8. Liliaceae
9. Meliaceae	9. Nymphaeaceae
10. Proteaceae	10. Cruciferae
	11. Hippocrateaceae
	12. Onagraceae

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EXPLANATION OF PLATES

(All photomicrographs are enlarged *ca.* × 300)

Plate 1

1. *Todisporites flavatus* Sah & Kar. Slide no. 4350/5.

2. *Dictyophyllidites* sp. Slide no. 4351/29.

3. *Osmundacidites* sp. Slide no. 4352/31.

4-5. *Schizaeoisporites palanaensis* sp. nov. Slide nos. 4353/22, 4363/2.

6. *Schizaeoisporites* sp. Slide no. 4353/3.

7-10. *Cheilanthoidspora enigmata* gen. et sp. nov. Slide nos. 4354/4, 4354/11, 4355/1, 4356/10.

11-14. *Cheilanthoidspora monoleta* sp. nov. Slide nos. 4357/11, 4358/2, 4358/7, 4358/4.

15-16. *Cheilanthoidspora reticulata* sp. nov. Slide nos. 4354/11, 4359/11.

17. *Dandotiaspora plicata* (Sah & Kar) Sah, Kar & Singh. Slide no. 4350/1.

18. *Retipilonapites arcotense* Ramanujam. Slide no. 4360/1.

19. *Retipilonapites* sp. Slide no. 4357/2.

20. *Palmaepollenites* sp. Slide no. 4361/3.

21-22. *Liliacidites reticulatus* sp. nov. Slide nos. 4361/5, 4354/6.

23. *Liliacidites ellipticus* Venkatachala & Kar. Slide no. 4362/11.

24-25. *Liliacidites* sp. Slide nos. 4363/3, 4371/7.

26-27. *Couperipollis rarispinosus* (Sah & Dutta) Venkatachala & Kar. Slide nos. 4354/3, 4357/8.

28. *Couperipollis brevispinosus* (Bis.) Venkatachala & Kar. Slide no. 4355/5.

29. *Couperipollis* sp. Slide no. 4355/7.

30. *Couperipollis kutchensis* Venkatachala & Kar. Slide no. 4355/3.

Plate 2

31. *Nymphaeoipollis marginatus* Venkatachala & Kar. Slide no. 4354/11.

32. *Nymphaeoipollis* sp. Slide no. 4364/2.

33. *Nymphaeoipollis flanatus* Venkatachala & Kar. Slide no. 4365/4.

34. *Tricolpites reticulatus* Cookson. Slide no. 4353/25.

35. *Tricolpites pachyexinus* Couper. Slide no. 4365/1.

36. *Tricolpites* cf. *T. reticulatus* Cookson. Slide no. 4352/2.

37. *Tricolpites matauraensis* Couper. Slide no. 4359/11.

38. *Cupuliferoipollenites* sp. Slide no. 4366/12.

39-40. *Tricolpites paucireticulatus* sp. nov. Slide nos. 4361/2, 4354/9.

41. *Tricolpites levis* Sah & Dutta. Slide no. 4364/4.

42. *Tricolpites* sp. Slide no. 4367/10.

43-44. *Rhoipites pilatus* sp. nov. Slide nos. 4360/19, 4360/21.

45-46. *Hippocrateaceaedites constrictus* sp. nov. Slide nos. 4368/7, 4354/9.

47-49. *Calophyllumpollenites rotundus* gen. et sp. nov. Slide nos. 4360/25, 4355/2, 4369/29.

50. *Diporites* sp. Slide no. 4370/8.

51. *Verrutricolpites triangulus* Sah & Kar. Slide no. 4366/11.

52. *Caprifoliipites subglobosus* sp. nov. Slide no. 4359/10.

53. *Triorites hirsutus* sp. nov. Slide no. 4373/4.

54. *Verrucolporites verrucatus* Sah & Kar. Slide no. 4371/5.

55-56. Tetracolporate pollen type-1. Slide nos. 4372/1, 4362/1.

57-59. *Platoniapollenites ovatus* gen. et sp. nov. Slide nos. 4360/26, 4374/43, 4368/16.

60-61. *Kielmeyerapollenites eocenicus* gen. et sp. nov. Slide nos. 4368/24, 4360/34.

62. Pollen mass type-1. Slide no. 4353/24.

Plate 3

63-64. *Botryococcus palanaensis* sp. nov. Slide nos. 4352/8, 4371/6.

65. *Tetraporina apora* sp. nov. Slide no. 4353/26.

66. *Tetraporina pachyderma* sp. nov. Slide no. 4351/31.

67-70. *Psilosphaera plicata* gen. et sp. nov. Slide nos. 4360/17, 4360/17, 3474/36, 4368/19.

71-73. *Temporina globata* gen. et sp. nov. Slide nos. 4360/24, 4368/6, 4374/44.

74-75. *Temporina dentata* sp. nov. Slide nos. 4376/1, 4374/40.

76-77. *Cephalia globata* gen. et sp. nov. Slide nos. 4360/6, 4375/2.

78-80. *Cephalia ovata* sp. nov. Slide nos. 4377/22, 4378/5, 4376/17.

81. *Octaplata rotunda* gen. et sp. nov. Slide no. 4368/21.

82. *Octaplata palanaensis* sp. nov. Slide no. 4363/8.

PLATE 4

83-84. *Palanaea granulosa* gen. et sp. nov. Slide nos. 4379/18, 4379/8.

85. *Palanaea laevigata* sp. nov. Slide no. 4360/12.

86a-86b. *Cryptosphaera pachyderma* gen. et sp. nov. Slide no. 4351/7.

87-88. *Cryptosphaera valvata* sp. nov. Slide nos. 4350/4, 4350/2.

89-90. *Coraplanktona fracta* gen. et sp. nov. Slide nos. 4377/17, 4363/7.

91. *Coraplanktona unicorna* sp. nov. Slide no. 4379/26.

92. *Coraplanktona* sp. Slide no. 4352/17.

93. cf. *Coraplanktona* sp. Slide no. 4379/25.

94. Microplankton type-1. Slide no. 4350/16.

95. Microplankton type-2. Slide no. 4366/3.

96. *Inapertisporites kedvesii* Elsik. Slide no. 4377/4.

97. *Inapertisporites globatus* sp. nov. Slide no. 4377/16.

98. *Inapertisporites* sp. Slide no. 4366/13.

99. *Dicellaesporites constrictus* sp. nov. Slide no. 4352/14.


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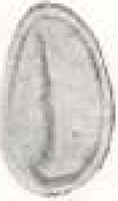
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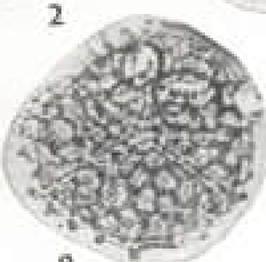
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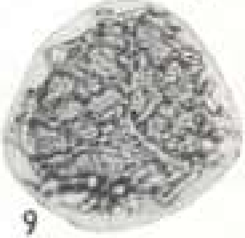
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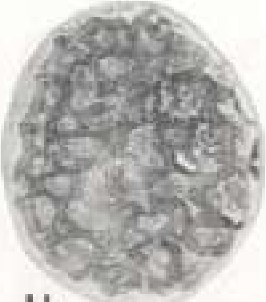
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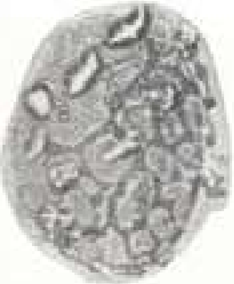
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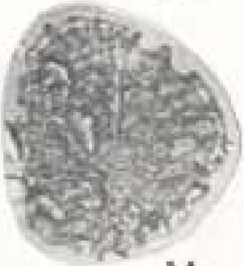
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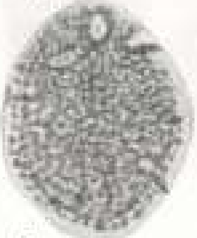
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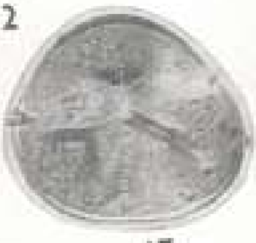
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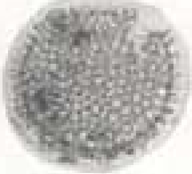
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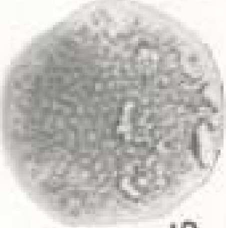
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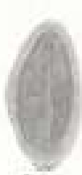
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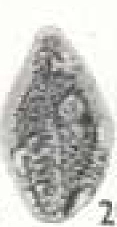
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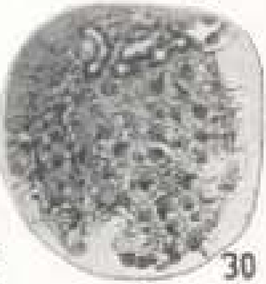
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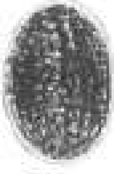
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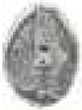
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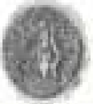
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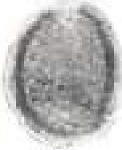
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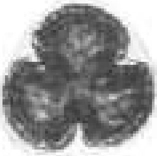
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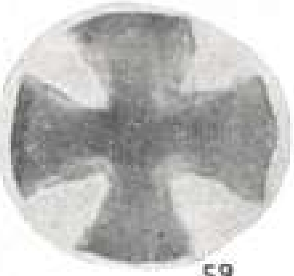
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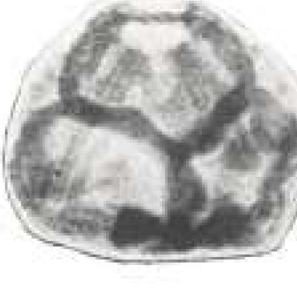
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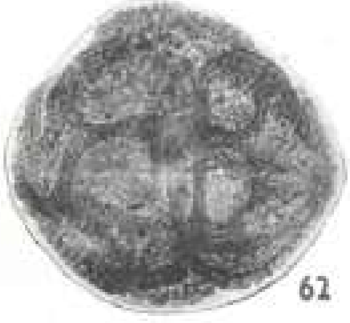
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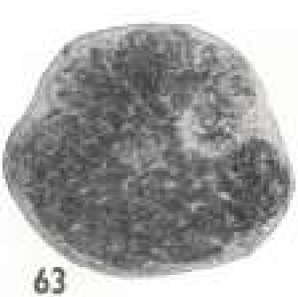
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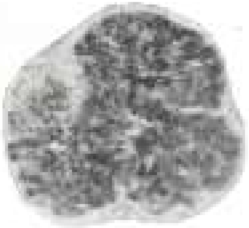
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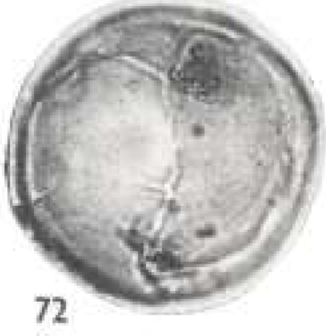
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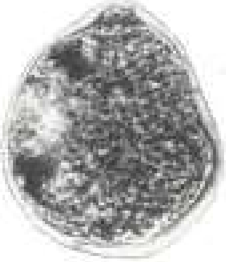
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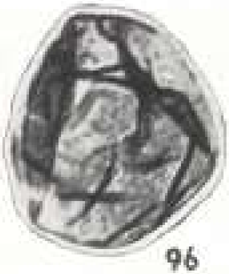
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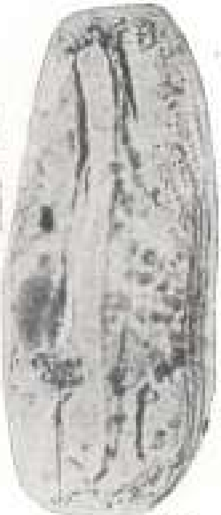
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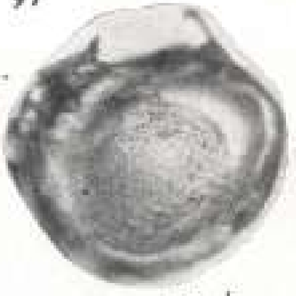
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FOSSIL ALGA FROM THE MIOCENE OF CUTCH, INDIA

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ABSTRACT

Coralline algae from the Khari Series of Cutch are recorded. Five species (two of them new) belonging to four genera (one new) are described. These are *Lithophyllum* aff. *L. kladosum* Johnson, *Mesophyllum commune* Lemoine, *Aethesolithon problematicum* Johnson, *A. cutchensis* sp. nov. and *Archaeoporolithon miocenicum* gen. et sp. nov. The algal evidence suggests a Lower Miocene age for the formation containing them.

INTRODUCTION

In course of micropaleontological investigation of the Tertiary rocks of Cutch, a rich algal flora was discovered. Cutch area may be regarded as the type area for the marine Tertiary rocks of India as this is the only area where a complete sequence from Paleocene to Pliocene is found (Biswas, 1965, 1970). Systematic study of the fossil algae in these rocks will be of value in the stratigraphic and paleoecological interpretation of these formations.

In the present paper, the coralline algae are reported from the Khari series (L. Miocene) exposed near Waior (23°25′ :68°41′) in south-western Cutch.

STRATIGRAPHY, LITHOLOGY AND SAMPLING LOCALITIES

Lower Tertiary rocks are exposed along 'nala' sections in and around the village Waior and Cheropodi. The formation serving as the host of the algal forms, constitute a distinct lithological unit. This is named as 'Ochreous marls'. It is underlain by a compact white limestone containing foraminifers like *Spiroclypeus ranjanae* and *Lepidocyclina* (*Nephrolepidina*) sp. and is overlain by a 'yellowish brown marl' containing distinct Lower Miocene foraminifera like *Miogypsina dehartii*, *Austrotrillina howchini* associated with *Nephrolepidina* sp.

This Ochreous marl is variable in thickness, the maximum thickness being nearly 150 ft. It is brown in colour with inpersistent iron-stained bands. The rock is composed of fossil fragments of various sizes (mostly foraminifera, algal bodies and worm tubes), the cementing material being calcareous mud. Under the microscope the fragments constitute up to 60% of the rock. Besides, there are also angular grains of quartz (medium to fine sand-sized, poorly sorted and rounded). The ferruginous staining may be the result of strong oxidation under subaerial condition.

SYSTEMATIC DESCRIPTION

Phylum — RHODOPHYCOPHYTA
Order — CRYPTONEMIALES
Family — CORALLINACEAE
Subfamily — MELOBESIOIDEAE

Genus — Lithophyllum Philippi 1837

Lithophyllum aff. *L. kladosum* Johnson, 1954

Pl. 1, Figs 1,2

L. kladosum Johnson, 1954, U.S.G.S. Prof. Paper 260-M, p. 539, Pl. 192, Figs. 1-8, 403-G, p. 21. L. cf. *kladosum* Johnson, Johnson, 1964, U.S.G.S. Prof. Paper 403-G, p. 21.

Description — Fragments of long slender branches showing well developed medullary hypothallus and marginal perithallus. Hypothallus formed of arched layers of cells, length 16-40 μ, width 12-20 μ. Perithallic cells nearly square or rectangular, length 16-20 μ, width 10-16 μ. Conceptacles of moderate size, diameter 280-320 μ, height 136-160 μ. Conceptacles show single aperture.

Remarks — The present materials closely resemble *L. kladosum* described by Johnson from the Lower Miocene of Bikini (Johnson, 1954) and Guam (Johnson, 1964). The dimensions of the cells and of the sporangia are well within the range observed in *L. kladosum*. However, the latter has, in general, somewhat longer hypothallic cells and a bit larger sporangia.

Figured Slide — C/05.

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Genus — *Mesophyllum* Lemoine, 1928

Mesophyllum commune Lemoine, 1939
Pl. 1, Figs. 3-4; Pl. 2, Fig. 5

M. commune Lemoine 1939, Mat. Carte geol. de l'Algerie, ser. 1, Paleont., no. 9, p. 86, Figs. 55-57.

M. commune Lemoine Johnson, 1964, U.S.G.S. Prof. Paper 403-G, p. 14-15, Pl. 2, Fig. 7.

Description — Thallus develops short, thick branches probably from basal crust. Branches composed of medullary hypothallus and marginal perithallial tissue showing pronounced growth zones, each zone formed of 6-8 layers of rectangular cells. The hypothallial cells are 16-24 μ long and 12 μ wide. The perithallial cells are squarish to rectangular, 12-16 μ × 10-12 μ. Conceptacles numerous, 136-140-160 μ in height and 320-360-800 μ in diameter.

Remarks — The material from Cutch exactly fits the description of Lemoine (1939) for the type from the Miocene of Algeria. The sporangial diameters in the present material are sometimes larger than the type. The material described by Johnson (1964) from the Maemong Limestone Member (L. Miocene) of the Umatac Formation of Guam closely resembles the present material.

Figured Slide — CF/03, CF/05.

Genus — *Aethesolithon* Johnson, 1964

Aethesolithon problematicum Johnson, 1964
Pl. 2, Figs. 2-3

A. problematicum Johnson, 1964, U.S.G.S. Prof. Paper 403-G, p. 27-28, Pl. 1, Figs. 1-3.

Description — Plant starts as irregular crust with warty protuberances or small mammillae and develops branches. Branches are 5 cm or more in length and show well-developed medullary hypothallus and marginal perithallus. Thickness of medullary hypothallus 1200-1500 μ; strongly arched layers arranged in definite growth zones which in some specimens appear as vertically elongated hexagons; cells alternate in position in successive rows so that one cell fits between the points of those above and below. Usually the lowest layer in a zone contains largest cells, uppermost the smallest. In a given layer, cells also decrease in size from centre to margins. Cells are usually 40-56 × 20-40 μ.

Marginal perithallus of branches formed of very irregular layers, commonly 2 or 3 layers to a growth zone. Cells rounded to polygonal. Cells are 16-20 × 8-20 μ.

Conceptacles develop in outer layers of crusts and in perithallic tissue of branches, small and highly arched. Number of opening not very clear but arching suggests a single opening. Conceptacles are 160-200 μ in length and 96-112 μ in diameter.

Remarks — The present specimen shows essential similarity with *A. problematicum* Johnson from the Bonya Limestone (L. Miocene) of Guam. The tissue of the hypothallium and perithallium are essentially similar and the dimensions are within the range observed in *A. problematicum*. However, the hypothallic cells are, in general, short in the present material. *A. grandis* Johnson resembles the present material in general appearance and growth habit; it differs by having larger cells, longer and thicker branches, and larger conceptacles. *A. guatemalaensum* Johnson differs from the present material in having larger hypothallic cells and smaller sporangial conceptacles.

Figured Slide — CF/03.

Aethesolithon cutchensis sp. nov.
Pl. 2, Fig. 8; Pl. 3, Fig. 9

Diagnosis — Branches develop from a basal crust. Tissue irregular with lenses of cells. Branches with medullary hypothallus of large polygonal cells 16-40 μ × 16-24 μ, cells largest at the bottom of each layer and progressively smaller upwards and laterally. Marginal perithallus of nearly rectangular cells, 16-32 × 12-24 μ, with lenses of larger polygonal cells 24-32 × 16-24 μ. Conceptacles arched, probably with a single aperture, height 160 μ and diameter 640 μ.

Description — Plant starts as irregular crust and then develops branches. Branches attain 3-4 mm in length with diameter of about 1200 μ. Thickness of medullary hypothallus 800-1000 μ. Strongly arched layers arranged in definite growth zones which appear like thick lenses, each zone with 3-5 layers of large polygonal cells which appear as vertically elongated hexagons. The lowest layer in a zone shows largest cells, and the uppermost the smallest. Thus the variation in size of cells in a zone from bottom upwards is as follows:

40 × 32 μ, 32 × 24 μ, 24 × 16 μ

Marginal perithallus of branches formed of very irregular layers, commonly 2 or 3 layers to a growth zone. Cells rectangular, 16-32×8-20 μ. Cells in lenses larger and polygonal, 24-32×16-24 μ. Conceptacles arched, 160 μ in height and 640 μ in diameter. Conceptacles probably open with a single aperture.

Remarks — This species closely resembles the genotype, *A. problematicum* Johnson, but differs from it in having smaller cells in the hypothallial tissue. Also, the conceptacles in the present species have larger diameter.

Figured Slides — C/03, C/04.

Genus — *Archaeoporolithon* gen. nov.

Genotype — *Archaeoporolithon miocenicum* sp. nov.

Generic Description — Plants crustose, mammillate, sometimes branching upward; basal hypothallus of curved rows of cells, perithallus of horizontal rows of cell; megacells occur in the perithallic tissue, in lenses up to 8 cells high, often extending as layers parallel to the substrate; conceptacle with a single aperture.

Comparison — The nature of the tissue and the conceptacles with single aperture place the alga under the tribe Lithophylleae. It differs from *Lithophyllum* primarily in the possession of thick lenticular groups of megacells in the perithallial tissues, a unique character that envisages the creation of new genus, *Archaeoporolithon*. Of the closely allied genera, the horizontal grouping of megacells distinguish *Archaeoporolithon* from *Goniolithon* in which they occur singly or in short vertical columns. In *Paraporolithon* the megacells occur in both horizontal and vertical clusters (Johnson, 1957, p. 233). The only other genus having horizontal grouping of megacells is *Porolithon*, known from Pleistocene to Recent, but the latter differs in the fact that the lenticular groups of megacells are only one cell high. Further, the multi-cell high lenses often extend with diminutive height as layers parallel to the substrate. Regarding phylogenetic relationship, Johnson (in Johnson & Adey, 1965, p. 12) noted that "*Porolithon* and *Goniolithon* appear to have developed from *Lithophyllum* during the Miocene". From the present study it appears that *Archaeoporolithon* evolved from *Lithophyllum* in Lower Miocene time and possibly it is ancestral to *Goniolithon*, *Paraporolithon* and *Porolithon*. The lineage may be represented as:

Archaeoporolithon miocenicum gen. et sp. nov.

Pl. 3 Figs. 10-11

Diagnosis — Plants crustose, branching upwards; basal hypothallus of curved rows of cells, perithallus of horizontal threads; megacells in the perithallic tissue, 3-5 cells high; megacells occur in lenses, often extending as layers parallel to the substrate; conceptacle with a single aperture.

Description — Plants crustose, often branching upwards. Crusts show basal hypothallus of curved rows of cells, 12-29 ×12-18 μ. Hypothallus is sometimes thin, the cells appearing as irregularly arranged. The perithallus with heterocytes. The perithallial cells are 16-32×18-24 μ. The megacells occur in lenses up to 5 cells high. These sometimes occur as layers parallel to the perithallial cell threads. Often the lenses extend with decreased height on either side parallel to the substrate.

Conceptacles are small with a single opening, usually 80-96 μ high and 272-280 μ in diameter.

Figured Slide — F/C/1; FC/2.

DISCUSSION

Of the 5 species described *L.* aff. *L. kladosum* Johnson is closely allied to *L. kladosum* described by Johnson from the Lower Miocene of Bikini (Johnson, 1954) and Guam (Johnson, 1964). *Mesophyllum commune* Lemoine is known from the Miocene of Algeria. More recently it was reported by Johnson (1964) from the Maemong Limestone Member (L. Miocene) of the Umatac Formation of Guam. *Aethesolithon* Johnson is so far known only from the Miocene. *A. problematicum* Johnson is known from the Bonya Limestone (L. Miocene) of Guam. *A. cutchensis* sp. nov. is a new one but with clear affinities to the genotype. As for the new genus *Archaeoporolithon*, it evolved from *Lithophyllum* in L. Miocene and is ancestral to *Goniolithon*, *Paraporolithon* and *Porolithon*. All these suggest a Lower Miocene age for the 'Ochreous marls' where the absence of characteristic foraminifers prohibits an exact age determination.

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EXPLANATION OF PLATES

Plate 1

1-2. *Lithophyllum* aff. *L. kladosum* Johnson:

1. Showing part of the hypothallus, perithallus and conceptacle (150 ×).

2. Perithallial tissue and conceptacle with a single aperture (300 ×).

3-4. *Mesophyllum commune* Lemoine: 4. Enlargement showing the conceptacle (300 ×).

Plate 2

5. *Mesophyllum commune* Lemoine (75 ×).

6-7. *Aethesolithon problematicum* Johnson (70 ×).

8. *Aethesolithon cutchensis* sp. nov. (50 ×).

Plate 3

9. *Aethesolithon cutchense* sp. nov. (150 ×), enlargement showing the nature of the cells.

10-12. *Archaeoporolithon miocenicum* gen. et sp. nov.

10. Showing the hypothallus (h), perithallus (p) and the megacells in the perithallial tissue (70 ×).

11. Showing the arrangement of the megacells (150 ×).

12. Showing the arrangement of the megacells (100 ×).

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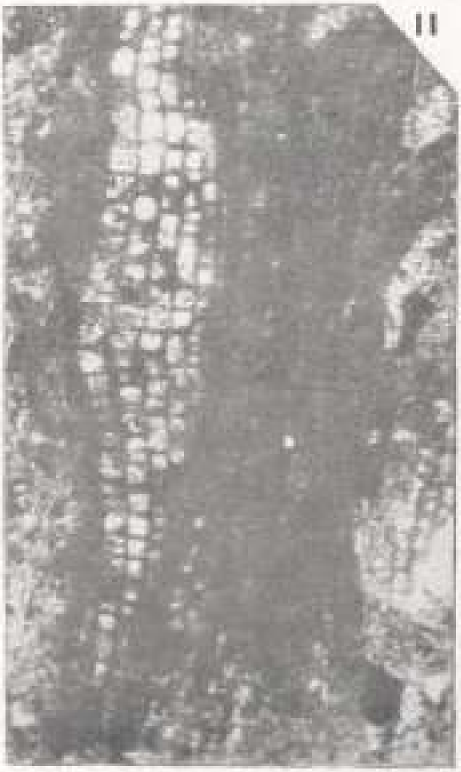

11

FLORISTIC EVIDENCE ON THE AGE OF GONDWANA BEDS NEAR NIDPUR, SIDHI DISTRICT, MADHYA PRADESH*

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ABSTRACT

On the evidence of mega- and microfossils, the fossiliferous beds at Nidpur are considered to be of Triassic age. The various Triassic mega- and microfloral assemblages from southern hemisphere have been compared with the floral assemblage of Nidpur. Floristically, the age of Nidpur fossiliferous bed is younger than the Panchet Stage. The most characteristic feature of the Nidpur flora is the overwhelming dominance of the genus *Dicroidium*.

INTRODUCTION

THE earliest survey of plant bearing rocks from the Gopad River Valley in Sidhi District, M. P. was made by Hughes (1881). So far, from this general area only mega- and microplant fossils of Raniganj affinities were known (Feistmantel, 1882; Ahmad, 1953; Ahmad & Rao, 1954 in Krishnan, 1958 and Maheshwari, 1967). But Satsangi's (1964) discovery of *Dicroidium* bearing beds in Gopad river cutting, near Nidpur, has revealed the presence of Triassic sediments too in the Gondwana succession of Gopad valley.

MEGAFLORA OF NIDPUR

In the Triassic formations of India (summarized below), as far as the cuticular study is concerned the fossil flora of Nidpur is, so far, the best known. This is because at Nidpur most of the plants are preserved in the form incrustations while at other Triassic localities the plants are present either as impressions or in the form of ferruginous crust. Because of this indifferent mode of preservation, surface structure of a few species of *Dicroidium* has been studied under transmitted light from the Parsora Stage of South Rewa Gondwana Basin. The details of cuticular structure are not known in other Indian Triassic plants. In addition to the mode of preservation, in the Triassic of India, the species are very poorly represented as shown in the table below.

Recently, the detailed and illustrative palaeobotanical work of Nidpur megaplant fossils has been done by Srivastava (1969, 1971, 1974a,b) Bose & Srifvastava (1970, 1971, 1972, 1973a,b) and Srivastava & Maheswari (1973). The Triassic flora of Nidpur is characterized by the overwhelming dominance of the genus *Dicroidium*

Standard Scale	Gondwana	Division	Damodar Valley	Auranga Valley	Son Valley	Satpura Basin	Pranhita Godavari Valley
Rhaetic	Mahadeva Series	Maleri	—	—	Tiki	Bagra Denwa	Maleri
—	—	Pachmarhi	—	—	—	Pachmarhi	—
Keuper-Muschelkalk	—	Parsora	—	—	Chichariya Parsora	—	—
Bunter	Panchet Series	—	—	—	Nidpur	—	—
—		Panchet	Panchet	Deobar	Daigaon, Ramkola-Tattapani (Karamdiha, Ledho nala)	Almod	Mangli

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Gothan. There are three species of *Dicroidium* and out of these *D. nidpurensis* Bose & Srivastava and *D. papillosum* Bose & Srivastava are the commonest. At places the whole fossiliferous bed is almost made up of these two species. The third species, viz., *D. gopadensis* Bose & Srivastava is rather rare. Along with the specimens of *Dicroidium*, a single specimen of *Lepidopteris* (*L. indica*) Bose & Srivastava has also shown its presence in these beds. Besides *Dicroidium*, the genus *Glossopteris* Sternberg is also fairly well represented by distinct species, viz., *G. senii* Srivastava, *G. papillosa* Srivastava, *G. nidpurensis* Srivastava, *G.* Sp. A, *G*, sp. B., *G.* sp. and *G.* sp. cf. *G. linearis*. The Glossopteridales also comprises the genus *Rhabdotaenia* Pant but this genus is very rare at Nidpur. The specimens are extremely fragmentary so they have been described as *Rhabdotaenia* sp. The other genera present are *Taeniopteris* Brongniart (*T. glandulata* Srivastava), *Noeggerathiopsis* sp., *Conites* sp. and a new genus *Glottolepis rugosa* Bose & Srivastava. Out of these, *T. glandulata* is present in fairly good number. *Noeggerathiopsis* and *Conites* are very fragmentary and poorly represented in the assemblage whereas *Glottolepis rugosa* Bose & Srivastava is quite common. In addition to these genera, three fragmentary conifer shoots have also been described. Recently some pollen and seed-bearing strobili have been described as *Nidistrobus harrisianus* Bose & Srivastava and *Nidia ovalis* Bose & Srivastava. Besides these, a new genus *Satsangia* (*S. Campanulata*) Srivastava & Maheshwari has also been instituted for some fructification-like bell shaped plant organs. Along with these a new species of *Pteruchus* (Thomas) Townrow (*P. nidpurensis* Srivastava) has also been discovered. But amongst all these fertile organs *N. harrisianus* occurs most abundantly in these beds.

MIOFLORA OF NIDPUR

Miofloristically, the Triassic beds in India have been only scantily surveyed. A few publications on the mioflora of extra-peninsular Triassic are also available. From peninsular India, the Triassic mioflora of Nidpur, has been described by Bharadwaj and Srivastava (1969) in detail and about this, Chandra and Satsangi (1965) had already made a preliminary report.

The mioflora of Nidpur is represented by one each of the trilete and monolete genera, 17 genera of saccate pollen grains, 2 genera of non-saccate pollen grains and one genus of praecolpate pollen grains. Bisaccate gymnospermous pollen grains occur fairly in abundance in this assemblage whereas representatives of trilete and monolete spores occur very rarely.

The miofloral assemblage is constituted by the genera, *Laevigatosporites*, *Densipollenites*, *Platysaccus*, *Nidipollenites*, *Striatites*, *Verticipollenites*, *Lahirites*, *Lunatisporites*, *Striatopodocarpites*, *Faunipollenites*, *Chordasporites*, *Distriatites*, *Satsangisaccites*, *Sulcatisporites*, *Klausipollenites*, *Alisporites*, *Trochosporites*, *Weylandites*, *Aumancisporites* and *Praecolpatites*. *Punctatisporites* and *Taeniaesporites* have not been encountered in counting. Out of these, 4 genera (*Nidipollenites* Bharadwaj & Srivastava, *Satsangisaccites* Bharadwaj & Srivastava, *Weylandites* Bharadwaj & Srivastava and *Praecolpatites* Bharadwaj & Srivastava) have been newly erected. Besides these new genera, 18 new species, viz., *Densipollenites densus*, *Nidipollenites monoletus*, *Striatites sidhiensis*, *Lunatisporites gopadensis*, *Striatopodocarpites nidpurensis*, *Faunipollenites gopadensis*, *Satsangisaccites nidpurensis*, *S. triassicus*, *Sulcatisporites triassicus*, *S. royii*, *Alisporites indicus*, *Weylandites indicus*, *W. circularis*, *W. minutus*, *W. bilateralis*, *W. irregularis*, *Aumancisporites indicus* and *Praecolpatites nidpurensis* have also been reported by Bharadwaj and Srivastava (1969) from this assemblage.

As a whole the miofloral assemblage is dominated by non-striate bisaccate grains and the genus *Satsangisaccites* is the most dominating element in Nidpur mioflora.

MEGAFLORISTIC COMPARISON

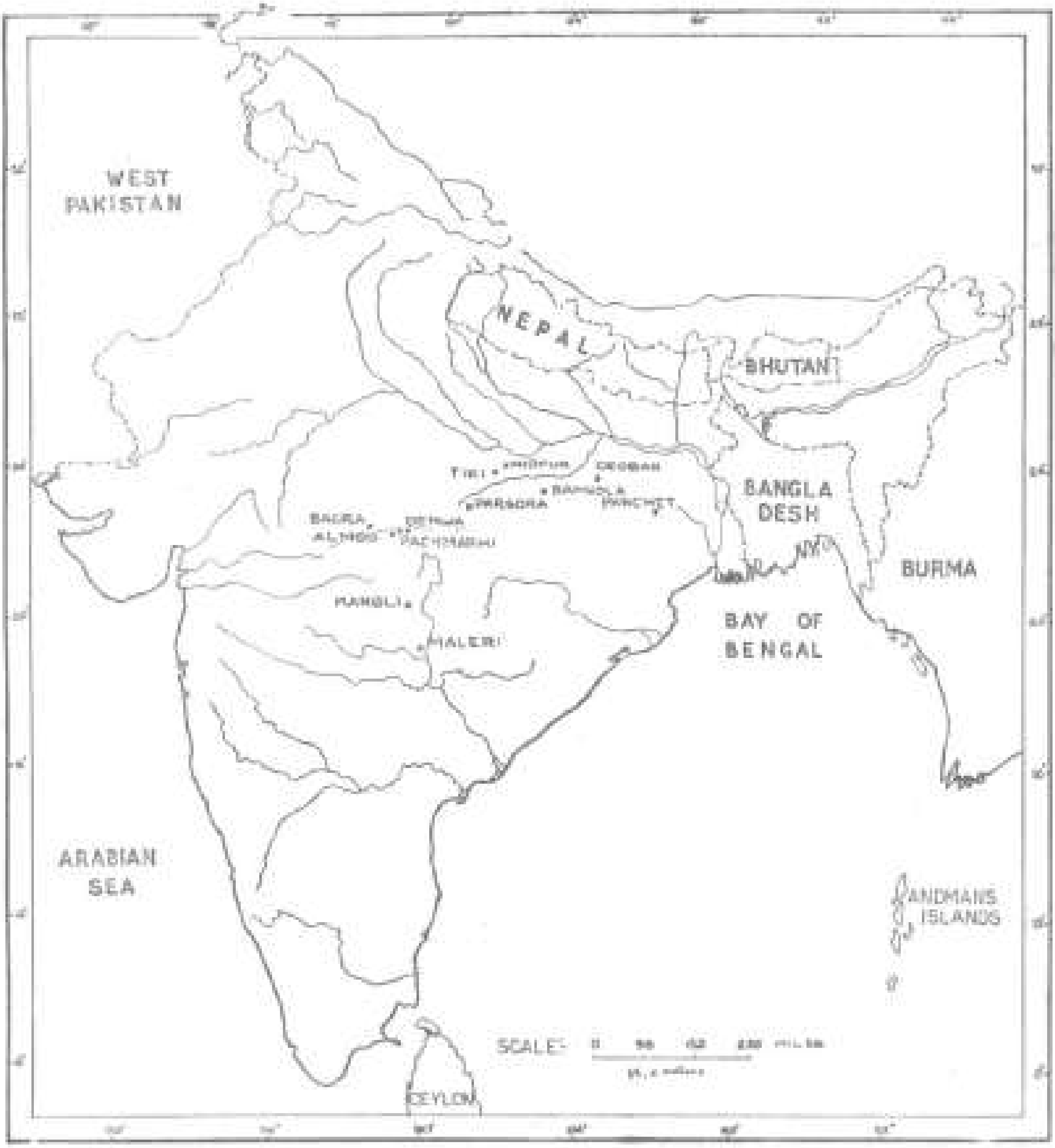
The relation of megascopic flora of Nidpur to Triassic floras of extra- and peninsular India has been discussed here in detail. The floral assemblage has also been compared with some of the Triassic floras known from Gondwanaland countries viz. Australia, Tasmania, New Zealand, Madagascar, Africa, Argentina, Brazil, Chile and Antarctica.

PENINSULAR INDIA

Amongst the known Triassic formations of India (Map 1) the fossil floras of Panchet and Parsora are well diversified.

The Lower Triassic flora from Panchet formations of Raniganj coalfield was described by Feistmantel (1881), Ghosh and Mitra (1970) and Satsangi (1971).

The floral assemblage comprises *Schizoneura gondwanensis* Feistmantel, *Vertebraria indica* Royle, *Pecopteris concinna* Presl, *Cyclopteris pachyrhachis* Göeppert, *Taeniopteris* sp. cf. *T. stenoneuron*, *Glossopteris indica* Schimper, *G. communis* Feistmantel, *G. angustifolia* Brongniart, ?*Dicroidium* sp., *Podozamites* and *Samaropsis* ?sp. Göeppert. Out of these *S. gondwanensis* and *G. communis* are the commonest. *S. gondwanensis* is so far not known from Nidpur and so is *G. communis*. However, in external characters *G. papillosa* Srivastava resembles very much *G. communis*. Since the *Dicroidium* reported by Satsangi (1971)



Map 1.

is a doubtful form and also not followed by any description or figure, hence, it is difficult to say whether they are pinnate, bipinnate or they have forked rachis.

None of the remaining species, viz., *Pecopteris concinna*, *Cyclopteris pachyrhachis*, *Glossopteris indica*, *G. browniana* and *Samaropsis* sp. are so far known from Nidpur. So except for the presence of *Dicroidium*-like leaves and species of *Glossopteris* the Panchet flora seems to be quite distinct from the Nidpur floral assemblage. Even the genus *Dicroidium* which is so common at Nidpur, is very rare in the Panchet Assemblage.

Floral assemblage from Deobar, Auranga Valley Coalfield described by Bhattacharya (1963) is characterized by the frequent presence of *Dicroidium sahnii* (Seward) Rao & Lele along with *Schizoneura*, *Glossopteris*, *Vertebraria*, *Rhabdotaenia* and *Samaropsis*. Because of the lithological similarity and the presence of *Dicroidium*, Deobar beds exposed in the vicinity of Auranga river are considered to be Lower Triassic in age. *Dicroidium* specimens from Deobar are known in small bits and they are pinnate. Pinnae (?pinnules) are very small as compared to the pinnules of the various species of *Dicroidium* from Nidpur. Almost all the species of *Glossopteris* known from the Deobar are similar to the Raniganj form whereas from the Nidpur all the species are new on the basis of cuticular features.

Lower Triassic flora of Ramkola and Tattapani area from Madhya Pradesh was first recorded by Griesbach (1880) and later megafossils were described in detail by Feistmantel (1881). The megafloral constituents are: *Glossopteris indica* Schimper, *G. angustifolia* Brongniart, *G. communis* and *Dicroidium odontopteroides* (Morris) Gothan. When Ramkola and Tattapani floral assemblage is compared with Nidpur flora, it becomes quite evident that both the floras agree only in having two common floral constituents namely, *Glossopteris* and *Dicroidium* and rest of Nidpur plant fossils are absent from Ramkola area. From the other Lower Trissic formations, viz., Almod beds (Satpura Basin) recognized by Medlicott (1873) and Mangli beds (Pranhita-Godavari valley) named by Hughes (1877), comparison with Nidpur flora could not be made because these beds have not yielded recognizable plant remains. These beds are known to belong to Triassic either on the basis of lithology or palaeontology.

The Parsora Stage (Middle-Upper Triassic) is represented by quite a few genera and species which are not known from Nidpur. The flora from Parsora Stage in detail has been described by Feistmantel (1882), Cotter (1917), Seward (1932), Saksena (1962), Lele (1953, 1955, 1961a, 1961b, 1962, 1969), Rao & Lele (1960, 1962), Vimal & Singh (1968) and Rao (1954; in Krishnan, (1958), Rao & Shukla (1954; in Krishnan 1958). *Lycopodites sahnii* Lele, *Schizoneura gondwanensis* Feistmantel, *Neocalamites foxii* Lele, *Marattiopsis* sp. *Danaeopsis gracilis* Lele, *Cladophlebis* sp. and *Sphenopteris polymorpha* Feistmantel, belonging to the Pteriodophyta are completely missing at Nidpur. Among the gymnosperms, described from the various localities in the Parsora Stage, *Pseudoctenis* (*P. balli* (Lele), *Pterophyllum* (*P. sahnii* Lele & *P. barkatiensis* Vimal & Singh), *Baiera* (*B. indica* Lele), *Araucarites* (*A. parsorensis* Lele and *A. indica* Lele), *Desmiophyllum* (*D. indicum* Lele and *D. taeniatum* Lele), *Cordaicarpus* (*C. chichariensis* Lele and *C. ovatus* Lele), *Samaropsis* (*S. srivastavi* Lele, *S. menisca* Lele and *S. surangei* Lele) and a new genus *Parsorophyllum indicum* Lele are also completely missing at Nidpur. The common genera are *Glossopteris*, *Dicroidium*, *Taeniopteris* and *Conites*. But among these genera none of the species is common to both Nidpur and Parsora Stage. The species of *Glossopteris* (*G. indica*, *G. communis*, *G. browniana* and *G. angustifolia* Feistmantel) occurring at various localities in the Parsora Stage are similar to those present in the Panchet. As for *Dicroidium*, they are no doubt, dominant, at most of the localities in the Parsora Stage but are not so abundant as the Nidpur *Dicroidium*. Also in the Parsora Stage *D. odontopteroides* is the most common species and next to this species is *D. hughesii* (Feistmantel) Townrow. Both these species are missing at Nidpur. In addition to these two species *D. sahnii* (Seward) Rao & Lele is also absent at Nidpur. Moreover, all these three species are having forked rachises unlike the Nidpur species which are bipinnate. In the Parsora Stage species of *Taeniopteris* (*T. spatulata* McCl.) are also quite different from the Nidpur species (*T. glandulata* Srivastava). So taking over all the assemblages in the Parsora Stage and at Nidpur, it is quite evident that the constituents are quite distinct from each other. While in the Parsora Stage a few Jurassic elements, such as *Pseudoctenis*, *Pterophyllum*, *Araucarites* and *Desmiophyllum* are present, no such form is present at Nidpur.

The fossil flora from Pachmarhi Stage is meagrely known. The specimens reported by Crookshank (1936) are all fragmentary and indeterminable. So it is difficult to compare the Pachmarhi flora with the Nidpur flora. But recently, Wadia (1966, p. 193) listed a number of plant fossils without figuring or describing any one of them. Out of this list, *Dicroidium and Glossopteris* are in common in both the floral assemblages.

Like Pachmarhi flora the fossil plants from other Upper Triassic formations, viz., Tiki, Maleri, are very poorly known. These have been assigned an Upper Triassic age because of lithological and palaeontological evidences. Sahni (1931) described a piece of wood collected by Cotter (1917) from Tiki as *Mesembrioxylon malerianum*. Recently, Sahni and Rao (1956) also assigned these beds an Upper Triassic age because of the presence of *Dicroidium* and *Taeniopteris* near Ghiar.

From Maleri area near Naogaon some plant fossils have been recorded by Feistmantel (1877) and were described by Sahni (1931). The assemblage represents the characteristic Upper Jurassic and Lower Cretaceous elements, viz., *Araucarites cutchensis* Feistmantel and *Elatocladus jabalpurensis* (Feistmantel) Sahni. But none of these genera are present at Nidpur. Besides these plant fossils, Rao and Shah (1960) and Mahabale (1967) reported a mixed floral assemblage from Kota-Maleri beds, Adilabad District, Andhra Pradesh. The floral assemblage comprises *Schizoneura*, *Neocalamites*, *Glossopteris*, *Noeggerathiopsis*, *Dicroidium odontopteroides* and *D. hughesii* along with a few cycadophytes and conifers. Out of these genera *Glossopteris*, *Noeggerathiopsis* and *Dicroidium* are the common floral constituents in both the assemblages.

Since the Upper Triassic beds, viz., Bagra and Denwa (Medlicott, 1873) completely lack the plant remains, therefore, no comparison is possible with Nidpur floral assemblage.

EXTRA-PENINSULAR INDIA

Sitholey (1943) first described the Triassic flora from extra-peninsular deposit of Salt Range, Punjab and the floral assemblage comprises the genera *Equisetites*, *Sphenopteris*, *Cladophlebis*, and *Indotheca*, the first pteridospermous microsporophyll from India. Nidpur flora is not comparable to this Salt Range Triassic assemblage and markedly contrasts in the overwhelming presence of *Dicroidium* and also in complete absence of pteridophytic remains.

AUSTRALIA

In Australian Triassic there are two distinct floras — one belonging to the Lower Triassic and the other to the Middle and Upper Triassic. Out of these, Nidpur floral assemblage compares most with the Lower Triassic of Narrabeen Stage Hawkesbury Series, New South Wales, Eastern Australia (see Tenison-Woods, 1883; Etheridge, 1894; Feistmantel, 1890; Dun, 1910, 1911; Walkom, 1925, 1932; Burges, 1935; Jacob & Jacob, 1950; Townrow, 1956, 1957, 1966, 1967, 1970; Helby & Martin 1965; Branagon, 1969; Ragatt, 1969; McElroy, 1969 and Lovering & McElroy, 1969). So far, from Narrabeen beds, *Lycostrobus*, *Phyllotheca australis*, *Sphenopteris*, *Schizoneura gondwanensis*, *Coniopteris* sp. cf. *C. lobata*, *Cladophlebis* sp., *Calopteris*, *Todites*, *Hymenophyllites*, *Zeugophyllites*, *Glossopteris browniana*, *Lepidopteris madagascariensis*, *Dicroidium odontopteroides*, *D. feistmanteli*, *D. narrabeenensis*, *Taeniopteris tenisonwoodsii*, *T. crassinervis*, *T. triassica*, *T. wianamattae*, *Pterophyllum*, *Rissikia*, *Ginkgoites* sp. ?, *Rhipidopsis narrabeenensis*, *Phoenicopsis* ?, *Araucarites sydneyensis*, *Carpolithus* sp. and *Cyclostrobus* have been described. Among these *Glossopteris*, *Lepidopteris*, *Dicroidium* and *Taeniopteris* are common to both Nidpur and Narrabeen beds. *Glossopteris browniana* from Narrabeen beds resembles in external form the leaves of *G. papillosa* from Nidpur. In external and to some extent in cuticular structure the leaves of *D. feistmanteli* resembles very much the leaves of *G. nidpurensis* and *D. papillosum*. In general form and venation *Taeniopteris wianamattae* is very much like *Rhabdotaenia* sp. from Nidpur and also *Araucarites sydneyensis* resembles very much *Conites* sp. described from Nidpur in external form.

The other Lower Triassic flora described by Chapman and Cookson (1927) and

Douglas (1969) from Bald hill, Bacchus Marsh, Victoria has *Phyllotheca australis, Schizoneura microphylla, Coniopteris delicatula, D. odontopteroides, Taeniopteris wianamattae, Ginkgoites digitata, Baiera darlevensis* and some other doubtful forms. Among these, *Dicroidium feistmanteli* resembles most the species of *Dicroidium* described from Nidpur.

The Middle and Upper Triassic floras from Queensland, Australia, are quite distinct from the Nidpur flora because in them quite a few Rhaetic or Jurassic elements are present along with *Schizoneura, Glossopteris, Taeniopteris* and *Dicroidium*. In the Ipswich Series near Brisbane, Queensland (see Etherdgie Jr., 1889; Jack & Etheridge Jr., 1892; Shirley, 1898, 1902; Antevs; 1913; Walkom, 1915, 1917, 1918, 1921; Jones, 1948, 1949; Jones & deJersey, 1947; Jacob & Jacob, 1950; Townrow, 1957, 1960, 1966, Phillips, *et al.*, 1960; White, 1965, 1966, 1969, in Anderson & Anderson, 1970; Hill *et al.*, 1965), *Stenopteris, Doratophyllum, Ctenis* and *Czekanowskia* have been described. None of these Rhaetic and Jurassic plants are known from Nidpur. In addition to these, *Yabeilla* and *Fraxinopsis* the well known Upper Triassic forms are also known from Ipswich Series.

The fossil flora from Esk Series, too is quite distinct from the Nidpur assemblage (see Walkom, 1924, 1928 and Hill, 1930). This flora resembles more the flora from Parsora Stage in having *Schizoneura, Neocalamites, Sphenopteris, Pseudoctenis, Pterophyllum* and *Baiera.*

The Leigh Creek and Springfield assemblage from South Australia (see Chapman, 1926; Parkin, 1953 and Johnson, 1960) is also quite distinct from Nidpur assemblage in having *Schizoneura, Equisetites, Neocalamites, Cladophlebis, Stenopteris, Phyllopteris, Psyginophyllum, Frenelopsis, Podozamites* and *Araucarites.* Out of these, *D. feistmanteli*, resembles in external form *D. nidpurensis* and *D. papillosum* described from Nidpur.

TASMANIA

The Triassic flora from the Feldspathic Sandstone Series of Tasmania (see Walkom, 1924, 1925 and Townrow, 1957, 1959, 1965, 1966) and Townrow and Jones (1969) is supposed to be of Upper Triassic or Rhaetic in age. It is characterized by the presence of *Hepaticites, Muscites, Phyllotheca, Neocalamites, Cladophlebis, Sphenopteris Pecopteris, Linguifolium, Dicroidium, Pachypteris, Pteruchus, Pseudoctenis, Pterophyllum, Ginkgoites* and *Baiera.* None of these genera are present at Nidpur except *Dicroidium* and *Pteruchus.*

NEW ZEALAND

Triassic-Rhaetic flora of New Zealand from Mount Potts, Clent Hills, District Canterbury and from Hokonui Hills South Land, described by Arber (1907, 1909, 1913a, 1913b, 1917) is also quite distinct from the Nidpur assemblage in having *Phyllotheca, Chiropteris, Cladophlebis, Sphenopteris, Coniopteris, Dictyophyllum, Linguifolium, Elatocladus* and *Baiera.* The only common genera are *Dicroidium* and *Taeniopteris.* Somewhat similar flora from Black Jacks Waitaki river, South Canterbury of New Zealand has been described by Bell, Harrington and Mckellar (1956). Unlike Nidpur assemblage it has *Cladophlebis, Chiropteris, Callipteridium, Linguifolium* and *Carpolithus.*

MADAGASCAR

Nidpur floral assemblage resembles somewhat the Lower Triassic flora of Madagascar as described by Zeiller (1911), Carpentier (1935, 1936), Besairie (1960) and Townrow (1966). The common genera are *Glossopteris, Lepidopteris, Dicroidium, Noeggerathiopsis* and *Taeniopteris.* At Madagascar *Cladophlebis, Danaeopsis, Buriadia heterophylla, Voltzia* and *Carpolithus* are known to occur, but these genera are absent at Nidpur.

SOUTH AFRICA

In South Africa the Triassic formations are met within the Beaufort and Stormberg series. Both these series range in age from Lower to Middle-Upper Triassic. The fossil flora from the Beaufort Series as described by Dujoit (1927) and Townrow (1956, 1957) consists of *Equisetites, Schizoneura, Neocalamites, Odontopteris, Glossopteris, Lepidopteris, Dicroidium, Taeniopteris, Nilssonia. Pterophyllum, Strobilites* and

Ginkgoites. Out of these genera common to Nidpur assemblage are *Glossopteris*, *Lepidopteris*, *Dicroidium* and *Taeniopteris*. But among these genera none of the species are common to each other.

The Stormberg Series having the Molteno beds of Natal (Umkomass and Burnera Waterfall localities) described by Feistmantel (1889), Seward (1908), Du Toit (1927, 1932), Thomas (1933), Townrow (1956, 1957, 1960, 1962, 1967b) and Fabre & Greber (1960) has yielded one of the richest Triassic flora in the southern hemisphere. Besides *Glossopteris*, *Lepidopteris*, *Dicroidium*, *Pteruchus* and *Taeniopteris* which are present at Nidpur, the Molteno beds also have *Equisetites*, *Schizoneura*, *Neocalamites*, *Marattiopsis*, *Cladophlebis*, *Sphenopteris*, *Dictyophyllum*, *Pachypteris*, *Stenopteris*, *Stormbergia*, *Antevsia Peltaspermum*, *Pilophorosperma*, *Umkomassia*, *Spermatocodon*, *Pseudoctenis*, *Chiropteris*, *Pterophyllum*, *Zamites*, *Moltenia*, *Dadoxylon*, *Rhexoxylon* *Elatocladus*, *Voltzia*, *Strobilites*, *Rissikia*, *Conites*, *Ginkgoites*, *Baiera* and *Stachyopitys*. So this assemblage has also some common Jurassic elements such as Zamites and *Elatocladus*.

In Cape Colony the Mesozoic strata has also the Stormberg Series besides the Jurassic of Utenhage Series. The Stormberg Series has been described by Seward (1903, 1911) from Maclear, Tina river, Kenigha river, Materiale, Molteno and Stormberg. The assemblage comprises *Schizoneura*, *Neuropteridium*, *Cladophlebis*, *Glossopteris*, *Lepidopteris*, *Dicroidium*, *Stenopteris*, *Taeniopteris*, *Chiropteris*, *Strobilites*, *Phoenicopsis* *Baiera* and *Stachyopitys*. Out of these only *Lepidopteris*, *Dicroidium* and *Taeniopteris* are common to both Nidpur and Stormberg Series of Cape Colony.

Fossil flora of Somabula beds, Southern Rhodesia (Upper Triassic), described by Seward and Holttum (1921) and Walton (1923, 1926, 1929) is also comparable to some extent to Nidpur assemblage in the presence of abundance of *Dicroidium* and *Taeniopteris* but the former assemblage may be differentiated from the latter assemblage in having *Schizoneura*, *Pachypteris*, *Dadoxylon*, *Rhexoxylon* and *Cyparissidium*.

The fossil flora described by Seward (1922, 1934) from Msimbasi river, Tanzania (Tanganyika) is quite different from the Nidpur flora and it is supposed to be of Upper Triassic or Rhaetic in age. The assemblage consists of *Baiera*, *Cupressinocladus*, *Desmiophyllum* and *Voltziopsis*.

Recently, from the vicinity of Tanga, East Africa (Lower Triassic), Townrow (1967) has described *Voltziopsis africana*. This genus is so far not known from Nidpur.

SOUTH AMERICA

The Triassic flora of Argentina from South America has been worked out by various authors in fairly great detail. Most of the plants described are from Middle to Upper Triassic beds. Our knowledge of the Triassic flora from South America is based mainly on the work of Geinitz (1876), Szanocha (1888, 1889, 1891), Hauthal (1892), Kurtz (1921), Gothan (1925), Fossa-Mancini (1937), Frenguelli (1941a, 1941b, 1943a, 1943b, 1942, 1944a, 1944b, 1944c, 1944d, 1946, 1947, 1948, 1950), Archangelsky (1963, 1968), Archangelsky & Brett (1960, 1961, & 1963), Sota & Archangelsky (1962), Menendez (1951a,b, 1956, 1957), Stipanicic and Menéndez (1949), Gröeber & Stipanicic (1952), Stipanicic (1956, 1967), Stipanicic & Bonetti (1965, and 1967), Stipanicic *et al.*, 1968), Mésigos & Stipanicic (1967), Bonetti (1963, 1966a,b, 1968a,b), Herbst (1963), Bonetti & Herbst (1966), Jain & Delevoryas (1967), Brett (1968) and Yrigoyen (1967).

In Argentina the Triassic flora is known from Cerro de la Cabras (Upper Carnian), Estrato de Barreal (Upper Carnian), Estrato de Potrerillos (?Norian), Estrato de Cacheuta (Upper Norian) and Estrato de Ischigualasto (Upper Norian). The floral assemblage of Cerro de la Cabras (see Frenguelli, 1948 and Gröeber & Stipanicic, 1952) differs markedly from the Nidpur assemblage in having *Nilssonia*, *Desmiophyllum* and *Elatocladus*. Estrato de Barreal (see Frenguelli, 1944; Stipanicic & Menèndez, 1949; Bonetti, 1963, Stipanicic & Bonetti, 1965, 1966) assemblage is much diversified and differs from Nidpur assemblage in having *Equisetites*, *Neocalamites*, *Coniopteris*, *Thaumatiopteris*, *Xylopteris*, *Dicroidiopsis*, *Diplasiophyllum*, *Saportaea*, *Pseudoctenis*, *Chiropteris*, *Pterophyllum* and *Baiera*. The Cacheuta formation (see Frenguelli, 1941, 1942, 1943, 1944; Townrow, 1957, 1962; Jain & Delevoryas, 1967) too has a very rich floral assemblage associated with index genus *Dicroidium*. It has a large number of genera which are entirely missing at Nidpur, viz., *Phyllotheca, Equisetites, Neocalamites, Cladophlebis, Xylopteris, Yabeilla, Dicroidiposis, Diplasiophyllum, Umkomassia, Ginkgoites, Baiera, Sphenobaiera, Ginkgodium, Baierophyllites, Czekanowskia, Cycadocarpidium, Phoenicopsis, Podozamites, Fanerotheca, Chancitheca* and *Fraxinopsis*. Here, too, none of the species are common to both the assemblages. In the Ischigualasto formation (see Frenguelli, 1944 and Bonetti, 1966) the only genus which is also present at Nidpur is *Dicroidium*. But none of the species resemble each other. This has a large number of genera which are completely absent at Nidpur. They are *Phyllotheca, Equisetites, Neocalamites, Dicroidiopsis, Lepidanthium, Cardiopteridium, Elatocladus* and *Cycadocarpidium*.

BRAZIL

The Triassic flora described by Rau (1933), Dolianiti (1945), Gordon & Brown (1952), Barbosa (1953), Beltrão (1965) and Bortoluzzi & Barbeena (1967) from Brazil is meagrely known. These assemblages resemble Nidpur in the presence of *Dicroidium* in abundance. But the floral assemblages, apart from this similarity, are quite distinct from Nidpur in having *Schizoneura, Neocalamites, Sphenopteris, Samaropsis, Nilssonia, Pterophyllum, Otozamites, Cedroxylon, Sphenozamites* and ?*Podozamites*.

CHILE

Nidpur flora is also comparable to some extent to the Triassic assemblage of Chile described by Zeiller (1875), Solms-Laubach, Graf and Steinmann (1899), Fuenzalida (1937) and Nishida (1970) only in the presence of *Dicroidium*. The genera *Equisetites, Pecopteris, Lyginodendron, Chiropteris Baiera, Czekanowskia* and *Araucarioxylon* are absent from Nidpur.

ANTARCTICA

The Triassic fossil flora of Antarctica recorded by Plumstead (1962), Gunn and Warren (1962), Townrow (1967) and Rigby and Schopf (1969) shows similarity with the Nidpur assemblage in having the common elements, viz., *Glossopteris, Dicroidium, Taeniopteris* and *Noeggerathiopsis* but the Antarctican flora differs from Nidpur in the presence of *Schizoneura, Neocalamites, Vertebraria, Zylopteris* cf. *Diplasiophyllum* and cf. *Johnstonia trilobita, Phoenicopsis* and *Czekanowskia*.

MIOFLORISTIC COMPARISON

A comparison similar to megascopic flora has been carried out with regard to the Nidpur mioflora, though with attention paid to genera rather than species.

From a comparative study of the Nidpur mioflora with Gopad bridge miospore assemblage of Raniganj Stage (Maheshwari, 1967), it becomes apparent that the two agree in the presence of genera, namely, *Densipollenites, Platysaccus, Striatites, Lahirites, Lunatisporites, Striatopodocarpites, Verticipollenites, Faunipollenites, Sulcatisporites* qualitatively but not quantitatively. As against this similarity, Nidpur assemblage shows a clear distinction from it too, in having forms like *Nidipollenites, Distriatites, Chordasporites, Satsangisaccites, Klausipollenites, Alisporites, Trochosporites, Weylandites, Aumancisporites* and *Praecolpatites* and in lacking the typical genera of Raniganj Stage. Quantitatively, in Gopad bridge assemblage the genera *Densipollenites, Striatites, Striatopodocarpites, Faunipollenites, Lahirites, Cuneatisporites* and *Sulcatisporites* are dominating, whereas in Nidpur assemblage, *Nidipollenites, Satsangisaccites, Alisporites* and *Weylandites* occur in abundance.

Comparing Nidpur spore assemblage with Raniganj mioflora from the type locality (Bharadwaj, 1966), it has been observed that although some characteristic elements of Raniganj Stage, e.g. *Lunatisporites, Striatites, Faunipollenites are present* in Nidpur mioflora, there is virtually a complete lack of complementary trilete forms. As compared to the mioflora of Damuda Series as a whole, some genera which occur as important components of Nidpur assemblage seem to have appeared earlier but only as very rare components (refer. Bharadwaj & Srivastava, 1969).

PENINSULAR INDIA

The miofloral assemblage of Nidpur has been compared briefly to its older and younger miofloras of India along with meagrely known Lower Triassic miofloral assemblages of Peninsular India.

Recently a miospore assemblage described by Trivedi and Misra (1970) from Gopad river area near Nidpur has been considered by the authors to be of Triassic age because of dominance of striate bisaccate grains and variety of trilete spores. But the miofloral assemblage (Trivedi & Misra, 1970) shows affinity towards Upper Permian because of presence of typical miospores of Raniganj Stage, e.g. *Lophotriletes*, *Acanthotriletes*, *Distriomonosaccites*, *Striomonosaccites*, *Striatopodocarpites*, *Faunipollenites*, *Striatites*, *Lunatisporites*, *Verticipollenites*, *Sulcatisporites* and *Cuneatisporites*. Besides these genera, a few striate forms, e.g. *Granulostriatites*, *Gopadstriatites*, *Traveculosporites*, have been newly erected by Trivedi and Misra (1970) but in any case these new genera are not much different from *Striatopodocarpites* and *Striasulcites* Venkatachala & Kar. Likewise, *Lattisosporites* is exactly similar to *Weylandites*, Bharadwaj & Srivastava (1969). Nidpur flora markedly differs from the floral assemblage of Trivedi and Misra (1970) in the presence of *Nidipollenites* and *Satsangisaccites* but simultaneously it comes closer from the latter in the presence of striated bisaccate grains qualitatively. Quantitatively its presence is insignificant. Hence, on the basis of miofloristic evidence, it seems quite reasonable to place these beds of Trivedi and Misra (1970) along with Permian strata. In addition to this it can be further stated that the Permian sediments (Raniganj Stage) are exposed in Gopad river cutting in very close proximity of the Nidpur Triassic strata (refer. Bharadwaj & Srivastava, 1969).

Lately, the mioflora of early Panchet which overlies the Raniganj Stage has been described by Srivastava and Pawde (1962) and briefly reported by Satsangi *et al.* (1968, 1972). These assemblages lack the characteristic miospores of Raniganj Stage as well as those of Nidpur mioflora. Recently, a detailed work of Kar (1970) from a bore-core in Raniganj coalfield which belongs to Panchet Series has revealed that Panchet miofloral assemblage is dominated by trilete spores, i.e. *Biretisporites*, *Dictyophyllidites*, *Baculatisporites*, *Osmundacidites*, *Dinaripunctites*, *Subverrusporis*, *Decisporis*, *Discisporites*, *Rimaspora* and *Granuloperculatipollis*. This assemblage too lacks the characteristic miospores of Raniganj as well as of Nidpur. Further it is apparent that as compared to Nidpur assemblage, the mioflora of Panchet Stage is richer in pteridophytic spores and thereby it is closer to the mioflora of Raniganj Stage than Nidpur assemblage is to the latter. This Panchet mioflora appears to be poorer in the number of spore genera as compared to that of Raniganj Stage as well as Nidpur assemblage.

The Jurassic miofloras of India when compared with Nidpur assemblage, reveal that only *Alisporites* and *Platysaccus* are the common constituents and the rest of the genera are completely absent from Nidpur.

EXTRA-PENINSULAR INDIA

Miofloristically, Triassic exposures of extra-peninsular India are represented by two formations, namely, Kral Series and Salt Range, Punjab (the latter now in Pakistan).

Sitholey (1943) first recovered mega- and microspores from Sakesar, Salt Range, Punjab and he provisionally referred the larger spores under the genus *Triletes* species and the smaller spores under the genus *Sporites*. Also the author mentioned the presence of disc-like bodies, spore cast and bivalved structures. Later, Pant (1949) and Pant and Srivastava (1964) from the same sample described the maga- and miospores, viz., *Zeillerisporites*, *Triletes Talchirella*, *Punctatisporites*, *Lophotriletes*, *Perisaccus* and *Pityosporites*. Recently, a rich mioflora described by Balme (1970) from Lower to Middle Triassic of Salt Range comprises the genera *Punctatisporites*, *Calamospora*, *Cyclogranisporites*, *Verrucosisporites*, *Osmundacidites*, *Simeonospora*, *Tigrisporites*, *Nevesisporites*, *Perotriletes*, *Kraeuselisporites*, *Densoisporites*, *Lundbladispora*, *Guthoerlisporites*, *Aratrisporites*, *Cordaitina*, *Taeniaesporites*, *Guttulapollenites*, *Vitreisporites*, *Klausipollenites*, *Falcisporites*, *Alisporites*, *Sulcatisporites*, *Platysaccus*, *Fimbriaesporites*, *Ephedripites*, *Cycadopites* and *Schizosporis*. Thus it is quite obvious that the Triassic miofloral assemblage of Salt Range is dominated by trilete form. When Nidpur mioflora is compared with the miofloral assemblages of Salt Range, it is found that the bisaccate genera *Platysaccus queenslandii*, *Klausipol-*

lenites, *Alisporites* and *Sulcatisporites* are common to both and other genera, e.g. *Vitreisporites*, *Falcisporites* and *Cycadopites* are completely missing. *Taeniaesporites* is present in abundance in the Triassic of Salt Range but in Nidpur, this genus has been reported only on the basis of one or two grains. Also in Salt Range, none of the typical Triassic miospores of Nidpur is present. It is also noteworthy that Triassic of Salt Range completely lacks the striated bisaccate grains.

The mioflora from Krol series near Nainital was discovered by Sitholey *et al.* (1954) and in later years Lakhanpal, *et al.* (1958) and Sah *et al.* (1968) in the light of recent studies recognized the following genera, viz., *Calamospora*, *Planisporites*, *Dictyotriletes*, *Apiculatisporis*, *Laevigatosporites*, *Striatites*, *Lunatisporites*, *Strotersporites*, *Striatopodocarpites*, *Striatopiceites*, *Sulcatisporites*, *Cuneatisporites*, *Pityosporites*, *Succinctisporites*, *Alisporites*, *Triadispora*, *Platysaccus*, *Voltziaceaesporites* and cf. *Schizopollis*. Thus, Krol miofloral assemblage resembles Nidpur mioflora in having high frequency of non-striate bisaccate grains. However, miospores, viz., *Laevigatosporites*, *Striatites*, *Striatopodocarpites*, *Sulcatisporites*, *Alisporites* and *Platysaccus* are present in both the assemblages. Apart from this, another microfloral assemblage reported by Ghosh and Srivastava (1963) from the Mussorie Mule Track belonging to Krol Series could not be compared with the Nidpar mioflora because the authors have mentioned only a few spore types, e.g. triletes, monoletes, striated, disaccates and trisaccates.

AUSTRALIA

Hennelly (1958) investigated palynological fossils from the Permian-Triassic transition of New South Wales, Eastern Australia from a bore-core and attempted to demarcate the Permo-Triassic boundary distinctly by the abundance of striate bisaccates in the Upper Permian and the trilete spores in the lowermost Triassic. Contrary to this, Nidpur mioflora shows the majority of the nonstriate bisaccate grains.

Recently, Helby (1967, 1970) recovered Lower Triassic miofloral assemblages from Wollar Sandstone and Sydney Basin of New South Wales, Eastern Australia respectively. The assemblage is rich in pteridophytic spores and the frequency of striate disaccates and non-striate disaccate though present yet it is comparatively low. However, when it is compared with the Nidpur, it shows similarity in the presence of some of the miofloral elements, viz., *Striatopodocarpites*, *Lunatisporites*, *Sulcatisporites*, *Chordasporites*, *Klausipollenites*, *Alisporites*, *Aumancisporites* and *Praecolpatites*. But despite this closeness, the two assemblages can be distinguished fairly because Nidpur lacks almost all the trilete forms except *Punctatisporites* and also a few bisaccate and monocolpate grains. Also New South Wales mioflora shows complete absence of *Nidipollenites*, *Satsangisaccites* and *Weylandites*, the most characteristic forms of Nidpur.

Balme (1963, 1969a,b) studied the Lower Triassic miospores from the various basins, i.e. Perth, Canning and Canorvon of Western Australia and also tried to fix the Permian-Triassic boundary on the implications of palynological data. In all the localites his observation revealed that the triletes are dominated in the Lower Triassic while the underlying Permian assemblages are dominated by the striate disaccates. The trilete taxa described by him are, viz., *Kraeuselisporites* and *Lundbladispora*, the dominant miospores and rest have, however, been not recorded from India. *Taeniaesporites* is present in abundance while it is very poorly represented in Nidpur assemblage. *Platysaccus queenslandii* is common to both and *Aratrisporites* is missing in Nidpur.

DeJersey (1970) described early Triassic miospores from the Rewan Formation of Queensland which also reveals the dominance of trilete spores. Non-striate bisaccates are few in number. As far as Nidpur miofloral assemblage is concerned, it can be readily distinguished from the Rewan by presence of non-striate bisaccate grains in abundance. *Alisporites* is common to both.

As regards the Middle and Upper Triassic miofloras from various formations of Queensland, de Jersey (1949, 1962, 1964, 1965, 1970a, 1970b, 1971a, b); de Jersey & Hamilton (1965a, 1965b, 1965c, 1967, 1969); Evans (1964, 1966a, b & c); and Playford & Cornelius (1967) have made contributions of paramount importance.

Comparing Nidpur spores and pollen with the miofloras of Queensland Triassic, a close similarity in general aspects is apparent. The important constituents between them are: *Satsangisaccites*, *Alisporites*, *Chordasporites*, *Sulcatisporites*, *Klausipollenites*, and *Platysaccus queenslandii* but Nidpur assemblage differs in the complete absence of the genera, *Calamospora*, *Verrucosisporites*, *Converrucosisporites*, *Cingulatisporites*, *Aratrisporites*, *Triadispora*, *Leiotriletes*, *Circulisporites* *Calliatasporites*, *Dictyophyllidites*, *Pilasporites*, *Laricoidites*, *Granulatisporites*, *Stereisporites*, *Annulispora*, *Lycopodiumsporites*, *Osmundacidites*, *Foveosporites*, *Polycingulatisporites*, *Duplexisporites*, *Polypodiisporites*, *Tuberculatosporites*, *Partitisporites*, *Circulina*, *Discisporites*, *Cadargasporites*, *Rewanispora*, *Baculatisporites*, *Classopollis*, *Perinopollenites*, *Inaperturopollenites*, *Semiretisporites*, *Pustulatisporites*, *Guttatisporites*, *Tigrisporites*, *Rugulatisporites*, *Vitreisporites*, *Cycadopites*, *Araucariacites* and *Tenuisaccites*. Amongst all those trilete forms, only *Punctatisporites* is scantily represented in Nidpur but it shows its abundance in Queensland microflora.

A particularly, interesting and significant occurrence is that of the genus *Satsangisaccites* in the Rhaeto-Liassic of Leigh Creek Coal Measures of South Australia (Playford & Dettmann, 1965), which clearly indicates a long range for this genus. Besides this genus a few other common constituents are *Distriatites* (described by Playford & Dettmann as *Hamiapollenites*), *Alisporites*, *Platysaccus queenslandii*, *Punctatisporites* but this mioflora differs from Nidpur assemblage in the presence of *Apiculatisporis*, *Neoraistrickia*, *Ischyosporites*, *Foraminisporis*, *Guthoerlisporites*, *Lundbladispora*, *Punctatosporites* and *Aratrisporites* along with other Ipswich genera referred earlier.

TASMANIA

A comparison of Nidpur mioflora can also be made with the miospore assemblage of Late Triassic from Tasmania (Playford, 1965) in the common occurrence of genera like *Satsangisaccites*, *Alisporites*, *Platysaccus queenslandii*, *Taeniaesporites* and *Punctatisporites* but the latter differs by the presence of *Calamospora*, *Stereisporites*, *Concavisporites*, *Osmundacidites*, *Acanthotriletes*, *Apiculatisporis*, *Neoraistrickia*, *Tigrisporites*, *Annulispora*, *Krauselisporites*, *Baculatisporites*, *Nevesisporites*, *Lundbladispora*, *Densoisporа*, *Circulisporites*, *Guthoerlisporites*, *Aratrisporites* and *Protohaploxypinus*.

MADAGASCAR

Jekhowsky and Goubin (1964) and Goubin (1965) have described Triassic miofloral assemblages from Madagascar which are comparable to Nidpur favourably in the presence of *Platysaccus*, *Sulcatisporites*, *Taeniaesporites* and *Alisporites*. But other forms like *Classopollis*, *Inaperturopollenites*, *Applanopsis*, *Podocarpidites*, *Cuneatisporites*, *Lueckisporites*, *Striomonosaccites*, *Strotersporites*, *Rimaesporites*, *Graminoides*, *Laricoidites*, *Vitreisporites*, *Protohaploxypinus*, *Falcisporites*, *Samaropollenites*, *Guttulapollenites*, *Vittatina* and *Cycadopites* are missing in Nidpur.

SOUTH AFRICA

Regarding Triassic mioflora of South Africa, no definite record is available so far. But recently, a few miospore types have been recognized in a tabular form from Molteno beds (Middle-Upper Triassic) (refer. Anderson & Anderson, 1970, p. 13). This table of miospore types reflect the dominance of trilete forms though associated with striate non-striate and alete forms. However, with this knowledge of Molteno mioflora, no comparison is possible with Nidpur.

SOUTH AMERICA

The first record of plant microfossils was made by Orlando (1954) from Cacheuta formations (Mendoza) of Argentinian Triassic. But the author did not give any systematic account of pollen and spores. The microfloral components were described as *Pteruchus*, *Monocolpites*, *Zonatognites*, *Antholithus* and *Oedemosaccus*. Only *Alisporites* type of grains from Nidpur can be closely compared with the *Pteruchus* grain of Cacheuta formations.

The miospore assemblage from Minas de Petroleo beds of Cacheuta Formation (Middle Triassic), from Argentina described by Jain (1968), is dominated by non-striate bisaccates (46-50%) and monocolpate (24%) pollen grains. The alete forms are also copious (23%) while pteridophytic spores and striate saccates are rare (1% each). As compared to Nidpur assemblage, it lacks

Satsangisaccites, *Nidipollenites*, *Weylandites* and *Praecolpatites*, all the characteristic genera of the former. In over all nature this Argentinian assemblage has more pronounced Cycado-Ginkgoalean character as compared to Nidpur mioflora. Nidpur mioflora also compares a little in the presence of *Klausipollenites* cf. *K. staplinii*, *Alisporites* and *Punctatisporites* from that of Ischigualasto beds (Upper Triassic) of Argentina described by Herbst (1965) but the latter differs in the presence of trilete forms, e.g. *Cingulatisporites*, *Clavatriletes*, *Discisporites*, *Planisporites*, *Verrucosisporites* *Discisporites*, *Planisporites*, *Verrucosisporites* and other monocolpate genera, viz., *Cycadopites*, *Entylissa*, *Lagenella*, *Monosulcites* and *Gemmamonocolpites*.

ANTARCTICA

It is also worthwhile to compare Nidpur mioflora with spore assemblage described by Norris (1965) and Helby and McElroy (1969) from Middle-Upper Triassic beds of Antarctica. The assemblage is rich in pteridophytic spores associated with a few non-striate bisaccate grains, viz., *Alisporites* and *Vitreisporites*. *Alisporites* is a dominant constituent of Antarctican flora and in Nidpur too, this genus is represented fairly in abundance. Other forms, namely, *Converrucosisporites*, *Dictyophyllidites*, *Neoraistrickia*, *Nevesisporites*, *Osmundacidites*, *Polypodiisporites*, *Punctatosporites*, *Protohaploxypinus*, *Quadrisporites*, *Verrucosisporites*, *Cadargasporites* and *Aratrisporites* are completely missing from Nidpur.

CONCLUDING REMARKS

A perusal of foregoing comparative accounts reveal that megafloristically, Nidpur assemblage corresponds more to the Lower Triassic flora of southern hemisphere. The assemblage resembles most the assemblage from the Panchet Stage of India, Narrabeen Stage of Australia, Upper Beaufort beds of South Africa, Triassic deposits of Madagascar and Antarctica. But, in the overwhelming dominance of genus *Dicroidium*, Nidpur megaflora comes more closer to the Middle Triassic floras of Gondwana continents.

Miofloristically, Nidpur assemblage depicts closest qualitative agreement with the mioflora of Raniganj Stage (Upper Permian) of India which it overlies. However, with the latter it differs substantially in the quantitative composition of some pollen genera, chiefly, *Nidipollenites*, *Satsangisaccites*, *Alisporites* and *Weylandites* all of which are absent in the underlying mioflora from Gopad bridge. The early Panchet mioflora from Raniganj coalfield which is dominated by trilete forms, presents an older aspect as compared to the Nidpur flora and represents the transition between two well diversified miofloras of Raniganj Stage and Nidpur. The genera *Satsangisaccites* and *Alisporites* so characteristic of Nidpur are also well represented in the Middle Triassic miofloras of Australia. While in Australian assemblages *Satsangisaccites* and *Alisporites* are associated with non-Permian spore genera, in the Nidpur assemblage they are associated with Permian spore genera. Evidently, the Nidpur shales are younger than the Permian and older than the Upper Triassic.

Thus, in terms of Indian stratigraphical sub-divisions, on the basis of mega- and miofloristic evidences, Nidpur beds can be surmized to lie in the Panchet Series. However, the richness of *Dicroidium* as compared to *Glossopteris* in the Nidpur shales ascribes a younger aspect to it than the Panchet Stage.

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A NEW SPECIES OF FOSSIL GYMNOSPERMOUS WOOD *PLANOXYLON* STOPES FROM ADHARI (M.S.)

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ABSTRACT

A coniferous wood collected at Adhari, Dist. Chanda, Maharashtra State, shows combination of characters found in two different families Abietineae and Araucarineae. Its characters agree with those of the genus *Planoxylon* Stopes (1916) but the species seems to be different. It is from the Lower Triassic horizon (Kamthi Stage) of India whereas the species *Planoxylon Hectori* Stopes was from New Zealand belonging to the Cretaceous period.

INTRODUCTION

SEVERAL fossil woods were collected from Adhari (Lat. 20° 8', Long. 79° 11') in the District Chanda (Maharashtra State) belonging to the Lower Triassic horizon (Kamthi Stage). Most of them are of conifers and their preservation is good. One of them had mixed characters of the Abietineae and Araucarineae, and it forms the subject matter of this paper.

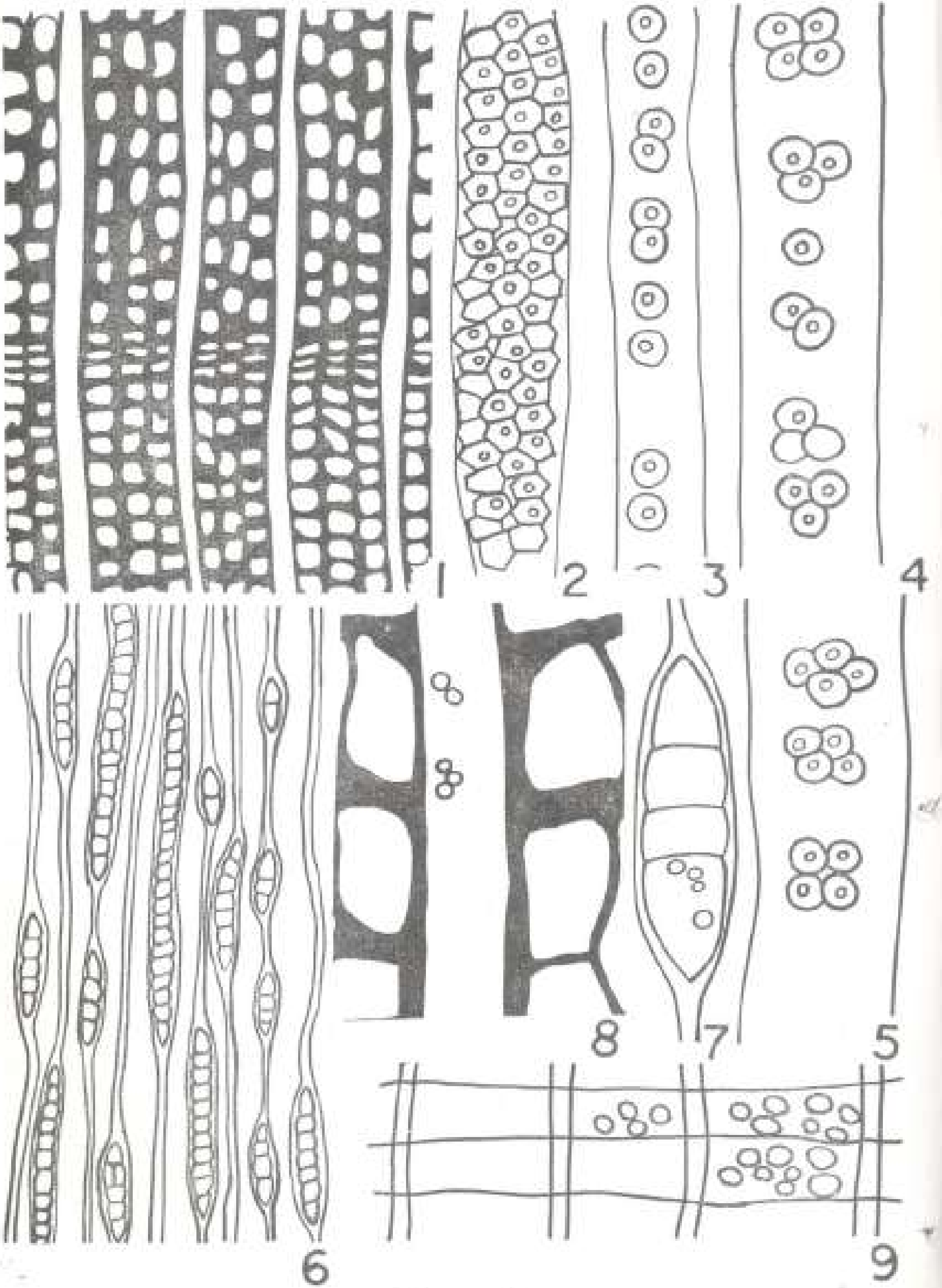
DESCRIPTION

A piece of yellowish-brown silicified coniferous wood measuring 16 × 12·4 cm was found interesting on account of strong mixture of characters. It is a piece of decorticated secondary wood without pith. The characters noticed in it are as follows: (1) T. S. shows 7-8 growth rings. The secondary xylem was differentiated into spring wood and autumn wood (Text-fig 1; Pl. 1, Fig. 1). The spring wood is 114 cells wide. The tracheids are 48 × 72 μ, thick-walled, rectangular, with rounded corners and broad lumen. The autumn wood is 2-3 cells wide. The tracheids are 40 × 16 μ, horizontally stretched and their lumen is small. (2) T. L. S. of the wood shows uniseriate and biseriate medullary rays (Text-fig. 6; Pl. 1, Fig. 6). The uniseriate condition is more predominant than the biseriate. The height of the medullary rays varies from 2-28 cells, average hight being 11 cells (25 counts). The ray-cells are barrel-shaped and measure 48 × 28 μ. An important feature of the wood is its medullary ray-cells. Pits of the Abietinean type are seen on them (Text-figs. 7,8; Pl. 1, Figs. 7, 8, 9,10). (3) The pits on radial walls of the tracheids are (a) multiseriate hexagonal and alternate (Text-fig. 2, Pl. 1, Fig. 2). They measure 12·4 × 11 μ. The pit-pore is circular, 4·3 μ in diameter. (b) Uniseriate circular and separate pits (Text-fig. 3; Pl. 1, Fig. 5). (c) Circular pits occur in stellate clusters of 3-4 cells and measure 11 μ (Text-figs. 4, 5; Pl. 1, Figs. 3, 4). These clustered or grouped pits in 3-4 are similar to those in *Cedroxylon transiens* of Gothan. (4) The number of crossfield pits in R. L. S. varies from 4-8. They are circular to oval, 8·1 × 7 μ. They constitute a special feature of this wood (Text-fig. 9; Pl. 1, Fig. 11).

IDENTIFICATION

The present wood has compressed hexagonal pits as in the Araucarineae and circular separata pits as in the Abietineae. Besides, it has 3-4 circular pits in groups and also Abietinean pits on the medullary ray-cells. This is a distinct feature of this wood. Presumably this wood, like some other Palaeozoic woods, is synthetic and has generalized characters of early gymnosperms, combining characters of different genera. In addition they have some different characters which might have been modified later or were lost. One of such composite generalized wood genera is *Planoxylon* Stopes (1916), as pointed by Bailey (1933). The present specimen closely agrees with that genus and can be seen from the details given in Table 1.

Only two species of the genus *Planoxylon* Stopes (1916) are known (1): *Planoxylon Lindleii* (Witham) Stopes from Upper



TEXT-FIG. 1-9

TABLE 1 — SHOWING THE CHARACTERS OF THE VARIOUS SPECIES OF *PLANOXYLON* STOPES

PART A

NAME OF THE SPECIES (1)	GROWTH RING (2)	RADIAL PITTING (3)	CROSS-FIELD PITS (4)	MEDULLARY RAYS (5)
Planoxylon indicum sp. nov.	Very distinct	Uniseriate, circular separate Circular pits in clusters of 3-4. Multiseriate, hexagonal, alternate.	Circular to oval 4-8	Uniseriate, sometimes biseriate, 2-28 cells
Planoxylon Lindlei (Witham) Stopes	Distinct	1-3 rows of alternate hexagonal. Clusters not known	Not known	Uniseriate, 1-12 cells
Planoxylon Hectori Stopes	Very distinct	Uniseriate, circular, separate. Circular pits in clusters of 3-4. 3-Seriate hexagonal alternate.	In vertical pairs of 1-3	Uniseriate rarely biseriate, 1-24 cells

PART B

ABIETINEOUS PITS ON RAY-CELLS (6)			PITH (7)	XYLEM PARENCHYMA (8)	HORIZON (9)	LOCALITY (10)
T.S.	T.L.S.	R.L.S.				
Present	Present	Not seen	Absent	Absent	Lower Triassic (Kamthi Stage)	Adhari (District Chanda), Maharashtra, India.
Not seen	Not seen	Present	Absent	Scanty	Upper Liassic	Whitbi, Yorkshire, England.
Present	Present	Present	Present	Scanty	Cretaceous (Upper or Middle)	Amuri Bluff, New Zealand.

Liassic of England, and (2) *Planoxylon Hector* Stopes from the Cretaceous of New Zealand.

In *Planoxylon Hectori* Stopes there are multiseriate hexagonal alternate pits, uniseriate circular separate pits, and also circular pits in clusters of 3-4. Our wood shows all these characters. In *P. Lindlei* (Witham) Stopes also there are multiseriate, hexagonal, alternate pits. In *P. Hectori* Stopes, the Abeitineous pits are seen on the medullary ray-cells and are seen in T. S. T. L. S. and R. L. S. In the present wood

TEXT-FIGS. 1-9 — A new species of fossil Gymnospermous wood *Planoxylon indicum* Mahabale & Vagyani from *Adhari* (M.S.). 1. T.S. of wood showing secondary xylem differentiated into spring wood and autumn wood × 143. 2. R.L.S. showing multiseriate, hexagonal, alternate pits × 595. 3. R.L.S. showing uniseriate, circular, separate pits × 595. 4 & 5. R.L.S. showing circular pits in clusters of 3-4 × 595. 6. T.L.S. showing uniseriate and biseriate medullary rays × 143. 7. T.L.S. showing medullary rays with Abietineous pits × 595. 8. T.S. showing medullary rays with Abietineous pits × 595. 9. R.L.S. showing 4-8 circular to oval, field pits × 595.

they are seen only in T. S. and T. L. S. (Text-figs. 7, 8; Pl. 1, Figs. 7, 8, 9 & 10).

In *P. Lindleii* they are seen only in R. L. S. The present wood differs from *P. Hectori* in having 4-8 field pits which are 1-3 in that species. The height of medullary rays in *P. Hectori* is 1-24 and in *P. Lindleii* 1-12. But in the present species it is 2-28. The present species thus though shows resemblance with *P. Hectori*, it is only generically identical with it. It mainly differs from it in having 4-8 field pits and medullary rays 2-28 cells high. Therefore, it seems to be a different species. Besides, it is from a still lower horizon than that of *P. Hectori*. However, it is worthy to note that both of them are from the Mesozoic Southern Hemisphere conifers.

DISCUSSION

In the Mesozoic period one comes across many coniferous woods which show a mixture of Araucarian and Abietinean characters, e.g. *Planoxylon* Stopes, *Protocedroxylon* Gothan, *Protopiceoxylon* Gothan, *Thylloxylon* Gothan, *Araucarionpitys* Jeffrey, *Cedroxylon* Krauss,*Xenoxylon* Gothan, *Anomaloxylon* Gothan, etc. The genus *Planoxylon* Stopes has a wide range within the Mesozoic period from Upper Liassic to Middle Cretaceous and it occurs in both the Southern and Northern Hemispheres. The present wood is from Lower Triassic horizon which is considered to be equivalent to the Middle Gondwanas and belongs to the Kamthi Stage. This shows that the genus *Planoxylon* Stopes evolved from Lower Triassic to Middle or Upper Cretaceous. According to Bailey (1933) these coniferous woods are transitional forms and can be classified as Protopinaceae or Araucariopityeae. Amongst the living gymnosperms they fall within the span of structural variability and relationships of the genera *Cedrus*, *Keteleeria* and a few others such as *Abies*, *Pseudolarix* and *Tsuga*; but they do not definitely belong to any one of them.

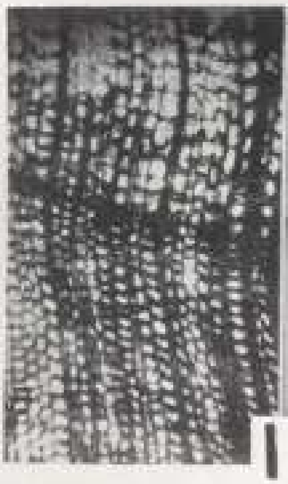
The presence of one species of *Planoxylon*, *P. Lindleii*, in Northern Hemisphere is of rare occurrence; but in the Southern Hemisphere it seems to be more abundant, being known from New Zealand and India. In India besides Adhari, some of the coniferous microfossils from Rewa coal basin studied by Saksena (1963) are having all these types of pits, especially clustered ones, which indicate that even in India the genus was of wider occurrence in the Middle Gondwanas. It is very likely that it might prove to be a characteristic conifer of Mesozoic period when several members of the Pinaceae were not sharply segregated into modern genera such as *Cedrus* or *Abies*; and, therefore, a comparison of these Mesozoic conifers with highly differentiated modern genera would be misleading regarding its affinities.

It is now generally believed that Permian onwards conifers of the Northern and Southern Hemispheres were differentiated not in the same way and in different environmental conditions, and as such they are different. The occurrence of *P. Lindleii* in Liassic of England and of *P. Hectori* in New Zealand and *Planoxylon* described here seems to be similar in distribution to that of *Podocarpus*, majority of which occur in Southern Hemisphere today, but a section of it '*Nageia*' with seven living species had representatives in the Pre-Cretaceous period in Northern Hemisphere in trans-Himalayan region.

That Southern and Northern Mesozoic conifers were different is shown to be so by Meyen (1971) on the basis of leaf impressions, and by Surange (1971) on the basis of his study of the Permian woods. The occurrence of *Planoxylon* in India and New Zealand fully confirms this view, and makes one believe that they were differentiated in entirely different climate, warm in Southern Hemisphere, and cold temperate in Northern Hemisphere. *P. Lindleii* was perhaps growing in warm temperate regions of the Northern Hemisphere. The genus *Planoxylon* seems to have emerged from Triassic, but it got differentiated in Liassic and lasted till Cretaceous. It is very likely that a critical re-examination of many Southern fossil coniferous woods may bring to light some more localities of *Planoxylon* or other similar transitional genera mentioned above.

Planoxylon indicum n. sp.

Diagnosis — Growth rings distinct, 7-8. Secondary xylem differentiated in spring and autumn wood; pith absent. Medullary rays uniseriate and biseriate, mostly uniseriate, 2-28 cells high, average height 11 cells. Abietineous pits present or medullary ray-cells in T. S and T. L. S. Radial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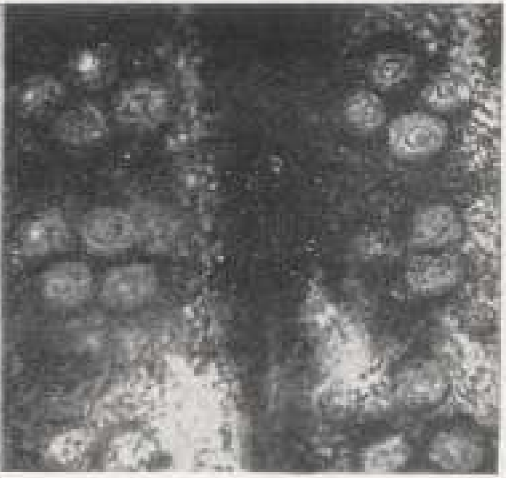
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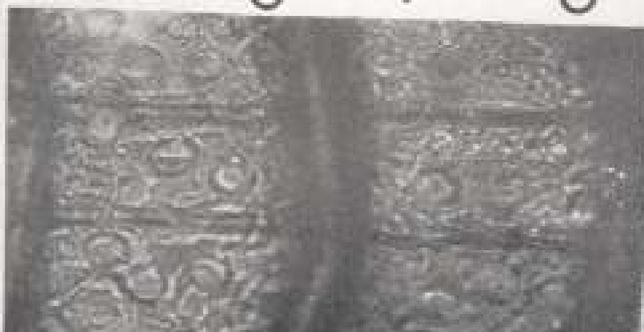
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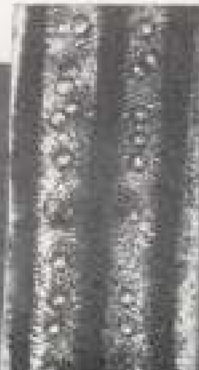
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4

pits uniseriate, circular, separate, and circular pits are in clusters of 3-4; also multiseriate hexagonal pits present. Cross-field pits 4-8, circular to oval.

Holotype — $\frac{ADR}{4/70}$ Museum Botany Department, University of Poona, Poona-7.

Locality — Adhari (Dist. Chanda), Maharashtra State.

Horizon — Lower Triassic (Kamthi Stage), India.

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EXPLANATION OF PLATE

PLATE 1

Figs. 1-11. A new species of fossil gymnospermous wood *Planoxylon* Stopes from *Adhari* (M.S.)

1. T.S. showing secondary wood differentiated into spring wood and autumn wood. × 20.

2. R.L.S. showing multiseriate, hexagonal, alternate pits. × 70.

3-4. R.L.S. showing circular pits in clusters of 3-4. × 70.

5. R.L.S. showing uniseriate, circular, separate pits. × 20.

6. T.L.S. showing uniseriate and biseriate medullary rays. × 15.

7-9. T.L.S. showing medullary ray-cells with Abietineous pits. × 100, 250, 90 respectively.

10. T.S. showing medullary ray-cells with Abietineous pits. × 100.

11. R.L.S. showing 4-8, circular to oval, field pits. × 50.

QUATERNARY STUDIES ON THE WESTERN COAST OF INDIA: PRELIMINARY OBSERVATIONS

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INTRODUCTION

WE present here the results of our studies on Holocene sea level changes on the Maharashtar coast and their inter-disciplinary implications*. In starting these investigations we had the following aims in view:

i) Determination of Quaternary eustatic changes and their dating;
ii) The effect of eustasy on coastal and fluvial geomorphology;
iii) The use of i) and ii) for dating the implementiferous fluvial sediments and thus defining the temporal placement of the Stone Age industries; and
iv) The reconstruction of palaeoclimatic and palaeoecological changes based on pollen and diatom studies.

The first (i) part is covered in this paper; the last aspect (iv) is being reported by Vishnu-Mittre and Guzder (in press). Other facts of the study will be reported elsewhere.

In the context of the problems discussed here, we may group the present controversies in the field of Holocene eustasy, round the two main theories that:

i) Sea level rose rapidly up to the end of the Atlantic period (7,700 to 5,000 B. P.) reaching a height of 2 to 3 m above the present level and has fluctuated with varying amplitude since then (Fairbridge, 1961).
ii) The sea level rose steadily, reaching the present level c. 3,600 B. P., but has not risen above this datum during the Holocene (Shepard, 1960, 1963; Fisk, 1951; McFarlan, 1961).

We will evaluate the significance of our data in the light of these controversies.

THE AREA STUDIED

To begin with, we have concentrated in the Maharashtra coastal region, between 15°-20°N latitude (Fig. 1); later on, we will extend the work to other areas also. Geologically this area is comprized of the Deccan basalts and the coastal laterites. The western Ghats ranging from 600-1300 metres rise abruptly to the east of the coastal plain, which is 30-60 km wide. The small rivers originating in the Ghats debouch into the Arabian Sea. South of Bombay, the rocky coast is broken by a series of small bays and beaches lying between prominent headlands.

The main cosideration in selecting the west coast was its length combined with the fact that peninsular India has remained relatively stable during the Quaternary (Chatterjee, 1962). The only major earthquake occurred in 1967 at Koyna and was allegedly caused by the tremendous pressure of water in the reservior of the Koyna dam. There is no other reported evidence of any major tectonic activity in this area during the Quaternary. The general stability of the coastline finds further support from port-records of the last hundred years, which show a steady rise of sea level south of 20°N latitude (Lele, 1967). North of this, however, the coastal regions are reported to be quite active tectonically (Pascoe, 1964), and by contrast, the sea level in the last hundred years at Bhavnagar (21°45′N Lat.) shows violent fluctuations (Lele, 1967).

Furthermore the Maharashtra coastal region is ideal for studying the geomorphological effect of eustatic changes on the lower reaches of the short rivers flowing from the

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*The main institutions that have helped us are: Birbal Sahni Institute of Palaeobotany, Lucknow and the National Institute of Oceanography, Panaji, Goa.

Ghats into the Arabian Sea. The correlation of fluvial geomorphology with a dated eustatic curve assumes greater importance in view of the fact that many of these river gravels contain Stone Age implements.

For the Holocene sea levels, on the west coast of India (Fig. 1), two main types of formations have been studied so far i) emerged beaches and coral; and ii) the continental shelf. We have concentrated on the emerged beaches preserved in the form of beach-rock between 20°-10°N. Lat. Nair (p.c. & 1971) has carried out investigations on the continental shelf and the samples collected by him were also dated at the Tata Institute. Gupta has studied raised beaches and inland reefs of the Saurashtra peninsula (24°-20°N. Lat.) (Gupta, in press). We have used all these results in the present discussion. The coastal swamps around Bombay have been examined for pollen by Vishnu-Mittre and Guzder (in press), while diatoms from the same deposits will be studied by Desikachary (Madras University). The foraminifera from the beach-rock samples and swamp deposits from Bombay have been preliminarily identified (Setty, p.c.; Singh & Kalia, p.c.).

In geological literature, (Pascoe 1964) littoral concrete (beach-rock) is reported from Daman (20°24′50″N. Lat.) to Goa (15°36′N. Lat.). We have ourselves observed it, in broken stretches, (Fig. 1) from Mahim (19°40′N. Lat.) to Ratnagiri (17°N. Lat.) and dated such samples (Table 1) from different sites. As a well preserved example, we describe below the beach-rock at Manori (19°12′10″N. Lat.) north of Bombay.

This formation extends over 3 km and lies between two rock outcrops on the north and south extremities. It appears that a sand-spit was formed between the two hills during the period of marine transgression. The subsequent regression probably resulted in the elevation of the sandspit above the HWL and its consolidation due to leaching down of $CaCO_3$. A situation, probably analogous to this, has resulted in the elevation of the sand bar at Bhatti-Mirya, Ratnagiri (Fig. 1). The maximum height of the Manori deposit is 3 to 5 m above the high water level (HWL) with a ~9° seaward dip. The angle of the strike of the beach-rock does not conform to that of the present day beach, thereby distinguishing it from the modern beach processes.

OUR DATA & C^{14} DATES

The beach-rock is a well consolidated deposit comprised of finely comminuted shells and sand. A typical sample of beach-rock from Erangal-Bhatti (19°11′N. Lat.) contained the following micro-fauna (Setty, p.c.):

a) *Ammonia beccari* ...predominant ...15-20%
b) *Elphidium excavatum* ...2-5%
c) *Quinqueloculina seminulum* } ...2-5%
d) *Milliammina fusca* } ...rare
e) *Cibicides mollis* }
f) *Nonion formosum* }

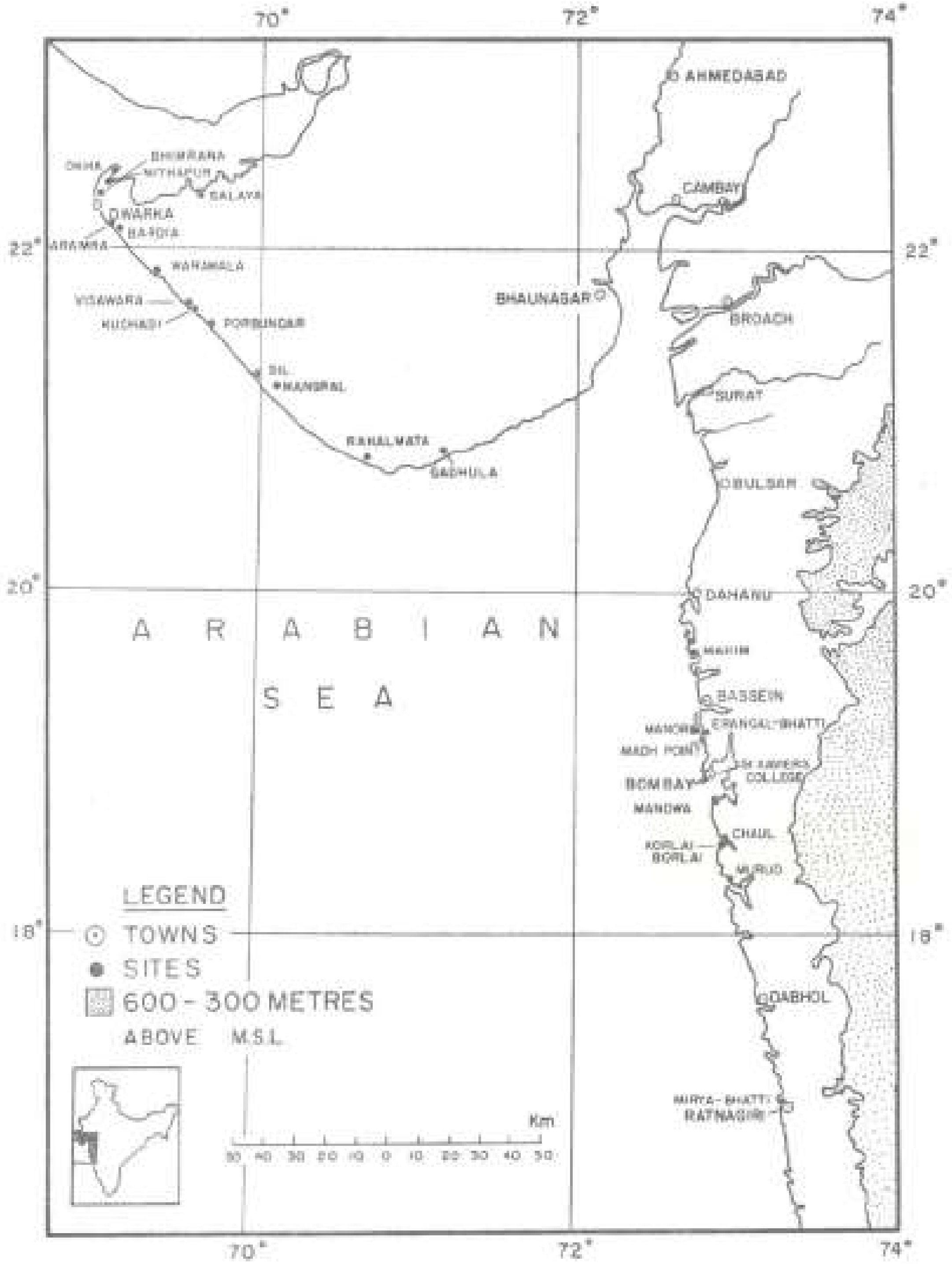
In addition, there appear fragments of shell and wood, whole and fragmented Ostracods and also bits of coral. This faunal assemblage constitutes nearly 25-30% of the given sample. The presence of (a), (b), (c) and (e) shows that the rock belongs to the littoral zone. *Ammonia beccari* especially thrives in the surface waters only.

The samples collected from the coastal swamps also yielded microforaminifera. Preliminary investigations (Singh & Kalia p.c.) indicate the presence of *Bulimina* sp., *Bolivina*, *Elphidium* sp., *Orbulina universa*, *Spiroloculina indica* and other Globigerinidae. These are essentially salt-water organisms and the changes in their frequency with depth in the cores, are being studied further to relate them with the marine transgressions and regressions.

DATES

Tables 1 and 2 and Figure 2 show the C^{14} dates of the changes in sea level. The data plotted are based on our samples and also on those collected by Gupta (in press), Nair (p.c. & 1971) and Prabhakar Rao (p.c; see also Agrawal *et al.*, 1967, 1970).

Fig. 2 clearly shows that the post-glacial marine transgression on the Western coast rises quite steeply from 9,000 to 6,000 B. P. Between 6,000 B. P. and today, the sea level has fluctuated. The Saurashtra coast samples show a rise of about +3 to +5 metres (above the HWL) around *c.* 5500 ± 1000 B. P. There are as yet no dates between *c.* 5,000-3,000 B. P. This period may represent a phase of regression. We have however, not been able to collect samples from any significant depth below



TEXT-FIG. 1 — Map of the West coast of India showing the main C^{14}-dated coastal sites.

TABLE 1

SITE	DISTRICT/ LOCATION	MATERIAL	TF No.	C^{14} DATE IN YEARS B.P. (5730±40 HALF-LIFE	HEIGHT IN METRES ABOVE/BELOW HWL
Manori	Bombay	Littoral concrete	1192	4,245±85	−1·0
Manori	,,	,,	1193	4,340±100	+1·0
Manori	,,	,,	1194	4,385±110	+3·0
Erangal-Bhatti	,,	,,	938	1,765±95	+3·5
Erangal-Bhatti	,,	,,	972	2,730±95	+3·0
Erangal-Bhatti	,,	,,	981	5,070±105	+0·80
Madh Point	,,	,,	1186	2,115±90	+0·55
St. Xavier's College	,,	,,	1197	2,800±110	+1·55
Mandwa	Kolaba	,,	1230	2,050±105	+0·05
Chaul	,,	,,	1231	2,180±94	−3·0
Korlai-Borlai	,,	,,	1232	2,410±95	+0·50
Mirya-Bhatti	Ratnagiri	,,	1080	2,800±110	+5·9
Mirya-Bhatti	,,	,,	1079	2,305±95	+6·0

Table 1 : C^{14} dates and elevations above HWL (high water level) of beach rock samples collected by the authors from the Maharashtra Coast. Fig. 2 shows the eustatic plot based on these and Table 2 data.

TABLE 2

SITE	DISTRICT/ LOCATION	MATERIAL	TF No.	C^{14} DATE IN YEARS B.P. (5730±40 HALF-LIFE)	HEIGHT IN METRES ABOVE/ BELOW HWL	REFERENCE
Bhimrana	Saurashtra Coast	Shell	908	5,430±110	+3·0	S. K. Gupta, in press*
Salaya	,,	Coral	911	5,220±105	+2·8	,,
Warawala	,,	Coral	1014	6,185±115	+3·2	,,
Warawala	,,	Coral	1015	4,575±105	+3·6	,,
Gadhula	,,	Shell	1044	6,670±280	+3·0	,,
Rahalmata	,,	Shell	1045	6,320±270	+4·8	,,
Mangral	,,	Shell& Coral	1051	4,700±245	+5·0	,,
Sil	,,	Shell	1052	5,820±300	+3·9	,,
Willington Island	Cochin-off Shore	Wood	965	8,315±125	−16·75	E. Nielsen, p.c.
Chavara-Kayankulum	Kerala-off Shore	Shell	203	5,610±115	−1·8 to −3·6	G. Prabhakar Rao, p.c.
Chavara-Kayankulam	,,	Shell	204	6,295±115	−3·9 to −5·2	,,
Karwar	Off Karwar-Continental Shelf	Shell	983	9,135±130	−58·5	R. R. Nair, p.c.

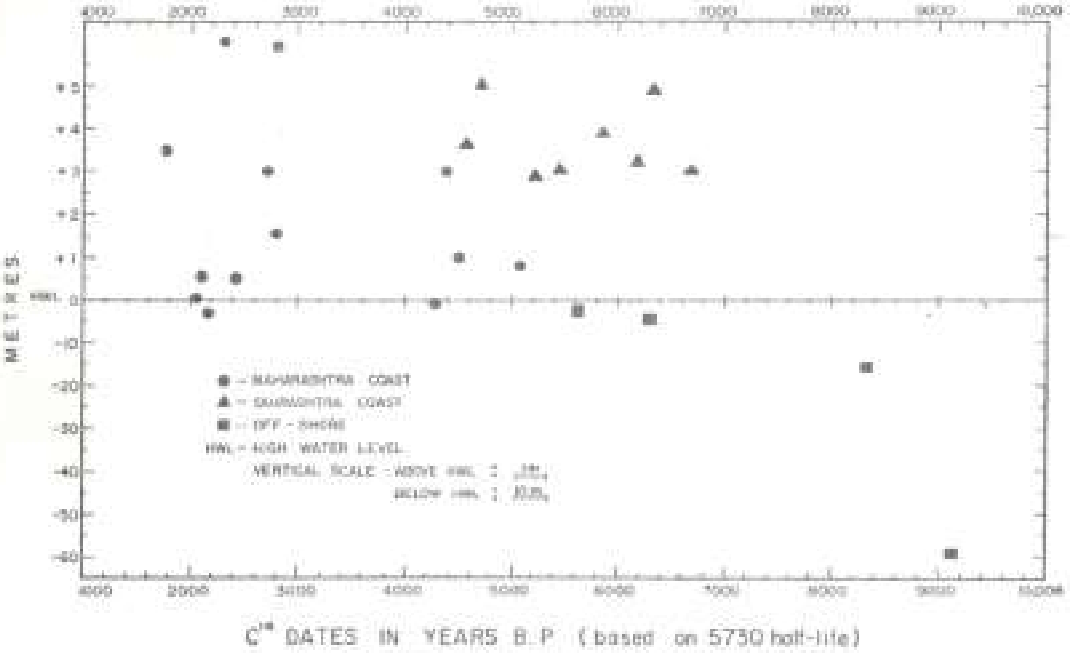
Table 2 : C^{14} dates and height/depth from the HWL (high water level) of samples collected from the Saurashtra Coast, and off the Malabar coast.

*Gupta's samples were originally collected with reference to Monsoon High Tide Level and have been re-calculated by him to HWL (high water level).

MSL for lack of coring facilities so far; therefore, without actual dates, the evidence for a regression cannot be emphasized. The sea level rises again c. 2,500±200 B. P. to about +2·5 m (HWL). Since the dates are so far based on beach rock and shells, too much precision cannot be expected.

TECTONICS VS. EUSTASY

Early geological literature (Blanford, 1867; Fox, 1922; Pascoe, 1964), explained the presence of the raised beaches on the west coast, as being the product of land movements. The raised beach at Manori



TEXT-FIG. 2 — Plot of the C^{14} dates of samples from raised beaches/corals and the continental shelf, and their respective height/depth from the present-day high water level (HWL).

(on the western side of Bombay) and the submerged forests discovered, *in situ*, during the excavations at Prince's Dock on the eastern side of Bombay, were believed to be caused by local upheaval and subsidence (Buist, 1851). Tectonic movements resulting from the presence of a strike fault may be quite a valid explanation for pre-Quaternary events, but we feel that the raised beaches and submerged forests can be better understood in terms of eustatic changes of the sea level. The occurrence of beach-rock from Daman (20°24′50″N. Lat.) to Goa (15°36′N. Lat.) and further south on the west coast without any signs of warping, is a point strongly in favour of the eustatic explanation, ruling out any major tectonic activity. Moreover, if the raised beaches and the submerged forests were the result of a tectonic tilting, both should be coeval. But the C^{14} dates of beach rock from different areas along this coast fall within the Holocene and are therefore more likely to be manifestations of world-wide phenomena (Fairbridge, 1961). The submerged forests of Bombay could not be dated for want of samples. But if the date from the Kulur (Mangalore) submerged forest further south can be used to extrapolate the age of the buried woods of Bombay, the C^{14} date (TF-966) places both beyond the dating range of radiocarbon. Another date from a buried forest in Ceylon is > 45,000 B. P. It is a known fact that during the last glaciation the sea levels were universally lowered by 100 metres below the present level. Correspondingly the vegetation belt would also shift into the then exposed area of the continental shelf. With the mid-Wisconsin and early Holocene marine transgressions all these forests were submerged. Thus the Holocene dates of the raised beaches and the late Quaternary (> 40,000 B. P.) ages of the buried forests indicate that these two events are separated in time, and hence both could not have been caused by a tilting of the land. On the other hand, glacio-eustasy convincingly explains these events as part of universal Quaternary phenomena. These inferences found further support from E. D. Gill with whom the data were discussed in detail.

DISCUSSION

For a number of years the magnitude of eustatic changes during the Holocene has been a much debated problem. Fairbridge (1961) and Schofield (1960) have collected data from Australia and New Zealand showing a rise of 1 to 4 metres above the present day sea level, between 6,000-1,000 B. P. On the other hand, Jelgersma (1961), on the basis of the Netherlands evidence, and Shepard and Curray (1967), on the basis of their work on the Gulf Coast of the United States, have stated that the sea level did not rise above the present level.

Our data, collected mainly from the Maharashtra coast, for the period from 10,000 to 6,000 B. P. agrees with the curves of Shepard, Curray, Jelgersma (we must keep in mind that the Continental Shelf samples were dredged and not cored). After 6,000 B. P., however, the curve shows a concordance with Fairbridge's oscillations. Haile has reported (Haile, 1970) +1 to +6 m higher than present sea levels, from Western Malaya and the Sunda Shelf area, datable to 5,000-5,5000 B. P. Similar high sea levels have been reported from Vietnam (+4 m) at 4,500 B. P., Madagascar (+1, +3 m) at 2,250 B. P. and from Morocco (+2 m) at 6,000 B. P. (Guilcher, 1969). The cumulative evidence certainly indicates a Holocene marine transgression of +1 to +6 m between 6,000 to 2,000 B. P. at least in the Indian ocean area. Even Curray, who was a leading critic of this view, has recently accepted it for certain areas (1969).

CLIMATIC IMPLICATIONS

In certain areas, like the Netherlands (Jelgersma, 1961) the correlation of sea level changes with pollen zones and climatic phases has been very successful. With growing data on regional pollen sequences similar correlations will be possible in India too. However, the extensive borings done in the Bombay coastal swamps have not yielded enough pollen to draw any significant inferences (Vishnu-Mittre & Guzder, in press) so far. Nevertheless, further studies on pollen, diatoms and foraminifera are in progress.

Recently Gurdip Singh's palynological work (1971) has brought important information on the climatic-ecological changes in Rajasthan. It is interesting to note a wet phase between c. 10,000-3000 B. P. in his diagram. Roughly this corresponds with the period of the steep rise of sea level also (Fig. 2). Perhaps it may give an indication that interglacial periods marked by marine transgressions — can be equated with pluvial conditions inland on the subcontinent. Further work on climatic geomorphology (Allchin & Goudie, 1971) and pollen sequences (G. Singh, 1971) will make regional and then continental climatic correlations feasible. At the moment, the interdisciplinary data are too nebulous to arrive at any viable climatic implications. But if more work is done along such cross-disciplinary lines, with an integrated approach, we should hope to have some valid reconstructions very shortly.

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ON THE OCCURRENCE OF AN IMPERFECT FUNGUS, *TETRACOCCOSPORIUM* OBTAINED FROM A FOSSIL WOOD BELONGING TO THE DECCAN INTERTRAPPEAN SERIES, (M.P.) INDIA

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ABSTRACT

A well preserved septate mycelium having 4-celled conidia with short conidiophores belonging to an imperfect fungus was found in the vessels of a fossil dicot wood. The wood is being described separately. It was collected from Mohgaonkalan, Dist. Chhindwara, M.P., India. Comparing its characters with those of living fungi, this fungus was found to belong to the genus *Tetracoccosporium* Szabo and is a new species. It has been named as *Tetracoccosporium eocenum* sp. nov.

INTRODUCTION

FOSSIL fungal remains in the form of spores, hyphae and perithecia etc. have been described from different localities of Tertiary deposits in India by several authors. Sahni (1943), Chitaley (1951, 1957), Dwivedi (1959), Lakhanpal *et al.* (1967), Mahabale (1968) have described them from the Deccan Intertrappean Series of Mohgaonkalan, Chhindwara, M. P., and Sahni and Rao (1943) from the cherts found at Sausar. Jacob & Jacob (1950), Ramanujam (1963) have described them from the South Arcot lignite (Tamil Nadu State); Rao (1950, 1958) from Palana (Bikaner) and South Arcot; Venkatachala and Kar (1969) from the bore hole no. 14, Matanomadh, Kutch; Jain & Gupta (1969) from Tertiaries of Kerala coast. The specimen on which the present account is based is from Mohgaonkalan and is well preserved. It has ramose hyphae and thick-walled brown coloured quadrate conidia on short conidiophores. Mycelium is septate and lodged in the vessels of a dicot wood resembling the wood of *Sonneratioxylon*.

SYSTEMATIC DESCRIPTION OF THE ENDOPHYTE

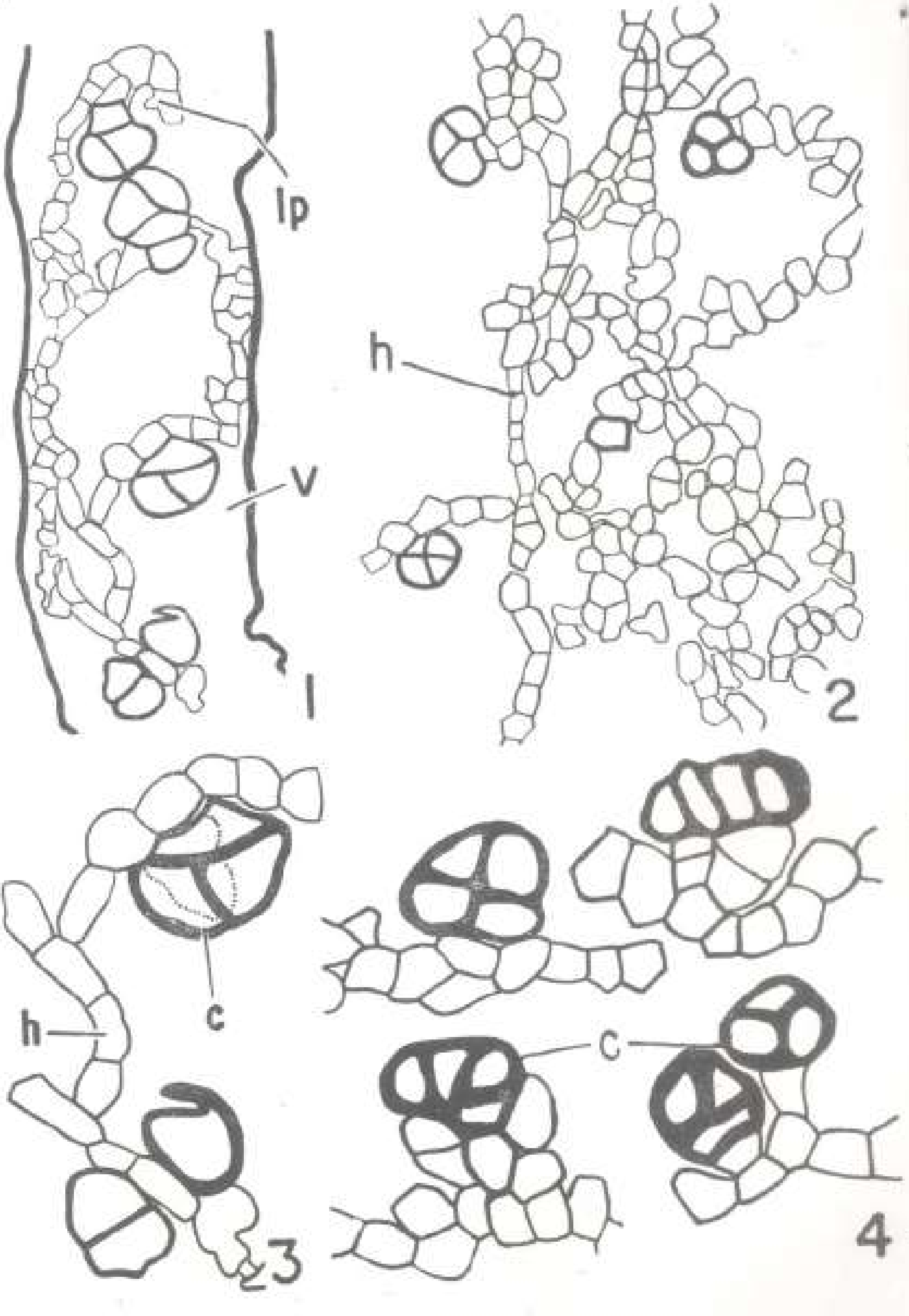
Class — DEUTEROMYCETES
Order — MONILIALES
Family — DEMATIACEAE

Genus — *Tetracoccosporium* Szabo

Tetracoccosporium eocenum sp. nov.

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

A piece of wood 5×3·5 cm belonging to dicots was collected by one of us (T.S.M.) from the well-known locality, Mohgaonkalan, M. P. This fossil wood after a thorough investigation turned out to be a species of the genus *Sonneratia* and hence has been named *Sonneratioxylon* of which it seems to be a distinct species. The wood is being described separately. While examining the tangential longitudinal sections of this wood it was observed that its vessels and adjoining tissues were heavily occluded by an endogenously grown, well preserved fungus at various places (Pl. 1. Fig. 1; Text-fig. 1). The hyphae produced conidia, characteristic of an imperfect fungus. They are sessile, or having very short conidiophores. The conidiophores measured 6×7μ across (Pl. 1, Figs. 2-4; Text-figs. 2-4). The conidia are variously arranged in groups of four cells. They are nearly spherical or Tetrahedral, horizontally linear or T-shaped. This arrangement seemed to be very typical of this fungus (Pl. 1, Figs. 2, 3, 4; Text-figs. 3 & 4). Conidia were thick-walled, smooth, dark brown to black 13×18 μ. An individual spore in the quadrate condidium measured 8·4×9 μ. Comparing these characters, branching of the hyphae, and conidia with those in the living fungi,



TEXT-FIGS. 1-4

it seemed to belong to the family Dematiaceae, Order Moniliales (Barnett, 1960; Bessey, 1964; Clements & Shear, 1954). Its features fully tally with those of the living genus *Tetracoccosporium* Szabo and it is identical with that genus. However, it differs in one or the other characters from those of the known living species and is a distinct new species. It is also very ancient being from the Tertiary deposits of India belonging to Eocene period in M. P. It has been named as *Tetracoccosporium eocenum* sp. nov.

DISCUSSION

The characters of conidia of the present fossil fungus are very much similar to those of the genera *Tetracoccosporium* and *Dictyoarthrinium*. Both of them have somewhat similar conidia, but they differ from each other in the nature and structure of hyphae and conidiophores (Barnett, 1960; Clement & Shear, 1954, and Hughes, 1952).

In *Tetracoccosporium* conidiophores are numerous. They may be very short or absent. Conidia arise as lateral swellings on branched, septate mycelium. They are 4-celled cross-shaped, dark and smooth . . . . *Tetracoccosporium*

Conidiophores are simple, sub-hyaline, crowded, straight or curved with thick dark septa; conidia dark brown, 4-celled, cross-shaped, either apical or lateral in position on conidiophore . . . . . *Dictyoarthrinium*.

In point of shape size and structure of the conidia and mycelium the fossil fungus shows close resemblance with the genus *Tetracoccosporium* rather than with *Dictyoarthrinium*. According to Hughes (1953) these two genera are different as indicated above.

The genus *Tetracoccosporium* was created by Szabo in 1905 for the fungus producing quadrate to rectangular, 4-partite conidia on hyphae. Mycelial hyphae being separate, hyaline and ramosus.

The genus *Tetracoccosporium* is represented all over the world by six living species. It is represented in India by three species occurring on dead leaves of *Saccharum officinarum*, *Asterina funtumiae* and in paddy fields on debris (Saccardo, 1906; Rao & Dev Rao, 1964; Ghosh & Dutta, 1962). The genus *Tetracoccosporium* was also previously known as *Stemphyllium* or *Epochnium* which are now considered its synonyms.

The present species does not tally with the known living species. It occurs in the Eocene beds of Mohgaonkalan which is of entirely distinct age from that of other species. Hence it is regarded as a new one. It has been named as *Tetracoccosporium eocenum* sp. nov.

Diagnosis — *Tetracoccosporium eocenum* sp. nov.

Hyphae septate, thin-walled to moderately thick-walled, hyaline, profusely branched; individual cell measuring 9·4 × 5 μ. Conidia 13 × 18 μ, thick-walled, smooth, dark brown to blackish brown, 4-celled, variously shaped, viz., cruciate or horizontally linear, T-shaped or nearly spherical. A single cell of conidia measures 8·4 × 9 μ. Conidiophores very short, 6 × 7 μ.

Locality — Mohgaon Kalan, Dist. Chhindwara, M. P., India.

Horizon — Deccan Intertrappean Series

Age — Eocene

Holotype — 1/68 Bot. Dept. University of Poona, Poona-7.

ACKNOWLEDGEMENT

We are thankful to Prof. M. N. Kamat, the well-known mycologist of India for help in identification and confirmation of the fossil fungus and to Dr. S. D. Patil.

←

TEXT-FIGS. 1-4 — A new species of an imperfect fossil fungus, *Tetracoccosporium eocenum* sp. nov. 1. Longitudinal section of a vessel — *V*, showing branched and septate hyphae: Note that at some places the single cell of an hypha shows lateral projections — *lp*. × 857. 2. Fungus magnified to conidiophores × 857. 3. A part of hyphae — *h* and conidia — *c* magnified to show the septate and branched nature of mycelium. × 1428. 4. Shows different types of conidia — *c*. × 1428.

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*Not seen in original.

EXPLANATION OF PLATE

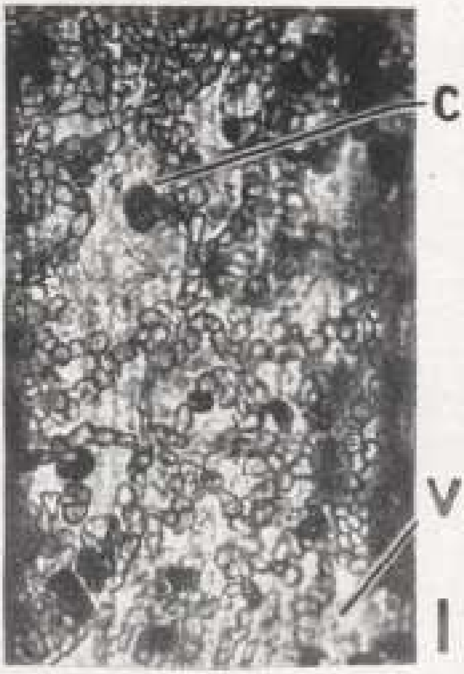
Plate 1

Figs 1-4. A new species of an Imperfect fossil fungus, *Tetracoccosporium eocenum* sp. nov.

1. Tangential longitudinal section of a vessel of a dicot wood heavily infected with fungus having branched hyphae and conidia — *c.* × 48.

2. An infected part of a wood magnified to show the branched hyphae — *h* and quadrate conidia — *c.* × 82.

3 & 4. Different types of conidia — *c.* stalked on a very short conidiophores (Fig. 3 × 140 and Fig. 4 × 160).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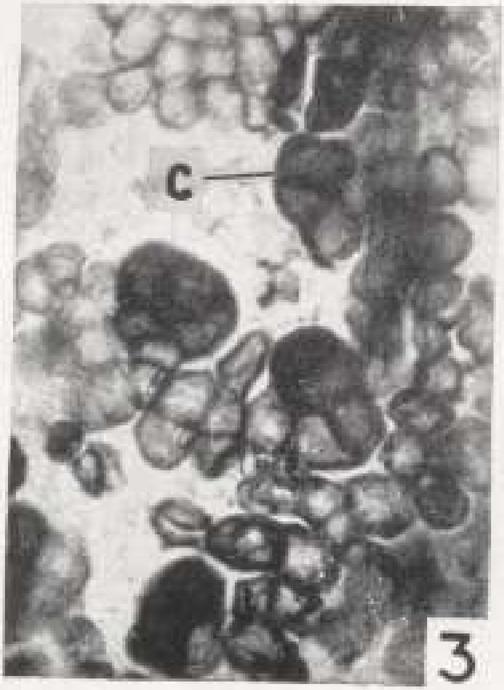
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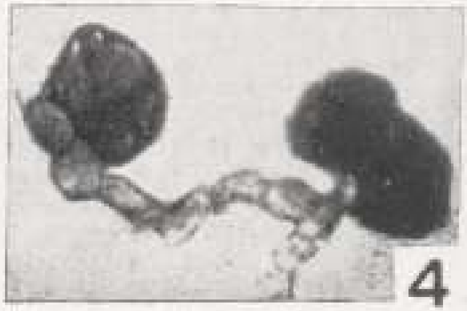
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ALGAL STROMATOLITES FROM THE KROL FORMATION OF THE MUSSOORIE SYNCLINE, UTTAR PRADESH

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ABSTRACT

The results of the study of the Algal stromatolites associated with phosphorite occurring in the top most member of the Krol Formation, the Mussoorie Phosphorite Member, which overlies the light grey dolomitic limestones, known as the Upper Krol Limestones, near Mussoorie in the Dehra Dun District of Uttar Pradesh have been recorded in the paper. The types of stromatolites that have so far been recognised from these are: (i) spheroidal or nodular (Oncolithes), (ii) conical cap shaped, (iii) cylindrical columnar branching upwards, (iv) laterally connected columns, (v) cylindrical columnar with detached columns. Excepting the first one which is rounded and without any root, the rest of the structures appear to be varieties of *Collenia*. The significance of the association of these algal stromatolites on the genesis of the phosphorite and the environment of deposition is obvious as the presence of these stromatolites indicate shallow intertidal to subtidal marine condition.

The oncolites present in this horizon appear to have affinity with the Late Palaeozoic to early Mesozoic forms. The columnar forms have to be defined and named properly for distinguishing them from the Proterozoic ones. The type (iv) form compares very well with the form *Malacostroma concentricum* (Gurich) reported from the Mississippian of Belgium (Johnson, 1961).

INTRODUCTION

ALGAL stromatolites occurring in association with the Mussoorie phosphorite near Mussoorie town, (30°27'30":78°4') have already been reported (Raha & Gururaj, 1970). The phosphorite occurs in the synformal Krol Nappé extending from Mussoorie to north of Narendranagar (30°09'30":78°17'30"), and has recently been designated as the upper most member of the Krol Formation by the author (Raha, 1971). Previously this horizon was thought to be the basal member of the overlying Tal Formation. Five different varieties of stromatolitic structures have so far been identified in 0·5 m thick dolomitic limestone interbedded within the phosphorites.

GENERAL GEOLOGY

The geological sequence of the area where the algal structures occur is as shown below. The classification given has been suggested by the author in a recent paper (Raha, 1971) on the basis of the fact that the limestone, chert, phosphorite and black shale are genetically related and occur commonly in association. The Mussoorie Phosphorite Member has been designated as the top most member of the Krol Formation in the Mussoorie area. Within these phosphorites, stromatolitic limestone (dolomite) of 0·5 m thickness has been reported (Raha & Gururaj, 1970).

DESCRIPTION OF THE STRUCTURES

Five different varieties of algal stromatolites have been recognized in this occurrence. Excepting some spheroidal stromatolites occurring near the base of the 0·5 m thick zone, the rest are mostly columnar varieties. Detailed description is given below.

I. *Spheroidal structures*

(Pl. 1, Fig. 1 & 2)

These are merely spherical to ellipsoidal, plicated and curved bodies. Diameter varies between 0·8 cm and 3·0 cm, but is occasionally as large as 5·0 cm.

A great number of the spheroids show eccentric radial arrangement because of

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Tal Formation	Gray silty shales and siltstones	
Krol Formation	Mussoorie Phosphorite Member	Black carbonaceous shales (2·0 m) Phosphorite (1·8 m) Dolomitic limestone with stromatolitic structures (0·5 m) Phosphorites (2·5 m) Black chert with shales (3·0 m)
	Light grey dolomitic limestone with some argillaceous limestones	

the shells of accretion being much thicker in one side, which is typical of algal growth (Carozzi, 1961).

The lamellae are formed of dark and light coloured crypto-crystalline calcitic material. The dark colour in the growth lamellae is most probably due to organic material present in them. The thickness of the growth lamellae varies from 75 to 375 microns with an average of 150 microns. The margins of these nodules are crenulated with protuberances. Some isotopic spongy material are occasionally found near the centre of these spheroids. Radial dark lines with light coloured segments are suggestive of growth filaments.

Similar structures have been described by Bradley (1929) from the Green River Formation of U.S.A. Bhargava (1969) has also reported such "algal pisolites" from the Krol E stage of Nigali syncline, H. P. These are "Oncolites" ranging in age from Pre-Cambrian to Recent. But in the geological columns their significant development is found in the upper Palaeozoic to early Mesozoic time and are rare in older rocks.

II. *Conical cup-shaped structures*

(Pl. 2, Fig. 7 & 8)

These are attached forms rising from base upwards and increasing in diameter in the upper parts like a cup.

The laminae occur as inverted bowls with convexity upwards. The individual structures comprising several laminae varying in thickness from 75 microns to 30 microns measure 0·3 cm to 1·4 cm in diameter and 1 cm to 5 cm in height. Their roots comprise earthy calcitic materials. Thick calcitic bands are also found at times in between the fine laminations. The microstrata are dome shaped with convexity upwards and slightly thinning at the margins. Curvature is higher near the margins. Interspaces between the stromatolites vary from 1 mm to 6 mm and some times it is even 1 cm. The increase in diameter with respect to the height is more, and ratio of the width of the base to that of the top is 1·5 on the average.

These simulate the *Collenia symmetrica* Fenton and Fenton described by Valdiya (1969) from different calcareous horizons of the lesser Himalayas, but sizes are quite small in the present case.

III. *Cylindrical columnar structures branching upwards*

(Pl. 1, Fig. 1)

Columns of inverted bowls often bifurcate upward. The individual branches are less in diameter than the orignial columns. Constriction near the base of the branches is rare. Branches are more or less of uniform dimensions.

Columns are separated from each other by clastic carbonate material such as pellets, intraclasts and lime-mud. But sometime the columns are pressed together. Width of columns remains more or less constant. The height of the columns vary from 1 cm to 12 cm and the width from 0·5 cm to 2·5 cm. Columns usually originate from Oncolites (Fig. 1).

These resemble *Collenia buriatica* Maslov described by Valdiya (1969) from the calcareous zone of Pithoragarh and the lower Shali limestone.

IV. *Laterally connected columns*

(Pl. 2, Fig. 3 & 4)

These are composed of stromatolitic microstrata continuing between columns of inverted bowls, thus giving a wavy look to the entire structure. Thickness and other characteristics are more or less similar to the columnar structures described above.

The diameter of individual columns vary between 1 cm to 4 cm with average of 3 cm. The base is polygonal to subrounded.

This form (Pl. 2, Fig. 3) is comparable with the *Malacostroma concentricum* reported from the Mississippian of Belgium (Gurich *in* Johnson 1961, p. 223).

V. *Cylindrical columns separated by narrow interspaces*

(Pl. 1, Fig. 1; Pl. 2, Fig. 5)

These are non-branching type columns of inverted bowls often originating from calcareous clay pellet or spheroidal stromatolitic structures. Columns are 0·5 to 2 cm in diameter. Normally columns of more or less uniform sizes are associated. Their heights vary from 3 cm to 12 cm. Other characteristics are more or less similar to the other columnar stromatolites. The individual microstratum does not extend much on sides. The interspace is filled with calcareous mud and pellets.

These are similar to *Collenia columnaris* Fenton and Fento described by Valdiya (1969) from the Fawn Limestone, Lower Vindhyan, and excepting that these are the calcareous zone of Pithoragarh, much smaller in size.

DISCUSSION

The occurrence of stromatolites in association with phosphorites of Mussoorie area was reported for the first time by the author (Raha & Gururaj, 1970) suggesting the mode of origin and nature of the environment of deposition of the phosphorite. Possible algal stromatolites from Krol Limestone of Mussoorie syncline was reported by Mithal and Chaturvedi (1969). The phosphorite-chert-shale association overlying the thick sequence of dolomitic limestones of the Krol Formation has been named as the Mussoorie Phosphorite Member, the top most member of the Krol Formation of Mussoorie syncline, which was earlier considered to be the basal member of the Tal Formation (Raha, 1971).

Most of the stromatolitic structures appear to be varieties of *Collenia*. The different stromatolite bearing horizons in the Himalayas have been correlated by Valdiya (1969) with the stromatolitic horizons of the Vindhyan Group (Up. Precambrian) with the help of the different varieties of *Collenia*. There are reports of Mesozoic fauna, probably of Jurassic age, from the upper part of Tal Formation which overlies the Krol Formation (Pascoe, 1959). There appears no significant break between the Krol and the Tal Formations. On the other hand, the Krol and the Infra-Krol Formations overlie the Balaini Formation which is believed to be equivalent to the Talchir Boulder Bed. Recently, the presence of Coccolithophorids of Jurassic age have been reported by Tewari (1969) from the contact between Krol B & C stages, which is much below the stromatolite bearing zone of the present area. Thus the stromatolite assemblage of the Krol characterized by smaller sizes is definitely much younger in age than those reported by Valdiya (1969). These forms appear to be more akin to Late Palaeozoic and Early Mesozoic forms, particularly the Oncolites. This also suggests the name *Collenia* is insufficient to distinguish the columnar stromatolites and use them as marker of stratigraphic horizon as adopted by Valdiya (1969). In this respect the different nomenclatures adopted by the Russian (Krylov, 1963; Raaben, 1969; Cloud & Semikhatov, 1969), are more useful. Similar classification and nomenclature for the younger forms has not been given much attention, as has been given for the Precambrian ones. However, in the younger rocks development of stromatolites are of restricted nature and the narrow zone with smaller forms in this case may be due to that. The resemblance of type IV with a Mississippian form *Malacostroma concentricum* is quite interesting.

The stromatolitic rocks were macerated for algal spores and pollen, but the results were negative. So we shall have to depend on the other available data for the age of this horizon.

ACKNOWLEDGEMENTS

The author is highly indebted to Shri M. V. A. Sastry, Director, Palaeontology Division, Geological Survey of India for his kind guidance and suggestions.

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EXPLANATION OF PLATES

PLATE 1

1. Algal stromatolites, spheroidal near base and columnar upwards. Columns originating from nodules and branching upwards.

2. Polished section of spheroidal stromatolites.

PLATE 2

3. Laterally connected columnar stromatolites. Dark bank is phosphatic.

4. Columnar stromatolite with columns separated by interspace giving rise upwards to laterally connected stromatolites.

5. Columnar stromatolites separated by narrow interspace filled up with calcareous mud.

6 & 7. Conical cup shaped stromatolites originated from calc. mud.

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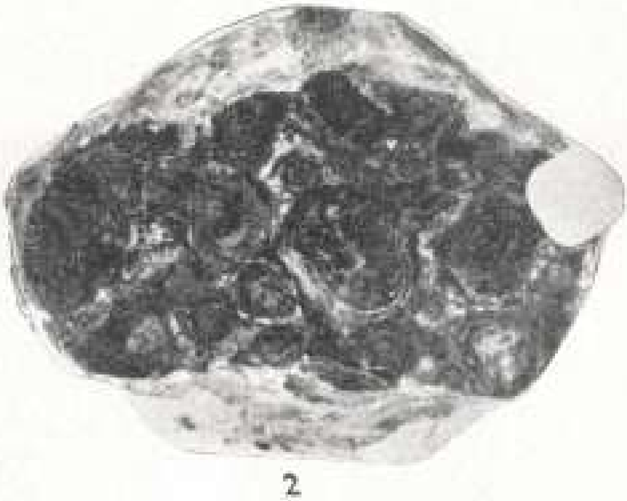

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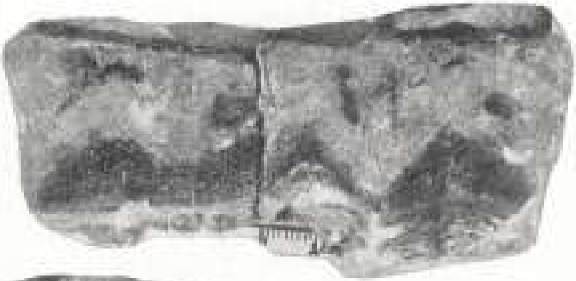

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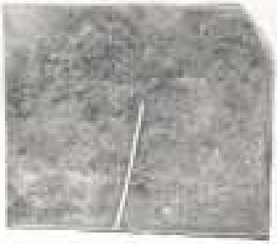

6

BIOSTATISTICAL ANALYSIS OF *ENIGMOCARPON* FRUITS

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Department of Botany, Institute of Science, Nagpur

ABSTRACT

150 specimens of *Enigmocarpon* fruit have been studied for size, thickness of wall, thickness of axis, length and breadth of seeds, to ascertain whether there is a single or more species of *Enigmocarpon* or whether there are varieties of the same species, *Enigmocarpon parijai* Sahni. The data was subjected to biostatistical analysis.

INTRODUCTION

On several visits to Mohgaonkalan, Chhindwara District, India I could collect about 125 specimens of *Enigmocarpon parijai* Sahni exposed in different planes. About 25 specimens were left at my disposal for further study by Dr (Mrs) Chitaley. These specimens were collected by her from the same locality. All these 150 petrified specimens were without any doubt of *Enigmocarpon* fruit. They showed the same characters as given by Sahni in his paper (1943).

The *Enigmocarpon* fruit is briefly described as a dry ellipsoidal capsule measuring 30 mm in length and 18 mm in breadth. Locules vary from 6-9 in number with axile placentation bearing many seeds in each locule in two rows. Seeds are dicotyledonous, each measuring 1·5-3·0 mm in length and 1-2 mm in breadth with spongy raphe. The fruit wall is differentiated into two regions, the outer made up of thick walled cells and the inner aerenchymatous. Dehiscence of the capsule is loculicidal (Pl. 1, Figs. 1-21).

From the study of these 150 new specimens some interesting facts are observed.

1. Thickness of the wall different in different fruits of the same size.
2. The thickness of the axis different in different fruits of the same size.
3. The size of the seed also different in different fruits of the same size.

For further analysis of the data I have tabled all the reported characters of the fruits.

The tables support my observations. The next step is to ascertain the speciation of the fruit whether there is a single species or more than one species of *Enigmocarpon* or whether there are varieties of the same species *E. parijai*.

To verify this position all these fruits with their prominent characters are subjected to statistical analysis as given below.

METHOD

Following method is applied for the statistical analysis. The important characters of which the measurements are taken into consideration are ... size of the fruit, thickness of the wall of fruit, thickness of the axis of the fruit, the length of the seed and the breadth of the seed.

These five types are the 5 variables ... $X_1 \ldots\ldots X_5$ as under.

X_1 — Size of fruit.
X_2 — Thickness of wall of fruit.
X_3 — Thickness of axis of fruit.
X_4 — Length of seed.
X_5 — Breadth of seed.

Sample means of the variables are denoted by $\bar{X}_1 \ldots \bar{X}_5$. They are computed as

$$\bar{X}_i = \frac{1}{n_i} \sum_{j=1}^{ni} (X_{ij})$$

where

$i = 1, 2, 3, 4$ and 5;

$j =$ the total number of fruits, viz., 31 in t.s. and 27 in l.s. of fruit.

Then the relation between the two variables say X_1 X_2 will be measured by the coefficient of correlation r, as

$$r = \frac{\mathrm{Cov}\ (X_1 X_2)}{\sqrt{V(X_1) V(X_2)}}$$

Since in the present case there are more than two variables the relationships between the variables are to be tested by computing the partial Correlation Coefficient which would give the relationship in between any two variables. Since we are considering Partial Correlation the effect of other variables has been accounted for.

The Correlation Coefficient between the variables X_1 and X_2 when the effect of the

TABLE 1 — OUT OF 150 SPECIMENS ONLY 31 IN T.S. AND 27 IN L.S. ARE TAKEN FOR CONSIDERATION IN THIS TABLE SINCE THEY SHOWED ALL THE NECESSARY CHARACTERS (PHOTOGRAPHS OF ONLY 21 SPECIMENS TAKEN)

MEASUREMENTS IN T.S. OF FRUIT

Sr. No.	Fruit No.	Size in mm X_1		Thickness of Wall in mm X_2	Thickness of Axis in mm X_3	Seed		Number of Locules
						Length in mm X_4	Breadth in mm X_5	
1	4	13 × 12	156	2·5	2·5	2·0	1·5	8
2	5	12 × 12	144	2·0	2·5	2·5	1·5	6
3	11	16 × 8	128	2·0	2·5	2·5	2·0	—
4	14	9 × 8	72	2·0	2·0	2·5	1·5	—
5	17	12 × 8	96	2·0	2·0	2·0	1·5	—
6	21	15 × 14	210	2·0	2·5	2·0	1·5	7
7	24	12 × 9	108	1·5	2·0	2·5	1·5	—
8	29	14 × 13	182	2·5	3·0	2·0	1·5	—
9	35	17 × 12	204	2·5	3·0	2·5	2·0	8
10	37	18 × 18	324	2·5	2·5	2·0	1·5	8
11	43	15 × 11	165	3·0	3·0	2·5	2·5	—
12	44	15 × 10	150	2·0	3·0	2·5	1·5	—
13	52	15 × 12	180	2·0	2·5	2·5	1·5	7
14	53	12 × 9	108	2·0	2·0	2·0	1·5	—
15	71	16 × 10	160	2·0	3·0	2·0	1·5	—
16	75	12 × 8	96	2·0	2·0	2·5	1·5	7
17	79	13 × 7	91	1·5	2·5	3·0	1·5	7
18	83	16 × 10	160	2·0	2·0	2·5	1·5	—
19	86	15 × 15	226	3·0	3·0	2·9	1·5	—
20	93	13 × 16	208	2·5	2·5	2·5	1·5	—
21	96	16 × 16	256	3·0	3·0	2·0	1·5	9
22	97	17 × 17	289	2·5	3·0	2·5	1·5	8
23	101	12 × 12	144	2·5	2·5	2·0	1·5	8
24	102	10 × 10	100	2·5	2·5	2·0	1·5	8
25	104	13 × 13	169	2·0	2·5	2·5	1·5	7
26	115	10 × 5	50	1·5	1·5	2·0	1·5	—
27	119	15 × 12	180	2·5	2·0	2·5	2·0	—
28	121	9 × 9	81	2·0	2·0	2·0	1·5	—
29	127	9 × 8	72	1·5	2·5	2·0	1·5	—
30	133	14 × 7	98	2·0	2·0	2·5	1·5	—
31	140	10 × 10	100	2·0	2·0	2·0	1·5	—
Total			4706	67·5	75·5	70·5	48·0	

other remaining variables X_3, X_4, and X_5 being removed, is computed as below.

$$r_{12\cdot 345} = \frac{r_{12\cdot 34} - r_{15\cdot 34} - r_{25\cdot 34}}{\sqrt{(1-r^2_{15\cdot 34})(1-r^2_{25\cdot 34})}}$$

After computing all the values of Partial Correlation Coefficient it is felt necessary to test the significance of this correlation coefficient by applying the 't' test. The value of 't' is computed as below

$$\frac{r^2_{1\cdot 2345}}{1-r^2_{1\cdot 345}}\, n-k = t^2(n-k)$$

Where $n = 31$ or 27 and $k = 5$ (number of variables).

The values of r and r^2 are computed from the data. Then these values are compared with the table values (Crammer, 1958) at 5% level of significance. If the computed value of r is more than the standard value the Correlation Coefficient is significant, if not, it is insignificant.

Calculations worked out from Table 1 raising the value to r^2 (*see* p. 234).

For the above collected data, the sample mean of the variables are

$\bar{X}_1 = 151{\cdot}8$ $\bar{X}_2 = 2{\cdot}17$ $\bar{X}_3 = 2{\cdot}43$

$\bar{X}_4 = 2{\cdot}22$ and $\bar{X}_5 = 1{\cdot}55$

Then the variance of X_1 viz. $V(X_1)$ is as—

$V(X_1) = 4128{\cdot}17$, $V(X_2) = 0{\cdot}2023$,

$V(X_3) = 0{\cdot}1999$, $V(X_4) = 0{\cdot}0971$ and

$V(X_5) = 0{\cdot}0169$

Then the Correlation Coefficients (r) are—

$r_{12} = 0{\cdot}646$, $r_{13} = 0{\cdot}276$, $r_{14} = 0{\cdot}041$,

TABLE 2

MEASUREMENTS IN L.S. OF FRUIT

SR. No.	FRUIT No.	SIZE IN mm X_1		THICKNESS OF WALL in mm X_2	THICKNESS OF AXIS in mm X_3	SEED		NUMBER OF LOCULES
						LENGTH in mm X_4	BREADTH in mm X_5	
1	9	10×10	100	2·0	3·0	2·0	1·0	—
2	16	12×8	96	2·0	2·0	2·0	1·5	—
3	18	17×15	255	2·0	2·0	2·0	1·5	—
4	19	19×17	323	3·5	3·5	2·5	1·5	—
5	23	15×10	150	1·5	3·0	2·5	1·5	—
6	28	12×10	120	2·0	3·0	1·5	1·5	—
7	34	12×8	96	2·0	2·0	2·0	1·5	—
8	47	12×11	132	2·0	2·0	2·0	1·5	—
9	58	12×11	132	2·0	2·0	2·0	1·5	—
10	63	10×8	80	2·0	2·0	2·0	1·5	—
11	65	7×6	42	2·0	2·0	2·5	1·5	—
12	68	15×9	135	1·5	2·0	2·5	1·5	—
13	70	15×8	120	1·5	2·0	2·5	1·5	—
14	73	12×8	96	1·5	2·5	3·0	1·5	—
15	76	13×9	117	2·0	2·0	2·5	1·5	—
16	81	13×9	117	2·0	2·0	2·5	1·5	—
17	84	12×12	144	3·0	2·0	2·5	1·5	—
18	87	17×11	187	2·0	2·0	2·5	1·0	—
19	90	12×10	120	2·0	2·0	2·0	1·5	—
20	98	15×12	180	2·5	3·0	2·5	1·5	—
21	100	18×16	288	3·0	2·5	2·5	1·5	—
22	111	10×8	80	2·0	2·5	2·0	1·5	—
23	118	15×10	150	2·5	2·5	2·5	1·5	—
24	124	15×11	165	2·5	3·0	2·5	1·5	—
25	131	14×10	140	2·0	3·0	2·5	1·5	—
26	136	12×8	96	1·5	2·0	2·0	1·5	—
27	139	20×15	300	2·5	3·0	2·5	1·5	—
Total			3961	57·0	64·5	60·0	39·5	—

$r_{15} = 0{\cdot}081$, $r_{23} = 0{\cdot}065$, $r_{24} = 0{\cdot}010$, $r_{25} = 0{\cdot}021$, $r_{34} = 0{\cdot}173$, $r_{35} = 128$ and $r_{45} = 0{\cdot}128$

After computerising the Partial Correlation Coefficient of the third order the '*t*' test of significance has been applied.

$r^2_{12\cdot345} = 0{\cdot}5098^*$ $r^2_{13\cdot245} = 0{\cdot}2683^*$
$r^2_{14\cdot235} = 0{\cdot}0055$ $r^2_{15\cdot234} = 0{\cdot}484$
$r^2_{23\cdot145} = 0{\cdot}4369^*$ $r^2_{24\cdot135} = 0{\cdot}0231$
$r^2_{25\cdot134} = 0{\cdot}2642^*$ $r^2_{34\cdot125} = 0{\cdot}0376$
$r^2_{35\cdot124} = 0{\cdot}0096$ $r^2_{45\cdot123} = 0{\cdot}00997$
(*significant values)

INFERENCE

From the above statistical calculations the following inferences are drawn:

There is a definite linear relation

1. Between size of fruit and thickness of wall.
2. Between size of fruit and thickness of axis.
3. Between thickness of wall and thickness of axis.
4. Between thickness of wall and thickness of seed.

Calculations worked out from Table 2 (*see* p. 235).

Above data have been 'processed, as table 1, to get the Partial Correlation Coefficient of the third order which later on subjected to '*t*' test to find out significant coefficient (*).

$r^2_{12\cdot345} = 0{\cdot}3576^*$, $r^2_{13\cdot245} = 0{\cdot}1197$,
$r^2_{14\cdot235} = 0{\cdot}2530^*$,
$r^2_{15\cdot234} = 0{\cdot}1170$, $r^2_{23\cdot145} = 0{\cdot}4470$,
$r^2_{24\cdot135} = 0{\cdot}3339^*$,
$r^2_{25\cdot134} = 0{\cdot}3016^*$, $r^2_{34\cdot125} = 0{\cdot}1376$,
$r^2_{35\cdot124} = 0{\cdot}0231$ & $r^2_{45\cdot123} = 0{\cdot}1798^*$

CALCULATIONS WORKED OUT FROM TABLE I RAISING THE VALUE TO x^2

SR. NO.	FRUIT NO.	SIZE OF WALL IN mm X_1^2	THICKNESS OF WALL IN mm X_2^2	THICKNESS OF AXIS IN mm X_3^2	SEED		NO. OF LOCULES
					LENGTH IN mm X_4^2	BREADTH IN mm X_5^2	
1	4	24336	6·25	6·25	4·00	2·25	—
2	5	20736	4·00	6·25	6·25	2·25	—
3	11	16384	4·00	6·25	6·25	4·00	—
4	14	5184	4·00	4·00	6·25	2·25	—
5	17	9216	4·00	4·00	4·00	2·25	—
6	21	44100	4·00	6·25	4·00	2·25	—
7	24	11664	2·25	4·00	6·25	2·25	—
8	29	33124	6·25	9·00	4·00	2·25	—
9	35	41616	6·25	9·00	6·25	4·00	—
10	37	104976	6·25	6·25	4·00	2·25	—
11	43	27225	9·00	9·00	4·00	2·25	—
12	44	22500	4·00	9·00	6·25	2·25	—
13	52	32400	4·00	6·25	6·25	2·25	—
14	53	11664	4·00	4·00	4·00	2·25	—
15	71	25600	4·00	9·00	4·00	2·25	—
16	75	9216	4·00	4·00	6·25	2·25	—
17	79	8281	2·25	6·25	9·00	2·25	—
18	83	25600	4·00	4·00	6·25	2·25	—
19	86	50625	9·00	9·00	6·25	2·25	—
20	93	43264	6·25	6·25	6·25	2·25	—
21	96	65536	9·00	9·00	4·00	2·25	—
22	97	83521	6·25	6·25	4·00	2·25	—
23	101	20736	6·25	6·25	4·00	2·25	—
24	102	10000	6·25	6·25	6·25	2·25	—
25	104	28561	4·00	6·25	6·25	2·25	—
26	115	2500	2·25	2·25	4·00	2·25	—
27	119	32400	6·25	4·00	6·25	4·00	—
28	121	6561	4·00	4·00	4·00	2·25	—
29	127	5184	2·25	6·25	4·00	2·25	—
30	133	9604	4·00	4·00	6·25	2·25	—
31	140	10000	4·00	4·00	4·00	2·25	—
Total		842314	152·25	189·25	162·75	75·00	—

INFERENCE

From the above statistical tests the following inferences are drawn:

There exists linear relations between size of fruit and thickness of wall, size of fruit and length of seed, thickness of wall and thickness of axis, thickness of wall and length of seed, thickness of wall and breadth of seed, length of seed and breadth of seed.

All the above tests confirm the correlation between the size of the fruit and that of wall, seed and axis.

In order to test the variety difference the intended sample was divided into two groups. The first group having the fruit wall up to 2 mm thick and the second group more than 2 mm in thickness. The same is done in case of axis thickness of the fruit.

It was then felt to find out whether these two groups have the real variety difference. For this following test is applied.

The mean size of the first group being denoted by $\bar{X}_1$ and $\bar{X}_2$.

$$s = \frac{\Sigma_i(X_{1i}-\bar{X}_1)^2+\Sigma_i(X_{2i}-\bar{X}_2)^2}{n_1+n_2-2}$$

Where n_1 is 16 and n_2 is 37.

Then

$$y = \sqrt{\frac{n_1 n_2}{n_1+n_2}}(\bar{X}_1-\bar{X}_2)$$

$$t = \frac{y}{s}$$

The values of the Statistic 't' is computed from the data and is compared with the standard table values (Crammer, 1958) at 5% level of significance.

CALCULATIONS WORKED OUT FROM TABLE 2

Sr. No.	Fruit No.	Size in mm X_1^2	Thickness of wall in mm X_1^2	Thickness of axis in mm X_1^2	Seed		No. of Locules
					Length in mm X_1^2	Breadth in mm X_1^2	
1	9	10000	4·00	9·00	4·00	1·00	—
2	16	9216	4·00	4·00	4·00	2·25	—
3	18	65025	4·00	4·00	4·00	2·25	—
4	19	104329	12·25	12·25	6·25	6·25	—
5	23	22500	2·25	9·00	6·25	2·25	—
6	28	14400	4·00	9·00	2·25	2·25	—
7	34	9216	4·00	4·00	4·00	2·25	—
8	47	17424	4·00	4·00	4·00	2·25	—
9	58	17424	4·00	4·00	4·00	2·25	—
10	63	6400	4·00	4·00	4·00	2·25	—
11	65	1764	4·00	4·00	6·25	2·25	—
12	68	18235	2·25	4·00	6·25	2·25	—
13	70	14400	2·25	4·00	6·25	2·25	—
14	73	9216	2·25	6·25	9·00	2·25	—
15	76	13689	4·00	4·00	6·25	2·25	—
16	81	13689	4·00	4·00	6·25	2·25	—
17	84	20736	9·00	4·00	6·25	2·25	—
18	87	34969	4·00	4·00	6·25	1·00	—
19	90	14400	4·00	4·00	4·00	2·25	—
20	98	32400	6·25	9·00	6·25	2·25	—
21	100	82944	9·00	6·25	6·25	2·25	—
22	111	6400	4·00	6·25	4·00	2·25	—
23	118	22500	6·25	6·25	6·25	2·25	—
24	124	27225	6·25	9·00	6·25	2·25	—
25	131	19600	4·00	9·00	6·25	2·25	—
26	136	9216	2·25	4·00	4·00	2·25	—
27	139	90000	6·25	9·00	6·25	2·25	—
Total		707307	126·50	160·25	145·00	58·25	—

WALL THICKNESS OF FRUIT

Fruit wall up to 2 mm thick

Sr. No.	Fruit No.	Size of fruit in mm I		1-126 difference X^2	X_1^2
1	23	15×10	150	24	576
2	28	12×10	120	−6	36
3	73	12×8	96	30	900
4	18	17×15	255	129	16641
5	87	17×12	204	78	6080
6	13	16×15	240	114	12996
7	91	14×10	140	14	196
8	76	13×9	117	−9	81
9	81	13×9	117	−9	81
10	47	12×11	132	6	36
11	90	12×10	120	−6	36
12	110	12×10	120	−6	36
13	16	12×8	96	−30	900
14	9	10×10	100	−26	675
15	94	10×8	80	−46	2116
16	111	10×8	80	−46	2116
17	12	9×6	54	−72	5184
18	79	13×7	91	−35	1225
19	1	10×10	100	−26	676
20	115	10×5	50	−76	5776
21	32	9×8	72	−54	2916
22	37	18×16	288	162	26244
23	83	16×12	192	066	4356
24	71	16×10	160	34	1156
25	11	16×8	128	2	4
26	21	15×14	210	84	7056
27	120	15×12	180	54	2916
28	30	15×10	150	24	576
29	5	12×12	144	18	324
30	4	12×10	120	−6	36
31	52	12×9	108	−18	324
32	75	12×8	96	−30	900
33	17	12×8	96	−30	900
34	89	11×11	121	−5	25
35	121	9×9	81	−25	625
36	15	7×6	42	42	7056
37	91	7×6	42	−84	7056
	Total	4662			111998·00
		Mean 126·00			

Fruit wall more than 2 mm thick

Sr. No.	Fruit No.	Size of fruit in mm		−199·44 difference X_1	X_1^2
1	29	17×12	204	4·56	
2	98	15×12	180	−9·44	
3	124	15×11	165	−34·44	
4	19	19×17	323	123·56	
5	100	18×16	288	88·56	
6	86	15×12	180	−9·44	
7	84	12×12	144	−55·44	
8	35	17×12	204	4·56	
9	78	17×12	204	4·56	
10	96	16×16	256	56·56	
11	44	16×11	176	−23·44	
12	110	15×12	180	−9·44	
13	66	14×11	154	−45·44	
14	101	12×12	144	−55·44	
15	102	10×10	100	−99·44	
16	97	17×17	289	89·56	
Total		3191		54495·53	
		Mean 199·44			

Since in this case the observed value of '*t*' is greater than the table value of '*t*', the supposition that there is no difference in the two types of varieties is rejected.

AXIS THICKNESS OF FRUIT

Up to 2 mm thick

Sr. No.	Fruit No.	Size of fruit in mm		X_2	X_2^2
1	91	7×6	42	−82	6724
2	18	17×15	255	131	17161
3	13	16×15	240	116	13456
4	76	13×9	108	−16	256
5	81	13×9	108	−16	256
7	90	12×10	120	−4	16
8	110	12×10	120	−4	16
9	34	12×8	96	−28	784
10	16	12×8	96	−28	784
11	29	17×12	204	80	6400
12	86	15×12	180	56	3136
13	84	12×12	144	20	400
14	115	10×5	50	−74	5476
15	91	7×6	42	−82	6724
16	32	9×8	72	−52	2704
17	37	18×16	288	164	26896
18	83	16×12	192	68	4624
19	30	15×10	150	26	676
20	53	12×9	108	−16	256
21	75	12×8	96	−28	764
22	17	12×8	96	−28	764
23	89	11×11	121	−3	9
24	121	9×9	81	−43	1849
25	14	9×8	72	−32	2704
26	15	7×6	42	−82	6724
Total			3225		118030
		Mean 124·00			

More than 2 mm thick

Sr. No.	Fruit No.	Size of fruit in mm		X_1	X_1^2
1	37	12×8	96	−67	4489
2	111	10×8	80	−83	6889
3	118	15×10	150	−13	169
4	100	18×16	288	125	15625
5	23	15×10	150	−13	169
6	28	12×10	120	−43	1849
7	87	12×12	144	−19	361
8	9	10×10	100	−63	3969
9	19	19×17	323	240	57600
10	98	15×12	180	17	289
11	124	15×11	165	2	4
12	79	13×7	91	−72	5184
13	21	16×15	240	77	5929
14	11	16×8	128	−35	1225
15	4	12×10	120	−43	1849
16	119	15×7	105	−58	3364
17	71	16×10	160	−3	9
18	5	12×12	144	−19	361
19	35	17×12	204	41	1681
20	44	16×11	176	13	169
21	107	12×12	144	−19	361
22	97	17×17	289	126	15876
Total			3587		127421·00
		Mean 163·04			

AXIS THICKNESS OF FRUIT

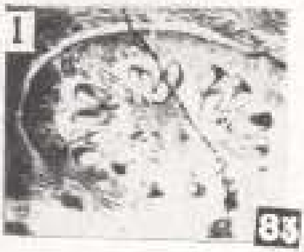
Here, the value of '*t*' is found smaller than the tabulated value 1·83, and hence the supposition that there is no significant difference in the two types of varieties cannot be rejected.

CONCLUSIONS

There exists correlation between the size of fruit and thickness of wall, thickness of wall and thickness of axis, and thickness of axis and length and breadth of seeds.

These correlations are positive and hence we expect, with the increase in size of fruit proportionate increase in the thickness of wall, thickness of seed and thickness of axis of the fruit. However, there are fruits in which thickness of wall of the fruit is more and the size of the fruit is small and the thickness of wall is less and the size of the fruit is large. The same is found true in the case of the axis of the fruit and fruit size.

Thus on the basis of the above facts these fruit samples were grouped into two: (1) thickness of fruit wall up to 2·0 mm and (2) thickness of fruit wall more than 2·0 mm. The same is done in the case of the axis.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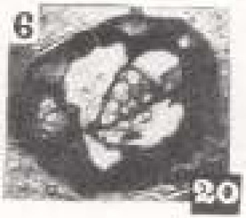
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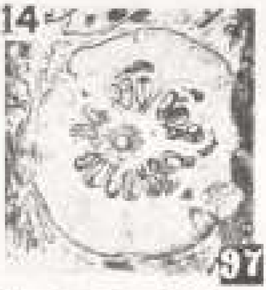
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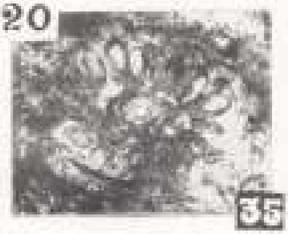
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From the statistical applications it has been observed that this grouping of fruits into two, stands true in the case of the fruit wall thickness and not of the axis thickness.

Hence, all these fruits are grouped into two varieties, A and B, on the basis of the wall thickness of the fruit.

Variety A will have the fruit wall less than 2 mm for 12×10 mm size of the fruit. *Variety* A will have the fruit wall more than 2 mm for the same size, 12×10 mm of the fruit. These varieties are named as follows:

Variety A, *Enigmocarpon parijai mohgaoense*

Variety B, *Enigmocarpon parijai intertrappea*

ACKNOWLEDGEMENTS

The author is highly greatful to Dr (Mrs) S. D. Chitaley, Head of the Department of Botany, Institute of Science, Nagpur, for her encouragement during the progress of this work. My thanks are also due to Mr S. V. Supekar, Statistical Officer, Directorate of Geology and Mining, Govt. of Maharashtra, Nagpur; Mr. J. N. Ganorkar, Research Assistant, Bureau of Economics and Statistics, Govt. of Maharashtra, Nagpur and Mr V. G. Bhamburkar, Lecturer, Department of Statistics, Institute of Science, Nagpur for their help in statistical analysis of the *Enigmocarpon* fruits.

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EXPLANATION OF PLATES

ENIGMOCARPON PARIJAI

1-21. Photos of 21 specimens × 2. Numbers in black ink plate figure numbers and number in white ink fruit specimen numbers.

1-13. Fruit wall thickness 1·5-2 mm.

14-21. Fruit wall thickness above 2 mm.

STUDIES IN THE TALCHIR FLORA OF INDIA—9. MEGASPORES FROM THE TALCHIR FORMATION IN THE JOHILLA COALFIELD, (M.P.), INDIA

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ABSTRACT

Megaspores belonging to the genera *Duosporites*, *Trilaevipillitis*, *Srivastavaesporites* and *Triletes* are for the first time described from the Talchir Formation of India. The fossils have been found associated with seed cuticles and miospores in typical Talchir siltstones exposed near Birsinghpur-Pali in the Johilla Coalfield, Madhya Pradesh. The assemblage is dominated by the genus *Duosporites*. The megaspores indirectly suggest the existence of Lycopsid plants at least towards the later part of the Talchir times.

External characters as well as the details of the inner sac have been carefully studied. It is suggested that the extent of the trilete trace and the bordering cushions in relation to the inner sac radius constitutes a character of taxonomic significance in delimiting megaspore species.

INTRODUCTION

STUDIES on the Lower Gondwana megaspores of India have begun comparatively recently. A significant start was made by Surange *et al.* (1953) followed by Srivastava (1954). However, these studies were mainly based upon external morphology of the transparent specimens. The importance of structures of different spore walls in the taxonomy of megaspores was particularly realized when Høeg *et al.* (1955) described the double wall structure of *Duosporites* from the Lower Gondwana of Congo. A notable advance in this direction was made in India by Pant and Srivastava (1961, 1962) on Indian and Tanganyikan material. They created four new genera. Studies on similar lines have been recently carried out in other countries by Balme and Hassel (1952), Dettmann (1961), Trindade and Sommer (1966) and Spinner (1968, 1969). More recently Kar (1968) added some new genera of megaspores from India. The latest work on the morphology, systematics and distribution of Indian megaspores by Bharadwaj and Tiwari (1970) provides a very comprehensive treatment of the known taxa together with the erection of six new genera on the basis of external morphological details as well as the internal structure of the megaspore walls. Evidently a number of previously described species and even genera have found new places in the scheme of Bharadwaj and Tiwari (1970).

Our knowledge of the megaspores from the Lower Gondwana of India was so far confined to the Karharbari, Barakar and Raniganj Formations (Bharadwaj & Tiwari, 1970). Goswami (1950-51, 1956) and Saksena (1971) recorded some megaspores from the Karharbari or Barakar beds of South Rewa Gondwana Basin. However, from the Talchir Formation (Basal-Lower Gondwana unit), megaspores were not known until Lele and Chandra (1967) briefly reported them from Barachada locality, Birsinghpur-Pali of South Rewa Basin, M.P. In that communication three types were recorded including one strongly recalling Duosporites. The megaspores were found in association with a number of seed cuticles and a rich mioflora. Stem impression of equisetalean type were sometimes encountered.

In the present study megaspores from the above locality have been investigated in detail both in dry as well as in wet conditions following a procedure of controlled, progressive overmaceration. The details of the external spore-coat and the inner body have been critically examined. The scheme suggested by Bharadwaj and Tiwari (1970) has been followed for the systematic description of megaspores. The assemblage has revealed the genera: *Trilaevipillitis* (1 new species), *Duosporites* (2 species), *Srivastavaesporites* (1 species) and *Triletes*. As these findings are entirely new, it is considered appropriate to describe all the forms in detail.

PROBLEMS OF MEGASPORE SYSTEMATICS

From an appraisal of the recent trends in megaspore studies, the impression gained is that while some workers (especially those working on the Gondwanas) lay emphasis on the external and internal studies under dry and wet conditions of the megaspores, there are several others who still adhere to the orthodox method of studying the megaspores only in dry state. In between, are also workers who have preferred to study megaspores in transparent conditions but have not necessarily gone into the details of the controlled maceration procedures or other techniques for isolating the inner body for detailed study. Nor is there any general agreement between different workers as to the value of the internal characters in the taxonomy of megaspores. This has led to very controversial determinations of one and the same species under widely different genera.

As an illustration of this state of affairs *Trileites* (al *Triletes*) *tenuis* may be cited as an example. This species was originally described in dry state by Dijkstra (1955) from Brazil but was transferred to *Banksisporites* by Dettmann (1961) and to *Duosporites* by Pierart (1959) and Spinner (1969). The same species has been retained under *Triletes* by Pant and Srivastava (1962) but transferred to the new genus *Srivastavaesporites* by Bharadwaj and Tiwari (1970). It is interesting to note that the above genera which have claimed *Trileites tenuis* are widely different from each other. *Banksisporites* and *Srivastavaesporites* have noncushioned inner bodies while *Duosporites* has cushioned inner body. Similarly while *Banksisporites* is externally laevigate, *Duosporites* and *Srivastavaesporites* are apiculate. Spinner (1969) also refers to this taxonomic problem.

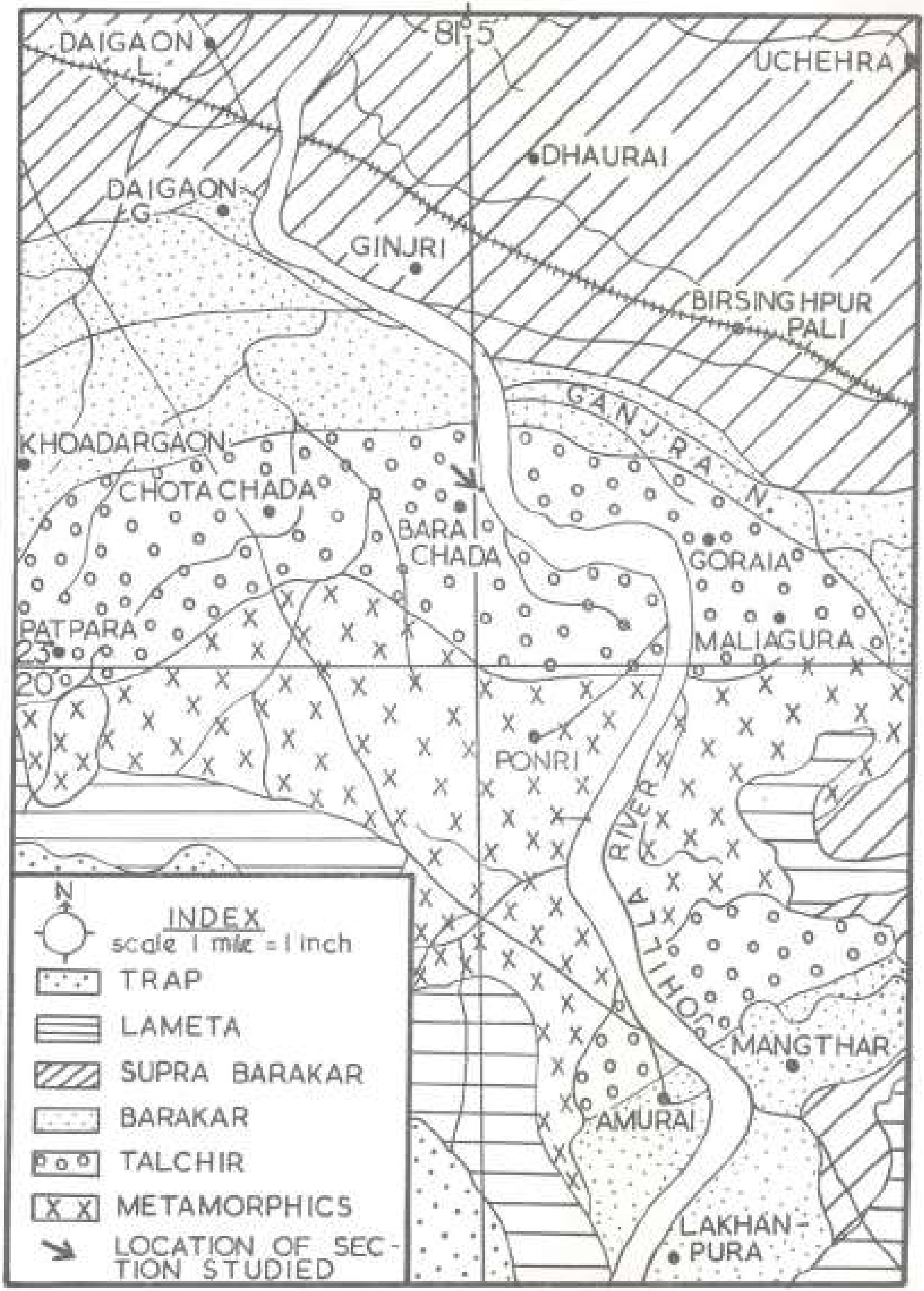
A similar interesting controversy exists around the circumscription of *Duosporites* Høeg, *et al.* (1955) which occurs in the present material. Since the genus was erected, there have been three emendations of it; first by Pierart (1959), second by Spinner (1969) and third by Bharadwaj and Tiwari (1970). All these emendations only express the underlying divergence of opinion on taxonomic procedures. Naturally during the present treatment, it was not very easy to make assignments for the megaspore specimens. However, we have found the procedure of Bharadwaj and Tiwari (1970) more suitable for systematic descriptions. We earnestly feel that the time has come for all interested workers on megaspores to resolve and standardize the methods of study and systematic procedure of describing the megaspores. Without that, the purpose of megaspore studies can have no real application.

MATERIAL AND METHODS

The megaspore material is recovered from the following section (Bed no. 5 and 6) of the Talchir Formation exposed near the village Barachada (Text Fig. 1), approximately two and a half miles south east of Birsinghpur Pali (M.P.) along Johilla River. In several beds of the section, fragmentary impressions of equisetalean stems were encountered.

	Thickness	Field nos.
7. Yellow silty sandstone (poor in miospores)	6 ft	B42
6. Yellowish laminated sandstone (poor in miospores and rich in megaspores)	10 ft	BC11-F
5. Greenish silty sandstone (containing plant fossils, rich in miospores and megaspores)	4 ft	BC10-F
4. Yellowish laminated sandstone	1 ft	BC9-F
3. Yellowish silty sandstones (containing plant fossils, rich in miospores)	4 ft	BC8F
2. Laminated sandstone (Poor in miospores)	3 ft	BC7F
1. Laminated yellowish greenish sandstone	30 ft	BC6
Total thickness	58 ft	

The beds dip average 10° gently towards north



TEXT-FIG. 1 — Geological Map of Birsinghpur- Pali (M.P.) India. After Hughes (1884).

The silty shales were macerated by treating them with hydrochloric acid for a short period followed by hydrofluoric acid treatment for about two weeks. The residue was washed and passed through 100 mesh sieve to separate the larger megaspores, seeds and cuticles from the fine miospore material. Residues left over the 100 mesh sieve were examined for picking up the megaspores. These megaspores were dried under room temperature and types were selected under the binocular and placed in separate cavity slides. Photographs of the megaspores in dry state were taken under the Panphot using brilliant reflected light of the arc lamp. FP_4, FP_3 plates and cut films were used for photography. The plates gave better results. Alternatively strong normal light was also used to directly illuminate the megaspores from one side. Illumination was properly balanced by manipulating a small mirror at a suitable distance on the other side of the megaspore opposite the source of illumination. In this way shadow effects could be toned down and desired relief could be obtained. In some cases the megaspores were placed on a tiny soft base which could be adjusted to obtain the maximum plane of uniform focus. A number of photographs were obtained in this way for the external morphological details and notes with regard to these features were simultaneously completed.

In the next phase the individual megaspore specimens were placed in watch glass and carefully subjected to remaceration in commercial nitric acid. In the case of opaque megaspores potassium chlorate was used with advantage to accelerate oxidation. Observations were made from time to time to check up the progress of oxidation. When the desired oxidation was achieved the megaspore was washed carefully in the watch glass by adding water successively. These specimens were then progressively cleared in 5% KOH. In between, the specimens could be carefully washed free of alkali for taking photographs. The alkali process was controlled and manipulated in such a way that the progressive dissolution of the outer coat could be verified before the inner body emerged out clearly. Generally the inner-body appeared to be attached to the exoexine along a small area proximally. Drastic alkali treatment sometimes, automatically released the inner body but at other times it was separated by fine needles. The inner-body though generally thin and more or less hyaline showed a very resistant membrane. It could be mounted in glycerine jelly or in more permanent media like canada balsam using a polyvinyl alcohol base. During course of the wet treatment, all photographs were taken in Olympus microscope using 35 mm 10 Din microfilm. The material and preparations are preserved in the Museum, Birbal Sahni Institute of Palaeobotany, Lucknow (Locality no. 854C, Registered slide nos. 4452-4456).

SYSTEMATIC DESCRIPTION

Anteturma — *Sporites* Potonié, H., 1893
Turma — *Triletes* (Reinsch) Potonié & Kremp, 1954
Subturma — *Azonotriletes* Luber, 1935
Infraturma — *Laevigati* (Bennie & Kidston) Potonié, 1956

Genus — *Trilaevipillitis* (Kar) Bharadwaj & Tiwari, 1970

Type species — *Trilaevipillitis psilatus* Kar, 1968.

Trilaevipillitis talchirensis sp. nov.

Pl. 1, Figs. 1-6

DIMENSIONS

Dry specimens untreated with alkali

Spore size	380 × 600 μ
Triradiate rays	200-240 μ 30-40 μ wide

Specimens treated with alkali

Spore size	400-640 μ × 500-700 μ
Inner-sac	400-450 μ
Triradiate rays	200-240 μ long
Outer spore-coat	10-15 μ
Cushions (diameter)	20-y-30 μ
Trilete trace (inner sac)	140-160 μ long

DIAGNOSIS

Trilete megaspore, circular to sub-triangular. Trilete mark distinct, rays not extending beyond arucate ridges. Contact area ± trilobed. Spore wall two layered, exosporium ± smooth, inner sac rounded to sub-roundad, thin, possessing single row of prominent rounded cushions bordering a weak triradiate trace; cushion-rows and trilete trace do not reach inner sac margin, length about 2/3 of inner sac radius.

Description

Dry specimens untreated with alkali — Trilete megaspore, circular to sub-triangular. Exosporium 10-15μ thick, surface ± smooth. Triradiate rays distinct, raised, thick, about 2/3 spore radius. Contact area trilobed. Occasionally cushion marking of the inner sac detectible on the surface (Pl. 1, Fig. 1).

Specimens treated with alkali — Overall size increases. Megaspores sub-circular to sub-triangular. Triradiate rays distinct to weakly developed. Spore wall two layered. Exosporium ± smooth. Inner sac 400-450 μ large, thin, hyaline, circular to sub-circular, frequently folded; traces of triradiate rays ± weakly developed on the inner sac, single row of conspicuous round cushions on either side of a triradiate trace. Rows of cushions and trilete trace extend up to about 2/3 radius of the inner sac (Pl. 1, Figs. 2, 3).

Comparison

The nearest comparable species *Trilaevipillitis nitens* (Dijkstra) Bharadwaj and Tiwari, 1970 is distinguishable by the following features:

Specimen studied — 6.

Holotype — Pl. 1, Figs. 1-3.

Locality — Barachada, Birsinghpur Pali, M.P.

Horizon — Talchir Formation (Lr. Perm.)

Infraturma – *Apiculati* (Bennie & Kidston) Potonié, 1956

Genus – *Duosporites* (Høeg, Bose & Manum) Bharadwaj & Tiwari, 1970

Type species — *Duosporites congoensis* Høeg, Bose & Manum, 1955.

Duosporites dijkstrae Bharadwaj & Tiwari, 1970

Pl. 1, Figs. 7-10

Synonymy (after Bharadwaj and Tiwari, 1970) —

Triletes endosporitiferous Singh in Dijkstra, 1955.

Triletes endosporitiferous (Singh) in Trindade, 1957;

Duosporites endosporitiferous (Singh) Pant & Srivastava, 1962;

Duosporites endosporitiferous (Singh) Pant & Srivastava in Canduro & Zingano, 1965;

Duosporites dijkstrae Bharadwaj & Tiwari, 1970.

Dimensions

Dry specimen untreated with alkali

Spore size	380-440 μ × 390-530 μ
Triradiate rays	180-240 μ in length
widening from	15-50 μ towards extremity

T. talchirensis sp. nov.	*T. nitens*
1. Overall size range smaller 380-600 μ	1. Spores large, size range 450-900 μ (Bharadwaj & Tiwari, 1970)
2. Contact area trilobed	2. Contact area ± circular
3. Inner sac 400-450 μ	3. Inner sac large, 800 μ asmeasured from photo (Pant & Srivastava, 1962)
4. Cushions on inner sac conspicuous and large, 20-30 μ in diameter, rounded. Trilete trace and rows of cushions do not reach the inner sac margin.	4. Cushions indistinct as judged from the photo (Pant & Srivastava, (1962), 10-25 μ in diameter, other details not known.
5. Inner sac thin, 1 μ, frequently folded.	5. Inner sac comparatively thicker, 2 μ, folding not described, perhaps uncommon.

Specimens treated with alkali

Spore size	460-540 μ× 480-680 μ
Triradiate rays	160-400 μ long widening from 20-60 μ towards extremity
Inner sac	220-290 μ
Cushions (diameter)	15-30 μ

DESCRIPTION

Dry specimens untreated with alkali — Trilete megaspores, rounded, sub-triangular or triangular. Triradiate rays conspicuous, raised, ± squal in lenght, reaching margin, usually becoming wider towards extremity. Arcuate ridges ± clear. Exosporium thick smooth or finely granular.

Specimens treated with alkali — Trilete megaspore, rounded, sub-rounded or triangular. Overall size increases conspicuously. Triradiate rays distinct, thick, sinuate, raised, reaching the margin. Prolonged alkali treatment obliterates rays beyond the area of inner sac; in some specimens individual rays fork beyond the inner sac. Spore wall two layered; exosporium ± smooth to verrucose (elements varying from conical to baculate), inner sac thin, smooth, roundly triangular, size about 1/2-1/3 of spore diameter, proximally having a triradiate mark bordered with one row of distinct dark cushions, trilete trace and row of cushions reaching inner sac margin.

Specimen studied — 12

Locality — Barachada, Birsinghpur, Pali, M.P.

Horizon — Talchir Formation (Lr. Perm.)

Duosporites congoensis Høeg, Bose & Manum 1955

Pl. 2, Figs. 11-13

Holotype — Høeg, Bose & Manum, 1955, Pl. 1, Figs. 1,2.

DIMENSIONS

Dry specimens untreated with alkali

Spore size	420-600 μ% 430-640 μ
Triradiate rays	190-240 μ long 20-40 μ wide, wider at extremity

Specimens treated with alkali

Spore size	400-800 μ× 480-800 μ
Triradiate rays	20-30 μ with up to 70 μ wide at extremity
Inner sac	240-400 μ% 300-420 μ
Cushions (diameter)	15-20 μ
Trilete trace (inner sac)	150-200 μ long

DESCRIPTION

Dry specimens untreated with alkali — Trilete megaspore, circular or sub-circular. Triradiate rays conspicuous, thick, raised, ± uniformly wide for most part but wider at extremity, sinuate, reaching ± up to margin. Exosporium granular, arcuate ridges seen in some specimens.

Specimens treated with alkali — Trilete megaspore, circular, sub-circular or roundly triangular. Overall size increases significantly. Trilete mark distinct, rays thick, ± uniformly wide, straight, sometimes sinuate. Spore wall two layered, exosporium granular, inner sac thin, translucent, smooth, rounded, sometimes sub-rounded, proximal side shows vague impression of triradiate mark bordered with one row of distinct dark cushions. Trilete trace and cushions do not extend up to inner sac margin, length about 2/3-3/4 of inner sac radius. Diameter of inner sac about half of the spore diameter or less.

COMPARISON AND REMARKS

The specimens figured earlier by Lele and Chandra (1967, p. 76, Figs. 1 & 2) may be taken as very good examples of *Duosporites congoensis*. The inner body in their figure 2 is almost identical with that of Høeg, Bose and Manum (155, Pl. 1, Fig. 3). In both cases it is striking to note that the trilete trace as well as the row of cushions do not extend up to the inner body margin. In the transparent specimen (Pl. 2, Fig. 12) the inner body is well seen beneath the outer coat. A single row of cushions is also decipherable along the trilete trace. The rows, as revealed by microscopic examination, are again shorter than the inner sac radius. The illustrations of Høeg, *et al.*

(1955, Pl. 1, Figs. 1-3), Bharadwaj and Tiwari (1970, Text-fig. 30) and Pant and Srivastava (1962, Pl. 17, Fig. 25) also exhibit similar features. We, therefore, contend that the shorter extent of the trilete trace as well as the cushion rows may serve as additional character in distinguishing *D. congoensis*.

From what we know so far, the differences between *D. congoensis* and *D. dijkstrae* are not sharp enough and the criteria used appear to be rather contradictory, when one compares the views of Pant and Srivastava (1962) with those of Bharadwaj and Tiwari (1970) on this issue, especially with regard to the size of cushions and the inner sac. The few other differences between the species as suggested by Bharadwaj and Tiwari (1970, pp. 17, 18) are that the spore coat is verrucose in *D. congoensis* and its inner margin is well-defined; whereas the spore coat of *D. dijkstrae* is finely granular and its inner margin is obscure. From our studies, we can now add a more reliable point of difference, i.e. in *D. congoensis* the trilete trace and bordering cushions are shorter (+2/3) than the inner-sac radius while in *D. dijkstrae* they are as long as the inner sac radius.

Specimens Studied — 10.

Locality — Barachada, Birsinghpur Pali, M.P.

Horizon — Talchir Formation (Lr. Perm.)

Genus — *Srivastavaesporites* Bharadwaj & Tiwari, 1970

Type species — *Srivastavaesporites karanpurensis* Bharadwaj & Tiwari, 1970.

Srivastavaesporites indicus (Singh) Bharadwaj & Tiwari, 1970

Pl. 2, Figs. 14, 15

Synonymy (after Bharadwaj & Tiwari, 1970) —

Triletes indica Singh, 1953;

Talchirella endonigra, Pant & Srivastava, 1961.

DIMENSIONS

Specimen untreated with alkali

Spore size	470-540 μ×
	600-660 μ
Triradiate rays	180-240 μ long
	20-30 μ wide
	wider at extremity

Specimens treated with alkali

Spore size	510-600 μ×
	640-820 μ
Triradiate rays	Not seen
Cushions	Not seen

DESCRIPTION

Dry specimens untreated with alkali — Trilete megaspores. Circular to sub-circular, sometimes oval. Triradiate rays conspicuous, thick, raised, 3/4 radius, not reaching margin, contact area marked by ridges. Exosporium ± granular.

Specimens treated with alkali — Overall size increase. Round to sub-circular. Triradiate mark obscure. Exosporium granular; inner sac dark and dense. Circular to subcircular; triradiate trace or cushions not seen.

Specimen studied — 6.

Locality — Barachada, Birsinghpur Pali, M.P.

Horizon — Talchir Formation (Lr. Perm.)

Genus — *Trileites* (Erdtman) ex. Potonié 1956

Type species — *Trileites* (al. *Triletes*) *spurius* (Dijkstra) Potonié, 1956.

Triletes sp.

Pl. 2, Figs. 16, 17

DESCRIPTION

Trilete megaspores, size range 500-620 μ; sub-circular to roundly triangular, triradiate rays distinct, raised, nearly reaching the margin, straight to sinuate. Contact area broad, ill defined.

On maceration an inner body did not separate out from the exo-exine (outer layer) as in the foregoing species. The outer layer enlarged about one third of original diameter becoming thinner but still showing fine papillae (coni to baculate elements), up to 8 μ long and 4 μ broad on its surface as well as along its margin (Pl. 2, Fig. 17).

REMARKS

As the nature of the inner body and its details are not known, it is not possible to place these few specimens under other genera recognized on the basis of internal and external morphology. We, therefore, prefer to provisionally accommodate these megaspores under *Triletes sensu* Pant & Srivastava, 1961 without assigning them to any species. Comparison with *T. uthalensis*, *T. tenuis* and *T. labiosus* described by Pant and Srivastava (1961, 1962 is precluded as these species have now been transferred to *Srivastavaesporites* by Bharadwaj and Tiwari (1970) on the basis of additional material.

Specimens studied — 3.

Locality — *Barachada*, Birsinghpur Pali, M.P.

Horizon — Talchir Formation (Lr. Perm.)

DISCUSSION

Composition of the Megaspore Assemblage: Following genera and species are present in the Talchir material of the Johilla Coalfield: 1. *Trilaevipillitis talchirensis* sp. nov.; 2. *Duosporites dijkstrae* Bharadwaj & Tiwari, 1970; 3. *Duosporites congoensis* Höeg, Bose & Manum, 1955; 4. *Srivastavaesporites indicus* (Singh) Bharadwaj & Tiwari (1970); 5. *Triletes* sp.

Among the above genera *Duosporites* seems to be dominant, followed by *Trilaevipillitis* and *Srivastavaesporites*. It may be interesting to note that the assemblage contains mostly laevigate to finely apiculate megaspores. According to the known distribution of the megaspore genera in the Lower Gondwana (Bharadwaj & Tiwari, 1970), *Trilaevipillitis* was so far known only from the Barren Measures. Its presence in the Talchir Formation is, therefore, interesting. The other genus *Duosporites*, was so far believed to be characteristic of the Karharbari and Barakar Formations. We find now that this genus is quite common in the Talchir Formation as well, being represented by two species. The third genus *Srivastavaesporites* was hitherto confined to the Barakar Formation. The present findings extend down its range to the Talchir Formation.

The discovery of megaspores has also a bearing on the floristics of the Talchir Formation. The meagre Talchir Flora is strikingly devoid of pteridophytes except for some fragmentary equisetalean remains. The finding of megaspores now indirectly suggests that in all probability some lycopsid plants existed at least during the later part of the Talchir times when the impact of glaciation had dwindled out giving way to more hospitable conditions for plant development.

Taxonomic aspect of the Inner Sac

The importance of the inner sac in the taxonomy of megaspores has become clear by the contributions of Pant and Srivastava (1961, 1962) and Bharadwaj and Tiwari (1970). However, there are certain features which have not received enough attention from the standpoint of specific delimitation. One such feature pertains to the extent of the trilete trace and the bordering cushion rows in relation to the inner sac radius. The other relates to the degree of prominence of the trilete trace.

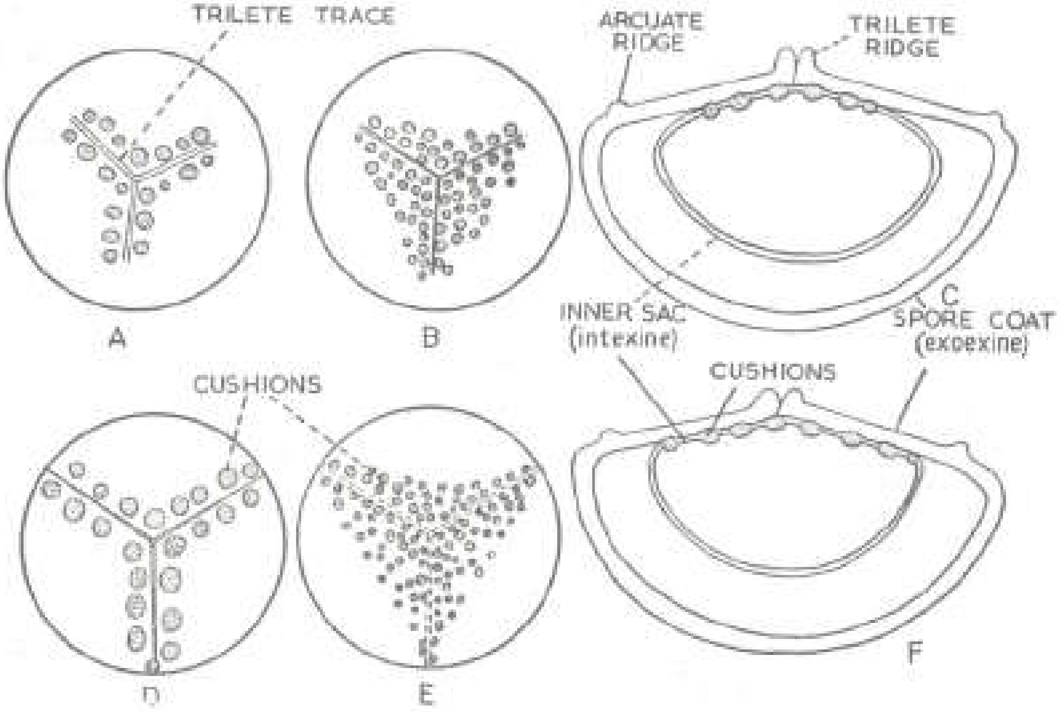
To illustrate the above point we may take some examples. In some species the trilete trace and the bordering cushion rows extend up to the inner sac margin. *Duosporites dijkstrae* is a good example. The holotype of the species (Pant & Srivastava, 1962, Pl. 17, Figs. 23-25) as well as our specimens demonstrate this feature. Similarly in *D. multipunctatus* Høeg & Bose (1960, Pl. 31, Fig. 11) the trigonally arranged cushions extend right up to the inner sac margin.

On the contrary, in *Duosporites congoensis*, the cushion rows as well as the trilete trace are distinctly shorter (±2/3 to 3/4) than the inner sac radius. The holotype of the species (Høeg, Bose & Manum, 1955, Pl. 1, Figs. 1, 2) shows identical features. All other good examples of *D. congoensis* including those described by us also confirm this (vide pp. 243-244).

The shorter extent of the trilete trace and the cushion rows is also met with in other genera. In the present material *Trilaevipillitis talchirensis* sp. nov. shows it. The same is true for the species *Talchirella trivedii* (Pant & Srivastava), Bharadwaj & Tiwari (1970, Pl. 4, Fig. 3) and *Surangaesporites rangiganjensis* Bharadwaj & Tiwari (1970, Pl. 15; Fig. 2, 3) which have trigonally arranged cushions. In several of the aforesaid examples the inner sac develops characteristic secondary folds surrounding the trilete trace extremities. Generally the trilete trace and the cushion rows are coextensive but exceptions may be found (e.g. Høeg, Bose and Manum, 1955, Pl. 2, Fig. 7).

Bharadwaj and Tiwari, (1970) have mentioned that the trilete trace on the inner sac varies in its length. However, the taxonomic value of this feature was hitherto not realized. The evidence at hand clearly points out that the extent of the trilete trace and the cushions is a feature of consistent development in a particular species, much like the tetrad mark on the spore coat. We are, therefore, inclined to recognize it as a useful criterion for specific delimitation. In addition we have also noted that the trilete trace varies in sharpness. Often it is weakly developed or is almost invisible but in some other cases it is very distinctly marked (e.g. *Surangaeasporites raniganjensis* Bharadwaj & Tiwari, 1970; Pl. 15, Fig. 3). These differences are also likely to be useful in determining a species.

It is well known that the trilete trace and the cushions (wherever present) play a vital role in the mechanism of attachment between the inner sac (intexine) and the outer spore coat (exoexine). There is also evidence to believe (e.g. *Duosporites congoensis*) that the border of the attachment area runs around the trilete trace and cushion rows (Høeg, Bose & Manum, 1955, p. 102, Pl. 1, Figs. 3-5). This means that at least two modes of attachment can be recognized. In the first case, the attachment of the inner sac is confined to a small proximal area (Text-figs. 2A-C), while in the other case the entire proximal face of the inner sac is attached to the exoexine (Text-figs. 2D-F).



TEXT-FIG. 2 — Morphological aspects of the inner sac (intextine). All figures are semi-diagrammatic.

A-B — Proximal view of two types of inner sacs in which the trilete trace and bordering cushion rows do not extend up to the inner sac margin: (A) *Duosporites congoensis*-type, (B) *Talchirella trivedii*-type.

C — Interpretation of the attached inner sac (as in A and B) with the outer coat (exoexine) in meridional section of a megaspore.

D-E — Proximal view of two types of inner sacs in which the trilete trace and bordering cushion rows extend up to the inner sac margin: (D) *Duosporites dijkstrae*-type, (E) *Duosporites multipunctatus*-type.

F — Interpretation of the attachment of the inner sac (as in D and E) with the outer coat (exoexine) in meridional section of a megaspore.

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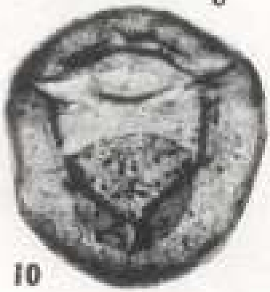

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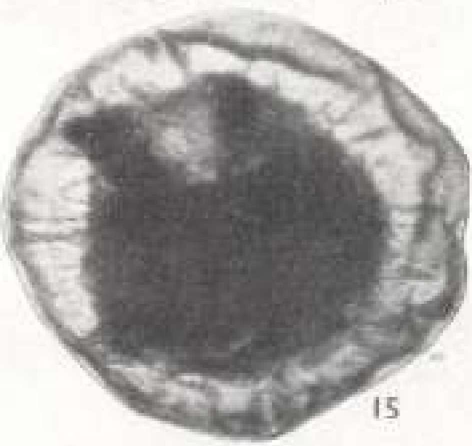

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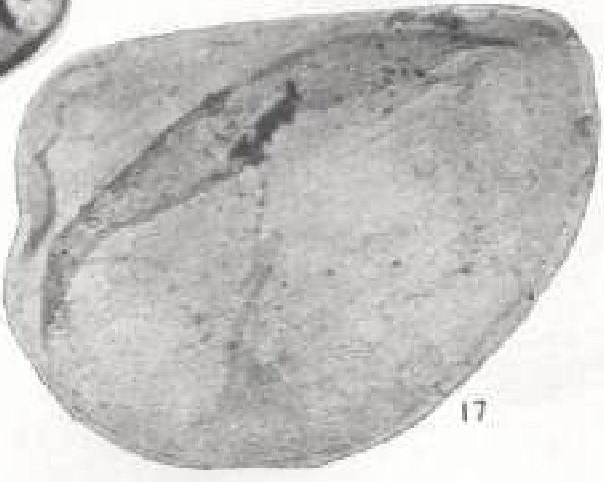

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EXPLANATION OF PLATES

(All photomicrographs are magnified 100 times unless mentioned specifically)

PLATE 1

1-3. *Trilaevipillitis talchirensis* sp. nov. Dry megaspore (proximal view); Inner sac (wet) detaching from the main body during alkali treatment; and inner sac showing weak trilete trace and cushion rows which do not extend up to inner sac margin (Slide no. 4452, Holotype, Bed no. 5).

4-6. *Trilaevipillitis talchirensis* sp. nov. Dry megaspore (proximal view); Alkali treated (wet) specimen showing distinct inner sac with cushion rows; and strong alkali treated specimen (wet) which disintegrated after further alkali treatment (Bed no. 5).

7-9. *Duosporites dijkstrae* — Dry megaspore (proximal view); Alkali treated specimen (wet) showing inner sac; and detached inner sac showing cushions. Note the trilete trace and cushion rows extending up to the inner sac margin (Slide no. 4453, Bed no. 5).

10. *Duosporites dijkstrae* — Alkali treated megaspore showing distinct inner sac; detached inner sac still lying within the outer-coat. Note the trilete trace and cushion rows extending up to the inner sac margin (Slide no. 4454, Bed no. 6 × 50).

PLATE 2

11, 12. *Duosporites congoensis* — Dry megaspore (proximal view); and alkali treated megaspore (wet) showing inner sac. The cushion rows are discernible. (Slide no. 4455, Bed no. 6).

13. *Duosporites congoensis* — Alkali treated megaspore showing distinct inner sac with cushion rows. Trilete trace and cushion rows do not extend up to the inner sac margin. Specimen earlier figured by Lele & Chandra, (1967, fig. 1) (Slide no. 4454, Bed no. 6) × 50.

14, 15. *Srivastavaeasporites indicus* — Dry megaspore (proximal view); and alkali treated specimen showing dark inner body. The specimen disintegrated after further alkali treatment. (Bed no. 5).

16, 17. *Triletes* sp. Dry megaspore (proximal view); and alkali treated specimen showing exosporium. (Slide no. 4456, Bed no. 6).

FURTHER OBSERVATIONS ON *GLOSSOTHECA* SURANGE & MAHESHWARI: A MALE FRUCTIFICATION OF GLOSSOPTERIDALES

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ABSTRACT

A new species *Glossotheca orissiana* is described. It has a fertile leaf different in shape than that of *Glossotheca utkalensis*. The fertile leaf bears three or more pedicels on the abaxial side of the petiole. Each pedicel bifurcates into two and each fork then further divides by dichotomy and the slender final branches bear one sporangium each. Each pedicel thus bears two sporangial clusters. The sporangia are like those of *Glossotheca utkalensis*. Further observations have been made on *Glossotheca indica* Surange and Maheshwari. It has a larger fertile leaf, spathulate in shape and a very long petiole.

INTRODUCTION

SURANGE and Maheshwari (1970) described a remarkable male fructification, *Glossotheca utkalensis* borne on a small fertile leaf having *Glossopteris* type of venation. This is the only male reproductive organ of Glossopteridales about which we know in detail. Some of Pant's (1958, 1960) isolated sporangia may resemble sporangia of *Glossotheca*, but one cannot be certain about their affinities. Surange's male fructification (1957) is entirely different. *Eretmonia* (Surange & Maheshwari, 1970) is another male fructification, which has one pedicel bearing sporangia.

A fresh collection was made recently from the same locality which yielded several specimens of *Glossotheca*. On examination is was found that, besides fertile leaves of *Glossotheca utkalensis*, there is another type of fertile leaf bearing sporangia. It is, therefore, described as a new species of *Glossotheca*. Further observations have also been made on *Glossotheca utkalensis*.

DESCRIPTION

Genus — *Glossotheca* Surange & Maheshwari

Emended Diagnosis — Male fructification borne on long petiole of small, fertile leaf; lamina spathulate or of different shape; no midrib, veins diverge from base of lamina, a few veins run in the middle as midveins, midveins and secondary veins bifurcate and anastomose; pedicels borne on the abaxial side of petiole or basal portion of fertile leaf; each pedicel bifurcate, each bifurcation further divides dichotomously; ultimate branches bear one sporangium sporangia in clusters, sporangia oval-elongate with longitudinal markings.

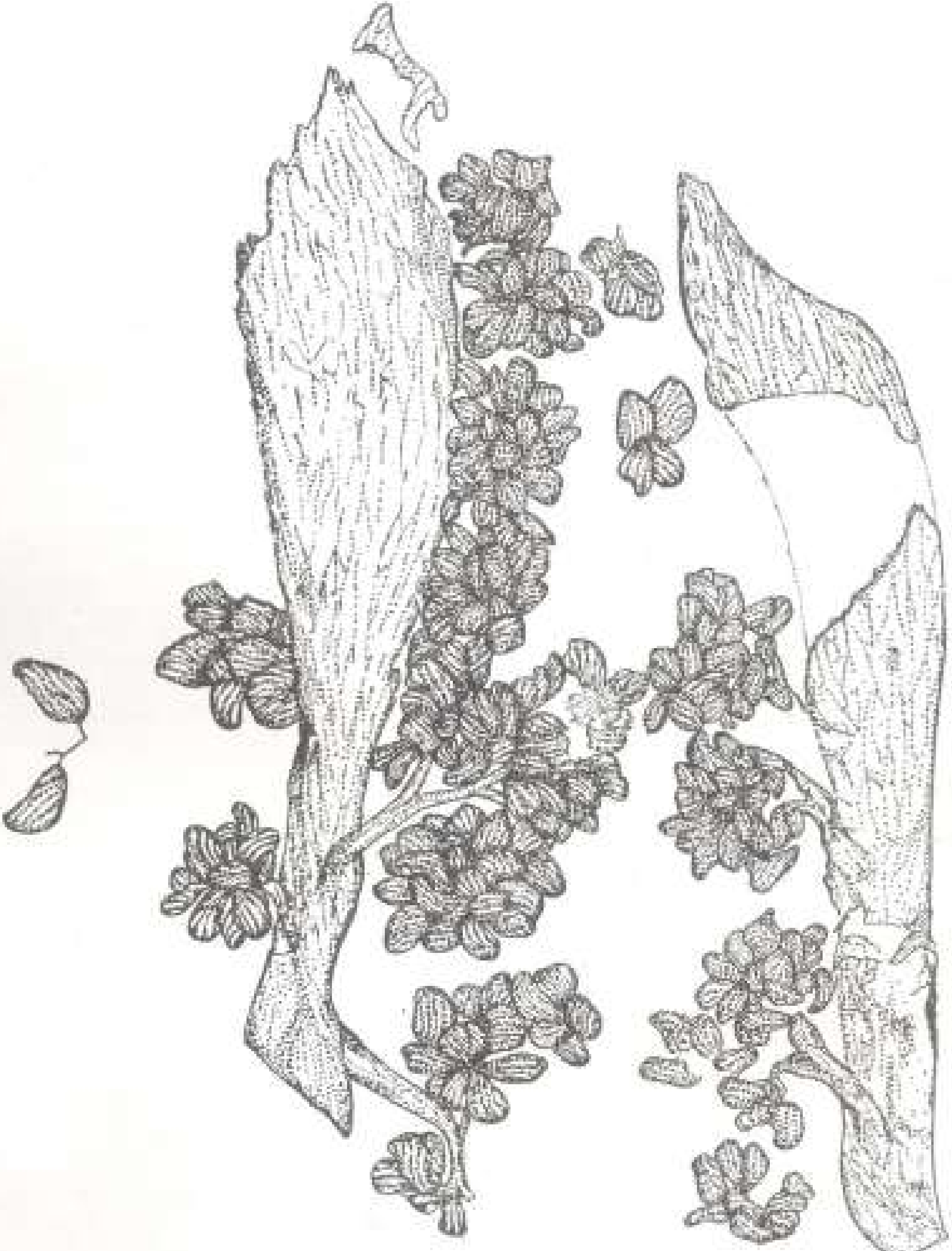
Type species — *Glossotheca utkalensis* Surange & Maheshwari.

1. *Glossotheca utkalensis* Surange & Maheshwari

Pl. 1, 2, Figs. 1-3, 7

Emended Diagnosis — Male fructification; fertile leaf spathulate with round apex and long petiole, lamina 1·5-2·5 cm long, 1-1.5 cm broad; petile 4-7 cm long and 2·5 mm broad; no midrib but a few strong veins run in the middle then bifurcate and form anastomoses, other veins diverge from base or given out by outer midveins, bifurcate, form small, hexagonal meshes; 3 or more pedicels borne on abaxial side of petiole, one below the other, each pedicel bifurcates, each bifurcation further divides by dichotomy; sporangia elliptical-oval with polar ends bluntly rounded, sporangial surface marked by fine longitudinal ridges and grooves.

We have a number of specimens preserved on grey shales and they are identical with *Glossotheca utkalensis*. Some of them are shown in Pl. 1 & 2, Figs. 1, 2, 3 & 7. The one shown in Pl. 1, Fig. 1 is almost a complete specimen of a fertile leaf, measuring 6·5-7 cm in lenth. The lamina is spathulate with broadly rounded apex and measures 2·5 cm in lenght and 1·5 cm in breadth at the broadest part. The lamina gradually tapers down into a long petiole, more than two or more times its length. The petiole is 4-4·5 cm long and 3 to 5 mm broad. It is broader where



TEXT-FIG. 1 — A drawing of the holotype of *Glossotheca orissiana* showing two fertile leaves with forked pedicels. The pedicel of the fertile leaf on the left has forked twice. Also note the attachment of sporangia on slender forks of a penultimate branch. × 6.

the pedicels bearing sporangial groups were perhaps attached. No pedicel is seen but sporangial groups are scattered all along the petiole on its either side. A very small leaf 1·2 cm long and 5 mm broad with 2 or 3 strong midveins and anastomosing secondary veins, is lying at the base of the petiole in such a position that it looks as if it was attached to the petiole. Is this a bract in the axil of which the fertile leaf is borne?

Pl. 1, fig. 2 shows another smaller but complete specimen of a fertile leaf of *Glossotheca utkalensis*. The entire leaf measures 5 cm in length, the lamina 1·5×1 cm and the petiole 3·5 cm in length and 2·3 mm in breadth. The lamina is oval-spathulate with bluntly rounded apex. The venation is more clear here. A few strong veins from the petiole enters the lamina and run as midveins up to about half its length. Then they dissolve into smaller veins, bifurcate and form anastomoses. Likewise, the outer veins give out secondary veins which bifurcate and form meshes up to the margin. The meshes are hexagonal and pointed at both the ends. Only one pedicel is seen attached to the petiole. Two groups of sporangial clusters are seen, but no attachment is evident.

Pl. 1, fig. 3 shows another specimen of a fertile leaf of the same species with almost complete lamina which looks somewhat elongated. The venation is well preserved and confirms to the description given above. Only one pedicel is visible, lying in the midst of sporangial clusters. Some sporangia look as if they are lying in a whorl round a central spot.

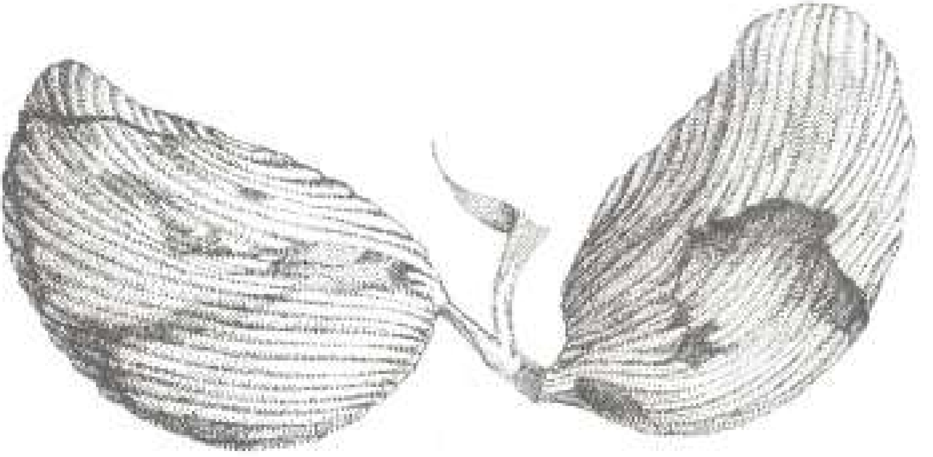
Pl. 2, fig. 7 shows only the petiole of a fertile leaf of *Glossotheca utkalensis* with three pedicels and clusters of sporangia. One of the pedicel shows bifurcation at a distance of about 5 mm from the petiole. The pedicels are 4-6 cm long and 1 mm broad.

The specimens of *Glossotheca utkalensis* studied by us, clearly shows that three or more pedicels spring from the abaxial side of the petiole of the fertile leaf, in a row, one below the other. Each pedicel bifurcates and most probably goes on dividing repeatedly. The sporangia are probably attached on the ultimate branches. The interpretation of Surange and Maheshwari that one main pedicel arises from the leaf stalk which further gives rise to three pairs of branches is not correct. Each pedicel is attached separately on the petiole. It was not possible to observe how sporangia are attached on the ultimate branches, whether singly or in whorls. The sporangia in our specimens have the same structure as described by Surange and Maheshwari. The organization of the pedicel and the branch system appears to be similar to that of *Glossotheca orissiana* described below.

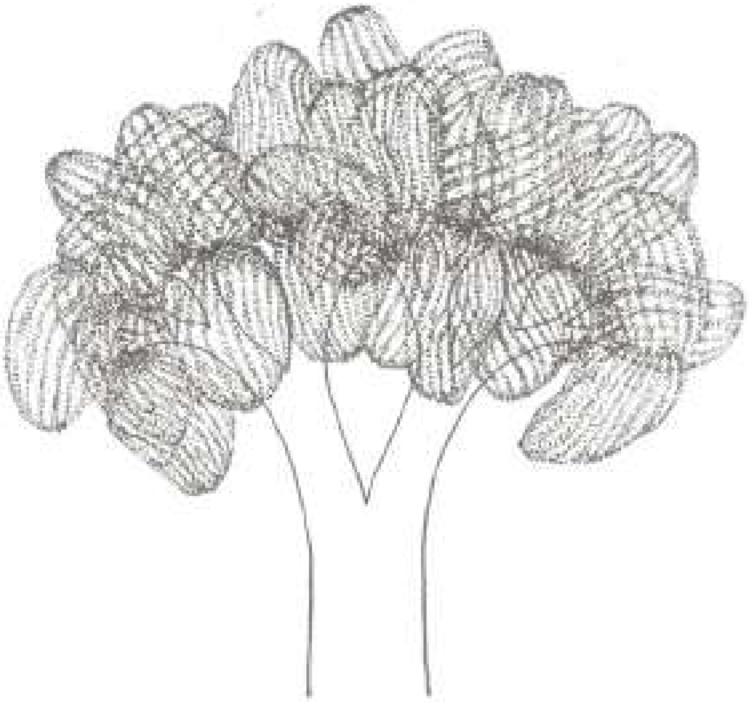
2. *Glossotheca orissiana* n. sp.

Pls. 1, 2, 3, Figs. 4-6, 8-12; Text-figs. 1-4

Diagnosis — Fertile leaf elongate-lanceolate with drawnout apical end; lamina 1·5-2 cm long, less than 1 cm broad; petiole



TEXT-FIG. 2 — A drawing of two attached sporangia of *Glossotheca orissiana*. × 40.



TEXT-FIG. 3 — A diagrammatic representation of the dichotomous branching of a pedicel. Each ultimate branch bears one sporangium and all sporangia on one pedicel form a cluster as seen commonly preserved on the shale. × 12.

3-4 cm long, 3-4 mm broad; veins spreading from base, a few veins in the middle run straight up for short distance before forking and anastomosing, rest of the viens diverge towards margin, forking and anastomosing, meshes elongate, pointed at two ends; 3 or 4 pedicels attached in a single row on abaxial side of petiole, each pedicel forks several times, producing slender ultimate branches; sporangia attached on ultimate branches, one on each branch; sporangia oval-elliptical with prominent longitudinal striations.

Holotype — B.S.I.P. No. 35039

In the same collection from Orissa, there are a number of specimens with a fertile leaf of different shape than that of *Glossotheca utkalensis* preserved on whitish compact shales. The shale pieces on which *Glossotheca utkalensis* are preserved are grey in colour and were collected at a different level from the same fossiliferous bed which is about 15′-20′ thick.

Pl. 2 fig. 8 shows a fertile leaf of *Glossotheca orissiana* showing the typical shape of the lamina. The apical part is drawn out into a pointed apex (see also Pls. 2, 3; Figs. 6, 9) as against a broadly rounded apex of *Glossotheca utkalensis*. The lamina narrows down into a thick petiole. The venation is well preserved. A number of veins enter the lamina from the base and, except for a few veins in the middle, spread out towards the margin, forking and anastomosing. A few veins in the middle go straight upwards almost upto half the length of the lamina, then starts forking and anastomosing. The meshes in the upper half of the lamina are arranged end to end, two or three entering the drawn out apical end (Pl. 2, Fig. 6). The petiole or the basal part of the fertile leaf is shorter than that of *Glossotheca utkalensis*. A few sporangial clusters are seen, but no pedicel is visible.

Pl. 2, fig. 5 shows a well preserved specimen showing two well preserved fertile leaves lying side by side. This is the holotype of *Glossotheca orissiana* (see Text-fig. 1). Pl. 2, fig. 6 shows one fertile leaf and Pl. 3, fig. 9 shows the other leaf with forked pedicels and clusters of sporangia.

The fertile leaf in Fig. 6 is small and about 3 cm long with a part of the petiole preserved on another shale piece. The lamina is 1·5 cm long and about 7-8 mm broad. Meshes in the apical region of the lamina are clearly seen, arranged end to end. The leaf tapers down into a petiole, 3 mm in breadth. Two forked pedicels are attached at a distance of 8 mm. One pedicel springs out almost at the base of the lamina and forks immediately. The forks are embedded below two sporangial clusters and therefore, further branching is not visible (Text-fig. 1).

The other fertile leaf shown in Pl. 3, fig. 9 is also elongate with a long, drawn out apex. The entire leaf measures 2·5 cm in length; the lower part of the petiole is missing. The lamina is 1·8 cm long, the drawn out apex being 3 mm in length. The petiole is 2 mm in breadth and shows beautifully preserved two forked pedicels, about 7 mm apart (Pl. 2, Fig. 5; Text-fig. 1). The pedicels are 1 mm in breadth and fork after about 2-3 mm distance from the petiole. The pedicel (Pl. 3, Fig. 9) which is attached near the base of the lamina is shown enlarged in Pl. 3, fig. 10 with groups of sporangia lying nearby. The pedicel is forked and the forks are reduced to almost half in breadth. The upper branch of the fork on the left has gone under the groups of sporangia, but the lower branch shows second bifurcation. This pedicel has, therefore, forked twice. The other pedicel also shows two bifurcations (Text-fig. 1). Pl. 3, fig. 9 shows two sporangia (see arrow on the left bottom) each attached to a slender branch of the fork, about 0·1 mm in breadth (Text-fig. 1). The attached sporangia are shown enlarged in Pl. 3, fig. 11 and Text-fig. 2. The ultimate branches of the pedicels are thus forked. It, therefore, follows that the pedicel divides repeatedly by dichotomy and the slender ultimate branches bear sporangia. The main pedicel is 1 mm broad and it must be dividing four to five times before the size of the ultimate branch, about 0·1 mm as seen in Pl. 3, fig. 11, is reached. The number of sporangia on each cluster, therefore, should not exceed 32. The accurate count was not possible but the sporangia counted in many clusters did not exceed 32. The sporangia in *Glossotheca orissiana* thus are borne on the ultimate branches of a dichotomous branch system. This has been shown diagrammatically in Text-fig. 3.

Forked pedicles are also seen in another specimen (Pl. 1, Fig. 4) in which the lamina is not preserved. The pedicels are attached to a petiole and are embedded under sporangial clusters.

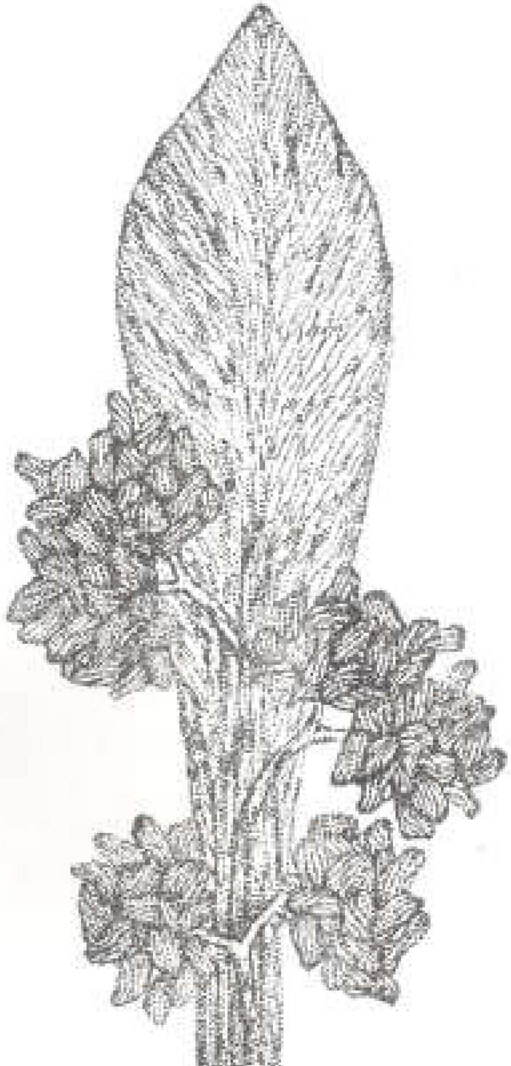
In Pl. 3, fig. 12 and Text-fig. 2 are illustrated two sporangia enlarged to show their structure. The sporangia are elongated, about 1 to 1·5 mm in leaght. They also appear oval, their shape depending upon the way they are flattened. Generally one side is semicircular and the other is straight, the polar ends are drawn out and rounded. The sporangial surface is marked by fine longitudinal striations which appear as ribs and grooves. Many isolated sporangia which have been described by various authors, show this character prominently. This type of sporangia are very common in the Glossopteris flora.

RECONSTRUCTION

Text-fig. 4 shows a restoration of a fertile leaf and sporangia of *Glossotheca orissiana*. Three pedicels are shown arising from the abaxial side of the basal part of the fertile leaf, the upper one springing almost from the base of the lamina. Each pedicel forks and the daughter branches are hidden under the crowded groups of sporangia. Text-fig. 3 shows diagrammatically how a pedicel branches five times by repeated dichotomy. Subsequent dichotomies occur at much shorter distances and hence the sporangia in the group look crowded, burying dichotomous branches under them.

COMPARISON AND DISCUSSION

Glossotheca orissiana resembles closely the other species from the same locality, *Glossotheca utkalensis*. Both are male reproductive organs carrying sporangia on branched pedicels. In both, the pedicels are borne on the abaxial side of the petiole or the basal part of the fertile leaf and the sporangia in the two species look almost identical. *Glossotheca orissiana*, however, differs from *Glossotheca utkalensis* in being smaller in size, the fertile leaf and petiole in the latter are much longer. The most important difference lies in different shapes the two fertile leaves have in the two species. It would be difficult to imagine that one species



TEXT-FIG. 4 — Restoration of *Glossotheca orissiana*. × 6.

will carry two different types of fertile leaves. Further, the number of sporangia in *Glossotheca orissiana* does not exceed 32, whereas the number in *Glossotheca utkalensis* is given as ±100. Even if it is assumed that the number in the latter could be less, it would certainly be much higher than that of *Glossotheca orissiana*. The pedicels bearing sporangia are borne in the same way on the fertile leaves in both the species. But the occurrence of sporangia in whorls in *Glossotheca utkalensis*, if correct, suggest that 4 or more sporangia are borne on one ultimate branch (this fact may explain large number of sporangia on each pedicel), whereas in *Glossotheca orissiana* only one sporangium is borne on each ultimate branch. There is no doubt, however, that these two types of fertile leaves belonged to closely related plants. If, however, one goes by the resemblance of sporangia, both the fertile leaves will have to be kept under one species.

Other fructifications of Glossopteridales like *Scutum* and *Cistella* are borne on fully developed sterile(?) *Glossopteris* leaves on their abaxial surface, their stalks being attached almost to the midrib in the basal region of the leaf. Sporangia bearing pedicels in *Glossotheca* are also borne on the abaxial surface, attached by their stalks in the region of midveins of small fertile leaves. The fructifications such as *Scutum*, *Cistella* and *Glossotheca*, therefore, are borne in the same manner.

The sporangia are attached on fertile branch system in some pteridosperms such as *Diploteridium teilianum*. In *Glossotheca* also sporangia are borne on a branch system. But the resemblance between the two ends here. In *D. teilianum synangial* discs are borne on slender rachises with wide angled forkings, whereas in *Glossotheca orissiana* one sporangium is carried on each slender brach.

Eretmonia of Du Toit (1932) has been regarded as male fructification by Surange and Maheshwari (1970). It has small, stalked fertile leaves with dichotomous venation. Although there is no evidence of a pedicel carrying sporangia attached to the stalk of the fertile leaf, there appears to be fair chances of this being the case. However, *Glossotheca* has more than one pedicel attached in a row on the fertile leaf, whereas *Eretmonia* appears to have only one forked pedicel. Further comparison cannot be made as *Eretmonia* is not known in detail.

In the fossil locality from where *Glossotheca* has been collected, no species of *Gangamopteris* is present. On the other hand *Glossopteris* dominates the flora. It is undoubtedly difficult to relate fertile leaves with sterile leaves of *Glossopteris*, unless they are found in organic connection. Most of the scale leaves (including fertile leaves) present in our collection do not have solid midrib like that of *Glossopteris* leaves, but many show profuse anastomoses. The venation pattern in the two categories is different. However, there can be hardly any doubt that *Glossotheca* is the male reproductive organ of one of the species of *Glossopteris*.

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EXPLANATION OF PLATES

Plate 1

1. A complete fertile leaf with rounded apex *Glossotheca utkalensis*. Note sporangial groups on either side of the petiole. × 2.

2. Another complete specimen of *Glossotheca utkalensis* showing one pedicel attached to the long petiole (see arrow). × 2.

3. A specimen of *Glossotheca utkalensis* showing well preserved venation and large groups of sporangia. × 2.

4. A petiole (lamina is not preserved) of a *Glossotheca orissiana* fertile leaf showing three attached pedicels and groups of sporangia. × 3.

Plate 2

5. A piece of shale showing two fertile leaves and groups of sporangia of *Glossotheca orissiana*. Forked pedicels are attached on the petiole of each leaf. Holotype B.S.I.P. No. 35039. × 4.

6. One of the leaf shown in fig. 5 enlarged. Note the drawn out leaf apex and the anastomosing veins. Two forked pedicels (see arrows) are clearly seen. × 5.

7. A petiole (lamina is not preserved) of a fertile leaf of *Glossotheca utkalensis* showing three pedicels (see arrows) attached on the petiole and groups of sporangia. × 3.

8. Another specimen of *Glossotheca orissiana* showing the typical shape of a fertile leaf. Groups of sporangia are seen lying nearby. × 2.

Plate 3

9. Another fertile leaf of *Glossotheca orissiana* enlarged from Fig. 5, Plate 2. Note a beautifully preserved formed pedicel. Also note two sporangia attached on two slender forks on the leaf (see arrow). × 5.

10. The forked pedicel seen in Fig. 9 enlarged. The fork on the right side has branched twice (see arrows). × 8.

11. Two sporangia seen in Fig. 9 enlarged to show their attachment to slender forks. × 20.

12. Two sporangia seen in Fig. 11 in different focus to show their surface structure. × 20.

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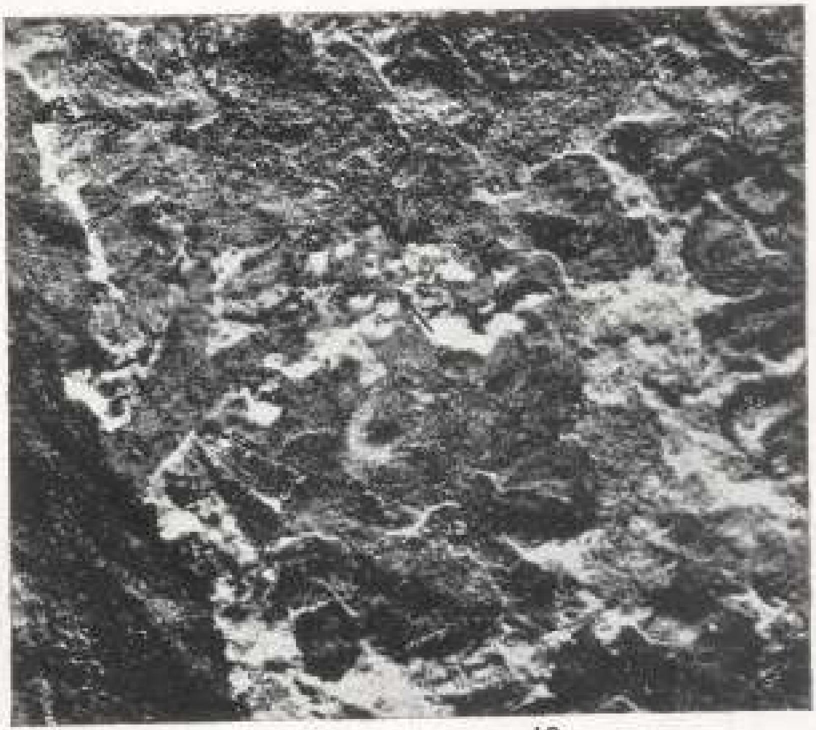

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SOME MALE FRUCTIFICATIONS OF GLOSSOPTERIDALES

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ABSTRACT

A long, slender, stalked cylindrical male fructification, described earlier by Surange (1957), has been named here as *Kendostrobus cylindricus* gen. et sp. nov. 4-5 sporangia are arranged in whorls and these whorls are borne in close spirals on the cone axis. Its monolete, striped spores are named *Kendosporites*. A new species of *Eretmonia*, *E. ovata*, another male fructification, is also described. It is shown that in *Eretmonia*, as in *Glossotheca*, the sporangia are carried on the ultimate branches of a dichotomizing branch system.

INTRODUCTION

ARBER (1905) was the first to discover from Australia retort-shaped sporangia associated with the scale leaves of *Glossopteris browniana*, agreeing more closely with the microsporangia of a cycad. Du Toit (1932) described a scale leaf as *Eretmonia*, which bore sporangia similar to those described by Arber and regarded it as the male fructification of *Glossopteris*. Recently Pant and Nautiyal (1966) placed the retort-shaped sporangia of Arber under a new generic name *Arberiella* and showed that they contain two winged pollen grains. Earlier Sen (1955) had also found two winged pollen grains in detached, ex-annulate sporangia which he attributed to *Glossopteris*. Sen (1956) also described another type of unilocular, ex-annulate sporangia which dehisced in a longitudinal direction from the apex, liberating *Pityosporites* type of pollen grains.

In 1957, Surange described a new type of male fructification without naming it. It consisted of a long, fleshy axis on which were embedded exannulate sporangia, containing striated, monolete spores. Pant and Nautiyal (1960) found detached unilocular sporangia containing similar type of monolete spores as those in Surange's fructification. They placed these sporangia under a new name *Lithangium*. Pant and Nautiyal (1960) also instituted another genus of detached sporangia, *Polytheca*, which contained triradiate, monocolpate spores. Fructification which bore *Polytheca* is not known.

Surange and Maheshwari (1970) recently described two species of *Eretmonia* from India which differed from each other in the shape and size of their fertile leaves. They bore sporangia in two clusters carried on a pair of branches which were attached on the leaf stalk. The sporangia were found in groups of 6 to 8.

Another male fructification of *Glossopteris* known from India is *Glossotheca* (Surange & Maheshwari, 1970; Surange & Chandra, 1974). It consists of a stalked fertile leaf with *Glossopteris* type of venation. The stalk of the fertile leaf bears three or more pedicels. Each pedicel bifurcates into two branches and each branch further divides by repeated dichotomy. The final slender branches bear one sporangium each.

These are the only records of sporangia and male fructifications with suspected affinities to Glossopteridales. In our collections from Orissa, some better specimens of *Eretmonia* were found which gave indications as to the attachment of sporangia on ultimate branches. Further, the type material of the male fructification described by Surange (1957) from Raniganj was reexamined which revealed the attachment of sporangia. These two types of male fructifications, which in all probability belonged to Glossopteridales, are described below.

DESCRIPTION

Kendostrobus gen. nov.

Male fructification, Surange, 1957, p. 47, 48, Pl. 1, Figs. 1 & 2

Diagnosis — Long, slender, stalked, cylindrical cone bearing spirally arranged naked, exannulate sporangia in groups; sporangial surface covered with minute pits; spore oval, elliptical to subcircular, monolete with longitudinal stripes on its surface.

Type species: — *Kendostrobus cylindricus* gen. et sp. nov. (Pl. 1; Figs. 1, 2).

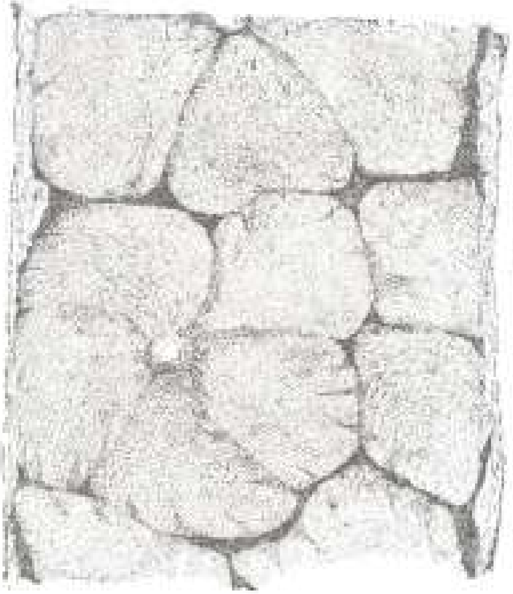
Specific Diagnosis — Male cone, cylindrical, 4 cm long, 5 mm broad, borne on long stalk; 4 to 5 sporangia attached in whorl on small hemispherical projections on cone axis; sporangia ex-annulate, crowded large 2-2·5 mm long; spores oval to elliptical, monolete with longitudinal, parallel running stripes.

Holotype — B.S.I.P. No. 19512.

Locality — New Kenda Colliery, Raniganj coalfield.

Horizon — Raniganj Stage.

The fructification was preserved in the form of compression. In the type material the cone was lifted from the shale and was mounted on a slide separately. The impression left behind by the cone on the shale, when examined under strong reflected light, revealed how the sporangia were attached on the axis. (Pl. 1, Fig. 1). The fructification is a long, slender cone, borne on a long stalk. Its parent plant is unknown. The long, slender stalk is 1 mm in breadth and more than 1·5 cm in length. The cone itself is 4 cm long and about 5 mm broad, narrowing upwards into an acute apex. In living condition the cone must have been a slender, cylindrical organ.



TEXT-FIG. 1 — *Kendostrobus cylindricus* gen. et sp. nov. showing sporangial arrangement on the cone. × 12·5.

Pl. 1, Fig. 2 shows an enlarged photograph of a part of the cone impression on the shale. Impressions of sporangia are clearly visible at some places. On closer examination groups of 4-5 sporangia are seen arranged in whorls around a small, circular protuberence on the cone axis (Text-fig. 1). This explains the arrangement as described by Surange (1957, p. 47) earlier that some sporangia pointed their narrow ends towards the base, while in others they were pointed towards the apex. The whorl of sporangia occupies almost the entire breadth of the cone. The groups of sporangia are borne in close spirals, so that the sporangia appear crowded on the cone surface. No scale or a vegetative leaf is found associated with the cone, but there is present a thick ridge all along its margin (Text-fig. 1). Is it the remnant of a scale leaf similar to that of *Dictyopteridium*? If it is so then this cone is also protected by a spathe-like covering in young stage.

The sporangia are ex-annulate and are borne naked on the cone. They are oval in shape with one end narrower than the other. The end which is attached to the protuberance on the cone is generally narrower. The sporangial surface, unlike those of *Glossotheca* and *Eretmonia*, is studded with tiny, oval to circular depressions. A sporangium measures 1·5 to 2·5 mm. in length and about 1-1·5 mm in breadth.

We tried to isolate sporangial wall by controlled maceration of the sporangial mass taken out from the compressed cone, but could not recover any cellular tissue. Pant and Nautiyal (1960) who described some detached sporangia under the name *Lithangium surangei*, also did not give details of the sporangial surface cells. The spores of *Lithangium* are identical with the spores from the male fructification (Surange, 1957) described here as *Kendostrobus cylindricus* and therefore, it is safe to assume that the *Lithangium* type of sporangia were attached on the cone of *Kendostrobus cylindricus*. The sporangia of *Lithangium surangei* are described as round to oval, 1·2 mm × 1·07 mm in size which are somewhat smaller than those on the cone. The slight difference in size between the sporangia of *Kendostrobus* and those of *Lithangium surangei* is insignificant. The surface cells appear to be thin walled and therefore, easily destroyed in maceration as is indicated by the fact that Pant and

Nautiyal did not find them and we also failed to recover them from the remaceration of the type material.

Monolete spores similar to those derived from *Kendostrobus cylindricus* have geen found in isolated condition also from the Raniganj Stage of India. Bharadwaj (1962) figured one such spore under the name *Latosporites* sp., a genus from the northern hemisphere. The parent fructification which produced this type of spore is a southern hemisphere plant, most probably belonging to Glossopteridales. We therefore, propose a new generic name *Kendosporites* for the reception of such spores.

Turma — ***Monoletes*** **Ibrahim 1933**
Subturma — ***Azonomonoletes*** **Luber, 1935**
Infraturma — ***Perinomonoliti*** **Erdtman, 1947**
Genus — ***Kendosporities*** **gen. nov.**
Genotype — ***Kendosporites striatus*** **(Salujha)**
comb. nov.

Generic Diagnosis — Monolete spore, generally oval to subcircular; unmacerated spore with thick, irregular, sculptine ridges running parallel to longitudinal axis; macerated spore with parallel stripes in place of ridges parallel to monolete slit; exine smooth.

Type species — *Kendosporites striatus* (Salujha) comb. nov. (Pl. 1 & 2; figs. 7-25)

Specific Diagnosis — Spore oval, elliptical to subericular; size 55μ-$110\mu \times 50\mu$-90μ; sculptine folded into thick, sometimes broken, slightly curved, ridges and grooves, running parallel to longitudinal axis; during maceration sculptine ridges destroyed, leaving behind longitudinal stripes on body; exine up to $1{\cdot}5\mu$ thick, laevigate, irregularly folded; monolete mark parallel to stripes, when open extends up to 3/4th of longer axis.

Neotype — 1952 B.S.I.P. Collection (Surange's slide).

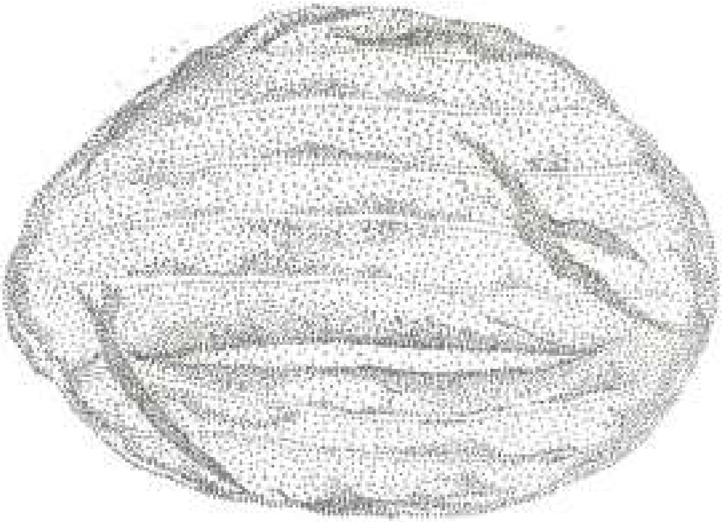
Locality — New Kenda colliery, Raniganj coalfield, Bengal.

Horizon — Raniganj Stage.

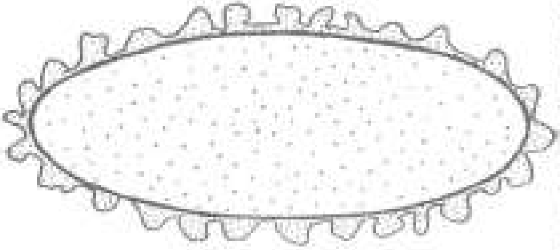
Description — A small part of the sporangial mass from the cone of *Kendostrobus cylindricus* was treated with HNO_3 for a few minutes and then some spores were taken out, washed and mounted on a slide. The acid had acted very little on the spores and the sculptine remained almost intact. The spore looked dark brown and the sculptine was folded into a number of thick, dark, somewhat arched ridges, running, parallel to the longitudinal axis of the spore (Pl. 2, figs. 9, 12, 14; Text-fig. 2). The grooves in between the ridges perhaps denoted unthickened part of the spore wall, which appeared as thin transparent stripes (Text-fig. 3) between the dark ridges. When remaining spores were subjected to further maceration, the sculptine dissolved completely, leaving behind long, thin stripes on the spore wall in place of ridges and grooves. It seems that the areas of sculptine ridges still remained darker after, maceration than the unthickened part (grooves) of the exine and they appear as lighter lines, imparting a striped appearance to the spore. In over macerated spores, even the stripes tend to disappear, giving a smooth appearance to the spore surface. A diagrammatic cross section of a spore is shown in Text-fig. 4.

TEXT-FIG. 2 — *Kendosporites striatus* comb. nov. unmacerated spore showing sculptine ridges. × 1000.

Spores were compressed in different ways which gave different shapes to the spores. Some of them are figured in Pl. 1 & 2, Figs. 7-25. There is also a considerable variation in size and surface features. The smallest spore measure $56 \times 50\ \mu$ (Pl. 1, fig. 8) and the largest was $107 \times 90\mu$. Very



TEXT-FIG. 3 — *Kendosporites striatus* comb. nov. macerated spore showing stripes, monolete mark and folds. × 1000.



TEXT-FIG. 4 — Diagrammatic cross section of *Kendosporites striatus* comb. nov. showing uneven sculptine ridges. Monolete mark is shown on the upper left side.

often the spores are compressed in such a way that monolete mark is not at all visible. In such a condition, the spore, could easily be mistaken for an alete form. The slit is lens shaped, convex in the middle and pointed at both ends and almost extending up to the margin. The exine is generally folded and one to three major folds appear on any part of the spore body.

Comparison and discussion — In 1957, Surange described these spores from a male cone without naming them. Bharadwaj (1962, Pl. 4, fig. 64) illustrated the same type of monolete, striped spore as *Latosporites* sp. from the coals of Raniganj Stage. Later in 1964, Bharadwaj and Salujha recorded a similar spore as *Latosporites* sp. form seam VIII of the Raniganj coalfield. In 1965, Salujha also found the same type of striped, monolete spore from seam IX of the East Raniganj coalfield and named it as *Latosporites striatus* sp. nov. There is hardly any doubt that all these spores are identical with the striped, monolete spores isolated from the male cone (Surange, 1957) now described as *Kendostrobus cylindricus*.

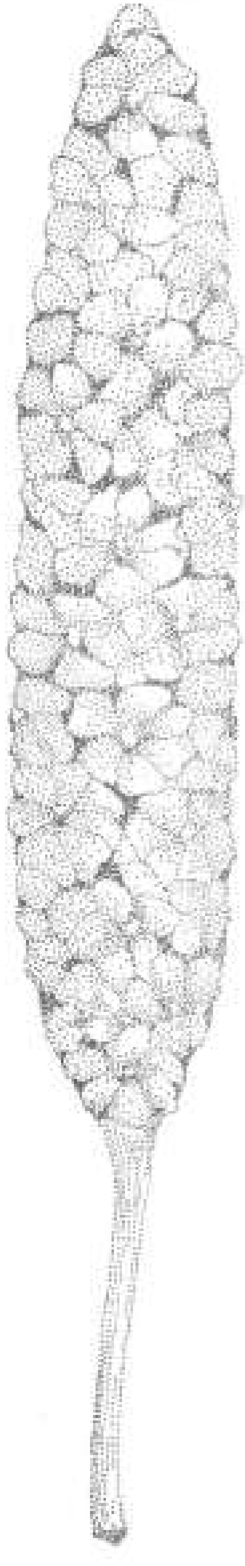
Kendosporites differs from *Laevigatosporites* in possessing sculptine ridges and grooves or stripes on its body. A separate genus *Latosporites* was established by Potonié and Kremp (1954) for those monolete spores which could also be accomodated under Schopf, *et al.* (1944) large genus *Laevigatosporites*. The genotype is *Latosporites latus* (Kosanke, 1950, Pl. 5, fig. 11) from the Upper Carboniferous (Pennsylvanian) and the type locality is from the northern hemisphere (Illinois, U.S.A.). The important generic characters of *Latosporites* are circular to subcircular shape, distinct monolete mark and laevigate to infrastructered exine. The southern *Kendosporites* could easily be distinguished from the northern *Latosporites* by the presence of prominent stripes and in possessing invariably a smooth spore wall. Furthermore, the striped spores occur in the Upper Permian of the southern hemisphere and now known to have belonged to a plant which could not have flourished in the northern hemisphere. The southern striped, monolete spore, therefore, is distinct from the northern Upper Carboniferous genus *Latosporites* and so a new generic name *Kendosporites* is proposed here for their reception.

Another genus *Luenaites* was established by Bose and Kar (1967) for monolete spore from the Palaeozoic of Congo. It differs from *Kendosporites* in the absence of stripes and in having punctate exine.

There is hardly any doubt that the striped spore described by Salujha (1965) as *Latosporites striatus* is identical to those obtained from the cone *Kendostrobus*. Although the single spore figured by Salujha (1965) is a little longer (longer axis 95-120μ) than the average spore of ours and possessed fewer stripes, these differences are insignificant. In our slides also many spores are much smaller and some much larger in size which depended on how the spores were compressed. Moreover, the number of stripes also vary in different spores; half a dozen stripes may become prominent while the others remain indistinct. The difference, therefore, are hardly sufficient to keep these two types under two different species. We have, therefore, merged them under *Kendosporites striatus* comb. nov.

Reconstruction — Text-fig. 5 shows a reconstruction of the cone of *Kendostrobus cylindricus*. The cone is compact, long, narrow, almost cylindrical organ which is attached on a long, slender stalk. Text-fig. 1 shows the mode of attachment of sporangia on the cone. 4 or 5 sporangia are attached in whorls to small knob-like protuberances on the cone axis. The sporangia are large, arranged in close spirals and appear crowded on the cone.

Comparison — *Kendostrobus cylindricus* is quite different from the other two known male fructifications, *Glossotheca* and *Eretmonia* assigned to Glossopteridales. *Kendostrobus* is a cone in which groups of sporangia are compactly arranged in close spirals on the cone axis, whereas in *Glossotheca* and *Eretmonia*, the sporangia are carried on a branched system, one sporangium being attached on each ultimate branch.



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TEXT-FIG. 5 — Reconstruction of *Kendostrobus cylindricus* gen. et sp. nov. × 4.

Furthermore, *Glossotheca* and *Eretmonia* bear sporangia whose surfaces are marked by longitudinally running parallel lines. Such sporangia when found in isolated condition are assigned to the genus *Arberiella*. They have elongated surface cells and contain two winged spores (Pant & Nautiyal, 1960). The sporangial surface of *Kendostrobus*, on the other hand, is studded with tiny, oval to circular depressions, giving it almost a spongy look. The genus *Lithangium*, to which isolated sporangia of *Kendostrobus* are referred, possesses relatively short sporangial cells and contain monolete spores. The arrangement of sporangia in whorls are also described in the genus *Perezlaria* by Delevoryas and Gould (1971) from the Middle Jurassic of Mexico, which are associated with leaves referable to *Glossopteris*. However, apart from similarity in the whorled arrangement of sporangia, there is absolutely no comparison whatsoever between *Kendostrobus cylindricus* and *Perezlaria oaxacensis* Delevoryas & Gould. The organization of *Kendostrobus* is thus quite different from those of *Glossotheca*, *Eretmonia* and other known male fructifications. Surange's (1957) original fructification, therefore, has been assigned here a new name.

It is true that this male reproductive organ has not been found attached to any scale leaf or a vegetative leaf as *Glossotheca* and *Eretmonia* which have been discovered borne on fertile scale leaves possessing *Glossopteris* type of venation. However, gymnospermic character of *Kendostrobus* cannot be doubted. The whole organizations of the fructification, viz., the aggregation of ex-annulate sporangia on a compact cone-like organ points to it's affinity with some gymnospermous plants. Glossopteridales is the dominant gymnospermous group present in this flora from Raniganj and it is likely that this male fructification may have also belonged to Glossopteridales.

Genus — *Eretmonia* Dutoit

Surange and Maheshwari (1970) emended the diagnosis of Du Toit's South African genus *Eretmonia* and described two species from India *Eretmonia utkalensis* and *Eretmonia hinjridaensis*. They also described another species *Eretmonia karanpurensis* from the Karanpura coalfield. We found a few more specimens of the first two species of *Eretmonia* from Orissa, which provided more details about it's structure. Besides, there is one more fertile scale leaf which is distinct from the other two species and so described below under a new specific name.

Eretmonia utkalensis Surange & Maheshwari

Pl. 1, fig. 3

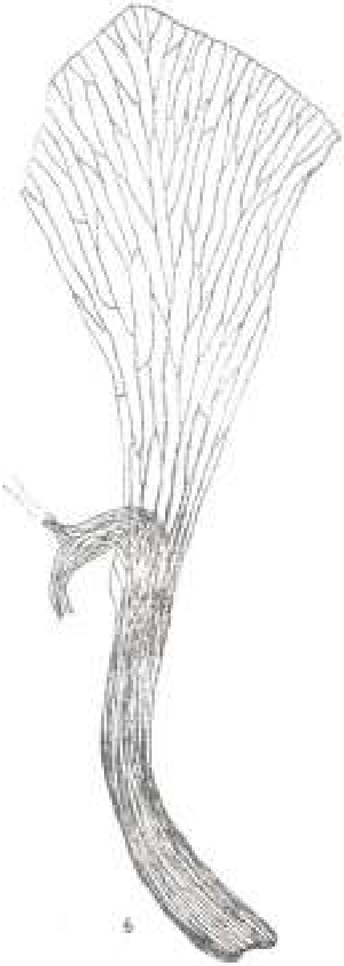
Pl. 1, fig. 3; Text-fig. 6 shows a fertile scale leaf of this species possessing characteristic short, diamond shaped lamina with an acute apex and a long stalk. The leaf is almost of the same size as described by Surange and Maheshwari (1970). Our specimen is 3·1 cm long and lamina is 8 to 10 mm. broad at the widest part. The stalk is 1·5 to 1·7 cm long and 2 mm broad. The thick lamina shows venation clearly (Text-fig. 6). There is no midrib, but about half a dozen vascular bundles enter the lamina from the stalk and bifurcate immediately into a dozen bundles. They diverge bifurcating twice or thrice, meeting one another and forming meshes. The bundles thin out towards the margin. The meshing is very distinct.

From near the base of the lamina arises a pedicel which is 1 mm in breadth. About 2 mm of it's entire length is preserved, but within this length the pedicel bifurcates (Text-fig. 6) into two branches, each brach is almost half its width. Neither further branching nor sporangial groups are preserved in our specimen. One thing is clear and that is only *one* pedicel is present in *Eretmonia utkalensis* as against three of four pedicels in *Glossotheca* Surange & Maheshwari. The two daughter branches must have further divided dichotomously to carry two sporangial clusters.

Eretmonia hinjridaensis Surange & Maheshwari

Pl. 1, fig. 6

Pl. 1, fig. 6; Text-fig. 7 shows a specimen of *Eretmonia hinjridaensis* in our collection. The fertile scale leaf is without a stalk, which shows that fructification bearing scale leaves were abscissed from the stalk once the pollen were released. The lamina is spathulate and broadest near the apex, the margins converging into an acute apex, which is



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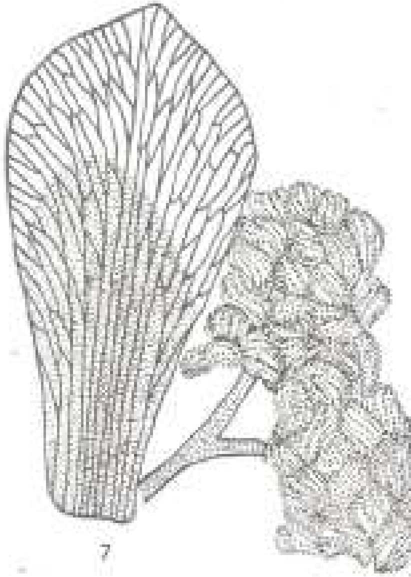

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not seen clearly in the type specimen. The lamina measures 1·7 cm in length and the maximum breadth reaches 7 mm, whereas at the base it is only 3 mm. The venation in our specimen is clearly preserved. About 8 or 9 strong vascular bundles enter into the lamina (from the stalk) and run straight upwards. The outer bundles give out secondary veins which dichotomise two or three times, anastomosing with the neighbouring bundles and forming meshes. In this species also the net venation is very clear.

Two sporangial clusters (Text-fig. 7) are seen here lying on the right side of the fertile scale leaf. There is a faint indication of a pedicel at the base of the lamina, bifurcating a little further up, and the daughter branches disappearing beneath the sporangial clusters. The sporangia are of same type as described by Surange and Maheshwari (1970). They are small and oval, showing parallel lines along the long axis. The sporangia look very much like those of *Arberiella* type described by Pant and Nautiyal (1960). This type of sporangia are common in the Glossopteris flora and were first recognized by Arber in 1905 *Glossotheca* also possesses *Arberiella* type of sporangia. Although no spores were present in our material, Pant and Nautiyal (1960) had earlier described two winged pollen grains from the *Arberiella* type of sporangia. It may, therefore, be safe to presume that both *Glossotheca* and *Eretmonia* also produced two winged pollen grains.

Eretmonia ovata sp. nov.

Pl. 1, figs. 4 & 5

Diagnosis — Male fructification; fertile scale leaf large, lamina ovate, 2·5 cm long, maximum breadth 1·6 cm; one pedicel bearing sporangial clusters branch by repeated dichotomy, one sporangium borne by each slender ultimate branch.

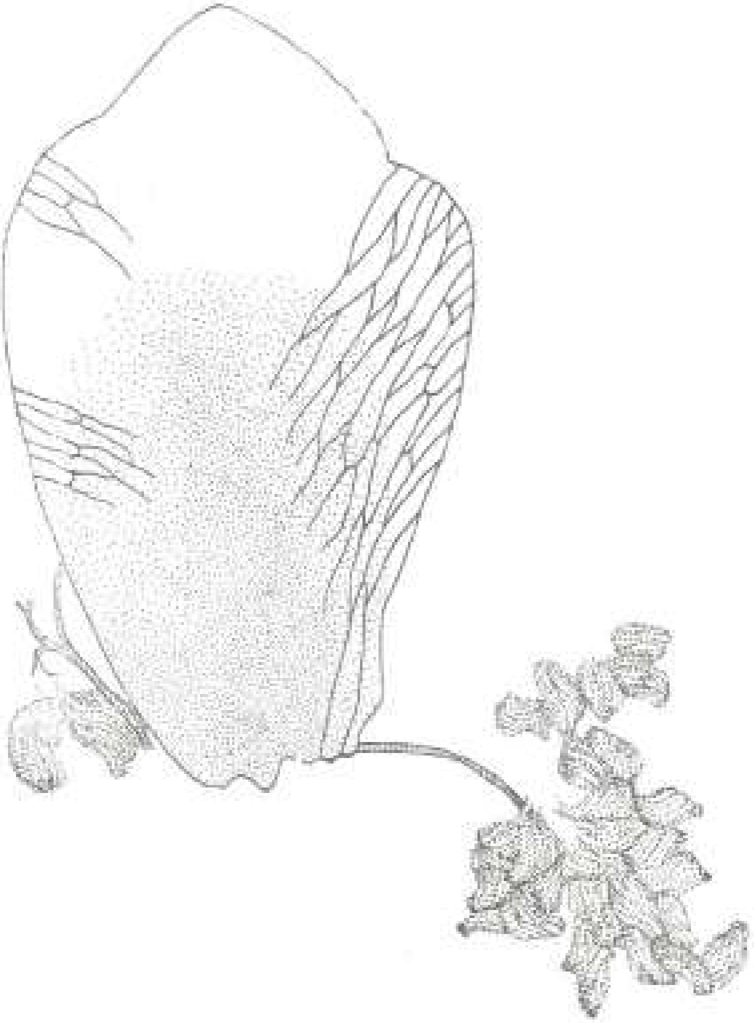
Holotype — 35143

Locality — Hinjrida Ghati, District Dhenkanal, Orissa.

←

TEXT-FIG. 6 — Fertile scale leaf of *Eretmonia utkalensis* Surange & Maheshwari showing venation and dichotomising pedicel. × 4.

TEXT-FIG. 7 — Fertile scale leaf of *Eretmonia hinjridaensis* Surange & Maheshwari showing venation and depression in the middle of the lamina. Note two sporangial clusters borne on a bifurcating pedicel. × 4.

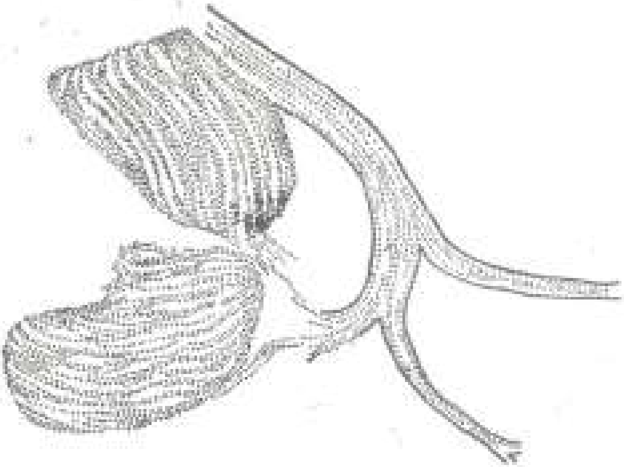


TEXT-FIG. 8 — Fertile scale leaf of *Eretmonia ovata* sp. nov. Note dichotomizing branches and two sporangia on the left side and a branch on the right side. Lamina shows depression in the middle and venation at the margin × 4.

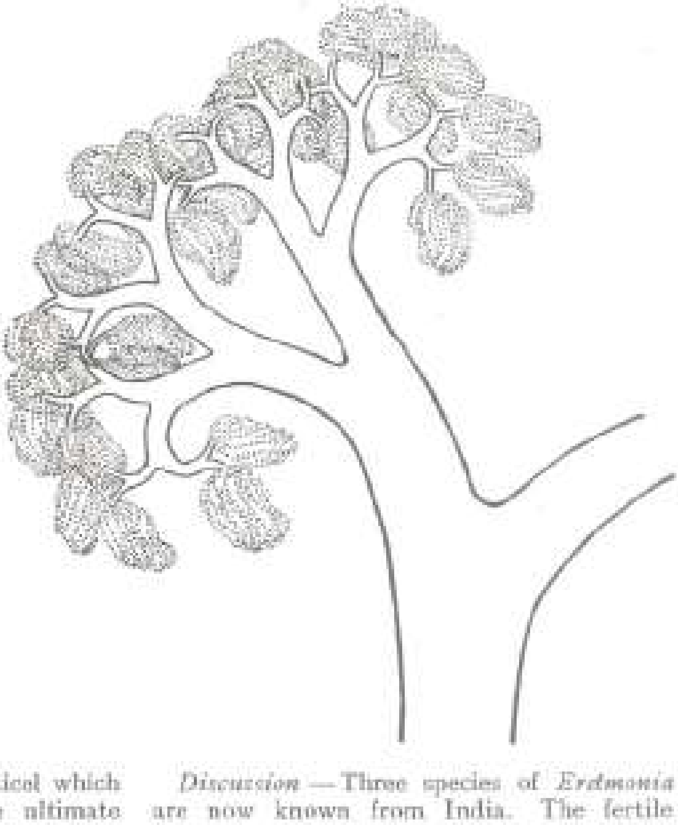
Horizon — Raniganj Stage.

Description — The fertile scale leaf (Pl. 1, fig. 4, 5; Text-fig. 8) is much larger than the scale leaves of *E. utkalensis* and *E. hinjridaensis*. The leaf without stalk measures 2·5 cm long and 1·6 cm broad at the widest part. The apical part forms a triangle with an actue apex. The venation is preserved only at some places towards the margin. The secondary veins dichotomise, anastomose with neighbouring veins and form meshes. The central bundles must have been similar to those in other species of *Eretmonia*.

One cluster is seen lying at the bottom with one branch of pedicel, 5 mm long and 5 mm broad (Pl. 1, fig. 4; Text-fig. 8). The pedicel is not actually attached to the fertile scale leaf, but it appears that it had broken off. There is, however, hardly any doubt that the sporangia were borne on this scale leaf. There are also some finer branches and some sporangia preserved on the other side of the leaf. Text-fig. 8



TEXT-FIG. 9 — A branch bifurcates thrice and the ultimate branches in one bear one sporangium each at their apices. × 20.



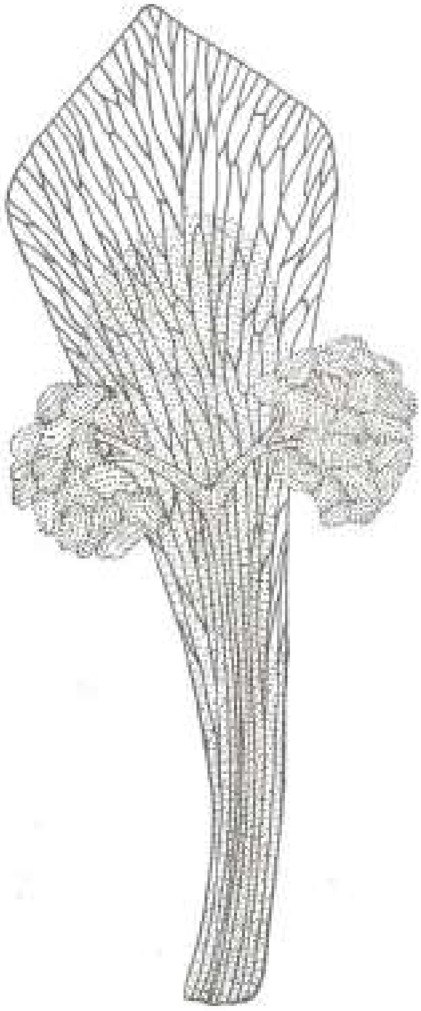
TEXT-FIG. 10 — Drawing of a dichotomously dividing branching system of a pedicel of *Eretmonia* bearing sporangia on the ultimate branches. × 15.

shows one slender branch of pedicel which bifurcates three times and the ultimate bifurcation carries one sporangium on each branch (Text-fig. 9). In *Eretmonia*, therefore, the sporangia are also borne on the dichotomising branch system as in *Glossotheca utkalensis* Surange and Maheshwari (Surange & Chandra, 1974).

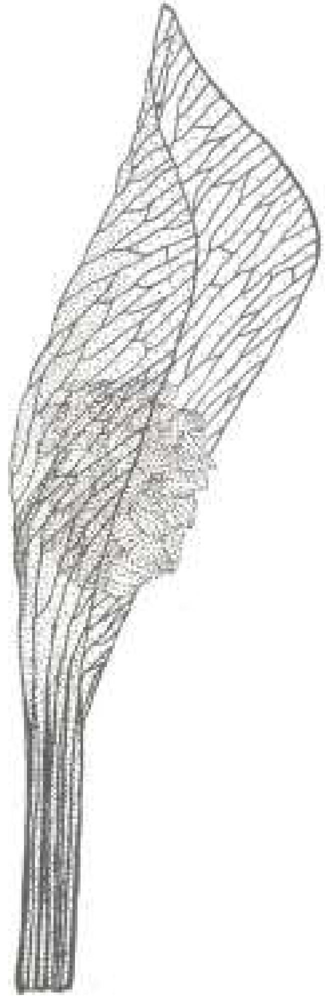
Discussion — Three species of *Eretmonia* are now known from India. The fertile scale leaf is different in shape and size in different species. It is safe to assume that different species of plants would possess different types of microsporophylls. All of them, however, have almost the same type of venation. There is no well defined midrib, but a number of strong vascular bundles enter from the stalk into the lamina and the outer bundles go on giving out dichotomising and anastomosing scondary veins. Mode of attachment of sporangia in all the three species is the same. The species, therefore, are distinguished at present on the basis of shape and size of the fertile scale leaves.

SPORANGIAL CLUSTERS IN *ERETMONIA*

The fertile leaves of *Eretmonia* are thin at the margin and often show a depression in the middle of the lamina (Text-fig. 11 & 12). Sometimes detached sporangia are also found compressed in the depressed part of the lamina. Du Toit (1932) had also found them in *Eretmonia natalensis* and in fact suspected that the sporangia were actually attached to the lamina. It appears that this type of fertile scale leaf served as protective covering to the sporangial clusters which were borne in its axil. The depression in the lamina might have covered the sporangial clusters and thus offering them protection in young condition. Text-fig. 12 illustrates diagrammatically a side view of the fructification of *Eretmonia* showing



TEXT-FIG. 11 — A reconstruction of *Eretmonia* showing front view. × 4.



TEXT-FIG. 12 — A diagrammatic reconstruction of *Eretmonia* in lateral view showing how the sporangial clusters could be protected in the depression of lamina of fertile scale leaf. × 4.

how the sporangial clusters could have been protected by the fertile scale leaf.

The mode of attachment of sporangia in *Eretmonia* is brought out by different types of branches seen in association with the sporangial clusters in three species of *Eretmonia* described above. In all the species of *Eretmonia* only one pedicel is present. It arises from base of the lamina of the fertile scale leaf and divides into two equal daughter branches, which are almost half in breadth (Text-figs. 6, 7, 10). Each daughter branch carries one sporangial cluster at its apex. The daughter branches then divide higher up by repeated dichotomy and at the same time reducing progressively in size (Text-fig. 11). By measuring the diameter of the pedicel and the ultimate branches, it can be surmised that each daughter branch divides five or six times. The number of sporangia in each cluster must have been normally from 28-32. In actual counting the number did not exceed 32. The last two to three divisions are shown in Text-figs. 8 to 9. The finer dichotomous divisions occur at short distances until fine, ultimate segments bearing sporangia are produced (Text-fig. 9). This is how the pedicel in *Eretmonia* must have divided repeatedly and dichotomously producing a three dimensional branch system which is shown diagrammatically in Text-fig. 10. Thus the sporangia bearing branch system in *Eretmonia* is on the same pattern as in *Glossotheca*. It is, therefore, safe to presume that *Eretmonia* and *Glossotheca* were closely related and both were perhaps related to Glossopteris plants.

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EXPLANATION OF PLATES

PLATE 1

1. The type specimen of *Kendostrobus cylindricus* gen. et sp. nov. B.S.I.P. no. 19512. Long slender stalk is seen on the left side. × *Ca* 1·5.

2. A part of the specimen shown in Fig. 1 enlarged to show groups of 4-5 sporangia arranged in whorls around a small circular protuberance. × 10.

3. *Eretmonia utkalensis* Surange & Maheshwari. The specimen shows short lamina with an acute apex and a long stalk. Note the pedicel bifurcating into two daughter branches. × *Ca* 2·5.

4. Type specimen of *Eretmonia ovata* sp. nov. B.S.I.P. 35143. Note the sporangial clusters at the bottom left with a long slender branch going under it. × Ca. 2.

5. Dichotomizing branches of the pedicel of *Eretmonia ovata* sp. nov. × Ca. 20.

6. *Eretmonia hinjridaensis* Surange & Maheshwari. Two sporangial clusters are seen lying on the right side of the fertile leaf. × Ca. 3.

7-8. Monolete spores from *Kendostrobus cylindricus*. × 400.

PLATE 2

9-25. Spores from *Kendostrobus cylindricus*, showing variations. Figures 9, 12, 13, 14 and 23 show unmacerated spores with sculptine ridges. × 400.


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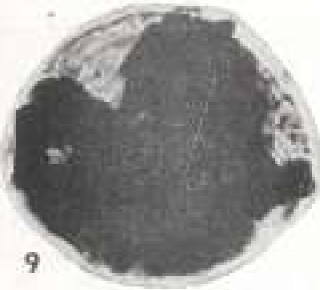
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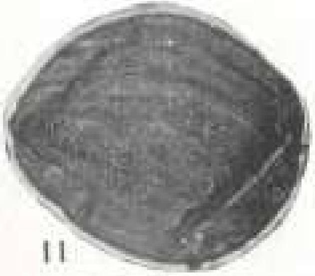
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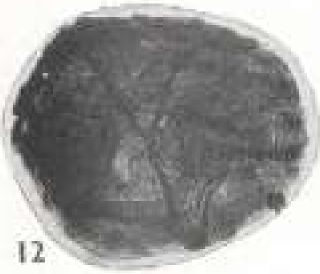
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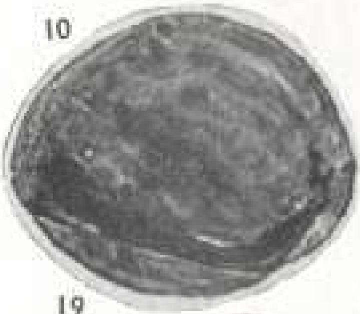
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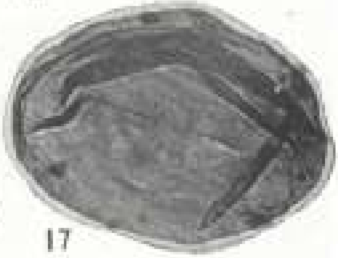
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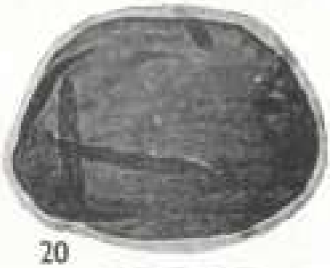
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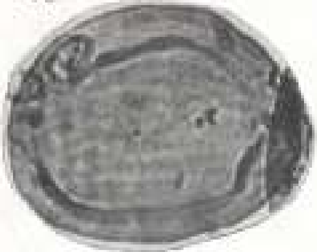
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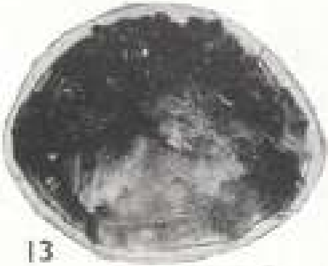
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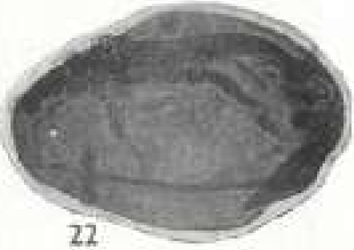
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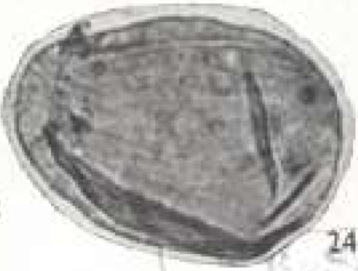
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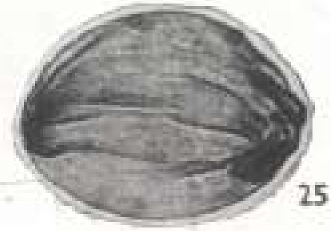
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PALYNOLOGY OF THE SOUTH SHILLONG FRONT PART II — THE PALAEOGENES OF KHASI AND JAINTIA HILLS

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ABSTRACT

Palynological study of 90 samples of the Palaeogene sediments collected from five traverses on the south of Khasi and Jaintia hills has yielded a rich assemblage of spores, pollen and microplankton including a few dinoflagellates and fungal spores. In this area, sediments of mainly shelf facies are exposed but near Haflong both shelf and geosynclinal facies lie very close. Stratigraphic sequence of the shelf facies consists of Langpar, Therria, Sylhet Limestone, Kopili and the undifferentiated Barail Sediments. In the geosynclinal part, over the Disangs lie the Barails which are differentiated into Laisong, Jenam and Renji Formations. The palynofossils recovered here are assigned to 41 genera and 67 species, out of which 23 species are newly proposed. Based on quantitative assessment of the marine and terrestrial forms, palaeoecological interpretations are made. The sediments studied here are homotaxial with the Palaeogene sediments of the Garo hills. The Disangs which were hitherto reported to be barren have yielded a good number of fossils.

INTRODUCTION

THE Khasi and Jaintia hills constituting eastern half of the Shillong Plateau or the Meghalaya show an excellent development of Tertiary rocks of both marine and non-marine nature. Palynological studies of the Tertiary sediments of Assam have been attempted by many workers like Sahni, Sitholey and Puri (1947), Sen (1948), Biswas (1962), Baksi (1962), Ghosh and Banerjee (1963), Sah and Dutta (1966, 1968), Srivastava and Banerjee (1969), Ghosh (T. K., 1969), Dutta and Sah (1970), Sah *et al.* (1970) and Kar *et al.* (1972), but no detailed regional study has so far been made. A systematic study of palynological fossils from the Palaeogene sediments along the South Shillong Front was taken up as a project at the Institute of Petroleum Exploration by the present authors. Results of a study of the palynofossil assemblages from the Palaeogene sediments of Garo hills are presented in the first part of this paper (Salujha *et al.*, 1971). The present paper incorporates results of a palynological study of the Palaeogene sediments of the Khasi and Jaintia hills. Ninety samples of shales, sandstones and limestones collected from five traverses of this area are studied here.

STRATIGRAPHY

Sediments of mainly shelf facies are exposed in the Khasi-Jaintia hills but towards east of the area near Haflong both shelf and geosynclinal facies lie very close. The oldest sediments lying unconformably over the Sylhet Trap or rocks of the Shillong Series are the Mahadeks which are divided into Mahadek and Langpar Formations. These beds show gradual thinning towards north as well as to east. The Langpar Formation is overlain by the Therria Formation. It consists of limestone at the base followed by sandstone at the top. The limestone is developed only on the southern side of the plateau and its place in the plateau area is taken over by the Cherra Sandstone. The contact between the Langpar and Therria Formations seems to be conformable. The Tura Sandstone of Garo hills has been correlated with the Cherra Sandstone. The Cherra Sandstone seems to be conformably overlain by the Sylhet Limestone Formation which consists of alternation of thick limestone and coarse grained sandstone. Based on broad lithological characters this formation has been divided into 5 members namely Lakadong Limestone, Lakadong Sandstone, Umlatdoh Limestone, Narpuh Sandstone and Prang Limestone. The Sylhet Limestone Formation is conformably overlain by the Kopili Formation, youngest member of the Jaintia group. It consists of alternation of sandstone and shales. The Kopili Formation is conformably overlain by sediments of the Barail group. The Barail rocks were deposited both in the shelf and geosynclinal parts with the only difference that in the shelf part it is very thin and more arenaceous and carbonaceous in comparison to the geosynclinal part. In the geosynclinal part the Barails are more than 10,000 ft. thick (Srivastava *et al.* 1969) and have been divided into three formations i.e. Laisong, Jenam and Kenji depending upon predominance of sandstone over shale. The Barail group shows general thinning to the west.

Generalized rock stratigraphic sequence in the geosynclinal and the shelf facies is as follows.

Geosynclinal facies:

Probable age	Group	Formation
Oligocene	Barail	Renji Jenam Laisong
Eocene to Upper Cretaceous	Disang	

Shelf facies:

Probable age	Group	Formation	Member
Oligocene	Barail	Undifferentiated	—
		Kopili	Prang Lst. Narpuh Sst. Umlatdoh. Lst.
Eocene	Jaintia	Sylhet Limestone	Lakadong Sst. Lakadong Lst.
		Therria	Cherra/Therria Sst. Therria Lst.
		Langpar	—
Upper Cretaceous	Mahadek	Mahadek	Mahadek Sst. Borghat conglomerate member
	Unconformity		
Lr.-Mid. Jurassic	Sylhet Trap		Sylhet Trap

MATERIAL AND METHODS

Ninety samples belonging to various formations of the Palaeogenes of Khasi-Jaintia hills are studied. These samples belong to five traverses namely Umsohryngkew, Hari river, Prang river, Lubha river and Bali-chara Nadi (Map). The stratigraphic formations to which these samples belong are tabulated as under:

Barails ... 11	Renji	5	
	Jenam	15	
	Laisong	26	
Jaintia	Kopili	12	
	Sylhet	3	Disangs ... 9
	Therria	2	
	Langpar	7	

Microfossils are recovered from the rock samples by the use of Hydrofluoric acid, Nitric acid and Potassium hydroxide. An alternative treatment by the use of Sodium pyrophosphate is also given for this purpose. Sporiferous material is separated by using heavy liquid of specific gravity 2·2. Polyvinyl alcohol and Canada balsam are used for mounting slides.

Quantitative assessment of the various palynomorphs is made by counting 200 grains for each sample and their frequencies are plotted for zonation and correlation of sediments.

SYSTEMATIC PALYNOLOGY

The palynomorphs recovered from the Palaeogene sediments of Khasi-Jaintia hills consists of 41 genera and 67 species. Spores and pollen are classified according to the system proposed by Potonié (1956, 1958, 1960, 1966). Microplankton are arranged according to the system of classification proposed by Downie *et al.* (1963). The species already recorded are listed whereas others which are new are described.

Anteturma — *Sporites* H. Pot. 1893.
Turma — *Triletes* (Reinsch, 1881) Pot. & Kr. 1954.
Subturma — *Azonotriletes* Luber, 1935.
Infraturma — *Laevigati* (Benn. & Kids. 1886) Pot. 1956.

Genus — *Cyathidites* Couper, 1953.

Genotype — *Cyathidites australis* Couper, 1953.

Cyathidites (Leiotriletes) dehiscensi (Baksi, 1962) Sal., Kind. & Keh. 1971.

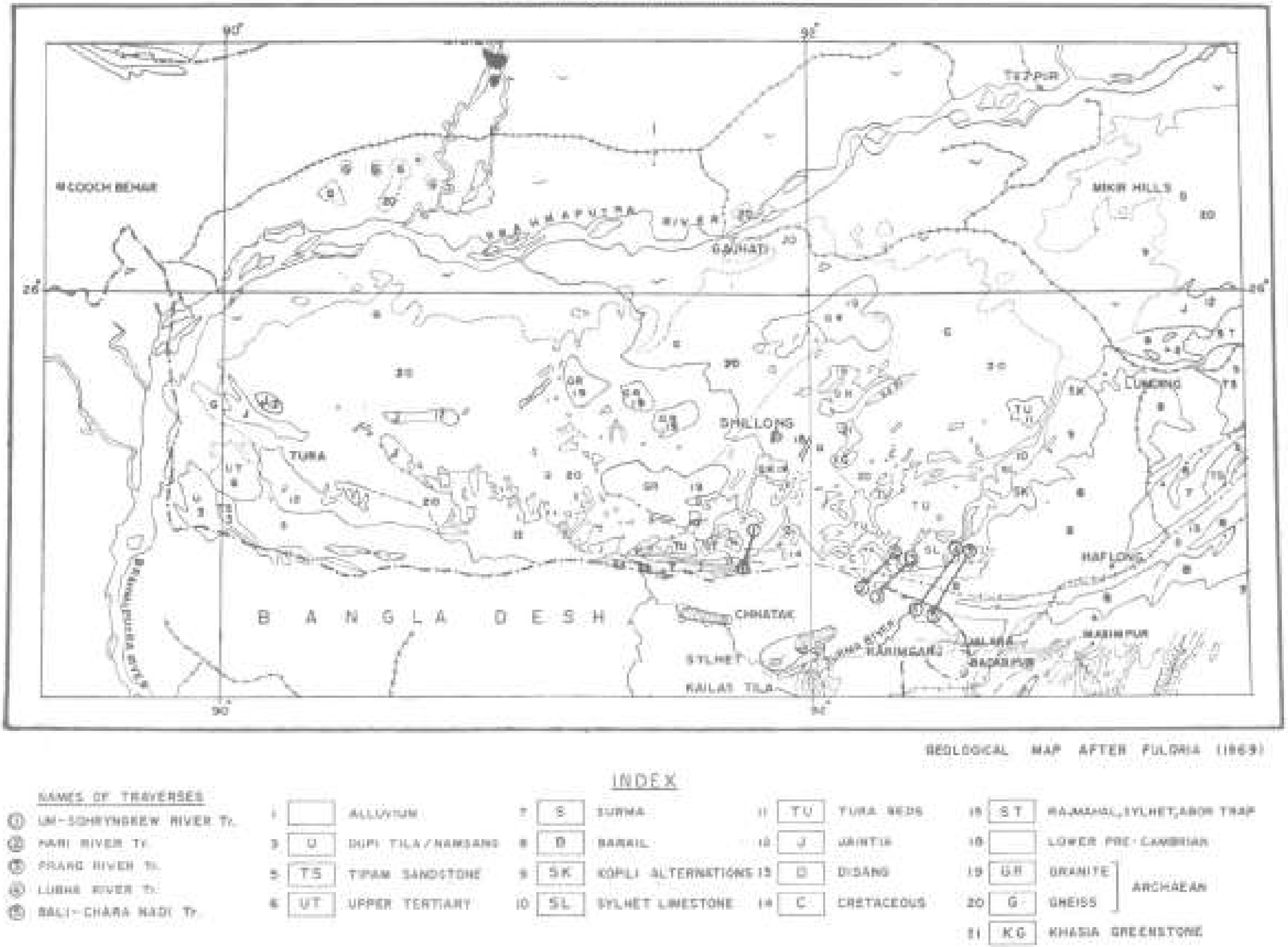
Pl. 1, fig.1

Cyathidites magnanimus sp. nov.

Pl. 1, figs. 2-3

GEOLOGICAL MAP SHOWING POSITION OF TRAVERSES ON THE SOUTH OF KHASI-JAINTIA HILLS

SCALE :- 1:1000,000 OR 1" TO 15·78 MILES



Holotype — Pl. 1, fig. 2.

Type locality — Jenam Formation, Haflong Silchar road traverse, District Cachar.

Diagnosis and description — Golden yellow, triangular with straight to slightly convex sides, size 48·4-74 μ; trilete mark distinct, open, indicated by a triangular, thin area, rays 3/4 or more the radius long, with a 4-6 μ wide inter-ray thickening; exine over 1 μ thick, faintly structured with sparsely arranged foveolations.

Comparison — The present species differs from *Cyathidites* (*Leiotriletes*) *garoensis* (Salujha *et al.*, 1971; Pl. 1, figs. 3-4) in having a wider inter-ray thickening and the exine bearing distinct foveolations.

Botanical affinity — Cyatheaceae.

Cyathidites sp.

Pl. 1, fig. 4

Description — Golden yellow, triangular with rounded angles and almost straight sides, size 56 μ; trilete mark faintly discernible, rays 1/2-2/3 the radius long with pointed ends; exine 1·2-1·5 μ thick, granulose, grana ±1 μ in diameter, sparsely spaced.

Comparison — *Leiotriletes virkii* (Biswas, 1962; Pl. 9, fig. 53) distinguishes in having a finely granulose ornamentation and the transverse folds at the tip of the rays.

Genus — *Stereisporites* Thoms. & Pfl. 1953.

Genotype — *Stereisporites stereoides* (Pot. & Ven. 1934) Thoms. & Pfl. 1953

Stereisporites formosus sp. nov.

Pl. 1, figs. 5-6

Holotype — Pl. 1, fig. 5.

Type locality — Jenam Formation, Haflong-Silchar road traverse, District Cachar.

Diagnosis and description — Brown, triangular to subcircular with convex sides, size 33·4-58·6 μ; Y-mark distinct, rays 3/4 the radius long or more with blunt ends; exine ±1·5 μ thick, distinctly granulate, grana over 1 μ wide, closely spaced, occasionally coalescing to give a reticulate appearance.

Comparison — *Stereisporites assamensis* (Sah & Dutta, 1968; Pl. 1, fig. 2) has a thicker exine which is smooth with elevated lips of the laesura. cf. *S. ambiguus* recorded by Salujha *et al.* (1971; Pl. 1, figs. 6-7) is bigger in size with a distinct labra along the Y-rays and the exine is foveolate.

Botanical affinity — ? Cyatheaceae.

Genus — *Biretisporites* (Delc. & Sprum. 1955) Delc., Dettman & Hughes, 1963.

Genotype — *Biretisporites potoniaei* Delc. & Sprum. 1955

Biretisporites singularis sp. nov.

Pl. 1, fig. 7

Holotype — Salujha *et al.* 1971; Pl. 1, fig. 9.

Type locality — Renji Formation, Lubha river traverse, Khasi-Jaintia hills.

Diagnosis and description — Light brown, roundly triangular with straight sides, size 44·8-54·2 μ; trilete mark distinct, arms raised, almost 2/3 the radius long, enveloped by a 1·5-2 μ broad lip on either side of the rays, lips appear to be over turning; exine 1·2-1·5 μ thick, almost smooth to faintly ornamented, occasionally giving a variegated appearance.

Comparison — *Biretisporites triglobosus*, (Sah and Dutta, 1966; Pl. 1, figs. 11-12) which is later included under *Dandotiaspora dilata* by Sah *et al.* (1971), differs from the present species in being larger in size with its exine thickened on distal side and the ray ends dilating into globular structures. *B. bellus* (Sah and Kar, 1969; Pl. 1, figs. 4-5) is smaller in size and the trilete rays extendingupto the equator. *Biretisporites* sp. recorded by Dutta and Sah (1970; Pl. fig. 12) has laesura of the trilete mark extending upto the periphery.

Botanical affinity — ?Matoniaceae.

Infraturma — *Murornati* Pot & Kr. 1954.

Genus — *Foveosporites* Balme, 1957.

Genotype — *Foveosporites canalis* Balme, 1957.

Foveosporites spectabilis sp. nov.

Pl. 1, fig. 8

Holotype Salujha *et al.* 1971; Pl. 1, fig. 14.

Type locality — Kopili Formation, Lubha river traverse, Khasi-Jaintia hills.

Diagnosis and description — Golden yellow, roundly triangular with straight to curved sides, measuring 28·8-52·8 μ; trilete mark distinct, sometimes open, rays 2/3-3/4 the radius long, ends pointed; exine ±1 μ thick, microfoveolate, foveola ±1 μ wide, sparsely spaced.

Comparison — *Foveosporites canalis*, the genotype illustrated by Balme (1957; Pl. 1, figs. 15-17) has laesurae with raised lips and extending right upto the periphery of the spore. *F. pachyexinous* and *F. triangulus* (Dutta and Sah, 1970; Pl. 2, figs. 24-27, Pl. 2, figs. 22-23 differ in having a thicker exine and laesura of the trilete mark reaching the equator. *Foveosporites* sp. (Sah and Kar, 1969; Pl. 1, fig. 23) is subcircular, bigger in size with a thick exine.

Botanical affinity — Uncertain.

Genus — *Lycopodiumsporites* (Thierg. 1938) Delc. & Sprum. 1955.

Genotype — *Lycopodiumsporites agathoecus* (R. Pot. 1934) Thierg. 1938.

Lycopodiumsporites parvireticulatus Sah & Dutta, 1966.

Pl. 1, fig. 9

Lycopodiumsporites rarus sp. nov.

Pl. 1, figs. 10-11

Holotype — Pl. 1, fig. 10.

Type locality — Therria Formation, Umsohryngkew traverse, Khasi-Jaintia hills.

Diagnosis and description — Brown, triangular with rounded angles with almost straight sides, size 36·8-72 μ; trilete mark distinct, rays 3/4 the radius long; exine 1-1·5 μ thick, faintly but finely reticulate, muri over 1 μ thick, lumina usually 1-1·5 μ wide, muri seen protruding at the margin.

Comparison — The present species differs from *Lycopodiumsporites parvireticulatus* (Sah and Dutta, 1966; Pl. 1, figs. 1-4 in having a faintly reticulate exine with incomplete muri forming lumina of varying shapes. *L. bellus* recorded by Sah and Kar (1969; Pl. 2, figs. 9a-11) differs in being smaller with a thicker exine and coarsely reticulate ornamentation. *L. palaeocenicus* (Dutta and Sah, 1970; Pl. 2, figs. 53-55, 58-59) has comparatively larger meshes and distinctly raised muri.

Botanical affinity — Lycopodiales

Lycopodiumsporites insignis sp. nov.

Pl. 1, figs. 14-15

Holotype — Pl. 1, fig. 14.

Type locality — Kopili Formation, Umiew river traverse, Khasi Jaintia hills.

Diagnosis and description — Light brown, subcircular, measuring 42·6-50·8 × 52·8-61·2 μ; trilete mark distinct, rays 2/3-3/4 the radius long, ends pointed; exine over 1·5 μ thick, finely reticulate with prominent 1-1·5 μ broad lumina, muri ±1 μ thick, grains occasionally folded.

Comparison — *Lycopodiumsporites elegans* recorded by Salujha *et al.* (1971; Pl. 1, figs. 19-20) resembles the present species in its subcircular appearance but differs in having longer laesura and coarsely reticulate exine. *L. bellus* (Sah and Kar, 1969; Pl. 2, figs. 9a-11) differs in being smaller with a thicker exine and coarsely reticulate ornamentation. *L. palaeocenicus* (Dutta and Sah, 1970; Pl. 2, figs. 53-55, 58-59) has larger meshes and distinctly raised muri.

Botanical affinity — Lycopodiales.

Lycopodiumsporites sp. A

Pl. 1, fig. 12

Description — Brown, triangular with convex sides, measuring 56·8 μ; trilete mark present, rays reaching almost upto the equator; exine over 1·5 μ thick, finely reticulate, muri over 1 μ thick enclosing ±1·5 μ wide lumina, muri seen protruding at the margin.

Comparison — *Lycopodiumsporites abundans* recorded by Salujha *et al.* (1971; Pl. 1, figs. 17-18) is bigger in size with a thin inter-ray thickening and exine ornamented with incomplete mesh work.

Lycopodiumsporites sp. B

Pl. 1, fig. 13

Description — Brown, triangular with rounded angles and concave sides, size 62·8 μ; trilete mark distinct, rays reaching almost upto the equator; inter-ray area showing a 3-4 μ wide thickening; exine over 2 μ thick, coarsely reticulate, muri broken, forming an incomplete meshwork.

Comparison — The present species distinguishes in having a very wide thickening along the Y-rays and a coarsely reticulate ornamentation on the exine. *L. palaeoconicus* recorded by Dutta and Sah (1970; Pl. 2, figs. 53-55, 58-59) lacks the characteristic thickening along the laesura of the trilete mark.

Genus — Magnastriatites Germ., Hopp. & Muller, 1968.

Genotype — *Magnastriatites howardi* Germ., Hopp. & Muller, 1968.

Remarks — Germeraad, Hopping and Muller (1968) created a new genus *Magnastriatites* distinguishing it from *Cicatricosisporites* by its coarsely striate ornamentation, larger size and a circular ridge surrounding the proximal contact area. The specimens recovered here and those included under *Cicatricosisporites venustus* by Salujha *et al.* (1971; Pl. 1, figs. 22-23) conform to the generic diagnosis of *Magnastriatites*, thus they are transferred to this genus.

Magnastriatites venustus Sal., Kind, & Reh. 1971

Pl. 1, fig. 16

Genus — Cicatricosisporites (Pot. & Gell. 1933) Pot. 1966

Genotype — *Cicatricosisporites dorogensis* Pot. & Gell. 1933.

Cicatricosisporites sp.

Pl. 1, fig. 17

Description — Golden yellow roundly triangular, measuring 56·8 μ; trilete mark faintly discernible, terminating limits of the laesura not clear; exine ±1·2 μ thick, striated, striations 1·5-2 μ wide, area in between the adjoining striations 3·5-4·5 μ wide, smooth.

Comparison — *Cicatricosisporites pudens* recorded by Salujha *et al.* 1971; Pl. 1, figs. 24-25) differs in having a distinct and raised trilete mark with a thick labra and foveolate inter-striation area.

Botanical affinity — Parkeriaceae.

Genus — *Corrugatisporites* (Thoms. & Pflug) Weyl. & Greif. 1953.

Genotype — *Corrugatisporites toratus* Weyl. & Greif. 1953.

Corrugatisporites sp.

Pl. 1, fig. 18

Description — Brown, triangular with straight to slightly convex sides, measuring 53·6 μ; trilete mark distinct, arms 3/4 the radius long, with a ±2·5 μ wide inter-radial thickening; exine ±2·5 μ thick, rugulate, rugulae coalescing to give a reticulate appearance, sometimes protruding at the margin.

Comparison — The present species differs from *Corrugatisporites lepidus* (Salujha *et al.*, 1971; Pl. 2, figs. 27-28) in being larger, with short laesura and a wide thickening inbetween them. *C. formosus* (Dutta and Sah, 1970; Pl. 2, figs. 16-20) has a faint trilete mark and lacks the inter-radial thickening.

Botanical affinity — *Lygodium* (Schizaeaceae).

Turma — *Zonales* (Benn. & Kidst. 1886) Pot. 1956
Subturma — *Zonotriletes* Waltz, 1935
Infraturma — *Cingulati* Pot. & Kl. 1954

Genus — *Polypodiaceoisporites* Pot. 1951

Genotype — *Polypodiaceoisporites speciosus* (Pot. 1934) Pot. 1951.

Polypodiaceoisporites idoneus Sal., Kind. & Reh. 1971.

Pl. 1, fig. 19

Remarks — The cingulum enveloping the body is 4·5 μ wide whereas its width in the specimens recorded earlier is 2·5-4 μ. Thus the cingulum may be considered to be ranging from 2·5-4·5 μ in width.

Polypodiaceoisporites sp.

Pl. 1, fig. 20

Description — Golden yellow, roundly triangular with slightly convex sides, size 35·6 μ; cingulum 2-2·5 μ wide enveloping the inner body; trilete mark distinct, arms reaching up to the margin of the inner body; cingulum smooth, body faintly structured.

Comparison — The present species lacks distinct muri covering the body distally which is a characteristic feature of *P. idoneus* (Sal., Kind, & Reh. 1971; Pl. 2. figs. 29-30).

Botanical affinity — Uncertain.

Turma — *Monoletes* Ibr. 1933
Subturma — *Azonomonoletes* Luber, 1935
Infraturma — *Laevigatomonoleti* Dyb. & Jachow. 1957

Genus — *Laevigatosporites* Ibr. 1933

Genotype — *Laevigatosporites vulgaris* (Ibr. 1932) Ibr. 1933.

Laevigatosporites copiosus Sal., Kind, and Reh. 1971.

Pl. 1, fig. 21

Laevigatosporites caecus sp. nov.

Pl. 1, figs. 22-24

Holotype — Pl. 1, fig. 22.

Type locality — Renji Formation, Lubha river traverse, Khasi-Jaintia hills.

Diagnosis and description — Light brown, elliptical, measuring 18·6-54·6 × 12·4-42·8 μ; monolete mark faintly discernible in most of the specimens, occasionally distinct, running over 3/4 or whole length of the, longer axis; exine 2-3·5 μ thick, foveolate, foveola of irregular shapes, sparsely spaced.

Comparison — *Laevigatosporites lakiensis* (Sah and Kar, 1969; Pl. 2, figs. 13-18) is bigger in size with its monolete mark less than half the longer axis and laevigate exine. *L. copiosus* described by Salujha *et al.* (1971; Pl. 2. figs. 35-36) is smaller in size with a thinner exine. *Psilamonoletes* sp. (Banerjee, 1966; Pl. 1, fig. 2) compares closely and may belong to this species.

Infraturma — *Sculptatomonoleti* Dyb. & Jachow. 1957

Genus — *Schizaeoisporites* Pot. 1951

Genotype — *Schizaeoisporites eocaenicus* (Selling, 1944) Pot. 1956.

Schizaeoisporites sp.

Pl. 2, fig. 25

Description — Brown, oval, measuring 74·2 × 52·8 μ; monolete mark faintly discernible, its terminating limits not clear, exine 1·5-2 μ thick, striated, striations 1·2-1·5 μ wide, running parallel to each other, exine in between the striations coarsely, foveolate, foveola of varying shapes and sizes.

Comparison — *Schizaeoisporites crassimurus* (Dutta and Sah, 1970; Pl. 3, figs. 32-34) differs in being smaller in size with a distinct monolete mark and laesura 2/4 the longer axis with few but thicker ridges on the exine.

Genus — *Polypodiisporites* (Pot. 1934) Pot. 1956

Genotype — *Polypodiisporites favus* (Pot. 1931) Pot. 1934.

Polypodiisporites speciosus Sah, 1967.

Pl. 2, figs. 26-28

Polypodiisporites splendidus Sal., Kind, and Reh. 1971.

Pl. 2, fig. 29

Anteturma — *Pollenites* Pot. 1931
Turma — *Saccites* Erdt. 1947
Subturma — *Disaccites* Cooks. 1947
Infraturma — *Podocarpoditi* Pot., Thoms. & Theirg. 1950

Genus — *Podocarpidites* (Cooks. 1947) Pot. 1958

Genotype — *Podocarpidites ellipticus* Cooks, 1947

Podocarpidites classicus Sal., Kind. & Reh. 1971

Pl. 2, fig. 30

Infraturma — *Pinosacciti* (Erdt. 1945) Pot. 1958

Genus — *Alisporites* Daugherty, 1941

Genotype — *Alisporites opii* Daugherty, 1941.

Alisporites sp.

Pl. 2, fig. 31

Description — Golden yellow, bilateral, bisaccate, overall size 94·4 × 48·6 μ; central body broadly oval, outline faintly discernible, measuring 52·8 × 40 μ, smaller than the bladders in height, foveolate, foveola sparsely arranged, 1·2-1·5 μ broad, bladders hemispherical, microreticulate, attached distally leaving *a* ± 20·8 μ wide straight to slightly biconvex sulcus.

Comparison — *Alisporites clarus* recorded by Salujha *et al.* (1971; Pl. 2, figs. 46-47) has a distinct central body ornamented with grana and with a narrower sulcus distally. *Alisporites* sp. (Sah and Dutta, 1968; Pl. 1, fig. 10) is smaller in size with a vertically oval central body.

Turma — *Aletes* Ibr. 1953
Subturma — *Azonaletes* (Lub. 1935) Pot. & Kr. 1954
Infraturma — *Psilonapiti* Erdt. 1947

Genus — *Inaperturopollenites* (Thoms. & Pflug, 1953) Pot. 1958

Genotype — *Inaperturopollenites dubius*, (Pot. & Ven. 1934) Thoms. & Pflug, 1953.

Inaperturopollenites mirabilis sp. nov.

Pl. 2, figs. 32-34

Holotype — Pl. 2, fig. 32.

Type locality — Kopili Formation, Prang river traverse, Khasi-Jaintia hills.

Diagnosis and description — Golden yellow, normally circular, usually folded giving a subcircular appearance, size 32·4-62 μ; exine over 1 μ thick, granulose, grana ±1·5 μ wide, closely spaced, occasionally coalescing to give a reticulate appearance.

Comparison — *Retiinaperturites depressus* recorded by Mathur (1966; Pl. 1, fig. 11) has a reticulate exine. The present species distinguishes in having a coarsely granulate exine.

Infraturma — *Spinonapiti* Erdt. 1947

Genus — *Peltandripites* Wodehouse, 1933

Genotype — *Peltandripites davisii* Wodehouse, 1933.

Peltandripites fastidiosus sp. nov.

Pl. 2, figs. 35-38

Holotype — Pl. 2, fig. 35.

Type locality — Kopili Formation, Lubha river traverse, Khasi-Jaintia hills.

Diagnosis and description — Light brown, normally circular, appearing subcircular due to folding or compression, size 18·6-35·6 μ; without any germinal mark; exine 1-1·5 μ thick, ornamented with sparsely arranged 1·5-2 μ long, ±1·5 μ wide uniformly, sharp to blunt tipped coni, sometimes coni protruding at the margin.

Comparison — *Peltandripites dubius* recorded by Sah and Dutta (1966; Pl. 1, figs 23-24) is smaller in size and covered with densely arranged spiny processes.

Turma — *Plicates* (Naum. 1937, 1939) Pot. 1960
Subturma — *Polyplicates* Erdt. 1952
Infraturma — *Costati* Pot. 1966

Genus — *Ephedripites* Bolch. 1953

Genotype — *Ephedripites mediolobatus* Bolch. 1953.

Ephedripites sp. A.

Pl. 2, fig. 39

Description — Brown, longish oval, with broadly rounded ends, size 50·6×30·4 μ; exine ±2·5 μ thick, bearing 4 prominent ridges with distinct septations inbetween, ridges ±2 μ wide, inter-ridge area smooth.

Comparison — Ghosh *et al*, (1963) have recorded closely comparable specimens from the Dharamsala (Tertiary) Formation of Kangra District in Punjab. These specimens (Ghosh *et al.*, 1963; figs. 1-4), are smaller in size and bearing larger number of ridges

Ephedripites sp. B

Pl. 2, fig. 40

Description — Golden yellow, longish oval with narrowly rounded ends, size 35·2 ×14·5 μ; exine ±1·2 μ thick, smooth, bearing 7 ridges, running from pole to pole without septations, ridges 1·2-1·5 μ thick.

Comparison — The present species differs from the one described above in having larger number of ridges without any septations.

Subturma — Monocolpates Iver. & Troels. 1950

Genus — Monocolpites Erdt. 1947

Lectogenotype — *Monocolpites longicolpatus* V. d. Hamm. 1956.

Monocolpites infrequens sp. nov.

Pl. 2, figs. 41-43

Holotype — Pl. 2, Fig. 41.

Type locality — Therria Formation, Umsohryngkew traverse, Khasi-Jaintia hills.

Diagnosis and description — Brown, oval with broadly rounded to flattened ends, size 38·6-50 × 16·8-32·5 μ; monocolpate, colpi 2·5-3 μ deep; exine ±1·2 μ thick, faintly structured, presumably beset with ±1 μ wide grana.

Comparison — A specimen illustrated as *Monocolpites* sp. by Salujha *et al.* (1971; Pl. 2, fig. 51) is bigger in size with deeper colpi. *Monocolpites* sp. (Sah and Dutta, 1966; Pl. 1, fig. 22) compares closely with the present species.

Botanical affinity — Uncertain.

Monocolpites sp.

Pl. 2, fig. 43

Description — Brown, elliptical, size 22·4 × 75·6 μ; monocolpate, colpi 3·5-4 μ wide, running from pole to pole; exine over 1 μ thick, smooth.

Comparison — The present species differs from *Monocolpites infrequens*, described above in having pointed ends and its longer axis is larger.

Subturma — *Relectines* (Malawk. 1949) Pot. 1948.

Genus — *Couperipollis* Venkat. & Kar 1969

Genotype — *Couperipollis perspinosus* (Coup.) Venkat. & Kar. 1969.

Couperipollis exsertus sp. nov.

Pl. 2, figs. 44-45

Holotype — Pl. 2, fig. 44.

Type locality — Kopili Formation, Prang river traverse, Khasi-Jaintia hills.

Diagnosis and description — Brown, circular to subcircular, measuring 48-64·6 × 35·2-61·2 μ (including processes), sometimes folded; monosulcate; sulcus 2·6-8 μ wide, sometimes more; exine 1.5-2 μ thick, ornamented with 3·5-6 μ long and 2·5-3·5 μ broad processes with pointed tips and bulbous base, processes closely spaced coalescing to give a reticulate appearance; exine inbetween the processes foveolate.

Comparison — *Couperipollis kutchensis* (Venkat. & Kar, 1969; Pl. 1, figs. 15-16) differs in having longer spines. *Monosulcites rarispinosus* recorded by Sah and Dutta (1966; Pl. 1, figs. 26-28) has smaller and sparsely arranged processes. Dutta and Sah (1970) have recorded quite a few species of *Monosulcites*. Out of these *M. magnus* (Dutta and Sah, 1970; Pl. 5, figs. 1-2) comes close to the present species but differs in being bigger in size and bearing longer spines for ornamentation. *Couperipollis achinatus* (Sah and Kar, 1970; Pl. 1, figs. 8-9) differs in being smaller, oval in shape and colpus extending from one end to the other.

Botanical affinity — Nymphaeaceae/Palmae.

Couperipollis sp.

Pl. 2, fig. 46

Description — Light brown, circular, measuring 35·6 μ; monosulcate, sulcus faintly discernible, its limits not clear; exine ± 1·5 μ thick, ornamented with 2·4 μ long, 2·5-3 μ broad, closely spaced processes with pointed to blunt tips; exine inbetween the processes smooth.

Comparison — The present species distinguishes in its smaller size with a faintly discernible sulcus and smaller, closely spaced processes.

Botanical affinity — Nymphaeaceae/Palmae.

Subturma — Monoptyches (Naum. 1937) Pot. 1958

Genus — *Palmaepollenites* Pot. 1951

Genotype — *Palmaepollenites tranquillus* Pot. 1934) Pot. 1951.

Palmaepollenites subtilis Sal., Kind. & Reh. 1971.

Pl. 2, fig. 47

Palmaepollenites sp.

Pl. 2, fig. 48

Description — Golden yellow, longish oval to elliptical, measuring 76·4 × 30·8 μ; monosulcate, sulcus 3·5-4 μ wide; running from one pole to the other; exine ±1 μ thick, faintly granulose, grana over 1 μ in diameter, sparsely arranged.

Comparison — *Palmaepollenites ovatus* (Sah and Kar, 1970; Pl. 1, fig. 13) is smaller, roundly oval with a thicker, intragranulose exine. *P. plicatus* also recorded by Sah and Kar (1970; Pl. 1, figs. 14-15) resembles the present species in its sulcus running from one end to the other but differs in having a laevigate exine. *P. subtilis* recorded by Salujha *et al.* (1971; Pl. 2, figs. 53-54) is smaller in size with a wide sulcus. *P. communis* (Sah and Dutta, 1966; Pl. 1, fig. 10) is also smaller in size with slightly raised lips.

Botanical affinity — Palmae.

Subturma — Dicolpates Erdt. 1947

Genus — Dicolpopollis (Pflan. 1956) Pot. 1966

Genotype — *Dicolpopollis kockeli* Pflan. 1956.

Dicolpopollis fragilis Sal., Kind. and Reh. 1971.

Pl. 2, fig. 49

Dicolpopollis sp.

Pl. 2, fig. 50

Description — Golden yellow; oval, size 44·6×39·8 μ; dicolpate, colpi 4·5-6·2 μ deep; exine ±1·5 μ thick, distinctly reticulate, muri 1·2-1·5 μ thick with ±1·5 μ wide lumina.

Comparison — *Dicolpopollis proprius* recorded by Salujha *et al.* (1971; Pl. 3, figs. 57-58) is smaller in size with faintly reticulate structure.

Botanical affinity — Palmae.

Subturma — Triptyches Naum. 1937, 1939
Genus — Tricolpites (Erdt. 1947, Cooks. 1947, Ross, 1949, Coup. 1953) Pot. 1960

Lectogenotype — *Tricolpites reticulatus* Cooks. 1947

Tricolpites gracilis Sal., Kind. & Reh. 1971.

Pl. 2, fig. 51

Tricolpites iniquus sp. nov.

Pl. 2, figs. 52-53

Holotype — Pl. 2, fig. 52.

Type locality — Jenam Formation, Haflong-Silchar road traverse, District Cachar.

Diagnosis and description — Golden yellow, roundly triangular to subcircular, size 19·8-34·6×18·2-28·6 μ; tricolpate, colpi 5·2-9·6 μ wide, extending to almost 1/2 the radial distance; exine over 1 μ thick, smooth to sparsely foveolate, uneven, giving a mat like appearance.

Comparison — *Tricolpites levis* recorded by Sah and Dutta (1966; Pl. 2, figs. 9-10) has longicolpate furrows. *T. longicolpus* (Sah and Dutta, 1966; Pl. 2, figs. 11-12) differs in having a thicker exine with long, tenuimarginate colpi. *T. brevis* (Sah and Kar, 1970; Pl. 1, figs. 5-6) is bigger in size with colpi placed in interapical margin. *T. minutus* also recorded by these authors (Sah and Kar, 1970; Pl. 1, fig. 7) has a thicker exine with narrow and uniformly broad colpi. In *T. gracilis* (Salujha *et al.*, 1971; Pl. 3, figs. 59-60) exine is ornamented with closely set grana.

Botanical affinity — Uncertain.

Tricolpites horridus sp. nov.

Pl. 2, figs. 54-55

Holotype — Pl. 2, Fig. 54.

Type locality — Oligocene, Mupa-Langting traverse, Haflong area.

Diagnosis and description — Brown, roundly triangular with three prominent slits, size 25·6-33·6 μ; tricolpate, colpi 3-6·5 μ deep; exine 2-2·5 μ thick, pilate, pila 2·5-3 μ long with globular heads, closely spaced; occasionally coalescing to give a reticulate appearance.

Comparison — The present species distinguishes from all other species recorded earlier in having pila for exine ornamentation. Dutta and Sah (1970; Pl. 6, Figs. 7-8) have assigned comparable specimens to *Retitrescolpites minor* but they have longer colpi and exinal layers are clearly distinguished.

Botanical affinity — Uncertain.

Tricolpites strigosus sp. nov.

Pl. 2, figs. 56-57

Holotype — Pl. 2, Fig. 56.

Type locality — Kopili Formation, Prang river traverse, Khasi-Jaintia hills.

Diagnosis and description — Golden yellow subcircular, measuring 24-35·2×22·4-30·8 μ; occasionally bearing folds; tricolpate, colpi 2·5-4·5 μ deep with a 2-3 μ wide thickening; exine ±1·2 μ thick, finely granulate, grana ±1 μ in diameter.

Comparison — *Tricolpites strigosus* differs from *T. gracilis* (Salujha *et al.*, 1971; Pl. 3, figs. 59-60), *T. horridus*, *T. brevis* and *T. minutus* (Sah and Kar, 1970; Pl. 1, figs. 5, 6, 7) in having a wide thickening along the colpi.

Botanical affinity — Uncertain.

Tricolpites ovatus sp. nov.

Pl. 2, figs. 58-59; Pl. 3, fig. 60

Holotype — Pl. 2, fig. 58.

Type locality — Disangs, Bali-Chara nadi traverse, Khasi-Jaintia hills.

Diagnosis and description — Golden yellow, oval, size 30·6-38·4×21·2—27·8 μ; occasionally bearing folds; tricolpate, colpi 2-3·5 μ wide extending almost from one pole to the other; exine ±1·5 μ thick, granulose, grana ±1 μ wide, closely spaced.

Comparison — *Tricolpites longicolpus* (Sah and Dutta, 1966; Pl. 2, figs. 11-12) has a thicker exine with tenuimarginate colpi. *T. levis* also recorded by these authors (Sah and Dutta, 1966; Pl. 2, figs. 9-10) has thinner furrows.

Botanical affinity — Uncertain.

Tricolpites sp.

Pl. 3, fig. 61

Description — Brown, triangular with lobed angles, size 46·4 μ; tricolpate, colpi inter-angular, 5-5·5 μ deep; exine ±1·5 μ thick, reticulate, muri over 1·5 μ thick, lumina of irregular shapes; muri 2-2·5 μ broad, usually protruding at the margin, angles lobed.

Comparison — *Tricolpites brevis* recorded by Sah and Kar (1970; Pl. 1, figs. 5-6) resembles the present specimen in having colpi at the interapical margin but differs in having laevigate-finely scrobiculate exine without any angular lobes.

Botanical affinity — Uncertain.

Genus — Meyeripollis Baksi & Venkat. 1970

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

Meyeripollis laudabilis Sal., Kind. & Reh. 1971

Pl. 3, fig. 62

Genus — Marginipollis Clarke & Frederik. 1968

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

Marginipollis grandis Sal., Kind. & Reh. 1971.

Pl. 3, fig. 63

Subturma — *Polyptyches* (Naum. 1937, 1939) Pot. 1960

Genus — *Stephanocolpites* (V. d. Hamm. 1948, 1956) Pot. 1960

Lectotype — *Stephanocolpites costatus* V. d. Hamm. 1954.

Stephanocolpites emendatus sp. nov.

Pl. 3, figs. 64-66

Holotype — Pl. 3, fig. 64.

Type locality — Kopili Formation, Lubha river traverse, Khasi-Jaintia hills.

Diagnosis and description — Golden yellow, circular to oval, measuring 25·6-45·6×24·2-35·4 μ; tetracolpate, colpi 2·5-3 μ deep, 1·5-2 μ wide; exine ±1·5 μ thick, finely granulose, grana ±1 μ wide.

Comparison — *Stephanocolpites optabilis* described by Salujha *et al.* (1971; Pl. 3, figs. 69-71) is bigger in size with wider colpi and smooth to foveolate exine. *S. minutus* also recorded by the above authors (Salujha *et al.*, 1971; Pl. 3, figs. 72-73) is smaller, hexacolpate and the exine is smooth. *Polycolpites ornatus*, *P. multirimatus* (Dutta and Sah, 1970; Pl. 6, figs. 27-28; Pl. 7, figs. 1-3; Figs. 18-20) *P. granulatus* and *P. flavatus* (Sah and Kar, 1970; Pl. 2, figs. 41, 42, 47) differ in having 6-8, 8-10, 7-8 and 9-10 colpi respectively and exine is coarsely reticulate or sub-reticulate or granulose. *P. speciosus* also recorded by Dutta and Sah (1970; Pl. 6, figs. 24-25) has a granulose exine but is hexacolpate.

Stephanocolpites sp. A

Pl. 3, fig. 67

Description — Light brown, oval to subcircular, size 30×33·6 μ; hexacolpate, colpi 1·5-2 μ wide, prominently seen in the centre; exine ±2 μ thick, finely reticulate, muri over 1 μ thick, with an equally broad lumina in the centre.

Comparison — The present species differs from *Polycolpites obscurus*, *P. cooksonii* (Sah and Dutta, 1966; Pl. 2, figs. 13-14, 17-18), *P. speciosus* (Dutta and Sah, 1970; Pl. 6, figs. 24-25), *Stephanocolpites optabilis* and *S. minutus* (Salujha *et al.*, 1971; Pl. 3, figs. 69-70, 72-73) in having a distinctly reticulate exine.

Botanical affinity — ?Rubiaceae.

Stephanocolpites sp. B

Pl. 3, fig. 68

Description — Light brown, subcircular, size 32·8×30·2 μ; septacolpate, colpi 2·5-3 μ wide; exine ±1·5 μ thick, coarsely foveolate, foveola ±1·5 μ broad, sparsely arranged.

Comparison — *Stephanocolpites optabilis* (Salujha *et al.*, 1971; Pl. 3, figs. 69-70), though having foveola for exine ornamentation, is much bigger in size with only 4-5 colpi. *Polycolpites ornatus* recorded by Dutta and Sah (1970; Pl. 6, figs. 27-28; Pl. 7, figs. 1-3) differs in having a coarsely reticulate exine.

***Botanical affinity* — ? Rubiaceae**

Subturma — *Ptychotriporines* (Naum. 1937, 1939) Pot. 1960

Infraturma — *Prolati* Erdt. 1943

Genus — *Favitricolporites* Sah, 1967

Genotype — *Favitricolporites eminens* Sah, 1967.

Favitricolporites usitatus Sal., Kind, & Reh. 1971.

Pl. 3, fig. 69

Remarks — The specimen illustrated here measures 64·5 μ, whereas the size range already mentioned for this species is 20·6-57·6 μ. Thus size range of the specimens included under this species may be taken as 20·6-64·5 μ.

Botanical affinity — Rubiaceae

Genus — *Nyssapollenites* Thierg. 1937

Genotype — *Nyssapollenites pseudocruciatus* (Pot. 1931) Thierg. 1937.

Nyssapollenites laudabilis sp. nov.

Pl. 3, figs. 70-72

Holotype — Pl. 3, fig. 70.

Type locality — Kopili Formation, Umiew river traverse, Khasi-Jaintia hills.

Diagnosis and description — Brown, roundly triangular to oval, size 24-42·4×18·2-33·6 μ; tricolporate, colpi 2·2-2·6 μ wide, pores 1·5-2 μ in diameter; exine ±1·5 μ thick, smooth to faintly structured.

Comparison — The solitary specimen of *Nyssapollenites* sp. illustrated by Sah and Dutta (1966; Pl. 2, fig. 8) is spheroidal with a finely pitted to reticulate sculpture. *N. barooahii* also described by Sah and Dutta (1968; Pl. 2, fig. 9) has lalongate pores and a distinct thickening at the apertural region.

Botanical affinity — ?Nyssaceae.

Genus — *Talisiipites* Wodehouse, 1933

Genotype — *Talisiipites fischeri* Wodehouse, 1933.

?*Talisiipites* sp.

Pl. 3, fig. 73

Description — Brown, roundly triangular to subcircular, size 65·6×56 μ; tricolporate, syncolpate, pores 3·5-4·5 μ in diameter, colpi almost reaching up to the pole; exine ±2 μ thick, reticulate, muri ±1·5 μ thick with 1-1·2 μ wide lumina.

Comparison — *Talisiipites mundus* (Sah and Dutta, 1968; Pl. 2, fig. 6) has a distinctly triangular shape with its colpi distinctly joining at the pole. *T. wodehousei* recorded by Dutta and Sah (1970; Pl. 7, figs. 9-12) has a distinctly triangular amb and smooth to faintly scabrate, exine.

Botanical affinity — Uncertain.

Genus — *Myrtaceidites* (Cooks. & Pike, 1954) Pot. 1960

Genotype — *Myrtaceidites mesonesus* Cooks. & Pike, 1954.

Myrtaceidites pretiosus Sal., Kind. and Rehman, 1971.

Pl. 3, fig. 74

Subturma — *Ptychopolyporines* (Naum. 1937, 1939) Pot. 1960

Genus — *Tetracolporites* Coup. 1953

Genotype — *Tetracolporites camaruensis* Coup. 1953.

Tetracolporites similis Sal., Kind. & Reh. 1971.

Pl. 3, fig. 75

Tetracolporites manifestus sp. nov.

Pl. 3, figs. 76-77

Holotype Pl. 3, Fig. 76.

Type locality — Laisong Formation, Lubha river traverse, Khasi-Jaintia hills.

Diagnosis and description — Golden yellow, circular to subcircular, size 30·8-38·2×26-30·4 μ; tetracolporate, colpi 3·5-4 μ wide, pores ±3·8 μ in diameter; exine ±1·5 μ thick, distinctly reticulate, muri over 1·5 μ thick, leaving lumina of varying shapes, usually measuring 1·5-2 μ in width.

Comparison — The present species differs from *T. similis* (Salujha *et al.* 1971; Pl. 3, Figs. 82-83) in having a reticulate ornamentation. *T. paucus* and *T. onagraceoides* described by Sah and Dutta (1968; Pl. 2, Figs. 14, 16) have pores with a thickened rim alround. *T. longicolpus* (Sah and Dutta, 1968; Pl. 2, Fig. 7) has long colpi extending almost up to the poles and an undifferentiated exine ornamentation.

Botanical affinity — ?Rubiaceae /?Onagraceae.

Genus — *Polygalacidites* Sah & Dutta, 1966

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

Polygalacidites pulidus sp. nov.

Pl. 3, figs. 78-79

Holotype — Pl. 3, fig. 78.

Type locality — Jenam Formation, Haflong-Silchar road traverse, District Cachar.

Diagnosis and description — Golden yellow, circular to subcircular to oval, size 24-33·6 μ; penta to hexacolporate, colpi 6-8·5 μ deep, pores 3-4 μ in diameter with a faint thickening around them; exine almost 1·5 μ thick, smooth to finely granulate, grana less than 1 μ in diameter.

Comparison — *Polygalacidites clarus* recorded by Sah and Dutta (1966; Pl. 2, figs. 24-25) has longer colpi and faintly discernible ora. *P. insignis* (Dutta and Sah, 1970; Pl. 7, fig. 29) is smaller in size with 8 colpi and smooth to faintly scabrate exine ornamentation.

Botanical affinity — Polygalaceae.

Turma — *Poroses* (Naum. 1937, 1939) Pot. 1960

Subturma — *Monoporines* (Naum. 1937, 1939) Pot. 1960

Genus — *Graminidites* Cooks. 1947

Graminidites sp.

Pl. 3, fig. 80

Description — Brown, circular, flattened on one side, size 26·4 μ; monoporate, pore 2-2·5 μ wide, with an equally wide, dark brown thickening alround; exine up to 2 μ thick, smooth.

Comparison — *Graminidites assamicus* (Sah and Dutta, 1968; Pl. 2, fig. 21) is bigger in size and lacks a thickening around the pore.

Botanical affinity — Gramineae.

Subturma — *Diporines* (Naum. 1937, 1939) Pot. 1960

Genus — *Diporites* V. d. Hamm. 1954, 1956

Genotype — *Diporites grandiporus* V. d. 1954.

Diporites sp.

Pl. 3, fig. 81

Description — Brown, oval to longish oval, size 73·4×30·5 μ; diporate, pores 4·5-5·2 μ wide with a 1·8-2 μ wide thickening alround; exine over 1·5 μ thick, finely granulose.

Comparison — Out of the many species of the diporate pollengrains recorded by Varma and Rawat (1963), *Diporisporites ankleswarensis* (Varma and Rawat, 1963; Elsik, 1968; Pl. 1, figs. 11-12) compares well with the present species. It differs in having larger pores with a wider thickening around them and the exine is foveolate. The specimens assigned to a new genus, *Diporopollis* as *D. assamica* by Dutta and Sah (1970; Pl. 8, figs. 21-24) do not compare with any of the known species of diporate pollengrains.

Botanical affinity — Apocynaceae/Proteaceae.

Subturma — *Triporines* (Naum. 1937, 1939) Pot. 1960

Genus — *Triporopollenites* (Pflug, 1952) Thoms. & Pflug, 1953

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

Triporopollenites exactus Sal., Kind. & Reh. 1971.

Pl. 3, figs. 82-83

Subturma — *Polyporines* (Naum. 1937, 1939) Pot. 1960

Infraturma — *Stephanoporiti* (V.d. Hamm. 1954) Pot. 1960

Genus — *Stephanoporopollenites* Pflug in Thoms. & Pflug, 1953

Genotype — *Stephanoporopollenites hexaradiatus* (Thierg. 1940) Thoms. & Pflug, 1953.

Stephanoporopollenites sollemnis Sal., Kind. and Reh. 1971.

Pl. 3, fig. 84

Stephanoporopollenites sp.

Pl. 3, fig. 85

Description — Golden yellow, circular with a wavy margin, size 36·6 μ; octaporate, pores located below each furrow, 3-3·5 μ in diameter, with a ±1·5 μ wide thickening around each pore; exine ±1·2 μ thick, finely granulate, grana less than 1 μ wide, closely spaced.

Comparison — The grains assigned to *Stephanoporopollenites solitus* by Salujha *et al.* (1971; Pl. 3, figs. 96-97) seem to compare closely with the present species but differ in being hexaporate with a prominent thickening in between the pores. *Polyporina excellens* (Dutta and Sah, 1970; Pl. 8, figs. 10, 12) differs in having 50 pores and finely punctate ornamentation on the exine.

Botanical affinity — ?Chenopodiaceae.

Group — *Acritarcha* Evitt, 1963

Subgroup — *Polygonomorphitae* Dow., Evitt & Sarj. 1963

Genus — *Simsangia* Baksi, 1962

Genotype — *Simsangia trispinosa* Baksi, 1962.

Simsangia magna Sal., Kind. & Reh. 1971.

Pl. 3, fig. 86

Simsangia rustica sp. nov.

Pl. 3, figs. 87-89

Holotype — Pl. 3, fig. 87.

Type locality — Kopili Formation, Umsohryngkew traverse, Khasi-Jaintia hills.

Diagnosis and description — Golden yellow, triangular with slightly convex sides, size 28·8-34·6 μ (including processes), one process at each corner; processes 4-4·5 μ long, 3-3·5 μ broad uniformly from base to the top, with blunt tips; exine ±1 μ thick, smooth.

Comparison — *Simsangia trispinosa* (Baksi, 1962; Pl. 3, fig. 34) and *S. magna* (Salujha *et al.* 1971; Pl. 3, figs. 99-101) differ in having longer processes with pointed tips.

Botanical affinity — Uncertain.

Subgroup — *Acanthomorphitae* Dow., Evitt. & Sarj. 1963

Genus — *Baltisphaeridium* (Eis. 1958) Dow. & Sarj. 1963

Genotype — *Baltisphaeridium longispinosum* (Eis. 1931) Dow. & Sarj. 1963.

Baltisphaeridium sp.

Pl. 3, fig. 90

Description — Golden yellow, circular to subcircular, size 36·4×31·8 μ (excluding processes), folded; exine over 1 μ thick bearing 4-4·8 μ long, 1·5-2 μ broad (at the base) processes with pointed tips, processes sparsely arranged, exine inbetween the processes finely granulate, grana ±1 μ in diameter.

Comparison — *Baltisphaeridium* sp. recorded by Sah *et al.* (1970; Pl. 2, fig. 26) has many, longer and closely spaced processes. The present species distinguishes in having grana inbetween the spine-like processes.

Genus — *Micrhystridium* (Defl. 1937) Dow. & Sarj. 1963

Genotype — *Micrhystridium inconspicuum* Defl. 1935.

Micrhystridium modestus Sal., Kind. & Reh. 1971.

Pl. 3, figs. 91-92

Micrhystridium proprium sp. nov.

Pl. 3, figs. 93-95

Holotype — Pl. 3, fig. 93.

Type locality — Kopili Formation, Lubha river traverse, Khasi-Jaintia hills.

Diagnosis and description — Golden yellow normally circular, subcircular in folded condition, measuring 14·4-32 μ (excluding processes); exine ±1·5 μ thick, bearing sparsely arranged, 2-3·5 μ long and 1·5-2 μ broad (at the base) processes with pointed tips, 9-15 processes observed at the margin; area inbetween the processes smooth.

Comparison — *Micrhystridium modestus* recorded by Salujha *et al.* (1971; Pl. 3, figs. 102-103) differs in having longer processes, a distinct thin, circular area in the centre and granulose exine inbetween the processes.

Genus — *Hystrichosphaeridium* (Defl. 1937) Eis. 1958

Genotype — *Hystrichosphaeridium tubiferum* (Ehren, 1938) Eis. 1958.

Hystrichosphaeridium sp.

Pl. 3, fig. 96

Description — Golden yellow, subcircular, size 45·6×38·8 μ (including processes); processes needle like, 8-8·5 μ long, 1·5-2 μ broad at the base, occasionally furcating into two or three branches; exine ±1·2 μ thick, area inbetween the processes faintly structured.

Comparison — *Hystrichosphaeridium scaffoldi* recorded by Baksi (1962; Pl. 2, fig. 25) differs in having longer processes joining with one another to form a scaffolding structure. *H. sylheti* also recorded by the above author (Baksi, 1962; Pl. 2, fig. 26) has longer but simple, unbranched processes. *H. robustum* and *H. assamicum* recorded by Sah *et al.* (1970; Pl. 2, figs. 16-17, 20-21) are bigger in size, bearing tubular processes and laevigate exine.

Incertae Sedis

Phycopeltis iucundus sp. nov.

Pl. 3, fig. 97

Holotype — Salujha *et al.*, 1971; Pl. 3, Fig. 106.

Type locality — Jenam Formation, Haflong-Silchar road traverse, District Cachar.

Diagnosis and description — Brown, circular to subcircular, measuring 30·3-36·8 ×28·8-33·6 μ; margin wavy, each wave bifurcating, below each notch a ±1·5 μ wide pore with equally wide thickening alround present; exine ±2 μ thick, faintly structured.

Remarks — This is the first record of *Phycopeltis* from the Palaeogene sediments of Assam.

Fusiformisporites foedus sp. nov.

Pl. 3, figs. 98-99

Holotype — Pl. 3, fig. 98.

Type locality — Disangs, Bali-chara nadi traverse, Khasi-Jaintia hills.

Diagnosis and description — Brown, oval with pointed ends, size 43·2-46·4× 24·5-27·2 μ; on the equator a 2-2·5 μ wide disc with a wavy margin present, exine ±1·2 μ thick, ridged, ridges 10 in number, ±1·5 μ wide, running from one pole to the other.

Comparsion — A comparable specimen under *Fungus striata* is illustrated by Baksi (1962; Pl. 4, fig. 50).

Fungal spores

Pl. 3, figs. 100-101

DISCUSSION

The present paper incorporates results of a palynological study of the Palaeogene sediments along the southern edge of the United Khasi and Jaintia hills. The palynoflora recovered here is assigned to 41, genera and 67 species. It is observed that Pteridophytes and Angiosperms were the main constituents of the flora during the Palaeogene times. Gymnosperms were rather rare represented by comparatively fewer species. Microplankton were poorly represented.

Out of the five traverses studied here, two of them i.e. Umsohryngkew and Lubha river traverses are studied in detail including both qualitative and quantitative analysis. Most of the samples studied from the Umsohryngkew traverse belong to the Kopili formation. Besides this one sample is from the lower most part of the Barails and two samples from the Langpars. The solitary sample from the Barails has yielded a very poor assemblage. The Kopilis on the other hand show a richer assemblage but the complete representation is indicative of a single zone. All other samples studied from the Sylhet Limestone Formation are devoid of palynological fossils. Samples from the Langpar Formation show an abundance of hystrichosphaerids. The Lubha river traverse shows an excellent distribution of palynofossils in the Barails. The Renji and Jenam Formations have yielded a rich assemblage of palynofossils. The Laisong Formation, on the other hand, has palynomorphs poor both in quality and quantity.

A comparison of palynofossils from the Barails of Garo hills and Khasi and Jaintia hills shows that most of the genera represented in the two assemblages are common. Considering the qualitative aspect further, there are a few genera which are present in the Barails of Garo hills but do not show up in the Khasi and Jaintia hills, while there are still others which are present in assemblage of the Khasi and Jaintia hills but absent in the Garo hills. All these genera have a very poor occurrence, represented by stray specimens which are at times not encountered in the countings. Thus on the whole the Barails of Garo hills compare closely with the Barails of Khasi and Jaintia hills. The assemblage obtained from the Kopilis of Garo hills also shows a close resemblance to that from the Kopili counterpart in the Khasi and Jaintia hills.

The Therria and Langpar sediments are studied only from the Khasi and Jaintia hills whereas their equivalents from the Garo hills have not been studied due to nonavailability of samples. Thus their comparison with similar sediments in the Garo hills cannot as yet be attempted.

Palynological study of both shelf and geosynclinal sediments is dealt with above. Out of two traverses studied in detail, Umsohryngkew traverse represents the shelf facies whereas Lubha river traverse represents the geosynclinal facies. The Barails of shelf facies show a richer assemblage as compared to that of the geosynclinal facies. It is interesting to note that the Disangs which were hitherto reported to be barren have yielded a diversified assemblage of palynofossils but it is comparatively poorer than that obtained from the Jaintia Series of the shelf facies. Thus relationship of the Disangs with the richly fossiliferous Jaintia Series still remains a problem.

A perusal of the assemblages shows that the Langpar Formation has dominance of microplankton followed by angiosperms and pteridophytes. Gymnosperms on the other hand are poorly represented. Abundance of microplankton in this formation indicates its deposition under shallow marine conditions. The paucity of microplankton in assemblages of the Barail, Kopili and Therria Formations indicates that their deposition took place under terrestrial conditions with brackish to marine influence.

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EXPLANATION OF PLATES

(All magnifications × 500)

PLATE 1

1. *Cyathidites* (*Leiotriletes*) *dekiseusi* (Baksi) Sal., Kind. & Reh. 1971; Photo no. 21/4.

2-3. *Cyathidites magnaximus* sp. nov.; Photo nos. 27/16, 27/5.

4. *Cyathidites* sp.; Photo no. 22/10.

5-6. *Stereisporites formosus* sp. nov.; Photo nos. 27/18, 21/6.

7. *Biretisporites singularis* sp. nov.; Photo no. 21/13.

8. *Foveosporites spectabilis* sp. nov.; Photo no. 19/30.

9. *Lycopodiumsporites parvireticulatus* Sah & Dutta, 1966; Photo no. 7/11.

10-11. *Lycopodiumsporites rarus* sp. nov.; Photo nos. 7/8, 18/11.

12. *Lycopodiumsporites* sp. A; Photo no. 27/20.

13. *Lycopodiumsporites* sp. B; Photo no. 27/13.

14-15. *Lycopodiumsporites insignis* sp. nov.; Photo nos. 17/26, 19/29.

16. *Magnastriatites granulus*, Sal., Kind. & Reh., 1971; Photo no. 21/25.

17. *Cicatricosisporites* sp.; Photo no. 22/21.

18. *Corrugatisporites* sp.; Photo no. 18/6.

19. *Polypodiaceoisporites ideosus* Sal., Kind. & Reh. 1971; Photo no. 21/24.

20. *Polypodiaceoisporites* sp.; Photo no. 18/27.

21. *Laevigatosporites copiosus* Sal., Kind. & Reh. 1971; Photo no. 21/21.

22-24. *Laevigatosporites sacrus* sp. nov.; Photo nos. 22/1, 16/12, 19/32.

PLATE 2

25. *Schizaeoisporites* sp.; Photo no. 27/21.

26-28. *Polypodiisporites speciosus* Sah, 1967 Photo nos. 24/4, 14/25, 18/28.

29. *Polypodiisporites splendidus* Sal. Kind. & Reh. 1971; Photo no. 17/22.

30. *Podocarpidites classicus* Sal., Kind. & Reh. 1971; Photo no. 27/14.

31. *Alisporites* sp; Photo no. 24/5.

32-34. *Inaperturopollenites mirabilis* sp. nov.; Photo nos. 19/10, 19/3, 12/13.

35-38. *Pollandripites justillimus* sp. nov.; Photo nos. 16/27, 20/12, 19/4, 8/9.

39. *Ephedripites* sp. A.; Photo no. 16/21.

40. *Ephedripites* sp. B.; Photo no. 17/1.

41-42. *Monocolpites infrequens* sp. nov.; Photo nos. 7/16, 15/11.

43. *Monocolpites* sp.; Photo no. 27/19.

44-45. *Couperipollis exsertus* sp. nov.; Photo nos. 19/5, 17/23.

46. *Monosulcites* sp.; Photo no. 26/26.

47. *Palmaepollenites subtilis* Sal., Kind. & Reh. 1971; Photo no. 17/20.

48. *Palmaepollenites* sp.; Photo no. 18/30.

49. *Dicolpopollis fragilis* Sal., Kind. & Reh. 1971; Photo no. 20/33.

50. *Dicolpopollis* sp.; Photo no. 27/10.

51. *Tricolpites gracilis* Sal., Kind. & Reh. 1971; Photo no. 21/19.

52-53. *Tricolpites iniquus*. sp. nov., Photo nos. 27/13, 21/9.

54-55. *Tricolpites horridus* sp. nov., Photo nos. 21/23, 12/19.

56-57. *Tricolpites stupidus* sp. nov., Photo nos. 18/19, 18/22.

58-59. *Tricolpites ovatus* sp. nov.; Photo nos. 26/18, 8/4.

PLATE 3

60. *Tricolpites ovatus* sp. nov.; Photo no. 7/21.

61. *Tricolpites* sp.; Photo no. 18/21.

62. *Meyeripollis laudabilis* Sal., Kind. & Reh. 1971; Photo no. 21/3.

63. *Marginipollis grandis* Sal., Kind. & Reh. 1971; Photo no. 20/8.

64-66. *Stephanocolpites emendatus* sp. nov.; Photo nos. 12/14, 22/3, 16/14.

67. *Stephanocolpites* sp. A; Photo no. 7/22.

68. *Stephanocolpites* sp. B; Photo no. 7/26.

69. *Fusitricolporites usitatus* Sal., Kind. & Reh. 1971; Photo no. 27/4.

70-72 *Nyssapollenites laudabilis* sp. nov.; Photo nos. 17/18, 22/7, 17/13.

73. *Talisiipites* sp.; Photo no. 18/24.

74. *Myrtaceidites pretiosus* Sal., Kind. & Reh. 1971; Photo no. 22/15.

75. *Tetracolporites similis* Sal., Kind. & Reh. 1971; Photo no. 22/22.

76-77. *Tetracolporites manifestus* sp. nov.; Photo nos. 22/17, 7/15.

78-79. *Polygalacidites palidus* sp. nov.; Photo no. 27/3, 27/8.

80. *Graminidites* sp.; Photo no. 26/29.

81. *Diporites* sp.; Photo no. 16/13.

82-83. *Triporopollenites exactus* Sal., Kind. & Reh. 1971; Photo nos. 7/9, 26/28.

84. *Stephanoporopollenites solemnis* Sal., Kind. & Reh. 1971; Photo no. 24/6.

85. *Stephanoporopollenites* sp.; Photo no. 21/7.

86. *Simsangia magna* Sal., Kind. & Reh. 1971; Photo no. 22/5.

87-89. *Simsangia rustica* sp. nov.; Photo nos. 18/17, 11/13, 10/13.

90. *Baltisphaeridium* sp.; Photo no. 18/9.

91-92. *Micrhystridium modestus* Sal., Kind. & Reh. 1971; Photo nos. 11/6, 19/22.

93-95. *Micrhystridium proprium* sp. nov.; Photo nos. 16/22, 16/11, 17/9.

96. *Hystrichosphaeridium* sp.; Photo no. 18/16.

97. *Phycopeltis iucundus* sp. nov.; Photo no. 27/17.

98-99. *Fusiformisporites fodus* sp. nov.; Photo nos. 26/27, 26/21.

100-101. Fungal spores; Photo nos. 26/23, 27/12.


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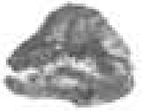
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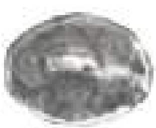
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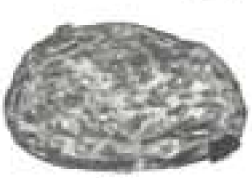
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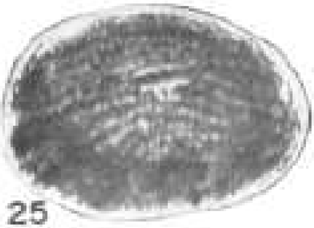
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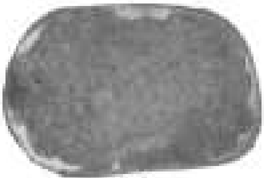
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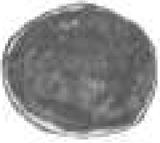
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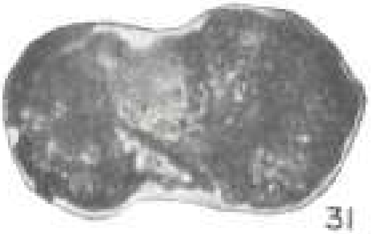
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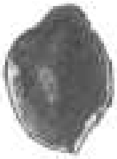
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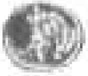
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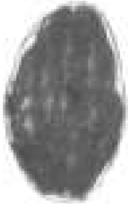
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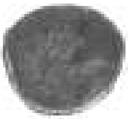
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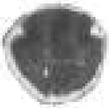
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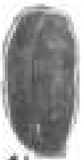
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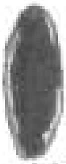
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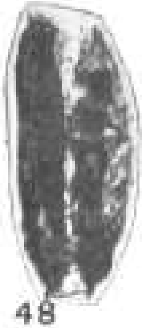
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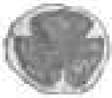
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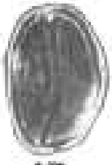
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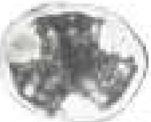
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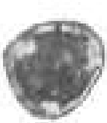
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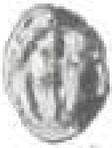
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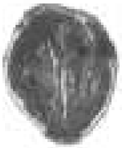
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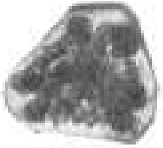
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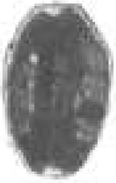
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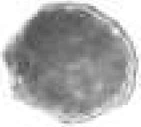
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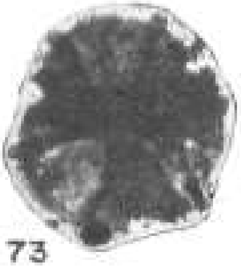
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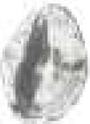
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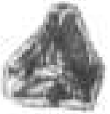
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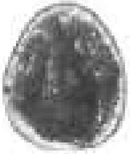
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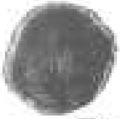
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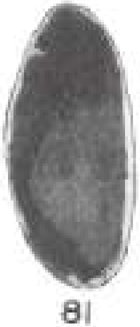
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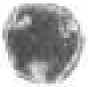
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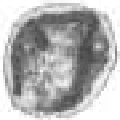
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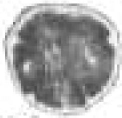
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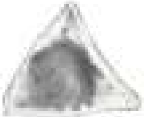
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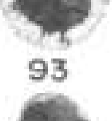
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PALYNOLOGY OF THE SUBSURFACE SEDIMENTS OF MANHERA TIBBA STRUCTURE, JAISALMER, WESTERN RAJASTHAN, INDIA*

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ABSTRACT

Palynological studies on the sub-surface sediments namely the Shumar, Kirthar, Laki, Ranikot, Parh and Goru sediments from the Manhera Tibba Jaisalmer district, Rajasthan, have been carried out. The sporomorphs recorded in the sediments have been listed according to the successive rock units and the age and environment of the sediments have been discussed. The results are based on the data obtained from the study of 370 samples.

The study indicates that the Tertiary and the Mesozoic sediments were deposited mainly in shelf zone environment and there has been repeated transgression and regression of the sea. The data further tend to suggest a warm, humid climate and a luxuriant flora during the deposition of Goru sediment (Albian-Cenomanian), changed to a semi-humid to semi-arid climate during the deposition of Parh (Upper Cretaceous) is subsequently changed over to an arid climate with considerably poor vegetation during the deposition of Tertiary (Ranikot, Laki, Kirthar) sediments (Paleocene-Middle Eocene) had changed over to desert conditions during the deposition of Shumar formation.

INTRODUCTION

THE Manhera Tibba structure is located north west of Jaisalmer town. A number of wells have been drilled by Oil & Natural Gas Commission on this structure. Palynological studies on subsurface samples from the wells namely Manhera Tibba well No. 3 & 4 have been carried out and the data obtained from the various rock formations are presented here. The various rock units encountered in the Manhera Tibba structure in general from top are, Shumar, Kirthar, Laki, Ranikot, Parh and Goru formations. Palaeontologically the Goru and Parh formations are dated as Aptian to Coniacian in age; the Ranikot, Laki, and Kirthar is Paleocene to Middle Eocene (Lutetian) in age, while the age of Shumar formation is unknown due to absence of reliable microfossils. Dasgupta *et al.* (1958) on field evidence consider the the Shumar sediments as sub-recent deposits. The subsurface stratigraphy of Manhera Tibba in general be summarized as in Table-1. The data and interpretations are based on the results obtained from 370 samples studied from the two wells.

1. Shumar Formation

This is a sand, limestone, shale unit differentiated into four members from top to bottom namely, α, β, γ, δ members. The α member is mainly buff to brown eolian sand at the top followed by an intercalation of clay with medium to fine grained sandstone. The β member is characterized by dirty white, yellowish limestone bands with buff sandstone. Reworked foraminifera are observed in α and β members. The γ member is medium to coarse grained gravel sandstone, and sticky veriegated clay at the base. The δ member is characterised by alternations of medium grained to gravelly sands with bands of variegated clays with glauconitic clay at the base. Reworked microfauna have been observed in γ and δ members.

Palynologically, the sediments are found practically devoid of sporomorphs except a few *Trilites*, *Tricolpites*, *Triporites*, *Tricolporites*. The frequency of the sporomorph is very poor. Based on the poor sporomorph data, it is not possible to establish the age and environment of deposition of the Shumar formation. However, the total absence of microplanktons in the sediments tends to suggest that these sediments might have been deposited under non-marine, environment.

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TABLE 1 — GENERAL SUB-SURFACE STRATIGRAPHY OF MANHERA TIBBA JAISALMER BASIN

GROUP	SYSTEM	SERIES	STAGE	FORMATION	MEMBER	LITHOLOGY
Quaternary		Recent			Dune sands α	Sand
		? Sub-Recent		Shumar	β	Limestone and Calcareous Sst.
					γ	Sandstone and variegated clay
					δ	Alternating variagated clay and coarse grained sandstone and glauconitic clay UNCONFORMITY
Tertiary	Eocene	Middle Eocene	Lutetian	Kirthar	Bakhri Tibba Habib Rahi	Clay Limestone (A4) Clay Limestone (B2)
		Lower Eocene	Ypresian	Laki	Ghazij	Shale Limestone (B4) Shale
	Paleocene				Dunghan	Limestone (C2) Marl Limestone (C4)
				Ranikot		Marl/Clay/Shale DISCONFORMITY Limestone (D4) Clay & Marl Sandstone (D6) Clay Sandstone UNCONFORMITY
Mesozoic	Cretaceous		Coniacian Turonian	Parh		Marl (Fd) Clay/Marl/Limestone (Fe). Clay (Ff) Clay & Marl (Fg) Limestone (Fh)
			Cenomanian Aptian	Goru		Marl (Ga) Shale (Gb) Clay (Gc) Shale (Gd) Calcareous Siltstone & Shale (Ge) Sandstone (Gf) Shale & Calcareous Siltstone (Gg) Sandy shale and argillaceous sandstone (Gh)

2. KIRTHAR FORMATION

The Kirthar formation underlies the Shumar with a distinct unconformity. In the Manhera Tibba structure, the top of this formation is represented by a marly clay bed succeeded by two principal members namely the Bakhri Tibba limestone and the Habib Rahi limestones. These two members are separated from one another by a clay bed. The clay bed at the top is devoid of sporomorphs.

The Bakhri Tibba limestone is whitish, grey, massive, locally bioclastic, foraminiferal limestone.

A few *Triletes* (psilate), *Monocolpites* (reticulate) *Tricolpites*, *Triporites* (reticulate) have been noticed in the Bakhri Tibba limestone. The frequency of the spores is very poor. As a whole the sediment is poorly fossiliferous. No *Hystrichosphaeridium* has been recorded in the sediment.

The intermediate clay bed between the Bakhri Tibba and Habib Rahi limestone is also poorly fossiliferous. The few sporomorphs recorded in the sediments are *Monolites*, *Polypodiaceaesporites* sp., *Cyathidites* sp., *Triletes*, *Inaperturopollenites*, *Monocolpites* (psilate & reticulate), *Palmaepollenites* sp., *Tricolpites* (reticulate). The distribution of these spores is very irregular and frequency very poor. No microplanktons have been recorded in the sediment.

The Habib Rahi limestone is characterized by whitish, cream to buff, massive foraminiferal limestone.

Monolites, *Triletes*, *Inaperturopollenites* (reticulate), *Monocolpites*, *Palmaepollenites* sp., *Retipilanopites* (cf. Potamogetonaceae pollen), cf. Malvaceae pollen, cf. Rubiaceae pollen, *Hystrichosphaeridium* sp., have been recorded in the sediment. The frequency and destribution is poor.

In general the Kirthar formation is poorly fossiliferous and the frequency and distribution of the sporomorphs recorded is poor. The sporomorphs therefore do not help to distinguish the various members of Kirthar formation from one another.

The *Hystrichosphaeridium* recorded in the Habib Rahi limestone is suggestive of a shallow marine environment.

3. LAKI FORMATION

The Laki sediments underlying the Kirthar formation are represented by two principal members, namely the Ghazij shale at the top and Dunghan limestone below. The Ghazij member is principally an argillaceous unit differentiable into an upper and lower shale bed which are separated by a limestone bed, B4 limestone. The Ghazij shales are mainly composed of bluish grey, soft, plastic, pyritic clay with thin bands of foraminiferal limestone and marly limestone. The foraminiferal limestone associated with clay constitute the limestone bed (B4 limestone) which separates the upper and lower shale beds of the Ghazij member.

The sporomorphs recorded in general in Ghazij shales are *Triletes* (psilate & reticulate), *Monocolpites* (psilate and reticulate), *Tricolpites* (psilate and reticulate), *Tetracolpites*, *Polycolpites* sp., (7 to 9 colpi), *Triporites* (reticulate), *Proteacidites* sp., *Tricolporites*, *Hystrichosphaeridium* sp., marine cyst, and the algae, *Pediastrum* and *Botryococcus*. Although various spore types have been recorded in the sediment, their frequency and distribution are very poor. The sediment in general is poorly fossiliferous.

The presence of *Hystrichosphaeridium* in the sediment is suggestive of a shallow marine environment of deposition. The sediments at various intervals, are devoid of the microplanktons and wherever present, their frequency is poor. Besides at intervals, the marine cysts are also observed. It tends to suggest that the Ghazij shales had deposited under unstable sea level conditions.

The presence of *Pediastrum* in the sediment is suggestive of a fresh water influx. But its presence in Ghazij is not very much characteristic in the sense that the *Pediastrum* is not always recorded in all the Ghazij sections studied in the various wells. Therefore, the fesh water influx might have been only a limited and localized feature.

The lower member of Laki formation namely the Dunghan limestone is mainly composed of white, cream, dull-white, soft, friable bioclastic limestone.

The sporomorphs recorded in the Dunghan limestone are *Microthyriacites*, *Triletes* (psilate), *Inaperturopollenites* (psilate and reticulate), *Monocolpites*, *Tricolpites* (psilate & reticulate), *Tetracolpites*, *Pentacolpites*, *Triporites*, *Tricolporites* *Hystrichosphaeridium* sp., and marine cyst. The frequency and presence of various spore types is poor. A few Hystrichosphaerids recorded are suggestive of a shallow marine environment.

TABLE 2

FORMATION	MEMBER	SPOROMORPH GENERA	FREQUENCY/ DISTRIBUTION
1	2	3	4
Shumar		Devoid of Palynomorph: except solitary *Triletes*, *Tricolpites* *Triporites*, *Tricolporites*	Very rare
	UNCONFORMITY		
Kirthar	Bakhri Tibba limestone	*Triletes* (Erdtman ex Couper) Dettmann, 1963, *Monocolpites* Erdtman 1947, *Tricolpites* Erdtman 1947, *Triporites* Van-der Hammen 1953	Rare
	Clay	*Monolites* (Erdtman) Potonié 1956, *Polypodiaceaesporites* Thiergart, 1940, *Cyathidites* Couper 1953, *Triletes* (Erdtman ex Couper) Dettmann, *Inaperturopollenites* Thomson & pflug 1953, *Monocolpites* Erdtman, 1947, *Palmaepollenites* Potonié 1951, *Tricolpites* Erdtman 1947.	Rare
	Habib Rahi Limestone	*Monolites* (Erdtman) Potonié, *Triletes*, (Erdtman ex Couper) Dettmann, *Inaperturopollenites*, Thomson & Pflug, *Monocolpites* Erdtman, *Palmaepollenites* Potonié, *Retipilonapites*, Ramanujam, 1966 (cf. Potamogetonaceae pollen), cf. Malvaceae pollen, cf. Rutaceae pollen, *Hystrichosphaeridium* sp.	Rare
Laki	Ghazij shale	Triletes (Erdtman ex Couper) Dettmann, *Monocolpites* Erdtman, *Tricolpites* Erdtman, *Tetracolpites* Erdtman 1947, *Polycolpites* Couper 1953, *Triporites* Van der Hammen, *Proteacidites* Cookson 1950, *Tricolporites* Erdtman 1947, *Hystrichosphaeridium*, Marine cyst, *Pediastrum* and *Botryococcus*.	Rare
	Dunghan Limestone	Triletes (Erdtman ex Couper) Dettmann, *Microthyriacites* Cookson 1947, *Inaperturopollenites* Thomson & Pflug, *Monocolpites* Erdtman, *Tricolpites* Erdtman, *Tetracolpites* Erdtman, *Pentacolpites* *Triporites* Van-der Hammen, *Tricolporites*, Erdtman, *Hystrichosphaeridium*, marine cyst.	Rare
Ranikot		*Microthyriacites* Cookson, *Monolites* Erdtman, *Polypodiaceaesporites* Thiergart, 1940, *Triletes* (Erdtman ex-Couper) Dettmann, *Schizaeoisporites* Potonié 1951, *Cyathidites* Couper, *Lycopodiacidites* (Couper) Potonié 1956, *Schizosporis* Potonié 1951, cf. *Pinus* pollen, *Inaperturopollenites* Thomson & Pflug, cf. Potamogetonaceae pollen, *Monocolpites* Erdtman, *Palmaepollenites* Potonié 1951, Nymphaeaceae pollen, *Tricolpites*, Erdtman, cf. Fagaceae pollen, *Palaeocaesalpiniaceaepites* Biswas, 1962, *Myrtaceidites* (Cookson & Pike) Potonié 1960., *Todisporites* Couper 1958, *Tetracolpites* Erdtman, *Hexacolpites*, Erdtman 1947, *Polycolpites* Couper 1953, *Triporites* Van der Hammen, *Proteacidites* Cookson 1950, cf. Tiliaceae pollen, *Tricolporites* Erdtman, *Ilexpollenites* Thiergart 1937, *Hystrichosphaeridium*, marine cyst.	Rare
	UNCONFORMITY		
Parh		*Triletes* (Erdtman ex Couper) Dettmann, *Ceratosporites* Cookson & Dettmann 1958, *Lycopodiacidites* (Couper) Potonié 1956, *Cicatricosisporites* Potonié & Gelletich 1933, *Schizosporis* Potonié, *Classopollis-classoides*	Rare

TABLE 2 — *Continued*

FORMATION	MEMBER	SPOROMORPH GENERA	FREQUENCY DISTRIBUTION
1	2	3	4
		(Pflug) Pocock and Jansonius 1961, *Inaperturopollenites* Thomson & Pflug, *Gnetaceaepollenites* (Thiergart 1938) Jansonius 1962, *Monocolpites* Erdtman, *Tricolpites* Erdtman, *Triporites* Van der Hammen, *Tricolporites* Erdtman, *Hystrichosphaeridium*, *Micrhystridium* (Deflandre) Staplin 1961, *Pterospermopsis*, Marine cyst, Microforaminifera. *Trilites* (Erdtman ex Couper) Dettmann, *Foveotriletes* (Van der Hammen) Potonié 1956, *Chomotriletes* (Naumova) ex Naumova 1953, *Lycopodiacidites* (Couper) Potonié 1956, *Cyathidites* Couper 1953, *Schizaeoisporites* Potonié 1951, *Sphagnumsporites* Raatz 1937, *Cingutriletes* (Pierce) Dettmann 1963, *Dictyophyllidites* Cookson Dettmann, *Cicatricosisporites australiensis* (Cookson) Potonié 1956, *Cicatricosisporites* Potonié & Gelletich 1933, *Dictyosporites* Cookson & Dettmann, *Polycingulatisporites* Kedves, *Crybelosporites* Dettmann 1963, *Biretisporites* (Delcourt & Sprumont) Dettmann & Hughes 1963.	
Upper Goru		*Equisetosporites* (Daugherty) Singh 1964, *Classopollis classoides* (Pflug) Pocock & Jansonius 1961, *Classopollis itunensis* Pocock 1962, *Araucariacites* Cookson, *Cycadopites* (Woodhouse) Wilson & Webster 1946, *Laricoidites* Potonié Thomson and Thiergart, *Clavatipollenites* Couper 1958, *Monocolpites* Erdtman, *Tricolpites* Erdtman, *Triporites* Van der Hammen, *Inaperturopollenites* Thomson & Pflug, *Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre, *Hystrichosphaeridium* spp., *Palaeoperidinium* Deflandre, *Palaeohystrichophora ovovispinosa* Pocock 1962, *Pterospermopsis* sp., *Odontochitina* Deflandre, Gonyaulacysta sp. *Baltisphaeridium* Eisenack, *Microforaminifera*.	Fairly rich
Lower Goru		*Trilites*, *Chomotriletes*, *Ceratosporites* Cookson & Dettmann 1958, *Cyathidites asper* Bolkhovitina, *Cyathidites* spp. Couper 1953, *Crybelosporites* Dettmann 1963, *Cicatricosisporites dorogensis* Potonié and Gelletich, *Cicatricosisporites-australiensis* (Cookson) Potonié 1956, *Cicatricosisporites* spp., Potonié & Gelletich, *Densoisporites* (Weyland & Krieger) Dettmann 1963, Lycopodiacidites (Couper) Potonié 1956, *Polypodiaceaesporites* Thiergart 1940, *Reticulatisporites castellatus* Pocock 1962, *Schizosporis* Cookson & Dettmann *Dictyosporites* Cookson & Dettmann, *Murospora* Somers 1952. *Aequitriradites* (Delcourt and Sprumont) Cookson & Dettmann, *Rouseisporites* Pocock 1962, *Classopollis* (Pflug) Pocock & Jansonius, *Laricoidites* Potonié, Thomson & Thiergart, *Coptospora* Dettmann 1963 *Callialasporites monoalasporus* Dev. 1961 *Callialasporites segmentatus* (Balme) Srivastava 1963, *Callialasporites trilobatus* (Balme) Dev 1961, *Araucariacites* Cookson, *Cycadopites* (Woodhouse) Wilson & Webster, *Sphaeripollenites* (Couper) Jansonius 1962, *Clavatipollenites couperii* Pocock 1962, *Clavatipollenites* Couper 1958, *Eucommiidites* (Erdtman) Hughes, *Inaperturopollenites* Thomson & Pflug, *Hystrichosphaeridium*, *Baltisphaeridium* Eisenack, *Pseudoceratium*, *Palaeoperidinium* Deflandre, *Gonyaulacysta*, *Odontochitina* Deflandre, Microforaminifera.	Fairly rich

Laki sediments in general is poorly fossiliferous and the distribution and frequency of the sporomorphs recorded are inconsistent and poor.

Hystrichosphaeridium suggests deposition of sediments in general under a shallow marine environment. The poor frequency, inconsistent distribution of sporomorphs and the presence of marine cysts in the Ghazij shale tend to suggest that the Ghazij shales might have deposited under an unstable sea level condition.

The occasional presence of *Pediastrum*, in Laki sediments in general suggests more or less a limited and localized fresh-water influx.

4. Ranikot Formation

In the Manhera Tibba structure, the, Ranikot formation underlies the Dunghan member of the Laki formation with a disconformity as suggested by the presence of Glauconitic pyritic shales. The upper part of the formation is glauconitic, pyritic marly clay succeeded by argillaceous fossiliferous limestone (D4 limestone) and grey, plastic sticky, and slightly calcareous clay. The lower part of the formation is mainly medium to coarse grained grey, moderately sorted sandstone (D6 sandstone) with calcareous clay at the base.

The sporomorphs recorded are *Microthyriacites* sp., *Monolites* sp., *Polypodiaceaesporites* sp., *Triletes*, sp. ,*Schizaeoisporites* sp., *Cyathidites* sp., *Lycopodiacidites* sp., *Schizosporis* sp., cf. *Pinus pollen*, *Inaperturopollenites* sp., cf. Potamogetonaceae pollen *Monocolpites* (reticulate), *Palmaepollenites* sp., cf. Nymphaeaceae pollen, *Tricolpites* (reticulate), *Tricolporites* sp., cf. Fagaceae pollen, *Palaeocaesalpiniaceaepites* sp., *Myrtaceidites* sp., *Todisporites* sp., *Tetracolpites*, *Hexacolpites*, *Polycolpites* (8-10 colpi), *Triporites*, *Proteacidites* sp., cf. Tiliaceae pollen, *Tricolporites*, *Ilexpollenites*, *Hystrichosphaeridium*, sp., and marine cysts.

The spore assemblage recorded in Ranikot sediments is relatively better than that recorded in Laki formation. But, the frequency and distribution of the various types are inconsistent. As such, it is not possible to delineate the sporomorph assemblage characteristic of Ranikot formation.

The sporomorphs recorded in this formation suggest that the Ranikot sediments had deposited under two environments namely fresh water and shallow marine environments. This is evidenced from the distribution of Nymphaeaceae pollen and *Hystrichosphaeridium* in the sediments. It is interesting to note that the *Hystrichosphaeridium* spp. have been recorded in the D4 limestone, the clay overlying and underlying the D4, and at the base of the D6 sediment, while they are absent in the major part of Ranikot sand designated as D6, which contain Nymphaeaceae pollen. This suggests, that the basal D6,D4 and the clay overlying & underlying D4 of Ranikot formation had deposited under shallow marine environment, while the upper part of D6 sand had deposited under fresh water environment. The Palynological data of Bakhri Tibba well No. 2 drilled in the area fruther supports the above observation. (Lukose and Srivastava, 1970 & 1971).

In general the Tertiary sequence represented by Kirthar, Laki and Ranikot formations are poorly fossiliferous. The distribution and frequency of the few sporomorphs recorded in these sediments are poor and inconsistent. Therefore, it is not possible to delineate a sporomorph assemblage caracteristic of each of the formation.

The palynological data obtained from these sediments suggest that the various rock formations had mainly deposited under a shallow marine environment except the D6 sand of Ranikot sediment, which had deposited under fresh water as well as marine environment. Further, the poor sporomorph frequency, inconsistent sporomorph distribution in the sediments in general, and presence of marine cysts in the Ranikot sediment tend to indicate, that the sediments have deposited under an unstable sea level condition.

Practically a complete absence of saccate coniferous pollen has been observed in the various Tertiary rock formations and it suggests that the topography near and around the basin of deposition had been low.

5. Parh Formation

Parh sediments unconformably underlie the Ranikot formation. In Manhera Tibba, the Parh formation is mainly constituted by greenish grey micaceous clay, whitish, bluish grey marl and marly clay and argillaceous limestone.

The sporomorphs recorded from this, sediment are *Triletes*, *Ceratosporites* sp., *Lycopodiacidites* sp., *Cicatricosisporites* sp., *Schizosporis* sp., *Classopollis classoides*, *In-*

aperturopollenites sp., *Araucariacites* spp., *Gnetaceapollenites* sp., *Monocolpites*, *Tricolpites*, *Triporites*, *Tricolporites*, *Hystrichosphaeridium*, *Micrhystridium* sp., *Pterospermopsis* sp., marine cyst and microforaminifera.

The frequency and distribution of the various spore types are poor. In general the sediment is poorly fossiliferous. The *Classopollis* sp., and microplanktons dominate among the sporomorph assemblage recorded from this formation. The various other spore types of the assemblage listed above are generally represented by solitary grains. Venkatachala (1966) indicated an Upper Triassic-Cretaceous range for sporegenus *Classopollis* with the exception of *Classopollis obidosensis* and *C. major* which have a Cretaceous-Paleocene range. *Classopollis classoides recorded* in Parh formation is so far not reported in sediments younger to Cretaceous. The presence of *Classopollis* and various types of angiosperm pollen along with the absence of important Lower Cretaceous sporomorphs suggests an Upper Cretaceous age for the Parh formation. The microplanktons recorded in the sediments are suggestive of a shallow marine environment.

6. GORU FORMATION

Underlying the Parh sediments, is the Goru sediments mainly composed of grey green marl, grey green shale with argillaceous fine grained sandstone and glauconitic shale at the bottom. On the basis of lithology this sediment is broadly recognizable into eight beds designated as Ga to Gh (Goru a to h). These beds from top are (a) marl, (b) shale, (c) silty clay stone with siltstone, (d) shale, (e) calcareous siltstone and shale, (f) argillaceous siltstone and sand (g) sandy shale and calcareous siltstone and (h) sandy shales and argillaceous sandstone at the base.

The sporomorphs recorded in this sediment are recognizable into two distinct assemblages. That is, the upper beds from Ga to Gd with an assemblage having angiosperm pollen and the lower beds from Ge to Gk with an assemblage devoid of angiosperm pollen but having the spore genus *Callialasporites*.

The sporomorphs recorded in Ga to Gd are *Triletes*, *Foveotriletes*, sp., *Chomotriletes* sp., *Lycopodiacidites* sp., *Cyathidites* sp., *Schizaeoisporites* sp., *Sphagnumsporites* sp., *Cingutriletes* sp., *Dictyophyllidites* *Cicatricosisporites australiensis*, *Cicatricosisporites* sp., *Dictyosporites* sp., *Polycingulatisporites* sp., *Crybelosporites* sp., *Birdtisporites* sp., *Equisetosporites* sp., *Classopollis classoides*, *Classopollis itunensis*. *Araucariacites* spp., *Cycadopites* sp., *Laricoidites* sp., *Clavatipollenites* sp., *Monocolpites*, *Tricolpites* *Triporites*, *Inaperturopollenites*, *Hystrichosphaeridium tubiferum*, *Hystrichosphaeridium* spp., cf. *Palaeoperidinium* sp., *Palaeohystrichophora breuispinosa*, *Pterospermopsis* sp., *Odontochitina* sp., *Gonyaulacysta* sp., *Baltisphaeridium* sp., *Microforaminifera*.

The sporepollen assemblage recorded in the lower Ge to Gh beds consists of *Triletes*, *Chomotriletes* sp., *Ceratosporites* sp., *Cyathidites*, *C. asper*. *Crybelosporites* sp., *Cicatricosisporites dorogensis*, *C. australiensis*, *Cicatricosisporites* sp., *Densoisporites* sp., *Lycopodiacidites* sp., *Polypodiaceaesporites* sp., *Reticulatisporites castellatus*, *Schizosporis*, *Dictyosporites* sp., *Murospora* sp., *Aequitriradites* sp., *Rouseisporites* sp., *Classopollis* sp., *Laricoidites* sp., *Coptospora* sp., *Callialasporites monalasporus*, *C. segmentatus*, *C. trilobatus*, *Callialasporites* sp., *Araucariacites*, sp., *Cycadopites* sp., *Sphaeripollenites* sp., *Clavatipollenites couperii*, *Clavatipollenites* sp., *Inaperturopollenites*. sp., *Eucommiidites* sp., *Hystrichosphaeridium* sp., *Baltisphaeridium* sp., *Pseudoceratium* sp., *Palaeoperidinium* sp., *Gonyulacysta* sp., *Odontochitina* sp., marine cyst, microforaminifera.

The known range of *Callialasporites* is Jurassic to Lower Cretaceous, with the* top limit to Albian. Undisputed, and well recognizable angiosperm pollen occur from Cenomanian and extend allthrough in the Tertiary. In the Goru sediments the assemblage with angiosperm pollen is recorded in the upper beds namely Ga to Gd member. In the lower members, namely, Ge to Gh, the sporomorph assemblage is devoid of angiosperm pollen (with the exemption of *Clavatipollenites*, a doubtful angiosperm pollen) but have *Callialasporites* spp. Since the known upper limit of the genus *Callialasporites* is Albian and this genus disappers at top of Ge bed (i.e. the Calcareous siltstone and shale bed) together with the appearance

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*Sah & Kar (1970) reported the occurance of *Callialasporites* in Laki sediments in Kutch. However, they did not discuss the importance of its occurance in Laki sediments or the age of Laki sediments. I consider, its occurance in the Laki sediments is due to redeposition of older (Mesozoic) sediments.

of angiosperm pollen at the base of Gd bed (shale) in Goru sediment, a floral break/ change may be demarcated between the beds Gd & Ge. As the known top limit of *Callialasporites* is Albian and the genus disappears at the top of Ge member supported with the appearance of angiosperm pollen from the base of Gd member in Goru sediments, the floral break between Gd and Ge may correspond to Albian/Cenomanian boundary. Based on this, it is possible to divide the Goru sediments into Lower Goru and Upper Goru, suggesting Albian and Cenomanian age respectively with the calcareous siltstone and shale member (Ge) as the top limit of the Lower Goru and the shale member (Gd) as the base of the Upper Goru. Micropalaeontological evidence suggests an ? Aptian-Cenomanian age for the Goru sediments.

The various types of microplanktons recorded in the sediment suggests that the Goru sediments are deposited under marine to shallow marine environment.

REGRESSION AND TRANSGRESSION

The present study indicates that the lower part of Ranikot formation i.e. the D6 sandstone and the Shumar formation that unconformably overly the Kirthar sediments, have been deposited under fresh water environment. Similarly, the Goru, Parh, Upper part of Ranikot, Laki and Kirthar formations have deposited under shallow marine environment. See chart 2. These fresh water facies between the marine facies suggest regressions of sea in the basin, one at the close of the Mesozoic i.e. after the deposition of Parh sediments and another at the close of the Lower Tertiary sediments namely the Kirthar formation. It may also be observed that after these two regressions, the basin had been inactive in deposition for a considerably long period, and is evidenced from the two unconformities, one between the Parh and Ranikot sediments and another between Kirthar and Shumar sediments. On Palaeontological evidence, the Parh sediments have been considered as Turonian to Coniacian in age. The Ranikot (Paleocene) sediments resting unconformably over the Parh (Turonian-Coniacian) sediments, indicate a break in sedimentation after the regression of sea at the close of Mesozoic deposition in this basin and this break corresponds to Santonian to Maastrichtian periods. Similarly, the Shumar (? Sub-recent) sediments, rest unconformably over the Middle Eocene Kirthar (Lutetian) sediments. It indicates once again that the basin had been inactive in sedimentation for considerably long period after the regression of sea at the close of the deposition of Kirthar sediments.

After the regression, and period of unconformity at the close of Upper Mesozoic (Parh) sediments the basin sank under fresh water and deposited the D6 sand of the Ranikot formation under the fresh water environment. Thereafter, the sea transgressed into the basin and the deposition of the upper part of Ranikot, Laki and, Kirthar sediments have taken place in marine environment, under unstable sea level condition. This has been evidenced from the presence of *Hystrichosphaeridium* and marine cysts in these sediments. The *Hystrichosphaeridium* in general suggests a shallow marine environment and the presence of marine cysts indicate an adverse environment-unstable sea level condition.

During the deposition of Kirthar sediments again the sea regressed and the basin remained inactive in sedimentaion for a long period as has been evidenced from the unconformity between the Kirthar and the overlying Shumar formation. After this period of unconformity the Shumar sediments had deposited under non-marine environment. Palynologically, there is no positive evidence to indicate as to under what exact environment the Shumar sediments had deposited. However, the, negative evidence i.e. a complete absence of any microplanktons, supported by the absence of micropalaeontological fossils other than a few reworked fauna in the Shumar sediments tends to suggest that the Shumars had deposited under non-marine environment.

PALAEOCLIMATE AND TOPOGRAPAY

The Goru, Parh, Ranikot, Laki and Kirthar sediments representing the Albian to Middle Eocene (Lutetian) period are devoid of disaccate coniferous pollen grains. It tends to suggest, that the topography near and around the basin of deposition would have been low.

The palynological data obtained from the various rock units shows a rich sporomorph assemblage with a good percentage of pteridophytic spores in the Goru (Albian-

Cenomanian) sediment, and a successive reduction in the total terrestial floral elements as well as equally reduced percentage of pteridophytic elements in the overlying Parh (Upper Cretaceous), Ranikot, Laki, Kirthar (Paleocene-Middle Eocene) sediments and almost complete absence of sporomorphs in the Shumar (? Sub-recent) formation.

The chart No. 1 shows the percentage of terrestrial and non-terrestrial elements calculated from the total sporomorph count obtained from the Goru to Shumar sediments. Out of a total 41% terrestrial sporomorphs 15% are pteridophytic elements in the Goru sediments. It suggest the existence of a luxuriant flora and a warm humid climate during the deposition of Goru sediments. The total percentage of terrertrial sporomorph is considerably reduced in the Parh sediments i.e. almost 1/6 to that of the Goru sediments and the percentage of pteridophytic spores are also relatively reduced in the Parh sediments. The considerable reduction in the total terrestrial sporomorph percentage and the reduction in the percentage of pteridophytic elements in the Parh sediments suggest a poor flora and a semi-humid to semi-arid climate during the deposition of Parh sediments.

While the total terrestrial sporomorph percentage remained unchanged, the percentage of pteridophytic spores has been considerably reduced (to 0·5%) in the Ranikot sediments. The total, terrestrial sporomorph percentage has been successively reduced in the Laki and Kirthar sediments. Equally, the pteridophytic elements are also reduced. It tends to suggest poor vegetation and a successive increase in degree of aridity during the deposition of Laki and Kirthar sediments.

The absence of sporomorph and the nature of Shumar sediments in general, suggests an almost complete absence of vegetation and probably the existence of a desertic condition during the deposition of Shumar sediments.

Thus, it is interesting to note that the warm and humid climate and the luxuriant flora during the deposition of Goru (Albian-Cenomanian) sediments changed to a semi-humid to semi-arid climate with considerably reduced flora during the deposition of Parh (Upper Cretaceous) sedimentss subsequently changed over to an arid climate and poor vegetation during the deposition of Ranikot, Laki and Kirthar (Paleocene-Middle Eocene) sediments had possibly changed over to desertic conditions during the deposition of Shumar sediments.

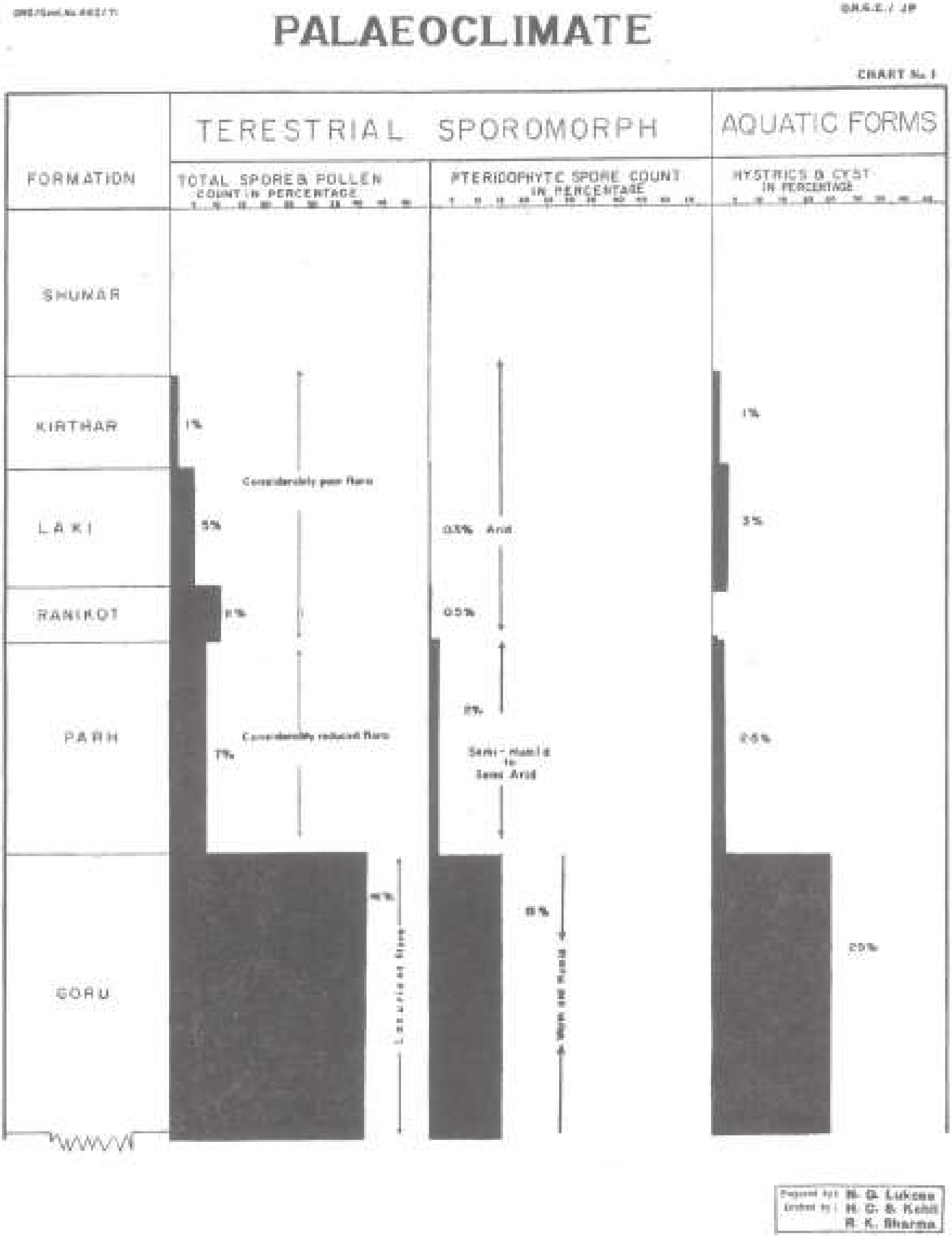
SUMMARY

Palynological studies on the subsurface sediments namely the Shumar, Kirthar, Laki, Ranikot Parh and Goru sediments from Manhera Tibba, Jaisalmer district, has been carried out. The topmost formation namely the Shumar is practically devoid of sporomorphs. As such, it is not possible to indicate the age and environment of the sediment. But from the total absence of any microplankton in the sediment suggests that the sediments might been deposited under non-marine influence.

The Kirthar formation unconformably underlie the Shumar formation. Bakhri Tibba and Habib Rahi limestones principally constitute the Kirthar formation. Underlying the Kirthar sediments is the Laki formation constituted by Ghazij shales and Dunghan limestone. Ranikot formation underlies the Laki formation. The sporomorphs recorded in the above Tertiary, sequence, in general are poor, and do not help to distinguish the various rock units. However, the data suggest that the various rock units have been deposited under shallow marine environment except the basal Ranikot (i.e. the D6 sand) which had deposited under fresh water environment. Limited and more or less localised fresh water influx is also evidenced in the Ghazij shales.

The Parh sediments unconformably underlie the Ranikot sequence. The sporomorph recorded in Parh sediments is suggestive of Upper Cretaceous age. The microplanktons recorded in the sediment are indicative of a shallow marine environment.

The Goru formation underlies the Parh formation. Based on the sporomorph assemblage recorded from this sediment, the Goru sediments be distinguishable into Upper and Lower Goru formation. The Upper Goru has angiosperm pollen and the Lower Goru devoid of angiosperm pollen, has the spore genus *Callialasporites*. Undisputed and well recognizable angiosperm pollen occurs from Cenomanian and extends throughout the entire Tertiary. The known range of *Callialasporites* is Jurassic to Lower Cretaceous extending the top limit, to Albian. Based on the floral break/change



ONG/Geol.No 482/71
PALAEOCLIMATE
O.N.G.C./ JP
CHART No. 1
FORMATION
TERESTRIAL SPOROMORPH
AQUATIC FORMS
TOTAL SPORES & POLLEN COUNT IN PERCENTAGE
PTERIDOPHYTE SPORE COUNT IN PERCENTAGE
HYSTRICS & CYST IN PERCENTAGE
SHUNAR
KIRTHAR
LAKI
RANIKOT
PARH
GORU
1%
5%
8%
7%
46%
Considerably poor flora
Considerably reduced flora
Luxuriant flora
0.5% Arid
0.5%
2%
Semi-humid to Semi Arid
15%
Warm and Humid
1%
3%
2.5%
25%
Prepared by: N. G. Lukose
Drafted by: H. C. & Kohli
R. K. Sharma

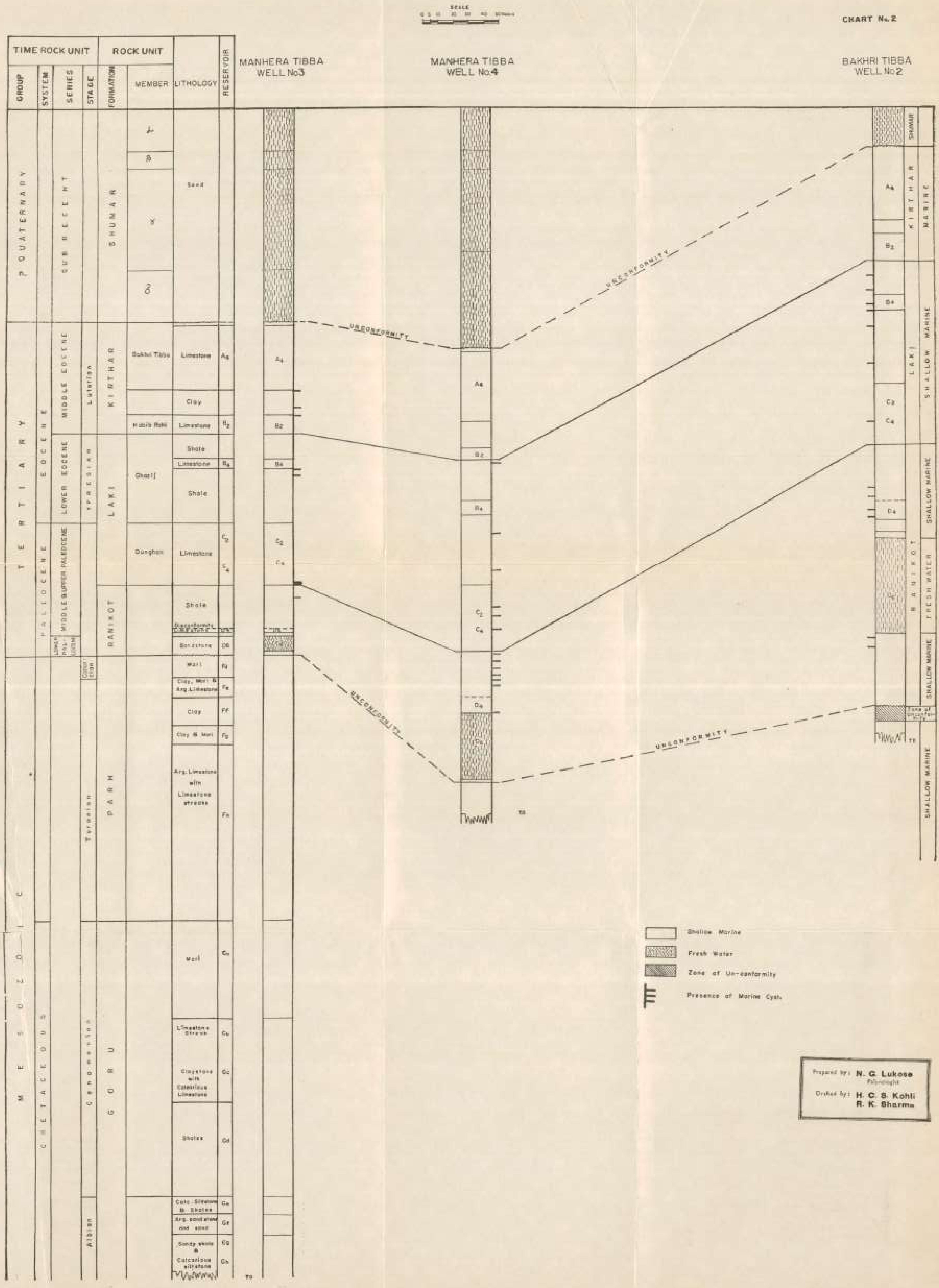
Chart 1

Pages 295-296

ONGC/JP

ENVIRONMENT OF DEPOSITION

CHART No. 2



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Drafted by: **H. C. S. Kohli**
R. K. Sharma

and two corresponding sporomorph assemblages noted in Goru sediment, Cenomanian age is suggested for Upper Goru and Albian age for Lower Goru sediments. The various microplanktons recorded in the Goru sediments are suggestive of shallow marine to marine environment.

It has been observed that the major part of D6 sandstone (i.e. the basal Ranikot formation) had deposited under fresh water environment. This fresh water facies suggests, regression of the sea in the basin; one at the close of Upper Cretaceous (Parh) sediments and another at the close of Lower Tertiary (Kirthar) sediments. After these two regressions, the basin had been inactive in deposition for a considerably long period, which is evidenced from the unconformity between Parh Ranikot and Kirthar Shumar formations. After the regression and the period of unconformity at the close of the Upper Mesozoic (Parh) sediments, the basin sank under fresh water and the basal Ranikot D6 sandstone (Paleocene) had deposited under fresh water environment. Thereafter, the sea transgressed into the basin and depositited the upper part of Ranikot, Laki and Kirthar sediments, under shallow marine environment. This is evidenced from the presence of microplanktons in these sediments. At the close of the deposition of Kirthar sediments once again the sea regressed and the basin remained inactive in deposition for a considerably long period and followed by the deposition of Shumar sediments under a non-marine environment.

The Cretaceous, the Tertiary and the Shumar (Sub-Recent) sediments have been found practically devoid of bisaccate coniferous pollen grains. It tends to suggest a low topography near and around the basin during the deposition of Goru, Parh, Ranikot, Laki, Kirthar and Shumar sediments.

The data further suggest a luxuriant flora and a warm humid climate during the deposition of Goru (Albian-Cenomanian) sediments; a semi-humid to semi-arid climate and considerably reduced flora during the deposition of Parh (Upper Cretaceous), and an arid climate with poor vegetation during the deposition of Ranikot, Laki and Kirthar sediments, (Paleocene-Middle Eocene-Lutetian). The climate changed over to desertic conditions during the deposition of the ? Sub-Recent Shumar formation.

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STUDIES IN THE GLOSSOPTERIS FLORA OF INDIA—41. *GONDWANOPHYTON* GEN. NOV. WITH A REVISION OF ALLIED PLANT FOSSILS FROM THE LOWER GONDWANA OF INDIA

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ABSTRACT

Gondwanophyton a new plant fossil from the Barakar Formation of the Raniganj coalfield is recorded. The fossil is characterized by fan-shaped leaf with a wide rounded entire apex and sessile truncate base with parallel running dichotomous veins without any interconnections. Leaves are at times found attached to a narrow axis. Cuticle is differentiated into stomatiferous and non-stomatiferous surfaces. Stomatiferous surface has distinct bands of stomatal and non-stomatal zones. In the stomatal zone, the stomata are arranged in a single discontinuous row. In addition to this the systematics of allied fronds (*Psygmophyllum* and *Rhipidopsis*) previously recorded from the Lower Gondwanas of India are discussed.

INTRODUCTION

FAN-SHAPED fronds with ± parallel, dichotomous veins are known from the Lower Gondwanas of India and equivalent formations of other countries in the Southern Hemisphere. The previous records are as follows:

Psygmophyllum kidstonii Seward
Psygmophyllum hollandii Seward
Psygmophyllum haydenii Seward
Psygmophyllum sahnii Ganju
Rhipidopsis densinervis Feistmantel
Rhipidopsis ginkgoides Feistmantel

In a recent collection a number of fan-shaped leaves were collected from the Churulia pit of the Raniganj Coalfield. The fronds are entire with ± parallel running dichotomous veins without any anastomoses. In some examples a number of them are found attached to an axis. Cuticular aspects of the leaves are also known. A comparison with the known records shows that these leaves are morphologically distinct and represent a new type for which the name *Gondwanophyton* is proposed. The systematic position of the previous records of fan-shaped leaf genera are discussed and suggestion are made for their proper taxonomic placements.

MATERIAL AND METHODS

The material described in this paper has been collected from the carbonaceous shale beds lying above the Churulia seam at the Churulia pit in the East Raniganj Coalfield (West Bengal). The beds belong to the Barakar Formation. In all the specimens carbonized crust is preserved. Preparations of cuticles were made after taking out pulls from the surface of leaf with the help of Cellulose acetate prepared in acetone. This pull was macerated in HNO_3 and subsequently treated with 5% KOH. After this the pieces of cuticles were stained in safranin and mounted in Canada balsam.

DESCRIPTION

Gondwanophyton gen. nov.

Generic Diagnosis — Fan-shaped entire leaves, apex broadly rounded, lateral margins converging to form narrow truncate base, base non-petiolate, attachment alternate to the axis. Veins erect, dichotomizing, running ± parallel to each other without any interconnections.

Genotype — *Gondwanophyton indicum* sp. nov.

Gondwanophyton indicum sp. nov.

Pls. 1, 2; Figs. 1-7; Text-figs. 1-3

Specific Diagnosis — Fan-shaped leaves, apex broadly rounded and entire; base, truncate and non-petiolate; closely spaced, erect, spreading ± parallel veins arise from the base, they run forward and dichotomize frequently at irregular intervals. Course of veins straight, density 20-26 veins per centimeter. Leaves attached obliquely to the narrow axis by their truncate base; arrangement alternate.

Cuticle differentiated into stomatiferous and non-stomatiferous surfaces. Non-stomatiferous surface has hair bases; cells elongate-rectangular in shape. Stomatiferous surface non-papillate; shows alternate zones of stomatiferous and non-stomatiferous bands. Stomata haplocheilic, not sunken, usually single stomata across the width of stomatiferous surface, linear or slightly oblique orientation, pit surface rectangular, stomatal opening a vertical slit; subsidiary cells 4-6 in number.

Syntypes — Specimen No. 35025/1216, 35026/1216 and 35027/1216· Slide No. 4457 and 4458. of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Churuliapit, Raniganj Coalfield.

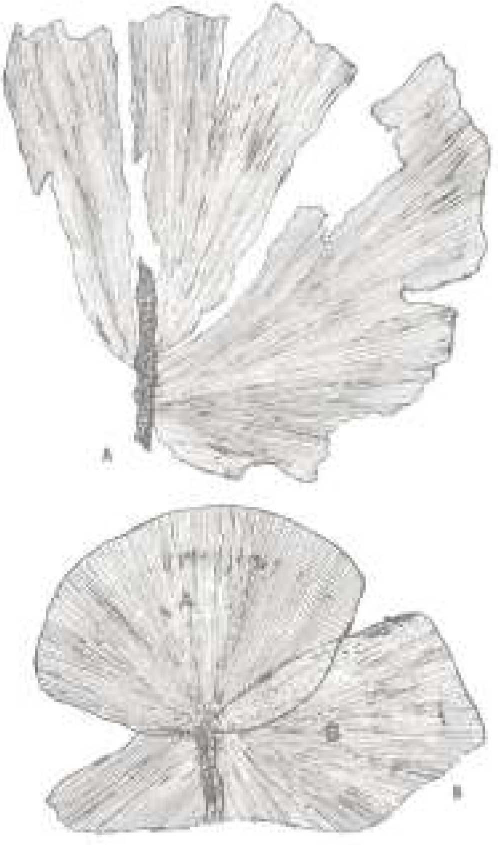
Horizon — Barakar Formation (Churulia Seam).

Age — Lower Permian

Description — The collection contain 40 specimens. Few of them are completely preserved and in cases are attached to an axis. The figured specimen in Pl. 1, Fig. 1 is a wide fan-shaped leaf, measuring 9·5 cm. long and 10·5 cm. broad at the widest regions. Lateral margins show convergence towards the base, which is narrow and truncate. In the basal portion of the leaf few longitudinal folds are preserved due to overlapping. From this it is evident that the leaves originally had an inner concavity near the point of their attachment. Eight erect divergent veins emerge from the basal portion of the leaf. Each of them dichotomize at the very basal region and show subsequent dichotomy as they run forward towards apical region. The veins are arranged ± parallel. The angle of divergence at the point of dichotomy between two veins is from 2°-3°. The density of veins varies from 20-24 veins per cm. Usually the density of veins is less towards the lower portion of the leaf in comparison to the apical region. The apical portion of the leaf is not preserved. The specimen does not show any attachment to axis. However, one axis is preserved near the leaf which is 6·5 cm. long and 4 mm. broad. A faint median ridge is present in the axis.

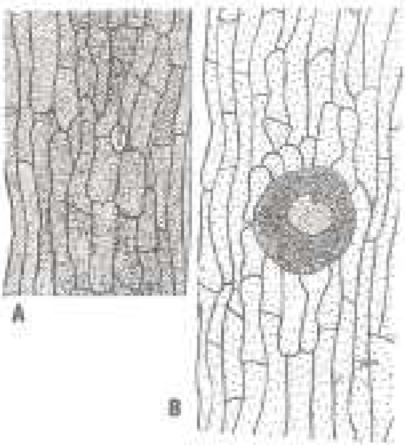
Another specimen figured here (Pl. 2, Fig. 6; Text-Fig. 1A) shows an axis measuring 2·5 cm. long and 3 mm. broad. To this axis a leaf is attached. The leaf is incomplete and has two major irregular longitudinal splits. The leaf shows attachment to the axis by its wide truncate base. A portion of leaf was cleared out from the rock matrix above the stem by careful manipulation with the help of fine needles to see the mode of attachment. It revealed that the leaf was attached by its wide truncate base somewhat obliquely to the stem.

The specimen figured (Pl. 2, Fig. 7; Text Fig. 1B) shows an axis alongwith two leaves preserved in a transverse plane. The axis is 12 mm. long and 2 mm. broad and has fine striations. The two leaves are attached to the axis alternately at two different points. They are oppositely arranged. The leaf (A) which is preserved above is complete, whereas the leaf (B) preserved below is comparatively bigger and incomplete at the apical portion. The complete leaf measures 2 cm. long and 3 cm. broad at the widest part. The widest region of the leaf is near the apex. The leaf is V-shaped with a rounded apex. Apical margin is entire. Attachment to axis is



TEXT-FIG. 1. A.— Solitary leaf with longitudinal splits attached to a narrow axis. ca. ×1.

B.— Two leaves attached to axis preserved superimposed to each other showing alternate attachment of leaf. ca. ×1.



TEXT-FIG. 2. A.—Cells of stomatiferous surface with stomata. × 500

B.—Cells of non-stomatiferous surface with hair base. × 500

by its truncate base. The lower leaf (B) is incomplete at the apical end. However, both the lateral margins are well preserved.

Epidermal Structure

All the leaves in the collection yielded identical cuticles. The cuticle is extremely thin. Two surfaces are easily distinguishable from each other. The gross difference are that on one surface (? lower) hair bases are absent and shows distinct longitudinal bands of stomatiferous zone and non-stomatiferous zones arranged alternately, whereas on the other surface (? upper) the hair bases are present and the epidermal surface is devoid of stomata.

The (?) lower surface of the cuticle shows distinct alternation of stomatiferous and non-stomatiferous bands (Pl. 1, Fig. 2). Non-stomatiferous bands are 8-10 cells wide. The cells of the non-stomatiferous bands are 4-6 sided, usually three to five times longer than broad, more or less arranged in rows and vary in shape from rectangular to trapezoid or rhomboidal. They measure 60-80 μ long 6-10 μ broad. The stomatiferous band is very narrow.

The cells in this zone vary from nearly isodiametric to linear elongated. The cells are 20-30 μ long and 8-10 μ broad. Usually one stoma (Pl. 1, Fig. 3; Text-Fig. 2A) is present across the stomatal band. Stomata 8-10 μ and longitudinally or slightly obliquely orientated. The guard cells are extremely thin and show little or no cutinization, with the result that the entire surface of the pit appears almost transparent. The pit surface is usually polygonal or occasionally rectangular in shape. It usually shows a narrow slit-like aperture between the guard cells. The slit may or may not extend up to the full length of the pit surface. The subsidiary cells are 5-7 in number. They are similar to the ordinary cells of stomatiferous zone. The two poles are not as a rule occupied by two polar cells. There may be a single polar cell also. In rare instances adjacent stomata may share common subsidiary cells.

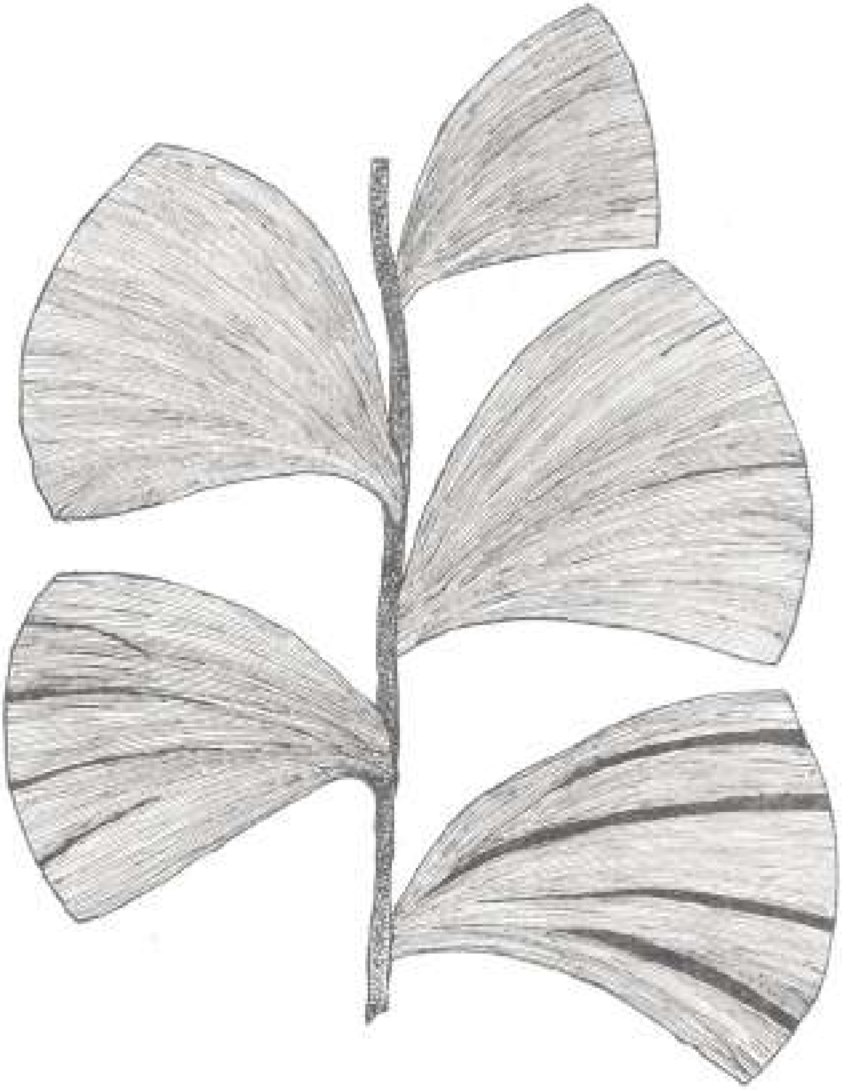
The non-stomatiferous surface of the cuticle is slightly thicker than the stomatiferous surfaces (Pl. 2, Fig. 4). It is characterized by linear elongated, 4 sided cells arranged in a definite rows. Cells are 60-120 μ long and 4-10 μ broad. They are usually rectangular, trapezoid to occasionally, rhomboidal. Remnants of hair bases are well marked. They are irregularly distributed. The remain of hair base is like a oval scar (Pl. 2, Fig. 5; Text-Fig. 2B), which is highly cutinized, measuring 20 μ.

Reconstruction

With the help of the data available an attempt has been made in Text-Fig. 3 to reconstruct the habit of the frond. In piecing together the detached fragments there always exists an element of error. This must be faced if a reconstruction is to be visualized. The reconstruction is based upon leaves found attached to an axis or in close association with stems. The evidence available gives the impression that the leaves were alternately arranged and were attached somewhat obliquely to the axis by their sessile truncate base. The old leaves towards the apical portion show irregular longitudinal splits.

Comparison

The present Gondwana form shows a close agreement with the members of order Palaeophyllales Høeg (in Boureau, 1967) in the morphology of leaves. *Ginkgophyllum* Saporta (1884) have pinnate leaves with large cuneate dissected leaflets, whereas in the present form, the leaf is essentially entire and the incision in some leaves is only a secondary feature accentuated by preservation.



TEXT-FIG. 3. A.— Reconstruction of *Gondwanophyton indicum*

Ginkgophytopsis Høeg (in Boureau, 1967) is characterized by broad cuneate or flabellate leaves, borne spirally on herbaceous or woody axes, usually with sheathing leaf bases and with a dense venation of delicate bifurcating veins with reticulate meshes (*Ginkgophytopsis flabellata* L. H.) Høeg, in Boureau, 1967). However, the Gondwana specimens differ in having fan-shaped leaf with sessile base. Veins do not show any interconnections. Beside this, the epidermal features of Gondwana specimens are known.

Enigmophyton Høeg (1962) superficially resembles the Gondawna forms, but the leaves show characteristic insertion at the point of dichotomy of stems. Another form, *Germanophyton* Høeg (1942) resembles the Gondwana forms, but the axis in the former is composed of tubes of *Prototaxite* type. A comparison with *Platyphyllum* (Dawson) Høeg (1942) is not possible, because it has been instituted for detached leaves showing a dissected apical margin comparable to Ginkgoalean remains.

Forms comparable with *Gondwanophyton* have been recorded from Lower Gondwanas of India and other countries of Southern hemisphere under *Rhipidopsis* and *Ginkgophyton* (*Psygmophyllum*). *Rhipidopsis densinervis* Feistmantel (1881), a single specimen recorded from the Raniganj formation of India is characterized by leaf, divided into six broadly cuneate segments with a lobed or incised apex. The other species *Rhipidopsis gondwanensis* Seward (1919), earlier known as *R. ginkgoides* Feistm. (1886) from the Barakars is characterized by palmisect leaves having 6-10 segments. Lateral segments are obovate, while the median segments are cuneiform and truncated distally. From both the records of *Rhipidopsis*, the present form differs by the absence of stalk and regular apical incision.

The forms described under *Ginkgophytopsis* (*Ginkgophyton*) *kidstonii* Hφeg (1967), *Ginkgophyton hollandii* Hφeg & Bose (1960), *Ginkgophyton haydenii* Hφeg & Bose (1960) and *Psygmophyllum sahnii* Ganju (1943) differ from the present form by long drawn petiolate base and incision of the leaves at the apical margin resulting into lobing of the forms.

The present Gondwana form is comparable to *Noeggerathiopsis* Feistmantel (1879) and *Euryphyllum* Feistmantel (1879) in its venation feature. However, both the genera have lanceolate to spathulate leaves. Beside, these leaves are much linear in shape and do not possess a prominent wide apex as in *Gondwanophyton*. The cuticle of *Gondwanophyton* shows a general agreement to *Noeggerathiopsis*. However, the stomatal band in *Gondwanophyton* is extremely narrow and the stomata are arranged in a single discontinuous row.

Megistophyllum Archangelessky (1958) recoreded from Argentina compares somewhat in venation features but it differs in having an overall circular leaves, veins radiating all round from the central point.

Trizygia Royle compares somewhat in venation, but differs in having 3 pairs of leaf attached to one point on an articulate axis. Furthermore, the epidermal structure is also different.

The systematic position of the genus *Gondwanophyton* remains open because it does not show any close affinity with any of the previous known groups except for some superficial resemblance to *Noeggerathiopsis*. In view of this, it is proposed here to provisionally place *Gondwanophyton* under 'Palaeophyllales' Hφeg (in Boureau, 1967), which has been instituted to accommodate similar forms whose affinities are yet not certain.

TAXONOMIC REAPPRAISAL OF PSYGMOPHYLLUM AND RHIPIDOPSIS FROM THE LOWER GONDWANA RECORDS

As mentioned in the introduction that the fan shaped leaves with, ± parallel running veins from the Lower Gondwanas have either been classed under *Psygmophyllum* or *Rhipidopsis*. A critical study of the past records shows that a revision is now needed especially for their placement.

Records of *Psygmophyllum*

Hφeg and Bose (1960) remarked that these Lower Gondwans leaves have evidentally nothing to do with *Psygmophyllum* Schimper (1870-72), if that genus is delimited as suggested by Saporta (1878), Zalessky (1918) and Hφeg (1942). They further remarked that when more information about these Gondwana plants will be known then they would constitute a natural genus of their own. However, they recommended to place these forms provisionally under the form genus *Ginkgophyton* Zalessky. Hφeg (1967) in Boureau pointed out that the genus *Ginkgophyton* is invalid because its name has earlier been used by Matthew (1909, cf. Stopes, 1914: 101; Halle, 1927; 215) for different plant. Therefore, he instituted a new generic name *Ginkgophytopsis* for those forms earlier placed under *Ginkgophyton*. To this new genus Hφeg (*l.c.* p. 380) assigned the species P. *kidstoni* Seward (1903) with a ? mark within brackets after the generic name *Ginkgophytopsis*. Hφeg (1942, p. 109) has already pointed out that there always remains an uncertainty about the placement when one is dealing with an intermediate form grading between the lobed *Ginkgophyllum* and the non-lobed *Ginkgophytopsis*. The Lower Gondwana forms always show dichotomy of leaf at least up to the middle portion of the leaf, therefore, their placement to *Ginkgophytopsis* is not justifiable because it has been instituted for entire forms. *Ginkgophyllum* Saporta has been instituted to accomodate leaves showing regular dissection into finer segments. The Lower Gondwana forms also show similar characters, therefore, it is proposed to transfer the records of *Psygmophyllum* to *Ginkgophyllum* till more details are known about these plants.

Ginkgophyllum kidstonii (Seward) n. comb.

Synonymy:

1903 — *Psygmophyllum kidstonii* Seward, Pl. 12, Fig. 1.
1942 — *Ginkgophyton* (?) *kidstonii* Høeg
1967 — *Ginkgophytopsis* (?) *kidstonii* Høeg
1969 — *Psygmophyllum kidstonii* Plumstead, Pl. X, Fig. 2.

Lectotype — Pl. 12, Fig. 1, South African Museum, Capetown.

Locality — Vereeniging, South Africa.

Horizon — Ecca Series.

Ginkgophyllum hollandii (Seward) n. comb.

Synonymy:

1907 — *Psygmophyllum hollandii* Seward, Pl. 13, Figs. 3-6

1960 — *Ginkgophyton hollandii* Høeg & Bose

Lectotype — Pl. 13, Fig. 5. Geological Survey of India, Calcutta.

Locality — Gangamopteris bed in the nieghbourhood of Khunmu, Kashmir.

Horizon — Lower Gondwana (Permian).

Ginkgophyllum haydenii (Seward) n. comb.

Synonymy:

1905 — *Psygmophyllum* sp. Seward & Woodwards
1912 — *Psygmophyllum haydenii* Seward, Pl. 3, Figs. 8-11
1943 — *Psygmophyllum haydenii* Sitholey, Pl. 10, 11; Figs. 1-8
1960 — *Ginkgophyton haydenii* Høeg & Bose

Lectotype — 52/293, Geological Survey of India, Calcutta.

Locality — Dandlutar, near Shopyan in the Pir Panjal range, Kashmir (India).

Horizon — Lower Gondwana.

Ginkgophyllum sahnii (Ganju) n. comb.

Synonymy:

1943 — *Psygmophyllum sahnii* Ganju, Pl. 14, Fig. 1.

Lectotype — R/5, Department of Botany, University of Lucknow.

Locality — Risin spur.

Horizon — Lower Gondwana.

Records of Rhipidopsis

Two species of *Rhipidopsis* viz. *R. densinervis* Feistmantel (1881) and *R. gondwanensis* (Feistm.) Seward (1919) are known from the Lower Gondwanas of India. The type specimen of the former form is now preserved at the Geological Survey of India, Calcutta, but the specimen of the latter species is misplaced or lost from the collection of the Geological Survey of India. It is, therefore, difficult to put any comment on the latter species.

Rhipidopsis densinervis Feist. is known from Kamthis of South Godavari district near Kuntcheru. Only a solitary specimen with its counterpart is known. The examination of the type specimen shows that the lamina is divided into six obcuneate segments and that too irregularly lobed on the truncate margins. Veins arise from the divergent base and pass forward showing frequent dichotomy. Veins are closely spaced and ± parallel to one another. Density of veins is 26-28 per centimeter.

In the specimen 5338, Feistmantel (1881, 56A, Fig. 2) has figured the presence of a small petiole. However, no such structure was seen in the present examination. Due to lack of petiole the placement of these specimen under *Rhipidopsis* is doubtful, because the genus was instituted by Schmalhausen (1879) for the specimen with large petiole. In view of this it is proposed here to place this form under *Platyphyllum* (Dawson) emend Høeg (1942). Under this genus Høeg (*l.c.*) has proposed to place all the (old) Palaeozoic detached fan-shaped leaves with parallel bifurcating veins.

Platyphyllum (Daws.) Høeg

Platyphyllum densinervis (Feistmantel) n. comb.

Synonymy:

1881 — *Rhipidopsis densinervis* Feistmantel, Pl. 56A, Fig. 2.

Diagnosis—As given by Feistmantel (1881)

Lectotype — 5338, Geological Survey of India, Calcutta.

Locality — South Godavari district near Kuntcheru.

Horizon — Kamthi (Upper Permian).

ACKNOWLEDGEMENTS

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EXPLANATION OF PLATES

Gondwanophyton indicum gen. et. sp. nov.

PLATE 1

1. A leaf showing cuneate base with parallel running dichotomus veins. × 2. Specimen No. 35025.

2. Cuticle of stomatiferous surface showing alternate band of stomatiferous and non-stomatiferous region. × 500. Slide No. 4457.

3. A stomata enlarged. × 1000.

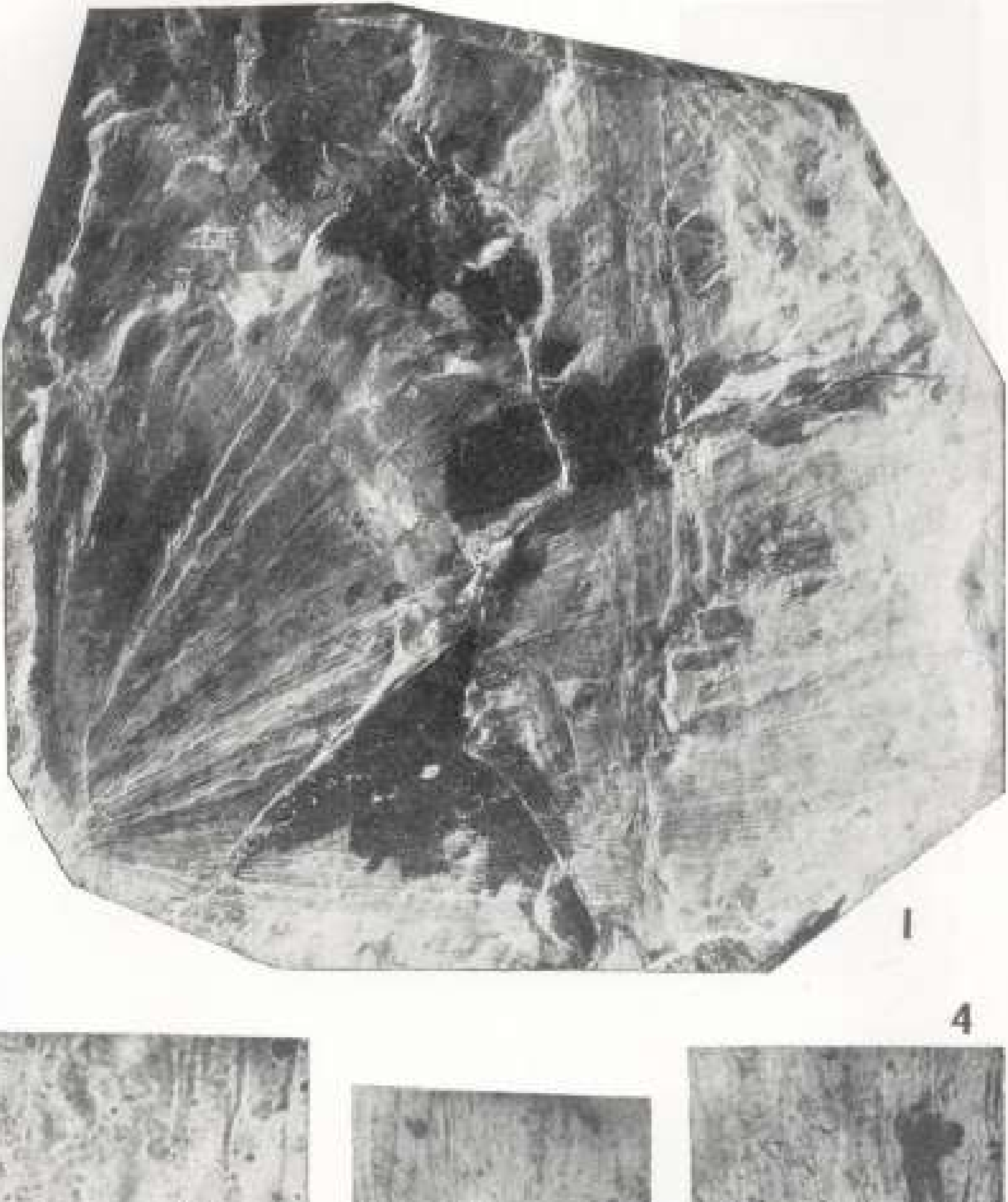
4. Non-stomatiferous surface showing the rectangular cells. × 500. Slide No. 4458.

PLATE 2

5. Non-stomatiferous surface showing a hair base. × 500. Slide No. 4458.

6. A leaf with irregular longitudinal splits attached to the axis. × 2. Specimen No. 35026.

7. Two leaves attached to axis dorsiventrally preserved. The leaf preserved above is V-shaped and complete. The leaf preserved below is incomplete. × 2. Specimen No. 35027.



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FOSSIL WOODS FROM THE TERTIARY OF ASSAM

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ABSTRACT

Fossil woods resembling modern woods of *Homalium*, *Sterculia*, *Vitex*, and a member of Lauraceae are described here from the Tipam sandstones of Rath Tila, near the town of Hailakandi, district Cachar, Assam. Modern equivalents of all these fossils are still found in the forests of Assam or Chittagong. The fossil woods of *Homalium* and *Vitex* are known for the first time from India and abroad.

INTRODUCTION

IN the present communication petrified dicot woods of *Homalium*, *Vitex*, *Sterculia* and a member of Lauraceae are described from near the town of Hailakandi (24°26′ N; 92°32′E) district Cachar, Assam. In addition to these, the fossil woods of *Adenanthera*, *Swintonia* (Prakash & Tripathi, 1969a), *Gluta-Melanorrhoea* (Prakash & Tripathi, 1969b), *Mangifera*, *Pometia*, *Lagerstroemia* (Prakash & Tripathi, 1970a), *Diospyros-Maba*, *Anisoptera* (Prakash & Tripathi, 1970b) and *Careya* and *Barringtonia* (Prakash & Tripathi, 1972) have already been recorded from the Tipam sandstones near the town of Hailakandi.

The age of these fossil woods is Upper Miocene being derived from the Tipam sandstones exposed near the town of Hailakandi in Rath Tila (Evans, 1932).

This work has been completed with the help of the modern wood slides so generously made available to the authors for comparison at the Wood Anatomy Branch of the Forest Research Institute, Dehra Dun. The authors wish to express their sincere appreciation to Mr K. Ramesh Rao, Officer Incharge, Wood Anatomy Branch of the Institute, for this kindness.

SYSTEMATIC DESCRIPTION

FLACOURTIACEAE

Homalioxylon gen. nov.

1. *Homalioxylon assamicum* sp. nov.

Pl. 1, Figs. 1, 3, 5, 6; Text-figs. 1, 2.

The present fossil wood is represented by a single piece of mature, secondary xylem measuring 4 cm. in length and 3 cm. in diameter. It shows satisfactory preservation.

Topography — Wood diffuse-porous (Pl. 1, Fig. 1). *Growth rings* indistinct. *Vessels*, small to large, mostly in radial rows of 2-5, sometimes solitary (Pl. 1, Fig. 1), evenly distributed, 11-14 vessels per sq. mm., contiguous with the rays on one or both the sides; tyloses absent. *Parenchyma* scanty paratracheal, limited to one or two cells around some vessels (Pl. 1, Fig. 6; Text-fig. 1). *Xylem rays* fine to medium, 1-5 (mostly 3-4) cells (Pl. 1, Fig. 3) and 12-100 μ wide, 12-16 per mm.; ray tissue heterogeneous (Pl. 1, Figs. 3, 5); uniseriate rays 2-12 cells and 100-844 μ high, 12-20 μ wide, homocellular, consisting only of upright cells; multiseriate rays, 2-5 (mostly 3-4) cells and 44-100 μ wide, 7-52 cells and 320-1240 μ high, heterocellular, consisting of procumbent cells through the median thickened portion and 1-7 marginal rows of upright cells at one or both the ends (Pl. 1, Fig. 3); end to end ray fusion quite frequent. *Fibres* aligned in radial rows.

Elements — Vessels thinwalled, the walls 4-5 μ thick, t.d. 32-160 μ, r.d. 48-220 μ, oval to irregular in shape due to pressure during fossilization, those in radial multiples flattened at the places of contact (Pl. 1, Fig. 1; Text-fig. 1); vessel-members short to medium, 250-950 μ in length, with tailed or truncated ends; perforations simple; intervessel pit-pairs small, 4-5 μ in diameter, bordered, alternate, with linear apertures (Text-fig. 2); vessel-ray and vessel-parenchyma pits not preserved. *Parenchyma cells* thinwalled, 50-170 μ in length, 20-30 μ in diameter. *Ray cells* thinwalled, procumbent cells 15-20 μ in tangential height, 40-130 μ in radial length; upright cells 30-50 μ in tangentiai height and 20-30 μ in radial length; cells frequently crystalliferous (Pl. 1, Fig. 3). *Fibres* libriform to semilibriform with small lumen (Pl. 1, Fig. 1), the walls 5-10 μ thick, septate, angular in the cross section, 18-30 μ in diameter, 600-1500 μ in length; interfibre pits not preserved.

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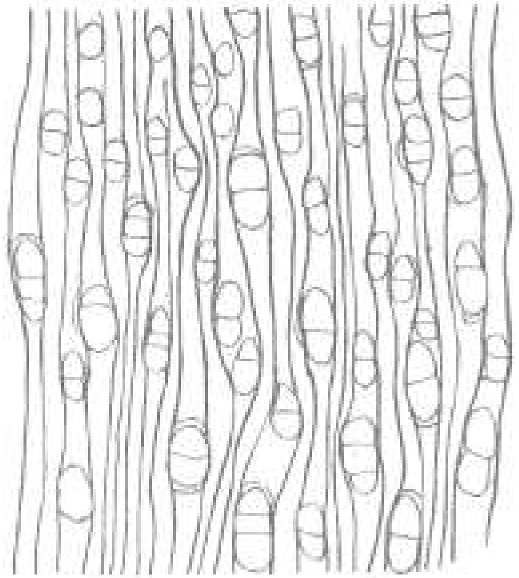
Affinities — The most important anatomical features of the present fossil wood are: vessels small to large mostly in short radial rows of 2-5, sometimes solitary; perforations simple; intervessel pit-pairs small, 4-5 μ in diameter, bordered, alternate, with linear apertures; parenchyma scanty paratracheal with 1-2 cells around some of the vessels; xylem rays 1-5 (mostly 3-4) seriate, with heterogeneous ray tissue and frequent crystalliferous ray cells; and semi-libriform to libriform, septate fibres. Taking into consideration all these important anatomical features, the present fossil wood shows nearest resemblance to the modern wood of *Homalium* Jacq. of the family Flacourtiaceae (Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Chowdhury & Ghosh, 1958).



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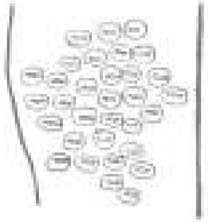

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Homalioxylon assamicum gen. et sp. nov.

Text-fig. 1 — Cross-section showing vessel distribution and the parenchyma pattern. × 25 (slide no. 4315).

Text-fig. 2 — Intervessel pit-pairs. × 330 (slide no. 4336).

A survey of all available woods of the genus *Homalium* indicates that the closest affinity of the fossil within this genus is with *H. tomentosum* Benth. This survey included the study of thin sections of *Homalium zeylanicum* Benth., *H. minutiflorum* Kurz, *H. grandiflorum* Benth., *H. bhamoense* Cubitt & Smith, *H. tomentosum* Benth., and the published description and photographs of *H. dictyoneuron* Pierre. (Lecomte, 1926, Pl. 57), *H. tomentosum* Benth. (Pearson & Brown, 1932, pp. 36-39, Fig. 15; Metcalfe & Chalk, 1950, p. 120, Fig. 31E; Chowdhury & Ghosh, 1958, pp. 49-51), *H. aylmeri* Hutch. & Dalz., *H. letestui* Pellegr. *H. aubrevillei* Keay and *H. molle* Stapf. (Brazier & Franklin, 1961, p. 38; Normand, 1960, Pl. 117, 118), *H. bhamoense* Cubitt & Smith, *H. grandiflorum* Benth., *H. minutiflorum* Kurz and H. *zeylanicum* Benth. (Chowdhury & Ghosh, 1958, pp. 49-51, Pl. 9, Fig. 49).

The present fossil wood resembles the modern wood of *Homalium tomentosum* in the size, shape and distributional pattern of the vessels, in the perforation plates, in the intervessel pit-pairs, in the parenchyma distribution and in the structure of the xylem rays and the fibres.

Because of the close resemblance of the present fossil wood with the wood structure of *Homalium tomentosum* Benth., the fossil wood is assigned to a new form genus *Homalioxylon* and specifically named as *H. assamicum* sp. nov.

As far as the authors are aware, the present finding is the first record of a fossil wood of *Homalium* from India and abroad.

The genus *Homalium* Jacq. consists of 200 species (Willis, 1966, p. 552) widely distributed throughout the tropics, with numerous representatives in Africa, the Indo-Malayan region and in tropical America. At least 10 species are indigenous to India and Burma. *Homalium tomentosum* Benth. with which the present fossil wood shows nearest resemblance grows in Northern Circars, Ganjam district of Madras, Chittagong and all over Burma (Gamble, 1902, p. 380; Pearson & Brown, 1932, p. 36; Chowdhury & Ghosh, 1958, pp. 49-50). In relation to the geographic locale of the fossil, the nearest tree species of *Homalium* is *H. bhamoense* which occurs in Cachar, Kamrup, Garo Hills and Chittagong (Kanjilal, Kanjilal & Das, 1934).

GENERIC DIAGNOSIS

Homalioxylon gen. nov.

Wood diffuse-porous. *Growth rings* distinct to indistinct, when distinct delimited by thicker walled fibres and smaller vessels. *Vessels* small to large, solitary as well as in radial rows of 2 or more; vessel-segments short to medium; perforations simple; intervessel pit-pairs, small, alternate, bordered, oval to angular, with linear orifices. *Parenchyma* scanty paratracheal. *Xylem rays* 1-5 or more cells wide; ray tissue heterogeneous; uniseriate rays composed of upright cells; multiseriate rays consisting of procumbent cells through the median portion and 1-several marginal rows of upright cells at one or both the ends; ray cells crystalliferous. *Fibres* libriform to semi-libriform, septate.

Genotype — *Homalioxylon assamicum* sp. nov.

SPECIFIC DIAGNOSIS

Homalioxylon assamicum sp. nov.

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* small to large, t.d. 32-60 μ, r.d. 48-220 μ, mostly in radial rows of 2-5, sometimes solitary, evenly distributed; vessel-members short to medium, 250-950 μ in length, with tailed or truncated ends; perforations simple; intervessel pit-pairs small, 4-5 μ in diameter, bordered, alternate with linear apertures. *Parenchyma* scanty paratracheal, occurring as 1-2 cells in association with some vessels. *Xylem rays* fine to medium, 1-5 (mostly 3-4) seriate, 12-100 μ in width, 12-16 per mm; ray tissue heterogeneous; uniseriate rays 12-20 μ wide, 2-12 cells and 100-844 μ high, homocellular, consisting only of upright cells; multiseriate rays, 2-5 (mostly 3-4) seriate, 44-100 μ wide, 7-52 cells and 320-1240 μ high, heterocellular, consisting of procumbent cells in the median thickened portion with 1-7 marginal rows of upright cells at one or both the ends; ray cells frequently crystalliferous; end to end ray fusion frequent. *Fibres* libriform to semi-libriform, the walls 5-10 μ thick, septate, angular in cross section, 18-30 μ in diameter, 600-1500 μ in length.

Holotype — B.S.I.P. Museum No. 33922.

Locality — Kuchila (24°38′ N; 92°35′ E), near the town of Hailakandi, district Cachar, Assam.

STERCULIACEAE

Sterculioxylon Kräusel, 1939.

2. *Sterculioxylon dattai* sp. nov.

Pl. 2, Figs 7, 9, 11, 12.

The present species is based on a piece of decorticated secondary wood measuring about 5 cm. in length and a few centimetres in diameter showing good preservation.

Topography — *Wood* diffuse-porous (Pl. 2, Fig. 12). *Growth rings* indistinct. *Vessels* small to large, majority solitary (Pl. 2, Figs. 7, 12)' occasionally in pairs, 6-9 per sq. mm., heavily tylosed (Pl. 2, Fig. 11), sometimes with brownish-black deposits. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric, forming 1-4 (mostly 1-2) cells thick sheath around some of the vessels (Pl. 2, Fig. 11); apotracheal parenchyma in fine, 1-2 cells thick, closely spaced lines, forming a sort of irregular reticulum, sometimes occurring as solitary cells, present also around the gum ducts, sometimes forming tangential bands, 1-6 (mostly 3-4) cells thick (Pl. 2, Fig. 7, 11, 12). *Xylem rays* fine to moderately broad (Pl. 2, Fig. 9), 1-10 (mostly 6-9) seriate, 17-140 μ in width, 4-6 per mm.; ray tissue heterogeneous (Pl. 2, Fig. 9); uniseriate rays, 17-32 μ in width, 2-15 cells and 160-500 μ high, homocellular, consisting of upright cells only; multiseriate rays 2-10 cells and 24-140 μ in width, 9-101 cells and 250-1500 μ high, heterocellular, consisting of procumbent cells in the median thickened portion and 1-3 rows of upright cells at one or both the ends; sheath cells frequently present at the flanks (Pl. 2, Fig. 9). *Fibres* not aligned in distinct radial rows. *Gum canals* frequent, traumatic, vertical, soliary as well as in tangential bands of 2-6 (Pl. 2, Fig. 12), 180-384 μ in diameter.

Elements — *Vessels* thick walled, the walls about 8-12 μ thick, t.d. 72-310 μ, r.d. 96-348 μ, the solitary vessels round to circular in cross section (Pl. 2, Fig. 11), those in pairs flattened at the places of contact; vessel-members 90-750 μ in length with truncated or short tailed ends; perforations simple; intervessel pit pairs indistinct; vessel-parenchyma and vessel-ray pits not preserved. *Parenchyma cells* thinwalled, 12-32 μ in diameter, 40-208 μ in length, storied. *Ray cells* thinwalled, tangential height of procumbent cells 11-20 μ, radial length 30-80 μ;

upright cells 20-40 μ in tangential height and 12-18 μ in radial length. *Fibres* thin-walled, the walls about 4-5 μ thick, non-septate, showing storied tendency, angular in cross section, 25-30 μ in diameter, 500-2000 μ in length; interfibre pits not observed.

Affinityies — The most important structural feature of the fossil wood under investigation, is the presence of traumatic, vertical gum canals. There are 25 families of the dicotyledons in which traumatic, vertical gum canals have been observed (Metcalfe & Chalk, 1950, p. 1353). These are:

Ampelidaceae
Bombacaceae
Boraginaceae
Burseraceae
Caesalpiniaceae
Combretaceae
Elaeagnaceae
Elaeocarpaceae
Euphorbiaceae
Hamamelidaceae
Lecythidaceae
Malvaceae
Meliaceae
Mimosaceae
Morinagaceae
Myrtaceae
Papilionaceae
Proteaceae
Rosaceae
Rutaceae
Sapindaceae
Simaroubiaceae
Sterculiaceae
Styracaceae
Vochysiaceae

Taking into consideration the parenchyma pattern, the ray structure and the nature of the fibres, it is with the members of the family Sterculiaceae only that the present fossil wood shows resemblance. On farther scrutiny the genus *Sterculia* shows nearest affinity. Detailed microscopic examination of thin sections from the modern woods of fifteen available species of *Sterculia* has been made in order to find out the nearest living counterpart of the present fossil wood. The species examined are *Sterculia alata* Roxb., *S. angustifolia* Roxb., *S. campanulata* Wall. ex Mast., *S. coccinea* Roxb., *S. colorata* Roxb., *S. foetida* Linn. *S. fulgens* Wall., *S. guttata* Roxb., *S. oblonga* Mast., *S. ornata* Wall., *S. populifolia* DC., *S. rhinopetala* K. Schum., *S. scaphigera* Wall., *S. urens* Roxb. and *S. villosa* Roxb. Besides this, published description and photographs of *Sterculia alata* Roxb., *S. villosa* Roxb., *S. campanulata* Wall., ex. Mast. *S. urens* Roxb. (Pearson & Brown, 1932; Desch, 1954; Henderson, 1953), S. *blancoi* Rolfe, *S. carthaginensis* Cav. (Metcalfe & Chalk, 1950), *S. rhinopetala* K. Schum., *S. oblonga* Most. (Henderson, 1953; Kribs, 1959; Brazier & Franklin, 1961), *S. hypochra* Pierre (Lecomte, 1926, Pl. 29), *Sterculia* spp. (Desch, 1954, pp. 581-583), *S. foetida* Linn., *S. colorata* Roxb., *S. populifolia* Roxb., *S. angustifolia* Roxb., *S. guttata* Roxb., *S. ornata* Wall., *S. coccinea* Roxb., *S. fulgens* Wall. and *S. scaphigera* Wall. (Chowdhury & Ghosh, 1958).

From this detailed study, it is evident that the present fossil wood shows resemblance with the wood structure of the modern species *Sterculia angustifolia* Roxb., *S. guttata* Roxb., *S. ornata* Wall. and *S. villosa* Roxb. These species are somewhat similar anatomically and can not be distinguished easily. Among these species, it is with *Sterculia villosa* that the present fossil wood shows nearest resemblance. The fossil wood resembles the modern wood of *Sterculia villosa* in the shape, size and distributional pattern of the vessels, in the perforation plates, in the parenchyma distribution and in the structure of the xylem rays and the fibres.

As the present fossil wood resembles the modern wood of *Sterculia* Linn. of the family Sterculiaceae, it is placed in the form genus *Sterculioxylon Krausel* (1939).

Only five species of fossil woods related to the modern genus *Sterculia* are known so far (Boureau, 1957a, p. 679). These are *Sterculioxylon aegyptiacum* Krausel (1939) from the Tertiary of Egypt, *S. giarabubense* (Chiarugi) Krausel (1939) from the Lower Oligocene to Lower Miocene of Somaliland, North Africa, *S. rhenanum* Muller-Stoll (1949) from the Eocene of South-West Germany, *S. freulonii* Boureau (1957b) from the Tertiary of Sahara, and *S. foetidense* Prakash (1973) from the Tertiary of Burma.

Sterculioxylon aegyptiacum differs from the present fossil wood in having slightly larger (r.d. 100-300 μ, r.d. 100-430 μ) vessels which are solitary or in groups of 2-3 or 4 cells and in less broader (2-6-7 seriate) and shorter (only up to 60 cells high) xylem rays. In the present fossil wood, the vessels are small to large (t.d. 72-310 μ, r.d. 96-348 μ), majority solitary, occasionally in pairs, the xylem rays are 1-10 (mostly 6-9) seriate, heterocellular, 17-140 μ in width, 2-101 cells and 160-1500 μ high, and the fibres are non-libriform and non-septate. *S. giarabubense* also differs markedly in possessing smaller vessels (165-245 μ in diameter), in having vasicentric parenchyma only, and in less broader (1-5 seriate) xylem rays. Similarly, *S. rhenanum* differs from the present fossil wood in the presence of growth rings and in having smaller vessels (t.d. 110-200 μ, r.d. 150-300 μ). *S. jeenlonii* Boureau (1957b) is also distinct in possessing smaller vessels (t.d. 120-200 μ, r.d. 200-300 μ) and libriform fibres, in the absence of paratracheal parenchyma, and in having less broader (1-6 seriate) xylem rays. Lastly *S. foetidense* also differs from *S. dattai* in having larger (t.d. 160-400 μ, r.d. 240-480 μ) vessels and in less broader (1-8 seriate) and somewhat higher xylem rays.

As the present fossil wood is quite distinct from all the species of *Sterculioxylon* Krausel (1939) known so far, it is described here as a new species, *Sterculioxylon dattai*. This species is named after Mr. A. N. Datta, Officer Incharge, Vijnan Mandir, Hailakandi, Assam, who helped the authors in collecting the fossil woods.

The genus *Sterculia* consists of 300 species (Willis, 1966, p. 1074) distributed throughout the tropics, and reaches its best development in tropical Asia (Pearson & Brown, 1932, p. 145). The species *Sterculia villosa* Roxb. with which the present fossil wood shows its nearest resemblance, is a medium-sized to large tree of the tropical forests reaching its best development in the Andamans and Burma, where it attains a height of 18-24 m. and a girth of 1·5-2·5 m. In India proper it is a much smaller tree reaching only 1-1·5 m. in girth in favourable localities in Uttar Pradesh. It ascends to over 1,000 m. and is found throughout India, Burma and the Andamans except in the arid regions (Chowdhury & Ghosh, 1958, p. 217).

SPECIFIC DIAGNOSIS

Sterculioxylon dattai sp. nov.

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* moderately small to very large, t.d. 72-310 μ, r.d. 96-348 μ, majority solitary, occasionally in pairs, round to circular, 6-9 per sq. mm., heavily tylosed; vessel-members 90-750 μ long, with truncated or tailed ends; perforations simple. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric forming 1-4 (mostly 1-2) cells thick sheath around some of the vessels; apotracheal parenchyma abundant, in fine, 1-2 cells thick, closely spaced lines forming a sort of irregular reticulum, sometimes occurring as solitary cells, also present around the gum ducts, and forming tangential bands, 1-6 (mostly 3-4) cells thick; parenchyma strands storied. *Xylem rays* fine to moderately broad, 1-10 (mostly 6-9) seriate, 17-140 μ in width, 4-6 per mm; ray tissue heterogeneous; uniseriate rays 17-32 μ in width, 2-15 cells and 160-500 μ high, homocellular consisting of upright cells only; multiseriate rays 2-10 cells and 24-140 μ in width, 9-101 cells and 250-1500 μ high, heterocellular, consisting of procumbent cells in the median thickened portion and 1-3 rows of upright cells at one or both the ends; sheath cells present. *Fibres* non-libriform, thin walled, the walls about 4-6 μ thick, non-septate, angular in cross-section, 25-30 μ in diameter, 500-2000 μ in length, storied. *Gum canals* frequent, traumatic, vertical, solitary, sometimes arranged also in tangential rows of 2-6, t.d. 180-350 μ, r.d. 200-384 μ.

Holotype — B.S.I.P. Museum No. 33912.

Locality — Sultanicherra (24°18'N; 92°33' E), near the town of Hailakandi, district Cachar, Assam.

VERBENACEAE

Vitexoxylon Ingle, 1972 emend.

3. *Vitexoxylon miocenicum* sp. nov.

Pls. 3-4, Figs. 13,15,17-19

The fossil wood consists of a single piece of petrified mature secondary xylem measuring 5 cm. in length and 4 cm. in diameter. It shows good preservation.

Topography — *Wood* diffuse-porous (Pl. 3, Fig. 13). *Growth rings* distinct, delimited by thicker walled fibres and smaller vessels. *Vessels* moderately small to very large, majority solitary, often in short radial multiples of 2-3 (mostly 2) (Pl. 3, Fig. 13), 12-18 per sq. mm., tylosed, brown gummy deposits also present. *Parenchyma* paratracheal mostly scanty to vasicentric, forming 1-4 (mostly 2-3) cells thick sheath around some of the vessels, rarely confluent joining the adjacent vessels (Pl. 3, Figs. 13, 17). *Xylem rays* broad to fine, 1-6 (mostly 3-4) seriate (Pl. 3, Fig. 15), 12-144 μ in width, 14-19 per mm.; ray tissue weakly heterogeneous (Pl. 3, Fig. 18); uniseriate rays 18-30 μ in width, 1-5 cells and 20-80 μ high, homocellular, consisting only of upright cells; multiseriate rays 2-6 (mostly 3-4) seriate, 25-144 μ in width, 2-62 cells and

109-2400 μ high, homocellular and heterocellular, when homocellular consisting only of procumbent cells, when heterocellular consisting of procumbent cells in the middle portion and 1-2 (mostly 1) marginal rows of upright cells at one or both the ends (Pl. 3, Fig. 15). *Fibres* aligned in more or less distinct radial rows between the two consecutive xylem rays (Pl. 3, Fig. 13).

Elements — *Vessels* thickwalled, the walls about 5-10 μ thick, t.d. 70-210 μ, r.d. 81-322 μ, the solitary vessels round to oval, those in radial multiples flattened at the places of contact; vessel-members 448-800 μ long, with truncated or tailed ends; perforations simple; intervessel pit-pairs small, 4-6 μ in diameter, bordered, alternate with linear-lenticular apertures (Pl. 4, Fig. 19); vessel-parenchyma pits numerous, opposite, large, 15-20 μ in diameter, simple and more or less elliptical in shape; vessel-ray pits not seen. *Parenchyma cells* thin walled, 21-39 μ in diameter, 109-161 μ in length. *Ray cells* thinwalled, procumbent cells 20-56 μ in tangential height, 72-160 μ in radial length; upright cells 48-64 μ in tangential height and 32-52 μ in radial length. *Fibres* thick walled, the walls about 4-7 μ thick, sometimes appearing thinwalled due to cell wall degradation, semi-libriform to libriform, septate, angular in cross-section, 12-16 μ in diameter, 624-1240 μ in length; interfibre pits not preserved.

Affinities — Structural features of the fossil wood indicate, after extensive comparison, that its closest affinities are with the wood of the modern genus *Vitex* Linn. of the family Verbenaceae (Pearson & Brown, 1932, pp. 803-812; Metcalfe & Chalk, 1950, pp. 1035-1038; Kribs, 1959; pp. 161-162).

A survey of all available woods of the genus *Vitex* indicates that the nearest affinity of the fossil within this genus is with the wood of *Vitex canescens* Kurz. This survey included the study of thin-sections of *Vitex negundo* Linn., *V. altissima* Linn., *V. limonifolia* Wall., *V. canescens* Kurz, *V. pubescens* Heyne ex Wall.; *V. peduncularis* Wall., *V. leucoxylon* Schan. and *V. glabrata* F. Muell., supplemented by published description and photographs of *Vitex altissima* Linn., *V. peduncularis* Wall. and *V. leucoxylon* Linn. (Pearson and Brown, 1932, pp. 805-811, Figs. 253-255), *V. coriacea* C.B. Clarke (Desch, 1954, p. 628), *V. pubescens* Heyne ex Wall. (Lecomte, 1926, Pl. 65; Desch, 1954, p. 628), *V. parviflora* Jussieu, *V. aherniana* Merrill (Kanehira, 1924, pp. 44-45), *V. keniensis* Turrill, *V. fosteri* C.H. Wright, *V. lignum-vitae* A. Cunn. (Metcalfe & Chalk, 1950, pp. 1036-1037, Figs. 248B & H), *V. micrantha* Gurke (Normand, 1960, Pl. 154), *V. gaumeri* Green, *V. kuylenii* Standl., *V. cooperi* Standl., *V. pachyphylla* Baker (Kribs, 1959, pp. 161-162, Figs. 473-475).

The present fossil wood resembles the modern wood of *Vitex canescens* Kurz in the size and distributional pattern of the vessels, in the perforation plates and the intervessel pit-pairs, in the parenchyma distribution and the fibre and ray structure.

As the present fossil wood shows anatomical characters of the extant genus *Vitex* Linn., it has been assigned to form genus *Vitexoxylon* and specifically named as *V. miocenicum* sp. nov. Recently Ingle (1972) described a fossil wood as *Vitexoxylon indicum* from the Deccan Intertrappean series of Mandla district in Madhya Pradesh. From its photographs and text-figures, it does not appear to show any affinities with the wood of *Vitex*. However, it would be appropriate to say more about its relationship only after the examination of its type slides. Therefore, the present finding is the first authentic record of a fossil wood of *Vitex* from India and abroad. As the description given by Ingle (1972) does not properly diagnose and include all the woods of *Vitex*, an emended diagnosis for the genus *Vitexoxylon* Ingle is being given here.

The genus *Vitex* Linn. consists of 250 species (Willis, 1966, p. 1184) distributed in the tropical and warm temperate regions of both the hemispheres, but from the standpoint of timber production the importance of this genus is mainly centered in the Indo-Malayan region. At least, 15 species grow in the Indian region (Pearson & Brown, 1932, p. 803). The species *Vitex canescens* Kurz, with which the present fossil wood shows nearest affinity, grows in Assam and dry forests of Burma (Gamble, 1902, p. 541).

EMENDED GENERIC DIAGNOSIS

Vitexoxylon Ingle emend. Prakash & Tripathi

Wood diffuse-porous. *Growth rings* distinct, delineated by thicker walled fibres and/or terminal parenchyma and smaller vessels. *Vessels* small to large, solitary as well as in short radial multiples, round to oval; perforations simple; intervessel pit-pairs, bordered, alternate, with linear to lenticular apertures. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma scanty to vasicentric rarely confluent, joining adjacent vessels; apotracheal parenchyma diffuse and terminal if present. *Xylem rays* 1-7 or more cells wide; ray tissue heterogeneous to homogeneous. *Fibres* non-libriform to libriform; septate or nonseptate.

SPECIFIC DIAGNOSIS

Vitexoxylon miocenicum sp. nov.

Wood diffuse-porous. *Growth rings* distinct, delineated by thicker walled fibres and smaller vessels. *Vessels* thick walled, the walls about 5-10 μ thick, t.d. 70-210 μ, r.d. 81-322 μ, mostly solitary, often in short radial rows of 2-3 (mostly 2), solitary vessels round to oval in cross-section, 12-18 vessels per sq. mm.; tyloses present; vessel-members 448-800 μ in length, with truncated or tailed ends; perforations simple; intervessel pit-pairs small, 4-6 μ in diameter, bordered, alternate, with linear-lenticular apertures; vessel-parenchyma pits simple, numerous, opposite, large, 15-20 μ in diameter. *Parenchyma* paratracheal, mostly scanty to vasicentric, forming 1-4 (mostly 2-3) cells thick sheath around some of the vessels, rarely confluent joining two adjacent vessels. *Xylem rays* fine to broad, 1-6 (mostly 3-4) seriate, 12-144 μ in width, 14-19 per mm.; ray tissue weakly heterogeneous; uniseriate rays 18-30 μ in width, 1-5 cells and 20-80 μ high, homocellular, consisting only of upright cells; multiseriate rays 2-6 (mostly 3-4) seriate, 25-144 μ in width, 2-62 cells and 109-2400 μ high, homocellular and heterocellular, when homocellular consisting only of procumbent cells, when heterocellular consisting of procumbent cells in the median thickened portion and 1-2 (mostly 1) marginal rows of upright cells at one or both the ends. *Fibres* semilibriform to libriform, the walls 4-7 μ thick, septate, angular in shape, 12-16 μ in diameter, 624-1240 μ in length.

Holotype — B.S.I.P. Museum No. 33927.

Locality — Kartikcherra (24°20′N; 92° 31′E), near the town of Hailakandi, district Cachar, Assam.

LAURACEAE

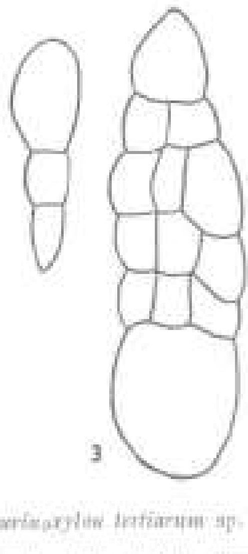
Laurinoxylon Felix, 1883

4. *Laurinoxylon tertiarum* sp. nov.

Pl. 4, Figs. 20-25; Text-fig. 3

Fossil wood is represented by a single specimen of secondary wood about 6 cm. in length and 3 cm. in diameter. The preservation is quite satisfactory.

Topography — *Wood* diffuse-porous (Pl. 4, Fig. 23). *Growth rings* distinct, delimited by thicker walled fibres (Pl. 4, Fig. 22). *Vessels* moderately small to medium-sized, solitary as well as in short radial rows of 2-4 (Pl. 4, Figs. 22, 23), 8-10 per sq. mm.; tyloses present, brownish deposits probably gum also occasionally present. *Parenchyma* paratracheal, scanty to vasicentric, forming 1-3 (mostly 1-2) cells thick sheath around some of the vessels, sometimes aliform rarely confluent, joining 2-3 adjoining vessels (Pl. 4, Fig. 23). *Xylem rays* 1-3 (mostly 2) seriate (Pl. 4, Fig. 24; Text-fig. 3), 6-8 per mm.; ray tissue heterogeneous (Pl. 4, Fig. 26); uniseriate rays 12-32 μ broad, 1-4 cells and 80-120 μ high, homocellular, composed wholly of upright cells; multiseriate rays 2-4 cells and 40-80 μ in width, 4-24 and 140-600 μ in height, heterocellular, composed of procumbent cells in the median thickened portion and upright cells at one



Laurinoxylon tertiarum sp. nov.

Text-fig. 3 — Two xylem rays with swollen oil cells. × 330. (slide no. 4346).

or both the ends (Pl. 4, Figs. 24); special oil-bearing marginal secretory cells quite frequent, resulting from the enlargement of upright cells (Pl. 4, Figs. 24, 25; Text-fig. 3); secretory cells 100-180 μ high along the grains. *Fibres* aligned in distinct radial rows. *Oil cells* 24-52 μ in diameter associated with the parenchyma, the xylem rays and the fibres (Pl. 4, Figs. 24, 25; Text-fig. 3).

Elements — Vessels thin walled, the walls about 4-5 μ thick, t.d. 60-152 μ, r.d. 80-200 μ, the solitary vessels round to oval in cross-section, those in radial multiples flattened at the places of contact (Pl. 4, Fig. 23); vessel-members 384-624 μ in length, with truncated or tailed ends; perforations simple as well as scalariform, the latter with 8-10 bars (Pl. 4, Fig. 21); intervessel-pit-pairs large, 8-10 μ in diameter, bordered, border round to oval with lenticular apertures (Pl. 4, Fig. 20); vessel-parenchyma and vessel-ray pits not preserved. *Parenchyma cells* thinwalled, 10-15 μ in diameter, 30-60 μ in length. *Ray cells* thinwalled, procumbent cells 16-32 μ in tangential height, 80-120 μ in radial length; upright cells 40-48 μ in tangential height, 12-20 μ in radial length. *Fibres* non-libriform to semi-libriform, the walls about 2-6 μ thick, septate, angular in cross-section, 25-30 μ in diameter, 700-1620 μ in length; interfibre pits not preserved.

Affinities — The most important diagnostic feature of the present fossil wood is the presence of oil cells in the parenchyma, fibres and the xylem rays. Oil cells have been reported in the following 15 families among the dicotyledons (Metcalfe & Chalk, 1950, p. 1354). These are:

Annonaceae
Aristolochiaceae
Burseraceae
Canellaceae
Dilleniaceae
Hernandiaceae
Lauraceae
Magnoliaceae
Monimiaceae
Myristicaceae
Piperaceae
Rutaceae
Saurauiaceae
Schisandraceae
Winteraceae

Taking into consideration the septate fibres found in the present fossil wood, the following eight families only need further comparison:

Burseraceae
Hernandiaceae
Lauraceae
Magnoliaceae
Monimiaceae
Myristicaceae
Piperaceae
Rutaceae

The families Burseraceae and Rutaceae can be easily distinguished from the present fossil wood in possessing exclusively simple perforations and intercellular canals.

The family Hernandiaceae can also be separated from the present fossil wood in having oil cells in the parenchyma only. The families Magnoliaceae, Monimiaceae and Piperaceae can also be distinguished from the fossil wood under investigation in the presence of oil cells in the xylem rays only. The family Myristicaceae is also quite distinct from the present fossil wood in possessing oil cells only in the parenchyma and xylem rays. In addition to this, the family Myristicaceae possesses tanniniferous tubes in the xylem. Therefore, it is only with the family Lauraceae that the present fossil wood resembles most (Kanehira, 1924, pp. 46-47; Tupper, 1927, pp. 520-525; Janssonius, 1928, pp. 5-292; 1930, pp. 293-835; Pearson & Brown, 1932, pp. 823-857; Dadswell & Eckersley, 1940, pp. 9-48; Metcalfe & Chalk, 1950, pp. 1145-1156; Stern, 1954, pp. 1-72; Desch, 1957, pp. 239-250). From a detailed comparison with the modern lauraceous woods it is seen that the present fossil wood is nearer to the woods of *Dehaasia cuneata* Bl., *Cinnamomum caudatum* Nees, *C. glanduliferum* Meissn. and *C. pauciflorum* Nees. in a number of features.

The study of wood structure of the family Lauraceae has received considerable attention by several wood anatomists, although, such investigations have been confined to describing specialized tissues in this family and the anatomical structure of individual species or groups. Macbride (1931) has pointed out that morphologically and anatomically species within a genus of the family Lauraceae often differ more from each other than they do from members of other genera.

Dadswell and Eckersley (1940) distinguished the Australian woods of the Persoideae (*Cinnamomum*, *Litsea* and *Persea*) from those of Lauroideae (*Beilschmiedia*, *Cryptocarya* and *Endiandra*) largely by means of the presence of concentric bands of parenchyma in the latter and their absence from the Persoideae. They also noted that the anatomical differences between genera are not clear cut and it is difficult to list features by which the various genera in each sub-group may be readily classified. It was found that species from two different genera were in some cases more similar than species with the same genus.

According to Metcalfe and Chalk (1950) the family Lauraceae is a remarkably uniform family throughout in its wood anatomy, and though some individual species, such as *Ocotea rodiaei Mez*, can be comparatively easily distinguished, the genera are by no means sharply defined.

Stern (1954) and Desch (1957) have studied the modern woods of a large number of species of the family Lauraceae and have remarked that individual genera of the family Lauraceae can not be distinguished.

An extensive study of the modern woods of the family Lauraceae was carried out by the authors at the Xylarium of the Forest Research Institute, Dehra Dun, and also at the Birbal Sahni Institute of Palaeobotany, Lucknow, which indicated that there are no clear cut anatomical structures in different genera of this family due to which it is difficult to separate them from one another.

Since taxonomic entities in this family are ill-defined groupings, and it is not possible to discern the limits of variation in wood patterns in any meaningful way, an unknown can be compared only with a known specimen and not with a generic complex. In short for our purposes only the family itself can be considered the significant taxon. For this reason it may be more useful in the future to define fossil wood species on the basis of only the few characters that are significant in modern lauraceous woods.

The name *Ulminium diluviale* was applied by Unger (1842) to a fragment of fossil wood which was later found by Felix (1883) to have the characteristics of a laurel wood rather than of elm as Unger had thought. After examining a fragment from the collection from which Unger had obtained his original specimen, Felix changed the name of this wood to *Laurinoxylon diluviale*. Süss (1958) agreed with his identification and suggested that the name *Laurinoxylon* Felix be conserved over *Ulminium* Unger to include all fossil woods anatomically similar to the modern woods of the family Lauraceae so as to avoid a lot of nomenclatural confusion.

Süss (1958) studied all the fossil woods of Lauraceae so far described and reclassified them into three groups (Süss, 1958, pp. 38-42). Those showing definite relationship with the family Lauraceae have been referred to the form genus *Laurinoxylon* Felix (1883). These as well as those recorded by Süss (1958), Huard (1967) and Selmeier (1967, 1968) are being listed below. The two fossil woods of Lauraceae described by Page (1967) as *Ulminium pattersonensis* and *U. mulleri* from the Upper Cretaceous of California are transferred here to *Laurinoxylon* and included in the following list:

1. *Laurinoxylon ligurinum* (Schuster) Berger (1950); Upper Cretaceous, Germany.
2. *L. radiatum* (Schonfeld) Berger (1953b); Upper Cretaceous, Germany.
3. *L. hofmannae* Berger (1950); Upper Cretaceous, Austria.
4. *L. weylandii* Berger (1953b); Upper Cretaceous, Austria.
5. *L. pattersonensis* (Page, 1967) comb. nov. Upper Cretaceous, California.
6. *L. mulleri* (Page, 1967) comb. nov. Upper Cretaceous, California.
7. *L. antiquum* (Felix) Berger (1950); Cretaceous ?, Hungary.
8. *L. haasii* (Wetzel) Berger (1953b); Upper Cretaceous, Germany.
9. *L. linderoides* Schonfeld (1933); Cretaceous or Tertiary, Germany.
10. *L. bakeri* Berry (1924); Eocene, Texas, U.S.A.
11. *L. algovicum* (Schuster) Süss (1958); Upper Oligocene, Germany.
12. *L. hasenbergense* Süss (1958); Middle to Upper Oligocene, Germany.
13. *L. bergeri* Süss (1958); Middle to Upper Oligocene, Germany.
14. *L. endiandroides* Süss (1958); Middle to Upper Oligocene, Germany.
15. *L. litseoides* Süss (1958); Middle to Upper Oligocene, Germany.
16. *L. microtracheale* Süss (1958); Middle to Upper Oligocene, Germany.
17. *Laurinoxylon* sp. Süss (1958); Oligocene, Germany.
18. *L. czechense* Prakash, Brezinova & Buzek (1971); Oligocene, Czechoslovakia.
19. *L. nectandroides* Krausel et Schonfeld (1924); Miocene, Holland.
20. *L. desioi* Chiarugi (1929); Miocene, Libyen.
21. *L. machiliforme* (Watari) Süss (1958); Lower Miocene, Japan.
22. *L. ehrendorferi* Berger (1953a); Lower or Middle Miocene, Greenland.
23. *L. aniboides* Greguss em. Süss (Süss & Müdel, 1958); Lower Miocene, Hungary.

24. *L. müller-stoll* Greguss em. Süss (Süss & Mädel, 1958); Lower Miocene, Hungary.

25. *L. seemannianum* Mädel (Süss & Mädel, 1958; Selmeier, 1967, 1968); Upper Miocene, Bavaria, ?Mio-Pliocene, Lower Bavaria, South Germany.

26. *Laurinoxylon* sp. Selmeier, 1967; Upper Miocene, Bavaria, South Germany.

27. *L. ebergi* (Platen) Süss (1958); Miocene, Colorado, U.S.A.

28. *L. iwamiense* (Watari) Süss (1958); Miocene, Japan.

29. *L. kuteense* (Watari) Süss (1958); Miocene, Japan.

30. *L. parenchymatosum* Schonfeld (1956) Pliocene, Germany.

31. *L. perfectum* Huard (1967); Neogene, France.

32. *L. intermedium* Huard (1967); Neogene, France.

33. *L. compressum* Huard (1967); Neogene, France.

34. *L. diluviale* (Unger) Felix (1883); Tertiary, Bohemia.

35. *L. L. aromaticum* Felix (1884); Tertiary, Hungary.

36. *L. meyeri* (Felix), Süss (1958); Tertiary, New Guinea.

37. *L. caiflornicum* (Platen) Süss (1958); Tertiary, California.

From the study of the published description and photographs of the above forms, it is evident that the present fossil wood differs markedly from all of them.

Therefore, the fossil wood under investigation is placed under the form genus *Laurinoxylon* Felix (1883) and described as a new species *Laurinoxylon tertiarum*. This finding is the first record of a fossil wood of the family Lauraceae from India, although leaf impressions belonging to the family Lauraceae have been described by Lakhanpal (1955) from the Eocene of Assam.

The family Lauraceae is widely distributed throughout the warmer parts of the world but most abundant in tropical and subtropical regions, a few genera extending into the Malay Archipelago, the other in the American tropics, chiefly in Brazil; relatively few species occur in Europe and the African continent (Pearson & Brown, 1932, p. 823). The genus *Dehaasia* Bl. has 20 species (Willis, 1966, p. 337) and the species *D. cuneata* which is nearer to the present fossil wood grows in Andaman Islands, extending into the Pegu, Arakan and Tenasserim (Hooker, 1885, p. 125; Gamble, 1902, p. 560). The genus *Cinnamomum* Bl. is represented by 250 species distributed mainly in East Asia (Willis, 1966, p. 248). The species *C. caudatum* Nees. grows in Central and Eastern Himalayas, Nepal, lower hills of Sikkim upto 1500 metres and the Kakhyen hills of Burma. *C. glanduliferum* Meissn. is a tree of the Central Himalayas, extending west to Kumaon, and of Khasia hills, while the species *C. pauciflorum* Nees, grows in Assam valley, Khasia hills and Sylhet (Hooker, 1885, pp. 129, 134, 135; Gamble, 1902, pp. 560, 562).

SPECIFIC DIAGNOSIS

Laurinoxylon tertiarum sp. nov.

Wood diffuse-porous. *Growth rings* distinct, delimited by thicker walled fibres. *Vessels* small to medium-sized, t.d. 60-152 μ, r.d. 80-200 μ, solitary as well as in short radial rows of 2-4, 8-10 per sq. mm., tylosed; vessel-members 384-624 μ in length, with truncated or tailed ends; perforations simple as well as scalariform, the latter with 8-10 bars; intervessel pit-pairs large, 8-10 μ in diameter, bordered, border round to oval, with lenticular apertures. *Parenchyma* paratracheal, scanty to vasicentric, forming 1-3 (mostly 1-2) cells thick sheath around some of the vessels, sometimes aliform, rarely confluent, joining 2-3 adjoining vessels. *Xylem rays* 1-3 (mostly 2) seriate, 6-8 per mm.; ray tissue heterogeneous; uniseriate rays 1-4 cells and 80-120 μ high, 12-32 μ broad, homocellular, composed only of upright cells; multiseriate rays 2-3 (mostly 2) cells and 40-80 μ in width, 4-24 cells and 140-600 μ in height, heterocellular, composed of procumbent cells in the middle portion and upright cells at one or both the ends. *Fibres* non-libriform to semi-libriform, the walls about 2-6 μ thick, septate, angular in cross section, 25-30 μ in diameter and 700-1620 μ in length. *Oil cells* 24-52 μ in diameter, associated with xylem rays, parenchyma cells and fibres.

Holotype — B.S.I.P. Museum No. 33921.

Locality — Sultanicherra, near the town of Hailakandi, district Cachar, Assam.

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EXPLANATION OF PLATES

Plate 1

1. Cross-section of the fossil wood of *Homalioxylon assamicum* showing vessel distribution and parenchyma pattern. × 30 (slide no. 4333).

2. Cross-section of *Homalium tomentosum* showing similar vessel distribution and the parenchyma pattern. × 30.

3. Tangential section of the fossil wood of *Homalioxylon assamicum* showing the type of xylem

rays and their distribution. × 60. (slide no. 4336).

4. Tangential section of *Homalium tomentosum* showing similar ray type and distribution. × 60.

5. Radial longitudinal section of *Homalioxylon assamicum* showing heterocellular xylem rays. × 120. (slide no. 4337).

6. Magnified cross-section of *Homalioxylon assamicum* × 90. (slide no. 4335).

PLATE 2

7. Cross-section of the fossil wood of *Sterculioxylon dattai* showing vessel distribution and parenchrma pattern. Also note the presence of vertical gum canals. × 60. (slide no. 4338).

8. Cross-section of *Sterculia villosa* showing similar vessel distribution, gum canals and the parenchyma pattern. × 60.

9. Tangential section of the fossil wood of *Sterculioxylon dattai* showing the type of xylem rays and their distribution. × 60. Note the sheath cells at the flanks. (slide no. 4339).

10. Tangential section of *Sterculia villosa* showing similar ray type and distribution. × 60.

11. Magnified cross-section of the fossil wood of *Sterculioxylon dattai* showing the parenchyma distribution and the fibre structure. × 140. (slide no. 4340).

12. Another cross-section of the fossil wood of *Sterculioxylon dattai* in low power showing vessel distribution, parenchyma pattern and the gum canals. × 30. (slide no. 4340).

PLATE 3

13. Cross-section of the fossil wood of *Vitexoxylon miocenicum* showing vessel distribution and parenchyma pattern. × 30. (slide no. 4341).

14. Cross-section of *Vitex canescens* showing similar vessel distribution and the parenchyma pattern. × 30.

15. Tangential section of the fossil wood of *Vitexoxylon miocenicum* showing the type of xylem rays and their distribution. × 55 (slide no. 4342).

16. Tangential section from the modern wood of *Vitex canescens* showing similar ray type and distribution. × 55.

17. Magnified cross-section of the fossil wood of *Vitexoxylon miocenicum* showing parenchyma distribution. × 60. (slide no. 4343).

18. Radial longitudinal section of *Vitexoxylon miocenicum* showing a xylem ray. × 110. (slide no. 4344).

PLATE 4

19. Magnified longitudinal section of *Vitexoxylon miocenicum* showing intervessel pit-pairs. × 500. (slide no. 4345).

20. Magnified intervessel pit-pairs of *Laurinoxylon tertiarum*. × 500. (slide no. 4346).

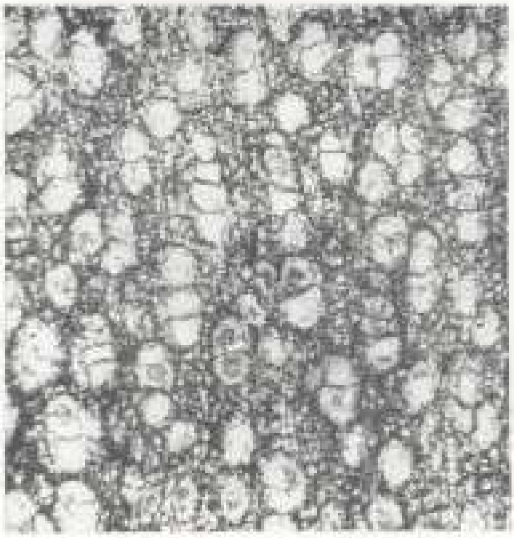
21. Magnified longitudinal section of *Laurinoxylon tertiarum* showing scalariform perforation plate. × 400. (slide no. 4347).

22. Cross-section of the fossil wood of *Laurinoxylon tertiarum* in low power showing vessel distribution and parenchyma pattern. × 30. (slide no. 4348).

23. Magnified cross-section of the fossil wood of *Laurinoxylon tertiarum* showing distributional pattern of vessels, parenchyma and the oil cells. × 60. (slide no. 4349).

24. Tangential section of the fossil wood of *Laurinoxylon tertiarum*. × 60. Note swollen oil cell of a xylem ray. (slide no. 4346).

25. Radial longitudinal section of the fossil wood of *Laurinoxylon tertiarum*. × 70. Note oil cell in the xylem ray. (slide no. 4347).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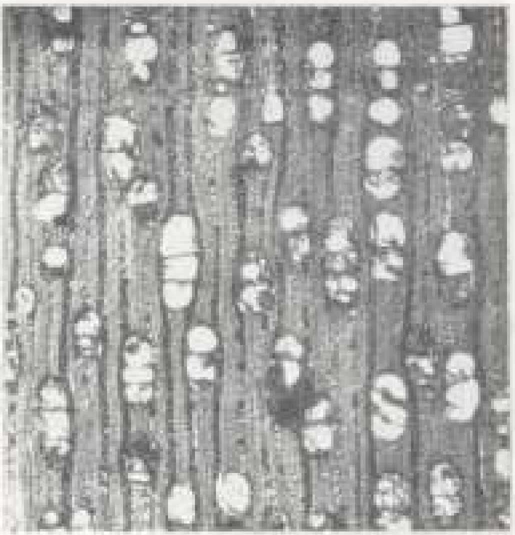
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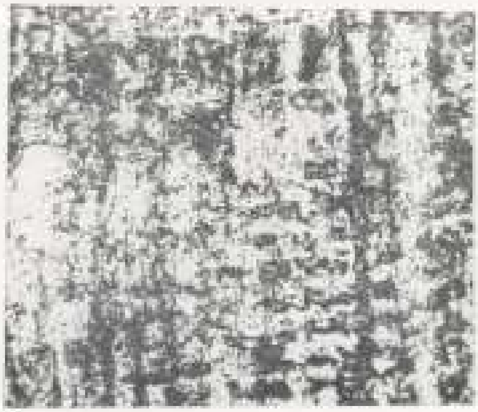
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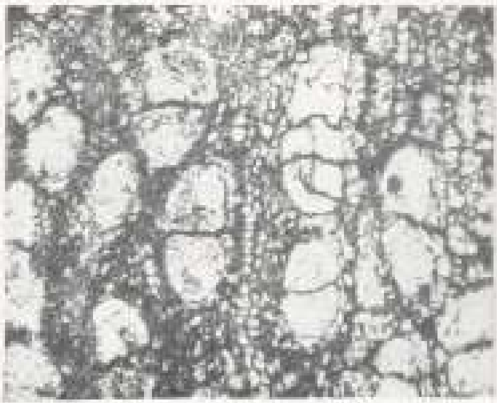
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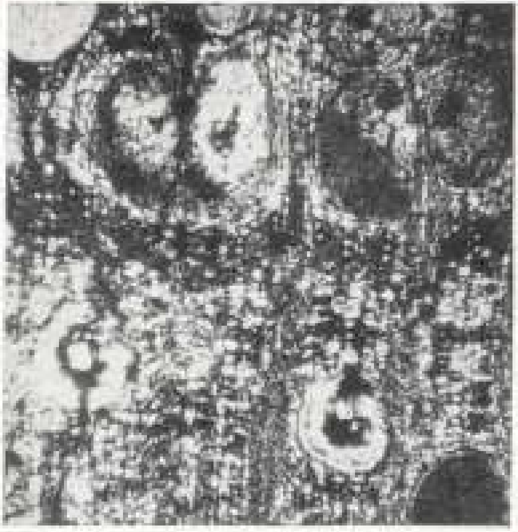

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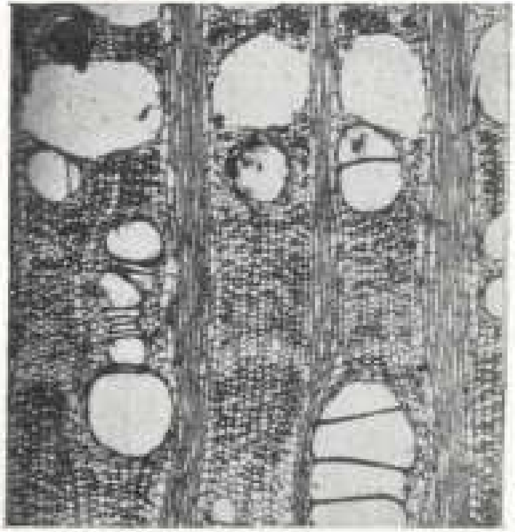

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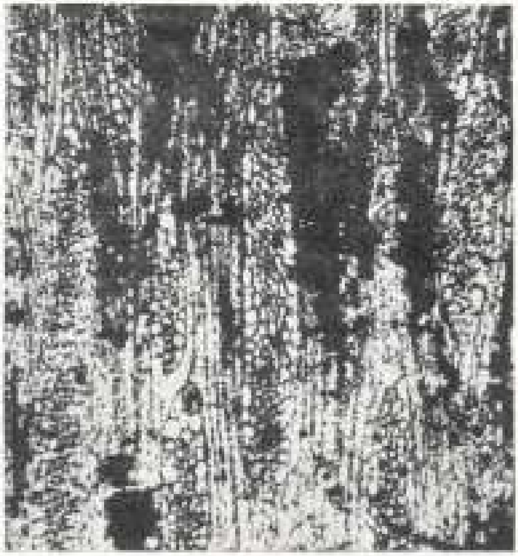

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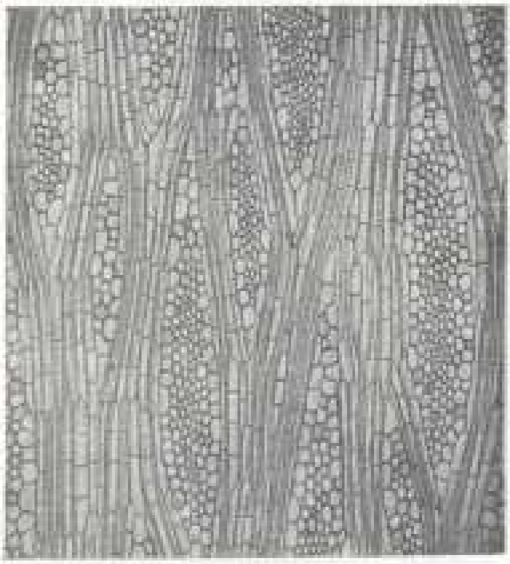

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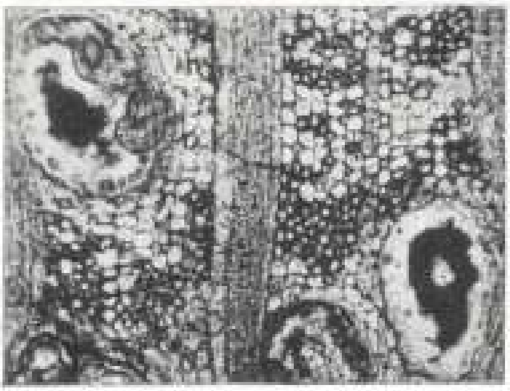

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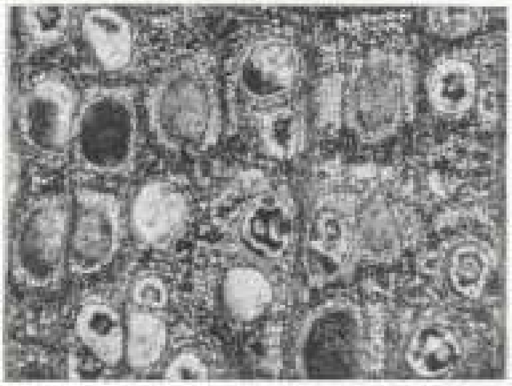

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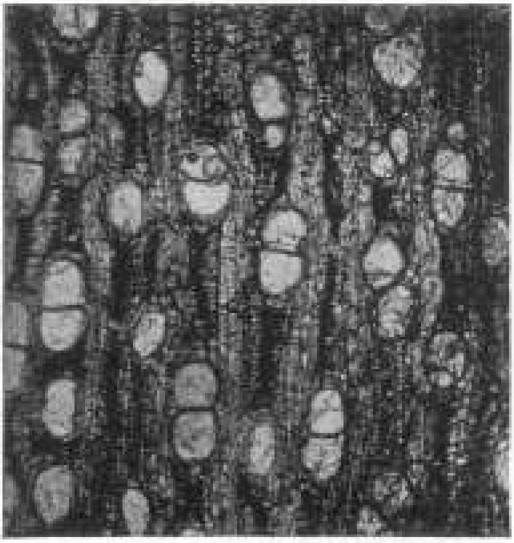

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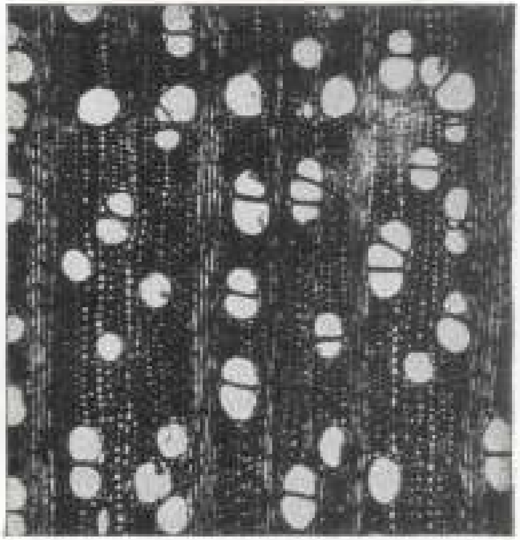

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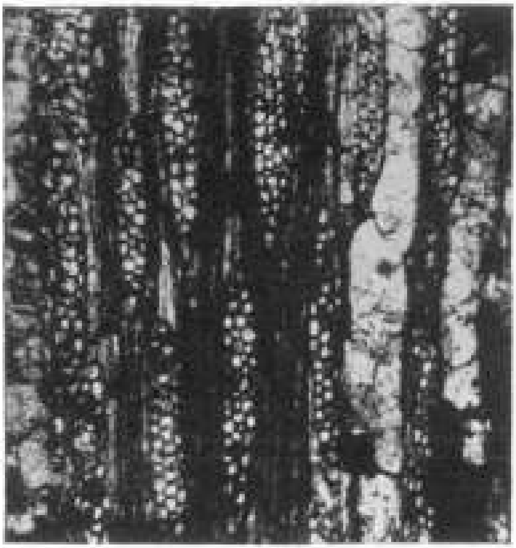

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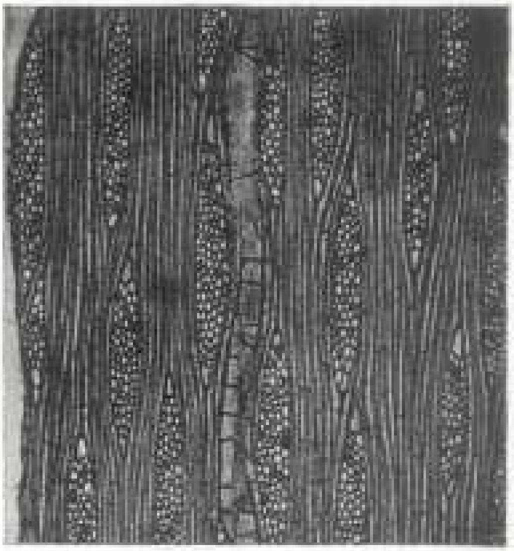

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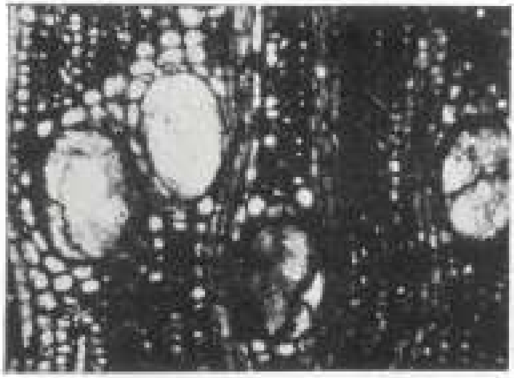

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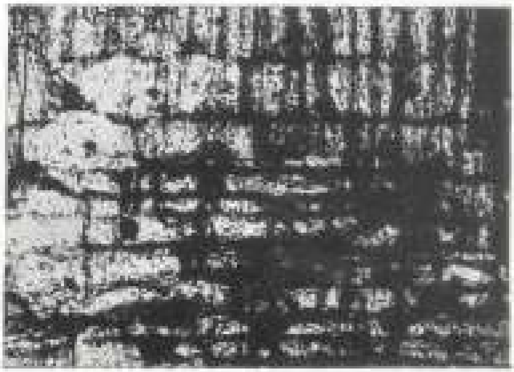

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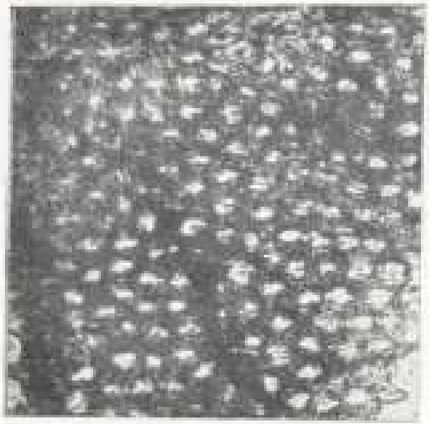

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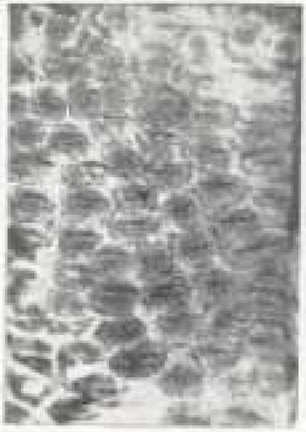

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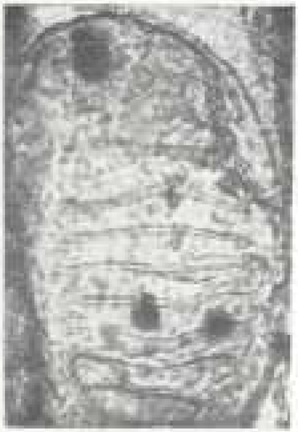

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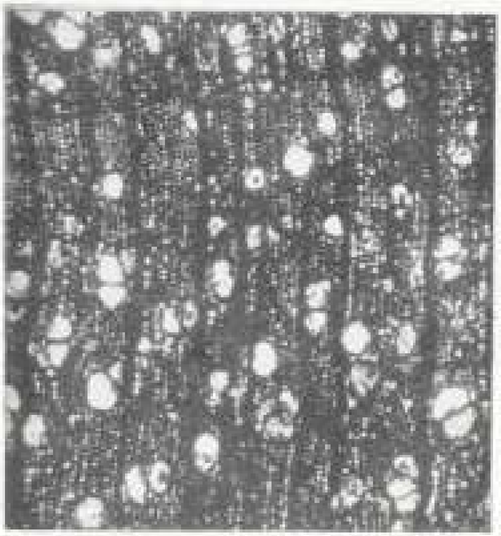

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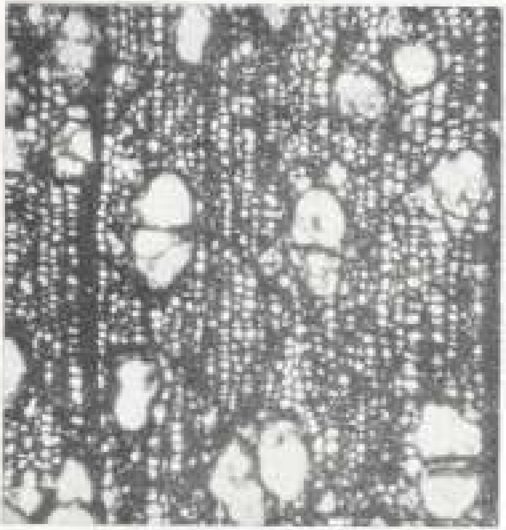

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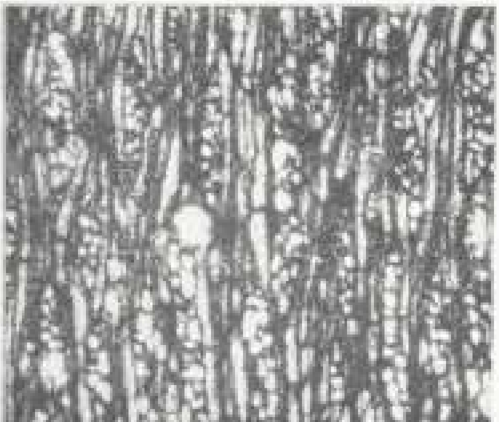

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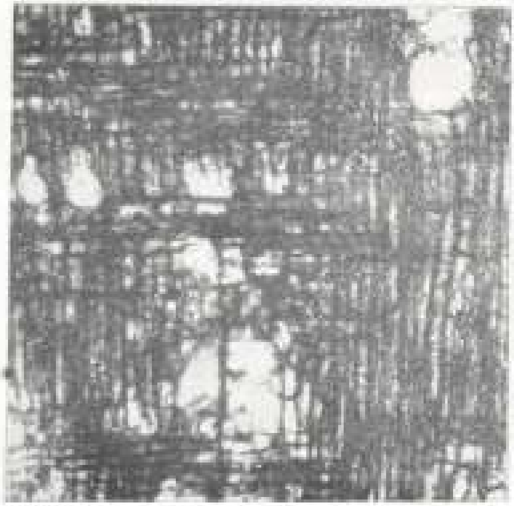

DECCANANTHUS SAVITRII, A NEW PETRIFIED FLOWER FROM THE DECCAN INTERTRAPPEAN BEDS OF INDIA

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ABSTRACT

The paper deals with the description of a new monocotyledonous, dichlamydeous, petrified flower from the Mohgaonkalan beds of the Deccan Intertrappean series of India. The flower is hermaphrodite, hypogynous, with six perianth members in two whorls, six epiphyllous stamens and tricarpellary, syncarpous ovary. Provisionally it is placed under *Deccananthus savitrii* gen. et sp. nov. with affinities shown to Palmaceae.

INTRODUCTION

THIS paper reports a new petrified flower from the Deccan Intertrappean locality of Mohgaonkalan in the Chhindwara District of M.P., India. So far only three petrified flowers have been described from this locality. They are *Sahnianthus parijai* (Shukla 1944; Chitaley 1955) *Sahnipushpam shuklai* (Prakash and Jain 1963; Prakash 1956; Chitaley 1964; Verma 1956) and *Chitaleypushpam mohgaoense* Paradkar (1971).

The present flower is different from all of them. The description is based on only one complete specimen. It was exposed in longitudinal section (Plate 1, Fig. 1). After studying it from many serial sections in l.s. the remaining piece was studied along the transverse plane.

DESCRIPTION

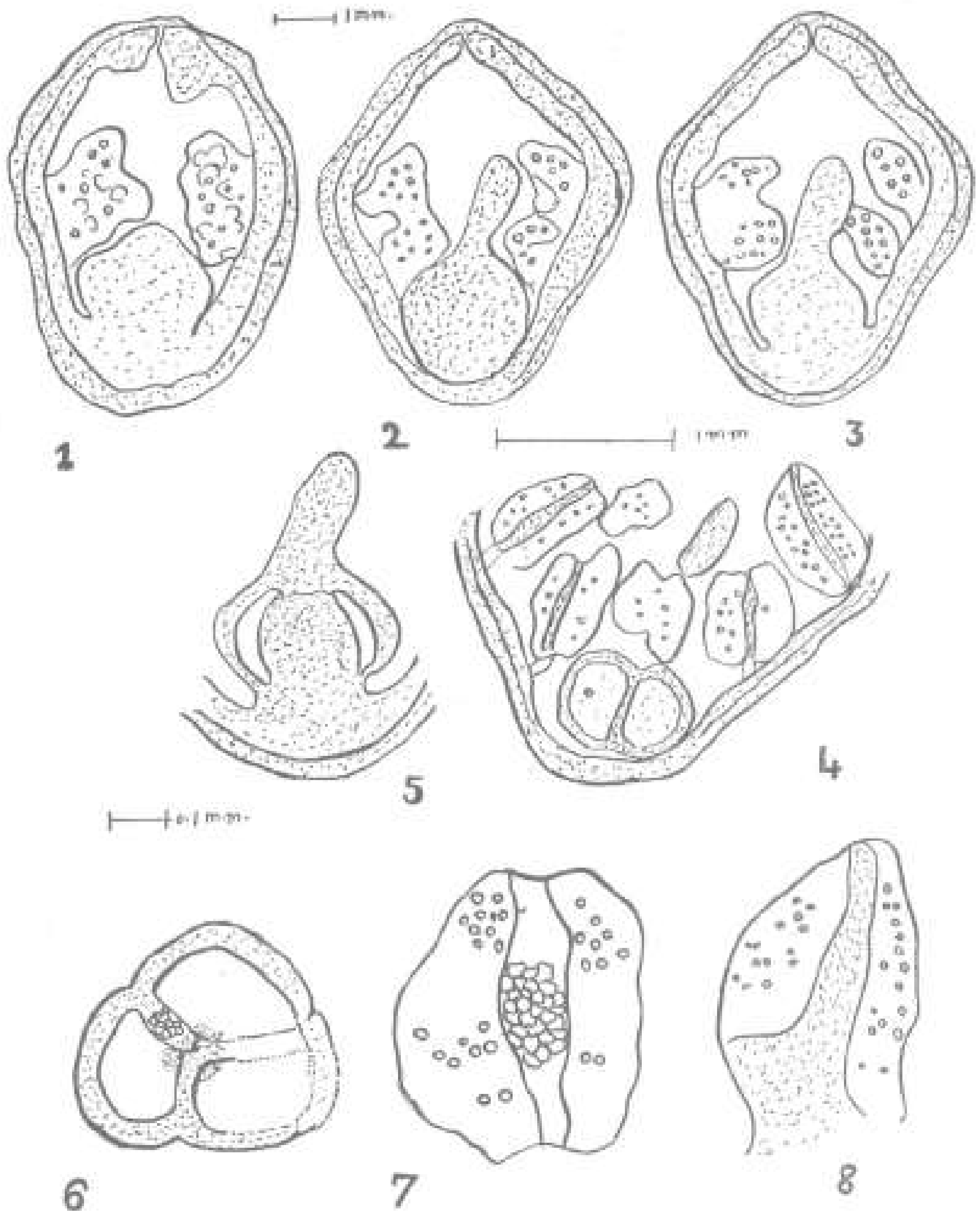
The flower is 4·2 mm long and 3·3 mm broad at its broadest part in the centre (Plate 1, Fig. 1). It shows a short, thick stalk, 945 μ long and 700 μ broad. The flower is narrow at the base and at the tip but broad in its middle portion. It is complete, gamopetalous, hermaphrodite and hypogynous (Text-Figs. 1, 2 & 3).

Perianth — The perianth is differentiated into two whorls, an outer and an inner (Plate 1, Fig. 1; Text-Figs. 1-3). The members of each whorl are fused with one another. The outer whorl is covering the inner one all over, suggesting a bud condition of the flower. The tips of the inner whorl are coiled inside forming two thick knob like structures (Plate 1, Fig. 1), where it is 250 to 350 μ thick, and the rest of the portion is 135 to 150 μ. Cells of this whorl are parenchymatous, thin walled, intermingled with a few thick walled cells (Plate 1, Fig. 2). Members of the outer whorl are 4-5 layered and 120 to 130 μ thick. Cells of the inner whorl have brown contents. The lobes of the inner whorl of the perianth at the tip of the flower differ in size, one being smaller than the other (Text-Fig. 1). The bigger one is 480 × 576 μ and the smaller is 300 × 380 μ.

Androecium — Stamens are six, epiphyllous, placed at different levels on the perianth lobes (Plate 1, Fig. 1; Text-Fig. 4). Three are at the lower level and three are on the higher level. Filaments are all of equal length, being 90 μ long each. The anthers are two lobed, with the connective (Plate 1, Fig. 5) running throughout the length (Text-Fig. 8). The attachment of the filament to the anther is dorsifixed. The anthers on the higher level are 750 to 800 μ long and 450 to 500 μ broad and those on the lower level are 600 to 625 μ long and 400 μ broad. Each anther is 4 locular. The cells of the anther wall and the connective are made of simple parenchymatous cells (Text-Fig. 7).

The two pollen sacs of each lobe are filled with mature pollen grains, thus showing the development of anthers earlier than the ovary which is in young condition. The pollen grains are seen in both polar and equatorial view (Plate 1, Fig. 3). Each pollen grain (Erdtman, 1966) is 20 × 15 μ to 18 × 15 μ, peroblate, trichotomosulcate, the subculi stand in relation to the pole in much the same way as the sides of an equilateral triangle to the centre of the triangle. Grains are psilate, with sexine slightly thicker than nexine.

Gynoecium — It is tricarpellary, syncarpous, trilocular (Text-Fig. 6) with an axile placentation (Text-figs. 5 & 6) (Plate 1,



TEXT-FIGS. 1-8 — 1, 2 & 3. Selected serial longitudinal sections of flower. 4. L. S. of flower showing anthers. 5. L. S. gynaecium. 6. T.S. ovary showing trilocular condition. 7. Anther showing cells of the connective and pollen grains. 8. Anther showing connective.

Fig. 6). The ovary is almost sessile, 1·5 mm. broad and 1·18 mm. long (Plate 1, Fig. 4) and its wall is 4 to 5 layered. Style is short, 560 μ long and 382 μ broad. Stigma is 350 μ long and 3·50 μ broad thus not much differentiated from the style. Ovules are not seen. However, remains of axile placenta are noticed.

DISCUSSION

From the above description of the flower it is clear that the petrified flower with the trilocular ovary and probably 6 lobes of the perianth looks like a monocotyledonous flower. Number of stamens is also six arranged in two whorls, placed at two levels on the inner whorl of the perianth. The structure of the pollen grains though not typically monocotyledonous as monosulcate or monocolpate, but such trisulcate structure as seen in the present flower is also noticed in the pollen grains of some of the palmaceae. Comparisons of this flower to the living ones bring it close to the family palmaceae.

Resemblances are found in the nature of perianth, condition of ovary, number of stamens and the structure of pollen grains. However, since the present study is based only on one specimen of the flower and that too in young condition, not showing distinct ovules, the present flower is named provisionally as *Deccananthus savitrii* gen. et sp. nov. The generic name is after the region of India from where it is being described and the specific name is after Mrs. Savitri Sahni, the first Director of Birbal Sahni Institute of Palaeobotany, Lucknow, and wife of Late Prof. Birbal Sahni.

We have compared this flower with the known petrified flowers from the Deccan Intertrappean beds of India. *Sahnianthus parijai* (Shukla, 1944, & Chitaley 1955) is different in having only one whorl of perianth, and more stamens and carpels. Also the pollen grains are different. *Sahnipushpam shuklai* and *Chitaleypushpam mohgaoense* also differ from our flower in having one whorl of perianth and pentacarpellary gynoecium. In the former flower, loculi are more. Thus, it is evident that the *Deccananthus savitrii* is different from all the known flowers from the Deccan Intertrappean beds of India.

DIAGNOSIS OF THE GENUS

Deccananthus Chitaley and Kate

Flower complete, with two perianth whorls, regular, hermaphrodite, ebracteate. *Androecium* of 6 stamens, epiphyllous, in two whorls; pollen grains trichotomosulcate. *Gynoecium* tricarpellary, syncarpus, trilocular with axile placentation.

DIAGNOSIS OF THE SPECIES

Deccananthus Savitrii Chitaley and Kate

Flower with short pedicel. *Perianth* members 6, the two whorls close against each other; outer whorl 120 to 130 μ thick, inner whorl 135 to 150 μ and at places 250 to 350 μ thick; members of inner whorl curved inside at the tip of flower forming a knob measuring 300 × 380 μ. *Stamens* 6, attached to perianth at two levels; anthers 4 locular, dorsifixed, each 750 to 800 μ long and 450 μ broad, anthers on lower level are smaller than those on higher level; filament length 90 μ long; connective running through the anther; pollen grains 20 × 15 μ, sexine slightly thicker than nexine, psilate, peroblate, trichotomosulcate; *Gynoecium* tricarpellary, syncarpus, trilocular; ovary large, round, 1·5 mm. broad and 1·18 mm. long; style 580 μ long and 380 μ broad; stigma solid, simple, 350 μ long and 350 μ broad, not much differentiated from style.

Holotype — Department of Botany, Institute of Science, Nagpur. Moh/KU-2.

Locality — Mohgaonkalan.

Horizon — Deccan Intertrappean series of India.

Age — ? Uppermost Cretaceous.

ACKNOWLEDGEMENT

We acknowledge with gratitude the suggestions made by Mrs. S. A. Paradkar for the identity of this flower. We are grateful to the Government of Maharashtra for awarding National Loan Scholarship to the Junior author. We also thank the Director, Institute of Science, Nagpur, for the laboratory facilities.

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EXPLANATION OF PLATE 1 — FIGS. 1-6

1. Part of the flower as exposed on the rock × 20.
2. Cells of perianth (arrows) × 130.
3. Pollen grains enlarged × 600.
4. L.S. flower showing gynoecium and anthers × 30.
5. Anther with connective and pollen grains × 75.
6. T.S. ovary showing trilocular condition × 70.


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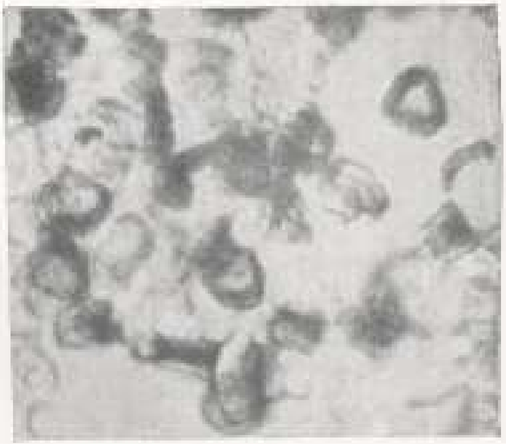
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STUDIES IN THE LATE-QUATERNARY VEGETATIONAL HISTORY IN HIMACHAL PRADESH—
2. REWALSAR LAKE

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ABSTRACT

The paper embodies the results of pollen analytical investigations carried out at Rewalsar lake in Himachal Pradesh. The whole pollen sequence has been divided into several stages (a-e) as to facilitate the description of the pollen diagram.

The Rewalsar lake is nearly 800 cm deep and is C-14 dated at two levels, i.e. 170 and 290 cm to 520 ± 55 and 1410 ± 60 years B.P. respectively. The date for bottom portion of the profile can be extrapolated to about 4000 years B.P. and thus whole sequence belongs to the "Post-glacial period".

The vegetational stages as marked in the pollen-diagrams do show the vegetational changes. The 'Stage a', the lowermost part of the lake basin is comprised of the forest in which oak appears to be the most dominant element followed by *Pinus* and *Corylus* with an undergrowth of grasses together with *Artemisia* and Cheno-Amarant. The succeeding 'Stage b' is almost in accordance with the preceding 'Stage a' except for a little rise in *Quercus*. 'Stage c' is differentiated from the preceding stages by the consistent rise in the values of *Corylus* and corresponding fall in the values of *Quercus*. The high altitude elements such as *Pinus wallichiana*, *Abies*, *Picea* and *Cedrus* have either gained or emerged during this stage. The ground flora except for minor fluctuations remain the same. 'Stage d' is marked by the tremendous decline in oaks and *Corylus* corresponding with a sudden rise in the values of *Pinus roxburghii* from the beginning of this stage. 'Stage e' is characterized by tremendous fall of *Quercus* giving pace to the grasslands comprising Gramineae Cyperaceae, Compositae, *Artemisia*, Cheno-Amarant type and Cerealia type.

INTRODUCTION

THE lake at Rewalsar (76°50'E, 31°33'N) is situated on the eastern slopes of the outer Himalaya facing Suketi Khad, about 16 km south-west of Mandi, at an altitude of about 1,280 m. A.S.L. (Figs. 1, 2). The lake is more or less triangular in outline and its circumference exceeds one and a half kilometre. The open water is studded with, seven main 'floating islands' of different sizes and shapes. The largest amongst these, called 'Parbati's island' (Kashyap, 1929) by the local people, measures about 18 and 3·6 m. in length and breadth respectively, whereas others are much smaller. A willow tree is also seen growing on one of the 'islands' known as 'Brahma's island'. The 'islands' are over grown with mainly *Phragmites communis* besides a few other grasses and herbs. The northern part of the lake-basin on the side of the main inlet, is filled with sediments consisting of organic detritus, clay, silt and gravel. The lake margins are grown with abundant *Phragmites communis*, and several other aquatics and amphibious plants.

It is mentioned that the lake was chosen as a place of retirement and devotion by the Rishi Lomas, whose name is mentioned in the 'Skandh Purana' of the Hindu mythology. It is said that the Rishi Lomas used to bathe in the waters of Ganga and Jamuna, and that, by the power of God, both the streams joined together to cast this lake for the Rishi (Punjab States Gazetteer, 1904). The lake is held sacred by the Hindus, the Budddists and the Sikhs. The presence of 'floating islands' (Sharma, 1971) is mainly attributed to its sanctity by the Buddhists. A number of places of worship have sprung up during the last century, though the religious sanctity of the lake may be of much greater antiquity. All around the lake, a narrow concrete road has been constructed for the pilgrims to circumambulate.

Rewalsar is one of the most important pilgrimage centres in Himachal Pradesh, and thousands of pilgrims flock to this place at the Baisakhi festival, held in the first half of April every year. Even though the local population of Rewalsar is rather small, the pressure of the pilgrims on the local vegetation at the time of festival is tremendous.

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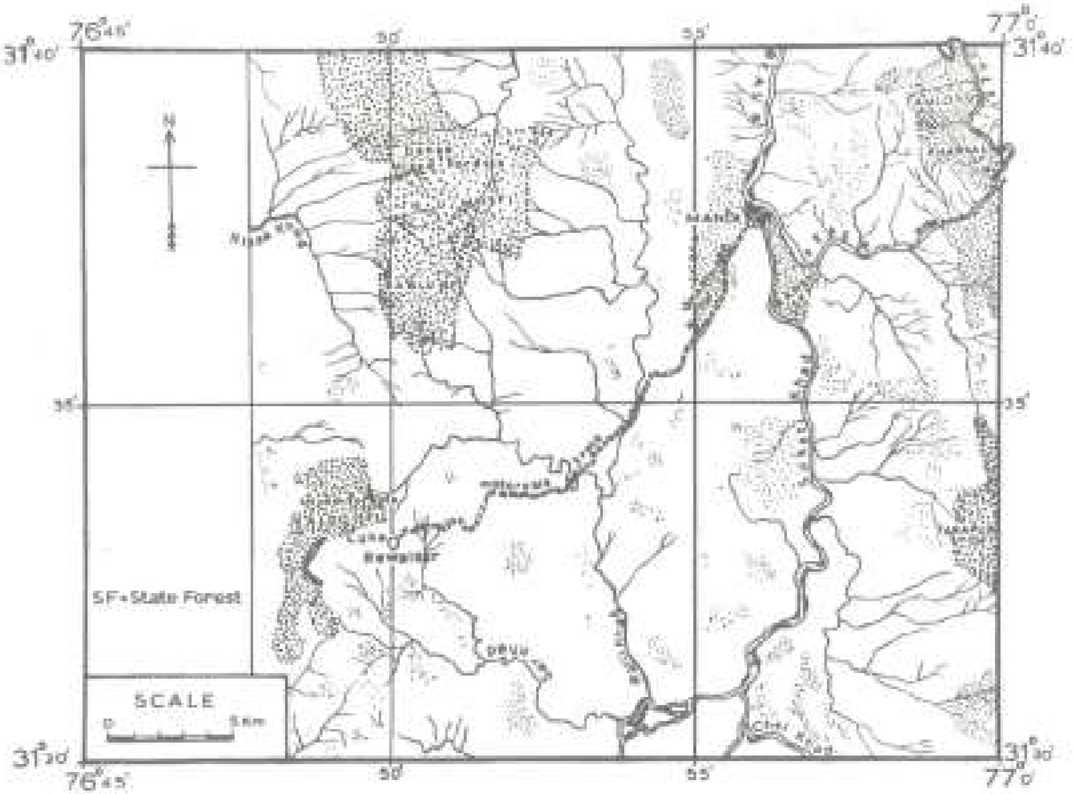


TEXT-FIG. 1 — Detailed map showing the location of the lake site.

To the north and the west of the lake, lies the main catchment area, but the water entering the lake is small except during the rainy season. The lake has its permanent supply of water from subterranean springs (Kashyap, *loc. cit.*), and there is a narrow outlet situated in the south-west.

METHODS

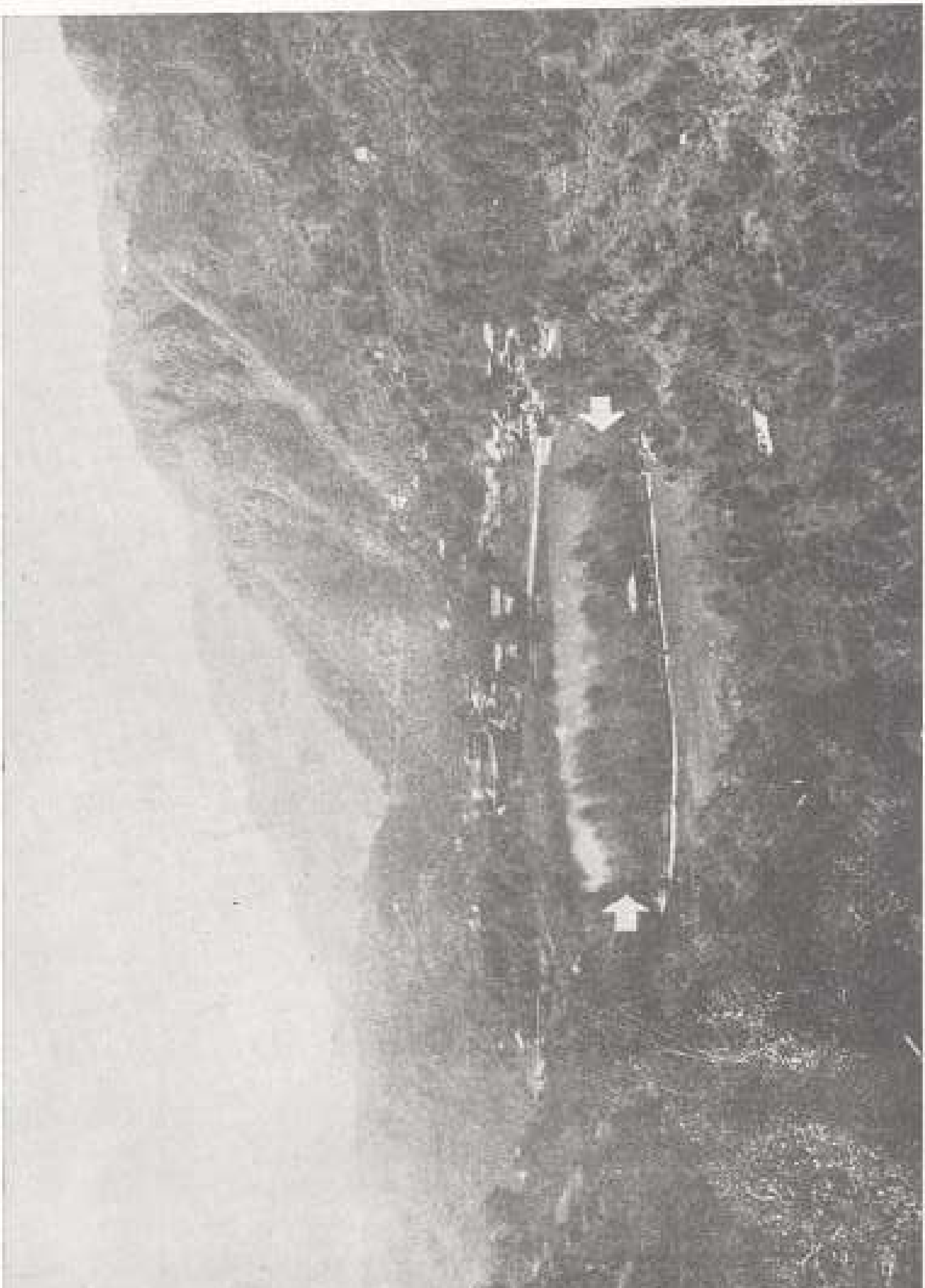
Stratigraphy was built up with the help of Hiller peat-auger provided with 50 cm. long chamber and samples collected at an interval of 10 cm. each. These samples were prepared for pollen analysis following the technique of Erdtman (1943) with slight modification (Sharma and Singh, 1972).

Pollen sum is based upon about 200 arboreal pollen grains except in some clay samples, in which the total sum was reduced to 150 arboreal pollen. All percentages were calculated in terms of this sum. Arboreal and non-arboreal pollen diagrams have been constructed separately. In addition, a total pollen diagram showing both arboreal and non-arboreal elements has also been constructed, calculating percentage frequencies in terms of total land plants pollen, excluding Ferns and Bryophytes.

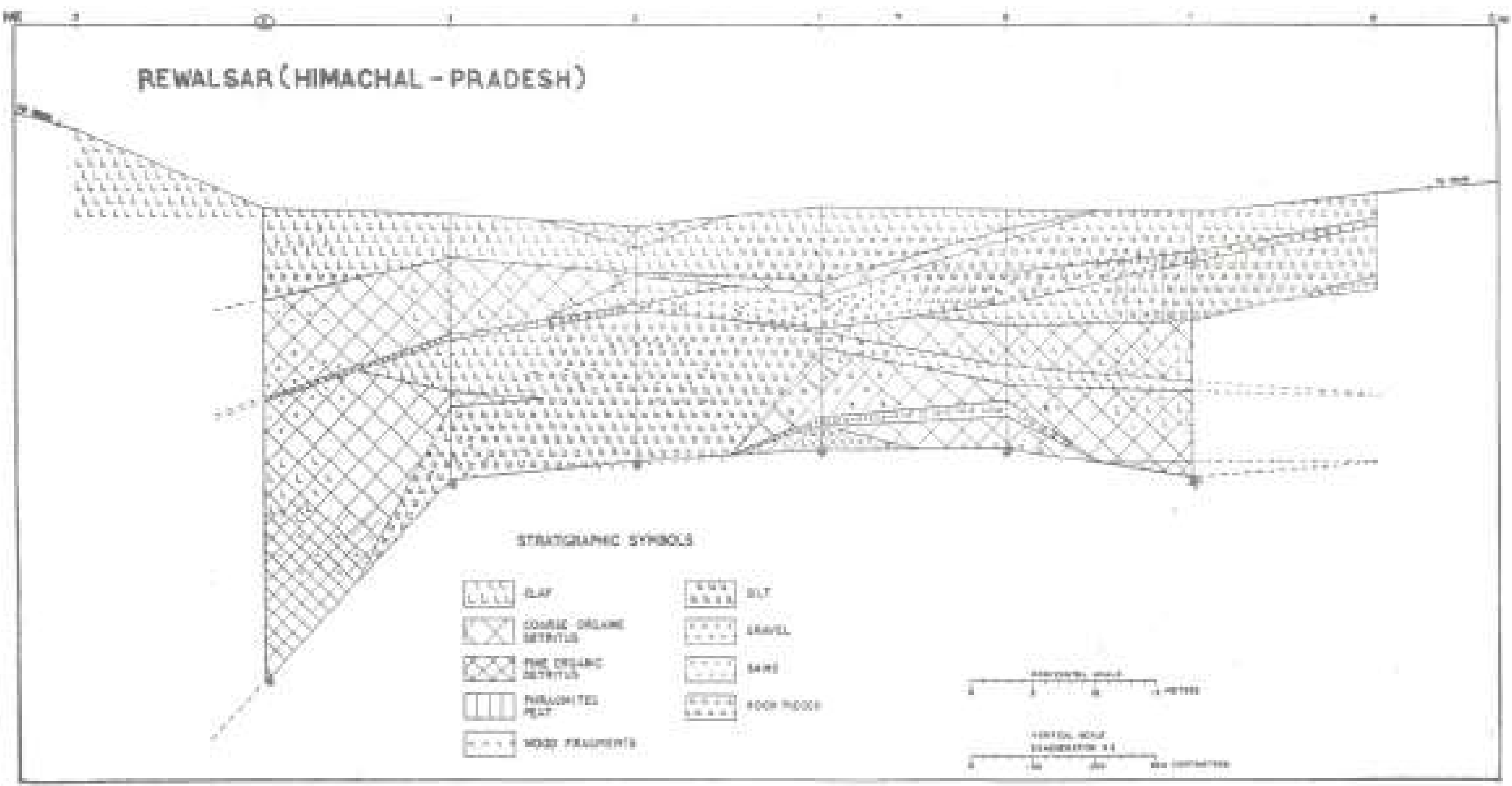
Percentages up to 0·5% are indicated by a plus (+) sign. The percentage frequencies of the elements met with extremely sporadically are given at right hand side of each AP and NAP diagram. In the case of the total AP/NAP diagram, the percentages are shown in the middle, as well as, to the right hand side of the diagram.

STRATIGRAPHY

The stratigraphy (Fig. 3) of the in-filled part of the lake-basin at Rewalsar, was studied by means of a series of eight bore-holes made along a section running in the northeast-southwest direction. The lake deposit, which is underlain by gravel in the



TEXT-FIG. 2 — A panoramic view of the Rewalsar lake and its surroundings (The borings were made along the line between the two arrows shown in the picture).



TEXT-FIG. 3 — Stratigraphical section of the lake deposit. The sampling was carried out from point 4, in the section.

section mainly comprises of fine and coarse organic detritus, intercalated with silt and clay. The lake basin is comparatively shallower in the southwest than in the northeast. Proceeding towards the southwest, the deposit is greatly influenced by the hill-wash, and several layers of silt, clay and gravel, are seen to form the basin deposit. The silt and gravel beds are intercalated with several layers of coarse organic detritus in the southwest. Fine organic detritus is mainly confined to the northeastern part of the section, where the lake depression appears to have been filled through a normal hydrosere succession followed by hill-wash, probably laid down as a result of deforestation in the area. The deposits in the southwestern part of the basin on the other hand, appear to have been laid down partly through the meandering action of the main inlet entering the lake basin. There is some evidence of *Phragmites*-peat, occurring together with silt, in the upper half of the deposit in the southwest of the section.

Bore-hole 4, made through the deepest part of the section, was selected for final sampling for pollen-analysis (Fig. 3). At this point, the lower-most sediment, after gravel, consists of fine organic detritus, a limnic deposit with abundant remains of *Botryococcus* colonies (Fig. 7), and some wood remains. The wood fragments appear to have been derived from some trees overhanging at the lake margins. This is succeeded by coarse organic detritus which is intercalated with a thin layer of sand. The organic detritus is overlaid by a thick sequence of silt and clay. The stratigraphical details of the bore-hole 4, as observed in the field and in the laboratory are as follows:

CM	
0-33	Grey clay, with seed of *Carex* and *Rubus* at 20 cm.
33-50	Grey clay, with one seed of *Chenopodium*.
50-70	Sand, wood fragments infrequent.
70-100	Dark grey clay, with a few wood fragments.
100-120	Silt, with a few wood fragments. *Carex* and *Chenopodium* seeds at 120 cm.
120-145	Silty clay, with some plant remains, and one seed of *Carex*.
145-150	Coarse organic detritus, with wood fragments.
150-155	Same as above.
155-200	Dark grey, coarse organic detritus. *Carex* seeds abundant; one seed of *Chenopodium*. Wood fragments frequent.
200-250	Coarse organic detritus with some sand and gravel. Wood fragments frequent.
250-300	Same as above, with a few seeds of *Carex* and *Scirpus*. Moss shoots also present.
300-305	Sandy.
305-350	Dark grey, coarse organic detritus with some gravel. Moss shoots rare. One seed of *Stellaria* at 310 cm. Wood fragments frequent.
350-400	Same as above, with one seed of *Rubus*.
400-450	Dark brown, coarse organic detritus with a little clay. *Carex* seeds, together with one seed of *Rubus* at 430 cm. Wood fragments frequent.
450-480	Same as above, but without seeds.
480-500	Dark brown, fine organic clay-mud. *Carex* seeds common. Wood fragments infrequent.
500-523	Same as above, but without seeds.
523-540	Same as above, but with one *Carex* seed.
540-550	Dark grey, fine organic detritus, with a few wood fragments.
550-600	Same as above, with one *Scirpus* seed at 580 cm.
600-650	Fine organic detritus. *Carex* and *Scirpus* seeds present. Moss shoots at 640 cm. Wood fragments very rare.
650-700	Fine organic detritus, with moss shoots. Some wood fragments present.
700-735	Same as above, but without moss shoots.
735-750	Fine organic detritus, with colour changing to light grey and becoming clayey.
750-770	Clay with gravel, with some wood fragments.
770-790	Gravel.

LOCAL VEGETATION

In view of its lower altitude, it enjoys a more or less subtropical type of vegetation and the hills around the Rewalsar

TEXT-FIG. 4 — A view of the plantation of *Pinus roxburghii* in the west of the Rewalsar lake.

TEXT-FIG. 5 — A view of the deforested slopes, now under terrace cultivation in the vicinity of Rewalsar.

lake, but for a few young, isolated plantations of *Pinus roxburghii* (Fig. 4), and *Cedrus deodara*, are largely devoid of natural forests (Fig. 5). The presence of elements, such as *Quercus incana*, *Celtis australis*, *Toona ciliata*, *Litsea* etc., along with species like *Skimmia laureola* and *Sarcococca saligna* indicate that thick forests existed in the past. However, the local as well as the surrounding vegetation of Rewalsar may be summed up as follows:

Starting from the centre of the lake outwards, the chief floating or submerged plants growing in the open water are — *Spirodela polyrhiza*, *Azolla pinnata*, *Nymphaea* sp., *Trapa* sp., *Callitriche stagnalis* and *Utricularia* sp. The lake margins, but for a few gaps here and there, are lined with a gregarious growth of *Phragmites communis*. The infilled part of the lake, above the water, is grown with *Acorus calamus*, *Scirpus squarrosus*, *S. triangulatus*, *Alisma plantago*, *Marsilea* sp., *Ranunculus laetus*, *Origanum vulgare*, *Geranium nepalense*, *Oxalis corniculata*, *Epilobium roylea-num*, *Aeschynomene indica*, *Plantago major*, *Nasturtium palustre*, *Lepidium ruderale*, *Anotis calycina*, *Myriactis nepalensis*, *Swertia alata*, *Eschenbachia stricta*, *Erigeron canadensis*, *Potentilla kleiniana*, *Coix lachryma-jobi*, etc.

Apart from the above aquatic, semiaquatic and terrestrial herbs, the marshy ground is also covered with some trees of *Salix tetrasperma* and *Alnus* sp. Trees, such as *Celtis australis*, *Toona ciliata*, *Machilus gamblei*, *Grewia optiva*, *Morus alba*, *Punica granatum*, *Murraya koenigii*, *Aegle marmelos*, *Prunus cornuta*, *Colebrookia oppositifolia*, *Clerodendrum fragrans*, *Rhamnus purpureus*, etc., grow a little away from the marshy areas.

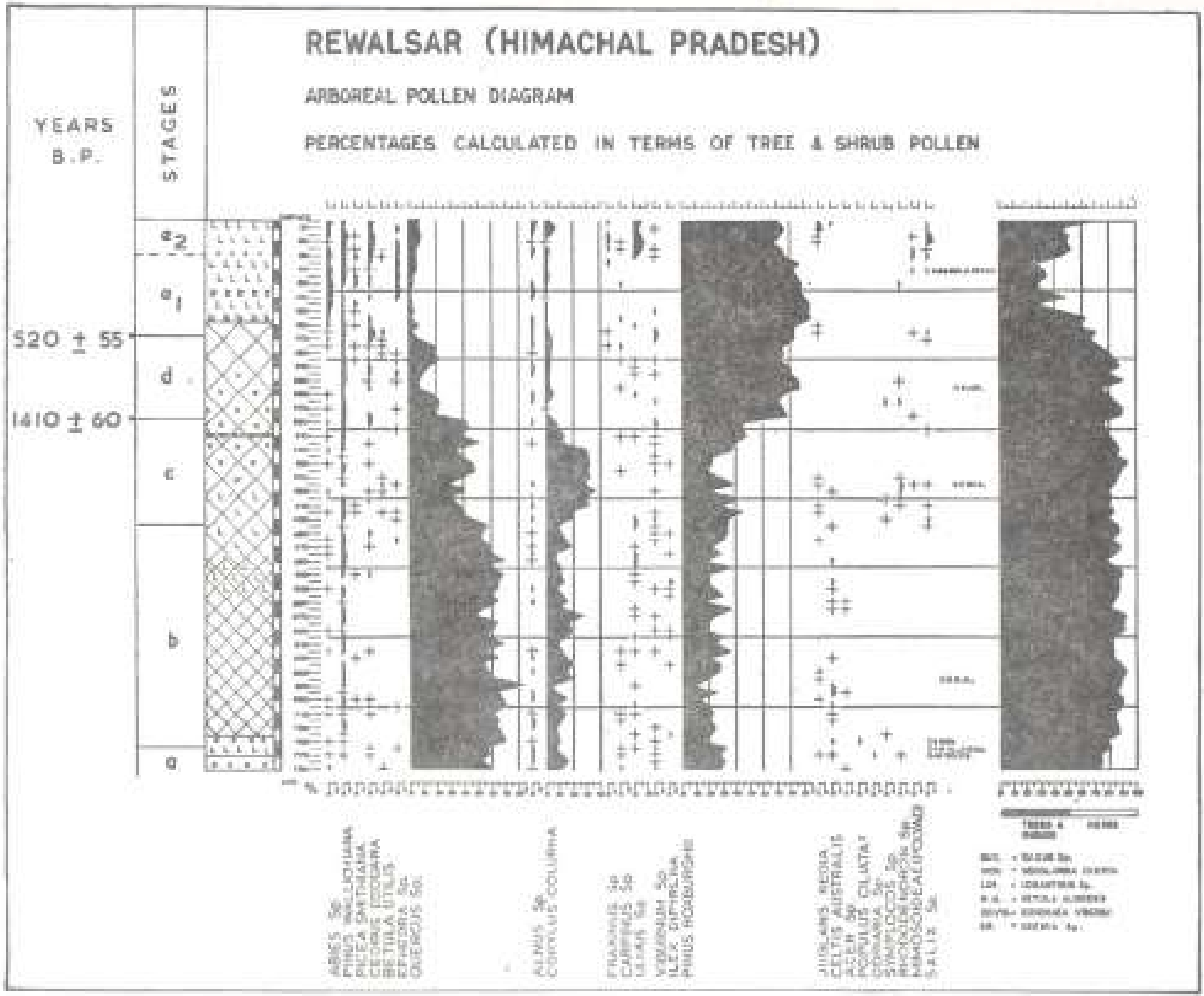
But for the small gap in the southeast, the lake is completely surrounded by hills (Fig. 2), which, on the whole exhibit a rather bare and desolate landscape. The mountain slopes are almost completely devoid of woodlands (Fig. 5). Much of the area is under terrace cultivation, and the mountain slopes facing Rewalsar lake in the west and northwest, are covered with a young plantation of *Pinus roxburghii* (Fig. 4). The slopes on the opposite side of the ridge in the west, are covered by a mixed plantation of *Cedrus deodara* and *Pinus roxburghii*. The plantation occurs together with scattered trees of *Quercus incana*. The oak trees are mostly found in a heavily lopped state, and appear to have been singled out for cutting purposes by the local inhabitants. The other most heavily lopped, of the timber trees, occurring in the area, is *Celtis australis*. Besides these, other trees and shrubs, commonly encountered on the slopes are *Euphorbia royleana*, *Berberis* sp., *Prinsepia utilis*, *Clerodendrum fragrans*, *Sarcococca saligna*, *Dodonaea viscosa*, *Woodfordia fruticosa*, *Viburnum* sp., *Rhododendron arboreum*, *Randia tetrasperma*, *Wendlandia heynei*, *Skimmia laureola*, *Mallotus philippinensis*, *Flacourtia indica* *Litsea* sp., *Alnus* sp., *Ulmus wallichiana*, *Juglans regia*, *Betula alnoides*, *Ilex dipyrena*, *Acer* sp., *Cotoneaster* sp., *Colebrookia oppositifolia*, *Rosa brunonii*, *Rhamnus purpureus*, *R. virgatus*, *Myrica esculenta*, *Mahonia nepalensis*, *Zanthoxylum armatum*, *Adhatoda vasica* etc. The most abundant climbers of these forests are *Clematis grata*, *C. buchananiana*, *Rubia cordifolia*, *Tinospora cordifolia*, *Galium* spp., *Dioscoria glabra*, *Jasminum* spp., etc. The ground flora is also vast and varied, attaining maximum of luxuriance after the monsoon.

The main crops grown in the area are rice, maize, wheat, barley, gram, and millets, besides *Eleusine coracana*, *Panicum miliaceum*, *Fagopyrum emarginatum*, *F. esculentum*, *Setaria italica*, etc. (Punjab States Gazetteer, 1904).

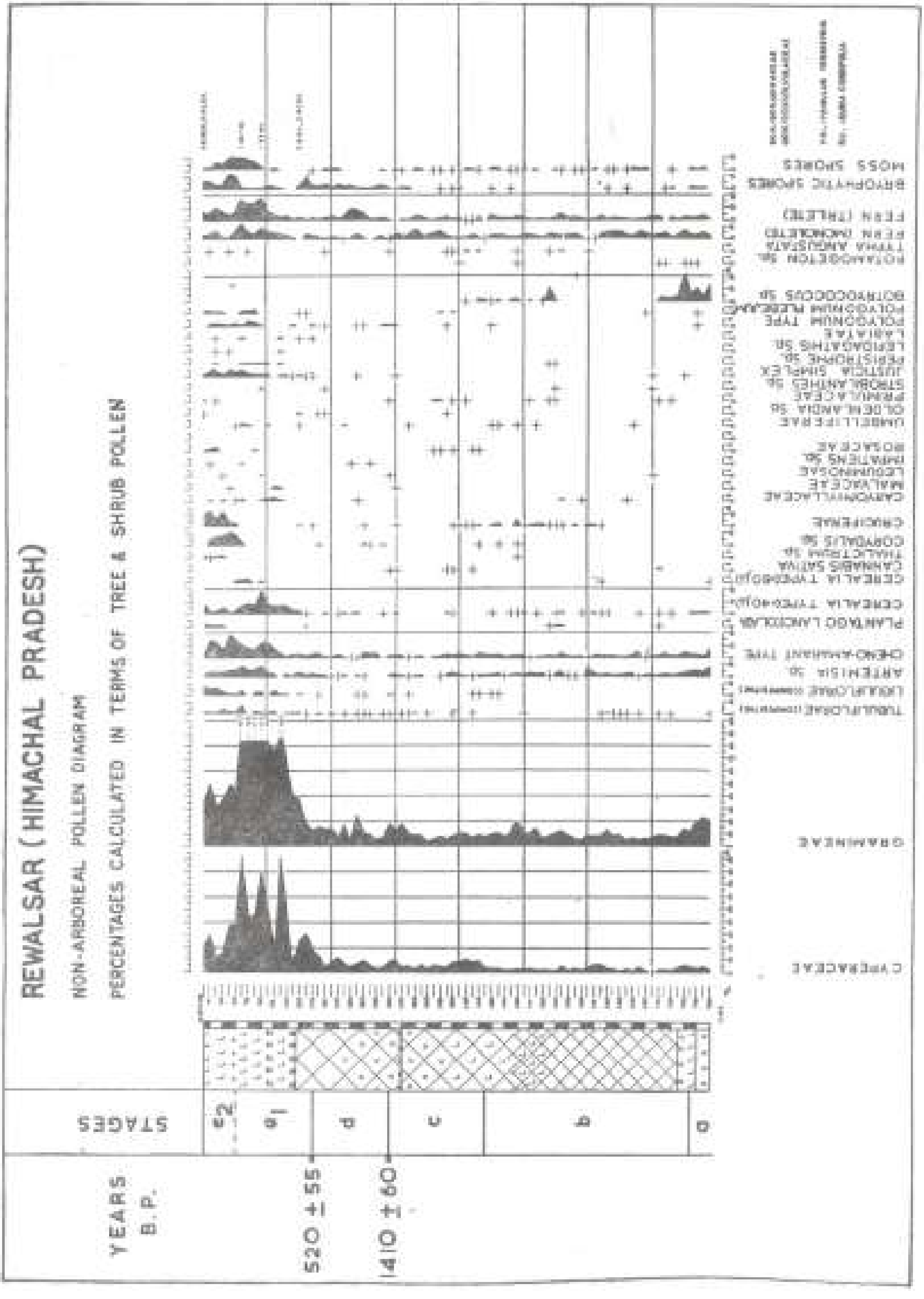
POLLEN DIAGRAM

The vegetational sequence, as deduced from the pollen diagram from the Rewalsar lake, has been divided into five stages namely a, b, c, d and e (Figs. 6, 7, 8).

The lower border of 'Stage a' (790-760 cm.) is not certain. The vegetational sequence begins with a partly open forest, dominated by high frequencies of *Quercus*, followed by *Pinus roxburghii* and *Corylus*, whose values reach upto 60%, 30% and 15% respectively, in this stage. The non-arboreal pollen ratios remain around 25% but fall at the top of the stage. *Alnus* forms a short curve. The pollen of *Abies*, *Carpinus*, *Viburnum* and *Coriaria* is seen in low values. Stray pollen grains of *Pinus wallichiana*, *Cedrus deodara*, *Betula utilis*, *Ephedra*, *Ulmus*, *Juglans*, *Celtis*, *Betula alnoides*, *Acer*, *Rhododendron*, *Grewia* and *Dodonaea viscosa*, are met with occasionally in this stage.



TEXT-FIG. 6 — Arboreal pollen (AP) diagram from Rewalsar lake. Percentages calculated in terms of total tree and shrub pollen.



TEXT-FIG. 7 — Non-arboreal pollen (NAP) diagram from Rewalsar lake. Percentages calculated in terms of total tree and shrub pollen.

Non-arboreal vegetation mainly comprises of Gramineae, *Artemisia*, Cheno-Amarant type and Cyperaceae, whose values reach upto 23%, 7%, 7% and 5% respectively. Cerealia type of pollen is seen from the beginning of the pollen sequence in the form of a low continuous curve. Other non-arboreal elements, represented in very low values, are Compositae (Tubuliflorae) and *Polygonum* type.

The aquatic component is largely represented by high values of *Botryococcus* colonies, reaching upto 12%. Pollen of *Potamogeton* and *Polygonum plebejum* occurs sporadically. The curves for Fern spores (both monolete and trilete) attain frequencies upto 5% and 3% respectively. Bryophytic and Moss spores are seen in low but continuous curves.

The subdued nature of the *Quercus* curve at the beginning of 'Stage a' together with the well developed curves for Gramineae (23%), *Artemisia* (7%) Cheno-Amarant type (7%) and Cerealia type (1%), is perhaps indicative of a partly open forest.

'Stage a' is brought to an end at the 760 cm. level, and 'Stage b' (760-440 cm.) begins where the curve for *Pinus roxburghii* declines with a corresponding rise in the curves for *Quercus* and the 'tree and shrub' pollen ratios. *Pinus wallichiana* starts a more or less continuous curve for the first time in this stage. The curve for *Quercus* maintains high value upto 82%. The curve for *Corylus*, shows a fluctuating course with a small rise in the middle of the stage. The *Alnus* curve becomes sporadic. The pollen of *Ulmus* forms a short curve towards the top of the stage. Stray pollen of *Picea* is seen for the first time in this stage. The pollen of *Carpinus* occurs sporadically in the lower half of the stage. Other tree and shrub elements, represented either in short curves or in a sporadic form, are *Abies*, *Cedrus deodara*, *Ephedra*, *Viburnum*, *Ilex dipyrena*, *Juglans*, *Celtis* and *Acer*. Stray pollen of *Symplocos*, Mimosoideae (polyad) and *Betula alnoides* is also met with in this stage.

Non-arboreal elements are comparatively poorly represented, and are mainly comprised of Gramineae, Cyperaceae, *Artemisia* and Cheno-Amarant type, whose values reach upto 20%, 6%, 6% and 5% respectively. The curves for *Artemisia* and Cheno-Amarant type become discontinuous at some places. The curve for Cerealia type becomes sporadic. A single grain of *Plantago lanceolata* is seen for the first time at 710 cm, and a short curve is also formed in the upper half of the stage. Stray pollen of *Corydalis* also occurs in the upper half. The pollen of Cruciferae is seen for the first time in the middle of the stage, and it continues thereafter, in the form of a discontinuous curve. The other non-arboreal constituents, present either in short curves or sporadically, are Compositae (both Tubuliflorae and Liguliflorae), Caryophyllaceae, Umbelliferae, Primulaceae, *Strobilanthes*, *Justicia simplex*, *Peristrophe*, and *Polygonum* type. A few pollen grains of *Cannabis*, *Thalictrum* and Leguminosae are also seen in this stage.

The aquatic vegetation is represented mostly by colonies of *Botryococcus*, which increase in their values, reaching upto 20% at the beginning of this stage, but soon decline afterwards and gradually disappear, reappearing once again in the upper half of the stage in low values. Other aquatics represented in low frequencies are *Typha angustata*, *Potamogeton* and *Polygonum plebejum*.

The curves for Fern spores (both monolete and trilete) maintain low values, as in the previous stage. The curve for Bryophytic spores becomes sporadic. Moss spores form a rather discontinuous low curve.

The fall in the ratios of the non-arboreal elements, coupled with the recovery of the *Quercus* curve at the beginning of this stage, is indicative of the regeneration and the closing-in of the oak forest. In the later part of the stage, there is little evidence of any large scale clearance, even though the fluctuating nature of the curve for the 'tree and shrub' pollen ratios, together with the occurrence of Cerealia type and *Plantago* pollen at the same levels, shows that occasional small-scale openings in the forest continued to be made throughout the stage.

'Stage b' comes to an end at 440 cm. and 'Stage c' (440-290 cm.) begins with a consistent rise in the values of *Corylus*, which reach upto about 35% at their maximum. Correspondingly, there is a fall in the curve for *Quercus*. The curve for *Pinus roxburghii* shows a slight increase at the lower end of the stage, accompanying the rise of the *Corylus* curve, but later on it falls, while the curve for *Corylus* reaches its maximum extent and importance. The

Pinus roxburghii curve, however, rises once again in the upper half of the stage, and the curve for *Corylus* falls to relatively lower values. The curve for *Pinus wallichiana* maintains low values, as in the earlier stage. The pollen of *Betula utilis*, which remain unrepresented in 'Stage b' is met with sporadically in the lower half of this stage. The pollen of *Salix* and Mimosoideae (polyad) is represented for the first time. The values of *Rhododendron* show a slight increase in the middle of the stage. The other tree and shrub elements, represented either in short curves or met with sporadically, are *Abies*, *Cedrus*, *Ephedra*, *Alnus*, *Ulmus*, *Viburnum*, *Juglans* and *Celtis*. Stray pollen of *Picea*, *Carpinus*, *Ilex*, *Symplocos* and *Buxus* is also seen in this stage.

The non-arboreal elements on the whole, are poorly represented. There is a slight increase in the curve for Cyperaceae at the beginning of the stage. Its values reach to about 10%, and then decline, but rise once again at the top of the stage. The curves for Gramineae, *Artemisia* and Cheno-Amarant type remain low, but their frequencies rise towards the top of the stage. This rise is accompanied by the occurrence of the pollen of both Cerealia type and *Cannabis* in small numbers. Other non-arboreal elements represented in low frequencies in this stage, are Compositae (both Tubuliflorae and Liguliflorae), Cruciferae, Rosaceae, Primulaceae, *Polygonum* type and stray pollen of *Corydalis*, Malvaceae, Leguminosae, Umbelliferae, *Oldenlandia* and *Justicia simplex*.

The aquatic vegetation is represented only in the lower half of the stage, by low values of *Botryococcus* colonies, and the pollen of *Typha angustata*, *Polygonum plebejum* and *Potamogeton*.

There is a slight increase in the curves for Fern spores (both monolete and trilete). Brophytic spores, in general, and Moss spores occur in low frequencies.

As the oak curve falls together with a small rise in the frequencies of plants of open habitat, such as Cyperaceae, *Cannabis*, Cruciferae, Rosaceae and Primulaceae at the beginning of the stage, it is suggested that the oaks perhaps fell as a result of some forest clearance. *Corylus* which, again is a tree of rather open forests, perhaps increased in response to this clearance. At first, the oaks fall and *Corylus* and *Pinus roxburghii* rise, but later on, oaks appear to recover and *Pinus roxburghii* falls. Towards the top of the stage, *Corylus* declines and the frequencies of *Pinus roxburghii* rise once again.

'Stage c' is brought to an end at 290 cm. and 'Stage d' (290-170 cm.) begins with a sudden fall in the curve for *Quercus*, corresponding with a sudden rise in the curve for *Pinus roxburghii*. The *Corylus* curve declines still further, and becomes discontinuous. *Pinus roxburghii* attains its maximum values of about 87%, but declines in the upper half of the stage, corresponding with a recovery of the oak curve. The oak curve, however, falls again towards the top of the stage, and the *Pinus roxburghii* curve rises once again. *Pinus wallichiana* forms a low continuous curve for the first time in this stage. There is a slight increase in the values of *Cedrus* and *Alnus*. The pollen of *Betula utilis* and *Picea* is seen sporadically in the upper half of the stage only. Other tree and shrub species, represented either in the form of short curves or sporadically, are *Abies*, *Ephedra*, *Carpinus*, *Ulmus*, *Viburnum* and *Rhododendron*. They occur together with stray pollen of *Fraxinus*, *Symplocos*, Mimosoideae (polyad), *Salix* and *Loranthus*. The 'tree and shrub' pollen ratios show a fall with some fluctuations.

The non-arboreal vegetation is poorly represented. It comprises of chiefly Cyperaceae and Gramineae, whose values in each case, increase in the upper half of the stage. *Artemisia* and Cheno-Amarant type form fresh curves in the upper half, and there is a slight increase in the pollen frequencies of Compositae (both Tubuliflorae and Liguliflorae) and Cerealia type. Other non-arboreal species represented in low values are *Corydalis*, Cruciferae, *Impatiens*, *Oldenlandia*, *Polygonum* type, Caryophyllaceae, Umbelliferae and *Strobilanthes*.

The aquatic vegetation is negligible and is represented by a single grain of *Typha angustata*. The curve for Fern spores (trilete), shows an increasing trend in the lower half of the stage. Bryophytic spores form a fairly continuous curve for the first time in this stage, and their values rise in the upper half. Moss spores form a short curve in the upper half of the stage.

The fall in the curves for *Quercus*, *Corylus* and *Pinus roxburghii*, at various intervals in this stage, invariably corresponds with a small rise in the values of Gramineae, Cyperaceae, *Artemisia*, Cheno-Amarant type and Cerealia type, indicating small scale clearance of these tree elements at different intervals. The lower border of 'Stage d' is C-14 dated at 1,410 ± 60 B.P. (WIS-417).

'Stage d' is brought to an end at 170 cm. and 'Stage e' (170-0 cm.) begins with the final decline in the curves for *Quercus* and *Corylus*. 'Stage e' is divisible into two sub-stages 'e_1' and 'e_2'. In 'Sub-stage e_1' (170-50 cm.) the curve for *Pinus roxburghii* rises largely as a result of the fall in the broad-leaved species. This is quite apparent from the total diagram (Fig. 8), in which the absolute values of *Pinus roxburghii* actually fall together with other tree elements, indicating a general felling of the tree vegetation. This is further substantiated by the overall fall in the 'tree and shrub' pollen ratios in this sub-stage. *Abies* forms a fresh and an almost continuous curve in this sub-stage. The curve for *Pinus wallichiana* declines in the lower half but increases once again in the upper half. *Cedrus* forms a short curve in the lower half of the sub-stage, and *Ephedra* in the upper half. There is a slight increase in the pollen frequencies of *Picea*. The pollen of *Betula utilis* is seen only in the beginning of the sub-stages. *Alnus* forms a fresh, short curve, and there is a slight increase in the values of *Viburnum*. The pollen of *Juglans* which remains unrepresented in 'Stage d' is met with sporadically in the lower half of this sub-stage. Other tree and shrub elements represented in low values are *Carpinus*, *Ulmus*, *Rhododendron* and *Salix*, together with stray pollen of *Fraxinus*, Mimosoideae (polyad), *Buxus* and *Wendlandia*.

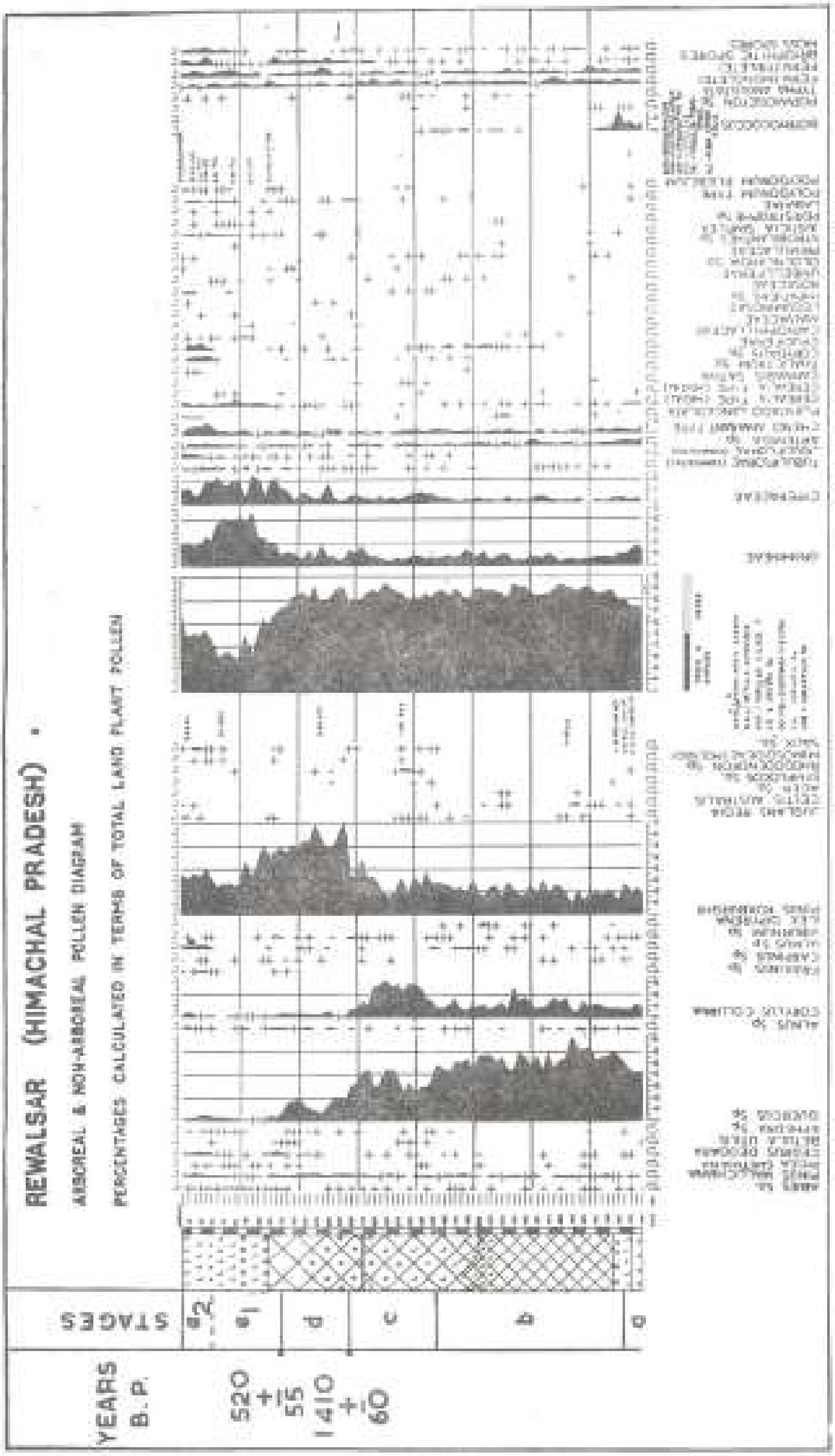
There is a sudden rise in the frequencies of most of the non-arboreal elements in this sub-stage. The curves for Gramineae and Cyperaceae increase from the beginning and their values reach upto 182% and 95% respectively, at their maximum. The curve for Cerealia type increases a little later, followed by Cheno-Amarant type, *Artemisia* and Compositae (both Tubuliflorae and Liguliflorae) Caryophyllaceae and Malvaceae form short curves for the first time in the middle of the sub-stage, and Umbelliferae, *Justicia* and *Peristrophe* in the upper half. The pollen of Labiatae and *Polygonum* type, also shows a slight increase. Other non-arboreal species represented in low frequencies are Leguminosae, *Impatiens*, Rosaceae, *Oldenlandia*, *Strobilanthes*, *Lepidagathis*, *Rubia cordifolia*, Convolvulaceae and *Tribulus*.

The aquatic vegetation is represented by low values of *Polygonum plebejum* and *Typha angustata*. The curves for Fern spores (both monolete and trilete) increase in the upper half of the sub-stage. The Bryophytic spores show a slight increase in the beginning and then decline. The Moss spores occur in low values only.

The catastrophic decline in the 'tree and shrub' pollen ratios, corresponding with the tremendous rise in the frequencies of almost all the non-arboreal elements, is indicative of large scale decimation of the tree vegetation. The rise in the Cerealia type curve, together with a similar rise in the values of other culture pollen, indicates that the clearance was followed by intensive agriculture in the area. The lower border of 'sub-stage e_1' is C-14 dated at 520 ± 55 B.P. (WIS-419).

'Sub-stage e_1' ends at 50 cm. and 'Sub-stage e_2' (50-0 cm.) begins with a small increase in the curves for *Quercus*, *Cedrus* and *Ulmus*. *Pinus roxburghii* also appears to mark a real increase, as seen in the total diagram (Fig. 8). The values of *Alnus*, *Corylus*, *Juglans* and *Salix*, also show a slight increase in the upper half of this sub-stage. *Fraxinus*, forms a short curve for the first time, and *Abies*, *Pinus wallichiana* and *Ephedra*, maintain low values. Other tree and shrub elements, represented either in short curves or sporadically, are *Picea*, *Carpinus*, *Viburnum*, *Celtis*, Mimosoideae (polyad) and *Betula utilis*.

Amongst the non-arboreal species represented, the curves for Gramineae, Cyperaceae and Cerealia type fall considerably, followed by Compositae (Tubuliflorae) and *Artemisia*. There is a sudden rise in the frequencies of *Corydalis* and Cruciferae. Both the elements form continuous curves for the first time in this sub-stage. The curve for Compositae (Liguliflorae) shows a slight increase and *Plantago lanceolata* forms a fresh low curve in this sub-stage. The pollen of Rosaceae and *Thalictrum*, also forms short curves. The curves for Cheno-Amarant type, *Justicia* and *Polygonum* type follow a fluctuating course throughout the sub-stage. Other non-arboreal elements represented in low values, are Caryophyllaceae, Malvaceae, Leguminosae, Impatiens, Primulaceae, *Oldenlandia*, Boraginaceae Con-



TEXT-FIG. 8 — Total pollen (AP/NAP) diagram from the Rewalsar lake. Percentages calculated in terms of total land plant pollen excluding Ferns and Bryophytes.

volvulaceae, *Peristrophe*, *Lepidagathis* and Labiatae.

Aquatic vegetation is represented by a low curve of *Polygonum plebejum*, and the sporadic occurrence of *Typha angustata* pollen.

The curves for Fern spores (both monolete and trilete), together with those of Bryophytic spores, follow a fluctuating course in this sub-stage. The values of Moss spores tend to decline.

The rise in the curves for most of the arboreal elements, together with a corresponding fall in the frequencies of non-arboreal plants, is indicative of a phase of regeneration of the forests. This phase may have started with the demarcation of reserved forests and with the recent forest plantations carried out by the State Forest Department.

DISCUSSION AND CONCLUSIONS

Stratigraphy and the Age of Lake deposit

The lake sediment at Rewalsar, remain to be investigated at a greater length than what, has, now been possible with the limited capacity of the boring equipment available. The lake sediments, so far, investigated, appear to constitute only a fraction of the Late-Quaternary deposit.

The gravel pan at the base (Fig. 3), gives the impression of a glacially scoured surface, but the outward impression seems to be incorrect as the gravel may have been deposited through the meandering action of flood stream entering the lake in the north of the lake basin. This view is substantiated by the two C-14 dates, 1410 ± 60 B.P. (WIS-417) and 520 ± 55 B.P. (WIS-419), from the upper half of the pollen profile (Fig. 3 point 4; Figs. 6, 7, 8) showing that the history of entire deposit studied may not extend beyond the last 4000 years, if due allowance is given for the differential rates of deposition at various intervals of the profile. It follows that either the deposits of the earlier period lie below the gravel pan or they were eroded before the deposition of the sediments overlying the gravel pan. But for the extreme north-eastern part of the section, the Rewalsar lake basin appears to have been under the influence of secondary deposition which may have been derived from the hill-wash. This is clear from the repeated interruptions seen in the organic deposit, which is intercalated with inorganic material at close intervals (Fig. 3). The north-eastern part of the section, except in the upper levels, is almost free of the effect of hill wash; here one witnesses the deposition of organic matters through a normal hydrosere succession. The absence of relatively older deposits in this part of the section may be due to the marginal position of the profile at point 4 (Fig. 3) with respect to the basin proper, as the section passes at a tangent to the deeper parts of the lake-basin. It is most likely that deposits of relatively older age lie below the open water in the deeper part of the lake basin.

Vegetational History

It is already established from the foregoing account that lake deposits investigated at Rewalsar is representative of the later part of the Post-glacial period, and reflect the history of vegetation of its area, through the pollen sequence worked out. The vegetational history uncovered, is however, limited to the present day sub-tropical belt, as the lake site is situated within this belt. The vegetational sequence is overwhelmingly dominated by *Quercus*, during early stages. The lower altitude of the site and its location in the outer Himalaya, has, however, resulted in the greater representation of the sub-tropical pine (*Pinus roxburghii*), in the pollen profile and other conifers are extremely lowly represented. The curve for *Corylus* is well developed which may partly be due to the comparatively drier conditions found in the Rewalsar area. *Corylus colurna*, the only species of *Corylus* represented in the western Himalayas, grows at 1524-3048 m., in dry temperate deciduous forests (Bor, 1953).

Stage a — The forest history, which starts with ' Stage a ' at the bottom of the stratigraphical column (Figs. 6, 7, 8), is representative of a partly open forest, in which, *Quercus* appears to have been by far, the most dominant element. *Pinus roxburghii* and *Corylus*, come next in order of importance, but as *Pinus roxburghii* pollen, is carried to long distances it is not certain whether the pine forest existed any where near the lake site. Considering the overall dominance of oak pollen in the pollen spectra in ' Stage a ', which in terms of modern pollen rain can only come from a fairly closed oak forest, it is likely that *Pinus roxburghii* grew at a relatively lower altitude, or at a considerable distance from the lake site.

Corylus, whose European relative *C. avellana* is known for its large pollen production, is much less known, as far as the Indian species *C. colurna* is concerned. The surface samples from Himachal Pradesh studied so far (Sharma, 1973), have failed to show up this element in any significant quantity, but this may be due to the present-day scanty distribution of this species in the areas visited. Thus, while no firm conclusion can be drawn regarding the actual relative abundance of *Corylus* at Rewalsar, from its pollen curve, it may well be that the species was more widely distributed in the outer Himalaya than the present-day, and that it was perhaps present in the vicinity of the Rewalsar area in 'Stage a'.

The partly open character of the forest, is testified by the AP/NAP curve, and also by the well developed nature of the curves for Gramineae, *Artemisia* and Cheno-Amarant type, all of which are well known light demanders. The presence of Cerealia type of pollen, from the very beginning of the sequence, together with the partially open character of the forest, is perhaps indicative of a phase of forest clearance, for agriculture.

The broad-leaved character of the forest vegetation in 'Stage a' at Rewalsar, is reminiscent of the mid-Post-glacial forest development in the Kashmir valley during the Climatic Optimum (Singh, 1963).

Stage b — In this stage, *Quercus* frequencies rise and attain their maximum values, and the non-arboreal elements decline, indicating the closing of the oak forest. *Pinus wallichiana* forms short curves for the first time in this stage, and it may have been represented in small number in the area. The introduction of the curve for *Pinus wallichiana*, a temperate element in the sequence, can be regarded as indicative of cooler climate, and this development may be compared with the onset of the period of decreasing warmth in Kashmir (Singh, 1963). *P. wallichiana* at present, grows at 1,829-3,048 m. (6,000'-10,000') in the temperate Himalaya.

The non-arboreal vegetation, mainly comprises of Gramineae, Cyperaceae, *Artemisia* and Cheno-Amarant type. A single grain of *Plantago lanceolata*, is seen for the first time in the lower half of the stage, and later, a short curve is seen to develop in the upper half. There is little evidence of any large scale forest clearance in this stage, even though, the occasional occurrence of the pollen of *Plantago lanceolata* and Cerealia type, together with the fluctuations seen in the curve for the 'tree and shrub' pollen ratios, shows that perhaps small scale felling of trees continued in the otherwise closed forest. As the rise in the curve for *Corylus* in each case, corresponds with the fall in the *Quercus* curve, it is likely that *Corylus* benefitted from such small scale clearance. The curve for *Pinus roxburghii*, also appears to play a more or less identical role, together with *Corylus*, in this stage. This is understandable because both *Pinus roxburghii* and *Corylus* prefer dry sunny slopes, and are able to encroach upon newly vacated areas with ease.

Stage c — This stage is marked by a consistent rise in the values of *Corylus*, corresponding with a fall in the *Quercus* curve. The curve for *Pinus roxburghii*, also shows a relative increase at the beginning of the stage, but later on, declines; it, however, rises once again, towards the top of the stage. *Pinus wallichiana* continues to occur in the form of short curves, as before, and the pollen of other temperate species, such as *Abies*, *Picea* and *Cedrus* also begin to occur more frequently. *Betula utilis*, the high altitude birch in the Himalaya, which remains unrepresented in 'Stages a and b', is represented by its pollen in 'Stage c'. All this can be taken to indicate the continuation of the trend towards decreasing warmth in the area, as suggested earlier, in 'Stage b'. Isolated grains of *Salix*, Mimosoideae (polyad) and *Buxus*, occur for the first time in this stage.

The fall in the oak curve is accompanied by the rise in the values of Cyperaceae, and a general fall in the 'tree and shrub' pollen ratios. The pollen of Cerealia type and *Cannabis*, also occurs frequently in small numbers in this stage, from which it is suggested that the oak forest fell as a result of forest clearance by man, for agriculture. *Corylus* and *Pinus roxburghii*, which are both light demanders, perhaps increase as a result of the above clearance. As the curve for *Quercus* falls in the beginning of the stage, the frequencies of both *Corylus* and *P. roxburghii* rise, but later on, oaks appear to recover and the *P.*

roxburghii values fall. *Corylus* declines towards the top of the stage and the curve for *P. roxburghii* rises, once again. As there is a small rise in the curve for Gramineae towards the top of the stage, it is likely that *Corylus* also fell as a result of forest clearance. The newly vacated areas appear to have been occupied by *Pinus roxburghii*, whose values continue to rise, hereafter. It has been argued earlier, that *Pinus roxburghii* was probably, not represented locally in the almost pure oak forest of 'Stages a and b'. In 'Stage c', on the other hand, it appears that the opening of the forest provided the opportunity for the expansion of *Pinus roxburghii*, into areas hitherto occupied by oak and hazel.

Stage d — The lower border of 'Stage d' is C-14 dated at 1,410±60 B.P. (540 A.D.) (WIS-417) and starts with the fall of the oak forest. The oak pollen curve, shows a consistent decline at the beginning of this stage, but recovers to some extent in the second half, falling, once again, towards the top end of the stage. Correspondingly, the *Pinus roxburghii* curve rises to high values. As there is no pronounced increase in the ratios of non-arboreal elements to match the catastrophic fall in the oak curve, it appears that *Pinus roxburghii*, actually replaces the oak forest, and that there is little change in the absolute forest cover over the area. It may well be that the elimination of the borad-leaved species, that is oak and hazel, in 'Stage c', disturbs the natural equilibrium of the forest, and it becomes relatively easy for *Pinus roxburghii* to make inroads into the oak-hazel forest, in 'Stage d'.

Corylus falls to insignificant values in this stage. It seems like that it is kept in check by *Pinus roxburghii*, which normally does not allow any undergrowth.

Pinus wallichiana forms a continuous curve, for the first time in this stage, and there is a slight increase in the values of *Cedrus* and *Alnus*. The pollen of *Betula utilis* and *Picea*, is seen sporadically in the upper half of the stage.

The non-arboreal vegetation is poorly represented. It comprises of mainly Cyperaceae and Gramineae. *Artemisia* and Cheno-Amarant type pollen forms fresh curves in the upper half of the stage, and there is also a slight increase in the pollen of Compositae and Cerealia type, at more or less the same level.

Stage e — This stage, whose lower border is C-14 dated at 520±55 B.P. (1430 A.D.) (WIS-419), begins with the final decline in the curve for *Quercus* which, hereafter, becomes an almost insignificant element. There is a marked rise in the non-arboreal vegetation, as evidenced by the general rise in the curve for Gramineae, Cyperaceae, Compositae, *Artemisia*, Cheno-Amarant type, and Cerealia type. The beginning of this stage is also marked by the sudden fall in the 'tree and shrub' pollen ratios, from which, it seems almost certain that the tree vegetation, in general, is cleared on a massive scale. Besides *Quercus*, which is suggested to have been completely decimated, *Pinus roxburghii* also appears to have been felled on a large scale, as it is clearly brought out in the total diagram (Fig. 8). This episode apparently took place in the early 15th century A.D., and was perhaps responsible for the clearance of forests in the Rewalsar area. There is at present, no historical record to connect this episode with any large-scale human migration into the area, but at the same time, it is difficult to visualize such massive clearance without some compelling reason, connected with the human history of this region. It may, however, be that the religious importance of the Rewalsar lake, which is now thronged with thousands of pilgrims every year, at the time of numerous religious festivals connected with Hindus, Buddhists and Sikhs, first rose to its present eminence during this period.

'Stage e' is divisible into 'Sub-stages e_1 and e_2'. In 'Sub-stage e_1' besides the aforementioned characteristics of the beginning of 'Stage e', there is general increase in the values of *Abies*, *Pinus wallichiana* (upper half) *Cedrus* (lower half), *Ephedra* (upper half), *Picea Alnus* and *Viburnum*. There is a sudden rise in the frequencies of most of the non-arboreal elements in this sub-stage. The curves for Gramineae and Cyperaceae increase considerably from the beginning of the sub-stage and reach their maximum values in each case. The curve for Cerealia type, increases a little later, followed by Cheno-Amarant type, *Artemisia* and Compositae. Caryophyllaceae and Malvaceae form short curves, for the first time in the middle of the sub-stage, and Umbelliferae, *Justicia* and *Peristrophe*, in the upper half of the sub-stage. The pollen of *Polygonum* type and Labiatae also show a slight increase.

The rise in the curve for Cerealia type, together with other culture pollen, suggests that the clearance is followed by intensive agriculture in the area, in this sub-stage.

'Sub-stage e_2' shows a small increase in the curves for *Quercus*, *Cedrus* and *Ulmus*. *Pinus roxburghii*, also appears to have marked a real increase, as shown by the total diagram (Fig. 8). The values of *Alnus*, *Corylus*, *Juglans* and *Salix*, also show a slight increase in the upper half of this sub-stage, and *Fraxinus* forms a short curve for the first time.

The non-arboreal vegetation on the whole declines, but there is a sudden rise in the frequencies of *Corydalis* and Cruciferae. The pollen of Compositae (Liguliflorae), *Plantago lanceolata*, Rosaceae and *Thalictrum*, also increases slightly.

The rise in the curves for arboreal elements, and the corresponding fall in the frequencies of non-arboreal plants, is perhaps indicative of some regeneration of the forest, which may have resulted from the Governmental protection given to the forest areas, in recent years, and also the forest plantations carried out by the State Forest Department. At present, the area surrounding the Rewalsar lake is devoid of natural thick forests; only young plantations chiefly of *Pinus roxburghii*, *Cedrus deodara* etc., occur in small patches, here and there.

The tentative sub-divisions of the present pollen sequence into five 'Stages a, b, c, d, and e' is independent of the one at Khajiar (Sharma and Singh, 1972), which is also situated in Himachal Pradesh. Although there is a strong similarity between the quality of pollen assemblages in the two pollen sequences, nevertheless, it is premature to suggest a common system of zonation from the two sites worked out, though both the pollen profiles are C-14 dated. It is envisaged that it will be possible to suggest a uniform system of zonation for the western Himalayas, in due course, as soon as sufficient number of C-14 dated Post-glacial pollen sequences are available from this region.

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OCCURRENCE OF SOME DIPTEROCARPACEOUS WOODS IN THE CUDDALORE SERIES OF SOUTH INDIA

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ABSTRACT

Dipterocarpaceous woods are very common in the Cuddalore Series of South India near Pondicherry. Investigations have revealed the occurrence of three more new species of dipterocarpaceous woods from this area. One of them, showing closest resemblance with the genus *Dipterocarpus*, has been named as *Dipterocarpoxylon pondicherriense*. Of the remaining two, one compares with some species of *Shorea*, *Parashorea* and *Pentacme*, while the other shows affinities with *Shorea acuminata* Dyer and many other Malayan shoreas. They have been described as *Shoreoxylon indicum* and *S. arcotense* respectively.

INTRODUCTION

OF all the Tertiary deposits of India the Cuddalore sandstones exposed near Pondicherry in the South Arcot district, Tamil Nadu is the richest in dipterocarpaceous woods. Earlier Ramanujam (1956, 1960), Ramanujam and Rao (1967, 1969), and Navale (1963) described quite a large number of them as *Dipterocarpoxylon indicum D. cuddalorense*, *Shoreoxylon holdeni*, *S. mortandrense*, *S. megaporosum*, *S. speciosum*, *S. krauseli*, *Anisopteroxylon cuddalorense*, *A. coromandelense* and *Hopeoxylon indicum*. However, based on the study of the modern woods of Dipterocarpaceae, Awasthi (1971) revised the affinities of many of these; consequently *Dipterocarpoxylon indicum* Ramanujam was renamed as *Dryobalanoxylon indicum* (Ramanujam) Awasthi, and *Shoreoxylon holdeni* Ramanujam, *S. mortandrense* Ramanujam, *S. megaporosum* Ramanujam and *Anisopteroxylon cuddalorense* Ramanujam were found identical to each other and placed under another new species of *Dryobalanoxylon*, viz., *D. holdeni* (Ramanujam) Awasthi. Awasthi (MS) also reinvestigated *Dipterocarpoxylon cuddalorense* Navale and found it identical to *Terminalioxylon grandiporosum* Ramanujam (1966), described from the same locality. Revised account of this together with other such woods will be published in due course.

Further investigation of the woods collected from the same area has yielded three new species belonging to the family Dipterocarpaceae. One of these closely resembles the wood of *Dipterocarpus*, and out of the remaining two one shows affinities with some species of *Shorea*, *Parashorea* and *Pentacme*, while the other with those of Malayan shoreas.

SYSTEMATIC DESCRIPTION

Family — DIPTEROCARPACEAE

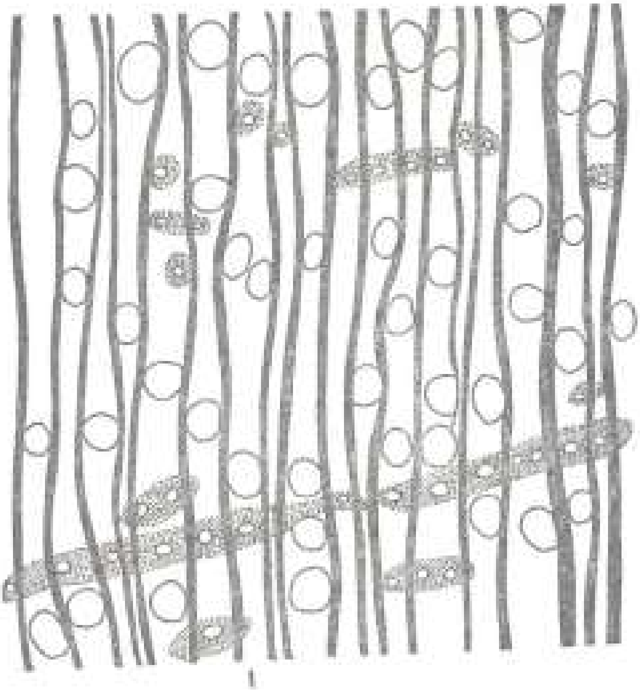
Genus — *Dipterocarpoxylon* Holden emend. Den Berger, 1927

1. *Dipterocarpoxylon pondicherriense* sp. nov.

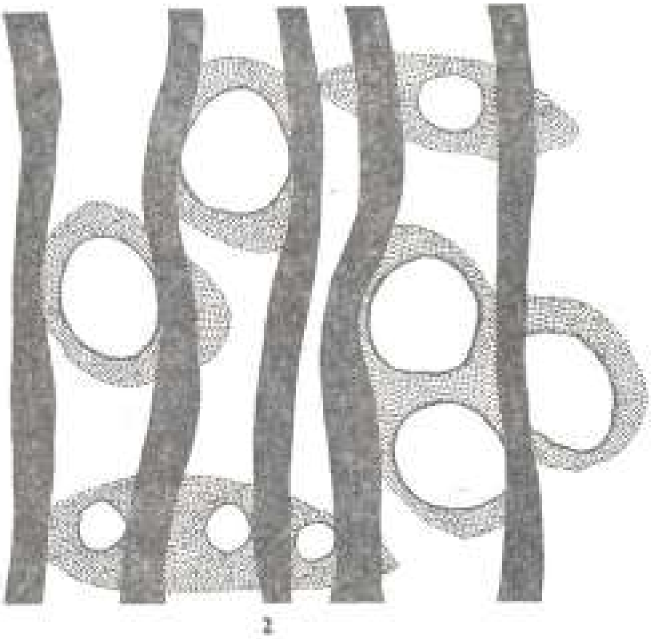
Pl. 1, Figs. 1, 3; Pl. 2, Figs. 5-6; Text-figs. 1-6

Material — Three small pieces of well preserved silicified wood. The colour is yellowish brown.

Topography — *Wood* diffuse-porous. *Growth-rings* absent. *Vessels* visible to the naked eye as white dots in cross-section, medium to large, forming prominent vessel lines along the grain, exclusively solitary (Pl. 1, Fig. 1, Text-Fig. 1), evenly distributed, 3-8 vessels per sq. mm., tylosed (Pl. 1, Fig. 1). *Tracheids* sparse, intermingled with paratracheal parenchyma, forming a narrow (1-2 seriate) interrupted sheath around the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma relatively sparse, intermingled with vasicentric tracheids, forming narrow sheath around the vessels, occasionally aliform, enclosing 2-3 vessels (Pl. 2, Fig. 5; Text-fig. 2); apotracheal parenchyma associated with vertical gum canals (Pl. 1, Fig. 1; Text-fig. 1), frequently extending laterally uniting with those of neighbouring gum canals, forming 3-6 (mostly 3-4) seriate bands reaching across a number of rays (Pl. 1, Fig. 1; Text-fig. 1); diffuse cells occasionally seen. *Xylem rays* fine to moderately broad,



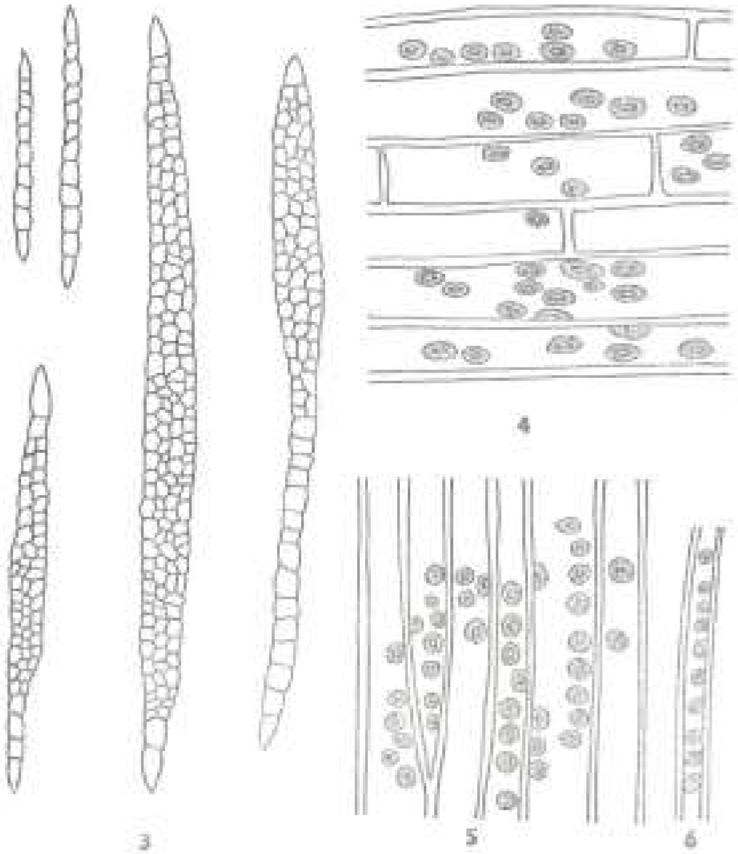
TEXT-FIG. 1 — Cross-section showing nature and distribution of gum canals. × 25.



TEXT-FIG. 2 — Another cross-section magnified to show vessels gum canals and parenchyma (stippled). × 70.

1-5 (mostly 3-4) seriate; ray tissue heterogeneous; uniseriate rays homocellular as well as heterocellular, consisting of upright cells as well as both upright and procumbent cells (Pl. 1, Fig. 3; Text-fig. 3), mostly 4-10 cells in height; multiseriate rays heterocellular, consisting of procumbent cells through the median portion and 1-several (mostly 1-5) uniseriate marginal rows of upright cells (Pl. 1, Fig. 3; Text-fig. 3), about 10-50 cells in height; sheath cells occasionally present. *Fibres* aligned in radial rows between the two consecutive xylem rays. *Gum canals* frequent, vertical, diffuse, enclosed by parenchyma, solitary and mostly in pairs as well as in short tangential rows of 3-8 (Pl. 1, Fig. 1; Text-fig. 1), occasionally upto 10, small, 5-10 per sq. mm.

Elements — *Vessels* circular to oval in cross-section, thin-walled, t.d. 120-370 μ, r.d. 150-345 μ; vessel-members 300-750 μ in length, with truncated ends; perforations simple; pits leading to contiguous tracheids arranged in vertical rows (Pl. 2, Fig. 6; Text-fig. 5), medium to large, 6-10 μ in diameter, vestured, aperture linear to lenticular; pits leading to contiguous ray cells oval, variable in shape and size, horizontally oriented, bordered, (Text-fig. 4), occasionally confluent, with wide aperture; vessel-parenchyma pits similar to vessel-ray pits; vessels filled with tyloses and crystalliferous contents. *Tracheidal cells* oval or peripherally flattened, 16-56 μ in diameter, nearly as long as fibres. *Parenchyma cells* those of paratracheal peripherally flattened, those associated with gum canals oval to angular, 80-120 μ in length; infiltration dark. *Ray cells* upright and procumbent; upright cells 48-80 μ in tangential height, 40-60 μ in radial length; procumbent cells 16-30 μ in tangential height, 48-100 μ in radial length. *Fibres* angular, mostly hexagonal in cross-



TEXT-FIGS. 3-6 — 3. Xylem rays. × 70. 4. Vessel-ray pits. × 300. 5. Vessel-tracheid pits. × 300. 6. Fibre with bordered pits. × 300.

section, 16-38 μ in diameter, nonseptate, thick-walled, with narrow lumen, common walls 6-10 μ in thickness, pits small, 2-3 μ in diameter, bordered, with circular or slit-like aperture (Text-fig. 6). *Gum canals* circular, upto 120 μ in diameter.

AFFINITIES

Comparison with the modern woods: The important and the characteristic features of the present fossil wood are the presence of normal vertical and diffuse gum canals, exclusively solitary vessels, vasicentric tracheids, paratracheal and apotracheal parenchyma, 1-5 seriate heterocellular xylem rays and fibres with small bordered pits. These features indicate its affinities with the woods of *Dipterocarpus Anisoptera*, *Vatica* and *Vateria* of the family Dipterocarpaceae. However, on the basis of the size and arrangement of vessels and the size and frequency of gum canals *Vatica* and *Vateria* can be easily differentiated from the present fossil wood. The wood of *Anisoptera* also differs from it in having almost continuous rows of sheath cells in the rays, and moreover, the gum canals in *Anisoptera* are usually small and solitary. It is the genus *Dipterocarpus* with which it shows close similarity in all anatomical details. Detailed comparison of this fossil wood was made with the available thin sections and with the published description and illustrations of many species of *Dipterocarpus* (Moll & Janssonius, 1906, pp. 348-360; Desch, 1941, pp. 62-75, pl. 21-32 Keyes, 1938, pp. 280-296, Figs. 49-54). From this it was found that the present fossil wood shows closest resemblance with that of *Dipterocarpus indicus* Bedd., and hence placed under the genus *Dipterocarpoxylon* Holden emend. Den Berger. Since it is quite different from hitherto known species of *Dipterocarpoxylon* as discussed below, a new specific name *D. pondicherriense* is given to it. The specific name indicates its occurrence near Pondicherry.

Comparison with the fossil species — The genus *Dipterocarpoxylon* was instituted by Holden (1916) to include the fossil woods showing resemblance with those of Dipterocarpaceae. Since then several earlier workers (Kräusel, 1922a, 1922b, 1925, 1926; Edwards, 1931; Chiarugi, 1933) used this generic term in a comprehensive sense to include all the fossil woods of the Dipterocarpaceae, though most of them expressed their doubts about the accuracy of Holden's identification of the fossil wood upon which the genus *Dipterocarpoxylon* was based, because it did not possess the anatomical characters of the family Dipterocarpaceae. Later, Chowdhury (1952) examined the slides of *Dipterocarpoxylon burmense* Holden prepared from the original specimen, and found it very similar to those of *Gluta* and *Melanorrhoea* of the family Anacardiaceae. Therefore, he transferred it to the genus *Glutoxylon* Chowdhury. Earlier, Den Berger (1927) emended the diagnosis of *Dipterocarpoxylon*, retaining this term for the fossil woods resembling those of *Anisoptera* and *Dipterocarpus* of the Dipterocarpeae. In 1958 Ghosh and Kazmi instituted another genus, *Anisopteroxylon* to designate the fossil woods resembling that of *Anisoptera*, and since then the generic term *Dipterocarpoxylon* is used to assign only those fossil woods which show resemblance with those of the genus *Dipterocarpus*. Recently Prakash and Tripathi (1970) transferred *Anisoptera* type of fossil wood described by Chowdhury (1938) as *Dipterocarpoxylon garoense* to *Anisopteroxylon* Ghosh and Kazmi, and named it *Anisopteroxylon garoense* (Chowdhury). The following is a upto date list of the species referred to *Dipterocarpoxylon* described from India and abroad. This list includes the fossil woods resembling *Dipterocarpus* as well as some of *Anisoptera* type of woods placed under *Dipterocarpoxylon* by the earlier workers.

All these species posses a number of anatomical features similar to our fossil wood, *Dipterocarpoxylon pondicherriense*. However, these differ from it in some significant features. *Dipterocarpoxylon porosum*, *D. goepperti* differ in having broad rays, and less frequent solitary gum canals. In *D. kraeuseli*, *D. gracile*, *D. resiniferum* and *D. javanicum* the rays are homogeneous. *D. anisopteroides* being closely allied to *Anisoptera* differs in the possession of abundant diffuse parenchyma and moreover, the gum canals are exclusively solitary and few than in the present species. In *D. perforatum* the vessels are more crowded, i.e. their frequency is much more than in *D. pondicherriense*. In *D. africanum* the gum canals are large, their shape and size being almost the same as in *D. pondicherriense*. However, it differs from the latter in having the vessels in multiples of 3-4,

List of the fossil woods referred to *Dipterocarpoxylon* with their locality and age

Name	*Locality*	*Age*
1. *Dipterocarpoxylon porosum* (Stopes) Kräusel, 1922a	England	Aptian ?
Schweitzer, 1958	Bedfordshire, Woburnsands, England	Lower Greensand?
2. *D. kraeuseli* (Den Berger) Edwards, 1931	South Sumatra	Tertiary
Schweitzer, 1958	W. Java	Pliocene
3. *D. goepperti* Kräusel, 1926	Java	Tertiary
Schweitzer, 1958	W. Java	Tertiary
4. *D. africanum* Bancroft, 1933, Syns. 1935; Schweitzer, 1958	East Africa	Tertiary
D. scebelianum Chiarugi, 1933		
D. somalense Chiarugi, 1933	East Africa	Plio Pleistocene
D. giubense Chiarugi, 1933		
5. *D. schenki* (Felix) Schweitzer, 1958	Java	Tertiary
6. *D. resiniferum* Schweitzer, 1958	W. Java	Pliocene
7. *D. javanicum* (Hofmann) Schweitzer, 1958	North West of Java	Tertiary
8. *D. gracile* Schweitzer, 1958	W. Java	Pliocene
9. *D. perforatum* Schweitzer, 1958	Middle Sumatra	Quaternary
10. *D. anisopteroides* Schweitzer, 1958	W. Java	Pliocene
11. *D. chowdhurii* Ghosh, 1956	Assam, India	Tertiary
12. *D. kalaicharparense* Eyde, 1963	Garo Hills, Assam, India	Tertiary
13. *D. malavii* Ghosh & Ghosh, 1959	Kutch, India	Pliocene
14. *D. tertiarum* Prakash, 1965b	Burma	Tertiary
15. *Dipterocarpoxylon* sp. Rawat, 1964	Mohand near Dehra Dun, India	Middle Miocene

D. schenki can also be distinguished from *D. pondicherriense* in having smaller vessels and somewhat different distribution of gum canals.

Of the Indian species, *D. chowdhuri* and *D. malavii* differ from the present species in having abundant diffuse parenchyma and the sheath cells being more prominent. In *D. kalaicharparense* the gum canals are mostly solitary or occasionally in pairs, while in *D. pondicherriense* they are solitary, paired as well as in short tangential rows of 3-8 or rarely up to 10.

Dipterocarpoxylon sp. Rawat (1964) is also quite different from the present species, especially in having large gum ducts. In having abundant diffuse parenchyma *D. tertiarum* can also be differentiated from *D. pondicherriense*.

DIAGNOSIS

Dipterocarpoxylon pondicherriense sp. nov.

Wood diffuse-porous. *Growth-rings* absent. *Vessels* medium to large, t.d. 120-370 μ, r.d. 150-345 μ, exclusively solitary, about 3-7 vessels per sq. mm.; perforations simple; pits leading to contiguous tracheids vestured with linear to lenticular orifices, vessel-parenchyma and vessel-ray pits horizontally oriented, bordered, occasionally confluent; tyloses present. *Tracheids* intermingled with paratracheal parenchyma forming a narrow sheath around the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma intermingled with tracheids, forming 1-2 seriate sheath around the vessels, occasionally aliform or tending to enclose 2-3 neighbouring vessels; apotracheal parenchyma associated with the gum canals, diffuse cells occasionally present. *Xylem rays* 1-5 (mostly 1-4) seriate; ray tissue heterogeneous; multiseriate rays heterocellular, consisting of procumbent cells and 1-5 uniseriate marginal rows of upright cells at both the ends; sheath cells occasionally present; rays about 10-50 cells in height. *Fibres* nonseptate, thickwalled, pits small, bordered, with slit-like aperture. *Gum canals* frequent, diffuse, solitary, and in paired as well as in short tangential rows of 3-8, occasionally up to 10, 80-120 μ in diameter.

Holotype — B.S.I.P. Museum No. 33695

Locality — Between Murattandichavadi, Tiruchitambalam and Pattanur, 8-10 km. N.W. of Pondicherry.

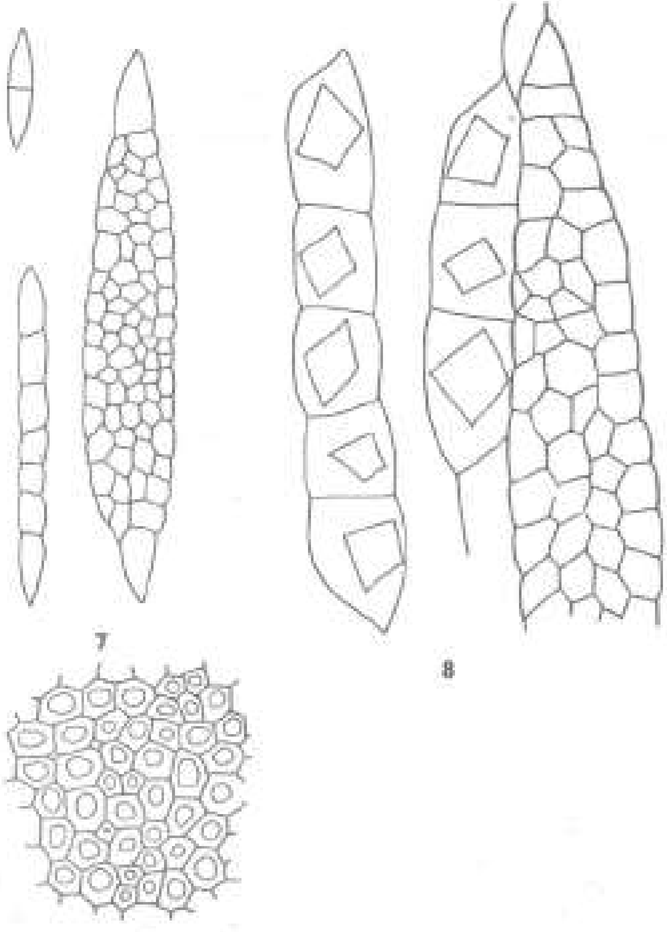
Genus *Shoreoxylon* Den Berger, 1923

2. *Shoreoxylon indicum* sp. nov.

Pl. 2, Figs. 7-11; Text-figs. 7-9

Material — Six pieces of well preserved silicified secondary wood.

Topography — *Wood* diffuse-porous. *Growth rings* indistinct, however, at places wide gap between two parenchyma bands indicates the presence of growth rings. *Vessels* visible to the naked eye, mostly medium to large, solitary and in radial multiples of 2-4 (Pl. 2, Figs. 8, 9), mostly solitary, vessel lines distinct along the grain, evenly distributed, 5-10 vessels per sq. mm., tyloses present (Pl. 2, Fig. 9). *Tracheids* vasicentric, intermingled with paratracheal parenchyma, difficult to distinguish in cross-section. *Parenchyma* abundant, paratracheal and apotracheal; paratracheal parenchyma vasicentric, aliform to aliform-confluent, often with numerous fine to broad and loose aliform-confluent bands (Pl. 2, Fig. 9), apotracheal parenchyma diffuse, usually forming 1-2 seriate irregular lines (Pl. 2, Fig. 9). *Xylem rays* fine to moderately broad, 1-6 seriate (Pl. 2, Fig. 10, Text-fig. 7); ray tissue heterogeneous; uniseriate rays few, homocellular to heterocellular, consisting of upright cells as well as both upright and procumbent cells; multiseriate rays heterocellular, consisting of procumbent cells and 1-2 marginal rows of upright cells at one or both the end (Pl. 2, Figs. 10, 11; Text-fig. 7); rays up to 60 cells in height, 5-9 per mm. *Fibres* aligned in radial rows between two consecutive rays. *Gum canals* vertical, occurring in regular, concentric tangential rings, embedded in parenchyma bands (Pl. 2, Figs. 8, 9).



TEXT-FIGS. 7-9 — 7. Xylem rays. × 150. 8. Crystalliferous parenchyma strand. × 300. 9. Fibres in cross-section. × 300.

Elements — *Vessels* circular to oval (Pl. 2, Figs. 8, 9), t.d. 45-240 μ, r.d. 45-300 μ, thickwalled, common walls 8-16 μ in thickness; vessel-members short, 150-450 μ in length, with truncated ends; perforations simple; intervessel pits and pits leading to contiguous tracheids, parenchyma and ray cells large (Pl. 2, Fig. 7), 8-10 μ in diameter, circular to oval, bordered, vestured, apertures circular or lenticular (Pl. 2, Fig. 7). *Tracheidal cells* oval to orbicular or peripherally flattened, 32-44 μ in diameter, 375-400 μ in length, pits similar to intervessel pits. *Parenchyma cells* 3-5 per strand, usually angular or oval in cross-section, those associated with gum canals tangentially flattened, 8-28 μ in diameter, 40-80 μ in length; crystalliferous parenchyma strands present with solitary crystal in each cell (Text-fig. 8); infiltration dark. Procumbent *Ray cells* circular in tangential section, 16-24 μ in tangential height, 52-120 μ in radial length, upright cells 40-60 μ in tangential height, 20-48 μ in radial length; infiltration dark. *Fibres* circular to oval, (Text-fig. 9), t.d. 8-20 μ, r.d. 8-18 μ, non-septate, thickwalled (Text-fig. 9), common walls 4-10 μ in thickness; pits simple. *Gum canals* circular, 40-120 μ in diameter.

AFFINITIES

Comparison with the modern woods: The above anatomical features of the fossil wood indicate its affinities with the woods of Dipterocarpaceae. In this family the concentric rings of gum canals are found in the woods of *Shorea*, *Doona*, *Hopea*, *Isoptera*, *Parashorea*, *Pentacme*, *Balanocarpus*, *Dryobalanops* and *Diolicarpus*. From a comparative study of the present fossil wood with the available thin-sections and published anatomical data of these genera (Desch, 1941, 1957; Kribs, 1959; Chowdhury & Ghosh, 1958; Henderson, 1953; Metcalfe & Chalk, 1950; Pearson & Brown, 1932; Moll & Janssonius, 1906; Reyes, 1938) it has been found that the fossil wood approaches to *Shorea*, *Parashorea* and *Pentacme*. Out of the species of *Parashorea* and *Pentacme*, the fossil wood shows somewhat similar anatomical details as exhibited by *Parashorea stellata* and *Pentacme suavis*. *Parashorea stellata* and the present fossil, both possess vessels solitary as well as in radial multiples; vasicentric tracheids; parenchyma vasicentric and aliform, aliform-confluent to confluent, forming bands, often in regular, uniseriate to biseriate lines; rays 1-5 seriate, heterogeneous; fibres thick walled, non-septate, with simple pits, gum canals arranged in several concentric rings. Similarly, *Pentacme suavis* has also many features common with the present fossil. Besides other characters, both have even similar type of crystalliferous parenchyma strands closely associated with xylem rays. Among the woods of *Shorea* it resembles *Shorea obtusa* in almost all the structural details. Thus our fossil wood has got close resemblance with *Shorea obtusa*, *Parashorea stellata* and *Pentacme suavis*. In view of this, it is placed under the genus *Shoreoxylon* Den Berger and named as *S. indicum* sp. nov.

Comparison with the fossil species — So far a large number of fossil woods have been described under *Shoreoxylon* from India and abroad as listed below.

From a detailed comparison with the above species of *Shoreoxylon* it has been found that the present species (*S. indicum*) is quite different from them. It is characterized by abundant, diffuse, loosely banded parenchyma, so much of parenchyma is not present in any of the hitherto known species. Of the Indian species, *S. kraeuseli* described by Ramanujam and Rao (1969) from the same area resembles the present fossil in most of the features. However, it differs from *S. kraeuseli* in having heterocellular rays consisting of 1-2 marginal rows of upright cells at one or both the ends.

DIAGNOSIS

Shoreoxylon indicum sp. nov.

Wood diffuse-porous. *Growth-rings* indistinct, however, at places wide gap between two parenchyma bands indicates the presence of growth rings. *Vessels* mostly medium to large, t.d. 45-240 μ, r.d. 45-300 μ, solitary and in radial multiples of 2-5 (mostly 2-3); perforations simple; intervessels pits and pits leading to contiguous tracheids, parenchyma and rays usually large, 8-10 μ in diameter, circular to oval, bordered with circular or lenticular, horizontal to oblique orifices; tyloses present. *Tracheids* vasicentric, forming 1-2 seriate sheath around the vessels. *Parenchyma* abundant, paratracheal and apotracheal; paratracheal parenchyma vasicentric to aliform,

List of the fossil woods referred to *Shoreoxylon* with their locality and age

Name	*Locality*	*Age*
1. *Shoreoxylon palembangense* (Kräusel) Den Berger, 1923	South Sumatra	Pliocene
2. *S. djambiense* Den Berger, 1923 Schweitzer, 1958	South Sumatra West Java	Tertiary Pliocene
3. *S. moroides* Den Berger, 1927	Java	Pliocene
4. *S. swedenborgi* (Schuster) Schweitzer, 1958	East Indies	Pliocene
5. *S. asiaticum* Schweitzer, 1958	Sumatra	Pliocene
6. *S. maximum* Schweitzer, 1958	Middle Sumatra	Pliocene
7. *S. parvum* Schweitzer, 1958	W. Java	Pliocene
8. *S. multiporosum* Schweitzer, 1958	Middle Sumatra	Quaternary
9. *S. pulchrum* Schweitzer, 1958	Middle Sumatra	Quaternary
10. *S. posthumi* Schweitzer, 1958	Middle Sumatra	Quaternary
11. *Shoreoxylon* cf. *posthumi* Schweitzer, 1958	Sumatra	Tertiary
11. *S. speciosum* Navale, 1963	South India	Miocene-Pliocene
12. *S. evidens* Eyde, 1963	Garo Hills, Assam	Miocene
13. *S. burmense* Prakash, 1965a	Burma	Tertiary
14. *S. kraeuseli* Ramanujam & Rao, 1967, 1969	Pondicherry, India	Miocene-Pliocene
15. *S. tipamense* Prakash & Awasthi, 1970	Jaipur, Assam, India	Miocene-Pliocene
16. *S. deomaliense* Prakash & Awasthi, 1971	Deomali, NEFA, India	Miocene-Pliocene

aliform-confluent or in regular bands; apotracheal parenchyma abundant, diffuse, usually forming 1-2 seriate lines. *Xylem rays* 1-6 seriate; ray tissue heterogeneous; rays homocellular to heterocellular, consisting of procumbent cells and 1-2 marginal rows of upright cells at one or both the ends, rays up to 60 cells in height. *Fibres* small, 8-20 μ in diameter, nonseptate, thick-walled, common walls 4-10 μ in thickness. *Gum canals* vertical, occurring in regular, concentric rings, circular, 40-120 μ in diameter.

Holotype — B.S.I.P. Museum No. 33696.

Locality — Between Murattandichavadi and Kasipalayam, about 8-10 km. N.W. of Pondicherry.

3. *Shoreoxylon arcotense* sp. nov.

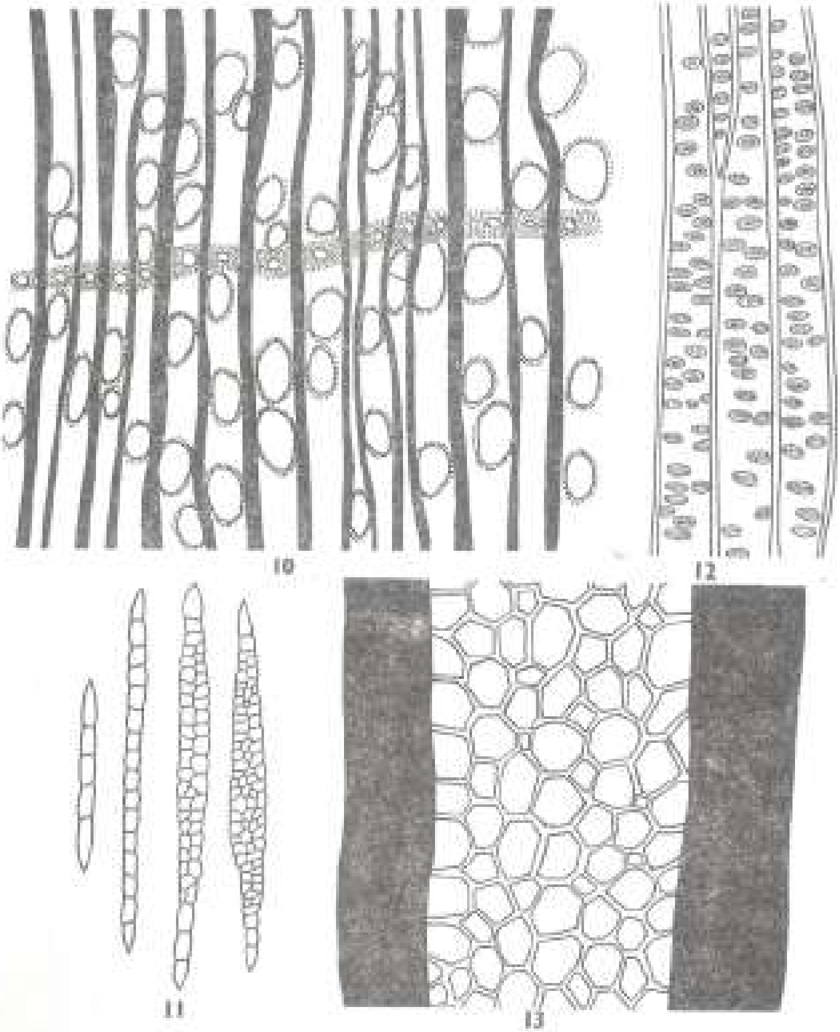
Material — Single piece of well preserved secondary wood measuring 22 cm. in length and 14 cm. in diameter.

Topography — *Wood* diffuse-porous. *Growth rings* not seen. *Vessels* visible to the naked eye as small dots, small to medium (mostly medium) in size, almost exclusively solitary (Pl. 3, Figs. 12, 13), very rarely in multiples of two, evenly distributed; about 15-20 vessels per sq. mm., tyloses present. *Tracheids* not distinguishable in cross-section from paratracheal parenchyma, forming 1-2 seriate sheath around the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma sparse, sometimes indistinguishable in cross-section from the neighbouring fibrous cells and vasicentric tracheids; however, strands seen in tangential longitudinal section, forming 1-2 seriate vasicentric sheath intermingled with tracheids; apotracheal parenchyma associated with gum canals, forming concentric, tangential lines (Pl. 3, Figs. 12, 13), each 2-4 cells wide. *Xylem rays* fine to moderately broad, 12-60 μ wide, 1-4 (mostly 2-3) seriate (Pl. 3, Fig. 14); ray tissue heterogeneous; uniseriate rays frequent, homocellular to heterocellular, consisting wholly of upright cells or both upright and procumbent cells (Text-fig. 11); multiseriate rays heterocellular, consisting of procumbent cells through the median portion and 1-6 marginal rows of upright cells at one or both the ends (Pl. 3, Figs. 14-15; Text-fig. 11); uniseriate rays 2-15 cells in height, multiseriate rays about 12-40 cells in height. *Fibres* aligned in radial rows between two consecutive xylem rays. *Gum canals* vertical, occurring in concentric, regular tangential rings, embedded in apotracheal parenchyma bands (Pl. 3, Figs. 12-13; Text-fig. 10).

Elements — *Vessels* circular to oval in cross-section, t.d. 45-165 μ, r.d. 45-195 μ, thinwalled, 4-6 μ in thickness; vessel-members 300-675 μ in length, with truncated or slightly tapered ends; perforations simple; pits leading to contiguous tracheids large, bordered, about 8-10 μ in diameter, vestured, with linear to lenticular aperture (Pl. 3, Fig. 16); pits leading to contiguous parenchyma and rays similar to vessel-tracheid pits, sometimes confluent; crystalliferous content present in the vessels. *Tracheidal cells* small, oval to orbicular, 16-24 μ in diameter; pits similar to vessel-tracheid pits (Text-fig. 12). *Parenchyma cells* circular to oval, diameter nearly same as of tracheids, those associated with gum canals rectangular to squarish. Upright *Ray cells* 48-80 μ in tangential height, 32-48 μ in radial length; procumbent cells 20-24 μ in tangential height, 40-75 μ in radial length. *Fibres* angular or hexagonal (Text-fig. 13), 12-24 μ in diameter, non-septate, thin-walled, common walls 2-3 μ in thickness; pits simple. *Gum canals* circular, 40-60 μ in diameter.

AFFINITIES

Comparison with the modern woods — The above anatomical features of the present fossil wood indicate its affinities with the woods of the family Dipterocarpaceae. As it has already been mentioned in the forgoing account that the concentric ring of gum canals are found in *Shorea*, *Doona*, *Dryobalanops*, *Parashorea*, *Pentacme*, *Balanocarpus* and *Dioticarpus* (*Hopea*). Considering other anatomical details as well, most of these genera can be easily eliminated from comparison with the present fossil wood. It is the only genus *Shorea* with which the fossil wood



TEXT-FIGS. 10-13 — 10. Cross-section showing the nature and distribution of vessels and parenchyma (stippled). × 45. 11. Xylem rays. × 70. 12. Vessel-tracheid pits. × 300. 13. Fibres in cross-section. × 300.

has been found to resemble most. In order to find out the nearest modern equivalent of the present fossil wood the author examined the thin-sections of woods of the following species of *Shorea* available at the xylarium of the Forest Research Institute, Dehra Dun and at the Birbal Sahni Institute of Palaeobotany, Lucknow.

1. *Shorea argentea* C.E.C. Fischer
2. *S. buchananii* C.E.C. Fischer
3. *S. ciliata* King
4. *S. dealbata* Foxw.
5. *S. foguetiana* Heim.
6. *S. farinosa* C.E.C. Fischer
7. *S. gibbosa* Brand.
8. *S. gratissima* Dyer
9. *S. guiso* Bl.
10. *S. hypoleuca* Meijer
11. *S. lamellata* Foxw.
12. *S. macroptera* Dyer
13. *S. mindanensis* Foxw.
14. *S. minor*
15. *S. oblongifolia* Thw.
16. *S. obtusa* Wall.
17. *S. oleosa* Meijer
18. *S. ovalis* Bl.
19. *S. plagata* Foxw.
20. *S. polita* Vidal
21. *S. robusta* Roth.
22. *S. scrobiculata* Burck
23. *S. seminis* V. Slooten
24. *S. superba* Sym.
25. *S. talura* Roxb.
26. *S. tumbuggaia* Roxb.
27. *S. almon* Foxw.
28. *S. assamica* Dyer
29. *S. acuminata* Dyer
30. *S. agsaboensis* W.L. Stern
31. *S. fallax* Meijer
32. *S. gysbertsiana* Burck
33. *S. kalunti* Merr.
34. *S. leprosula* Miq.
35. *S. leptoclados* Sym.
36. *S. palosapis* Merr.
37. *S. negrosensis*
38. *S. parvifolia* Dyer
39. *S. pauciflora* King
40. *S. philippinensis* Brand.
41. *S. polysperma* Merr.
42. *S. sericeiflora* C.E.C. Fischer & Hutch.
43. *S. stipularis* Thw.
44. *S. squamata* Benth. & Hook.
45. *S. smithiana* Sym.
46. *S. teysmaniana* Dyer
47. *S. waltonii* G.H.S. Wood ex Meijer
48. *Shorea* sp. (F.M.S.)
49. *Shorea* sp. (Java)

Of these, the first 26 species can be easily eliminated from comparison with the present fossil as they possess very thick to thick-walled fibres with narrow lumen which seems one of the distinctive features of these species. Since in the present fossil wood the fibres are thin-walled its modern allies can be searched out from the remaining 23 species having similar thin-walled fibres with wide lumen. However, considering other important anatomical features such as the shape, size, distribution of vessels, parenchyma and the xylem rays there is a close agreement in all the anatomical details between the present fossil wood and *Shorea acuminata* Dyer *Shorea* sp. F.M.S. (F.R.I., Dehra Dun slide No. F. 51).

It has been seen that none of the Indian shoreas shows a close similarity with the present fossil wood. *Shorea assamica*, which grows in Assam, resembles the fossil in having thin-walled fibres with wide lumen; however, it differs in several details, such as in the size, shape and the distribution of vessels and parenchyma. In view of its close similarity with the genus *Shorea* it has been placed under the genus *Shoreoxylon* Den Berger and named as *Shoreoxylon arcotense* sp. nov., after South Arcot district. It differs from hitherto known species of *Shoreoxylon* as discussed below.

Comparison with the fossil woods — All the species of *Shoreoxylon* listed on page 346 resembles the present species in several anatomical features. However, they differ from it in some important features. *Shoreoxylon asiaticum* is different in possessing horizontal gum canals in the rays besides the concentric rings of vertical canals. Moreover, the vessels in *S. asiaticum* are large, with t.d. 200-350 μ, r.d. up to 375 μ. The vessels in *S. maximum*, *S. multiporosum*, *S. djambiense*, *S. speciosum*, *S. palembangense* and *S. moroides* are large to very large while in *S. arcotense* they are small to medium-sized. In *S. evidens* the vessels are usually in multiples and the fibres are thick-walled. In *S. posthumi* the rays are 1-5 seriate and short, 20-30 cells in height, and the fibres are thick-walled with 3.8 μ in thickness. The xylem rays in *S. pulchrum* and *S. parvum* are very high, i.e. they are up to 100 and 94 cells in height respectively, while in present species they are not so high (i.e. they are only up to 45 cells in height). *S. swedenborgi* is quite different from it in having broad tangential band of parenchyma consisting of double rings of gum canals. In *S. burmense* the xylem rays are comparatively broad than in *S. arcotense*. In *S. speciosum* the paratracheal parenchyma is more than in the present species. The xylem rays in *S. speciosum* are also different in having usually single row of marginal upright cell at both the ends, whereas in *S. arcotense* they are more than one in a row. *S. indicum* (described in the preceding pages) and *S. kraeuseli* also differ from the present species particularly in having abundant paratracheal and apotracheal parenchyma.

DIAGNOSIS

Shoreoxylon arcotense sp. nov.

Wood diffuse-porous. *Vessels* small to medium (mostly medium) in size, t.d. 45-165 µ, r.d. 45-195 µ, exclusively solitary, rarely in multiples of 2, 15-20 vessels per sq. mm., perforations simple; pits leading to contiguous tracheids 8-10 µ in diameter, bordered, vestured with lenticular apertures; pits leading to contiguous parenchyma and ray cells slightly more in horizontal diameter; tyloses present. *Vasicentric tracheids* forming 1-2 seriate sheath around the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma sparse, only a few cells associated with the vessels, intermingled with vasicentric tracheids; apotracheal parenchyma represented by thin bands enclosing the concentric rings of gum canals, each 2-4 cells in width. *Xylem rays* 1-4 seriate; ray tissue heterogeneous; uniseriate rays frequent, homocellular to heterocellular; multiseriate rays heterocellular, consisting of procumbent cells through the median portion and 1-5 marginal rows of upright cells at one or both the ends; rays 4-40 cells in height; sheath cells occasionally present. *Fibres* 12-24 µ in diameter, nonseptate, thinwalled, common walls 2-3 µ in thickness; pit simple, minute. *Gum canals* vertical, in concentric rings, 40-60 µ in diameter.

Holotype — B.S.I.P. Museum No. 33697.

Locality — Between Murattandichavadi and Kasipalaiyam, about 8-10 km. N.W. of Pondicherry.

DISCUSSION

The genus *Dipterocarpus* Gaertn. f. consists of about 80 species (Willis, 1966 p. 222), distributed throughout the Indo-Malayan region, having maximum development in Borneo, Malay Peninsula and Sumatra. The range of its distribution is from South India and Ceylon in the West to Philippines in the east. About 13 species grow in the Indian region (India, Bangladesh, Ceylon and Andamans), which are large to very large trees of commercial value. In south India only 2 species occur, viz. *Dipterocarpus indicus* Bedd. and *D. bourdilloni* Brand. *Dipterocarpus indicus* Bedd. with which the present fossil wood of *Dipterocarpus* resembles most is one of the chief elements of the evergreen tropical rain forests, occurring in the Western Ghats from Kanara Southwards, Malabar and Travancore, common in South Kanara at the foot of the Hills elevation up to 900 m., especially in south Travancore. *Pentacme* A.D.C. is a small genus consisting of 3 species (Willis, *l.c.*, p. 844), with a very irregular distribution in South-East Asia. *Pentacme suavis* A.D.C. grows in Burma, Indochina, Thailand and Malay Peninsula, while *P. contorta* (Vidal) Merr. et Roelfe and *P. mindanensis* Foxw. occur in Philippines. The genus *Parashorea* is represented by 11 species (Willis, *l.c.*, p. 833), occurring over a wide area from Burma, Western limit to Borneo and the Philippines in the east. Only one species, i.e. *P. stellata* occurs in Burma. None of these two genera (*Pentacme* and *Parashorea*) is found in India proper. *Shorea* Roxb. is comparatively a large genus consisting of about 180 species (Willis, *l.c.*, p. 1036), distributed throughout sourth-East Asia, starting from Ceylon and India on the West and throughout Burma and other countries of the South-East Asia. However, the greatest concentration of the species is met within Borneo, Sumatra, and Malay Peninsula. There are about 10 species occurring in the Indian region, of which *Shorea robusta* Roxb., *S. assamica* Dyer, *S. talura* Foxw. and *S. tumbuggaia* Roxb. are found in India proper. Those shoreas which have been shown to be the nearest modern equivalents of the fossil woods described in the present paper are confined to the Malayan region. Besides these, Awasthi (1970) also identified another Malayan genus *Dryobalanops*, collected from the same area of Pondicherry. Unlike *Dipterocarpus* and *Shorea* the present distribution of *Dryobalanops* is very restricted. It occurs only in the tropical rain forests of West Malaya, Sumatra and Borneo.

Among the Dipterocarpaceae the genus *Dipterocarpus* is one which has been found so far in almost all the Neogene deposits of India, indicating undoubtedly the existence of tropical rain forest over a large part of the country during the Miocene-Pliocene epochs. On the basis of the occurrence of fossil dipterocarps alone it may also be imagined that along the eastern coast of South India, at least around Pondicherry, the physical conditions under which the plants grew during that time were somewhat similar to the present physical conditions prevailing in the Western coast (Kanara, Malabar and Travancore) of South India, and in the Malayan region since the modern equivalents of the fossil dipterocarps of the Cuddalore series of Pondicherry are chiefly confined to the tropical rain forests of these regions. Detailed account regarding the palaeoecology, phytogeography and other related aspects of the Tertiary flora of India with special reference to the flora of the Cuddalore series and the significance of the occurrence of Malayan dipterocarps and other Malayan plants in the Cuddalore series will be published later separately when this flora is completely worked out.

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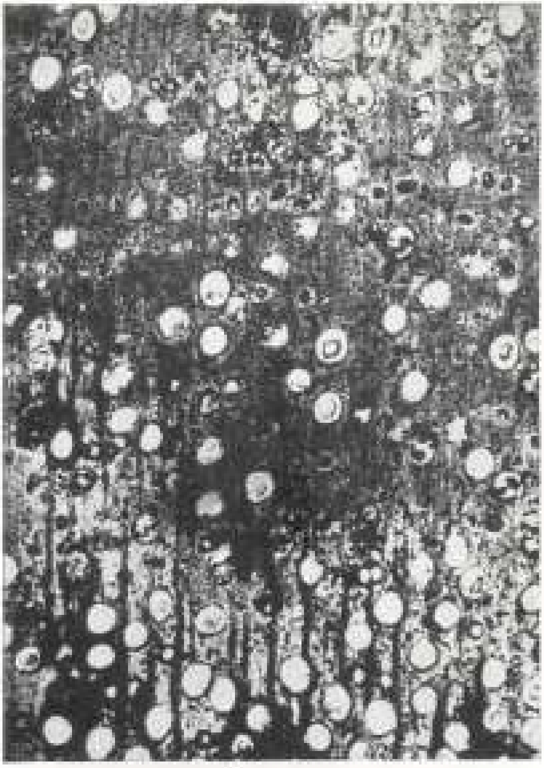

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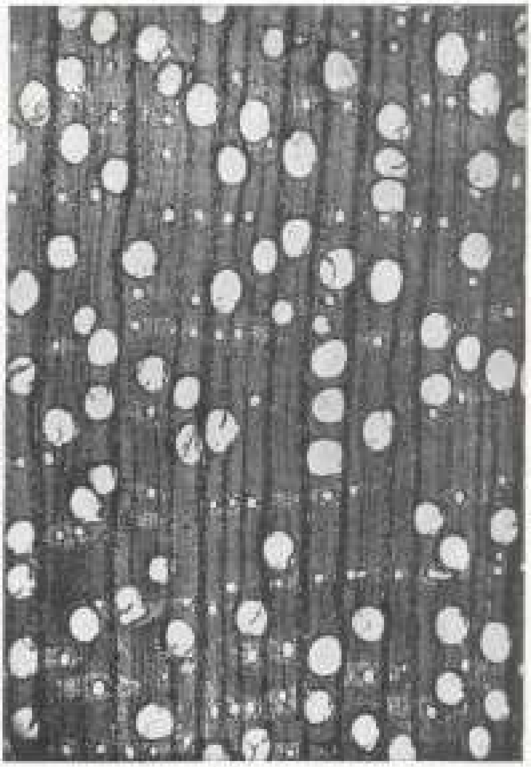

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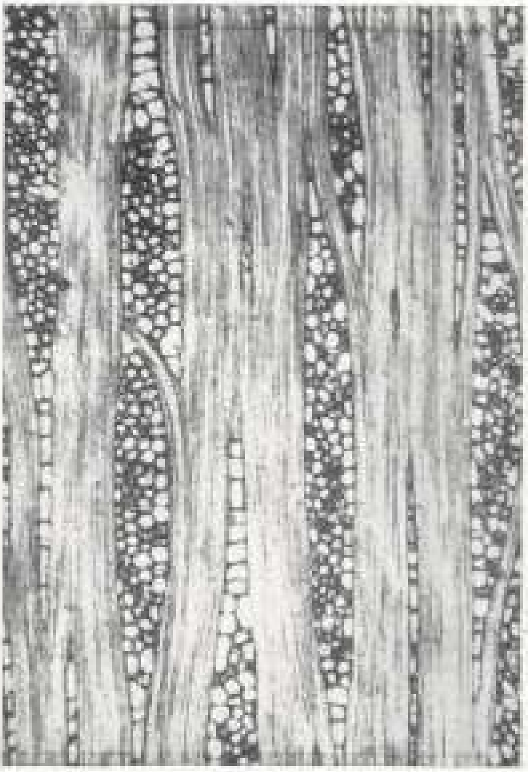

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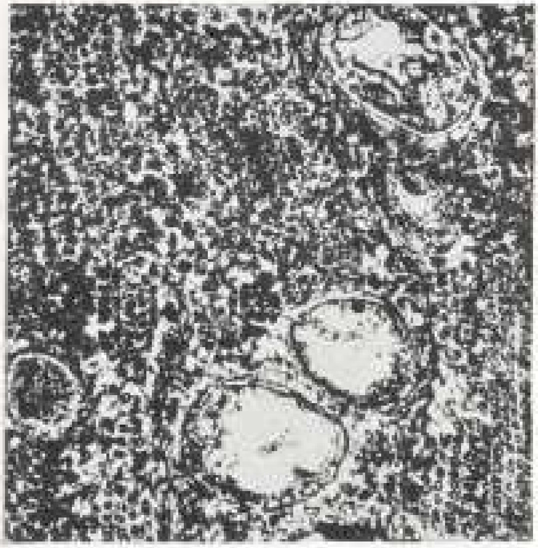
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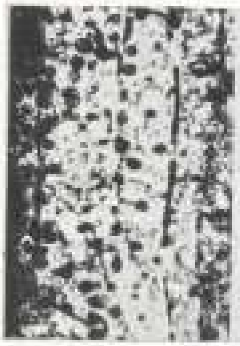
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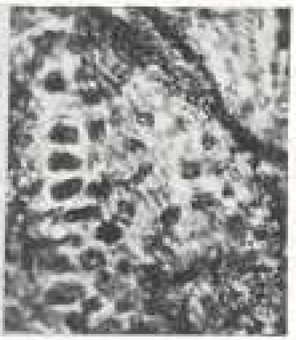
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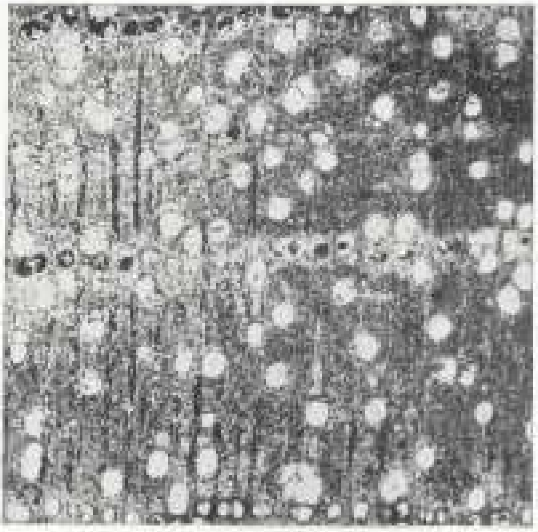
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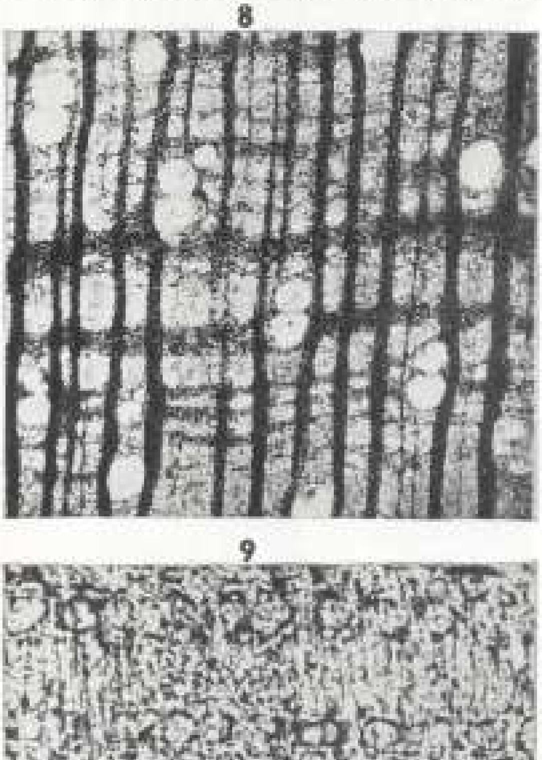
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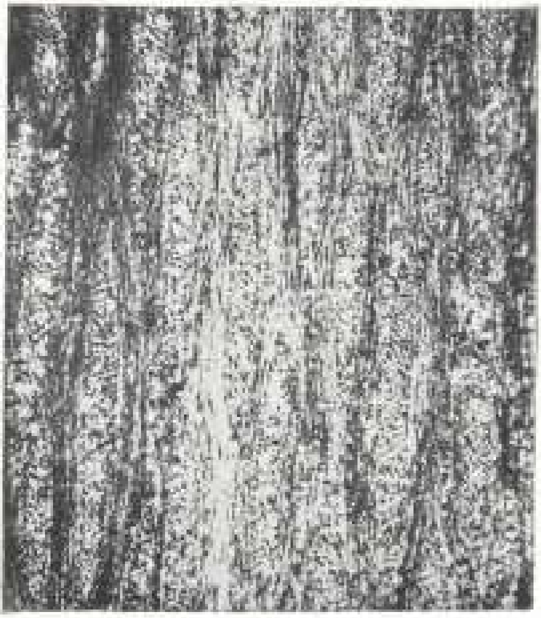
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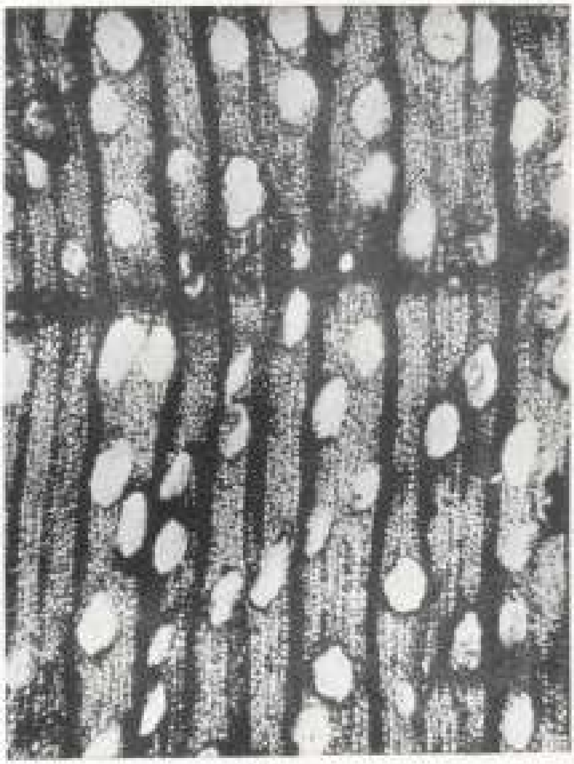

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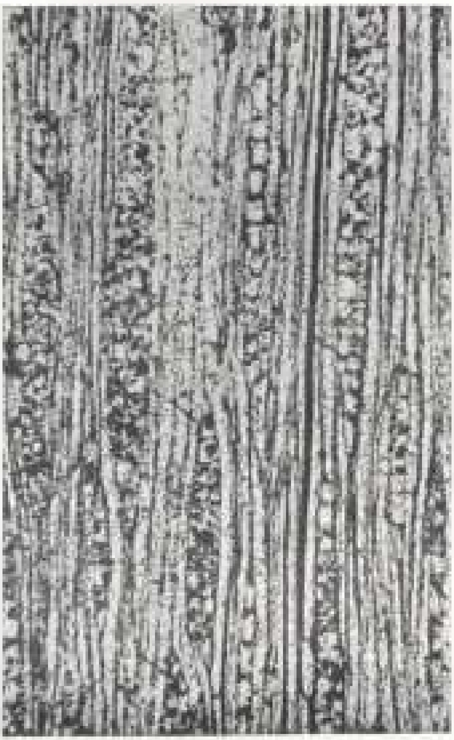

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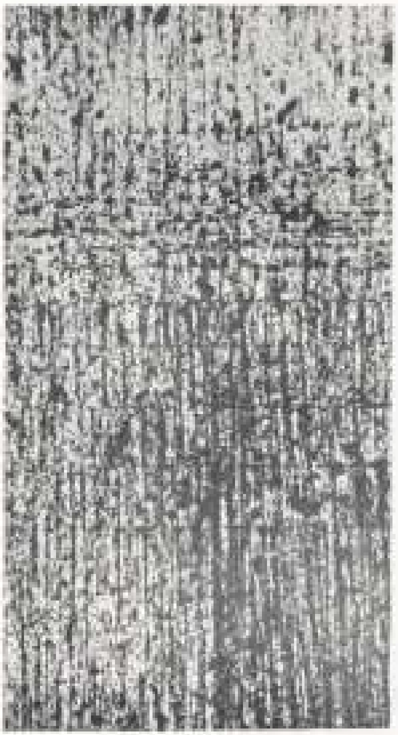

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EXPLANATION OF PLATES

PLATE 1

1. *Dipterocarpoxylon pondicherriense* sp. nov. Cross-section showing nature and distribution of vessels and xylem rays. × 15. B.S.I.P. Museum. Slide No. 4462.

2. *Dipterocarpus indicus* Bedd. Cross-section showing similar type and distribution of xylem rays × 15.

3. *Dipterocarpoxylon pondicherriense* sp. nov. Tangential longitudinal section showing xylem rays. × 72. B.S.I.P. Museum Slide No. 4464.

4. *Dipterocarpus indicus* Bedd. Tangential longitudinal section showing similar type of xylem rays. × 72.

PLATE 2

5. *Dipterocarpoxylon pondicherriense* sp. nov. Magnified cross-section showing paratracheal parenchyma and vasicentric tracheids. × 70. B.S.I.P. Museum Slide No. 4463.

6. *Dipterocarpoxylon pondicherriense* sp. nov. Vessel-tracheid pits. × 240. B.S.I.P. Museum Slide No. 4464.

7. *Shoreoxylon indicum* sp. nov. Intervessel pits. × 680. B.S.I.P. Museum Slide No. 4466.

Shoreoxylon indicum sp. nov.

8. Cross-section showing nature and distribution of vessels and gum canals. × 15. B.S.I.P. Museum slide No. 4465.

9. Another cross-section showing nature and distribution of vessels and parenchyma. × 28. B.S.I.P. Museum Slide No. 4465.

10. Tangential longitudinal section showing xylem rays. × 120. B.S.I.P. Museum Slide No. 4466.

11. Radial longitudinal section showing heterocellular xylem rays. × 55. B.S.I.P. Museum Slide No. 4467.

PLATE 3

Shoreoxylon arcotense sp. nov.

12. Cross-section under low magnification to show the nature and distribution of vessels and gum canals. × 8. B.S.I.P. Museum Slide No. 4468.

13. Another cross-section showing vessels and gum canals. × 50. B.S.I.P. Museum Slide No. 4468.

14. Tangential longitudinal section showing xylem rays. × 100. B.S.I.P. Museum Slide No. 4469.

15. Radial longitudinal section showing heterocellular xylem rays. × 100. B.S.I.P. Museum Slide No. 4470.

16. Vessel-tracheid pits. × 600. B.S.I.P. Museum Slide No. 4471.

PETRIFIED PALM STEM, *PALMOXYLON PENCHENSE* SP. NOV. FROM THE DECCAN INTERTRAPPEAN BEDS OF MADHYA PRADESH, INDIA

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ABSTRACT

The paper describes *Palmoxylon penchense* sp. nov. from the Deccan Intertrappean beds of Madhya Pradesh, India. This species is characterized by the presence of lacunar ground tissue, absence of ventral sclerenchyma, absence of both radiating and tabular parenchyma and absence of stegmata both from the fibrous bundles and fibrous part of fibrovascular bundles. It is compared with all the known species of *Palmoxylon*.

INTRODUCTION

LARGE number of petrified palm woods have been described from India and abroad, some of them are fragmentary while others are quite large. The petrified palm wood described here is quite large. It consists of cortical, dermal, subdermal and central zones. The palm wood was collected by the authors from Mohgaon Kalan in Chhindwara district, Madhya Pradesh, India. For detailed anatomical studies serial sections were prepared both in transverse as well as in longitudinal planes. The preservation of the wood is quite good hence no stains were used.

DESCRIPTION

MONOCOTYLEDONAE

PALMAE

Palmoxylon penchense sp. nov.

The petrified palm wood is quite large. Before sectioning it measured 15 cm. in diameter and about 5 cm. in thickness. In hand specimen cortex, dermal, subdermal and central zones are clearly seen (Text-fig. 1; Pl. 1, Fig. 1). The chert containing the wood is grey in colour and vascular bundles are clearly visible on the surface.

ANATOMY

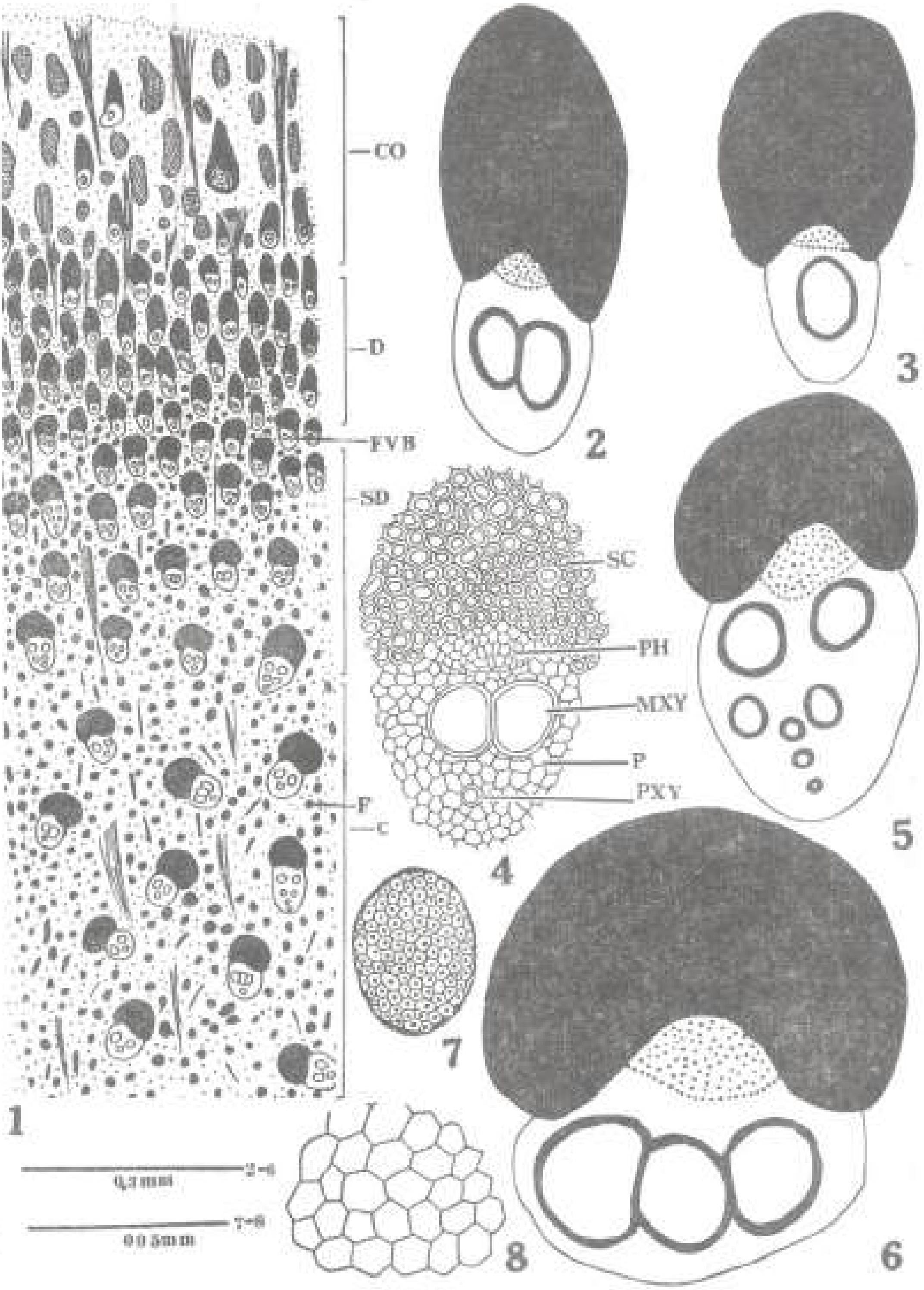
Cortex — Epidermal cells are not seen. The cortical zone is 1·5 cm. in thickness. It consists of numerous small and large fibrous bundles which are variable in shape; they may be oval or elongate and are 0·10-0·40 mm. in size (Pl. 1, Fig. 2). They are irregularly arranged in parenchymatous ground tissue. Usually only one vessel is present in fibrovascular bundles that occur towards the dermal zone (Text-fig. 3).

Ground tissue is made up of round, oval or polygonal parenchymatous cells (Text-fig. 8; Pl. 1, Fig. 2).

Dermal Zone — It is about 1·8 cm thick. Fibrovascular bundles are closely packed and normally oriented in parenchymatous ground tissue (Pl. 1, Fig. 5). They are small and assume various shapes; they have one or two metaxylem vessels (Text-fig. 2) which measure 0·18 to 0·22 mm. in diameter, phloem elements are also clearly seen. The average frequency of fibrovascular bundles in this zone is 110-120/cm.^{2} and their f/v ratio is 8:1 to 12:1. Purely fibrous bundles of small size and round shape are of common occurrence in this zone.

Subdermal Zone — It is about 2 cm. thick. The fibrovascular bundles in this zone are regularly oriented up to some distance towards the centre, becoming somewhat irregular in distribution (Text-fig. 1). The average frequency of the bundles is 70-90/cm.^{2} and their f/v ratio is 4:1 to 6:1. The

TEXT-FIGS. 1-8 — (*C*, central zone; *Co*, cortical zone; *D*, dermal zone; *F*, fibrous bundles; *FVB*, fibrovascular bundles; *MXV*, metaxylem vessels; *P*, parenchyma cells; *PH*, phloem; *PXV*, protoxylem vessel; *SC*, sclerenchymatous sheath). 1. A part of petrified palm stem in cross section, showing the cortical, dermal, subdermal and central zones with numerous fibrous and fibrovascular bundles ca × 4. 2. A fibrovascular bundle showing two metaxylem vessels placed side by side. 3. A fibrovascular bundle showing a single vessel. 4. A fibrovascular bundle showing cellular details. 5. A leaf trace bundle with many vascular elements. 6. A fibrovascular bundle showing three metaxylem vessels. 7. A fibrous bundle enlarged to show many fibrous cells. 8. Few cells of cortical zone.



TEXT-FIGS. 1-8

bundles here have two metaxylem vessels placed side by side and well developed dorsal sclerenchymatous sheath and measure 0·20-0·25 mm. in diameter. Phloem cells are clearly seen. Auricular lobes are round and median sinus concave. Tabular as well as radiating parenchyma round the fibrovascular bundles is absent.

Central Zone — It is about 10 cm. in thickness. The fibrovascular bundles are irregularly arranged in lacunate ground tissue (Text-fig. 1). Bundles are sparsely arranged in the ground tissue. The average frequency of the bundle is 30-35/cm.^{2} towards the subdermal zone but towards the centre it is 10-15/cm.^{2}. The f/v ratio of the bundles is 1 : 1 to 3 : 2.

The fibrovascular bundles are large, generally oval or elongate, and measure 0·25 to 0·3 mm. in diameter. The bundles have two or three metaxylem vessels and a protoxylem facing the centre; phloem elements are clearly visible (Text-figs. 4 & 6; Pl. 1, Fig. 3). Dorsal sclerenchymatous sheath is well developed, but ventral sclerenchyma is absent. Auricular lobes are round and median sinus is concave (Pl. 1, Fig. 3). Both tabular and radiating parenchyma are absent.

Purely fibrous bundles are present in this zone as well. One such bundle is 60 to 130 μ in diameter, usually with 25 to 30 fibrous cells (Text-fig. 7). Stegmata are not seen.

In longitudinal section of the wood the pitting of metaxylem vessel is multiseriate scalariform type and the pitting of protoxylem vessel is of spiral type (Pl. 1, Fig. 7). The end wall of the vessel shows 6-8 parallel bars of thickening (Pl. 1, Fig. 4).

The leaf trace bundles are also seen in this zone (Text-fig. 5; Pl. 1, Fig. 6). The ground tissue is lacunate i.e. it is formed by a net work of narrow cells forming large intercellular spaces of various shape.

DISCUSSION

Large number of petrified palm woods referable to the artificial genus *Palmoxylon* have been described from India and abroad. Mohl (1845, 1849), Schenk (1882), Stenzel (1904), Stevens (1912), Ogura (1952), Sahni (1931, 1943, 1946, 1964), Rode (1933), Shukla (1939, 1946), Ramanujam (1953, 1958), Lakhanpal (1955), Prakash (1958, 1961), Rao and Menon (1963, 1964, 1965, 1967), Menon (1964), Trivedi and Surange, 1968, 1969, 1971), Trivedi and Verma (1969, 1971), Trivedi and Chandra (1971) have reported 45 species of the genus *Palmoxylon* from India (Verma, 1972).

The species described here is characterized by the presence of lacunar ground tissue. Apart from this, *Palmoxylon penchense* is characterized by the (i) presence of fibrous bundles, (ii) presence of leaf trace bundles, (iii) absence of ventral sclerenchyma, (iv) absence of stegmata both from fibrous bundles and fibrous part of the fibrovascular bundles, (v) absence of both radiating and tabular parenchyma.

The present species has been compared with *P. dakshinense* (Prakash, 1958), *P. chhindwarense* (Prakash, 1958), *P. eocenum* (Prakash, 1961), *P. surangei* (Lakhanpal, 1955), *P. parthasarthyi* (Rao & Menon, 1963), *P. maheshwarii* (Rao & Menon, 1963), *P. kräuselii* (Rao & Menon, 1965) and *P. superbum* (Trivedi and Verma, 1969) in detail (Table 1).

The present species differs from all the known species of *Pamoxylon* listed by Verma, 1972 and also from species listed in Table 1, in shape, size, frequency, f/v ratio of the fibrovascular bundles, presence or absence of fibrous bundles and stegmata. The species described above is quite distinct and is not identical with any species described so far from India (Verma, 1972) or outside, hence it is given a new specific name *Palmoxylon penchense*.

DIAGNOSIS

Genus — *Palmoxylon*

Palmoxylon penchense sp. nov.

Fibrous and fibrovascular bundles irregularly oriented in cortical zone, size various; dermal bundles 110-120/cm.^{2}, f/v ratio 8/1 to 12/1, regularly oriented, median sinus concave, vessels 1 to 2; subdermal bundles regularly oriented, 70-90/cm.^{2}, f/v ratio 4/1 to 6/1, median sinus concave, vessels 2; central bundles irregularly oriented, 30-35/cm.^{2}, f/v ratio 1/1 to 3/2, median sinus concave, auricular lobes round, phloem well preserved, vessels 2 to 3; fibrous bundle 60-130 μ in diameter; stegmata absent;

TABLE I

NAME OF SPECIES	PARTS AVAILABLE	FREQUENCY OF FIBRO-VASCULAR BUNDLES PER cm²	F/V RATIO OF THE BUNDLE	SIZE OF BUNDLE IN mm	MEDIAN SINUS AND AURICULAR LOBE	XYLEM VESSELS	PHLOEM	LEAF TRACE BUNDLE	POSTERIOR SCLERENCHYMA	GROUND TISSUE: General parenchyma	GROUND TISSUE: Tabular parenchyma	GROUND TISSUE: Radiating parenchyma	FIBROUS BUNDLES AND STEGMATA
P. dakshinense (Prakash, 1958)	Cortex not clear, dermal, subdermal	D: 200-250/cm² SD: 50-80/cm²	D: 10/1-16/1 SD: 1.2/1-1.7/1	D: 0.16-0.32 SD: 0.48-0.64	Concave, lobes rounded	1-2	Not preserved	Present	Present	Lacunar	±	±	Fibrous bundle absent, stegmata present in the fibrous part of dermal bundle
P. chhindwarense (Prakash, 1958)	Cortex, dermal, subdermal & central	D: 200-250/cm² SD: 150-250/cm² C: 60-100/cm²	D: 4.5/1-8/1 SD: 3/1-5/1 C: 2.5/1-3/1	D: 0.2-0.62 SD: 0.48-0.72 C: 0.58-0.80	Deep, auricular lobe rounded, sometimes pointed	1-2	Not seen clearly	Present	Present	Lacunar	±	—	Both absent
P. [illegible] (Prakash, 1960)	Dermal, subdermal central	D: 300-360/cm² SD: 80-132/cm² C: 30-70/cm²	D: 6.5/1-10.5/1 SD: 3/1 C: 2.5/1-3.5/1	D: 0.28-0.36 SD: 0.52-0.64 (0.24-0.40 small bundles) C: 0.16-0.42 0.40-1.27	Concave, lobes rounded to pointed	1-2	Not preserved	Sporadic	—	Lacunar	+	±	Both absent
P. [illegible] (Lakhanpal, 1955)	Cortex, dermal, subdermal, central	D: 40-45/cm² [illegible]-40/cm² SD: 45-50/cm² C: 25/cm²	D: 7/8-7/1 SD: 5/1-6/1 C: 4/1	D: 1-1.2 SD: 0.45-0.6 C: 0.95-1.05	Lobes rounded	2-3 rarely 4	Poorly preserved	Present	Absent	Compact	+		Both fibrous bundle and stegmata present.
P. parthasarathyi (Rao & Menon, 1963)	Cortex, dermal, subdermal central	D: 300-380/cm² SD: 70-110/cm² C: 60/cm²	D: 3.2/1-1.8/1 SD: 1.2/1-0.9/1 C: 0.3/1-0.1/1	D: 0.16-0.12 SD: 0.20-0.42 C: 0.14-0.41	Concave, lobes rounded	2	Not preserved	Present	Absent	Compact	—	—	Fibrous bundle present
P. mohgaonense (Rao & Menon, 1964)	Cortex, dermal subdermal central	D: 340-600/cm² SD: 80-100/cm² C: 35-55/cm²	D: 6.3/1-1.6/1 SD: 1.2/1-0.9/1 C: 0.17-0.2/1	D: 0.12-0.25 SD: 0.28-0.42 C: 0.17-0.56	Crescent like	2	Preserved	Present	Present in leaf trace bundle	Compact	—	—	Both absent
P. [illegible] (Rao & Menon, 1965)	Cortex absent	SD: 50-55/cm²	D: 1.2/1-1.1/1 SD: 0.4/1-1/1	D: 0.12-0.3 SD: 0.2-0.4	Concave & lobes round	1-2 2-3	Not preserved	—	Absent	Lacunar	—	+	Fibrous bundle and stegmata present
P. superbum (Trivedi & Verma, 1969)	Cortex, dermal, subdermal, central	D: 100-120/cm² SD: 60-70/cm² C: 40-45/cm²	D: 9/1-12/1 SD: 10/1-17/1 C: 1.5/1-2/1	D: 0.15-0.43 SD: 0.40-0.47 0.40-1.37 C: 0.50-0.41 0.41-0.51	Concave, lobes round	D: 1-2 SD: usually 2 C: 2-3	Well preserved	Present in subdermal & central zone	Present	Extremely lacunar	+	—	Both fibrous bundle and stegmata present, stegmata spherical
P. prakashii sp. nov.	Cortex, dermal, subdermal, central	D: 100-120/cm² SD: 70-90/cm² C: 30-35/cm² in centre 10-15/cm²	D: 8/1-12/1 SD: 4/1-8/1 C: 1/1-3/2	D: 0.15-0.22 SD: 0.20-0.25 C: 0.25-0.5	Concave, lobes round	D: usually 1 2-3	Well preserved	Present	Absent	Lacunar	—	—	Fibrous bundles present, stegmata absent

D: Dermal zone, SD: Subdermal zone, C: Central zone, + Present, — Absent leaf trace bundles present in subdermal and central zone; ground tissue lacunate; radiating and tabular parenchyma absent.

Locality — Mohgaon kalan (22°1′N, 79°11′ E), a village in Chhindwara district, M.P.

Holotype — No. M/418, in Botany Department, Lucknow University.

Horizon and Age — Deccan Intertrappean series, Tertiary (Eocene).

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EXPLANATION OF FIGURES

Plate 1

Palmoxylon penchense sp. nov.

1. Cross-section of petrified palm stem showing all the zone. × 3.
2. A part of cortical region enlarged to show the fibrous bundles. × 22.
3. A fibrovascular bundle showing metaxylem vessels placed side by side × 35.
4. A vessel slightly oblique in l.s. showing 8-12 parallel bars of thickening. × 60.
5. Few fibrovascular bundles of dermal zone showing regular orientation. × 10.
6. A leaf trace bundle. × 30.
7. Vascular elements in l.s. showing multiseriate and spiral type of pitting. × 90.


1


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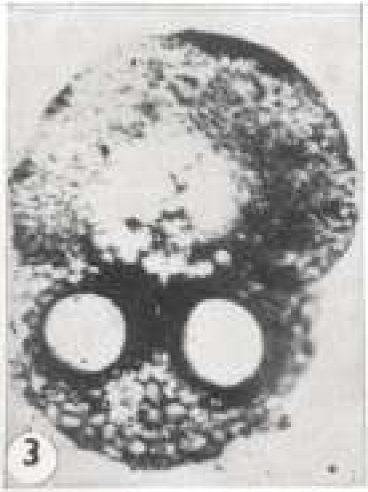
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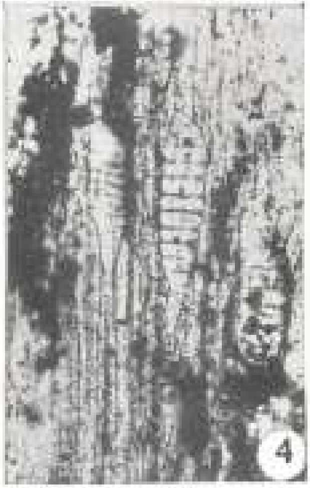
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BOTANICAL RESOLUTION OF SOME MICROSTRUCTURES OF NEYVELI LIGNITE, SOUTH INDIA

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ABSTRACT

Futher studies on the microscopic composition of Neyveli lignite, South-India have revealed that some microstructures show affinities to certain angiosperm taxa such as Guttiferae, Dipterocarpaceae, Leguminosae, Combretaceae, Euphorbiaceae, Palmae and Gramineae. The present paper records the xylotomical features of the newly recognized biostructures as seen in the polished surface sections, and their affinities to modern genera.

INTRODUCTION

NEYVELI lignite, the largest known brown Coal deposit in India occurs beneath the coastal plains near Cuddalore, South-India in association with the Tertiary rocks (believed to be of Upper Miocene age, Subramanyam 1969) known as Cuddalore Series. The following is the sequence of rock formations met with the lignite deposit.

Recent		Soils, alluvium, laterite, Kankar, blown sands
Tertiary	Upper Miocene (Cuddalores)	Argillaceous sandstones, Pebble bearing sandstones, grits, clays and lignites
	Probable unconformity	
	Eocene	Black clays, shales, grey sandstones, calcareous sandstones, limestones with fossils
Mesozoic	Cretaceous	Shell limestones, Siliceous limestones etc.
Archaean		Dolerite, Pegmatites and Quartz

The lignite deposit is found associated with the Cuddalore sandstones and clays. The sandstones contain layers of soft water-logged sand, grits and clays and contain lot of miosture which makes lignite soft and suitable for excavation. The lignite occurs in different forms each of them appearing to merge with one another. Some of the common types are woody, attrital and brown coal types each having characteristic features (Navale 1968b, 1971a). Woody lignites have been formed from lignified wood. It is hard, compact and blocky. The xylotomical features of some biostructures recognized in the lignite show affinities to modern woods.

XYLOTOMICAL DESCRIPTION OF BIOSTRUCTURES

The identification of woody structures of the lignite has been made mainly on the basis of cross-sectional view as seen in the lignite pellets prepared by polished surface technique (Navale 1968b). The other sectional views (radial or longitudinal) could not be prepared as it is not possible to isolate organic and inorganic entities from the general ground mass of the lignite. However the cross-sectional views as seen in the general ground mass of the lignite have given sufficient data to determine the botanical affinities. The diagnostic characters of the resembling taxa are given herewith.

GUTTIFERAE

Topography — Wood diffuse porous (Pl. 1, Fig. 1); *Growth rings* absent; *Vessels* numerous, medium to large in size, solitary, arranged in radial lines in cross-section (Pl. 1, Fig. 1); *Parenchyma* arranged in fine concentric tangential bands, apotracheal bands slightly wavy, interrupted by xylem rays (Pl. 1, Fig. 1); *Tracheids* paratracheal (Pl. 1, Fig. 1); *Xylem rays* fine, distinct, closely placed, mostly uniseriate, separated by many rows of fibres (Pl. 1, Fig. 1); *Fibres* arranged in radial rows in cross-section interrupted by parenchyma bands (Pl. 1, Fig. 1).

Elements — *Vessels* thickwalled, 10 μ, oval to squarish in cross-section, transverse diameter 84-100 μ, radial diameter 100 μ-140 μ, filled with contents; *Tracheids* cells oval to polygonal in cross-section, 12×20 μ; *Parenchyma* cells mostly round in cross-section, 20 μ in size; *Xylem rays* uniseriate; *Fibres* circular in cross-section, slightly flattened, 10 μ in width.

Affinities — The diagnostic structural features of the woody lignite are (1) Vessels solitary, arranged in oblique radial lines, (2) tracheids paratracheal (3) parenchyma apotracheal, tangential bands (4) rays uniseriate. The combination of the above characteristic features of the lignite show resemblance to the woods of *Callophyllum* or *Mesua* of the family Guttiferae (Metcalfe and Chalk 1950, Pearson and Brown 1932, Chowdhury and Tandon 1949, Lakhanpal and Awasthi 1963, 1964). However the exact affinity to the above genera could not be established due to the limited sectional view as seen in the polished surface of the pellet. Lakhanpal and Awasthi (1963, 1964) recognized both the fossil woods of *Mesua* and *Callophyllum* in the Cuddalore Series from the neighbouring locality. In view of their findings, it is reasonable to expect the above genera in the lignite also, which is associated with the Cuddalore sandstones.

Remarks — Fossil woods belonging to the family Guttiferae (*Garcinia*, *Mesua*, *Kayea*) have been described from the Tertiaries of South-Arcot, Tamilnadu and Assam (*loc. cit.*). *Kayea*, *Mesua* and *Callophyllum* are genera of evergreen moist deciduous forests of Assam and western ghats.

DIPTEROCARPACEAE

Topography — Wood diffuse porous (Pl. 1, Fig. 2); *Growth rings* not recognizable; *Vessels* medium to large in size, solitary, rarely radial, filled with tyloses (Pl. 1, Fig. 2); *Parenchyma* paratracheal or apotracheal (Pl. 1, Fig. 2), Paratracheal parenchyma vasicentric, 1-3 layered, incompletely surrounding the vessels, short, irregular often in tangential strips, apotracheal parenchyma continuous 1-4 cells thick; *Resin Canals* diffuse, solitary, covered by xylem parenchyma, Canals smaller than vessels (Pl. 1, Fig. 2); wood rays fine, close, one to four seriate, uniseriate common (Pl. 1, Fig. 2); *Fibres* form the ground mass of the tissue, aligned in radial rows in cross-section (Pl. 1, Fig. 2).

Elements — *Vessels* thickwalled, pore size 150-220 μ in transverse diameter, solitary, tylosed, 10-14 per mm; *Tracheids* absent; *Parenchyma* limited, paratracheal vasicentric type, one to four cells, small, round in cross-section, 10 μ in size, apotracheal type one to four cells thick, associated with resin Canals, 8 μ in size; *Resin Canals* cells smaller than vessels, 50-60 μ in size filled with resinous substance, epithelium cells small, 5 μ in size; *Woodrays* one to 4 celled rays, one celled rays common, 3 celled rays abundant and 4 celled rays rare, filled with substances; Fibres squarish to polygonal cells, 30 μ in size in cross-section.

Affinities — The presence and the nature of resin canals as described above, paratracheal and apotracheal types of parenchyma and uniseriate to multiseriate wood rays of the lignite biostructure suggests its affinities to the woods of Dipterocarpaceae. The genera belonging to Dipterocarpaceae are anatomically divisible into 2 categories, one with secretary canals aligned in concentric rows (*Shorea*, *Hopea* etc.) and the other with diffuse resin canals (*Dipterocarpus*, *Anisopteris* etc.). Genera *Vateria* and *Vatica* (Vaterine and vaticae) differ from the microstructure under consideration in having smaller vessels and diffuse parenchyma. It is only with the genera *Dipterocarpus* or *Anisopteris* the lignite microstructure shows close similarities. Among these two genera, the material resembles more with *Dipterocarpus* than *Anisopteris* as the latter has narrow rays and vasicentric tracheids.

Remarks — Large number of fossil woods belonging to the family Dipterocarpaceae from the rocks of the Cuddalore series have been catalogued (Ramanujam 1968, Awasthi 1972). It is probable that these woods were existing during the peat formation.

LEGUMINOSAE

Topography — Diffuse porous wood (Pl. 1, Fig. 3); *Growth rings* — not conspicuous, *Vessels* — abundant, uniformly distributed, small to medium in size, solitary or in radial rows of 2 to 4, filled with gummy deposit (Pl. 1, Fig. 3); *Parenchyma* conspicuous, paratracheal, vasicentric, forming eyelets, paratracheal Zonate parenchyma anastomose forming tangential strips or bands (Pl. 1, Fig. 3); *Wood rays* distinct, 2-5 seriate, separated by large tracts of fibres (Pl. 1 Fig. 3); *Fibres* distinct, thick celled, forming the ground mass of the wood (Pl. 1, Fig. 3).

Elements — *Vessels* thickwalled, 9 μ in size, vessel pore tangential diameter 130-200 μ, radial diameter 165-300 μ, shape oval in cross-section, filled with deposit; *Parenchyma* cells small, 18 μ in cross-section, paratracheal parenchyma 3 to 4 celled, aliform type, reticulate, 3-4 layered; *Wood-rays* 2-5, ray cells small (scarcely visible under hand lens), circular, 30 μ wide; *Fibres* cells small, angular, arranged in radial rows 9 μ broad in cross-section.

Affinities — Solitary or radial groups of vessels with uniform distribution, abundant paratracheal, vasicentric parenchyma anastomosing into few layers, multiseriate rays suggest affinities to the wood of Leguminosae. This family presents a great variation in almost all characters of the wood (nature of vessels, parenchyma, rays and fibres). However certain anatomical types have been made on the broad structural features (Gamble 1902) which are as follows:

1. *Ougeinia* — *Albizzia* type
2. *Acacia* — *Cassia* type
3. *Dalbergia* type
4. *Bauhinia* type
5. *Hardwickia* type
6. *Erythrina* type

The microstructure of the lignite shows affinities with *Acacia-Cassia* type which is characterized by paratracheal parenchyma forming eyelets or zonate type anastomosing to form tangential strips, medium sized solitary or radial vessels and limited multiseriate rays.

Remarks — *Cassia-Acacia* type of woods have already been reported by Ramanujam (1954) and Navale (1958 and 1962) from the Cuddalore Series of South-Arcot. In the lignite, both wood and pollen of this genus have been identified (Ramanujam 1966) to support the present, identification.

COMBRETACEAE

Topography — Diffuse porous Wood (Pl. 1, Fig. 4); *Growth rings* absent; *vessels* medium to large size, solitary or in multiples of two, filled with tyloses (Pl. 1, Fig. 4); *Parenchyma* both paratracheal and apotracheal, paratracheal parenchyma vasicentric to aliform, apotracheal parenchyma diffused scattered in the ground mass of the wood (Pl. 1, Fig. 4); *Wood rays* uniform, contiguous, uniseriate, crystals present in each cell (Pl. 1, Fig. 4); *Fibres* round to oval in cross-section, arranged in radial rows, cells thick walled (Pl. 1, Fig. 4).

Elements — *Vessels* thick walled, 10 μ, vessel pore round in cross-section, small, size (tangential × radial) 50 × 50 μ-60 μ; Density of the pores 5 to 13 per mm.^{2}; *parenchyma* associated with vessels, paratracheal cells form contour around vessels, thinly aliform, 4 cells, size of the cells 30 μ, apotracheal parenchyma 10 cells thick, size of the cells 20 × 25 μ along the radial direction of the bands, the apotracheal bands include secretary bands; *Wood rays* one celled, exceptional cases two celled, homogeneous, crystals present in ray cells.

Affinities — The general microscopic structural features show affinities with the woods of Leguminosae, Anacardiaceae, Sapindaceae, Combretaceae. Yet certain diagnostic structural features particularly diffuse, solitary or radial vessels with tyloses, paratracheal, vasicentric parenchyma forming eyelets, diffuse apotracheal cells, uniseriate rays with crystal content in ray cells strongly indicate resemblance to *Terminalia* of Combretaceae.

Remarks — Large number of fossil *Terminalia* woods have been recognized (Ramanujam 1956*a*, Navale 1955) in the neighbouring areas of the Cuddalore Series in which the Neyveli lignite is also associated.

EUPHORBIACEAE

Topography — Diffuse porous wood (Pl. 1, Fig. 5); *Growth rings* not distinct; vessels small to medium in size, arranged in radial rows of 2 to 5, rarely solitary, tyloses occasionaly present (Pl. 1, Fig. 5); *Parenchyma* apotracheal, diffused (Pl. 1, Fig. 5); *Wood rays* 2 to 5 seriate, sinuate, separated by fibres (Pl. 1, Fig. 5); *Fibres* — cells round to oval in cross-section, thickwalled aligned in radial rows.

Elements — *Vessel* pore size 80 μ-120 μ, Density 4-5 per sq. mm., multiples of 2-5, thick walled, size 20 μ, round when solitary, flattened when radial; *parenchyma* common, apotracheal, cells diffused, scattered, round to polygonal, size of the cells 35 μ in cross-section; *Wood rays* 1-4 cells broad, 10 to 50 cells high, small dissected rays intermingle with large rays, linkage in rays common, *Fibres* arranged in radial rows, more or less round in cross-section, fibre cells 10 μ diameter.

Affinities — Lack of any diagnostic characters as mentioned above necessitates a comparison with large number of families. However by evaluating on the basis of combination of characters and by process of elimination, the nearest taxa that the microstructure under consideration resembles is Euphorbiaceae. Even this family has divergent structural details of the wood. Yet on the basis of xylotomic principles, the family Euphorbiaceae may be classified into Phyllanthoidae group and Crotonoidae group (Metcalfe and Chalk 1950). The present material does not compare with Crotonoidae group. It is with the Phyllanthoidae group the wood structure shows its affinities. Although the Phyllanthoidae group is again subdivided into *Aporosa* type (abundant apotracheal parenchyma etc.) and *Glochidion* type (limited parenchyma etc.), the present material could not be assigned to the above types due to the overlapping of some characters, nevertheless, the microstructure resembles the woods of Phyllanthoidae group in general.

Remarks — Large number of fossil woods of Euphorbiaceae have been identified in the associated rocks of Cuddalore Series near Neyveli (Ramanujam 1956b, Navale 1960). It is reasonable to expect the woods of Euphorbiaceae in the lignite also. Recognition of euphorbiaceous pollen further supports the identification.

PALMAE

Topography — Central-zone preserved; *Fibrovascular bundles* scattered, irregular, orbicular to reniform, circular vessels lie side by side; *xylem parenchyma* preserved; *Phloem* not present; *Ground tissue* narrow, rectangular cells, meshes closely fitted with conspicuous intercellular spaces (lacunae).

Elements — Fibrovascular bundles in the central region scattered 20 to 25 per cm.^{2}, F/v-ratio 2:1, bundle size 170 μ, lacunae size 0·2 to 0·3 mm.

Affinities — The nature of the scattered bundles, narrow ground tissue with inter cellular spaces and other characters observed in the lignite structure undoubtedly place the woody tissue in palmae group. The limited microstructural features as revealed by the lignite and absence of any system of classification of the palms leave no alternative but to place it in the general group of this family. It may be mentioned here some palm woods and pollen are known from South-Arcot and Neyveli lignite (Ramanujam 1968, Navale 1972).

Remarks — Very few fossil Palms are known in the Tertiary rocks of the Cuddalore Series (Ramanujam 1953, 58, Sahni 1931) which is otherwise rich in dicotyledonous forms. Even in the lignite, mostly dicotyledonous xyloidal structures are common (Navale 1968a, 1971 and 1972).

GRAMINEAE

Apart from xyloidal structures, the lignite is composed of number of cuticles, dispersed tissues, spores and pollen (Navale 1968 b). Although studies have been made to know the botanical affinities of spores and pollen Navale 1961, 1971 Ramanujam 1966a, b) no attempt has been made to resolve the cuticles and other tissues due to lack of any diagnostic characters, however, some cuticles have been assigned to certain taxa (Jacob, K. & Jacob, C) and now probably a graminaceous type of cuticle has been identified.

Topography — Epidermis cells regular, rectangular, outer walls thick, *Mesophyll* no differenciation between palisade and spongy tissues, assimilatary cells appear in cross-section to be oriented in radial manner around the vessels, *Vascular bundles* small, widely spaced, surrounded by sheath.

Elements — *Cuticular cells* thick, 10 μ in size, shape round to rectangular, *Mesophyll cells* small to medium size, round to oval in shape, size 30 μ in cross-section *Vascular bundles* small, scattered 10 to 20 per cm^2., bundle size 70 μ-100 μ, sheath cells round to oval 3 μ in size.

Affinities — The chlorenchyma unlike that in the leaves of dicotyledonous leaves shows no differentiation into contrasting palisade and spongy tissues, and the nature of vascular bundles as described above are suggestive of graminaceous affinity of the material under study.

Remarks — Pollen grains of this family have also been recovered from the Neyveli lignite (Navale 1972, Ramanujam, 1966a.).

DISCUSSION

It is apparent from the above studies, and from the already known data that the Neyveli lignite has been formed from a recent angiospermic vegetation. The woody lignite is constituted by a diversified woody taxa. Some of the known genera are *Mesua* or *Callophyllum* (Guttiferae), *Dipterocarpus* (Dipterocarpaceae), *Cassia* or *Acacia* (Leguminosae), *Terminalia* (Combretaceae), *Diospyros* or *Maba* (Ebenaceae), *Bassia* (Sapotaceae), *Phyllanthinium* (Euphorbiaceae) and palms (Palmae). These genera must have formed part of the vegetation during the peat formation because of the presence of woody portions in the lignite although many of the pollen belonging to the above taxa are not known. This may probably be due to the lack of diagnostic characters for the generic identification of dispersed pollen and spores which are grouped under artificial forms like *tricolpites* or *triporites* etc., or pollen might have corroded or produced in small amount.

It is evident from the information so far accumulated that the Neyveli lignite was formed during Tertiary period as the angiospermic vegetation predominated in the composition. Further, abundance of some fossil genera such as *Dipterocarpus*, *Terminalia*, *Cassia*, *Cynometra* which are considered to be of upper Miocene times suggest the age of the Neyveli lignite deposit to be of upper Miocene.

A perusal of the present day vegetation in our country reveals that the taxa so far recorded in the lignite, grow in rain forest type of vegetation (Warm, humid, monsoon-type of climatic conditions) of Assam and W. Ghats. It is, therefore, reasonable to presume that the lignite might have been formed under tropical humid, rain forest type of climatic conditions in Neyveli during the Upper Miocene times of the Tertiary period.

CONCLUSION

Woody lignites form an important constituent of the Neyveli lignite deposit. They are formed from diversified angiospermic taxa, some of which are described in the present study. Further investigations on xyloidal portions of the lignite may supplement a good deal of information in establishing the extant vegetation of the source material that formed the Neyveli lignite.

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EXPLANATION OF PLATE 1

PLATE 1

1. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of the woods of *Mesua* or *Callophyllum* of the family Guttiferae. × 15.

2. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of the woods of *Dipterocarpus* of the family Dipterocarpaceae. × 35.

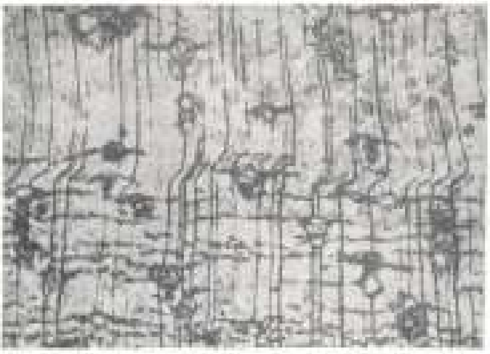
3. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of the woods of *Cassia* or *Acacia* of the family Leguminosae. × 3.

4. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of the woods of *Terminalia* of the family Combretaceae. × 50.

5. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of the woods of *Phyllanthoidae* group of the family Euphorbiaceae. × 75.

6. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of the woods of *Palmae*. × 10.

7. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of a monocot leaf. × 240.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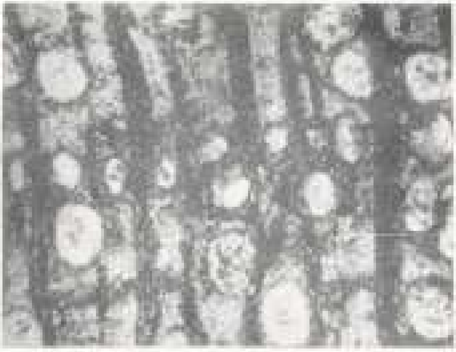
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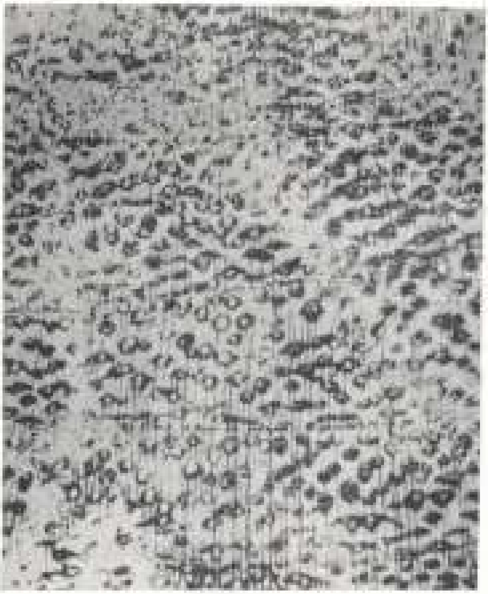
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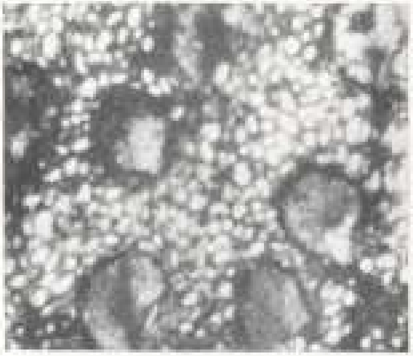
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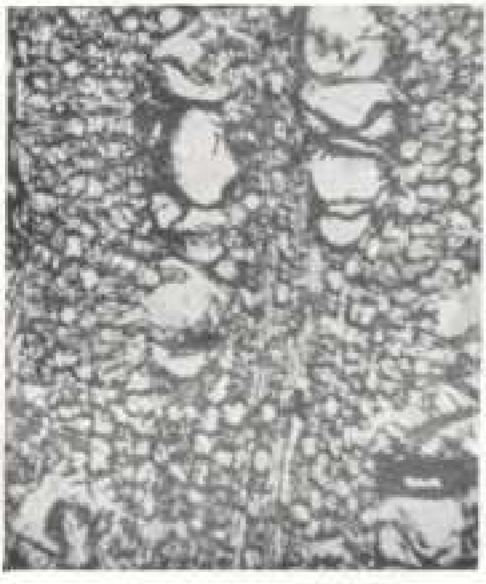
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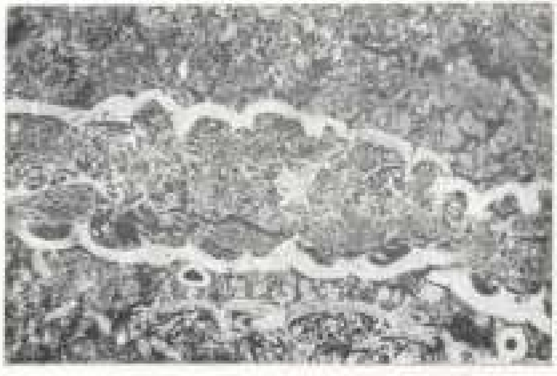

DICHOTOMOPTERIS, A NEW TYPE OF FERN FROND FROM THE LOWER GONDWANA OF INDIA

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ABSTRACT

Dichotomopteris gen. nov. is instituted for the fern fronds earlier described under *Merianopteris*, *Alethopteris* and *Ptychocarpus* from the Lower Gondwanas of India. Two species of *Dichotomopteris*, *D. major* n. comb. and *D. lindleyii* n. comb. are identified on basis of both sterile and fertile specimens.

INTRODUCTION

THE Indian Lower Gondwana ferns have hitherto been described under the northern genera, viz. *Sphenopteris*, *Pecopteris*, *Alethopteris*, *Merianopteris* and *Ptychocarpus*. It is felt by many that since during the Permian period the flora of the northern hemisphere was different from that of the southern, the Gondwanaland, the placement of Lower Gondwana plants under the northern genera may not always be correct. A detailed study of the specimens referable to *Merianopteris*, *Alethopteris* and *Ptychocarpus* from the Raniganj Stage has shown that they are morphologically distinct form from the northern genera under which they are described and so a new generic name has been proposed here for them.

DESCRIPTION

Dichotomopteris gen. nov.

Generic diagnosis — Fronds large, imparipinnate, tri-pinnate; pinnae contiguous at base, no veins in contiguous part; pinnules of pinnae lobed or entire and contiguous, with distinct mid-vein dissolving into secondary veins in distal region which further dichotomise, mid-vein also gives out two or more lateral veins on either side, each lateral vein dichotomises once or twice, when divided into three veins, only distal vein dichotomise and proximal remains undivided; sori present on underside of pinnules upon lateral vein endings, sori form two distinct rows one on either side of midrib; sporangia separate, 4-8 in a sorus, annulus absent; spores differently sculptured and trilete.

Genotype — *Dichotomopteris major* n. comb.

Comparison — The fronds described earlier under *Alethopteris*, *Ptychocarpus* and *Merianopteris* from the Lower Gondwanas of India have been placed under this genus. *Dichotomopteris* differs from *Alethopteris* Sternberg in the evanescent nature of mid-vein and the absence of veins from pinnae rachis in the base of pinnules. *Merianopteris* Heer differs from *Dichotomopteris* by the anastomosing of basalmost pair of lateral veins with the lateral veins of adjacent pinnules. Moreover, the mid-vein of pinnule in the former is persistent up to the apex. *Pecopteris* Brongniart differs from *Dichotomopteris* in the absence of basal contiguity of pinnules and the presence of a distinct mid-vein persisting right up to the apex. *Mariopteris* Kidston shows contiguity of basal pinnule as in *Dichotomopteris*, but differs from it in possessing a distinct sphenopteroid type of venation.

Among the fertile fronds, *Scolecopteris* Zenker differs from *Dichotomopteris* in having stalked sporangia and *Ptychocarpus* Weiss and *Asterotheca* Presl by the fusion of their sporangia. *Oligocarpia* Goeppert possesses annulus which is absent in *Dichotomopteris*. *Rajahia* Konno *et al.* (1970) differs from the Indian frond in having sporangia arranged in groups. Thus, the fern fronds described under *Dichotomopteris* differ from all the other fossil fern genera. The distinguishing characters of *Dichotomopteris* are the contiguous pinnules, evanescent mid-vein, characteristic dichotomizing lateral veins and the characteristic arrangement of sori. I have, therefore, proposed a new generic name for these fronds.

Two species of *Dichotomopteris* are recognizable from Indian Lower Gondwanas, viz., *Dichotomopteris major* n. comb. and *D. lindleyii* n. comb.

Dichotomopteris major (Feistmantel) n. comb.

Pl. 1, Figs. 1-4

Synonymy

1881 *Merianopteris major* Feistmantel, p. 83, pl. 19A, figs. 9-11.

Emended diagnosis — Frond large, tripinnate; rachis smooth, 3-4 mm. broad, lateral branches ± opposite, pinnae arranged at wide angle of 70°-80°, alternate to one another, oblong in outline, either distinctly lobed into pinnules (basal part of frond) or entire with crenulate margin; pinnules attached to pinnae rachis at wide angle, 80°-90°, contiguous to each other by base; cleft between pinnules deep; pinnule obovate with rounded apex, terminal pinnule, broadly triangular with rounded apex; mid-vein distinct up to half distance, then bifurcating into secondary veins which further dichotomise, mid-vein gives out two lateral veins on either side, each dichotomises once or sometimes twice; when dividing into three veins, distal vein always dichotomises but proximal remains undivided; 2 to 4 sori present only in basal half on under side of pinnules upon lateral vein endings, sori form two distinct rows on either side of mid-vein; sporangia separate, 5-6 in a sorus; spores triangular with rounded corners, exine ornamented with curved bacula longer than broad, Y-mark distinct. Spores identical to *Horriditriletes curvibaculosus* Bharadwaj and Salujha (1964).

Lectotype — 5194, Geological Survey of India, Calcutta.

Isotype — 35105 and 35106, Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Raniganj Coalfield, West Bengal.

Horizon — Raniganj Formation (Lower Gondwana).

Dichotomopteris lindleyii (Royle) n. comb.

Pl. 1, Figs. 5-8

Synonymy

1833 *Pecopteris lindleyana* Royle, p. 29, pl. 2, fig. 4.

1881 *Alethopteris lindleyana* Feistmantel, p. 80, pl. 18A, figs. 2, 2a, pl. 19A, figs. 3, 3a; pl. 23A, figs. 11, 11a, pl. 39A, figs. 10, 11.

1963 *Ptychocarpus srivastavae* Surange, p. 72, fig. 41, A-C.

Emended diagnosis — Frond large, tripinnate; rachis smooth, lateral branches alternate, pinnae alternate, oblong, distinctly lobed into pinnules, pinnules attached to pinnae rachis at wide angle, 80°-90°, contiguous laterally to each other towards the base, ±1/3 length of pinnule from base fused with adjoining pinnules, pinnule oblong with acutely rounded apex, margin show strong curvature; terminal pinnule elongate, triangular, mid-vein distinct up to 3/4th distance from base, bifurcating upwards into secondary veins which further dichotomises, lateral veins usually 4 or 5 on either side of mid-vein, each dichotomises twice, rarely once; when dividing into three veins, distal vein always dichotomises but proximal remains undivided; sori arranged in two rows on underside of entire length of pinnules upon lateral vein endings; 6, rarely 8 sori in each row, sporangia separate, 5-6 in a sorus; spores circular, 60-80 μ, Y-mark distinct, exine bearing minute, round elleptical, puncta usually clearly separated from adjacent ones. Spores identical with *Eupunctisporites poniatiensis* Bharadwaj (1962).

Holotype — V4192, British Museum (Natural History), London.

Isotype — 5184, Geological Survey of India, Calcutta and 8669, Birbal Sahni Institute of Palaeobotany.

Locality — Raniganj Coalfield, West Bengal.

Horizon — Raniganj Formation (Lower Gondwana).

Comparison — The specimens earlier described under *Alethopteris lindleyii* Feistmantel (1881) and *Ptychocarpus srivastavae* Surange (1964) are placed under this species. The present species differs from *D. major* in the shape and venation of the pinnules, the number of sori and its arrangement and the spores in the two plants.

ACKNOWLEDGEMENTS

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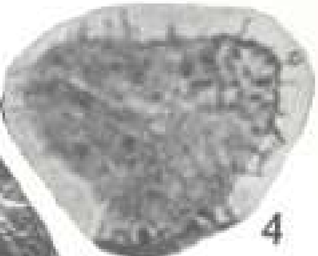
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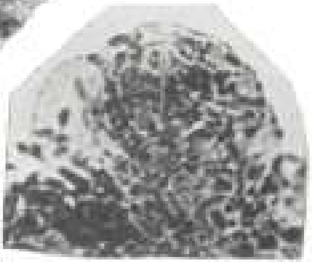
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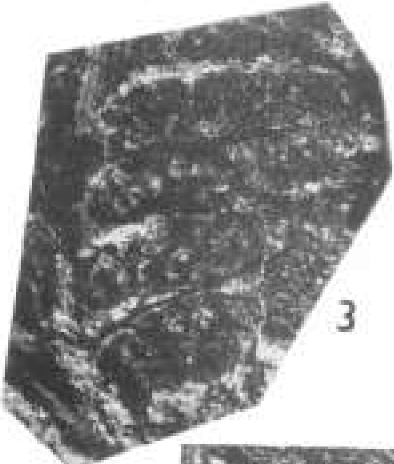
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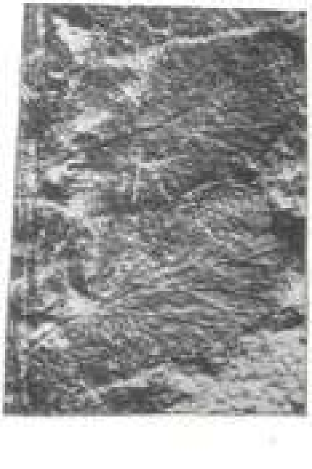
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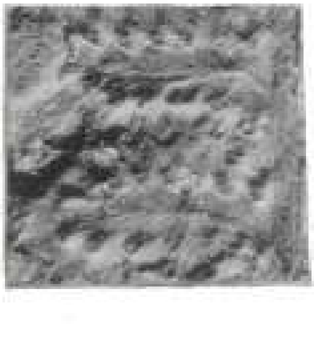
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of Feistmantel preserved at the Museum of G.S.I., Calcutta. I am thankful to Dr. John Pettit of British Museum (Natural History), London for sending me the photographs of the type specimen of *Dichotomopteris lindleyii* (V4192).

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EXPLANATION OF PLATE

PLATE 1

Dichotomopteris major (Feistm.) n. comb.

1. A portion of sterile frond showing arrangement of pinnae and pinnules, × 1; 35105, Birbal Sahni Institute of Palaeobotany.

2. Two sterile pinnules enlarged to show the lateral contiguity of pinnules near the base and the pattern of venation. × 6.

3. Two fertile pinnules showing the arrangement of sori. Two rows of sori arranged on both sides of midvein. × 6; 35106, Birbal Sahni Institute of Palaeobotany.

4. A spore identical to *Horriditriletes curvibaculosus* Bhard. & Saluj. recovered from the sporangia. × 1000.

Dichotomopteris lindleyii (Royle) n. comb.

5. A portion of sterile frond showing arrangement of pinnae and pinnules. × 1; 35107, Birbal Sahni Institute of Palaeobotany.

6. A sterile pinnule enlarged to show the venation pattern. × 3.

7. Two fertile pinnules showing the distribution of sori. 5187, Geological Survey of India, Calcutta.

8. A group of spores identical to *Expunctisporites pusiatensis* Bhard. recovered from the sporangia. × 500.

PALYNOLOGY OF THE PANCHET GROUP EXPOSED IN THE NONIA NALA, NEAR ASANSOL, WEST BENGAL

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ABSTRACT

The *Sporae dispersae* of the Maitur Formation (Panchet Group) exposed in the Nonia Nala, East of Kumarpur, near Asansol comprises 40 genera and 60 species of miospores. The beds just above the Raniganj-Panchet contact have abundance of striate bisaccate pollen as in the underlying Raniganj beds. In the beds farther above the contact, the number of trilete forms gradually increases while the bisaccate pollen decrease in frequency. The characteristic miospore genera of the Maitur Formation are *Verrucosisporites*, *Decisporis*, *Playfordiaspora* (*Guthoerlisporites*) and *Lunatisporites* (*Taeniaesporites*). There is a definite, though insignificant, miofloral change above the Raniganj-Panchet boundary, but whether this change took place in the late Palaeozoic or at the Permian-Triassic boundary is still not clearly known.

INTRODUCTION

THE Panchet Group was established for a series of rocks overlying the coal-bearing Damuda Group, and exposed in the Panchet Hill, Raniganj Coalfield, Bengal. The original Panchet of Blanford is now divided and the lower part retains the name, the upper part has been considered as representing the Mahadeva Group (Fox, 1931). The strata are slightly unconformable to the Raniganj Formation, especially in the Bokaro Coalfield. With the exception of occasional included coaly fragments, they are completely devoid of coal and carbonized plant remains.

The Panchet Group in the type area is divided into two formations, viz., the Maitur and the Hirapur formations. The Maitur Formation (90-120 m), comprising thick khaki-green silty shales and greenish-brown mudstones, is well-developed in and around Nonia Nala to the East of Kumarpur and North-West of Asansol, and at Jamat, North of Damodar. The Hirapur Formation consists of yellow-grey, soft, micaceous sandstones, alternating with dark-red and occasional light-coloured mudstones.

Not much information is available on the palaeontology and palaeobotany of the Panchet Group in the Raniganj Coalfield. *Estheria mangaliensis*, a fresh water crustacean, is very abundant in places.

Almost all the Panchet plant fossils known from the Raniganj Coalfield, were found in the Maitur Formation near Asansol. The Maitur megaflora has almost the same elements as that of the upper part of the Raniganj Formation except for the presence of *Cladophlebis concinna*, *Cyclopteris pachyrachis*, *Podozamites* sp., and ?*Dicroidium*/*Lepidopteris*.

Palynology of the Panchet Group is known through the works of Shrivastava and Pawde (1962), Kar (1970a), Satsangi, Chandra and Singh (1972) and Sarbadhikary (1972). The present study deals with the *Sporae dispersae* of the Maitur Formation exposed in the Nonia Nala, near Asansol.

MATERIAL AND METHODS

Material for the present study comprised samples collected from the Raniganj-Panchet section exposed in the north-western branch of the Nonia Nala, East of Kumarpur and North-West of Asansol in Burdwan District, West Bengal. Microfossils were recovered from the greenish-brown mudstones and shales. First sporiferous Maitur sample (NP-1) is from a bed about 5 metres above the Raniganj-Panchet contact. Other samples are from still higher beds. Sample NR-1 is from the last carbonaceous shale band below the contact.

QUANTITATIVE ANALYSIS

The palynological assemblage of the Maitur Formation (Panchet Group) exposed in the Nonia Nala comprises 60 species belonging to 40 genera of pollen and spores. Fifteen new species of megaspores belonging to 8 genera were also recovered but they are not discussed here.

A miospore count at the generic level has been shown in Table 1. The characteristic miospore genera of the assemblage are: *Punctatisporites*, *Verrucosisporites*, *Decisporis*,

TABLE 1 — PERCENT FREQUENCY OF MIOSPORE GENERA IN DIFFERENT SAMPLES

SAMPLE NOS. / GENERA	NE-1	NP-9	NP-1	NP-2	NP-8	NP-4 + NP-7	1358	1359
Cyathidites	—	0·8	—	—	—	0·4	—	0·4
Punctatisporites	—	2·0	4·4	2·0	14·8	4·0	8·4	1·2
Eupunctisporites	—	—	1·2	—	0·4	2·4	4·4	—
Biretisporites	1·0	—	1·2	0·8	—	—	0·4	0·8
Brevitriletes	2·4	2·8	3·6	5·6	0·8	1·2	1·6	—
Cyclogranisporites	—	—	0·4	0·4	1·2	—	—	—
Verrucosisporites	—	4·0	1·2	3·6	15·6	39·2	29·2	1·2
Decisporis	—	14·8	9·2	19·6	8·4	2·4	—	—
Kraeuselisporites	—	0·8	0·4	2·4	0·4	1·2	—	—
Lundbladispora	—	—	—	—	0·8	—	—	—
Playfordiaspora	—	4·8	4·0	4·8	—	2·0	—	—
Densipollenites	13·2	—	1·6	0·8	0·8	0·4	2·4	3·6
Podocarpidites	4·4	5·2	11·2	7·6	7·2	3·2	8·4	1·2
Klausipollenites	4·0	1·6	2·4	2·0	1·6	0·4	—	2·0
Alisporites	6·8	9·6	14·8	20·4	10·8	12·0	19·2	40·4
Chordasporites	0·4	0·8	5·2	2·0	0·4	—	—	0·8
Falcisporites	0·8	—	0·8	0·8	—	0·4	1·6	4·4
Lunatisporites	—	2·0	—	—	—	—	—	0·4
Jugasporites	—	0·4	0·4	—	—	—	0·4	—
Rhizomaspora	—	—	0·8	1·2	2·8	0·4	1·2	0·4
Lahirites	11·6	6·0	3·6	3·2	1·6	—	3·6	2·8
Gondwanipollenites	18·8	20·4	14·8	11·6	14·8	19·2	8·8	14·4
Protohaploxypinus	26·4	16·4	8·8	7·6	13·6	10·4	9·2	12·8
Striatites	5·8	0·4	0·8	0·8	1·6	—	—	3·2
Lunatisporites	—	4·8	8·4	1·2	2·4	0·8	—	—
Others	4·4	2·4	0·8	1·6	—	1·0	1·2	5·6

NOTES:

1. In this table percent frequencies of following genera have been considered together: (i) *Brevitriletes* + *Horriditriletes*. (ii) *Podocarpidites* + *Cuneatisporites* + *Platysaccus*. (iii) *Alisporites* + *Sulcatisporites*. (iv) Radial monosaccates + aletes — under *others*.
2. *Lunatisporites* is used *sensu stricto*.
3. *Gondwanipollenites* also includes *Lunatisporites* of Bharadwaj.

Alisporites, *Gondwanipollenites* and *Protohaploxypinus*. On the basis of miospore frequency the samples fall into 4 groups which correspond to the four different exposures of the section from where the samples were collected.

Sample group 1 comprising NP-1, NP-2 and NP-9 is dominated by the genera *Decisporis*, *Alisporites*, *Lunatisporites*, *Gondwanipollenites* and *Protohaploxypinus*. The genera *Punctatisporites*, *Brevitriletes*, *Verrucosisporites*, *Playfordiaspora*, *Cuneatisporites*, *Chordasporites*, and *Lahirites* are generally less than 5 per cent. *Playfordiaspora* is the characteristic element of this group.

Sample group 2 consisting only of sample no. NP-8 is characterized by a significant increase in the frequency of the genera *Punctatisporites* and *Verrucosisporites*. The genus *Densipollenites* is common but the genera *Decisporis* and *Brevitriletes* start declining. There is not much change in the frequency of the genera *Alisporites*, *Gondwanipollenites* and *Protohaploxypinus*. *Playfordiaspora* is absent.

Sample group 3 comprising samples NP-4 +NP-7 and 1358 is characterized by a very significant increase in the frequency of the genus *Verrucosisporites*. The genera *Punctatisporites* and *Decisporis* decline further. The striate-bisaccates are also on the decline.

Sample group 4 consisting of only sample no. 1359 is very interesting as here the triletes reach their lowest ebb while the non-striate bisaccates, represented mostly by *Alisporites*, are at their peak. The striate bisaccates do not show much change.

The azonate-triletes are lowest (20 per cent) in sample NP-1 which is the oldest of fossiliferous Maitur samples. The frequency gradually increases till it reaches its maximum (50 per cent) in the composite sample NP-4+NP-7. However, this group is meagrely represented in sample no. 1359 which probably is the topmost fossiliferous Maitur sample studied here.

The zonate-triletes are fairly well represented in the lower samples (NP-1, NP-2, NP-9), decrease in NP-4+NP-7 and are totally absent in sample nos. 1358 and 1359.

The monosaccates though present in all the samples are not well represented.

The striate bisaccates gradually decline from older to younger samples studied till they are only 23 per cent in sample no. 1358. Their maximum frequency (48 per cent) is in sample NP-9.

The non-striate bisaccates range between 15 and 35 per cent except for sample no. 1359 where they suddenly shoot up to 53 per cent.

The important elements of each sample group are as follows: (i) Group-1, *Decisporis*, *Playfordiaspora* (= *Guthoerlisporites* p.p.) and *Lunatisporites* (= *Taeniaesporites*); (ii) Group-2, *Punctatisporites*, *Verrucosisporites* and *Decisporis*; (iii) Group-3, *Verrucosisporites*, *Punctatisporites* and *Eupunctisporites*; and (iv) *Alisporites* and *Falcisporites* for Group-4. Sample no. 1359 is interesting as here the triletes are at their minimum whereas the non-striate bisaccates are at their maximum in the section.

COMPARISON

A comparison of the Maitur Formation samples with one of the topmost fossiliferous samples (NR-1) of the Raniganj Formation (Table 1) shows that the azonate-triletes which are scanty in the latter, gradually increase in frequency from older to younger Maitur samples. The zonate-triletes are absent in the Raniganj sample but are not uncommon in the Maitur samples. The monosaccates which are 18 per cent in NR-1 are never more than 5 per cent in the Maitur samples. The monosaccates in the Raniganj sample belong all to one genus — *Densipollenites*, — whereas in the Maitur samples a new monosaccate form × *Playfordiaspora* — comes up. The striate bisaccates which are 65 per cent in the Raniganj sample, gradually become reduced in numbers. The non-striate bisaccates which are about 14 per cent in the Raniganj are as much as 53 per cent in one of the Maitur samples (1359).

Satsangi, Chandra and Singh (1972) described a mioflora obtained from the Panchet beds exposed in the Nonia Nala. They report the abundance of bisaccate pollen in the assemblage, as we have also found in our samples. Some of the characteristic elements such as, *Punctatisporites*, *Verrucosisporites*, *Decisporis*, *Playfordiaspora*, *Lunatisporites* (= *Taeniaesporites*) etc. were, however, not observed by them. While we agree that the rich mioflora of the Raniganj Formation gradually declined during the Maitur times, we also find coming up of some new elements such as, *Decisporis* and *Playfordiaspora* in the Maitur Formation.

Shrivastava and Pawde (1962) described the *Sporae dispersae* of the Raniganj and Panchet beds occurring in the borecore no. R.O. 1(B) from the Ondal area of West Bengal. The range table given by them shows a significant change in the mioflora at 349 metres below ground level, at the point of Raniganj-Panchet contact. This indicates an appreciable gap in sedimentation as was also earlier reported by Gee (1932, pp. 365-366). This mioflora from R.O. 1(B) is definitely much younger than the Nonia Nala mioflora.

Pollen and spores were described by Kar (1970a) from the rocks of the Panchet Group in the borehole no. RE-9 in the eastern part of the Raniganj Coalfield. This mioflora has about 80 per cent trilete spore forms, the two dominant genera being *Decisporis* and *Divaripunctites*. Bisaccate pollen are comparatively less. From the very high percentage of the trilete spores, low percentage of the bisaccate pollen and the absence of the genera *Verrucosisporites*, *Playfordiaspora*, and *Lunatisporites* (= *Taeniaesporites*), we presume that the RE-9 mioflora is younger as compared to the Maitur mioflora.

Sarbadhikary (1972) has described a palynoflora from two samples of 'Panchet Formation' in the borehole no. RE-1, Raniganj Coalfield. The mioflora is almost exclusively composed of triletes, which is in sharp contrast to the striate bisaccate rich Raniganj mioflora obtained from the same borehole. The Panchet assemblage of this borehole is quite different from the Maitur assemblage but agrees with the Panchet assemblage from borehole RE-9. We, therefore, have concluded that in boreholes RE-1 and RE-9 the Maitur Formation is unrepresented and that the Upper Panchets rest directly on the Raniganj as is generally the case in the area (Gee, 1932).

Bharadwaj and Srivastava (1969) described a mioflora from grey micaceous shales exposed in the Gopad River, near Nidhpuri, Sidhi District. The assemblage is dominated by the non-striate bisaccates and the triletes are extremely rare. The almost total lack of the genera *Punctatisporites*, *Verrucosisporites*, *Decisporis*, *Playfordiaspora* and *Lunatisporites*, and the paucity of striate bisaccates differentiate this assemblage from the Maitur mioflora. The above Nidhpuri mioflora is younger even than the RE-1 or RE-9 miofloras and may probably belong to the Mahadeva Group.

Trivedi and Misra (1970) also described a 'Triassic' mioflora from the sandy shales, exposed in the Gopad River, 4 km N. of Nidhpuri. This mioflora has a dominance of striate-bisaccates, triletes are few and monosaccates are also not very common. This Nidhpuri assemblage is most probably homotaxial with the Upper Raniganj strata in the Nonia Nala section and hence may not be Triassic in age. It is definitely older than the Maitur mioflora described by us.

Balme (1970) has recently described the Triassic pollen and spores from the Salt Range, Pakistan. The Maitur Formation and the Mianwali Formation (Kathwai member), both have a dominance of bisaccate pollen in the basal part and then show a gradual increase in the frequency of the triletes. On the generic level the two formations, however, differ in composition; further in the Mianwali Formation the acritarchs are fairly common.

The palynology of the upper beds of the Raniganj Formation has been studied by Shrivastava and Pawde (1962), Maheshwari (1967) and Kar (1970b). In these beds the striate bisaccates dominate the mioflora and the triletes are only meagrely represented. *Densipollenites* is sometimes present in significant percentage (Maheshwari, 1967, Table 1 in the present paper). Quite a few of the miospore genera are found to be common between the Raniganj and Maitur samples presently studied. Some characteristic forms of the Raniganj Formation, viz., *Indospora*, *Gondisporites*, *Microbaculispora*, *Microfoveolatisporites* and *Vittatina* etc. are absent in both the upper Raniganj and the Maitur samples. At the same time the characteristic Maitur forms, *Decisporis* and *Playfordiaspora* have so far not been found in the Raniganj Formation.

It is thus seen that the Raniganj mioflora suffered a gradual decline in quality and quantity, the basal Maitur mioflora retained its Raniganj affinities in having a preponderance of striate bisaccate pollen. Only gradually the triletes increased in frequency. However, some new elements did appear in the Maitur Formation.

AGE OF THE MAITUR FORMATION

The age of the Maitur Formation, and in fact of whole of the Panchet Group, has generally been accepted to be Lower Triassic (see Tripathi and Puri, 1961), but sometimes an Upper Permian relationship has also been suggested for the formation (Das-Gupta, 1928). The latter view relies upon the occurrence of the fish *Amblypterus* in the basal Panchets. The fish has also been found in the Raniganj Formation (Mukherjee and Ghosh, 1973). *Lystrosaurus*, which is usually accepted as a marker of the Lower Triassic in the southern continents also does not occur in the Nonia Nala Maiturs. Cosgriff (1965) thinks that the *Lystrosaurus* Zone of South Africa should be assigned to the Upper Permian.

Glossopteris conspicua and *G. retifera*, which have been found in some Maitur beds also do not go beyond the Lower Beaufort (Upper Permian). Further no characteristic Triassic plant, e.g. *Dicroidium* is definitely known from the Maitur Formation. Singh and Shah (1972) and Maheshwari (1974) are of the opinion that if the Permo-Triassic boundary in India is taken as fixed on lithological evidences, then the flora of the Upper Permian and Lower Triassic is very akin but for minor differences. On the other hand, if the boundary is considered on the floral contents alone, it should be extended into the Maitur Formation. According to Chaloner (1969) the principal floral changes took place at different levels within the Upper Permian, and not at the Permian-Triassic boundary.

The strong Permian affinities of the basal Maitur mioflora are indicated by the preponderance of bisaccate pollen (particularly the striate ones). Of the characteristic Maitur miospore genera, *Lunatisporites* (= *Taeniaesporites*) and *Playfordiaspora* (= *Gutheorlisporites* p.p.), though not known from the Raniganj Formation of peninsular India, are, however, known from the Permian of Salt Range (Balme, 1970). *Decisporis* is, however, a characteristic Panchet genus.

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